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

HORIZONTAL & VERTICAL CONTROL REPORT

Type of Survey:	Hydrographic Survey
Project Number:	OPR-K379-KR-19
Time Frame:	April - August 2019

LOCALITY

State:	Texas
General Locality:	Gulf of Mexico
Sub-locality:	Corpus Christi, TX & Approaches

2019

CHIEF OF PARTY

John R. Bean

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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

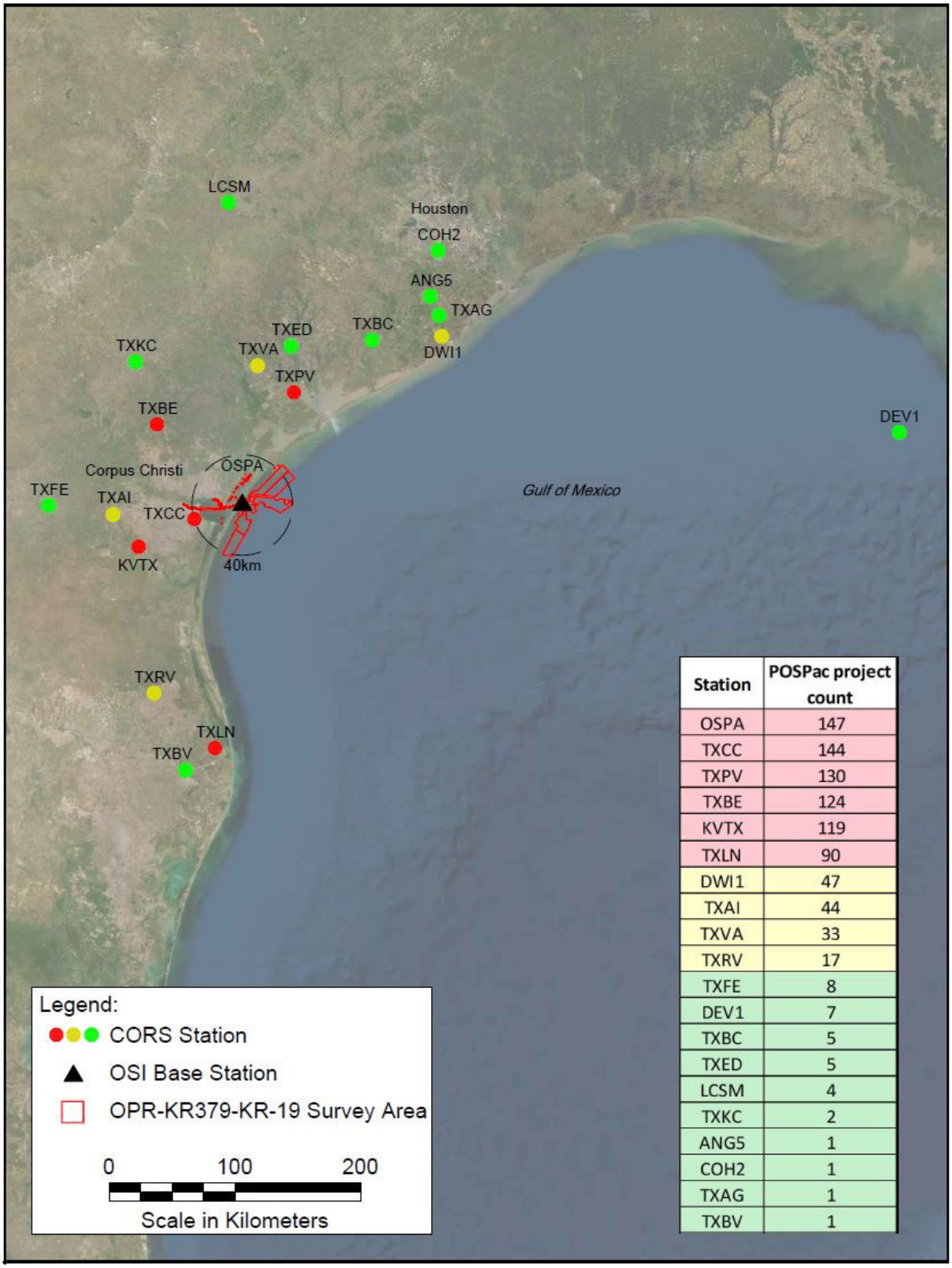
All soundings are referenced to Mean Lower Low Water (MLLW) using Ellipsoidally Referenced Survey (ERS) methods per the Project Instructions..

B.1 ERS Tide 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 Tide.

ASB processing was organized into POSPac projects by vessel and by day. A network including "primary" CORS stations and OSPA (see section B.5) served as the starting point for ASB processing. Stations were occasionally replaced or added to the network from one POSPac project to the next (i.e. vessel-day) based on CORS data availability and solution quality. The inset table on Figure 1 shows the POSPac IAPPK project count for each station. OSPA was used in all solutions.

SBET altitude corrected for heave, dynamic draft, and static draft was reviewed graphically in MATLAB and compared to local NOAA tide gauge water levels for trend and general agreement. If invalid or poor-quality altitude data were contained in the daily SBET, additional CORS stations were added to the ASB network and reprocessed to create an improved SBET. As a final step, NOAA's POSPacAutoQC application was used to interpolate through and replace any short time periods of bad data that remained.



Station	POSPac project count
OSPA	147
TXCC	144
TXPV	130
TXBE	124
KVTX	119
TXLN	90
DWI1	47
TXAI	44
TXVA	33
TXRV	17
TXFE	8
DEV1	7
TXBC	5
TXED	5
LCSM	4
TXKC	2
ANG5	1
COH2	1
TXAG	1
TXBV	1

Figure 1. CORS stations (along with OSPA) used in ASB SBET solutions supporting Project OPR-K379-KR-19.

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
3.6.1	2012	Composite of Texas Regional Grids	1	9.8 centimeters

B.3 ERS Tide Smoothing

ASB derived ERS tides were smoothed prior to inclusion in the data reduction process.

I. ERS MLLW Tide Smoothing Steps:

1) Create and export final SBETs.
2) Smooth SBETs using MATLAB,
    - Convert SBET altitude to a NAVD 88 tide by removing the following components of the SBET altitude:
        - Static draft based on time
        - Dynamic draft based on speed
        - Delayed heave based on time
        - SEP based on position
    - Smooth NAVD 88 tide with a 4th order low pass filter
    - Export smoothed SBETs after re-applying the above components
3) Import smoothed SBETs in CARIS HIPS
4) Run CARIS HIPS "Compute GPS Tides" with the provided SEP

II. ERS Smoothed Tide Curve QA/QC:

Graphical analysis was the primary QA/QC tool used during the development phase of the ERS smoothing routine described above. MATLAB graphs were generated for all conversion and correction steps to identify erroneous source data or MATLAB program code.

III. Choice of Smoothing Parameters:

Combined SBETs were smoothed with a 4th order Butterworth low pass filter using MATLAB's "filtfilt" function, which runs the filter in forward and reverse, resulting in a zero-lag solution.

When choosing the smoothing method to apply, OSI considered a number of approaches: those used by OSI on prior NOAA contract surveys (see OPR-K354-KR-18), those used by JOA Surveys (on behalf of OSI for a prior NOAA contract survey), and new approaches developed by OSI data analysts.

To determine the best smoothing parameter settings, the final SBETs were smoothed, converted to ERS tides and applied to the soundings using each of the following smoothing methods:

- 1, 5, and 10 minute averages
- 0.5, 1, 2, 3, 4, 5, and 6 hour low pass filters

Statistical comparisons were made of crossline and mainscheme difference data generated by CARIS HIPS. Standard deviation surfaces at intersections were reviewed, and the smoothed ERS tide was compared to local NOAA tide gauges and evaluated for trends and general agreement.

As a result of this iterative comparative analysis, a 4th order Butterworth low pass filter with a 0.5-hour cutoff frequency (i.e. 48-cycles per day) was chosen to smooth ERS tides.

B.4 Final Application of ERS Tides

For the final application of ERS tides, the final tide-smoothed SBET ellipsoid record was imported to CARIS. The CARIS "Compute GPS Tides" function was used in conjunction with the NOAA-provided SEP (buff_xyNAD83-MLLW_geoid12b.csar) to apply MLLW tide correctors to the soundings.

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

B.5 GNSS Base Station "OSPA"

To supplement IAPPK SBET processing, OSI installed a temporary GNSS base station on the roof of the University of Texas Marine Sciences Institute in Port Aransas, TX (Figure 2). The installed station was designated "OSPA" (Ocean Surveys Port Aransas) and consisted of a Trimble NetR9 GNSS receiver equipped with a Zephyr 3 Geodetic antenna (Model: TRM115000.00 None).

Figure 2. The local setting of OSI's temporary GNSS base station "OSPA."

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 receivers to internal storage as a backup.

Table 2
126-Day OPUS Projects Network Adjusted Position of OSPA

Latitude (NAD83-2011)	Longitude (NAD83-2011)	Ellipsoid Height (GRS80)
27° 50' 11.34879" N	097° 03' 08.57020" W	-11.981m

The HSSD requires "*The reference position of non-CORS antenna installations shall be verified at least once per week while the site is utilized for survey operations.*" OSI submitted 126 individual days of dual frequency GNSS observables (Rinex files) from OSPA to the NGS Online Positioning Users Service (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 in order to obtain access to OPUS projects).

Figure 3 shows a summary of the residuals for each of the 126 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 of the solutions. The error bars on each point indicate the 1-sigma peak-to-peak root mean square (RMS) error estimate of the 3-D position components. The offset in the apparent 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 (Table 2).

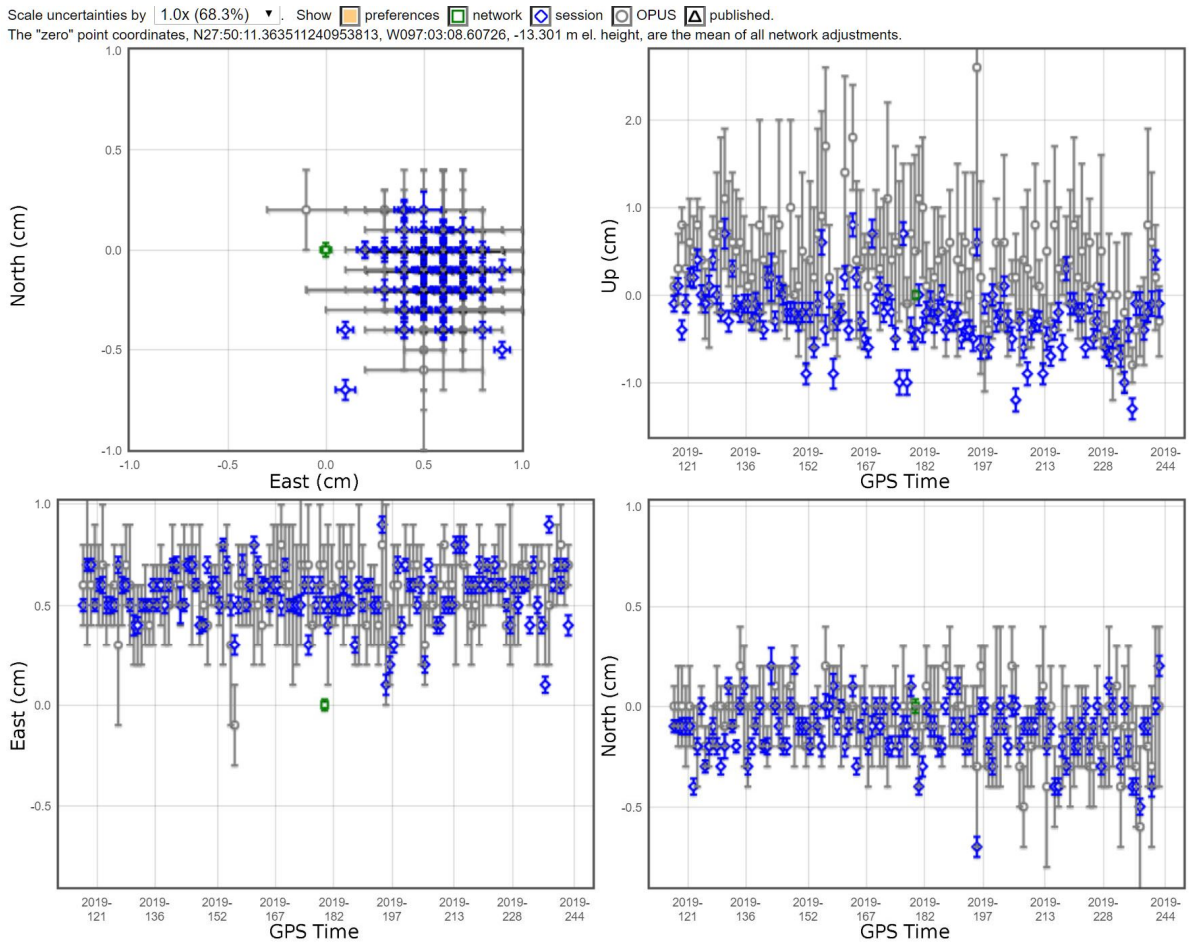


Figure 3. OPUS project coordinate residuals for all 126 days of GNSS observables at OSPA. OPUS solutions are in grey, improved OPUS Project session solutions are in blue. Error bars represent 1-sigma. Residuals are relative to the final network-adjusted and velocity corrected position (green) from OPUS Projects.

Individual OSPA 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 were reported in Latitude and Longitude and in Universal Transverse Mercator (UTM) Zone 14, in meters. The assigned project boundary falls entirely within UTM Zone 14.

C.2 Horizontal Control

Real-time vessel navigation was replaced during post-processing with Applanix SmartBase (ASB)-derived SBET positioning and attitude. Final SBET positioning is referenced to NAD83 (2011).

During the survey, the POSMV on the *R/V Ocean Explorer* received real-time correctors from Fugro's MarineStar corrections service. The POSMV on the *R/V H.F. Stout* received real-time CMR+ RTK correctors from OSPA via a cellular NTRIP stream.

Positioning system confidence checks for each vessel were performed at the start of the project 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.

Temporary navigation confidence check points were installed with a validated RTK-GPS Rover near each vessel's dock (Table 3). The RTK Rover received correctors from OSPA and was validated against local NSRS control by comparing the rover-reported position with the published position of the NSRS points (Table 4). Data sheets for the NSRS control used to validate the RTK Rover are included in the HVCR digital deliverables.

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

Vessel positions and distance measurements for each "nav check" were recorded in the acquisition log and are included here in Tables 5 and 6 and in Appendix IV of the DAPR.

Table 3
Temporary Navigation Confidence Check Points

Designation	RTK Derived Easting UTM 15N, NAD83 (meters)	RTK Derived Northing UTM 15N, NAD83 (meters)	Locale	For Survey Vessel
OSPA Pile-3	690912.80	3081033.28	Port Aransas	R/V Ocean Explorer
OSPA Pile-4	690901.27	3081025.26	Port Aransas	R/V Ocean Explorer
OSPA2-adj	690893.19	3081070.97	Port Aransas	R/V H.F. Stout
OSCC1	658709.46	3075400.97	Corpus Christi	R/V H.F. Stout

Table 4
RTK Rover Validation

Date	Time UTC	NSRS Point	PID	Published Easting UTM 15N, NAD83 (meters)	Published Northing UTM 15N, NAD83 (meters)	RTK Rover Reported XY Delta (m)	Locale
04/27/19 (DN 117)	22:58	877 5237 TIDAL 2	AC8428	689792.005	3080903.754	0.03	Port Aransas
04/27/19 (DN 117)	23:11	877 5351 9002 F	DP0725	658726.953	3075272.218	0.02	Corpus Christi

Table 5
***R/V Ocean Explorer* Tabulation of Navigation System Confidence Checks**

Date	Time UTC	Nav. Check-point	DGNSS Corr. Source	Observed Easting UTM 15N, NAD83 (meters)	Observed Northing UTM 15N, NAD83 (meters)	Calculated Distance RP to Nav. Checkpoint (meters)	Tape Measure RP to Nav. Checkpoint (meters)	Difference Calculated vs. Tape Measured (meters)
05/12/19 (DN 132)	13:55	OSPA Pile-4	Marine-star	690,910.2	3,081,025.1	8.9	8.8	0.1
05/13/19 (DN 133)	12:22	OSPA Pile-4	Marine-star	690,909.8	3,081,024.9	8.5	8.7	0.2
05/13/19 (DN 133)	23:25	OSPA Pile-4	Marine-star	690,913.0	3,081,028.2	12.1	12.3	0.2
05/14/19 (DN 134)	12:20	OSPA Pile-4	Marine-star	690,913.0	3,081,028.1	12.0	12.2	0.2
05/15/19 (DN 135)	00:17	OSPA Pile-3	Marine-star	690,912.9	3,081,028.1	5.2	5.2	0.0
05/15/19 (DN 135)	21:24	OSPA Pile-3	Marine-star	690,913.7	3,081,028.7	4.7	4.8	0.1
05/17/19 (DN 137)	11:41	OSPA Pile-3	Marine-star	690,913.5	3,081,028.5	4.8	4.8	0.0
05/18/19 (DN 138)	01:09	OSPA Pile-3	Marine-star	690,913.7	3,081,028.7	4.7	4.7	0.0
05/20/19 (DN 140)	03:24	OSPA Pile-3	Marine-star	690,913.5	3,081,028.5	4.8	4.8	0.0
05/30/19 (DN 150)	11:28	OSPA Pile-3	Marine-star	690,913.6	3,081,028.5	4.9	4.9	0.0
06/04/19 (DN 155)	05:28	OSPA Pile-3	Marine-star	690,913.3	3,081,028.2	5.1	5.2	0.1
06/04/19 (DN 155)	17:42	OSPA Pile-3	Marine-star	690,913.5	3,081,028.5	4.8	4.8	0.0
06/07/19 (DN 158)	04:27	OSPA Pile-3	Marine-star	690,913.6	3,081,028.5	4.9	5.0	0.1
06/11/19 (DN 162)	23:36	OSPA Pile-3	Marine-star	690,913.4	3,081,028.3	5.0	4.9	0.1

Date	Time UTC	Nav. Check-point	DGNSS Corr. Source	Observed Easting UTM 15N, NAD83 (meters)	Observed Northing UTM 15N, NAD83 (meters)	Calculated Distance RP to Nav. Checkpoint (meters)	Tape Measure RP to Nav. Checkpoint (meters)	Difference Calculated vs. Tape Measured (meters)
06/15/19 (DN 166)	01:51	OSPA Pile-3	Marine-star	690,913.6	3,081,028.3	5.0	4.9	0.1
06/18/19 (DN 169)	01:02	OSPA Pile-3	Marine-star	690,913.8	3,081,028.5	4.9	4.9	0.0
06/19/19 (DN 170)	12:10	OSPA Pile-3	Marine-star	690,913.6	3,081,028.5	4.9	4.9	0.0
06/26/19 (DN 177)	04:19	OSPA Pile-3	Marine-star	690,913.4	3,081,028.3	5.0	4.9	0.1
07/02/19 (DN 183)	02:31	OSPA Pile-3	Marine-star	690,913.3	3,081,028.2	5.2	5.0	0.2
07/10/19 (DN 191)	05:05	OSPA Pile-3	Marine-star	690,913.9	3,081,028.7	4.7	4.7	0.0
07/17/19 (DN 198)	11:36	OSPA Pile-3	Marine-star	690,913.4	3,081,028.4	4.9	4.9	0.0
07/21/19 (DN 202)	02:53	OSPA Pile-3	Marine-star	690,913.4	3,081,028.2	5.1	4.9	0.2
07/24/19 (DN 205)	13:57	OSPA Pile-3	Marine-star	690,913.6	3,081,028.4	4.9	5.0	0.1
07/28/19 (DN 209)	01:05	OSPA Pile-3	Marine-star	690,913.7	3,081,028.5	4.8	4.9	0.1
07/31/19 (DN 212)	02:44	OSPA Pile-3	Marine-star	690,913.6	3,081,028.5	4.9	4.8	0.1
07/31/19 (DN 212)	11:00	OSPA Pile-3	Marine-star	690,913.7	3,081,028.6	4.8	4.8	0.0
08/10/19 (DN 222)	16:23	OSPA Pile-3	Marine-star	690,913.2	3,081,028.3	5.0	5.1	0.1
08/11/19 (DN 223)	12:27	OSPA Pile-3	Marine-star	690,913.9	3,081,028.4	5.0	5.0	0.0
08/12/19 (DN 224)	00:52	OSPA Pile-3	Marine-star	690,913.5	3,081,028.4	5.0	5.0	0.0
08/12/19 (DN 224)	13:39	OSPA Pile-3	Marine-star	690,913.6	3,081,028.4	4.9	4.9	0.0

Date	Time UTC	Nav. Check-point	DGNSS Corr. Source	Observed Easting UTM 15N, NAD83 (meters)	Observed Northing UTM 15N, NAD83 (meters)	Calculated Distance RP to Nav. Checkpoint (meters)	Tape Measure RP to Nav. Checkpoint (meters)	Difference Calculated vs. Tape Measured (meters)
08/13/19 (DN 225)	01:15	OSPA Pile-3	Marine-star	690,913.5	3,081,028.4	5.0	4.9	0.1
08/13/19 (DN 225)	13:17	OSPA Pile-3	Marine-star	690,913.6	3,081,028.5	4.9	5.0	0.1
08/13/19 (DN 225)	19:07	OSPA Pile-3	Marine-star	690,913.7	3,081,028.5	4.8	4.9	0.1
08/14/19 (DN 226)	12:46	OSPA Pile-3	Marine-star	690,913.7	3,081,028.5	4.9	5.0	0.1
08/20/19 (DN 232)	12:08	OSPA Pile-3	Marine-star	690,913.4	3,081,028.3	5.0	5.1	0.1
08/28/19 (DN 240)	02:50	OSPA Pile-3	Marine-star	690,912.9	3,081,028.1	5.2	5.1	0.1
08/30/19 (DN 242)	17:50	OSPA Pile-3	Marine-star	690,913.2	3,081,028.1	5.2	5.2	0.0

Table 6
***R/V H.F. Stout* Tabulation of Navigation System Confidence Checks**

Date	Time UTC	Nav. Check-point	DGNSS Corr. source	Observed Easting UTM 15N, NAD83 (meters)	Observed Northing UTM 15N, NAD83 (meters)	Calculated Distance RP to Nav. Checkpoint (meters)	Tape Measure RP to Nav. Checkpoint (meters)	Difference Calculated vs. Tape Measured (meters)
04/27/19 (DN 117)	20:47	OSPA2 -adj	RTK	690,889.93	3,081,069.96	3.36	3.35	0.01
04/28/19 (DN 118)	15:57	OSPA2 -adj	RTK	690,889.90	3,081,070.22	3.37	3.33	0.04
04/28/19 (DN 118)	23:45	OSPA2 -adj	RTK	690,889.55	3,081,069.90	3.79	3.74	0.05
04/29/19 (DN 119)	13:38	OSPA2 -adj	RTK	690,889.56	3,081,069.93	3.78	3.75	0.03
04/29/19 (DN 119)	23:15	OSPA2 -adj	RTK	690,890.09	3,081,070.10	3.22	3.20	0.02
05/01/19 (DN 121)	13:45	OSPA2 -adj	RTK	690,889.88	3,081,070.17	3.41	3.44	0.03
05/01/19 (DN 121)	21:03	OSPA2 -adj	RTK	690,889.56	3,081,070.02	3.75	3.75	0.00
05/02/19 (DN 122)	12:25	OSPA2 -adj	RTK	690,889.53	3,081,069.99	3.79	3.79	0.00
05/02/19 (DN 122)	20:13	OSPA2 -adj	RTK	690,889.30	3,081,070.07	3.99	4.02	0.03
05/03/19 (DN 123)	17:17	OSPA2 -adj	RTK	690,889.28	3,081,070.03	4.02	3.95	0.07
05/03/19 (DN 123)	23:01	OSCC1	RTK	658,704.96	3,075,398.21	5.28	5.25	0.03
05/04/19 (DN 124)	12:16	OSCC1	RTK	658,705.24	3,075,397.91	5.21	5.20	0.01
05/04/19 (DN 124)	23:44	OSCC1	RTK	658,705.10	3,075,398.19	5.17	5.07	0.10
05/05/19 (DN 125)	12:45	OSCC1	RTK	658,705.28	3,075,398.05	5.10	5.12	0.02

Date	Time UTC	Nav. Check-point	DGNSS Corr. source	Observed Easting UTM 15N, NAD83 (meters)	Observed Northing UTM 15N, NAD83 (meters)	Calculated Distance RP to Nav. Checkpoint (meters)	Tape Measure RP to Nav. Checkpoint (meters)	Difference Calculated vs. Tape Measured (meters)
05/05/19 (DN 125)	22:16	OSCC1	RTK	658,705.09	3,075,398.17	5.19	5.14	0.05
05/06/19 (DN 126)	12:57	OSCC1	RTK	658,705.06	3,075,397.99	5.31	5.28	0.03
05/07/19 (DN 127)	11:42	OSCC1	RTK	658,704.98	3,075,398.30	5.22	5.25	0.03
05/07/19 (DN 127)	22:20	OSCC1	RTK	658,705.11	3,075,398.25	5.13	5.15	0.02
05/08/19 (DN 128)	11:41	OSCC1	RTK	658,704.84	3,075,398.34	5.32	5.35	0.03
05/08/19 (DN 128)	23:46	OSCC1	RTK	658,705.17	3,075,398.08	5.17	5.15	0.02
05/09/19 (DN 129)	12:10	OSCC1	RTK	658,705.01	3,075,398.18	5.25	5.23	0.02
05/09/19 (DN 129)	23:01	OSCC1	RTK	658,705.22	3,075,398.17	5.08	5.18	0.10
05/11/19 (DN 131)	12:55	OSCC1	RTK	658,705.28	3,075,398.05	5.10	5.12	0.02
05/11/19 (DN 131)	22:38	OSCC1	RTK	658,705.30	3,075,397.94	5.15	5.15	0.00
05/12/19 (DN 132)	12:25	OSCC1	RTK	658,705.28	3,075,397.85	5.22	5.20	0.02
05/12/19 (DN 132)	23:12	OSCC1	RTK	658,705.25	3,075,398.06	5.12	5.13	0.01
05/13/19 (DN 133)	11:48	OSCC1	RTK	658,705.20	3,075,397.98	5.20	5.20	0.00
05/13/19 (DN 133)	22:26	OSCC1	RTK	658,705.15	3,075,398.20	5.12	5.15	0.03
05/14/19 (DN 134)	11:51	OSCC1	RTK	658,705.15	3,075,398.01	5.23	5.21	0.02
05/14/19 (DN 134)	23:31	OSCC1	RTK	658,705.16	3,075,398.24	5.09	5.10	0.01

Date	Time UTC	Nav. Check-point	DGNSS Corr. source	Observed Easting UTM 15N, NAD83 (meters)	Observed Northing UTM 15N, NAD83 (meters)	Calculated Distance RP to Nav. Checkpoint (meters)	Tape Measure RP to Nav. Checkpoint (meters)	Difference Calculated vs. Tape Measured (meters)
05/15/19 (DN 135)	12:00	OSCC1	RTK	658,705.22	3,075,398.16	5.09	5.08	0.01
05/15/19 (DN 135)	23:57	OSCC1	RTK	658,705.03	3,075,398.16	5.25	5.25	0.00
05/16/19 (DN 136)	12:20	OSCC1	RTK	658,705.27	3,075,398.29	4.97	4.96	0.01
05/16/19 (DN 136)	19:38	OSCC1	RTK	658,705.18	3,075,398.16	5.12	5.10	0.02
05/16/19 (DN 136)	22:21	OSPA2 -adj	RTK	690,890.47	3,081,070.35	2.79	2.80	0.01
05/17/19 (DN 137)	11:45	OSPA2 -adj	RTK	690,890.47	3,081,070.33	2.79	2.80	0.01
05/17/19 (DN 137)	22:12	OSPA2 -adj	RTK	690,891.08	3,081,070.54	2.15	2.16	0.01
05/19/19 (DN 139)	12:09	OSPA2 -adj	RTK	690,890.11	3,081,070.02	3.22	3.22	0.00
05/19/19 (DN 139)	22:11	OSPA2 -adj	RTK	690,890.41	3,081,070.19	2.89	2.88	0.01
05/20/19 (DN 140)	12:01	OSPA2 -adj	RTK	690,890.42	3,081,070.20	2.87	2.88	0.01
05/20/19 (DN 140)	16:58	OSPA2 -adj	RTK	690,890.35	3,081,070.14	2.96	2.95	0.01
05/23/19 (DN 143)	13:59	OSPA2 -adj	RTK	690,890.27	3,081,070.24	3.01	3.00	0.01
05/23/19 (DN 143)	21:12	OSPA2 -adj	RTK	690,889.99	3,081,069.80	3.41	3.40	0.01
05/24/19 (DN 144)	12:54	OSPA2 -adj	RTK	690,889.98	3,081,069.83	3.41	3.40	0.01
05/24/19 (DN 144)	17:14	OSPA2 -adj	RTK	690,890.23	3,081,070.02	3.11	3.10	0.01
05/25/19 (DN 145)	12:35	OSPA2 -adj	RTK	690,890.12	3,081,070.03	3.21	3.20	0.01

Date	Time UTC	Nav. Check-point	DGNSS Corr. source	Observed Easting UTM 15N, NAD83 (meters)	Observed Northing UTM 15N, NAD83 (meters)	Calculated Distance RP to Nav. Checkpoint (meters)	Tape Measure RP to Nav. Checkpoint (meters)	Difference Calculated vs. Tape Measured (meters)
05/25/19 (DN 145)	22:08	OSPA2 -adj	RTK	690,889.89	3,081,069.76	3.51	3.50	0.01
05/26/19 (DN 146)	12:53	OSPA2 -adj	RTK	690,889.87	3,081,069.78	3.53	3.53	0.00
05/26/19 (DN 146)	22:39	OSPA2 -adj	RTK	690,890.15	3,081,070.02	3.18	3.18	0.00
05/27/19 (DN 147)	12:09	OSPA2 -adj	RTK	690,889.98	3,081,069.82	3.41	3.40	0.01
05/27/19 (DN 147)	21:52	OSPA2 -adj	RTK	690,890.02	3,081,069.87	3.36	3.36	0.00
05/30/19 (DN 150)	12:33	OSPA2 -adj	RTK	690,889.90	3,081,070.15	3.39	3.41	0.02
05/30/19 (DN 150)	23:28	OSPA2 -adj	RTK	690,889.76	3,081,069.94	3.58	3.58	0.00
05/31/19 (DN 151)	12:18	OSPA2 -adj	RTK	690,889.82	3,081,069.88	3.54	3.56	0.02
05/31/19 (DN 151)	22:31	OSPA2 -adj	RTK	690,889.74	3,081,069.72	3.67	3.70	0.03
06/01/19 (DN 152)	15:25	OSPA2 -adj	RTK	690,889.63	3,081,069.87	3.73	3.72	0.01
06/02/19 (DN 153)	00:09	OSPA2 -adj	RTK	690,890.06	3,081,070.01	3.27	3.27	0.00
06/02/19 (DN 153)	11:55	OSPA2 -adj	RTK	690,890.05	3,081,070.03	3.28	3.24	0.04
06/02/19 (DN 153)	23:01	OSPA2 -adj	RTK	690,890.24	3,081,070.09	3.08	3.10	0.02
06/03/19 (DN 154)	11:24	OSPA2 -adj	RTK	690,890.18	3,081,070.01	3.16	3.11	0.05
06/03/19 (DN 154)	22:32	OSPA2 -adj	RTK	690,890.50	3,081,070.25	2.78	2.80	0.02
06/04/19 (DN 155)	11:54	OSPA2 -adj	RTK	690,890.47	3,081,070.22	2.82	2.82	0.00

Date	Time UTC	Nav. Check-point	DGNSS Corr. source	Observed Easting UTM 15N, NAD83 (meters)	Observed Northing UTM 15N, NAD83 (meters)	Calculated Distance RP to Nav. Checkpoint (meters)	Tape Measure RP to Nav. Checkpoint (meters)	Difference Calculated vs. Tape Measured (meters)
06/04/19 (DN 155)	20:08	OSPA2 -adj	RTK	690,890.05	3,081,070.11	3.26	3.28	0.02
06/05/19 (DN 156)	15:46	OSPA2 -adj	RTK	690,890.18	3,081,070.01	3.16	3.18	0.02
06/05/19 (DN 156)	23:44	OSPA2 -adj	RTK	690,890.26	3,081,070.13	3.05	3.05	0.00
06/06/19 (DN 157)	11:30	OSPA2 -adj	RTK	690,890.26	3,081,070.14	3.05	3.08	0.03
06/06/19 (DN 157)	23:16	OSPA2 -adj	RTK	690,890.28	3,081,070.13	3.03	3.05	0.02
06/07/19 (DN 158)	11:32	OSPA2 -adj	RTK	690,890.29	3,081,070.11	3.02	3.04	0.02
06/07/19 (DN 158)	23:42	OSPA2 -adj	RTK	690,890.20	3,081,070.13	3.11	3.14	0.03
06/08/19 (DN 159)	11:37	OSPA2 -adj	RTK	690,890.20	3,081,070.12	3.11	3.13	0.02
06/08/19 (DN 159)	22:30	OSPA2 -adj	RTK	690,890.15	3,081,070.11	3.16	3.15	0.01
06/09/19 (DN 160)	11:30	OSPA2 -adj	RTK	690,890.15	3,081,070.06	3.17	3.20	0.03
06/09/19 (DN 160)	23:00	OSPA2 -adj	RTK	690,890.48	3,081,070.19	2.82	2.76	0.06
06/10/19 (DN 161)	12:13	OSPA2 -adj	RTK	690,890.50	3,081,070.16	2.81	2.80	0.01
06/10/19 (DN 161)	22:42	OSPA2 -adj	RTK	690,890.22	3,081,070.15	3.08	3.11	0.03
06/11/19 (DN 162)	11:56	OSPA2 -adj	RTK	690,890.16	3,081,070.14	3.14	3.17	0.03
06/11/19 (DN 162)	21:55	OSPA2 -adj	RTK	690,890.26	3,081,070.13	3.05	3.05	0.00
06/12/19 (DN 163)	11:49	OSPA2 -adj	RTK	690,890.27	3,081,070.09	3.05	3.10	0.05

Date	Time UTC	Nav. Check-point	DGNSS Corr. source	Observed Easting UTM 15N, NAD83 (meters)	Observed Northing UTM 15N, NAD83 (meters)	Calculated Distance RP to Nav. Checkpoint (meters)	Tape Measure RP to Nav. Checkpoint (meters)	Difference Calculated vs. Tape Measured (meters)
06/12/19 (DN 163)	23:00	OSPA2 -adj	RTK	690,890.30	3,081,070.16	3.00	3.00	0.00
06/27/19 (DN 178)	12:18	OSPA2 -adj	RTK	690,889.90	3,081,070.10	3.40	3.35	0.05
06/27/19 (DN 178)	23:03	OSPA2 -adj	RTK	690,889.90	3,081,070.10	3.40	3.43	0.03
06/28/19 (DN 179)	11:44	OSPA2 -adj	RTK	690,889.88	3,081,069.93	3.47	3.45	0.02
06/28/19 (DN 179)	21:25	OSPA2 -adj	RTK	690,889.93	3,081,069.90	3.43	3.42	0.01
06/29/19 (DN 180)	11:33	OSPA2 -adj	RTK	690,890.01	3,081,070.10	3.30	3.32	0.02
06/29/19 (DN 180)	22:44	OSPA2 -adj	RTK	690,889.86	3,081,070.03	3.46	3.48	0.02
06/30/19 (DN 181)	14:33	OSPA2 -adj	RTK	690,889.83	3,081,069.76	3.57	3.53	0.04
06/30/19 (DN 181)	21:27	OSPA2 -adj	RTK	690,889.89	3,081,069.98	3.45	3.48	0.03
07/01/19 (DN 182)	13:51	OSPA2 -adj	RTK	690,890.07	3,081,069.94	3.29	3.30	0.01
07/01/19 (DN 182)	21:56	OSPA2 -adj	RTK	690,890.03	3,081,070.02	3.30	3.32	0.02
07/02/19 (DN 183)	13:40	OSPA2 -adj	RTK	690,890.03	3,081,069.89	3.34	3.37	0.03
07/02/19 (DN 183)	20:30	OSPA2 -adj	RTK	690,889.93	3,081,070.01	3.40	3.42	0.02
07/03/19 (DN 184)	12:33	OSPA2 -adj	RTK	690,890.03	3,081,070.01	3.30	3.34	0.04
07/03/19 (DN 184)	20:45	OSPA2 -adj	RTK	690,889.91	3,081,070.02	3.41	3.35	0.06
07/05/19 (DN 186)	11:41	OSPA2 -adj	RTK	690,890.03	3,081,069.91	3.33	3.37	0.04

Date	Time UTC	Nav. Check-point	DGNSS Corr. source	Observed Easting UTM 15N, NAD83 (meters)	Observed Northing UTM 15N, NAD83 (meters)	Calculated Distance RP to Nav. Checkpoint (meters)	Tape Measure RP to Nav. Checkpoint (meters)	Difference Calculated vs. Tape Measured (meters)
07/05/19 (DN 186)	21:57	OSPA2 -adj	RTK	690,890.04	3,081,069.92	3.32	3.30	0.02
07/06/19 (DN 187)	12:46	OSPA2 -adj	RTK	690,890.06	3,081,069.92	3.30	3.30	0.00
07/06/19 (DN 187)	21:37	OSPA2 -adj	RTK	690,890.03	3,081,070.01	3.30	3.33	0.03
07/07/19 (DN 188)	12:04	OSPA2 -adj	RTK	690,890.00	3,081,069.93	3.35	3.31	0.04
07/07/19 (DN 188)	22:11	OSPA2 -adj	RTK	690,890.00	3,081,069.90	3.36	3.38	0.02
07/08/19 (DN 189)	12:15	OSPA2 -adj	RTK	690,889.92	3,081,070.04	3.40	3.44	0.04
07/08/19 (DN 189)	19:25	OSPA2 -adj	RTK	690,890.09	3,081,069.94	3.27	3.33	0.06
07/10/19 (DN 191)	12:09	OSPA2 -adj	RTK	690,889.96	3,081,070.03	3.36	3.39	0.03
07/10/19 (DN 191)	23:02	OSPA2 -adj	RTK	690,889.89	3,081,070.01	3.44	3.38	0.06
07/11/19 (DN 192)	11:34	OSPA2 -adj	RTK	690,889.96	3,081,070.02	3.37	3.40	0.03
07/11/19 (DN 192)	23:02	OSPA2 -adj	RTK	690,890.08	3,081,069.96	3.27	3.28	0.01
07/12/19 (DN 193)	11:43	OSPA2 -adj	RTK	690,890.08	3,081,069.92	3.28	3.30	0.02
07/12/19 (DN 193)	22:57	OSPA2 -adj	RTK	690,889.99	3,081,069.88	3.38	3.35	0.03
07/13/19 (DN 194)	11:43	OSPA2 -adj	RTK	690,890.02	3,081,069.90	3.35	3.34	0.01
07/13/19 (DN 194)	23:27	OSPA2 -adj	RTK	690,890.08	3,081,069.99	3.26	3.28	0.02
07/14/19 (DN 195)	11:37	OSPA2 -adj	RTK	690,890.06	3,081,069.97	3.29	3.28	0.01

Date	Time UTC	Nav. Check-point	DGNSS Corr. source	Observed Easting UTM 15N, NAD83 (meters)	Observed Northing UTM 15N, NAD83 (meters)	Calculated Distance RP to Nav. Checkpoint (meters)	Tape Measure RP to Nav. Checkpoint (meters)	Difference Calculated vs. Tape Measured (meters)
07/14/19 (DN 195)	21:46	OSPA2 -adj	RTK	690,890.04	3,081,069.93	3.32	3.34	0.02
07/23/19 (DN 204)	14:11	OSPA2 -adj	RTK	690,889.99	3,081,069.84	3.39	3.45	0.06
07/23/19 (DN 204)	23:22	OSPA2 -adj	RTK	690,890.06	3,081,069.93	3.30	3.32	0.02
07/24/19 (DN 205)	11:59	OSPA2 -adj	RTK	690,890.02	3,081,069.86	3.36	3.33	0.03
07/24/19 (DN 205)	22:35	OSPA2 -adj	RTK	690,889.98	3,081,070.07	3.33	3.35	0.02
07/25/19 (DN 206)	11:39	OSPA2 -adj	RTK	690,889.95	3,081,069.80	3.44	3.46	0.02
07/25/19 (DN 206)	20:57	OSPA2 -adj	RTK	690,890.11	3,081,070.10	3.20	3.20	0.00
07/26/19 (DN 207)	15:20	OSPA2 -adj	RTK	690,890.11	3,081,070.02	3.22	3.24	0.02
07/26/19 (DN 207)	22:14	OSPA2 -adj	RTK	690,889.92	3,081,070.01	3.41	3.43	0.02
07/27/19 (DN 208)	11:53	OSPA2 -adj	RTK	690,889.96	3,081,069.87	3.41	3.44	0.03
07/27/19 (DN 208)	21:43	OSPA2 -adj	RTK	690,890.14	3,081,070.04	3.19	3.20	0.01
07/28/19 (DN 209)	13:04	OSPA2 -adj	RTK	690,890.11	3,081,070.05	3.21	3.25	0.04
07/28/19 (DN 209)	21:25	OSPA2 -adj	RTK	690,890.14	3,081,069.98	3.21	3.22	0.01
07/29/19 (DN 210)	15:19	OSPA2 -adj	RTK	690,890.02	3,081,069.92	3.34	3.35	0.01
07/29/19 (DN 210)	22:10	OSPA2 -adj	RTK	690,890.12	3,081,069.95	3.23	3.25	0.02
07/30/19 (DN 211)	12:17	OSPA2 -adj	RTK	690,890.07	3,081,069.95	3.28	3.33	0.05

Date	Time UTC	Nav. Check-point	DGNSS Corr. source	Observed Easting UTM 15N, NAD83 (meters)	Observed Northing UTM 15N, NAD83 (meters)	Calculated Distance RP to Nav. Checkpoint (meters)	Tape Measure RP to Nav. Checkpoint (meters)	Difference Calculated vs. Tape Measured (meters)
07/30/19 (DN 211)	19:22	OSPA2 -adj	RTK	690,890.01	3,081,069.96	3.34	3.35	0.01
07/31/19 (DN 212)	12:09	OSPA2 -adj	RTK	690,889.93	3,081,070.07	3.38	3.38	0.00
07/31/19 (DN 212)	20:42	OSPA2 -adj	RTK	690,890.02	3,081,070.03	3.31	3.33	0.02
08/01/19 (DN 213)	11:40	OSPA2 -adj	RTK	690,890.01	3,081,069.99	3.33	3.34	0.01
08/01/19 (DN 213)	21:32	OSPA2 -adj	RTK	690,889.91	3,081,069.91	3.45	3.45	0.00
08/02/19 (DN 214)	12:23	OSPA2 -adj	RTK	690,889.90	3,081,069.92	3.45	3.48	0.03
08/02/19 (DN 214)	22:15	OSPA2 -adj	RTK	690,889.85	3,081,070.00	3.48	3.45	0.03
08/03/19 (DN 215)	13:04	OSPA2 -adj	RTK	690,889.98	3,081,069.92	3.38	3.43	0.05
08/03/19 (DN 215)	22:10	OSPA2 -adj	RTK	690,890.12	3,081,069.92	3.24	3.25	0.01
08/04/19 (DN 216)	12:37	OSPA2 -adj	RTK	690,890.06	3,081,070.01	3.27	3.24	0.03
08/04/19 (DN 216)	20:09	OSPA2 -adj	RTK	690,890.00	3,081,069.96	3.35	3.36	0.01
08/05/19 (DN 217)	12:33	OSPA2 -adj	RTK	690,890.04	3,081,069.97	3.30	3.34	0.04
08/20/19 (DN 232)	16:38	OSPA2 -adj	RTK	690,889.88	3,081,069.93	3.47	3.45	0.02
08/20/19 (DN 232)	23:59	OSPA2 -adj	RTK	690,889.99	3,081,070.06	3.33	3.36	0.03
08/21/19 (DN 233)	13:11	OSPA2 -adj	RTK	690,889.94	3,081,069.97	3.40	3.45	0.05
08/22/19 (DN 234)	00:18	OSPA2 -adj	RTK	690,890.34	3,081,070.23	2.94	2.97	0.03

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08/22/19 (DN 234)	12:38	OSPA2 -adj	RTK	690,890.29	3,081,070.19	3.00	3.00	0.00
08/22/19 (DN 234)	21:52	OSPA2 -adj	RTK	690,890.58	3,081,070.38	2.68	2.68	0.00
08/23/19 (DN 235)	12:59	OSPA2 -adj	RTK	690,890.59	3,081,070.34	2.68	2.71	0.03
08/23/19 (DN 235)	21:49	OSPA1	RTK	690,861.18	3,081,078.10	13.36	13.31	0.05
08/24/19 (DN 236)	13:55	OSPA2 -adj	RTK	690,890.55	3,081,070.37	2.71	2.75	0.04
08/24/19 (DN 236)	20:58	OSPA2 -adj	RTK	690,890.31	3,081,070.28	2.96	2.97	0.01
08/25/19 (DN 237)	12:55	OSPA2 -adj	RTK	690,890.27	3,081,070.14	3.04	3.06	0.02
08/25/19 (DN 237)	20:28	OSPA2 -adj	RTK	690,890.16	3,081,070.15	3.14	3.16	0.02

D. APPROVAL SHEET

This report and the accompanying data are respectfully submitted.

Field operations contributing to the accomplishment of Surveys F00767, and H13222 through H13227 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	01/22/2020	John R. Bean 2020.01.23 13:25:21 -05'00'
David T. Somers	Data Processing Manager	01/22/2020	David T. Somers 2020.01.23 13:25:42 -05'00'