U.S. DEPARTMENT OF COMMERCE
NATIONAL OCEANIC AND ATMOSPHERIC ADMINISTRATION
NATIONAL OCEAN SERVICE

HORIZONTAL & VERTICAL CONTROL REPORT

Type of Survey: Navigable Area

Project Number: OPR-Y398-KR-23

Time Frame: July – October 2023

LOCALITY

State(s): Wisconsin
Illinois

General Locality: Southwestern Lake Michigan

2023

CHIEF OF PARTY

John R. Bean

LIBRARY & ARCHIVES

Date:

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A. TIME BASIS

Coordinated Universal Time (UTC) was used to annotate the tide records and all other data obtained for this project.

B. VERTICAL CONTROL

All soundings are referenced to Low Water Datum, International Great Lakes Datum of 1985 (LWD IGLD-85) using Ellipsoidally Referenced Survey (ERS) methods per the Project Instructions.

B.1 ERS Water Level Source Data

Inertially Aided Post Processed Kinematic (IAPPK) ellipsoid heights were computed using POSPac MMS, Applanix SmartBase (ASB) processing. The ellipsoid heights in the resulting Smoothed Best Estimate Trajectory (SBET) data were used as the basis for the development of ERS Water Level.

ASB processing was organized into POSPac projects by vessel and day. Figure 1 illustrates the locations of Continuously Operating Reference Stations (CORS) stations, Wisconsin Continuously Operating Reference Stations (WISCORS), and OSI's locally installed base station, OSKE, which all contributed to ASB processing. WISCORS stations were continuously monitored by Wisconsin's Department of Transportation and fell within Applanix Smartbase quality parameters and QC checks during ASB processing. The total number of stations occasionally varied from one POSPac project to the next (i.e. vessel-day) based on CORS and WISCORS data availability and solution quality. The table inset in Figure 1 shows the POSPac IAPPK project count for each station. The final coordinates of OSKE were determined using the NGS' Online Positioning User Service (OPUS).

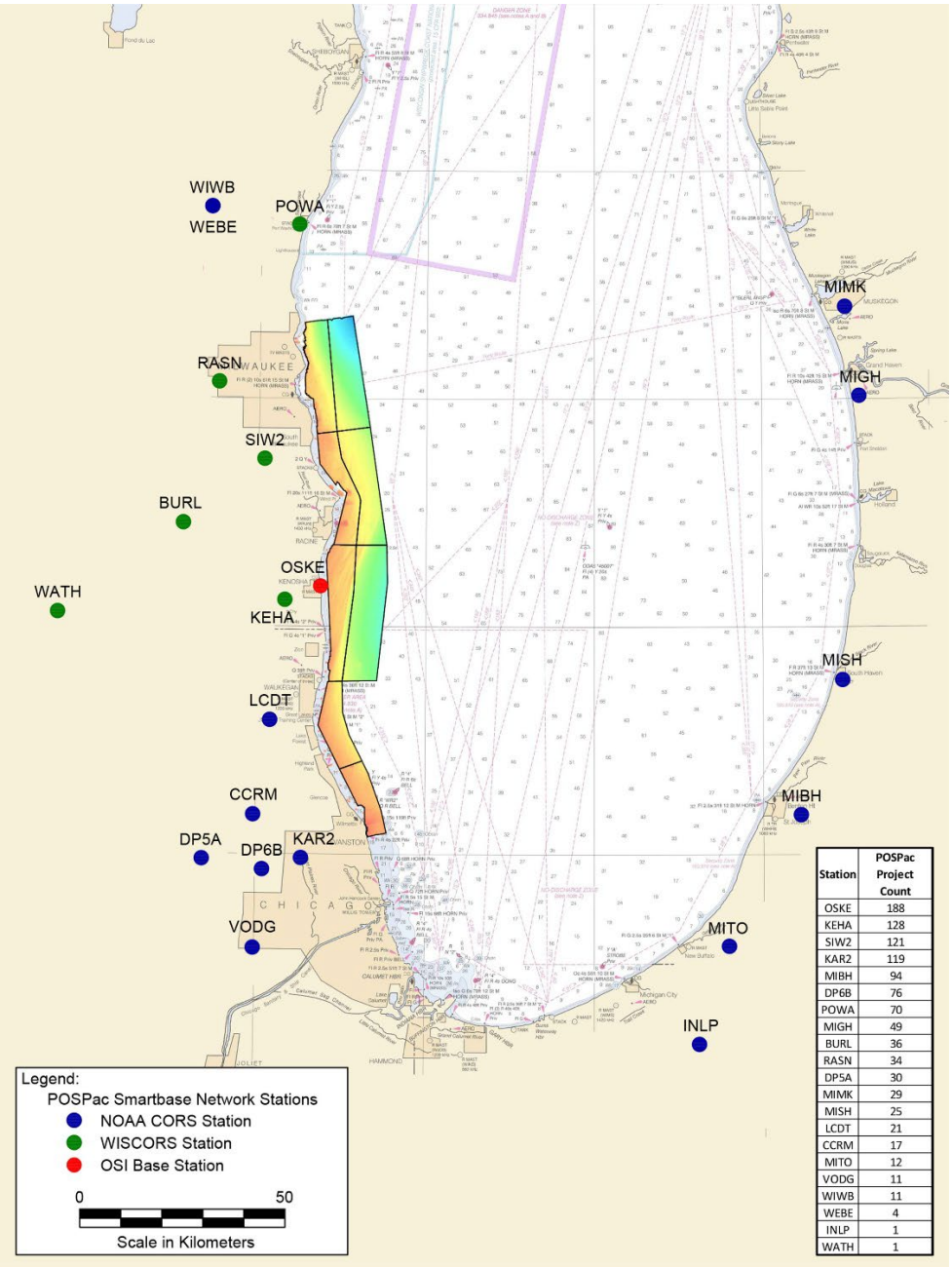
ERS water levels ("GPS Vertical Adjustments") were derived from SBET altitude with minimal intervention. When short periods of outlying altitude were present in the daily SBET, NOAA's POSPacAutoQC application was used to interpolate through and replace the outlying data.

B.2 VDatum Separation Model (SEP)

A VDatum Separation Model (SEP) was provided by NOAA with the original project files and described in the Project Instructions (Table 1).

Table 1

VDATUM Model				
VDatum Version	Geoid	Area	Area Version	Separation Uncertainty
4.1.2	2018	Southwestern Lake Michigan	2023.2	4.5 centimeters



Station	POSPac Project Count
OSKE	188
KEHA	128
SIW2	121
KAR2	119
MIBH	94
DP6B	76
POWA	70
MIGH	49
BURL	36
RASN	34
DP5A	30
MIMK	29
MISH	25
LCDT	21
CCRM	17
MITO	12
VODG	11
WIWB	11
WEBE	4
INLP	1
WATH	1

Figure 1. Local NOAA CORS, WISCORS, and "OSKE" in relation to the project site with corresponding station POSPac project counts.

B.3 Final Application of ERS Water Levels

For the final application of ERS water levels, the final processed SBET ellipsoid record was imported to CARIS. The CARIS "Compute GPS Vertical Adjustment" function was used in conjunction with the NOAA-provided SEP to apply LWD correctors to the soundings:

VDATUM_Coverage_100m_NAD83_2011-LWD_IGLD85_geoid18.csar

Qualitative and quantitative crossline analysis, as well as junction analysis, indicated that the final ERS correctors applied to reduce soundings to LWD were adequate for the purpose. The results of crossline and junction analysis are presented in the Descriptive Report (DR) for each survey.

B.4 GNSS Base Station "OSKE"

To supplement IAPPK SBET processing, OSI installed a temporary GNSS base station on a structure roof at O. Fred Nelson Water Production Plant, in Kenosha, WI (Figure 2). The installed station was designated "OSKE" [**O**cean **S**urveys **Ke**nosha] and consisted of a Trimble NetR9 GNSS receiver equipped with a Zephyr 3 Geodetic antenna (Model: TRM115000.00 None).

Figure 2. Ortho imagery and setup images of OSI's user-installed base station "OSKE" on the roof of the Kenosha Water Production Plant in Kenosha, WI.

The configuration of the NetR9 was based on UNAVCO standard configuration settings for this device. The NetR9 was configured to record GNSS observables continuously throughout the period of the survey and parse data observables into daily files for each 24-hour period. Data were delivered to OSI's home office processing center via regular automated FTP and e-mail "pushes." Pushes were transmitted over a network connection that was established on site for this purpose. Data were also saved to the receiver's internal storage as a backup.

The HSSD requires that: "*The integrity of the geodetic tie of non-NOAA CORS installations to the NSRS shall be verified at least once per week while the site is utilized for survey operations. Verification may be achieved by repeated OPUS sessions to demonstrate that the difference between adopted and check positions are within the error budget allotted per THU (Section 3.2).*"

OSI submitted all individual days of dual frequency GNSS observables (Rinex files) from OSKE to OPUS. Data were submitted with an ARP height of 0m. OSI used OPUS Projects (https://www.ngs.noaa.gov/OPUS-Projects/OpusProjects.shtml) for OPUS solution management, quality control, and to compute the final network-adjusted coordinates, which were then incorporated into ASB processing (Table 2). Processing steps and parameter selection were in accordance with the NGS-provided OPUS Projects Managers Training (required to obtain access to OPUS projects).

Table 2
OPUS Projects Network Adjusted Positions of OSKE

Time period	Latitude (NAD83-2011)	Longitude (NAD83-2011)	Ellipsoid Height (GRS80)
DN 199-278	42° 35’ 20.94543” N	87° 48’ 49.05267” W	162.671 m

Figure 3 shows a summary of the residuals for each of the daily OPUS solutions, and the improved residuals obtained with OPUS Projects session processing. The residuals are relative to the final network-adjusted position computed by OPUS Projects using all the solutions. The error bars on each point indicate the 1-sigma peak-to-peak root mean square (RMS) error estimate of the 3D position components, namely east, north, and ellipsoid height. The apparent offset in the mean position of the daily residuals and the final network-adjusted position is due to plate velocities as handled in OPUS Projects for the time span of the project. All processing was done in ITRF 2014; however, final network-adjusted coordinates are also provided by OPUS Projects in NAD 83 (2011) @ 2010.00 (i.e. Table 2).

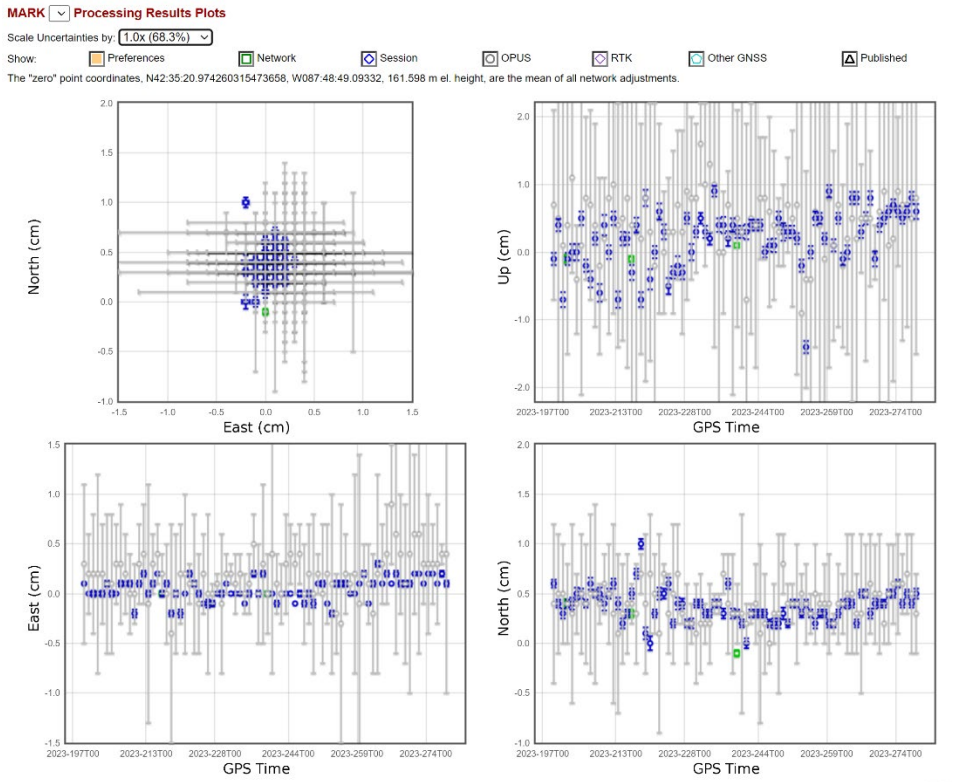


Figure 3. OPUS project coordinate residuals for GNSS observables at OSKE. OPUS solutions are in grey, improved OPUS Project session solutions are in blue. Error bars represent 1-sigma. Residuals are relative to the final network-adjusted and velocity corrected position (green) from OPUS Projects.

Individual OSKE OPUS Project results (OPUS solutions, sessions, and final network adjustment) are included in the HVCR digital deliverables.

C. HORIZONTAL CONTROL

C.1 Horizontal Datum

The horizontal datum for this project is the North American Datum of 1983 (NAD83). Horizontal coordinates are referenced to Latitude/Longitude and Universal Transverse Mercator (UTM) Zone 16N, in meters.

C.2 Horizontal Control

During the survey, the POSMV on all three survey vessels were configured to receive SBAS (FAA WAAS) correctors for real-time positioning. Real-time vessel navigation was replaced during post processing with ASB-derived SBET positioning and attitude. Final SBET positioning is referenced to NAD83 (2011).

Positioning system confidence checks for each vessel were accomplished at the start of survey and periodically thereafter. In practice, the distance between the vessel's reference point (RP) and the dockside horizontal control point as computed by the navigation system was compared to the tape-measured distance between the vessel RP and the horizontal control point. The RP of the *MV Northstar Challenger* is not readily accessible, therefore all measurements are referenced from the vessel's tracking point (TP), the sonar reference point of the RESON T50-R instead of the RP.

A temporary navigation confidence check point was installed on a bollard along the commercial dock at Waukegan, IL prior to calibrations and survey data acquisition (Figure 4). The purpose of this check point was to ensure that the survey vessels' positioning system was functioning properly before commencing data collection. The temporary point, "CDOCK1" was established in UTM Zone 16, meters using a single OPUS observation with a duration of approximately 4 hours.

Another temporary point was established at the *RV North Cove's* dock in Milwaukee at the McKinley Marina (Figure 5). The purpose of this point was to establish the vessel's positioning system was functioning properly after replacing system components (POS MV and RESON T50-R). Temporary point "McKinley Marina" was established using a rover system, a Trimble R10 GNSS interfaced with a TSC3 data collector. The rover system, programmed to receive real-time RTCM RTK corrections from the base station "OSKE", was verified by occupying nearby NGS survey disk "SHOREWOOD GPS" (PID DF9545). Once the rover system's accuracy was confirmed, it was used to install the temporary point at the vessel's dock at Mckinley Maraina in Milwaukee, WI. Five observations of 10 seconds each were collected by the rover system and these observations were averaged to get the X,Y coordinate for the temporary point "McKinley Marina."

The X,Y coordinates for both navigation confidence check points are presented in Table 3. The OPUS report for "CDCOK1" installation is included in the HVCR digital deliverables.

In all cases, dockside navigation system accuracy checks demonstrated an accuracy that was substantially better than 1.0 meter.

Table 3
Temporary Navigation Confidence Check Points

Designation	Easting UTM 16N, NAD83 (meters)	Northing UTM 16N, NAD83 (meters)	Locale	For Survey Vessel
CDOCK1	432,177.93	4,690,392.26	Waukegan, IL	*MV Northstar Challenger, RV North Cove, RV South Cove*
McKinley Marina	427,574.69	4,766,529.14	Milwaukee, WI	*RV North Cove*

Figure 4. “CDOCK1” is the center of a small yellow bollard along the Commercial Dock in Waukegan, IL.

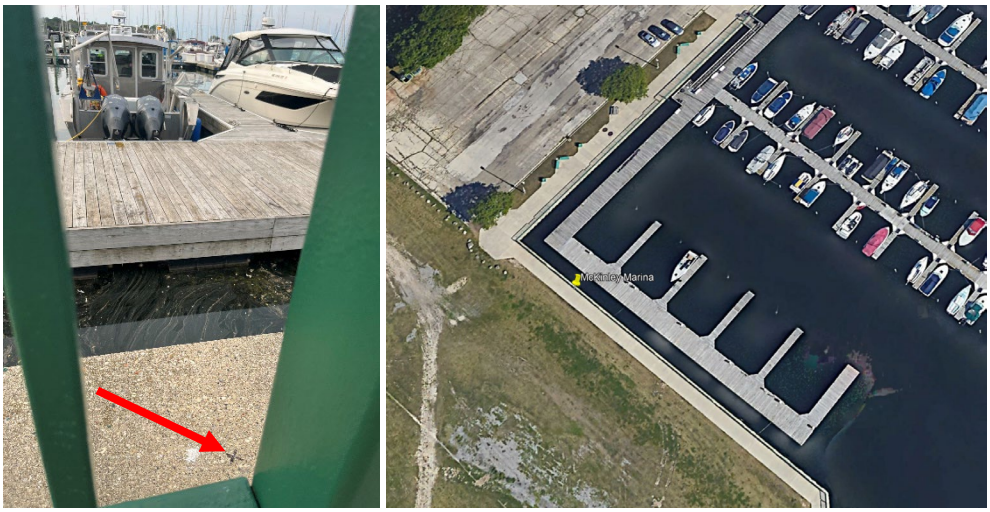


Figure 5. “McKinley Marina” is a point marked by permanent black paint in the concrete cap of the bulkhead in the southwest corner of the Center Docks at McKinley Marina in Milwaukee, WI.

Navigation system confidence checks for each vessel are included below in Table 4 through Table 6.

Table 4

MV Northstar Challenger Tabulation of Navigation System Confidence Checks

Date	Time UTC	Nav. Check-point	DGNSS Corr. Source	Observed Easting UTM 16N, NAD83 (meters)	Observed Northing UTM 16N, NAD83 (meters)	Calculated Distance TP to Nav. Checkpoint (meters)	Tape Measure TP to Nav. Checkpoint (meters)	Difference Calculated vs. Tape Measured (meters)
08/04/2023 (216)	12:11	CDOCK1	WAAS	432,186.95	4,690,404.57	15.26	14.90	0.36
08/26/2023 (238)	20:53	CDOCK1	WAAS	432,187.24	4,690,411.37	21.26	21.35	0.09
08/31/2023 (241)	10:33	CDOCK1	WAAS	432,187.31	4,690,413.42	23.15	22.31	0.84
09/20/2023 (263)	04:28	CDOCK1	WAAS	432,186.87	4,690,408.14	18.22	17.95	0.27

Table 5
RV North Cove Tabulation of Navigation System Confidence Checks

Date	Time UTC	Nav. Check-point	DGNSS Corr. Source	Observed Easting UTM 16N, NAD83 (meters)	Observed Northing UTM 16N, NAD83 (meters)	Calculated Distance RP to Nav. Checkpoint (meters)	Tape Measure RP to Nav. Checkpoint (meters)	Difference Calculated vs. Tape Measured (meters)
07/16/2023 (197)	15:49	CDOCK1	WAAS	432,180.71	4,690,396.58	5.14	5.45	0.31
07/19/2023 (194)	11:22	CDOCK1	WAAS	432,180.81	4,690,397.95	6.38	6.81	0.43
*08/07/2023 (219)	19:23	McKinley Marina	WAAS	427,583.73	4,766,539.85	14.01	14.04	0.03

* Navigation System Confidence Check after replacement POS MV installation

Table 6
RV South Cove Tabulation of Navigation System Confidence Checks

Date	Time UTC	Nav. Check-point	DGNSS Corr. Source	Observed Easting UTM 16N, NAD83 (meters)	Observed Northing UTM 16N, NAD83 (meters)	Calculated Distance RP to Nav. Checkpoint (meters)	Tape Measure RP to Nav. Checkpoint (meters)	Difference Calculated vs. Tape Measured (meters)
07/15/2023 (196)	19:00	CDOCK1	WAAS	432,177.93	4,690,392.26	4.67	5.45	0.28

D. APPROVAL SHEET

This report and the accompanying data are respectfully submitted.

Field operations contributing to the accomplishment of Surveys H13808, H13809, H13810, H13811, H13812, H13813, H13814, and H13815 were conducted under my direct supervision with frequent personal checks of progress and adequacy. This report and associated data have been closely reviewed and are considered complete and adequate as per the Statement of Work.

Approver Name	Approver Title	Approval Date	Signature
John R. Bean	Chief of Party	04/04/2024	Digitally signed by John R. Bean
David T. Somers	Data Processing Manager	04/04/2024	Digitally signed by David T. Somers