C. HORIZONTAL AND VERTICAL CONTROL

Traditional zoning from water level stations was used for OPR-E349-KR-09 with zoning and verified water level files provided by the Center for Operational Oceanographic Products and Services (CO-OPS).

Prior to survey acquisition, a global positioning system (GPS) base station with a dual frequency (L1/L2) receiver was established to enable post-processing of survey vessel navigation and attitude data. The base station was located at the Smith residence on Tangier Island and logged raw dual frequency (L1/L2) GPS observables at one second epochs. A base station position relative to the North American Datum of 1983 (NAD83), (CORS96), and (Epoch 2002) was derived from the National Geodetic Survey (NGS) On-line Positioning User Service (OPUS) and based on a 24 hour data file, with one second epoch logging prior to commencement of survey operations.

DGPS navigation was logged during acquisition but ultimately overwritten with a post-processed Inertially-Aided Kinematic Ambiguity Resolution (IAKAR) navigation solution. The HIPS Load Attitude and Navigation tool was used to load position, heading and attitude data from a smooth best estimate trajectory (SBET) file created from Applanix POSPac 5.2 MMS. Post-processed uncertainty estimates for position, attitude and heading were applied using the HIPS Load Error Tool and used during the calculation of TPE.

The Tangier base station was not operating during the survey acquisition on December 11 and December 15, 2009 (DN 345 and 348). As a result there was no base station data available to post-process the navigation solution in Single Base mode. Instead, data was post-processed using the Applanix POSPac MMS SmartBase option which creates a virtual reference station from a network of GPS base stations. The network was created from NGS Continuously Operating Reference Stations (CORS) VIMS, MDSI, HNPT, VAGP, DRV5, VAWI, DRV6, and LOY1. Post-processing with the SmartBase option generated an IAKAR navigation solution in SBET format and an associated error file. After the solution was created the POSPac NAVDIF routine was used to compare the SmartBase solution to real-time DGPS navigation as a check to the input base station coordinates and the quality of the final solution. SBET files created from SmartBase processing were loaded in Caris HIPS just like their Single Base counterparts. Table 6 lists the NAD83 coordinates of the base stations used in the GPS network.

Table 6. CORS Base Stations Used During SmartBase Processing

CORS Base Stations	Coordinates NAD83(CORS) ARP (NGS Data Sheet)		
	Latitude	Longitude	Ellipsoid Height (m)
VIMS*	37/36/30.045 N	075/41/13.207 W	-27.739
MDSI	38/19/08.073 N	076/27/13.956 W	-16.774
HNPT	38/35/19.711 N	076/07/49.333 W	-26.645
VAGP	37/14/55.009 N	076/29/57.731 W	-19.809
DRV5	36/57/31.136 N	076/33/23.903 W	-21.358
VAWI	37/56/03.500 N	075/28/15.949 W	-22.315
DRV6	36/57/30.556 N	076/33/23.214 W	-21.425
LOY1	37/03/43.812 N	076/24/12.356 W	-22.722

* Primary station

A complete description of horizontal and vertical control for survey H12044 can be found in the *OPR-E349-KR-09 Horizontal and Vertical Control Report*, submitted under separate cover. A summary of horizontal and vertical control for this survey follows:

C1. Vertical Control

The vertical datum for this project is Mean Lower-Low Water (MLLW). The operating National Water Level Observation Network (NWLON) primary water level stations at Windmill Point, Virginia (863-6580) and Lewisetta, Virginia (863-5750) served as control for datum determination and provided water level correctors for the project.

C2. Discussion of Tide Zoning

Tide zoning was included within the Tide and Water Level Instructions for OPR-E349-KR-2009. A modified version of the HIPS Zone Definition File (ZDF) *E349KR2009_RevisedCORP* provided by CO-OPS was used to apply zoned tides to the multibeam data. The modified file, named *E349KR2009_RevisedCORP*_1s, used a HIPS Interval value of 1 second rather than the default value of 360 seconds which was used in the file received by CO-OPS. The interval value controls the frequency of tide zoning interpolation. The default value of 360 seconds is too infrequent to properly correct for the assigned zoning boundaries, allowing the survey vessel to pass through a zone without a zoned tide corrector being applied. Assuming the vessel was not within the zone boundary for longer than 359 seconds. No modifications were made to zone boundaries or time and range correctors.

Table 7 includes the zoning information for each zone used for the survey.

Table 6. Tide Zones

Zone	Reference Station	Corrector (min.)	Ratio
SCB95	8636580	18	1.12
SCB96	8636580	18	1.29
SCB102	8636580	30	1.29
SCB103	8636580	30	1.12
SCB108	8636580	48	1.12
SCB109	8636580	48	1.29

It is difficult to associate a precise vertical error due to tides. However, this survey included the logging of GPS water levels and follow-on deliverables will include soundings reduced to chart datum from GPS observations. Errors observed are a composite from various sources such as measurement error, tides, heave, refraction, transducer draft, settlement and squat. In addition, there is a known frequency dependent offset between the R2Sonic 2024 at 200 kHz (*R/V Chinook*) and the Reson 7125 at 400 kHz (*R/V Theory*) which is not related to tides, but still manifests itself as a vertical offset when comparing overlapping data from the two survey vessels. Though vertical errors are still visible in the data, they are small and are generally ten centimeters. In some extreme cases errors approach 20 centimeters however this is well within the 20 centimeter to 45 centimeter maximum allowable error for tides and water levels. The largest contributing factor to water level errors in the Chesapeake Bay is meteorological influences which cannot be accounted for by zoning. The hydrographer strongly recommends the application of GPS tides to improve vertical accuracy when applying this survey to the nautical chart. ***Concur with clarification. Analysis at AHB shows that bathymetric data corrected with discrete zoned tides compares well to the ERS corrected grid. AHB chose to source bathymetric data corrected with discrete zoned tides as it was the official deliverable for survey H12044.***

C3. Horizontal Control

The horizontal datum for this project is NAD83. Differential GPS (DGPS) corrections were received from the U.S. Coast Guard (USCG) beacon at Driver, Virginia (301 kHz) or from the secondary beacon at Annapolis, MD (289 kHz). Some DGPS outages from the primary beacon occurred during operations. The system was set up to automatically switch to the secondary beacon when the primary signal was lost. All of the primary navigation data was collected in DGPS mode. Additionally, during acquisition GPS base stations were constructed and logged data simultaneously with acquisition to provide post-processed IAKAR navigation solutions.

Navigation and attitude data were post-processed using Applanix POSPac MMS software, which produced an IAKAR navigation solution relative to NAD83. The real-time navigation and attitude logged during acquisition was overwritten with post-processed data during HIPS processing. Post-processed navigation, attitude and GPS heights were applied to all HIPS data, though only the navigation and attitude were used in the creation of the survey deliverables. As discussed in the DAPR*, post-processed GPS heights were used to compute a GPS tide using utilizing an ellipsoid to MLLW separation file created using VDatum. Though present for each survey line GPS Tides were not applied to the survey data during the merge process (the Apply GPS Tides box was not checked during merge in CARIS HIPS, are for reference only, and should not be used. Further discussion on the computation of GPS tides and the creation of the separation model can be found in the pending *OPR-E349-KR-09 Ellipsoid Referenced Survey Deliverables.* ****Submitted with original field records.***