Contract Hydrography: An Opportunity for Innovation in Hydrographic Surveying

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Abstract

The Brooks Architect Engineer (A-E) Act, which requires a public announcement of survey services, has provided numerous hydrographic opportunities for the private sector. Fugro GeoServices, Inc. (FGSI - formerly the geophysical division of John E. Chance and Associates, Inc.) has performed contract hydrographic work south and southwest of Sabine Pass in the Gulf of Mexico for the National Oceanic and Atmospheric Administration (NOAA). The purpose of the contract was to provide NOAA with modern, accurate hydrographic data, acquired using shallow water multibeam and side scan sonar technology, in order to update the nautical charts of the assigned area. Contract specifications, outlined in the NOAA Statement of Work (SOW), provided the framework in which the work was performed. All work was performed with a side-mounted multibeam and side scan sonar from a single vessel. All multibeam data collection and post processing were performed with the Fugro IP400 software; all side scan sonar data were collected with the Tritrion-Elics Isis system. After the first field season and discussions with NOAA, FGSI developed a real-time draft sensor and utilized an undulating velocimeter for all remaining data collection. The real-time draft sensor decreased the draft component of the error budget and the undulating velocimeter increased the accuracy and efficiency of the velocity data collection. The working relationship with NOAA has allowed innovation that improved the accuracy of the final data set and smooth sheet submitted under the contract.

Introduction

The Brooks A-E Act has provided numerous hydrographic opportunities for the private sector. In 1997, NOAA contracted FGSI to perform hydrographic surveys to support nautical charting south and southwest of Sabine Pass in the Gulf of Mexico (Contract OPR-K171-KR). Multibeam and side scan sonar data were collected over five survey areas (or sheets) from 1998 to 2000. During the 1998 field season Sheet I (May-August) and Sheet H (October-November) were completed. Sheet N (June-July) and Sheet O (August-October) were completed during the 1999 field season and Sheet J (February-May) was completed in 2000 (see Figure 1). Weather downtime dominated total survey time during the spring months (see Figure 2).

Contract specifications outlined in the NOAA SOW include a maximum 10 meter horizontal error and maximum 30 cm vertical error, with all survey products traceable and reconstructible from the original raw data. A swath width at least two times the water depth, meeting these specifications was required. For Sheet I, NOAA required 100 percent multibeam coverage. A 10 meter overlap of outer beams ensured full coverage based upon the uncertainty in positioning and vessel motion. The maximum distance between sections of the swath meeting specifications was 100 meters. Reconnaissance data not meeting the specifications were included for coverage.

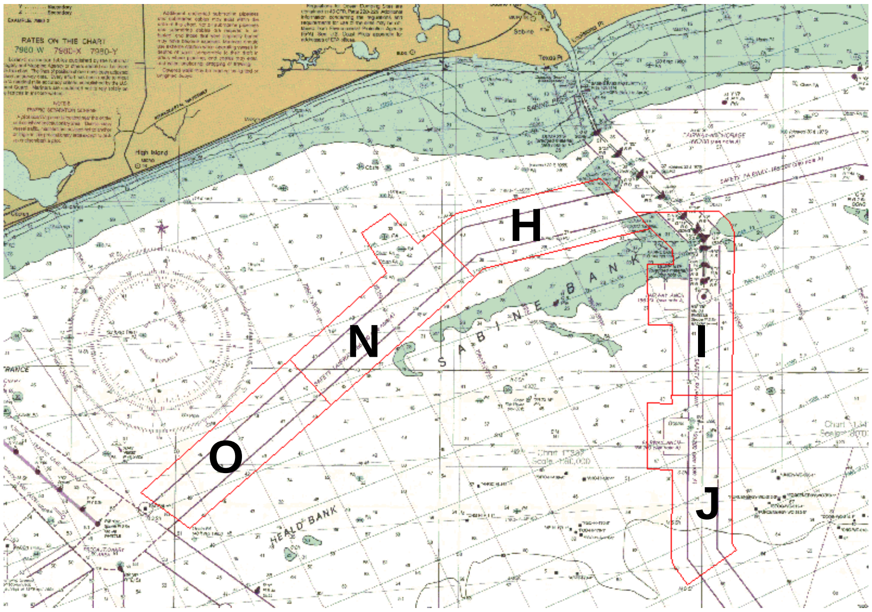

***Figure 1**. Location map with all survey areas superimposed on a section of NOAA nautical chart 11330.*

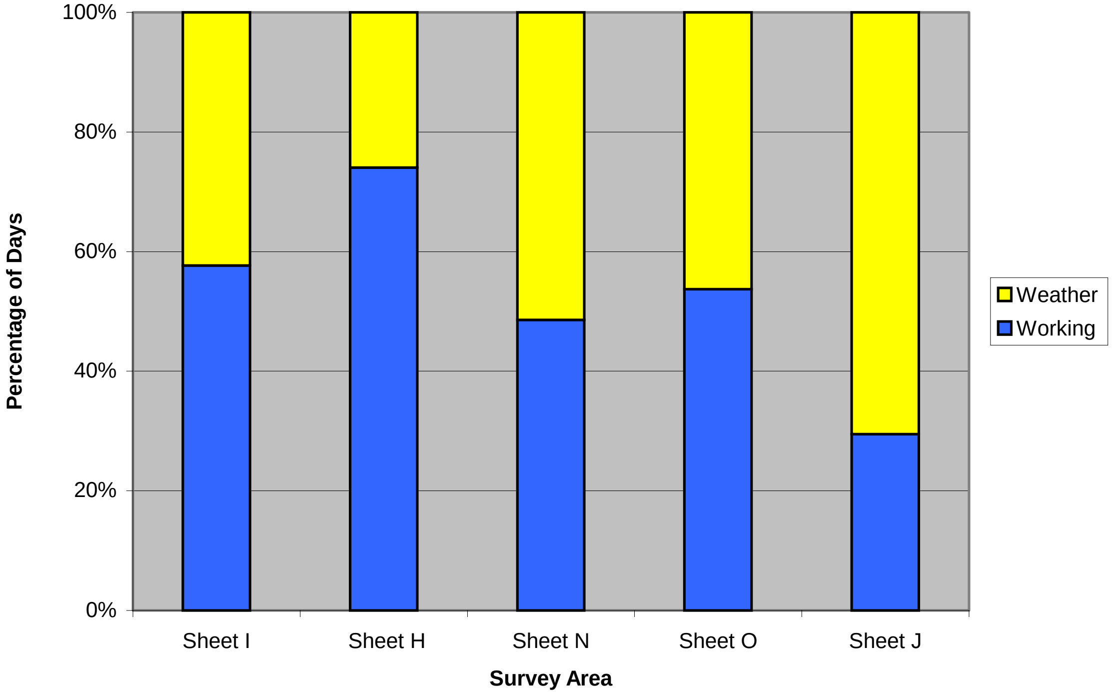

***Figure 2**. Weather downtime dominates the Sheet J survey that was collected in the spring months.*

After the first sheet, the contract allowed for gaps up to 50 meters between multibeam swaths meeting the accuracy requirements; reconnaissance data were no longer used. The total amount of data collected decreased significantly (see Figure 3).

Two hundred percent insonification was required for all side scan sonar data collection and sediment samples were collected during the 1998 field season. All sheets have been completed and delivered to NOAA.

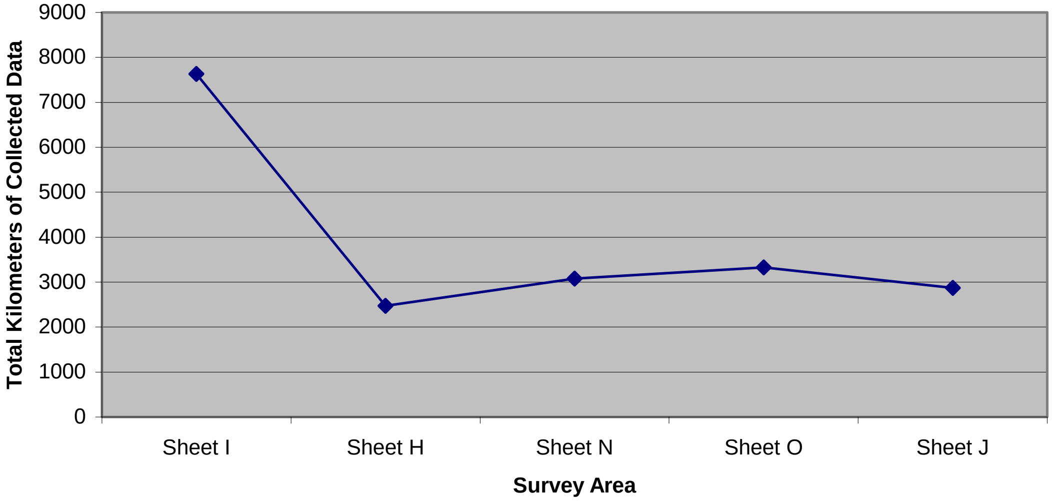

***Figure 3**. The amount of data collected decreased significantly when the SOW was modified after the first sheet.*

Objectives

The error budget was evaluated after the 1998 field season. It was evident that the transducer draft and velocity error budget values were excessively large (DaSilva et al., 2000). After discussions with NOAA, to assure that any changes would still meet specifications, FGSI developed a real-time draft sensor and purchased a Chelsea undulating velocimeter towbody.

The objective of this paper is to illustrate that the working relationship between NOAA and FGSI has allowed innovation that has resulted in the improvement of data quality and overall productivity while performing contract hydrographic work.

Methodology

Vessel Configuration

Three survey vessels were utilized during this contract. The *R/V Beacon* was used for all Sheet I data collection. The *M/V Geodetic Surveyor* was used to collect data for Sheets H, N, and O. The *M/V Universal Surveyor* was used to collect all data for Sheet J, side scan infill data for Sheet H, and Investigation data for Sheets N and O. Primary survey lines were collected parallel to bathymetric contours, along the short axis of the survey area for Sheets I and J and along the long axis of the survey area for Sheets H, N, and O. Survey lines were run with distinct starting and ending points. Each individual line contained fix marks, or shot points, which were logged every 150 meters. This methodology of line numbering and annotating allows for quick comparison between adjacent lines. This is extremely useful in the comparison between side scan sonar lines.

A Reson 8101 Seabat multibeam transducer and an Odom 1 MHz DF3200 vertical beam transducer were mounted on the starboard side of the vessel. The pole mount and the alignment bracket were welded to the ship (see Figure 4). The Fugro StarFix® satellite navigation system provided primary navigation. The Fugro Multi-Site DGPS is the first system in the industry that implements the concept of Wide Area DGPS (WADS). The Fugro system uses the MX 4200 GPS receiver and differential corrections from the Fugro DGPS network transmitted via StarFix®. The current Fugro DGPS network covers the continental United States. Coast Guard DGPS was used as the secondary navigation for the contract. The navigation antenna location was assigned to the center of the multibeam transducer.

Figure 4. *Ram being lowered for testing. The top pipe is the multibeam transducer pipe with vertical beam transducer mount; the bottom pipe is the draft sensor pipe. Also shown is the stabilization fin.*

A TSS POS/MV Model 320 was used as the multibeam motion sensor. The accuracy of the sensor is better than 0.05 meters for roll, pitch measurement, 5% of heave amplitude for periods up to 10 seconds, 0.05 meters for true heading, and 0.75-5 meters circular error of probability (CEP), depending on reference station.

Processing

IP400, an “in-house” FUGRO software package was used for data acquisition and processing. This software possesses a data acquisition package (DAP), a post processing package (PPROC), a charting package (CHART), and a digital terrain modeling package (DTM). The software is UNIX driven and runs on GML scripts, IP400 programs, and basic UNIX scripts. TerraModel and TerraVista software packages by Spectra Precision Software were used to manually edit the data of noise spikes.

Squat and Settlement

On the Fly (OTF) Kinematic GPS Squat and Settlement surveys were performed at the start of every field season, when a new vessel was used, or when there were changes to the survey vessel. The OTF refers to the ability to resolve the ambiguities, while the rover is in motion without returning to the reference sight for reinitialization.

Before mobilization, a current GPS almanac was downloaded and consulted in order to perform the survey when the maximum number of GPS satellites were available. The vessel was mobilized with two dual channel GPS receivers: one mounted at the stern and the other mounted approximately mid ship. Both receivers were mounted either along the centerline of the vessel or starboard side. A third GPS receiver was set at the dockyard to be used as a base station. All receivers were set with consideration of 360 degrees of visibility in order to make best use of available GPS satellites.

Data were logged by the receivers at one-second intervals with an elevation mask of 10 degrees. GPS data were downloaded and processed into xyz coordinates using John E. Chance and Associates version of On the Fly (OTF) software. This software takes collected L1 and L2 RINEX formatted GPS data strings and solves for position by differentiating carrier phase observations between the base and each rover. The solutions were then read into a spreadsheet and averaged and compared for each separate speed run.

Survey operations were conducted at speeds less than or equal to 4.8 knots to assure that any 1 meter side scan sonar contact would be insonified 3 times. The squat values at the survey speed were less than 5 centimeters. Squat and Settlement values were applied during post processing using a look up table (See Figure 5).

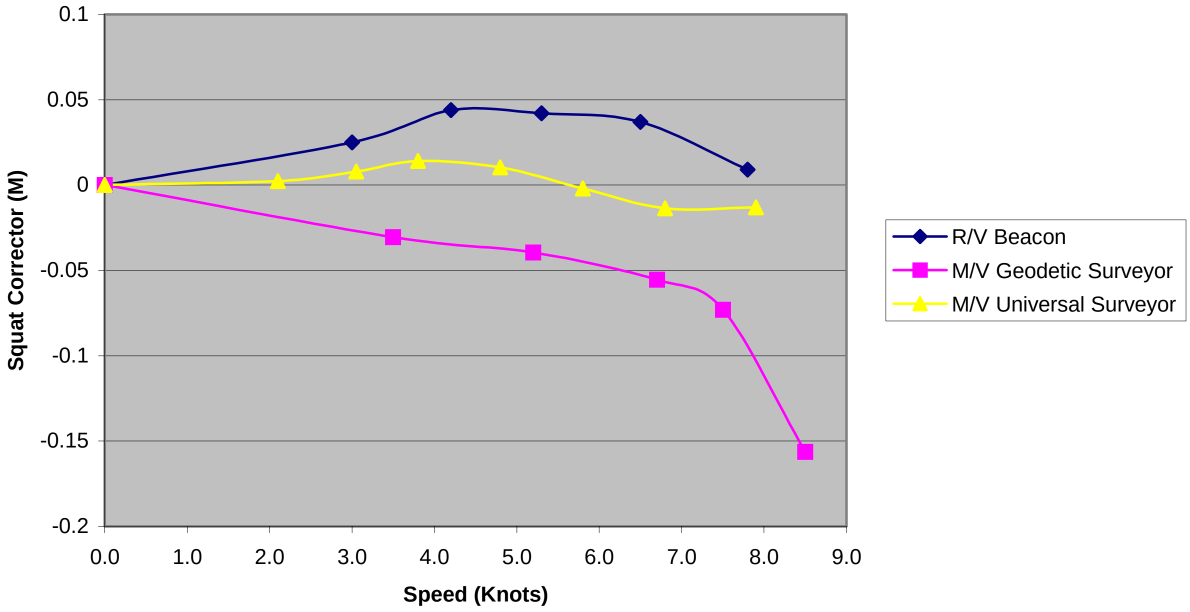

Figure 5. *Squat correctors for project OPR-K171-KR.*

<u>Draft</u>

During the 1998 field season, static draft was observed daily by reading markings on the transducer pole while the vessel was stationary during velocity casts (see Figure 6). When the static draft value differed from that previously recorded, it was noted and applied during post-processing. The accuracy of this method was limited and relied on the individual measuring the draft and the sea state. The accuracy of the reading decreased as the seas increased. The magnitude of the error budget values required by the measurement inaccuracy prompted FGSI to develop a real-time draft sensor.

Figure 6. *Draft markings on stabilization fin of transducer pole.*

The real-time draft sensor incorporates the use of a 52 kilohertz Lundahl model IRU-5280 acoustic transducer mounted inside of a multipipe system (see Figure 7). The design was adapted from a tide gauge configuration that used a multipipe system to dampen wave action. Holes were drilled to allow for proper water inflow. The draft pipe was welded directly to the Reson transducer pole to provide the most accurate reading possible of the draft affects introduced to the multibeam data. As the vessel sinks (or squats) in the water, the water inside of the pipe rises, resulting in a difference in the draft sensor reading. The draft sensor measures the distance from the fixed draft transducer reference point to the surface level of the water inside of the pipe. The distance from the reference point of the draft sensor to the Reson transducer reference point equals 4 meters.

Figure 7 *Draft sensor showing multipipe system.*

Draft sensor calibration is done in conjunction with the OTF kinematic settlement and squat test. To accurately calibrate the draft sensor, the sensor readings are compared with the actual change of vessel position in the vertical plane. To do this a GPS antenna mounted directly over the transducer head is used (see Figure 8). While the vessel is at 0 knots (static), a GPS reading and a digital draft reading are taken. A visual draft reading and water level measurement within the pipe are also taken to check the digital draft value. Once the static test is complete, GPS and draft monitor values are recorded as the vessel travels at various speeds (1-7 knots). The recorded values are then processed, which entails subtracting the static values (both the GPS and draft sensor) from the values obtained while the vessel was in motion. The draft at the Reson transducer head is derived by subtracting the draft values from the 4 meter offset between the draft sensor and the reference point.

The draft sensor was used real-time during the 1999 field season when the pipe configuration allowed proper flow through the system, resulting in accurate readings while underway. During data collection in 1999, the draft sensor readings were stored on the processing computer, which averaged values over a one-second interval for each line. After line completion, the draft data were cleaned of erroneous spikes and all draft readings for that line were averaged into a single draft value to be used for the line. As part of our quality control plan, the draft values were reviewed and compared with previous readings before being applied during post-processing. In addition, the digital draft values are compared to tick marks, manually drawn on the exterior of the draft pole at 5 cm intervals (see Figure 6).

The transducer pipe unit (see Figure 4) was removed from the *M/V Geodetic Surveyor* and welded onto the *M/V Universal Surveyor* for the 2000 field season. During this transfer, the pipe was damaged. During the calibration tests, it was evident that the system was no longer accurate while underway. The static digital reading were still accurate, so the draft values were taken at regular intervals during data collection and applied during post processing.

Figure 8. *Static Calibration of real-time draft sensor. GPS Antennas mounted for OTF Kinematic tests.*

Velocity

The survey areas for Sheet I and Sheet H were south and southwest of Sabine respectively (see Figure 1). During the first field season, velocity casts were obtained at least twice daily and more frequently if necessary. An average of 1.5 to 3.5 hours per day were spent collecting velocity data during Sheets H and I. The frequency of velocity cast collection was based upon degradation of the multibeam outer beams, which was monitored real-time by observing the Reson monitor and an Applied Microsystems smart sensor real-time velocity data.

During Sheet H data collection, the survey area was broken into three sections to compensate for velocity differences likely due to an influx of freshwater brought by the west running long shore current and radiant heating. A Chelsea Instruments, Ltd. Nv Shuttle (see Figure 9) was purchased to provide more accurate velocity readings along line.

Velocimeters that are used within the Chelsea undulating shuttle are calibrated within six months of data collection. The Chelsea vehicle is used to measure all depth values because it has a greater accuracy than the velocimeters. To calibrate the Chelsea depth sensor, the towing cable is marked every ten centimeters and the Chelsea vehicle is lowered through the water column. Readings are obtained from the depth sensor and then are compared with the markings on the towing cable.

The velocity probe sends data every ten seconds. These data are used to create a velocity profile at a user defined interval. This profile is called a major profile and is generally created every 15 minutes from data collected during the down cast of the undulation. Between each major velocity profile minor velocity profiles are interpolated every

100 pings. The velocity data are time referenced and applied to the corresponding multibeam data during post processing. The frequency of velocity casts can be redefined by the user anytime degradation of the multibeam outer beams becomes visually apparent. Degradation of the multibeam outer beams is monitored real-time by observing the Reson monitor and the real-time velocity display on the DAP computer. Small sections of multibeam data with velocity data applies are profiled with the CHART program to insure that proper velocity data are applied. In addition, the swath profiles are visually inspected in TerraModel as a velocity QC.

Figure 9. *Chelsea Systems undulating towbody. An Applied Microsystems Ltd. Sound Velocity SVP-16 velocity profiler is bolted in place.*

The undulating real-time velocimeter is run continuously from two meters to 80% of the water depth, and dropped 95 percent of the water depth at least once during every line. To provide complete depth coverage, the velocity data are extrapolated by taking ten percent of the deepest depth and adding that value to the deepest depth. The velocity data are extended to the extrapolated depth based upon the velocity curve above the extrapolated depth values.

Results

A comparison between draft values collected during Sheet H and Sheet O displays an increase in the number of draft values provided (See Figure 10 and Figure 11). All comparisons and quality checks indicate that the real-time draft sensor has an accuracy of 1 to 2 centimeters. Thus decreasing the error budget value of the draft sensor.

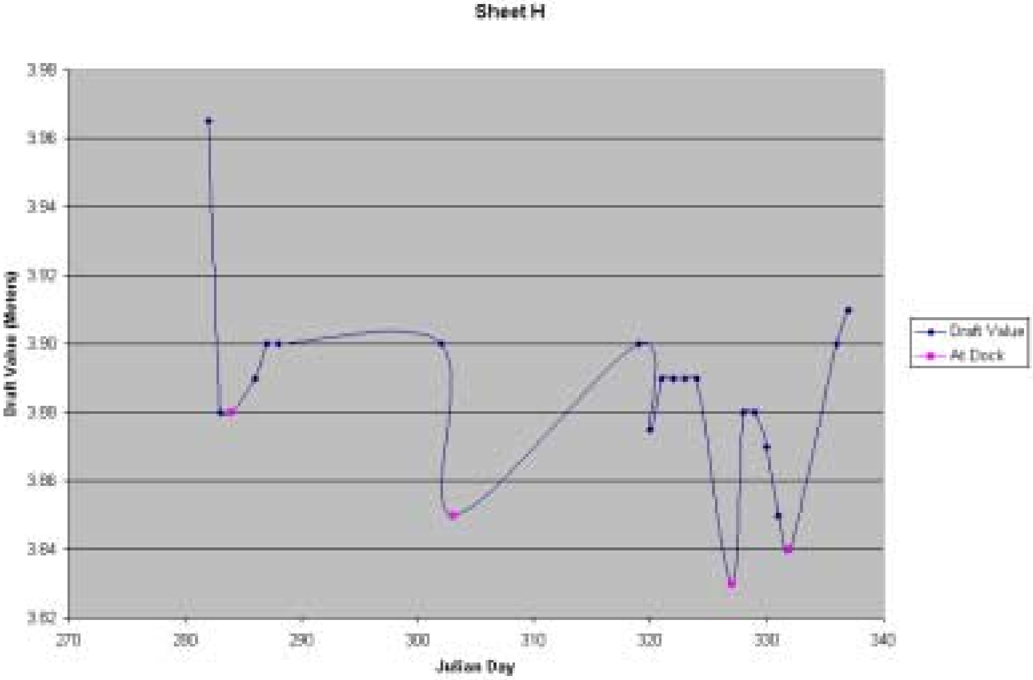

Figure 10. *Sheet H - Draft Values vs. Time*

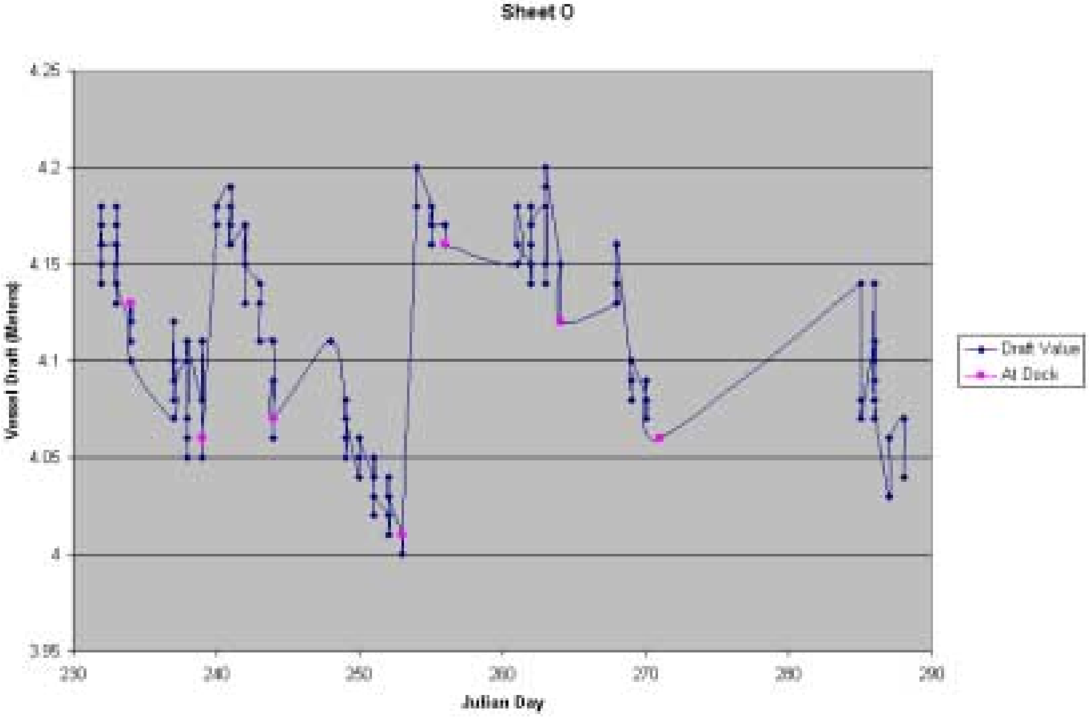

Figure 11. *Sheet O - Draft Values vs. Time.*

A climb rate of 2 meters/minute was assigned to the Chelsea shuttle. The shuttle undulated an average of eleven times per line (see Figure 12). While many of the lines did not display large velocity differences, some lines displayed differences up to 10 meters per second (see Figure 13).

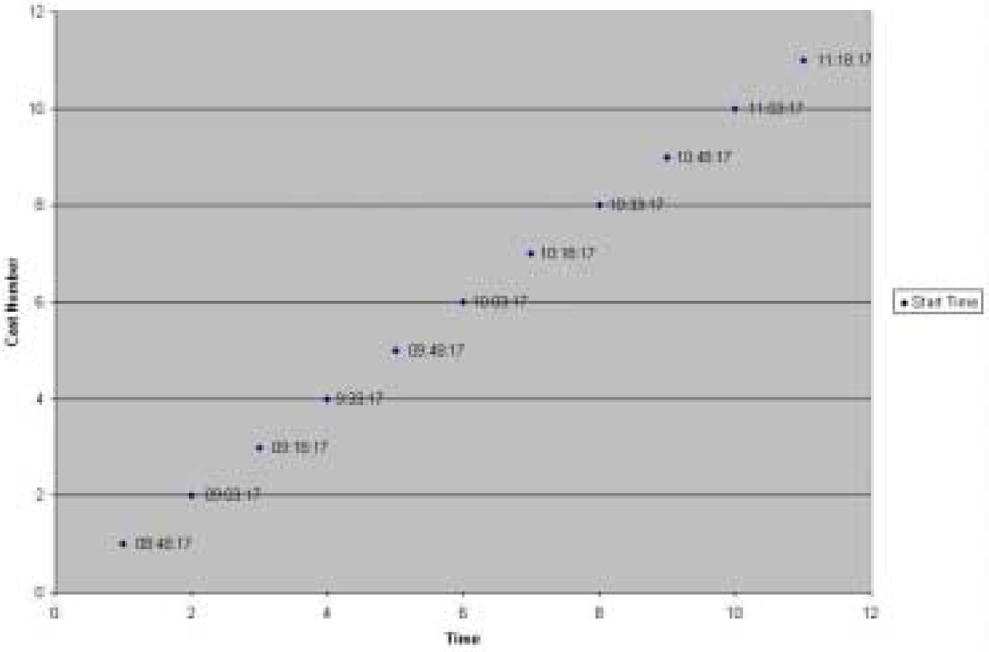

Figure 12. *Major cast values are produced every fifteen minutes. Seventy-two minor casts are interpolated between every major cast.*

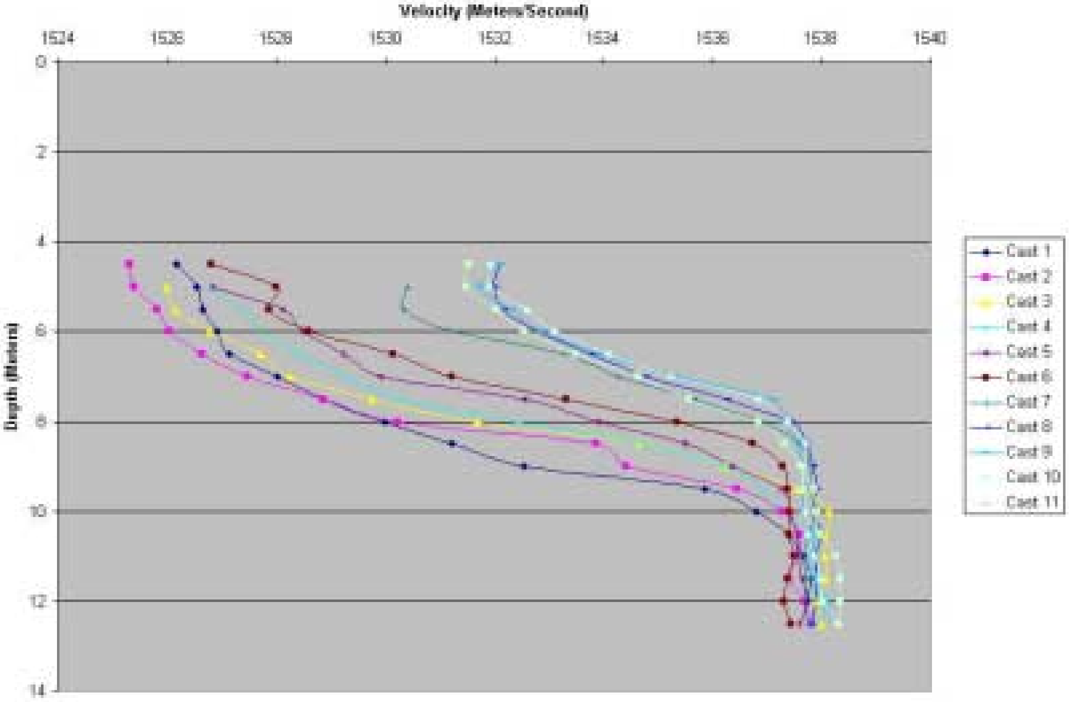

Figure 13. *Velocity profiles along a single line demonstrate the extreme changes in velocity, that will affect multibeam data if not available during processing.*

Conclusions

NOAA's progressive stance on innovation has provided opportunities to improve data quality and efficiency while performing contract hydrography. These results are evident when looking at the amount of time spent on each survey and increased productivity. (see Figures 14 and 15).

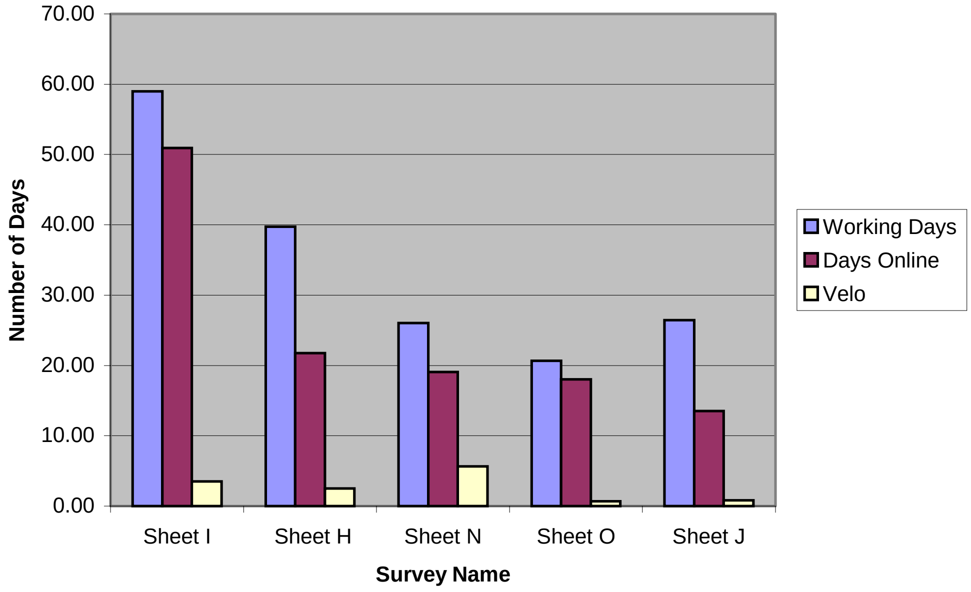

Figure 14. *FGSI has improved data collection procedures with experience. Collection of grab samples was not required for Sheet N and Sheet O. Please Note: The velocity time for Sheet I and Sheet H are actual hours spent collecting static velocity casts. The velocity time for Sheets N, O, and J is equivalent to shuttle down time and necessary static casts.*

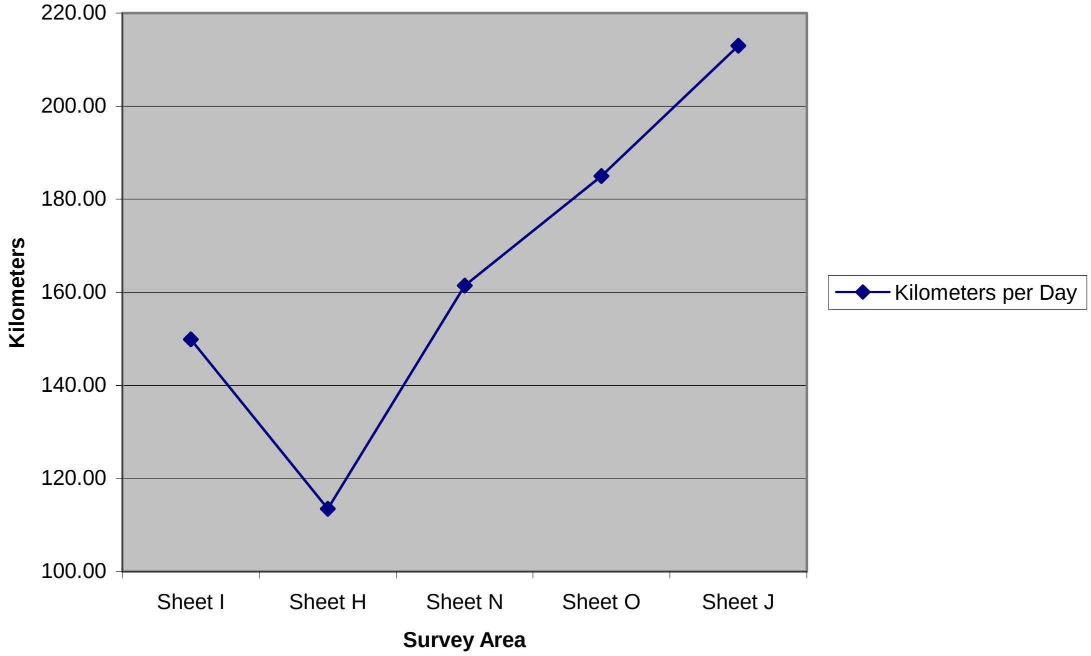

Figure 15. *FGSI has improved data collection procedures and thus improved productivity.*

References

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