Bathymetric Survey of the Mississippi River Gulf Outlet (MRGO), Gulf Intracoastal Waterway (GIWW), and Inner Harbor Navigation Canal (IHNC) from Lake Pontchartrain to Bayou La Loutre: Methodology, Quality Control, and Error Analysis



Environmental Science Services, Inc.
P.O. Box 1289
Denham Springs, Louisiana 70727-1289

7 March 2008

INTRODUCTION

In order to provide up-to-date data as input for numerical hydrodynamic modeling efforts, a bathymetric survey of the Mississippi River Gulf Outlet (MRGO), Gulf Intracoastal Waterway (GIWW), and Inner Harbor Navigation Canal (IHNC) from Lake Pontchartrain to Bayou La Loutre was conducted 23 -27 January 2008 (Figure 1).

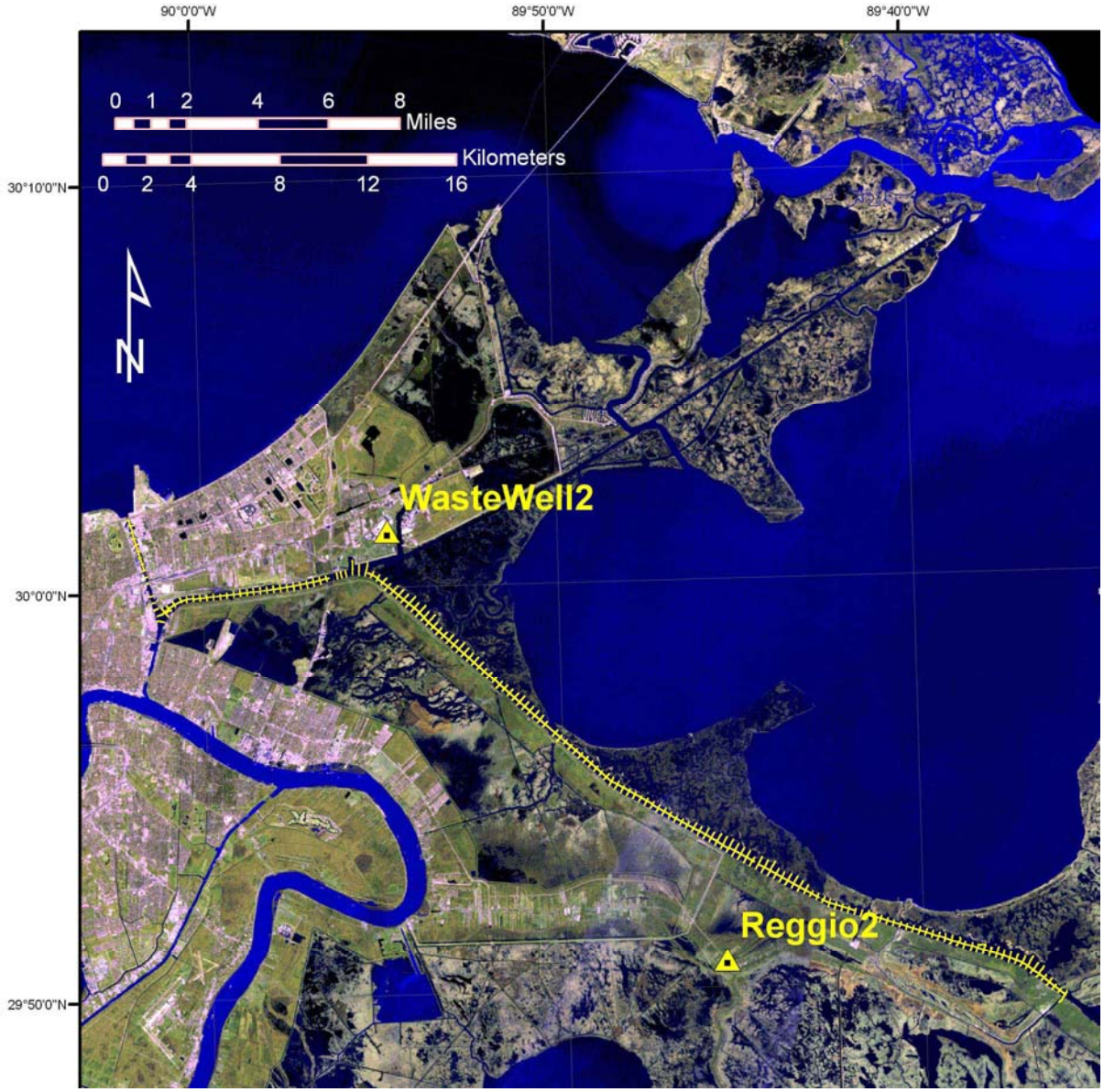


Figure 1. Satellite image showing the survey transects and locations of National Geodetic Survey (NGS) benchmarks occupied during the survey. Benchmarks are part of the NGS Louisiana Height Modernization Network.

METHODOLOGY

Planned Lines

The survey was planned using Coastal Oceanographics HYPACK survey software. Cross-channel line spacing was set at 1000 ft (Figure 1). The planned line files were used to navigate transects during the bathymetric survey.

Basics of Data Acquisition

The survey was conducted using a single-beam echosounder for depth measurements and post-processed kinematic global positioning system (GPS) for horizontal positions and elevations. During the processing the depth measurements from the echosounder are integrated with the 3-dimensional XYZ GPS position to convert the depths to reference an Earth-centered ellipsoid model, eliminating errors associated with water surface elevation or tidally-based hydrographic surveys. The final Z values are in elevations relative to the North American Vertical Datum of 1988 revision 2004.65 [NAVD88(2004.65)]. Horizontal positions are reported relative to North American Datum of 1983 revision 2007 [NAD83 (2007)].

National Geodetic Survey (NGS) Benchmarks and Base Station Hardware

GPS base stations were set at two NGS benchmarks, Reggio 2 and Waste Well 2, during the survey to provide a static dataset within the survey coverage area (Figures 2-5). Rover (survey vessel) GPS data is referenced to the base station data during the post-processing. The base stations used are part of the NGS Louisiana Height Modernization Project and reference the most recent revision (2004.65) of NAVD88. This is important in South Louisiana because of the rapid subsidence rates in the region. NGS benchmark datasheets for Reggio 2 and Waste Water Well 2 are included as Appendix A.

During survey days the static base stations are set above the NGS benchmarks on survey tripods within 15 km of the area being surveyed. On days when surveys extended beyond the 15-km limit, a second static base was set on another benchmark to provide seamless base station coverage for survey areas completed within a day. Thus the entire survey area was completed by sequentially linking together coverages that were obtained within benchmarked GPS base stations.

Static GPS data including satellite positioning and satellite health, was continuously recorded at 1-second intervals using an Ashtech Z-Max.net dual frequency GPS receiver with a data logger and a choke-ring antenna (Figures 2-3; Appendix C). The receiver and antenna combination record 12-channel full-carrier (L1/L2) phase positioning signals from the NAVSTAR GPS satellite constellation. Antenna elevation was measured for input during post-processing.



Figure 2. A) Photograph of static GPS base set on NGS benchmark Reggio 2. Note choke-ring antenna and survey tripod. B) Close-up photo of tripod base set in stainless steel rod at station

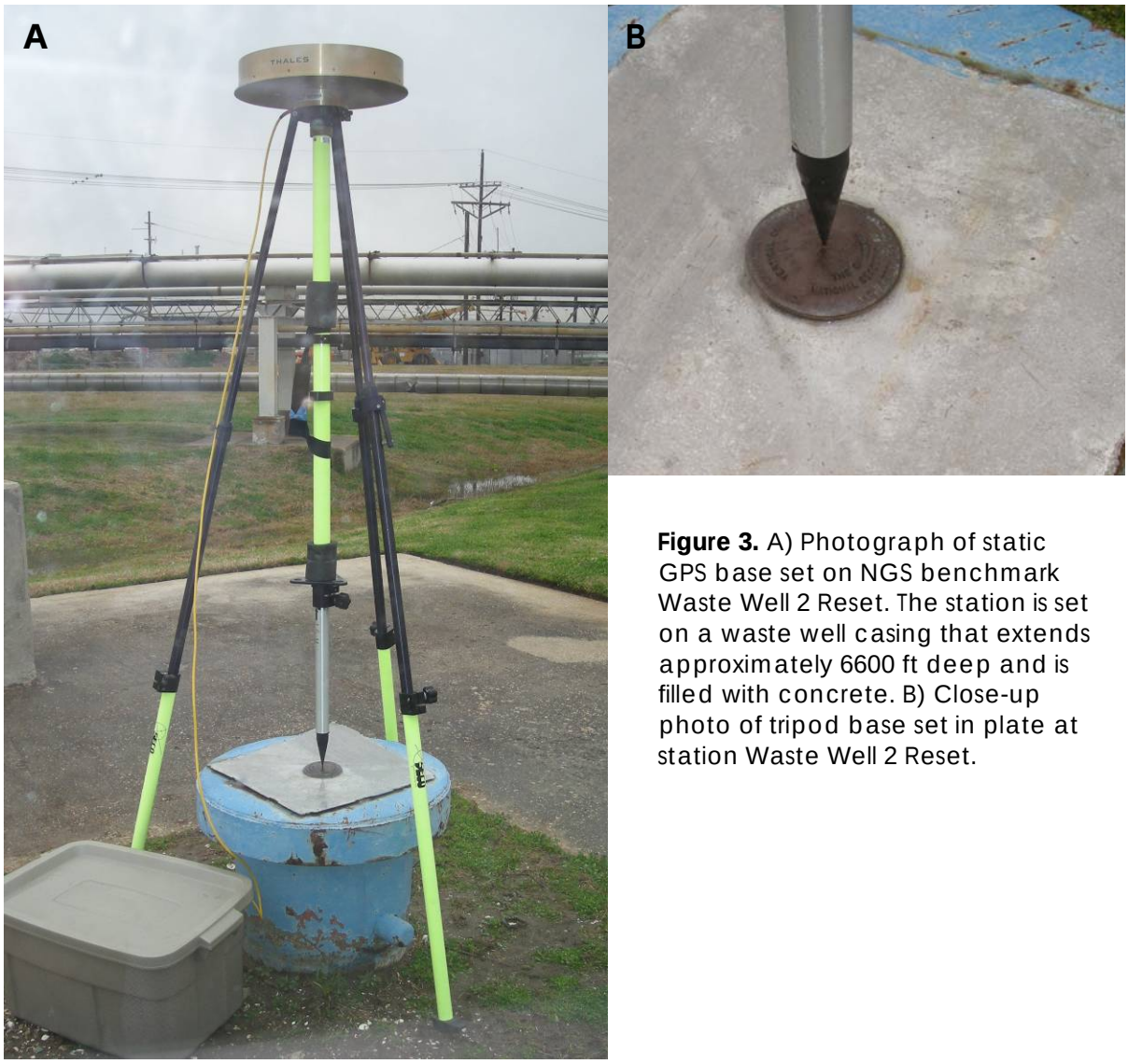


Figure 3. A) Photograph of static GPS base set on NGS benchmark Waste Well 2 Reset. The station is set on a waste well casing that extends approximately 6600 ft deep and is filled with concrete. B) Close-up photo of tripod base set in plate at station Waste Well 2 Reset.

Survey Vessel (Rover) Hardware and Data Collection

The survey was conducted using a 22-ft shallow draft vessel with a side-mounted Odom Hydrographics Model SMBB200-9 single-beam 200kHz transducer with a 9 degree beam width (Figure 4). An Odom Hydrographic Hydrotrac echosounder with a factory specified accuracy of 0.1 ft was used for sounding (Appendix C). The echosounder system was set to record soundings at a rate of 50 ms, and assumed a velocity of sound through the water to be 1500 m/s. Any variation in velocity of sound through water is accounted for and corrected by the bar-check and during post-processing which is discussed in the quality control section below.

An Ashtech Z-Max.net dual frequency GPS receiver with a data logger and Thales choke-ring antenna were used to log XYZ GPS position (Figure 6). Vertical and horizontal offsets between the antenna L1/L2 phase center and transducer face were measured and recorded for input during post-processing.

Sounding and GPS data were streamed in real-time to an onboard ruggedized notebook computer for data logging and navigation using HYPACK hydrographic survey software.

Post-Processing of Bathymetric Data

Post-processing consists of two main steps: 1) kinematic GPS processing for rover positioning and 2) integration of depth soundings with post-processed kinematic rover position.

The first step is carried out using Waypoint Inc. GrafNav software. This software is a static/kinematic baseline processing engine designed to achieve accuracies down to the centimeter level and can incorporate multiple base-station data. GPS data logged at the base station, base station antenna height, and the NGS specified XYZ coordinates for the benchmark are incorporated with rover data to process kinematic trajectories (rover positions). Grafnav outputs a single precise boat position and quality control information at 1-second intervals.

The second step is the merging of rover position from Grafnav output with the soundings. In this step the soundings as logged in HYPACK are input along with boat position, horizontal and vertical offsets between antenna and transducer face, and any corrections applied based on echosounder calibration during the survey (bar check to be discussed in following section). The corrected depth is calculated by:

$$D = \tfrac{1}{2}(v * t) + dS + dGPS$$

Where v equals the average velocity of sound in water column, t equals the measured elapsed time from transducer to bottom and back to transducer, dS is the offset from transducer face to GPS antenna center, and dGPS equals GPS ellipsoid height relative to the GPS antenna center.

The ellipsoidal heights are then converted to orthometric heights (NAVD88 2004.65) using the NGS GEOID03 revised 10/2005 version for southern Louisiana.

Data Quality Control

In shallow water surveys (<100 m), the high sound velocity to depth ratio, and assumed mixing of the water, tend to decrease the significance of sound velocity variations due to salinity and temperature gradients in the water column. For these reasons, the use of an average sound velocity is suitable within the depth range of this survey. A fixed "bar check" is an accepted method used to correct for sound velocity variations and index variability that is recorded by the echosounder. A pipe with a top plate was suspended a measured distance below the transducer. This known distance was compared to the distance determined by the sounding system, using an assumed average sound velocity of 1500 m/s. This check is conducted on a daily basis. In addition, as part of the daily quality control procedures, the depth of the water was measured manually using a graduated rod. That depth was also compared with the depth determined by the sounding system.

GPS Percent Dilution of Position and Root Mean Square Error

The GPS antennae receive position information from the NAVSTAR satellite constellation, which includes the Percent Dilution of Position (PDOP). PDOP is a

measurement of the relative signal strength of the GPS satellite configuration, measured internally by the GPS system and displayed as a value typically between 1 and 4. The PDOP is a proxy for position error, the lower the value the higher the accuracy. When PDOP readings exceeded a value of 3, operations were halted, or data was removed from the dataset during post-processing.

During post-processing, GrafNav determines a root mean square (RMS) error for each point based on GPS cycle slips, PDOP, satellite health, and base station RMS. Any RMS values greater than 0.14 m were removed during quality control and assessment. After removing outliers, the final mean RMS value was 0.07 m.

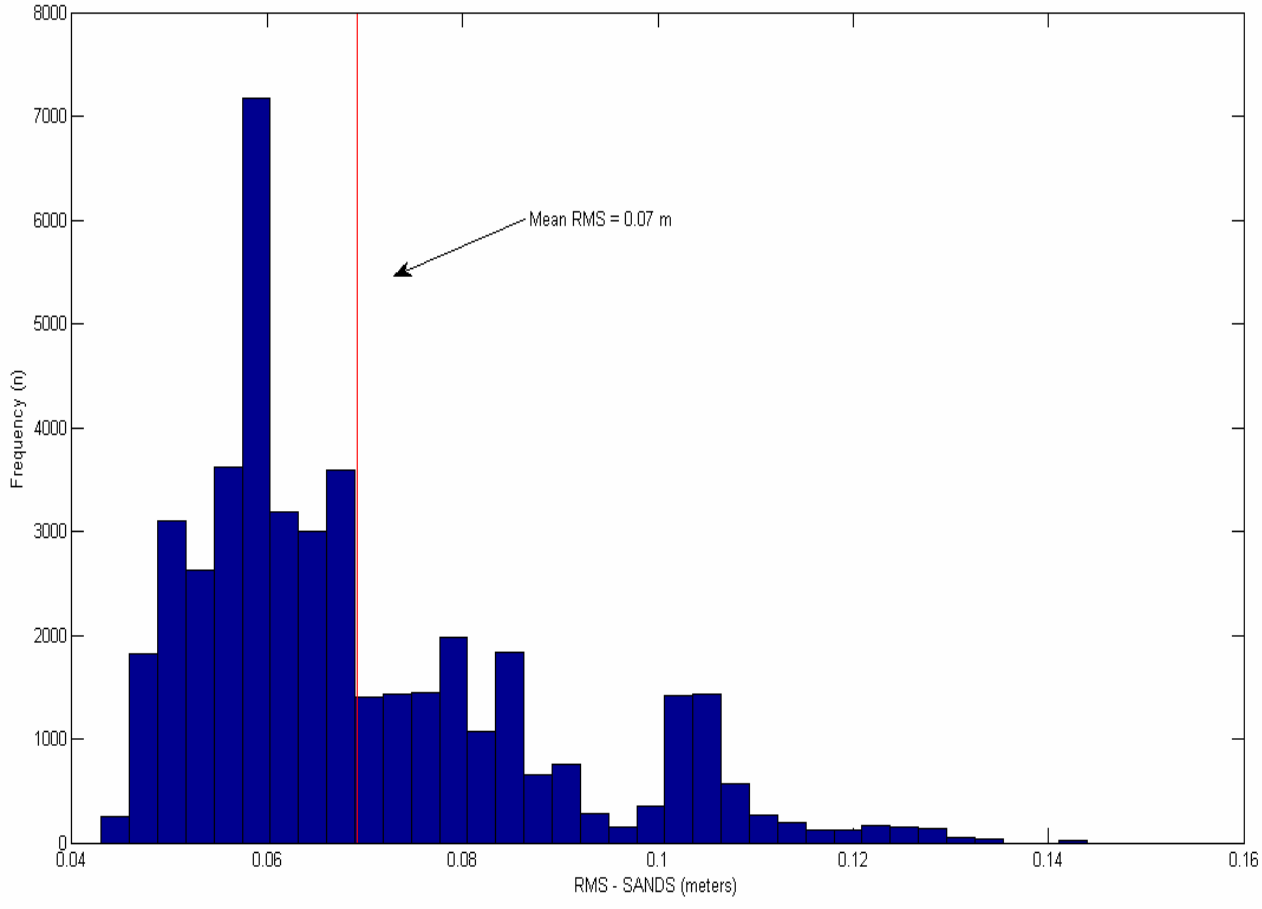


Figure 4. Histogram showing distribution or Root Mean Square (RMS) values for the total population of survey points. The RMS is calculated in GrafNav software based on rover and base station satellite health, Percent Dilution of Precision (PDOP), and base station RMS. The mean RMS for the survey was 0.07 m, any points with an RMS value greater than 0.14 m were eliminated from the dataset.

Wild Point Editing

During wild-point editing, the sounding data are plotted with the processed survey elevation in NAVD88 versus time (Figure 5). Time is used as a proxy for distance traveled, as the survey speed was slow and consistent, rarely exceeding 4 knots, and

the time, unlike the distance traveled, always moves forward. Once plotted, the data were manually evaluated and edited through the selection of points that were not representative of the local trend in the data set. On a separate plot, the Z value (GPS-derived elevation) for each point is plotted against the sounding (echosounder-derived depth). Ideally the plot would have a linear trend, in cases where points do not plot on the line it is assumed that they resulted from GPS error and are removed. Errant points in the dataset were likely the result of poor GPS signal quality, sea conditions, echo sounder returns from below the seabed or from objects within the water column, such as marine life.

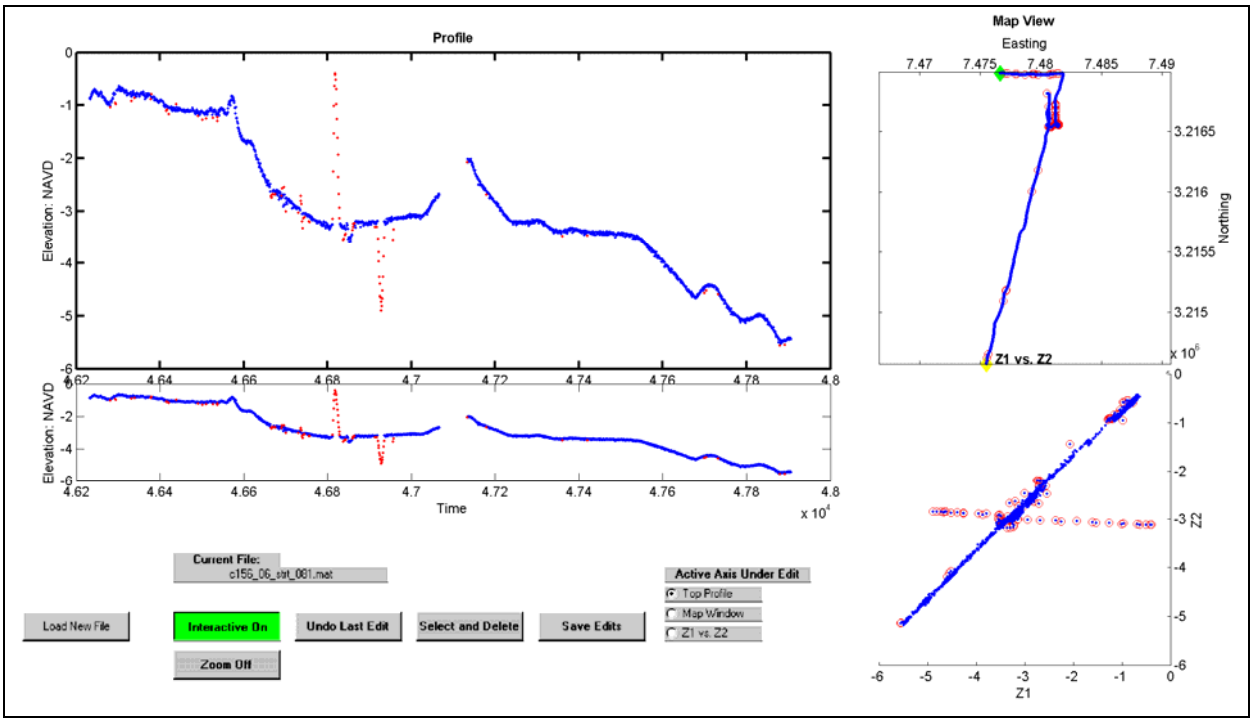


Figure 5. Screen capture of the wild-point editor program. The two plots on the left show the soundings in profile as elevation versus time. The upper one is editable through graphical user interface. The upper right plot shows the map view of the survey transect. The lower right plot shows Z1 (GPS elevation) versus Z2 (depth from echosounder only). Points that do not plot along the Z1 vs Z2 linear trend contain GPS errors and are removed from the dataset.

Data Validation Through Crossline Check

During the survey, an along-channel line trending perpendicular to the cross-channel transects was surveyed. The along-channel line crossed every transect providing an opportunity to assess consistency of elevation measurement throughout the study. At each location where the rover crossed itself the difference in elevation (DZ) is calculated (Figure 6). Ideally, the processed elevation at any given crossing point should be identical (DZ=0). However, this is rarely the case. An ideal crossing would have two boat paths acquiring a measurement at the exact same position (Northing and Easting). However, this was also rarely, if ever, the case, so comparative elevation measurements were conducted by proximity. A script is then run to: 1) identify all crossings, 2) interpolate the elevation for each survey line at the XY location of that

crossing, and 3) calculate the DZ between survey lines. The general mechanics of this script are described below.

For a crossing analysis run, each survey line was compared against all others. If the paths crossed, an intersection point was interpolated from the four nearest survey measurements: two from each line. From the interpolated crossing position, a representative elevation measurement was interpolated for each boat path using an average of the measured Z (elevation) within a given search radius of 5 m. This local averaging technique was employed in order to remove any exaggerated DZ discrepancy that could result from an erratic Z measurement associated with any of the four survey points used to determine the crossing position.

Based on the crossings analysis, the mean DZ was 0.0 m and standard deviation was +/- 0.14 m (Figure 7). The sampling of data points at crossings and validation is used to estimate the error associated with the bathymetric data set. Therefore the error associated with the final processed bathymetric data is +/- 0.14 m (0.46 ft).

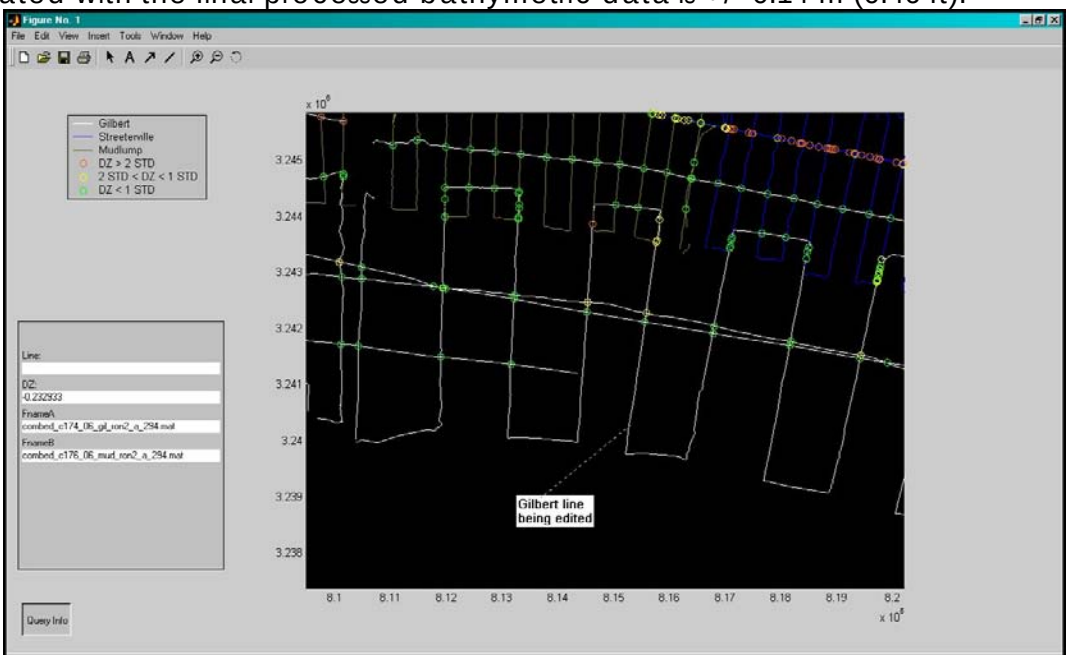


Figure 6. Screen capture of the crossings editor program (not from this survey) in which line survey line crossings are identified and difference in elevation (DZ) between the two lines is calculated for editing and final estimation of error associated with dataset.

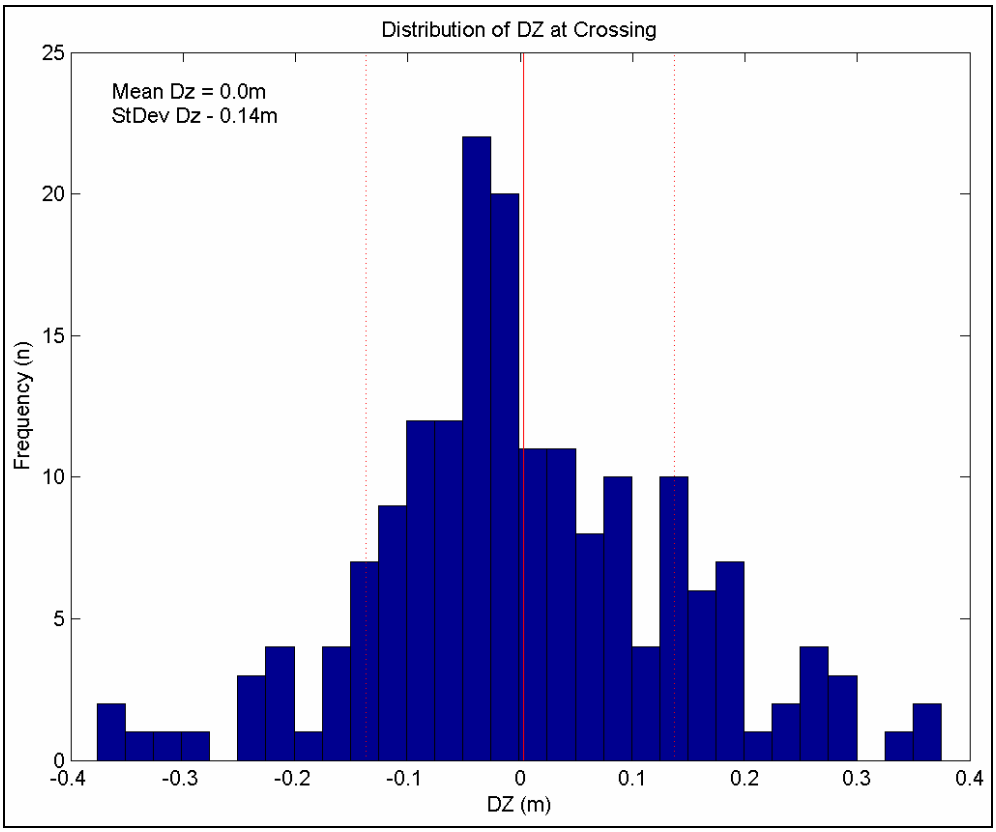


Figure 7. Histogram showing distribution of DZ at crossings after editing. The mean difference in elevation between all crossings is 0.0 m with a standard deviation of +/- 0.14 m. This sampling is assumed to be representative of the entire population and therefore provides an estimate of the error associated with the elevations reported here.