Improved Tides Support for NOAA Hydrographic Surveys

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Marine Transportation System safety and improved technology have placed great demands on the National Oceanic and Atmospheric Administration's National Ocean Service (NOS) to increase the efficiency of processing hydrographic surveys in order to update our Nation's suite of nautical charts. As bathymetric data collection continues to become more precise and the processing more automated, the requirement for a quantification of error associated with each data point becomes more apparent. In many tidal areas, water-level reducers are the largest vertical correction to sounding data, and uncertainties in their determination can dominate the total error budget (see Figure 1).

This feature article discusses a specific improvement that is underway for determining water level reducers for increased efficiency and accuracy of hydrographic survey data, which will provide more timely and accurate chart products to the user.

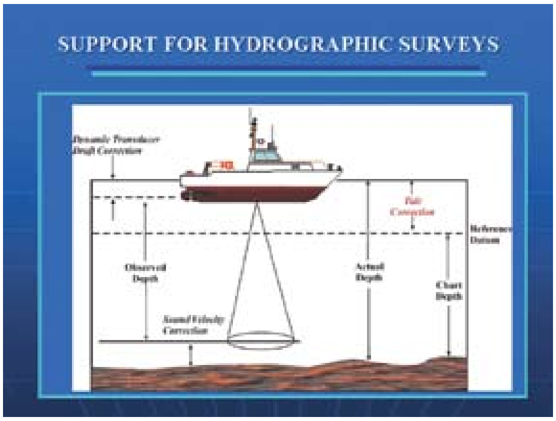

Figure 1. The concept of a tide correction to soundings.

Overview of Tides Support

Operational tides support for hydrographic surveys is managed by the NOAA Center for Operational Oceanographic Products and Services in collaboration with the NOAA Office of Coast Survey, as part of the NOAA Nautical Charting Program. The tides support is comprised of the following functional areas:

- o Tide and water level requirement planning;
- o Preliminary tidal zoning development;
- o Short-term and control water level station operation;
- o Data quality control, processing, and tabulation;
- o Tidal datum computation and recovery; and
- o Generation of water-level reducers and final tidal zoning.

The portion of the total accepted error due to the process of obtaining water-level reducers must be balanced against all other sounding errors to ensure that the total sounding error budget is not exceeded. The total tide reducer error has the following component errors:

- o The measurement error of the tide gauges and processing error to reduce the data to datum;
- o The error in the estimation of accepted tidal datums relative to National Tidal Datum Epoch 19-year periods; and
- o The error in the extrapolation of the observed tide to a survey area using tidal zoning.

Project planning by NOS attempts to minimize and balance these potential sources of errors through the use of accurate, reliable water-level gauges, the optimization of the mix of tidal zoning, the number of station locations, and the length of observations required within the practical limits of the survey area and survey duration. The tidal zoning error typically dominates the other two error sources (measurement error and datum error).

Currently, NOS utilizes a technique called "discrete tidal zoning," which defines geographic areas of similar tidal characteristics using polygons (or discrete zones) to assign water level reducers to sounding data.

Discrete tidal zoning is the construction of an extrapolated tide curve at the hydrographic survey location by applying a time correction and tide range correction to the observed tide curve from a nearby tide station.

Figures 2 and 3 show the implementation of discrete tidal zoning in southern Chesapeake Bay through the construction of co-tidal maps of the survey region, the overlay of the co-tidal maps on top of the survey area, and the construction of the tidal zones in alignment with the co-tidal lines.

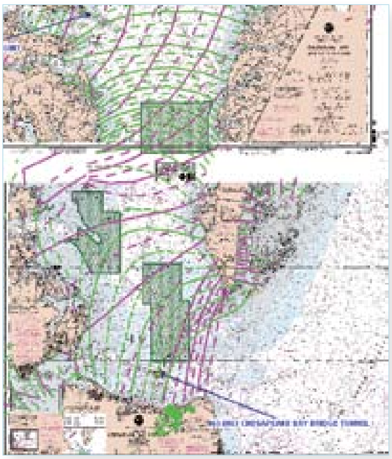

Figure 2. Co-tidal lines (Range in purple, Time in Green) and the survey areas for southern Chesapeake Bay.

There are inherent errors in the application of discrete tidal zoning:

- o Discontinuities at the edge of the zones;
- o Resolution in areas of complex tidal characteristics, where the location and number of zones is not adequate to describe the changes in the tide over the survey area;
- o Where large time corrections and large range ratios are required; and
- o The fact that placement of the zones becomes subjective when the co-tidal lines are based upon inconsistent or inadequate source data.

These known limitations have led to the investigation of new techniques for the provision of water-level reducers for hydrographic surveying.

Tidal Constituent and Residual Interpolation

TCARI was developed by Dr. Kurt Hess of the NOAA Office of Coast Survey (OCS) in 1990. This numerical, continuous tidal zoning solution uses

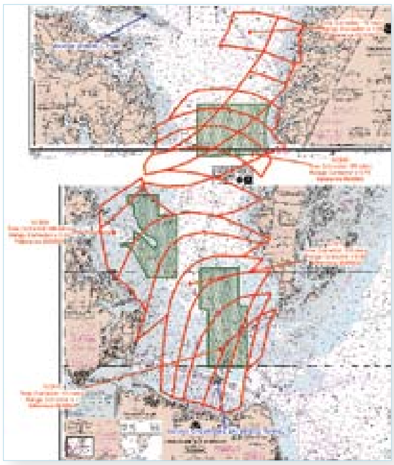

Figure 3. The discrete tidal zones constructed from the co-tidal lines and the survey areas in lower Chesapeake Bay.

spatially interpolated harmonic constituents and spatially interpolated observed water levels and datum offsets to compute a tidal reducer for bathymetric soundings. TCARI does not have the limitations of discrete tidal zoning. CO-OPS and OCS are currently working together to implement TCARI into NOS hydrographic and photogrammetric operations. Initially, a TCARI model domain needs to be determined for the survey areas. TCARI requires high resolution vector shoreline (Figure 4) to construct a model mesh grid (Figure5).

Figure 4. TCARI shoreline.

Historical tide stations with harmonic constants and computed datums are queried from the CO-OPS database and entered into TCARI for interpolation. Only those water level stations that are operating at the time of a survey can produce desired residuals (predicted – observed water levels). Residuals capture non-tidal effects produced by weather or river discharge during the time period of the hydrographic survey.

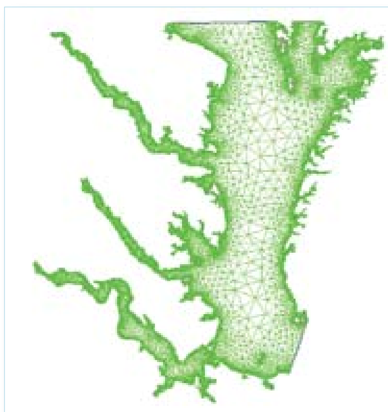

Figure 5. TCARI model grid.

TCARI uses tide station locations and the boundary condition established by the mesh grid to compute weighting percentages. These percentages determine the influence each station will have at any particular location. By using weighting percentages, TCARI can interpolate harmonic constants (both amplitude and phase) and residuals from multiple stations in an area (historical and active water level gauges) to provide an interpolated water level elevation relative to the MLLW for any grid cell at the time and location of the ship's sounding track.

Figure 6 shows how the weighting percentages change as you move away from the Chesapeake Bay Bridge tunnel station. The red areas represent 100% weighting. The percentage for CBBT starts to drop as you move up the bay towards Kiptopeake (Figure 7).

The 6-minute preliminary or verified water level data are loaded into the TCARI grid for all operating water level gauges. Once the water level data is loaded, TCARI can generate a tide curve at any location on the grid by summing up the interpolated harmonics, residuals, and datum offsets.

The interpolated tide curves can then be used to tide correct bathymetric soundings. The table below shows track line TCARI-derived tide reducer information for a 3-minute segment.

1	2006-226 16:00:43.266 00000000: Accepted	0.496
2	2006-226 16:01:13.465 00000000: Accepted	0.495
3	2006-226 16:01:43.467 00000000: Accepted	0.495
4	2006-226 16:02:13.666 00000000: Accepted	0.495
5	2006-226 16:02:43.667 00000000: Accepted	0.495
6	2006-226 16:03:13.866 00000000: Accepted	0.494
7	2006-226 16:03:43.868 00000000: Accepted	0.494

Summary

The traditional process of the iteration of preliminary and final discrete tidal zoning, as well as

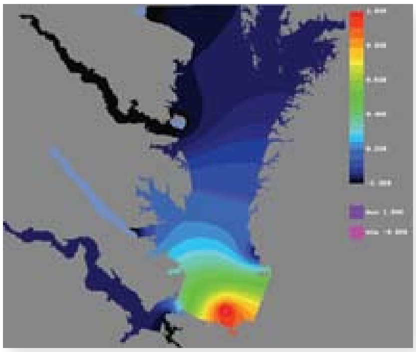

Figure 6. Chesapeake Bay Bridge tunnel weighting (%).

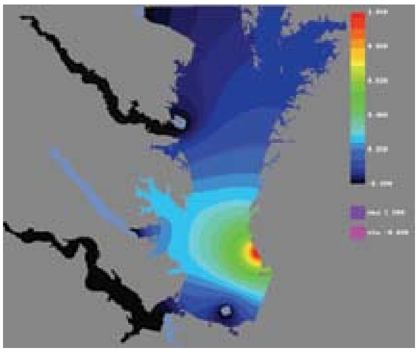

Figure 7. Kiptopeake weighting (%).

the need to post-process tide station data for the computation of tidal datums and tide reducers, has been a delaying factor in the production of nautical charts.

However, with the introduction of TCARI, the post processing steps are all but eliminated and the TCARI application is made by the on-board ship processing system before the data are sent to a marine center for chart compilation. This enhancement also eliminates one of the known error sources and limitations in tide reducer compilation, that of the discrete tidal zoning.

TCARI uncertainty analysis studies are underway which will allow for spatial depiction and computation of errors across the model grid. TCARI implementation will also support NOS efforts towards modernizing bathymetric databases and using KGPS technology in the future.

For more information on NOAA's navigation services and tides and currents program, visit: http://chartmaker.ncd.noaa.gov/ and http://tidesandcurrents.noaa.gov/.

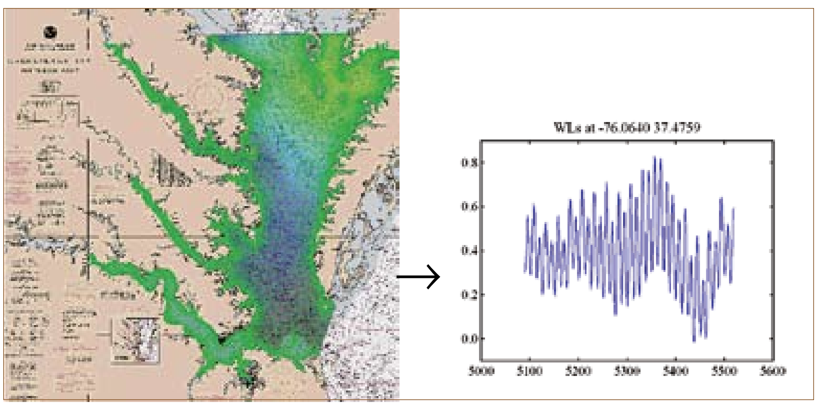

Figure 8. TCARI derived tides for a grid cell in the middle of the lower Chesapeake Bay.