Requirements for Relocating NWLON Stations

Procedure Number: 3.2.3.5 E26
Original Creation Date: January 18, 2012
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1. **Title:** Requirements for Relocating NWLON Stations.

2. **Purpose:** This SOP documents procedures and steps required to ensure maintaining data and datum continuity when physically moving NWLON stations to nearby locations.

3. **Background/History:** The National Water Level Observation Network (NWLON) is the network of tide and water level stations operated by the National Ocean Service along the marine and Great Lakes coasts and islands of the United States. The NWLON is composed of the primary and secondary control tide stations of the National Ocean Service. This Network provides the basic tidal datums for coastal and marine boundaries and for chart datum of the United States. Tide observations at a secondary control tide station or tertiary tide station are reduced to equivalent l9-year tidal datums through comparison of simultaneous observations with a primary control tide station. In addition to hydrography, nautical charting, and delineation of coastal and marine boundaries, the Network is used for coastal processes and tectonic studies, tsunami and storm surge warnings, and climate monitoring. The National Water Level Observation Network also includes stations operated throughout the Great Lakes Basin. The network supports regulation, navigation and charting, river and harbor improvement, power generation, various scientific activities, and the adjustment for vertical movement of the Earth's crust in the Great Lakes Basin.

   The official list of NWLON Stations is maintained by CO-OPS' Engineering Division in the document found at: O:\NWLON\Official NWLON Lists by FY. Quite often, in the course of the history of a NWLON station operation, the tide gauge must be moved to a new location for various reasons. These include pier reconstruction, abandonment or opportunity to install new technology at a more appropriate location. In some cases, existing infrastructure is destroyed during a storm, and relocation is required. Moving an NWLON to a new location must be planned in advance to ensure station data and datum continuity.

   Data Continuity **requires** maintaining a long-time series of data relative to the same station datum so that record of sea level variations and extreme events is maintained without gaps. It ensures tidal predictions products are not significantly different at a new location. It means minimizing gaps for which measurements of significant short-term events may be lost (storm surge, tsunami, etc.).

Datum Continuity – Datum Continuity means that the record of water level and tidal variations is not disrupted or changed necessitating start of a new record for datum computation and datum control for subordinate stations. NWLON stations are intended to operate indefinitely with ongoing coverage and without creating a new gap in the time series. The original Station Datum, referenced on the active bench mark network, must be maintained or extended to the new location including transferring the Station Datum to new bench marks.

In some instances, maintaining data and datum continuity is difficult or impossible to do, requiring a new start for essentially a new station and temporary loss of accurate datum control for the region. This is not desirable and it is important to attempt to minimize the discontinuity in order to maintain a viable NWLON network.

4. Scope/Applicability This SOP affects all CO-OPS personnel involved with NWLON requirements and operational planning, with operationally moving a tide station, with tidal datum computation and tidal analysis, and with computation of relative sea level trends. The SOP applies to management of the NWLON (including the Great lakes) as an observational network and the ability of the NWLON to provide multi-purpose services.

5. Main Processes

A) Determine scope and extent of the move as that will generally drive the complexity of meeting the requirements of the various Cases that follow:

- Case 1: New location is < 0.5 km away and changes in tidal/water level datum elevations on the bench marks are not expected (e.g. the same tidal/water level characteristics).
- Case 2: New location is > 0.5 km away and requires installation of new bench marks that can be connected to the existing marks at the old location with leveling and changes in tidal/water datum elevations are not expected.
- Case 3: New location is > 1.0 km away and requires a completely new network of bench marks that cannot be connected by traditional levels to the old network. Changes in tidal/water level datum elevations and tidal characteristics are uncertain.
- Case 4: New location is > 1.0 km away and changes in tidal characteristics and tidal/water level datum elevations are certain.

B) Depending upon the Case above, assess the needs for:

- Simultaneous data between old and new locations
- Level connections between locations
- Datum recovery at new location

- Tidal prediction recovery at new location
- Relative Sea Level/ vertical land motion analysis at new location
- NWLON Gaps impacts analysis due to moving the location

C) Determine the timing and impact of the move on other ongoing operations and the impact of potential downtime. Prepare a data report summarizing the comparisons between new and old locations, and assess the impacts of the move on users and products. In some instances, a station may have been destroyed by a storm or a tsunami and the required actions will depend upon how the infrastructure is rebuilt and if bench mark networks remain intact.

6. Detailed Sub-Processes/Checklists

More detailed discussion of requirements for each of the 4 Cases are found below:

Case 1:

Simultaneous Data – requires a few hours of simultaneous data to ensure the new station is producing data on the correct station datum and that offsets have been determined and applied correctly. This may not be possible.

Level Connections – the same PBM and bench mark network is used and close out levels are run to the old station sensor '0'' and installation levels run to the new station sensor '0'. A new station number is not required; however, DCP assignments will have to be coordinated.

Datum Recovery – new sets of accepted datums are not required to be produced at the new location as the data series become a continuation of the old series, however datum recoveries are required at various time increments as new data are collected to document datum continuity between old and new locations.

Tidal Prediction Recovery – no new sets of harmonic constants or prediction products are required.

Relative sea level/vertical land motion – relative sea level trend updates will use the new series appended to the old station series, so sea level trends should remain the same. However, this is accomplished only after careful analysis over time of the data and the bench mark leveling histories

NWLON Gaps Analysis – There is no impact on NWLON coverage in this scenario.

Case 2:

Simultaneous Data - A minimum of one-month of simultaneous observation is required to ensure continuity and to verify no change to datum elevations and tidal characteristics between new and old location.

Level Connections – A new PBM and local bench mark network are required. A minimum of two level connections (three if differences are found in the first two) between the old and new PBM are required so that station datum can be transferred. A new station number is not required; however DCP assignments will have to be coordinated.

Datum Recovery - a datum computation should not be required if the tidal characteristics are verified to be equivalent. New sets of accepted datums are not required to be produced at the new location as the data series become a continuation of the old series, however datum recoveries are required at various time increments as new data are collected to document datum continuity between old and new locations.

Tidal prediction recovery – a simultaneous 29-day harmonic analysis is required using the one-month overlap period to ensure no impact in tide predictions.

Relative sea level/vertical land motion – no difference in relative sea level trends is expected, however desktop research should be performed to ensure no local gradients in vertical land motion between locations. However this is accomplished only after careful analysis over time of the data and the bench mark leveling histories

NWLON Gaps Analysis – Using the Technical memorandum NOS CO-OPS 0048 as a guide, a new coverage polygon and error analysis should be performed after preliminary datums are established at the new location.

Case 3:

Simultaneous data – a minimum of one-year of simultaneous data are required to establish differences in datum elevations, water level variations, tidal characteristics and tidal prediction products.

Level connections – traditional level connections between old and new locations is not possible, however, static GNSS surveys should be performed on bench mark(s) at each of the old and new locations to attempt to determine an accurate difference in the elevation of new and old station datums. The GNSS surveys should be performed simultaneously if possible and in conjunction with leveling among the bench mark networks at the old and then at the new location. If not performed in conjunction with leveling, then at least three marks shall be occupied by static GNSS and elevation relationships to NAVD88 are established. A new station number is required at the new location. Close out levels are run at the old location at the end of the one-year period.

Datum recovery – the new location will be required to fall under the CO-OPS Declare Operational pipeline, thus will require datum updates as data are accrued. Subsequent downstream analysis will determine the level of datum recovery between old and new locations.

Tidal prediction recovery – sets of new harmonic constants are computed per the Declare Operational SOP and new tidal prediction products are computed and disseminated.

Relative sea level/vertical land motion – analysis of the simultaneous one-year of data will help determine if sea-level trends can be continued and appended to the old series at the new location. This may require analysis of several years of data at the new location however to assess the sea level variability. In some cases, monthly mean data series can be extended using both old and new stations for purposes of estimating relative sea level trends, even if tidal datum differences are found. The GNSS surveys are required to determine elevation difference between old and new station datums for this purpose.

NWLON Gaps Analysis – Using the Technical memorandum NOS CO-OPS 0048 as a guide, a new coverage polygon and error analysis should be performed after preliminary datums are established at the new location.

Case 4:

Simultaneous data – there is generally no requirement for simultaneous data between old and new locations as the new station will be used to establish a completely new record.

Level connections – level connections are not possible and not required. Simultaneous static GNSS surveys are not required.

Datum recovery – there is no requirement for a datum recovery between old and new location as new datums will be established. Datum elevation differences relative to geodetic datums will be determined during the Declare Operational pipeline phase for the new location.

Tidal prediction recovery – new harmonic constants will be established and a new station in the tidal prediction products will be established as there is no continuity expected between the locations.

Relative sea level trends/vertical land motion – establishing a relationship between old and new locations of for sea level trends will take place only after several years of data have been obtained at the new location. New trends at the new location will be published after 30-years of data are obtained.

NWLON gaps analysis – using the Technical memorandum NOS CO-OPS 0048 as a guide, a new coverage polygon and error analysis should be performed after datums are established at the new location.

Comparison Summary Report

A comparison summary report should be prepared regardless of the Case. The report should provide information on:

- Statistics of the differences in water level variations and tidal characteristics based on the simultaneous comparison
- Comparison of extremes
- Comparison of tidal datum elevations relative to station datum and/or geodetic datum
- Comparison of harmonic constants
- Comparisons of the residual time series (observed minus predicted water levels)
- Comparisons of simultaneous wind speed, gust and wind direction; barometric pressure; and air and water temperature

7. **Quality Assurance/Control**: Status reports and project tracking are required to ensure this SOP is followed and the transition steps are followed over the transition time period, which may be several years if sea-level trends analyses are required. The Declare Operational SOP is invoked for new locations established in Case 3 and Case 4. Ongoing analyses is required of the station metadata and leveling records along with the series of preliminary datum updates and harmonic analyses updates to aid in the decision-making process for requiring new accepted datums and accepted harmonic constants.

8. **Management/Responsibility**: The CO-OPS Observing Systems Manager (or interim counterpart) has operational responsibility to coordinate the transition. FOD, OD, and ED all have responsibilities from planning to successful implementation of the re-location and to down-stream analyses.

9. **Examples**

Case 1: Solomons Island: The existing pier is being replaced by a new pier and the tide station must be moved during construction. The temporary replacement station will be located on a pier a few hundred yards away and replaced by a permanent station on the new pier.

Case 2: Atlantic City/Ventnor City, NJ: The original pier was scheduled to be completely demolished so the tide station had to be removed. The pier reconstruction would take several years. Field recon found a suitable pier for a temporary location 4.6 km to the south along the shore at Ventnor City until the Atlantic City pier was rebuilt. A

short period of simultaneous data was observed at each end of the temporary deployment time. New bench marks were established at Ventnor City and level connections were made to the PBM and bench marks at Atlantic City to connect the series. The data observed at Ventnor City were then used to fill the gap in the old location data series using the same station datum. Tidal characteristics were found to be the same at both locations. Data and datum continuity were established in the long-term record.

Case 3: Sabine Pass:

The new Sabine Pass SPIP Sentinel (Texas Point) is far enough away from the current location that it is uncertain whether the tidal characteristics will be the same to enable Accepted Datum continuity. It is expected that the sea level trends will be the same at each location. The SPIP will require a new Station ID and Station Datum; however it is close enough to the present location that land leveling can be performed to establish the direct datum connection. This leveling connection should be performed at installation and one-year after to bracket the one-year simultaneous comparison period. The one-year data analysis will provide information if datum continuity and data continuity can be maintained. The time series may have to restart to obtain an Accepted datum at the new location, however the SPIP location is eventually expected to provide NWLON coverage very similar to the present location and no new coverage gaps will result. The Texas Point station automatically comes under the CO-OPS Declare Operational pipeline.

Case 4: Cutler, ME

The NWLON station at Cutler, ME was relocated because we could no longer maintain a tide station on the USCG pier. The only other viable infrastructure found during field recon was the Cutler Farris Wharf located 7.2 km northeast of the old location in a completely separate body of water. The distance and topography between the stations prohibited a level connection and a completely new bench mark network was established. Being in the entrance to the Bay of Fundy, significant differences in tidal datum elevations and tidal characteristics over short distances were expected and were found between the stations. The old station was discontinued and a new series started at the new location. There was no overlap in data series. Data and datum discontinuities were not desired, but the options limited the new location to be any closer to the old location than it is. As data are collected at the new location, analyses will be performed to see if the relative sea level trend computed for the old location can be continued using the new location. NWLON gaps analysis shows moving the station does not affect NWLON coverage and no new gaps have been created as there is large overlap in coverage among Bar Harbor, Cutler, and Eastport. Accepted datums and harmonic constants will be updated as new data are accrued over time.