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May 13, 2017

Mr. Dane Nelson
Project Engineer
Great Lakes Dredge and Dock Company
VIA E-mail: DNelson@GLDD.com

RE: Dare County Beach Renourishment Project
Statistical Analysis of Pre-Construction Multi-Beam Hydrographic Surveys
Borrow Area A and Borrow Area C

Mr. Nelson,

TI Coastal Services, Inc. (TIC) performed multi-beam hydrographic surveys of the Dare County Project's two Borrow Areas (BA-A and BA-C) between April 29, 2017 and May 4, 2017. TIC utilized the 28' survey vessel "Endeavor" utilizing a Reson 7125 multi-beam sonar, a Teledyne velocity probe for surface speed of sound, and an Applanix POS/MV Wavemaster RTK-GPS/IMU combined with a Trimble SPS461 RTK-GPS. Water column speed of sound was obtained using an Odom Digibar. All data was collected and processed using Hypack 2016.

All data collection, quality control and processing procedures conformed to the standards for soft bottom surveys contained in the USACE Hydrographic Survey Manual (EM 1110-2-1003 "Hydrographic Surveying", 30 November 2013) and associated Engineering Circulars (EC's). A Patch test was performed onsite and Speed of Sound/draft calibrations were conducted twice daily. Tidal data was collected via the RTK GPS system using the North Carolina Virtual Network System (NC-VRS) as the base station reference. At the beginning and end of each survey day the vertical and horizontal calibration of the vessel was checked against USGS ground control located at the Oregon Inlet Fishing center. Data was collected using a 120 degree (60 degree each side) swath setting with trackline spacing sufficient to provide approximately 130% to 150% coverage pending vessel tracking. A minimum of 3 tracks of multi-beam data was collected perpendicular to the main track lines to be utilized as quality control.

Survey data for each borrow area was processed as a bulk data set with all of the borrow area data visible simultaneously. This allows the technician to easily discern if there are day-to-day issues with the data, such as RTK system failures or improper application of SOS velocity casts. Upon completion of the processing the data is binned into 3'x3' cells utilizing the average elevation of all sounding within the cell as the sounding for that cell.

A statistical analysis of the 100% data set was then compared to the binned data to determine the 95% confidence level of the entire data set for each borrow area. The results of the statistical analysis was compared to the standards of Table 3-1 of the USACE Hydrographic Survey manual. For the purposes of this project the standards for Coastal Deep Draft projects was utilized which requires a typical repeatability of 0.3ft and a Standard Deviation of +/- 0.8 ft. Table 3-1 is shown below for easy reference. It should be noted that Hypack utilizes 2 Standard Deviations as 95 % confidence not a single SD.

EM 1110-2-1003
30 Nov 13

Table 3-1. Recommended Depth Accuracy Standards for Corps of Engineers Surveys of Federal Navigation Projects based on Performance Test Results. ¹

Project	Typical ² Repeatability (feet)	Typical ³ Standard Deviation (± feet at 95%)
Coastal Deep Draft Projects (15 > d < 75 ft):		
Dredge measurement & payment surveys		
Channel clearance/acceptance		
Project condition surveys		
Maintenance Dredging (soft sand/silt bottom)	0.3 ft	±0.8 ft
New Work or Rock Cuts ⁴	0.2 ft	±0.8 ft
Coastal Shallow Draft Projects (d < 15 ft)	0.3 ft	±0.8 ft
Inland Navigation Projects (d < 15 ft)	0.3 ft	±0.5 ft

For Borrow Area A, the Standard Deviation of all data within each cell is 0.20' with a 95% confidence (2SD) of 0.40' from the average elevation within the cell. For Borrow Area C, the Standard Deviation is 0.23' with a 95% confidence (2SD) of 0.45'. Both of these analyses indicate that the confidence level for the data sets are well within the standards set forth in the USACE Hydrographic Survey Manual.

Below, we have shown the following graphics for each Borrow Area:

1. Statistical Analysis output from HyPack
2. Figure showing the multi-beam sounding tracklines
3. Color graphic showing the depicting standard deviation within the bin cells
4. Typical Profile cut across the tracklines showing data overlap.

Should you have any questions, feel free to contact me at cgibson@ticoastal.com or on my cell 910-512-3096.

Sincerely,



Chris Gibson, PE
President



BORROW AREA A

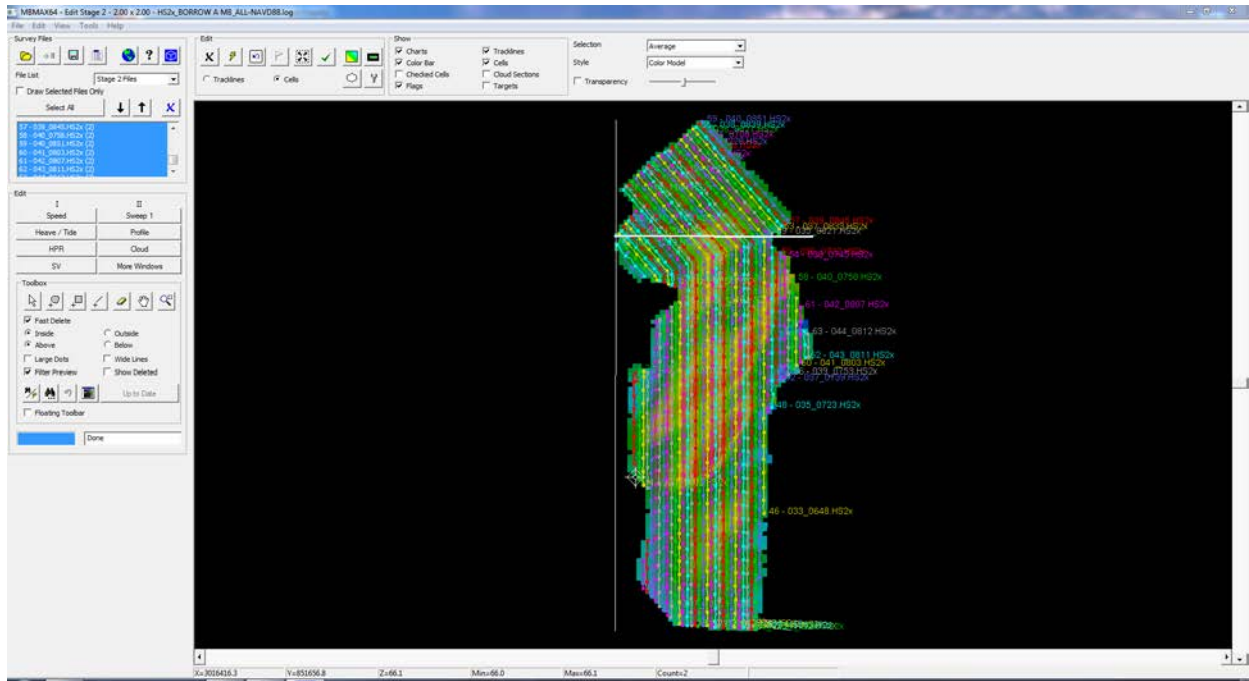


Figure A-1 Vessel Tracklines

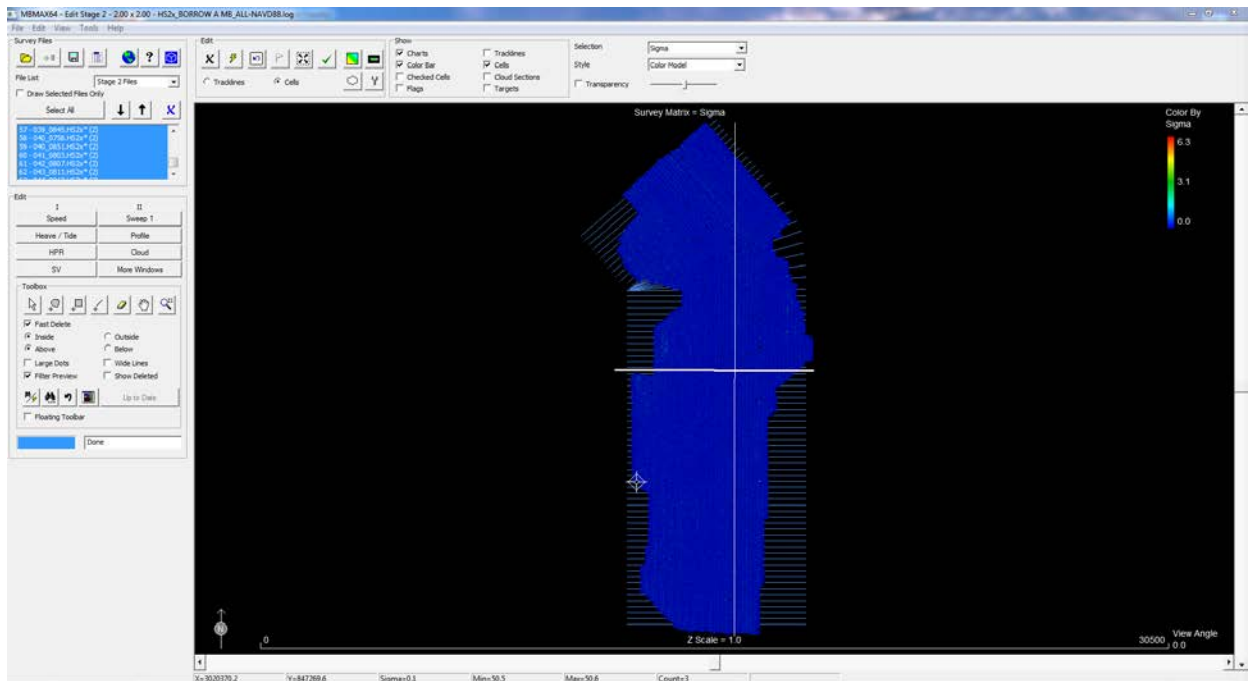


Figure A-2 Standard Deviations & Typical Profile Location



Figure A-3 Typical Cross-Section

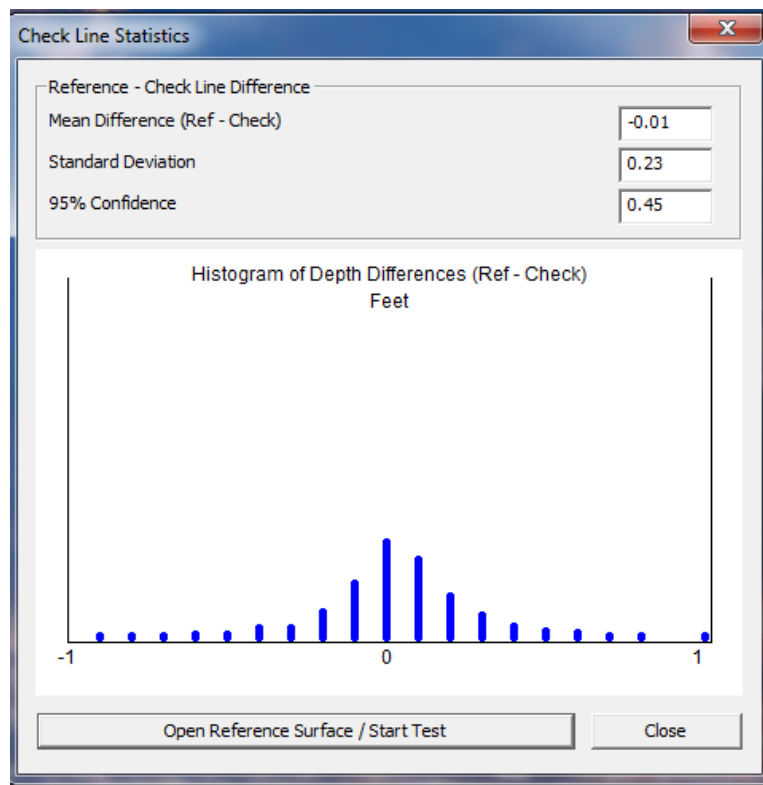


Figure A-4 Statistical Analysis Histogram for Borrow Area A

BORROW AREA C

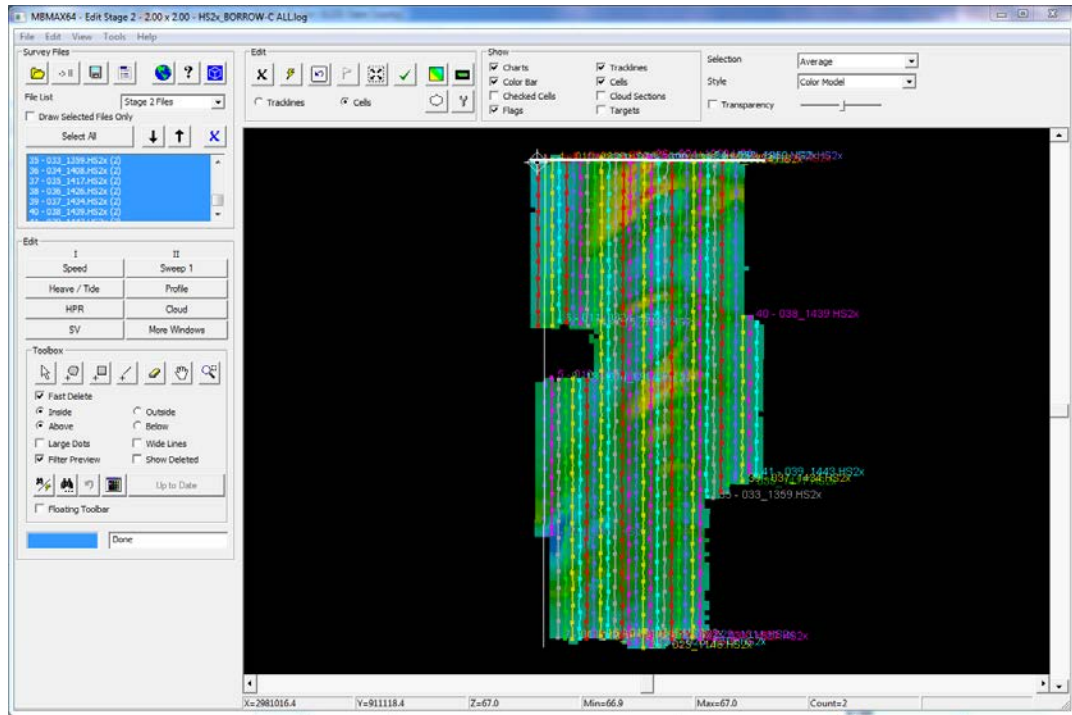


Figure C-1 Vessel Tracklines

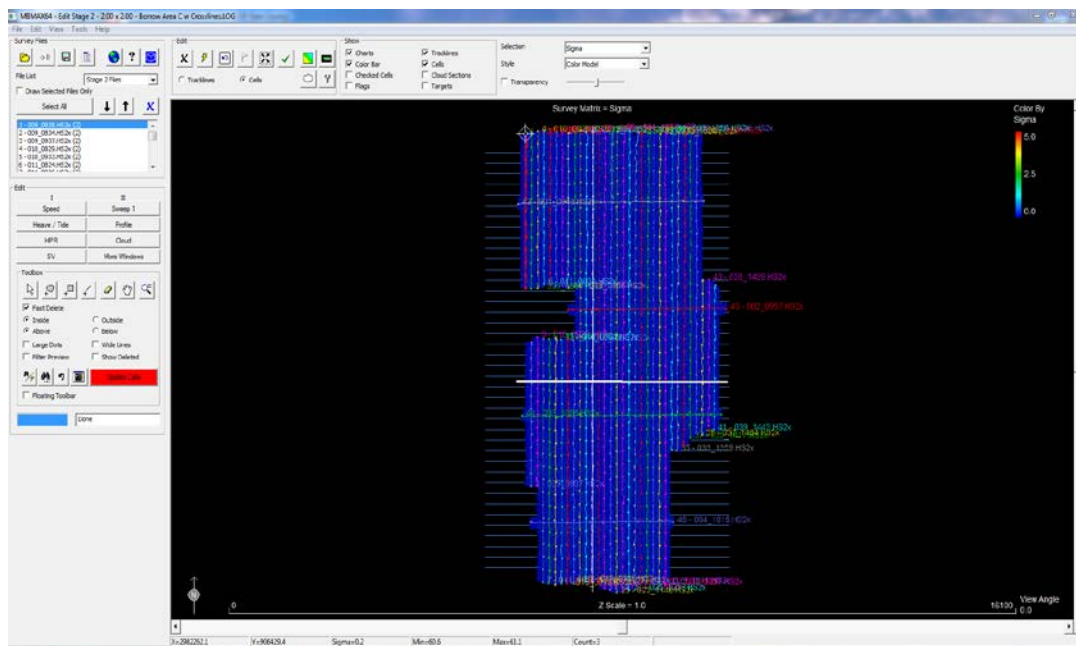


Figure C-2 Standard Deviations & Typical Profile Location

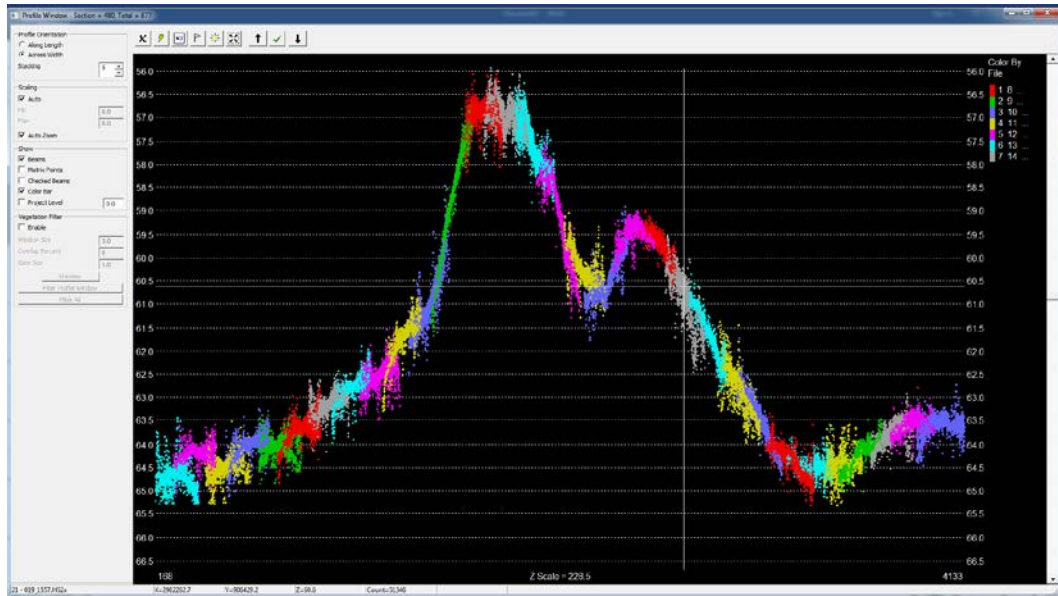


Figure C-3 Typical Cross-Section

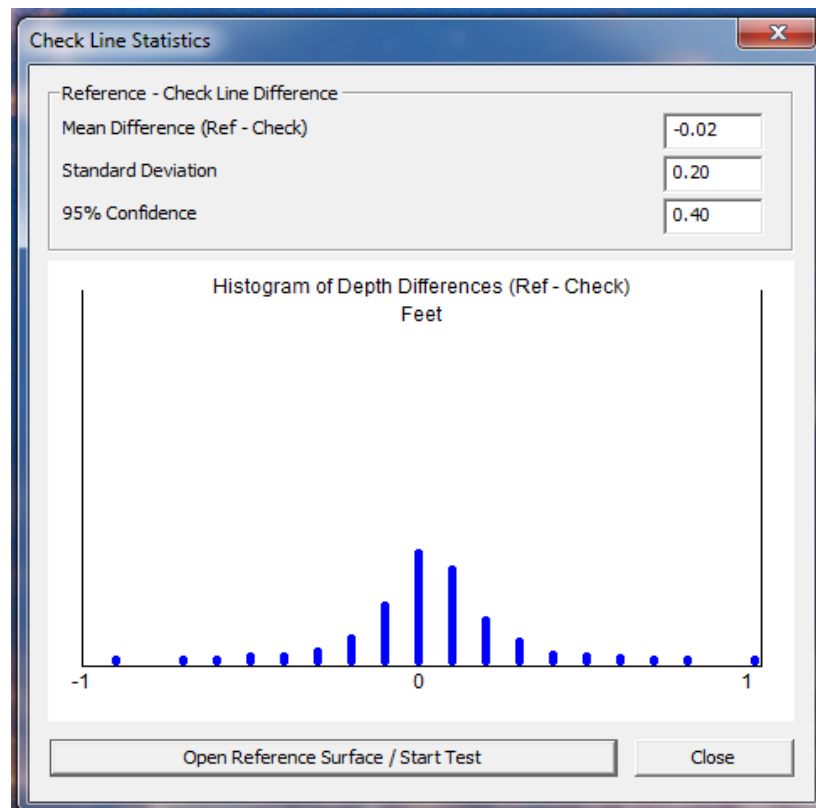


Figure C-4 Staticistical Analysis Histogram for Borrow Area C