SECOORA
SOUTHEAST
COASTAL OCEAN OBSERVING
REGIONAL ASSOCIATION

SOUTHEAST WATER LEVEL NETWORK
STANDARD OPERATING PROCEDURES

Acquiring Vertical Elevation of Water Level Sensors

VERSION 1
MAY 2023

Version Control

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0.10	Initial SOP draft	Feb 8-20, 2023
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A. SECOORA Water Level Survey Procedure

The SECOORA Water Level sensor elevation measurements will use an ellipsoidal method as the minimum acceptable approach to establish vertical control of the water level sensor and to achieve the desired uncertainty in vertical position. A survey consists of establishing and maintaining the vertical position of water level sensors relative to a station datum to enable high-quality observations of coastal flooding. The goal is to establish an easily repeatable process using Global Navigation Satellite System (GNSS) that enables tracking sensor vertical position relative to the ellipsoid as well as water level transformation to the North American Vertical Datum of 1988 (NAVD88) or National Spatial Reference System (NSRS) datum. The elevation uncertainty tolerance for vertical elevation is 5 centimeters (cm). This represents the total vertical uncertainty relative to the ellipsoidal reference (GNSS uncertainty plus any additional vertical position uncertainty). At least 3 benchmarks and the sensor (or a level point above/below the sensor where the surveyor can tape to the sensor) will be surveyed using a Real Time Kinematic (RTK)/Real Time Network (RTN) with a dual frequency GNSS receiver.

B. SECOORA Water Level Survey Periods

Surveys will be conducted when a water level station is installed and every two years thereafter, provided that the sensor does not move (e.g., displaced during weather event, damaged by pedestrian/vehicle traffic) within the 2 year period. If there is apparent movement in the sensor, based on the data quality control tests, or if sensor maintenance or replacement needs to be performed, then a new survey must be conducted for the sensor (e.g., GNSS survey or tape up/down to the sensor).

C. Survey Process

Field Preparation

Field Equipment and Supplies

- RTK/RTN with dual frequency GNSS receiver/antenna on a tripod that can connect into the real-time network that is properly aligned to the national spatial reference system (NSRS)
- Make sure your RTK/RTN antenna calibration is available through NOAA National Geodetic Survey. You can look up the brand and model of your RTK/RTN here: https://www.ngs.noaa.gov/ANTCAL/
- RTK/RTN must be able to output data in GNSS Vector Exchange file format (e.g., .gvx format https://geodesy.noaa.gov/data/formats/GVX/index.shtml).
- Camera or phone with a camera
- Field datasheet (Example Word version for download): https://secoora.org/wp-content/uploads/2022/10/SECOORA-Survey-Field-Data-Sheet.docx
- List of benchmarks with known coordinates or addresses and photos so they can be found once in the field
- Survey worksheet; pen/pencil
- Magnetic nails or other materials for establishing a benchmark (Image 1 for example of a magnetic nail). Other survey materials available here: https://www.berntsen.com/
- Yellow or orange paint to mark new benchmarks if they have to be added

- NIST calibrated steel tape, and any other tape down/up equipment needed to acquire sensor vertical measurement above/below level point
- Two carpenters levels (12 in and 3 ft)
- Sharpie or other marker

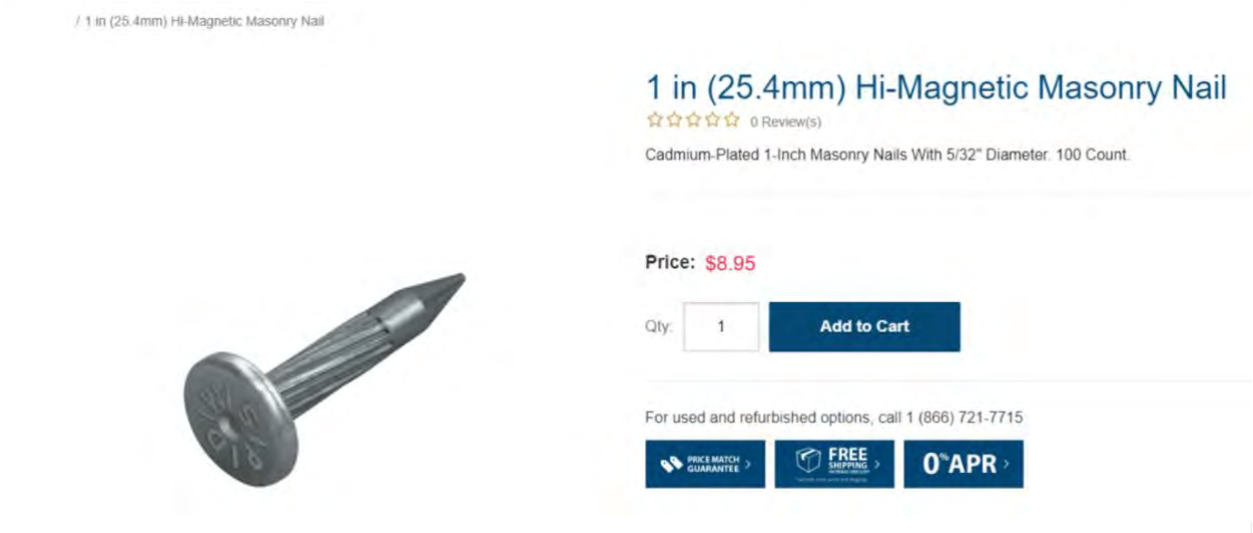

Image 1: Magnetic Nail

Before Going to the Field

- Identify or establish a minimum of 3 benchmarks (BMs) as vertical controls. BMs should be 60 meters (m) to 1 kilometer (km) from the sensor mounting location, with at least 60 m separation between marks.
- At least one of the 3 marks should be an existing mark with a NAVD88 tie, such as a state Geodetic Survey, Department of Transportation (DOT) or NOAA National Geodetic Survey (NGS) benchmark (BM).
- Try to avoid establishing BMs on the same structure (e.g., road, pier, bulkhead, building, etc.), to better ensure independence and minimize the chance of disturbance or loss of multiple marks over the same time (e.g., if a road was re-paved or a bulkhead damaged).
- Ensure BMs have a clear view of the sky, clear of overhead obstructions (trees, buildings, etc.) and will be able to be surveyed by GNSS.
- Use the link below to help identify benchmarks near water level sensor installation locations: https://noaa.maps.arcgis.com/apps/webappviewer/index.html?id=190385f9aadb4cf1b0dd8759893032db
- If 3 BMs are not available, you will need to use google maps and on-site field reconnaissance to determine location(s) for establishing a new BM.
- Be prepared to establish new BMs if existing BMs were found to be disturbed, missing, or have significant movement relative to each other.
- Review your field datasheet and pre-fill any information that is known (e.g., address, photos of BMs and the sensor, previous survey elevations).
    - Example Word version field data sheet found here: https://secoora.org/wp-content/uploads/2022/10/SECOORA-Survey-Field-Data-Sheet.docx
- For each sensor, ensure that a sensor leveling point (a marking or physical feature on the sensor housing) is established, visible, and can be repeatedly measured to with a tape in the field. Make sure a photograph is taken of each sensor showing this point.

- For each sensor that will be deployed (or is currently deployed), measure the distance from the sensor leveling point to the sensor reference point (i.e., where the sensor would measure a distance of 0). This is the sensor offset. Record this measurement and the sensor number in the field datasheet prior to deploying the sensor in the field. See image 2.
- Print the field datasheet for each survey site and take the datasheet to the field.

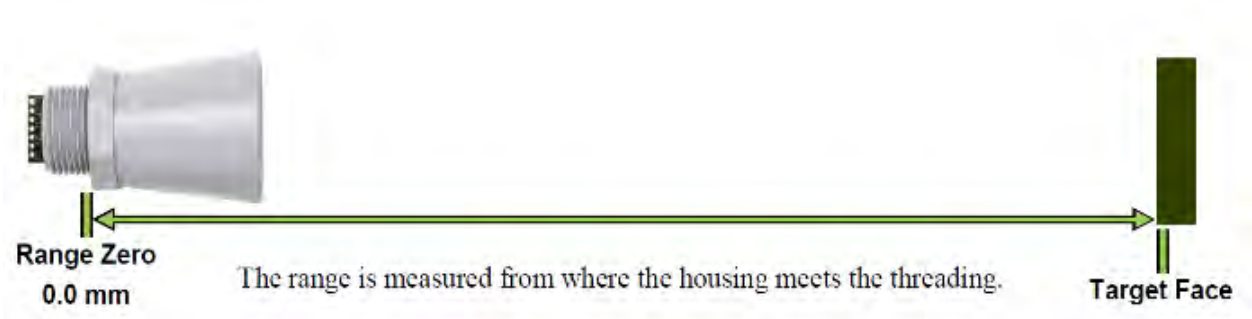

Image 2: Sensor offset measurement

Field Process

Finding your benchmarks

- Find each BM that was identified prior to going into the field. Make sure the BMs are not disturbed or missing.
- Photograph each BM and the sensor. Make sure you take photos so that they are useful for finding BMs at a later date. Show not only the BM, but include nearby landmarks (e.g., house, pole/piling, bridge rail). You can always review the BMs against existing photos and that will help determine if you need to reinstall a BM if it shows degradation over time.

Image 3: North Carolina DOT benchmark with RTN placed vertically above the BM. Note the DOT metal disc has yellow paint around it to help identify it more easily.
Image 4: Chisel square with yellow paint around it to help identify the BM in the field. The square is similar to the ND DOT benchmark and the RTK/RTN should be held vertically above the square.

Establishing a new benchmark

- The BM may be a random point decided by the surveyor. The point must be appropriately marked so that it can be repeatedly accessed for future surveys.
- The BM itself can be a survey monument installed by the surveyor, a corner of a concrete pad with a chisel square marking the corner, or a magnetic nail. See images on the next page for examples of BMs.
- BMs should be established in an open area. They should not be placed under a bridge or other structure or under dense tree canopy.
- Close up photos of the BM should be made as well as photographs that show the BM relative to the surrounding area so that it can be found at a later date.
- In the field survey sheet, provide a descriptive location of the newly established BM to help others find it again.
- Record BM locations by describing the general surrounding of where the BM's are set. Make sure to pull distances with tape measurements in metric units, reference cited landmarks and use a compass to confirm directions. Refer to the User's Guide for Writing To Reach Statements And Bench Mark Descriptions for additional information.

- Sample: From the Post Office in (city), proceed north on Main Street for 3.4 km (2.1 mi), then go east on Columbia Boulevard for 0.8 km (0.5 mi) to the city harbor and Municipal Pier No. 11 North, the BM is a disk set in top of the concrete footing for a building on the east end of Municipal Pier No. 11 North (Marine Police and Fire Boat Pier), 14.57 m (47.8 ft) north of the south face of the pier, 9.81 m (32.2 ft) south of the north face of the pier, 6.49 m (21.3 ft) west of the east end of the pier, and 0.37 m (1.2 ft) south of the north end of a steel door opening.

Survey benchmarks

- The RTK unit connects to the Geodetic Survey Real Time Network server that receives CORS data and generates correction data that is provided to the RTK unit.
- Set up the RTK/RTN tripod so that it is centered vertically over the BM.
- Use the RTK/RTN, to **take two (2) sets of 7-minute-long occupations for each of the 3 benchmarks.**
- The second occupation should be a minimum of **2 hours** after the first occupation. Ideally, the occupations are 6 - 12 hours apart.
- For some locations, especially when increased accuracy is required, 10-minute occupations on the sensor and benchmarks may be needed.
- Save each file on the RTK GPS so they can be downloaded once you return to the lab.

Survey sensor

- Ideally you should be able to set up the RTK unit on the sensor or sensor housing; however, for some locations, you may not be able to survey directly to the sensor so you will need to place a temporary or permanent mark at a location where you can conduct repeatable occupations at the same spot. This may be directly in front of the sensor or at the place where the sensor attaches to a structure (i.e., on a bracket). You will need to survey to a location where you can then tape up/down to the sensor in order to determine the sensor elevation. A survey mark should be selected that minimizes the vertical tape up/down distance and horizontal distance to the sensor to limit error in tape measurement. Taping instructions and options to consider when taping are found in the Survey and Taping Guide.
- You can use a chisel square, a magnetic nail, or another type of permanent identification to mark the location where you will conduct the RTK/RTN occupations. This ensures repeatability.
- Use the RTK/RTN, to **take two (2) sets of 7-minute-long occupations at each survey site (sensor plus 3 benchmarks).**
- The second occupation should be a minimum of **2 hours** from the first occupation. Ideally, the occupations are 6 - 12 hours apart.
- You can survey the sensor while also surveying the benchmarks.
- Save each file on the RTK/RTN so they can be downloaded once you return to the lab.

Procedures to tape up/down to sensor are provided by National Oceanic and Atmospheric Administration (NOAA) CO-OPS and a guide is found here in the SECOORA Survey and Taping Guide.

- Ideally, the goal is to survey the sensor; however, this may not always be possible.
- The elevation of sensor zero to sensor leveling point(s) must be measured using a National Institute of Standards and Technology (NIST) approved steel-tape measure with millimeter graduations (see link here: Lufkin HW226ME). This measurement should be completed in the lab. Record this measurement on the datasheet as the sensor offset (see Image 1).

- The chisel square, a magnetic nail, or other type of identification used to mark the location where you conducted the RTK GPS occupations must be used as one of the measurement points to determine the sensor height.
- The steel taped distance from the “ground” mark to the sensor should be performed during a lull in the wind activity.
- A carpenter's level shall be used at the top and bottom of the steel tape. When the tape is dropped from the sensor the tape is held as vertical as possible.
- A set of three measurements must be made by a minimum of two people for six measurements.
- Each reading must have the zero of the steel tape positioned at the high point of the “ground” mark and the elevation shall be read from the tape at the sensor.
- The steel tape must be moved away from the TBMs and repositioned for each measurement.
- Record the 6 individual measurements on the field data sheet along with the time the measurements were taken.
- The six readings shall be averaged to acquire the height between the “ground” TBM and the sensor LP. Use a calculator to determine the average height.

Sensor Maintenance/Replacement

1. If you disturb or replace the sensor within the two year survey window, you must repeat the GNSS survey of the sensor OR tape up/down process (depending on which method was used to establish sensor vertical position).
   - Review the previous field survey datasheet prior to conducting the sensor swap and review any tape up/tape down measurements. This will help you determine if the sensor position or bracket have moved when you go to the field to swap a sensor.
   - Before uninstalling the faulty sensor, take 3 measurements using the tape up/down procedures. For each measurement, also record the date and time.
   - Record the measurements in a station data sheet and average the measurements.
   - Replace the sensor.
   - Take 3 measurements using the tape up/down procedures after installing the new water level sensor. For each measurement, also record the date and time.
   - Record the new tape measurements in a station data sheet and average the measurements.
   - Compare 1st and 2nd set of tape measurements to determine if the mounting bracket moved during the sensor swap or if the sensor is slipping within the mounting bracket over time. If there are changes, then this may change the datum calculation.
   - Enter the pre- and post-vertical positions in the station metadata along with the date/time of the sensor swap. Update Axiom Data Science (dmac@secoora.org) of the new vertical position so that the new datums can be calculated and there are no errors in the on-line resources.
2. If the survey point is disturbed (sensor bracket, mounting assembly or infrastructure disturbance) within the two-year survey window, then you must repeat the GNSS survey of the sensor AND tape up/down process.
   - Enter the pre- and post-vertical positions in the station metadata along with the date/time of the measurement.
   - Repeat *Field Survey Process* as described above for the sensor.

Leveling

SECOORA does not require leveling; however, some sensor locations may need more accurate surveys. When needed, project teams can also include leveling with the ellipsoidal survey process. Beginner guide for leveling process can be found here:

- https://drive.google.com/file/d/1DsJ6exI1EDFi8INyJFT6VACEPw11eUea/view?usp=sharing.

NOAA Leveling resources include:

- https://www.ngs.noaa.gov/PUBS_LIB/Geodeticleveling_nos_3.pdf
- https://tidesandcurrents.noaa.gov/publications/Users_Guide_to_Vertical_Control_and_Geodetic_Leveling_for_CO-OPS_Observing_Systems-May_2018.pdf

D. Processing GNSS Observations

Uploading project data

- SECOORA will use OPUS Projects to manage survey data
- All survey data must be available in .gvx format
- At least one person from each project team must take the in person or virtual OPUS Projects training.
- OPUS Projects will process the RTK data for each occupation and provide error estimates. If the error is not within tolerance, then the survey for the water level station or BM that is outside of the tolerance will need to be repeated using the same BMs and sensor locations.
- OPUS Projects will do a geometric adjustment (lat, long, ellipHt) then do an Orthometric adjustment holding valid NAVD88 control. This will provide a NAVD88 elevation for the sensors.
- If taping to the sensor was required, then the tape down information should be included in the monument description file for the site in OPUS Projects.
- Elevations for each station and benchmarks can be saved in OPUS Projects and downloaded by the station operator so that the information can be saved in the metadata record for the site.

E. Metadata and Metadata Updates

- Station metadata can be accessed through the individual station pages in the SECOORA data portal and can be viewed using ERDDAP. A subset of water level metadata can also be found in the SECOORA project tracking form - https://docs.google.com/spreadsheets/d/10KN3sdkzaUR-Kf_TbC-YI0d1mcCqWH6pvWowcQVbB8o/edit?usp=sharing
- All metadata should be included in the station API so that anyone can access it. At minimum all fields in the station log template (Word document) should be included in the metadata. You may also fill out this template for each station and send it to Axiom.
- Specific measurements, which must be included in the metadata, are required to calculate station datum:
    - Sensor technology (Microwave, Pressure, Acoustic)
    - Sensor survey point (elevation of the survey point on or next to the sensor)
    - Tape up/down average measurement
    - Sensor offset
    - Station datum 0 value relative to the ellipsoidal reference (e.g. some distance relative to the ellipsoid to set as station datum)

F. What happens when things move?

Tape up/down measurements change

- Sensors may move due to many factors, such as the sensor slipping in the bracket or the bracket starting to tilt or move. Always repeat the tape up/down measurement to confirm the measurements.
- If there is demonstrated movement, then check the mounting bracket to assure that it is securely in place, look at the sensor to determine if the sensor slipped inside the bracket.
- To correct these issues, you may need to replace a bracket or the sensor in order to correct the issue.

BM elevations change

- Survey conducted incorrectly - this may be spotted during the OPUS projects data processing. The BMs will need to be resurveyed if this occurs.

There are times when the BM elevations may have actually moved

- Land movement
- Structure the benchmark is on has shifted

Sensor survey point changes

- Survey conducted incorrectly, such as occupying a different location than the original survey point. This may be spotted during the OPUS projects data processing. The BMs will need to be resurveyed if this occurs.

There are times when the BM elevations may have actually moved.

- Land movement
- Structure the benchmark is on has shifted