NOAA FORM 76-35A

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

DATA ACQUISITION AND PROCESSING REPORT

Type of Survey Hydrographic

Project No. OPR-R341-KR-10

Time Frame June – September 2010

LOCALITY

State ALASKA

General Locality Kuskokwim River

2010

CHIEF OF PARTY

ANDREW ORTHMANN

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DATE

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NOAA FORM 77-28 (11-72) U.S. DEPARTMENT OF COMMERCE NATIONAL OCEANIC AND ATMOSPHERIC ADMINISTRATION	REGISTER NO.
HYDROGRAPHIC TITLE SHEET	**H12164, H12165, H12166, H12167, H12168, H12169, H12170**
INSTRUCTIONS – The Hydrographic Sheet should be accompanied by this form, filled in as completely as possible, when the sheet is forwarded to the Office	FIELD NO. **N/A**

State Alaska

General Locality Kuskokwim River

Locality Mouth of Kuskokwim River to Bethel

Scale 1:10,000 Date of Survey June 16, 2010 to September 3, 2010

Instructions dated March 11, 2010 Project No. OPR-R341-KR-10

Vessel M/V JELLA SEA (AK7395AC) , M/V DUCER (AK4059M), M/V LATENT SEA (AK6828AK)

Chief of party ANDREW ORTHMANN

Surveyed by TERRASOND PERSONNEL (L. BENNETT, W. BOWEN, K. CIEMBRONOWICZ, C. GILL, M. KRYNYTZKY, T. LANDRY, P. PACK, B. POULSON, D. SEAMOUNT, S. SHAW, M. STEVIE, ET. AL.)

Soundings taken by echo sounder, hand lead, pole ECHOSOUNDER -- RESON SEABAT 8101 (POLE MOUNTED), AND ODOM ECHOTRAC CVM/CV100 (HULL MOUNTED)

Graphic record scaled by N/A

Graphic record checked by N/A

Protracted by N/A Automated plot by N/A

Verification by

Soundings in METERS at MLLW

REMARKS:

The purpose of this work is to provide NOAA with modern and accurate hydrographic survey data for the mouth of the Kuskokwim River to Bethel, Alaska.

Contract No. DG133C-08-CQ-0005

ALL TIMES ARE RECORDED IN UTC

Hydrographic Survey:

TerraSond Ltd.
1617 South Industrial Way, Suite 3
Palmer, AK 99645

Tide Support:

John Oswald & Associates LLC
2000 E. Dowling Rd., Suite 10
Anchorage, AK 99503

Data Acquisition and Processing Report

OPR-R341-KR-10

December 20th, 2010

Local skiffs in Bethel, Alaska

Vessels: ***M/V Latent Sea, M/V Jella Sea, M/V Ducer***

Locality: ***Kuskokwim River, Alaska***

Sublocalities:

H12164 – Mouth of Kuskokwim River
H12165 – West of Eek Island
H12166 – West of Helmick Point
H12167 – 10 NM NNE of Helmick Point
H12168 – 5 NM SW of Tundra River
H12169 – South of Napakiak
H12170 – South of Bethel

Lead Hydrographer: ***Andrew Orthmann***

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A. *Equipment*

A.1. Echosounder Systems

To collect sounding data, this project utilized Odom Echotrac CV100 Single-beam Echosounder (SBES) systems, an Odom Echotrac CVM SBES system, and Reson SeaBat 8101 Multibeam Echosounders (MBES).

A.1.1. Single-beam Echosounders

Three Odom Echotrac CV100 and one Odom Echotrac CVM SBES systems were used on this survey. System setups were nearly identical, though acquisition settings were changed online as necessary to maintain data quality.

The Odom Echotrac CV100 and CVM systems are digital imaging echosounders. Both system types require Odom eChart software to serve as the user interface. They are nearly identical in configuration except the CVM is multi-frequency capable while the CV100 is a single-frequency model. However for this survey both system types were coupled to single-frequency (200-kHz) transducers.

Power, gain, depth filters, and other user-selectable settings were adjusted as necessary through eChart to maximize data quality. Values from sound-speed measurements were input daily into the device calibration so that the correct depth would be output. The system was configured to output bathymetric data via Ethernet network connection to an acquisition PC running QPS QINSy (Quality Integrated Navigation System) software, which logged to ".XTF" file as well as the QPS database format ".DB".

Since the Echotrac CV100 and CVM are all-digital units that do not create a paper record, eChart was utilized to log ".DSO" format files continuously during survey operations. The DSO files, which can be re-played in eChart, contain the bottom track detail and were used routinely by processing instead of a paper trace. See section B of this report for more information regarding the use of eChart DSO files.

Each Odom was configured to accept a serial input from Qinsy which contained time sync data and event markers. The event markers were written to the DSO files and when replayed in eChart resemble paper trace events.

The Odom CVM, which was used for the first portion of the project on the *M/V Jella Sea,* was removed from the project on July 17, 2010 (JD198) to accommodate other survey operations and replaced with an Odom CV100.

A.1.2. Multibeam Echosounders

Two Reson SeaBat 8101 MBES systems were also used on this project. System setups were nearly identical, though acquisition settings were changed online as necessary to maintain data quality.

The Reson SeaBat 8101 is 240 kHz radial-array system which forms 101 separate beams. The system was configured to output bathymetric data including snippets and backscatter via Ethernet network connection to an acquisition PC running QPS Qinsy, which logged XTF and DB files. Note that to conserve disk space, QPS Qinsy was configured to log backscatter and snippet data to DB file only.

Range scales, power, gain, pulse width, and depth-filter settings were adjusted as a function of water depth and data quality. Settings were tracked in the survey line logs (see *Separate I* of the Descriptive Report). Spreading and absorption values were set to manufacturer recommended ranges for a mix of salt and fresh water.

The Reson 8101 was synchronized to UTC time via a serial input from QPS Qinsy. QPS Qinsy was configured using its "SeaBat Synchronizer" driver to output a UTC string to the Reson, which re-synced its internal clock at a rate of 1 Hz.

During data acquisition, optimal sonar range scales along with limited vessel speed were used to ensure the Reson 8101 was operated in a manner cognizant of the 2010 Specifications and Deliverables (section 5.2.2.2) requirements for the "complete multibeam" coverage category.

A.1.3. Echo-sounder Technical Specifications

Odom CV100	
Firmware Version	4.09
Sonar Operating Frequency	100 – 750 kHz (200 kHz used)
Output Power	300 W RMS Max
Ping Rate	Up to 20 Hz
Resolution	0.01 m
Depth Range	0.3 – 600 m, depending on frequency & transducer

Table 1 – Odom CV100 single-beam echosounder technical specifications.

Odom CVM	
Firmware Version	3.29
Sonar Operating Frequency	100-340 kHz (200 kHz used)
Output Power	350 W RMS Max
Ping Rate	Up to 20 Hz
Resolution	0.01 m
Depth Range	0.2 – 200 m @ 200kHz

Table 2 – Odom CVM single-beam echosounder technical specifications.

Reson SeaBat 8101	
Firmware Version (Dry)	8101-2.09-E34D
Firmware Version (Wet)	8101-1.08-C215
Sonar Operating Frequency	240 kHz
Beam Angle, Across Track	1.5°
Beam Angle, Along Track	1.5°
Number of Beams	101
Max Swath Coverage	150°
Max Depth Range	300 m

Table 3 – Reson SeaBat 8101 multibeam echosounder technical specifications.

A.2. Vessels

All data for this survey was acquired using the *M/V Latent Sea*, the *M/V Jella Sea* and the *M/V Ducer*.

A.2.1. M/V Latent Sea

The *M/V Latent Sea*, shown in Figure 1, was used to collect both single-beam and multibeam data. It is a 7.01 meter aluminum hulled vessel with a 2.62 meter beam and a 0.51 meter draft, manufactured by Workskiff, Inc. The vessel is powered by twin 150Hp Honda four-stroke outboard motors. Electrical power is provided by two Honda 2-kilowatt portable generators.

Figure 1 – M/V Latent Sea near Bethel, AK.

The *M/V Latent Sea* was equipped with a POS MV 320 V4, an Odom Echotrac CV100 SBES system (with 200 kHz/3° hull-mounted transducer), and a pole-mounted Reson SeaBat 8101 MBES system. Detailed vessel drawings showing the location of all primary survey equipment are included in Section C of this report.

Line orientation for the *M/V Latent Sea* was generally perpendicular to the river during SBES data collection and parallel to the river channel during MBES data collection.

M/V Latent Sea survey operations were conducted concurrently with those of the *M/V Jella Sea* and *M/V Ducer*.

The survey equipment on the *M/V Latent Sea* performed well with no major issues encountered.

***M/V Latent Sea* Survey Equipment**

Description	Manufacturer	Model / Part	Serial Number
Single-Beam Sonar	Odom	Echotrac CV100	3498
Single-Beam Transducer	Odom	SMBB 200-3	n/a
Multibeam Transducer	Reson	SeaBat 8101	3507006
Multibeam Processor	Reson	81-P	8002029

Description	Manufacturer	Model / Part	Serial Number
Positioning System	Applanix	POS MV 320 V4	3190
Motion Sensor	Applanix	POS MV IMU	135 402628
SV Casting Probe	Applied Microsystems	SV Plus v2	3279
RTK Signal Receiver	Pacific Crest	RFM96W	196160
RTK Signal Receiver	Pacific Crest	RFM96W	99129771
Secondary Positioning System	Trimble	DSM-232	255127581

Table 4 – Major survey equipment used aboard the M/V Latent Sea.

A.2.2. M/V Jella Sea

The *M/V Jella Sea*, shown in Figure 2, was used to collect both single-beam and multibeam data. It is a 7.62 meter aluminum hulled vessel with a 2.62 meter beam and a 0.61 meter draft, manufactured by USCOLA Boatworks. The vessel is powered by twin 135Hp Honda four-stroke outboard motors. Electrical power is provided by two Honda 2-kilowatt portable generators.

Figure 2 – M/V Jella Sea.

The *M/V Jella Sea* was equipped with a POS MV 320 V4, an Odom Echotrac CVM SBES system (with 200 kHz/3° hull-mounted transducer), and a pole-mounted Reson SeaBat 8101 MBES system. Detailed vessel drawings showing the location of all primary survey equipment are included in Section C of this report.

The Odom Echotrac CVM was removed from this vessel on July 17, 2010 (JD198) to accommodate other survey operations that required a dual-frequency system. It was replaced with an Echotrac CV100.

Line orientation for the *M/V Jella Sea* was generally perpendicular to the river during SBES data collection and parallel to the river channel during MBES data collection.

The *M/V Jella Sea* was removed from the project prematurely on July 27th (JD208) when the vessel for unknown reasons filled with water through open scuppers and sank during the night. The vessel was successfully re-floated the same day and equipment recovered. However the decision was made to remove the vessel from the project to allow for remediation, and to send the affected survey equipment to the manufacturers for testing and restoration. The *M/V Latent Sea* daily survey hours were extended and used to survey the areas assigned to the *M/V Jella Sea* in addition to its own survey areas.

The survey equipment on the *M/V Jella Sea* performed well, with the exception of the following:

- A slight roll artifact was noted on various multibeam lines and attributed to the multibeam arm on the vessel not coming to rest in the same alignment relative to the IMU during deployment. The effect on the data is minor and well within specifications but noticeable on the affected days. The issue was becoming more prevalent but the vessel was removed from the project abruptly before it became a serious problem. Most of the affected lines were confined to H12164. Effects on data quality are discussed in more depth in the appropriate Descriptive Report.

***M/V Jella Sea* Survey Equipment**

Description	Manufacturer	Model / Part	Serial Number
Single-Beam Sonar	Odom	Echotrac CVM (until 7/17/10)	20031
Single-Beam Sonar	Odom	Echotrac CV100 (installed 7/17/10)	3505
Single-Beam Transducer	Odom	SMBB 200-3	n/a
Multibeam Transducer	Reson	SeaBat 8101	3507006
Multibeam Processor	Reson	81-P	32030
Positioning System	Applanix	POS MV 320 V4	3167

Description	Manufacturer	Model / Part	Serial Number
Motion Sensor	Applanix	IMU 200	778
SV Casting Probe	Applied Microsystems	SV Plus v2	3259
RTK Signal Receiver	Pacific Crest	RFM96W	196164
RTK Signal Receiver	Pacific Crest	RFM96W	99412569
Secondary Positioning System	Trimble	DSM-212	220273384

Table 5 – Major survey equipment used aboard the M/V Jella Sea.

A.2.3. M/V Ducer

The *M/V Ducer*, shown in Figure 3, was used to collect single-beam data in addition to shore operations and bottom samples. Shore operations included water level observations at tide stations and RTK site installation and maintenance. It is a 5.79 meter aluminum hulled vessel with a 2.13 meter beam and a 0.46 meter draft, manufactured by Grayling Boat Works. The vessel is powered by twin 70 Hp Yamaha two-stroke outboard motors. Electrical power is provided by one Honda 2-kilowatt portable generator.

Figure 3 – M/V Ducer near Bethel, AK.

The *M/V Ducer* was equipped with a POS MV 320 V4 and an Odom Echotrac CV100 SBES system (with 200 kHz/4° transducer mounted in moon pool). Detailed vessel drawings showing the location of all primary survey equipment are included in Section C of this report.

Line orientation for the *M/V Ducer* was generally perpendicular to the river during SBES data collection.

The survey equipment on the *M/V Ducer* performed well, with no major issues encountered.

***M/V Ducer* Survey Equipment**

Description	**Manufacturer**	**Model / Part**	**Serial Number**
Single-Beam Sonar	Odom	Echotrac CV100	3504
Single-Beam Transducer	Odom	SMSW200-4A	n / a
Positioning System	Applanix	POS MV 320 V4	2147
Motion Sensor	Applanix	LN200	135 402628
SV Casting Probe	Odom	Digibar Pro	98427-021110
SV Casting Probe	Odom	Digibar Pro	98014-030910
RTK Signal Receiver	Pacific Crest	RFM96W	99412579
RTK Signal Receiver	Pacific Crest	RFM96W	1500472
Secondary Positioning System	Trimble	DSM-212	220061769

Table 6 – Major survey equipment used aboard the M/V Ducer.

A.3. Speed of Sound

Speed of sound data was collected by vertical casts on the *M/V Latent Sea and M/V Jella Sea* using Applied Microsystems (AML) SV Plus v2 sensors. Two Odom Digibars were used onboard the *M/V Ducer.* The sensors were calibrated prior to the start of survey operations and then compared weekly to each other with good results.

Sound-speed profiles were taken as deep as possible and were geographically distributed within the survey area. Sound-speed profilers were lowered by hand and extend to the river bottom.

Sound-speed casts were taken at an interval not exceeding 12 hours during SBES operations and 4 hours during MBES operations.

In general, sound-speed profiles were consistent with well-mixed conditions, showing little variance through the water column and between casts. An exception is the mouth of the river (in particular H12164) where there was more saline influence and a less-mixed profile became apparent.

Refer to the CARIS ".SVP" file submitted with the digital data for specific cast positions and times. Refer to each Descriptive Report (DR), *Separate II: Sound Speed Data* for the sound-speed comparison checks.

Copies of the manufacturer's calibration reports are included in the DR, *Separate II* for each survey sheet. The following instruments were used to collect data for sound-speed:

A.3.1. Sound-Speed Sensors

Sound-Speed Gauge	Manufacturer	Serial number	Calibration Date
SV Plus v2	Applied Microsystems, Ltd. Sydney, British Columbia, Canada	3259	3/15/2010 by AML Oceanographic
SV Plus v2	Applied Microsystems, Ltd. Sydney, British Columbia, Canada	3279	2/10/2010 by AML Oceanographic
Digibar	Odom Hydrographic Systems, Inc Baton Rouge, Louisiana	98427-021110	2/11/2010 by Odom Hydrographic
Digibar	Odom Hydrographic Systems, Inc Baton Rouge, Louisiana	98014-030910	3/09/2010 by Odom Hydrographic

Table 7 – Sound-Speed Gauges and calibration dates.

A.3.2. Sound-Speed Sensor Technical Specifications

Applied Microsystems SV Plus v2	
SV Precision	0.03 m/s
SV Accuracy	0.05 m/s
SV Resolution	0.015 m/s
Pressure Precision	0.03 % of full scale
Pressure Accuracy	0.05 % of full scale

Applied Microsystems SV Plus v2	
Pressure Resolution	0.005 % of full scale

Table 8 – AML SV Plus v2 specifications

Odom Digibar Pro	
SV Accuracy	0.3 m/s
SV Resolution	0.1 m/s
Depth Sensor Accuracy	0.31 m

Table 9 – Odom Digibar Pro specifications

A.4. Positioning & Attitude Systems

To provide positioning data and attitude corrections, all survey vessels were equipped with an Applanix POSMV 320 V4 Position and Orientation system. The system utilized two Trimble Zephyr Geodetic dual-frequency GPS antennas and an IMU (inertial measurement unit) to generate position, heave, pitch, roll, and heading data. The data was output from the POSMV via RS-232 serial cables to an acquisition PC where it was logged in conjunction with bathymetry in QPS QINSy software.

For real-time GPS corrections, each POSMV was interfaced with a Pacific Crest radio which received Real Time Kinematic (RTK) Corrections transmitted from stations established by the survey crew on shore.

An Ethernet interface between an acquisition PC and with the POSMV allowed logging of a ".POS" file continuously during survey ops. The POS file contained the raw accelerometer and GPS data necessary for post-processing, which was done later in Applanix POSPac software in conjunction with base station data. The POS file also contained TrueHeave records which were loaded into each survey line in processing.

The POSMV also provided the timing synchronization for the survey systems. The POSMV was configured to output a 1-PPS over coax and a ZDA time string over serial connection to QPS Qinsy. The ZDA was split to also provide time stamps for vessel engine RPM data.

The POSMV is self-calibrating upon startup except for its GPS Azimuth Measurement Subsystem (GAMS) – a component of the system's heading computations – which requires an initial calibration. GAMS calibrations were done once for each POSMV after mobilization on the vessel, prior to the vessel patch test. During GAMS calibration the POSMV computes the separation between the primary and secondary antennas and the vector between them. Results are shown in the table below.

POSMV GAMS Calibration Results				
Vessel	POSMV SN	GAMS Cal Date	Ant. Separation	Baseline Vector (X, Y, Z)
Jella Sea	3167	6/20/2010 (JD171)	1.952 meters	0.003, 1.952, 0.010
Ducer	2147	6/21/2010 (JD172)	1.065 meters	-0.037, 1.064, -0.017
Latent Sea	3190	6/20/2010 (JD171)	1.744 meters	0.012, 1.743, -0.074

Table 10 – POSMV GAMS Calibration Results.

To provide a real-time positioning confidence check, each vessel was outfitted with a Trimble DSM 212 or 232 beacon receiver. Although outside of the nominal range of USCG DGPS corrections the beacons did receive corrections semi-continuously from the Continually Operating Reference System (CORS) station at Cold Bay. Positions computed by the POSMV and DSM receivers were viewed simultaneously as nodes in QPS Qinsy's Navigation screen to allow real-time comparison and gross error checking.

Detailed position confidence checks were compiled weekly by processing using Applanix POSPac software. Refer to section B of this report for methods used to compute weekly checks and to each DR, *Separate I: Acquisition and Processing Logs* for position confidence check results.

A.4.1. Position & Attitude System Technical Specifications

Applanix POS MV 320 V4	
Firmware Versions	SW04.22-Feb02/09 SW03.42-May28/07
Roll, Pitch Accuracy	0.01° with RTK
Heave Accuracy	5 cm or 5% for periods of 20 sec or less
Heading Accuracy	0.02° with 2 m antenna baseline
Position Accuracy	0.02 - 0.10 m with RTK
Velocity Accuracy	0.03 m/s horizontal
Ethernet Logging	50 Hz

Table 11 – Applanix POS MV V4 technical specifications.

Trimble DSM 212	
Differential Speed Accuracy	0.1 kn
Differential Position Accuracy	Less than 1 m RMS

Table 12 – Trimble DSM 212 technical specifications.

Trimble DSM 232	
Accuracy (WAAS enabled)	Typically 1.0 m horizontal
Accuracy (DGPS)	Typically 1.0 m horizontal
Antenna Type	DGPS

Table 13 – Trimble DSM 232 technical specifications.

A.5. Vessel Engine RPM Logging

Dynamic draft corrections for this project were primarily engine RPM (revolutions per minute) based. Speed-based corrections were not used except in a relatively few cases where RPM data was not logged. Due to the strong river and tidal currents, typically averaging 3 kts, RPM-based corrections more accurately captured vessel vertical response.

To replace error-prone manual notation of engine RPMs used in the past, and to maintain a continuous and accurate log of engine RPM data for dynamic draft corrections, a custom-designed tachometer ("TerraTach") was designed for and utilized on this project.

On each vessel, TerraTach was interfaced with both engines and configured to accept a ZDA time string from the POSMV. It then computed each engine's RPM with a resolution of 60 RPM and output the time-tagged result at 1 Hz over serial interface to a PC where it was logged in Windows Hyperterminal. The RPM file was later used in office processing for application of delta draft.

During pre-project testing and periodically through the survey, TerraTach was compared to each vessel's own tachometers with good results.

A.6. Base Stations

Over the course of the project nine RTK base stations were deployed along both shores of the Kuskokwim River at intervals designed to provide overlapping RTK radio coverage. At any one time two stations were normally broadcasting in the vicinity of survey operations.

Each base station consisted of a Trimble 5700 GPS receiver with Zephyr Geodetic Antenna setup over a pre-surveyed benchmark and interfaced with a Pacific Crest PDL radio with pole-mounted antenna. In addition to logging dual frequency GPS data to compact flash card, the stations were configured to broadcast “CMR+” (Trimble format) corrections over 464.5 and 464.7 MHz using a 35-watt transmission for best possible range. Station power was normally provided by four 12V batteries coupled with two 75-watt solar panels. A 12V timer was utilized to turn the Pacific Crest radio off at night to conserve power when survey operations were not being conducted. However the 5700 receiver bypassed this system so that base station data would log 24 hours a day even if the voltage dropped below the radio’s power requirements.

Each vessel was configured to receive the CMR+ signal via Pacific Crest bluebrick radios, which output the correction message to the vessel POSMV to compute an RTK solution. Reception of the signal was highly distance and line of sight dependent with interruptions common.

Base station data logged to compact flash card in a Trimble (*.T01) format. The data was downloaded periodically throughout the survey, usually at intervals ranging from two days to two weeks. The accuracy of base station solutions was checked often using position confidence checks with good results. See section *B.4.4* and *B.4.5* of this report for information regarding base station position confidence checks.

Overall base station performance was excellent. Base data was rarely interrupted -- the RTK07 base station was interrupted on at least two occasions due to local wildlife that chewed through the cable that connects the GPS antenna to the GPS receiver. However these interruptions in base data did not affect survey data processing because an alternate, nearby station was always logging.

Base station data logged at each of the RTK stations was used to produce the final PPK navigation solution applied to all data. Section *B.3.6* of this report contains more information regarding processing of PPK data using these base stations, and section *B.2.5* describes base stationing installation and retrieval QC measures. A typical base station setup is shown below.

Figure 4 – Base station setup on shore of Kuskokwim River at RTK03. September 2, 2010.

A.6.1. Base Station Equipment Technical Specifications

Trimble 5700	
Accuracy (Static)	Horizontal 5 mm + 0.5 ppm RMS Vertical 5 mm + 1 ppm RMS
Output Standard Used	CMR+

Table 14 – Trimble 5700 specifications

Pacific Crest PDL (High Power Base)	
Power (TX nominal)	110 Watts (35W)
Power (RX nominal)	1.9 Watts
External Antenna	50 Ohm, BNC

Pacific Crest PDL (High Power Base)	
Link Protocol	TRIMTALK™
Frequencies Used	464.5 and 464.7 MHZ

Table 15 – Pacific Crest PDL radio specifications

A.7. Tide Gauges

The National Water Level Observation Network (NWLON) tide stations at Bethel, AK (946-6477) and Quinhagak, AK (946-5831) were used to provide tide data for OPR-R341-KR-10. In direct support of this survey, three additional tide stations were installed in May and June 2010 by John Oswald and Associates (JOA) of Anchorage, AK. Stations were installed at a historic U.S. Coast and Geodetic Survey tide station Popokamute, AK (946-6057) and new tide stations at Lomavik Slough, AK (946-6328), and Helmick Point, AK (946-6153).

JOA installed three WaterLOG series DAA H350XL bubbler gauges near Popokamute (60°06'53.5"N, 162°30'07.7"W) and (60°07'24.5"N, 162°29'59.6"W). Two each WaterLOG series DAA H350XL bubbler gauges were installed on the Kuskokwim River adjacent to Lomavik Slough (60°33'13.9"N, 162°17'46.9"W) and near Helmick Point (60°16'13.5"N, 162°24'38.0"W). Data from the tide gauges was monitored remotely via GOES and downloaded periodically throughout the survey to be combined with the staff observations and meteorological data collected during the project.

The WaterLOG gauges were calibrated prior to the start of survey operations. In the field they were installed in pairs for redundancy and as a check on each other. Additionally their installation stability was checked weekly throughout the survey with staff shot observations.

In addition Sea-Bird SBE 26plus Wave and Tide Recorder submersible tide gauges were set in six strategic deployment locations for minimum 7-day periods during survey operations. The gauges were synced to UTC and set to log at a 6-minute interval using a 180 second averaging period and logged to internal memory. The gauges were downloaded upon retrieval prior to re-deployment at other sites. Barometric pressure was logged concurrently with a digital barometer on shore and used to provide atmospheric pressure corrections. Data from the gauges with accompanying staff observations was used to assist with tide zoning and to provide additional ellipsoid to MLLW ties. The Sea-Bird gauges were calibrated prior to the start of the survey season.

Final processing of the tide data was completed by TerraSond, Ltd. and JOA of Anchorage, Alaska. Refer to the Horizontal and Vertical Control Report (HVCR) for detailed information regarding the calibration, installation, and data processing procedures used for these stations.

A.7.1. Tide Gauge Technical Specifications

WaterLOG H-350XL	
Pressure Sensor Accuracy	0.02% of full scale
Temperature Accuracy	1° C
Pressure Resolution	0.002%
Temperature Resolution	0.002%
Pressure Accuracy 0-15 PSI	0.007 ft
Pressure Accuracy 0-30 PSI	0.014 ft

Table 16 – WaterLOG H-350XL Tide Gauge Specifications

Sea-Bird SBE 26plus Wave & Tide Recorder	
Pressure Sensor Accuracy	0.01% of full scale
Pressure Resolution	0.2 mm for 1-minute integration
Repeatability	0.005% of full scale

Table 17 – Sea-Bird SBE26plus specifications

A.8. Software Used

A.8.1. Acquisition Software

Each survey launch was outfitted with two dual-core PCs running Windows XP Professional. A summary of the primary software installed and used on these systems during data collection follows.

- QPS QINSy (Quality Integrated Navigation System) hydrographic data acquisition software was used on the acquisition vessels for navigation and to log all bathymetric (both SBES and MBES), position, and sensor data to ".DB" format. Along with the DB file, Qinsy was configured to simultaneously write an ".XTF" format file which was compatible with CARIS HIPS processing software.

- Odom eChart was used during acquisition as well as processing. During acquisition of SBES data, eChart served as the user interface into the Odom Echotrac echosounders and displayed the digital bottom track trace and waveform to assist the operator with ensuring proper bottom tracking. eChart also logged the bottom track data to ".DSO" file, which was then reviewed in processing alongside the digitized depth in CARIS Single-beam editor to assist the processor during data cleaning.

- POSMV POSView was used as the interface with the POSMV. The software was used for initial configuration and GAMS calibration and on a daily basis for real-time QC of the POSMV navigation and attitude solutions. The software was also used to continuously log a ".POS" file during survey operations. The POS file contained the raw accelerometer and GPS data necessary for post-processing, which was done later in Applanix POSPac software in conjunction with base station data. The POS file also contained TrueHeave records which were loaded into each survey line in processing.

- Applied Microsystems SmartTalk software was used to communicate with, configure, and download data from the AML SV+ v2 sound velocity sensors.

- Windows HyperTerminal was used to continuously log RPM data generated by the TerraTach tachometer to file. HyperTerminal was also used for capturing Digibar Pro sound velocity data to file and for general I/O troubleshooting.

- Microsoft Office applications – particularly Excel – were used on-board for log keeping, including recording of position and results of bottom sample collection.

- Trimble GPS Configurator was used as necessary to configure common options in the Trimble 5700 base station receivers prior to deployment,

- Sea-Bird Seasoft was used to configure the Sea-Bird tide gauges prior to deployment and to download the data after retrieval.

Program Name	Version	Date	Primary Function
Applanix POSMV POSView	3.4	2007	Pos MV setup, monitoring, and logging
Odom eChart	1.3.6	2008	Single-beam echosounder interface, digital echotrace logging
QPS QINSy	8.0	3/1/10	Multibeam and single-beam acquisition suite and navigation.
Applied Microsystems SmartTalk	2.27	2007	Configuration and download of AML SV Plus v2 sound-speed sensors
Microsoft Office	2003		Log keeping
Windows HyperTerminal	5.1	2001	Logging of engine RPM data; download of Odom Digibar data
Trimble GPS Configurator	n/a	2008	Configuration of Trimble 5700
Sea-Bird Seasoft	2.0	2007	Configuration and data download for Sea-Bird SBE26 Plus tide gauges

Table 18 – Software used aboard the survey vessels.

A.8.2. Processing and Reporting Software

Processing and reporting was done on dual-core PCs running Windows XP Professional. A summary of the primary software installed and used on these systems to complete planning, processing, and reporting tasks follows.

- CARIS HIPS and SIPS 7.0 was used extensively as the primary data processing system. HIPS was used to apply all necessary corrections to soundings including corrections for motion, sound speed, and tide. HIPS was used to clean and review all soundings and to generate the final BASE surfaces.

- CARIS Notebook was used to create the S-57 deliverable. Bottom samples, survey extents, and shoreline detail (where required) were imported and edited in Notebook and an S-57 file created.

- ESRI ArcGIS was used for pre-survey line planning, during survey operations to assist with tracking of work completed, and during reporting for chartlet creation and other documentation.

- Applanix POSPac MMS 5.1 was used extensively to produce post-processed kinematic (PPK) data. POSPac produced a smooth best estimate of trajectory files (.SBET) which were directly read by CARIS HIPS and applied to all lines.

- TerraSond Simple SVP was used to process sound-speed profiles. The software decimated raw profile data to a consistent depth interval of 1 meter and produced a CARIS-compatible output.

- Trimble Terramodel was used during planning to convert the SBES line plan created in ESRI ArcGIS to a format readable in QPS Qinsy.

- Odom eChart's replay feature was used extensively to review the raw bottom tracking data available in the DSO files to the digitized depth during review in CARIS HIPS single-beam editor.

Program Name	**Version**	**Date**	**Primary Function**
CARIS HIPS and SIPS	7.0.1 7.0.2	2010	Multibeam data processing software
CARIS Notebook	3.1	2009	Feature attribution and creation of S-57 deliverables
ESRI ArcGIS	9.3.1	2009	Desktop mapping software

Program Name	Version	Date	Primary Function
POSPac MMS	5.1	2008	Post-processed kinematic GPS positioning and confidence checks
TerraSond, Ltd. Simple SVP	1.0	2007	Convert sound-speed raw data to CARIS compatible format.
Trimble Terramodel	10.4	2004	Conversion of ArcGIS lines to QPS QINSy compatible format
Odom eChart	1.3.6	2008	Playback of bottom tracking data to assist with SBES processing
Microsoft Office	2007	2007	Reporting and misc. processing

Table 19 – Software during processing and reporting

A.9. Bottom Samples

The *M/V Ducer* collected most bottom samples for this survey. The *M/V Latent Sea* also collected samples in the more exposed areas of H12164.

At a planned interval of 2 kilometers, a Van Veen grab sampler was lowered and a bottom sample collected. Aboard the vessel, the sample was examined and its S-57 (SBDARE object) attributes noted along with time and position in an Excel logsheet.

The logsheet was later imported by processing into CARIS Notebook software for producing the S-57 deliverable. A table with bottom sample locations is available in each DR's *Appendix V, Supplemental Survey Records and Correspondence.*

A.10. Shoreline Verification

Shoreline verification for OPR-R341-KR-10 was required only for H12170, which consisted of the Bethel city waterfront. The work was accomplished on September 3rd, 2010 (JD246).

The equipment was setup in an RTK-backpack design. A Trimble 5700 receiver was interfaced with a Trimble Zephyr Geodetic GPS antenna and Trimble RTK antenna, which were mounted on a survey rod. A Trimble Survey Controller (TSCe) was used to monitor the positioning quality and to log positions. Altitudes were corrected for height of instrument within the TSCe. The receiver was configured to accept NAD83 RTK corrections broadcast from TerraSond's RTK01 base station. See the HVCR for more information regarding project RTK base stations.

With this configuration the survey crew walked the approximate 2.2 mile Bethel waterfront and took positions at any significant change in shoreline vector or shoreline type. In areas of sloping shoreline the position was taken on the estimated mean high water line, while along the city wharf or wall the position was taken on the edge as shown in the photo below. Field notes were kept and digital photos taken to document the data and to facilitate S-57 attribution.

Additional information and results including point descriptions are available in the DR for H12170. The scanned field notebook and corresponding photos are available in the DR's *Separate I: Acquisition and Processing Logs.*

Figure 5 – Shoreline survey of Bethel waterfront in H12170

After data collection the data points were exported to text file from the TSCe and then imported into CARIS Notebook 3.1. In Notebook, the points were then assembled into line objects as necessary and assigned mandatory S-57 attributes. The photos were used to assist in making object type and attribute determination.

Results were compared to the multibeam and single-beam data sets to ensure consistency in positioning between systems, with good results.

Heights on object types that have height as a mandatory attribute were obtained by reduction of the RTK altitude to MLLW or MHW as necessary by way of the computed local MLLW-ellipsoid separation. See the HVCR for more information regarding MLLW-ellipsoid separations in this area.

B. *Quality Control*

B.1. Overview

The traceability and integrity of the echosounder data, POSMV positional and inertial data, and other supporting data was maintained as it was moved from the collection phase through processing. Consistency in file naming combined with the use of standardized data processing sequences and methods formed an integral part of this process.

CARIS HIPS was used for the multibeam and single-beam data-processing tasks on this project. HIPS was designed to ensure that all edits, adjustments, and computations performed with the data followed a specific order and were saved separately from the raw data to maintain the integrity of the original data. Applanix POSPac MMS was used for processing the inertial and GPS data.

Frequent and comprehensive quality control checks were performed throughout the survey on all survey equipment and survey results. In addition, as standard practice, all edits and corrections done were reviewed at least twice before deliverable production.

The following sections outline the quality control efforts used throughout this project in the context of the procedures used from acquisition through processing and reporting.

B.2. Data Collection

B.2.1. QPS QINSy

QPS Qinsy data acquisition software was used to log all single-beam and multibeam data and to provide general navigation. The software features an abundance of quality assurance tools which were taken advantage of during this survey.

Using the raw echosounder depth data, QINSy generated a real-time digital terrain model (DTM) during data logging that was tide and draft corrected. To accomplish real-time tide correction QINSy applied a user-specified datum offset to the RTK altitude from the POSMV. This offset was entered by the survey crew into QINSy depending on area from a table of preliminary MLLW-ellipsoid separation values.

The DTM was displayed as a layer in the QINSy “Navigation” view. The vessel position was plotted on top of the DTM along with other common data types including CAD files containing survey lines and boundaries, S-57 charts when applicable, waypoints, and Geo-tiff images exported from Google Earth or CARIS HIPS as necessary.

The DTM was used to determine when required minimum depth was achieved (1 meter for SBES, 4 meter for MBES) and greatly assisted in preventing over-surveying (where depths significantly shoaler then required are collected) and under-surveying (where the survey vessel would need to return to an area to develop it further). The DTM was also instrumental in allowing real-time coverage analysis, displaying most data holidays immediately to the survey crew.

Note that the DTM was only used as a field quality assurance tool and was not used during subsequent data processing. Tide and offset corrections applied to the DTM and other real-time displays had no effect on the raw data logged by QINSy and later imported into CARIS HIPS.

In addition to the DTM and standard navigation information, QINSy was configured with various tabular and graphical displays that allowed the survey crew to monitor data quality in real time. Alarms were setup to alert the survey crew immediately to certain quality-critical situations. These include but are not limited to:

- Plot of Reson 8101 nadir depth versus Odom Echotrac depth for direct comparison
- Plot of POSMV-computed RTK position versus Trimble DSM-computed DGPS position
- Alarm for loss of 1-PPS/ZDA timing string from POSMV
- Alarm for loss of attitude or positioning data from POSMV
- Alarm for age-of-RTK correction exceeding 10 seconds
- Alarm for loss of sonar input

B.2.2. POSMV POSView

Applanix POSMV POSView was the interface software for the POSMV. It was used to continuously log the ".POS" files used in producing the PPK solution.

POSMV POSView was also used to monitor the POSMV's constantly-updated error estimates for its attitude and position computations. POSView was used to monitor the estimated accuracies to ensure the POSMV was operating normally. Additionally POSView would alert the survey crew if accuracy thresholds for position, velocity, attitude, or heading were exceeded.

B.2.3. Draft and Sound-Speed Measurements

Vessel static draft was measured at least once daily. With the vessel at rest, a calibrated measure-down pole or tape was used to measure the distance from the waterline to the measure-down point on the vessel gunwale. The measurement was taken on both sides of the vessel and an effort made to ensure the vessel was loaded similarly to that experienced during survey operations. Time and measurement values were noted in the logsheet for later inclusion in the CARIS HVF file by processing.

Sound-speed profiles were collected normally at a 12-hour (or once daily) interval during SBES data collection, and at a 4-hour interval during MBES data collection. More frequent profiles were deemed unnecessary as there was generally little variation between profiles. Upon transiting a large distance (generally more than 10 kilometers) or entering a new survey sheet an additional profile was normally collected to ensure any spatial component of changes in sound speed were accounted for.

Deployed by hand, the sound-speed sensor was held at the surface for approximately one minute to achieve temperature equilibrium before being lowered slowly to the bottom (typically no more than 1 meter/second). When back aboard the sensor was downloaded to ensure a profile was successfully acquired. If a profile was not acquired or contained obvious problems another profile was collected. Position, time, and filename were noted in the logsheet for later use in processing.

B.2.4. Logsheets

Logsheets were kept continually during survey operations. On each vessel, at the start of each survey shift, an Excel logsheet template was copied and named according to the vessel and Julian day. The logsheet was then used to record all significant events occurring during the shift which could affect data quality or assist with data processing and reporting. The logsheet was transferred along with all corresponding data to processing personnel at the completion of each shift.

The following common events along with the event time were normally recorded by the survey crew in the logsheets:

- Generic line information including line name and start and stop times
- Sonar setting changes during MBES ops including range, gain, and power
- RTK stations in use and status
- POS filename(s)
- Static draft measurements
- Sound-speed filenames and positions
- Comments on any unusual observations or problems

Logsheets are available in the DR *Separates I: Acquisition & Processing Logs*.

B.2.5. Base Station Deployment

Base stations were deployed periodically throughout the survey over pre-surveyed monuments. Specific equipment utilized is described previously in this report in section *A.6*.

During deployment, the GPS antenna was leveled and its tripod secured to minimize movement. Antenna height over the monument was recorded and checked by at least one other surveyor. Battery voltage, logging status, and other important parameters were logged to a base station deployment logsheet.

During retrieval, the levelness of the GPS antenna was checked. If out of level it was re-leveled. Antenna height was measured again. Battery voltage, logging status, and other important parameters were again noted in the base station deployment logsheet.

Discrepancies between the deployment and retrieval antenna heights were typically less than 0.01 m. For simplicity, during PPK processing the beginning antenna height was used instead of end antenna height. No large discrepancies between beginning and ending antenna heights occurred on this project, with typical discrepancies not exceeding 0.01 m. The base station deployment logsheets as well as base station confidence checks are available in the project HVCR.

B.2.6. File Naming and Initial File Handling

A file-naming convention was established prior to survey commencement for all raw files created in acquisition. Files were named in a consistent manner with attributes that identified the originating vessel, survey sheet and processing block (for sheet-specific data types), and Julian day (for non-sheet-specific data types).

The consistent file-naming convention assisted with data management and quality control in processing. Data was more easily filed in its correct location in the directory structure and more readily located later when needed. The file-naming system was also designed to reduce the chance of duplicate file names in the project.

The table below lists raw data files commonly created in acquisition and transferred to data processing.

Type	**Source / Contents**	**Example Filenames**
.DB	QPS Qinsy – all sensor data input into QINSy including Reson backscatter and snippets (when applicable).	0002 - 3A01.DB (for MBES ops) 3A-01-SB03990.DB (for SBES ops)
.XTF	QPS Qinsy – produced coincident with DB file. For conversion into CARIS. Configured to contain only necessary data fields.	0002 - 3A01.XTF (for MBES ops) 3A-01-SB03990.XTF (for SBES ops)

.SVP	Odom Digibar or AML SV+ – sound-speed profile.	3-2010-203-2353.SVP
.POS	POSView – POSMV data for PPK/TrueHeave	2010-190-1920-1A.POS
.DSO	Odom eChart – digital bottom trace record	MK3_2010_05_20_13_33_59.dso
.RPM	TerraTach RPM meter – vessel RPM record.	2010-190-1925-1A.RPM
.XLS	Excel – daily logsheet	1-2010-190-Logsheets.xls
.HEX	Seasoft – binary file from Sea-bird tide gauge	2010_212-236_SN1155_RTK04.hex
.T01	Trimble 5700 Receiver – base station GPS data	17841404.T01
.A0x	WaterLOG tide gauges – bubbler download files from tide stations	94628081.A05

Table 20 – Common raw data files

Files that were logged over Julian day rollovers were named (and filed) for the day in which logging began. This was adhered to even if the majority of the file was logged in the "new" day. This was a common occurrence since Julian day midnight occurred at 16:00 local time during prime daylight hours.

During data collection, the raw data files were logged to a local hard drive in a logical directory structure on the acquisition PCs. At the end of each survey shift the data was consolidated and copied to a portable hard drive and handed over to processing personnel aboard the accompanying housing/processing vessel (*M/V Dream Catcher*). The processing personnel would then check the included Excel logsheet against the files on the portable hard drive to confirm all necessary files were included, and then transfer the data to the appropriate location on the processing server. Raw data was stored in its unaltered state in an access-limited "Acquisition" directory.

Initial data processing was then conducted aboard the *M/V Dream Catcher*. To ensure the continued integrity of the raw data, all processed data was stored within "Processing" and "CARIS" directory structures that were independent of the Acquisition directory.

All server data was backed up once each day onto LTO3 tapes. Additionally a full copy of all data was sent off the vessel to TerraSond's Palmer office at regular intervals. The system of using data storage servers with redundant disk arrays, automatic backups and off site data copies minimized the potential for data loss due to equipment malfunction or failure.

B.3. Data Processing

Preliminary data processing was done in the field, aboard the *M/V Dream Catcher*. Raw data was converted, cleaned, and checked on site. This method provided near real time coverage determination and infill analysis in the field.

A 24-hour per day processing schedule allowed initial processing and cleaning to be completed overnight. This made it possible for processing to identify any major problems and provide feedback to the acquisition crews prior to their departure each morning.

All checks and data corrections applied by processors were recorded in the acquisition logsheets which were also used to track processing tasks. These are available in each DR, *Separate I: Acquisition and Processing Logs.*

B.3.1. Conversion into CARIS HIPS

CARIS HIPS software was used to create a directory structure organized by project, vessel and Julian day to store data. The XTF files written by QINSy were imported into CARIS HIPS using the HIPS XTF conversion wizard module. The wizard created a directory for each line and parsed the XTF components into sub-files which contained individual sensor information. All data entries were time-referenced using the time associated within the XTF file to relate the navigation, azimuth, heave, pitch, roll, and slant range sensor files.

XTF files often contained simultaneous multibeam and single-beam data since QINSy would log both if available. Sounder-specific settings in the conversion wizard were selected depending on which sounder's data was being extracted from the file.

HIPS vessel files (HVF) were then updated with a new waterline value. Port and starboard measure-downs recorded in the acquisition logsheet daily were averaged and reduced to the vessel's reference point using the surveyed vessel offsets to determine the static draft. This value was entered as a new waterline value in each vessel's HVF and checked to confirm the values fell within the normal range for the vessel.

B.3.2. Load TrueHeave

After conversion, "TrueHeave" data was loaded into each line using the HIPS "Load TrueHeave" utility from the applicable POS file. TrueHeave is a better estimate then real-time heave for actual heave experienced by the vessel. Computed by the POSMV 110 seconds after the valid time, TrueHeave application requires that the POS file be logged for at least two minutes after end of line. For this reason a small number of lines could not be loaded with TrueHeave as the POS file logging was stopped prior to the end of the line, or too soon after the end of line, usually due to a PC crash.

Additionally some POS files could not be read by the Load TrueHeave utility. Usually this occurred when the POS file was logged over the GPS week-rollover on Saturday. In these cases TrueHeave was still available but needed to be extracted from the POS file to text and imported using the "Generic Data Parser" (GDP) utility. Note that this method overwrites the real-time heave record and that the line will not show as having TrueHeave loaded in a HIPS query. Lines that could not be loaded with TrueHeave or were loaded through GDP are listed in the acquisition and processing logs included with each DR.

B.3.3. Sound-Speed Corrections

Sound-speed profiles were processed using SimpleSVP, a TerraSond in-house program. The software was used to graph and review each profile for erroneous sound-speed values and to output a CARIS-compatible format at a regular 1-meter interval. The output was checked for incorrect time stamps and positions. The output was appended to the appropriate master CARIS SVP file based on vessel and survey sheet.

After loading TrueHeave, each line was corrected for sound speed using HIPS' "Sound Velocity Correction" utility. "Nearest in distance within time" was selected for the profile selection method. For the time constraint, 12 hours was used for SBES data and 4 hours was used for MBES data. These values were chosen to match the cast interval done in acquisition, which was determined by examining the average variance or difference between subsequent casts. Any deviations from this method are described in the corresponding DR.

B.3.4. Total Propagated Uncertainty

After sound-speed correction, HIPS was used to compute total propagated uncertainty (TPU). The HIPS TPU calculation assigned a horizontal and vertical error estimate to each sounding based on the combined error of all component measurements.

These error components include uncertainty associated with navigation, gyro (heading), heave, pitch, roll, tide, latency, sensor offsets, and individual sonar model characteristics. Stored in the HVF, these error sources were obtained from manufacturer specifications, determined during the vessel survey (sensor offsets), or while running operational tests (patch test, settlement and squat). The individual system uncertainties used on this project are shown below and are common among all three unless noted since identical equipment was used.

TPU Entry	Error Value	Source
Gyro	0.020°	http://www.caris.com/tpu/gyro_tbl.cfm (Applanix POSMV 320 -- 2m baseline)
Heave	5% or 0.05m	http://www.caris.com/tpu/heave_tbl.cfm (Applanix POSMV 320 -- whichever is higher)
Roll and Pitch	0.010°	http://www.caris.com/tpu/roll_tbl.cfm (Applanix POSMV 320 -- RTK)
Navigation	0.10 m	PPK processing result reports indicate RMS positioning errors better than 0.10 m on average
Timing – (Transducer)	0.005 sec. for Reson MBES	Reson synced to UTC and time tagging bathymetry prior to output over network. No timing error evident above 0.005 seconds.
	0.050 sec. for Odom SBES	Odom bathymetry time tagged in QINSy after output over network. Latency values determined to within +/- 0.050 seconds.
Timing – (Gyro, Heave, Pitch, and Roll)	0.005 sec.	All sensors computed with same system (POSMV) and therefore have the same timing uncertainty. QINSy synced with POSMV via 1-PPS and ZDA. No timing errors evident above 0.005 seconds.
Offset (X and Y)	0.020 m	X and Y offsets were determined to better then 0.020 meters.
Offset Z	0.025 m	Z offsets were determined to better then 0.025 meters.
Vessel Speed*	2.5 knots	Average river current estimated to be 2.5 knots. Note this TPU entry will only affect the minority of lines that do not have delta draft loaded.
Loading*	0.020 m	Vessel loading typically changed by up to 0.020 meters between static draft measurements.
Draft*	0.010 m (0.030 m for *M/V Ducer*)	Static draft was measured to within 0.010 meters, except on the *M/V Ducer,* which could be measured to within 0.030 meters.
Delta Draft*	0.020 m	Delta draft was measured to within 0.020 meters.
MRU Gyro and MRU Roll/Pitch Alignment	0.100°	Patch test results for gyro, roll, and pitch consistent to within 0.100°.

Table 21 – TPU values used

* Note that errors associated with draft, delta draft, vessel speed, and loading are negated when using the GPSTide method since these items are components included in the total error of GPS vertical positioning. However they were still computed separately here to account for potential additional GPS vertical positioning error and to provide practical TPU for tide-based comparisons of the same data.

For “MRU to Trans” offsets under “TPU values”, the offset from each vessel’s IMU to the sonar was entered. This duplicated the values already entered under “Swath 1” since the IMU also served as the vessel reference point.

For “Nav to Trans” offsets, once again the offset from each vessel’s IMU to the sonar was entered. The offset from the primary GPS antenna was not entered because navigation error estimates used are for the POSMV computed position of the IMU, not the GPS antenna.

For “Trans Roll”, the value for the IMU to sonar misalignment determined by multibeam patch test was entered. This duplicated the value for roll entered under “Swath 1”. Note that this was left zeroed in the single-beam HVFs.

During TPU computation a value of 0.050 meters was entered for tide error. This value accounts for vertical error from GPS positioning and is derived from the estimated average peak RMS error reported for the PPK SBET solution in Applanix POSPac. For tide zoning error, a value was entered that represented the estimated error associated with the MLLW – ellipsoid separation model used. Specific entries for the tide zoning error varied by sheet and are discussed in the appropriate *Descriptive Report*.

In general, 1 m/s was used for the measured sound-speed error. An analysis of the average variance between subsequent sound-speed casts revealed that for most survey sheets profiles varied by less than 1 m/s for both 4-hour and 12-hour intervals. Any difference is discussed in the appropriate *Descriptive Report*.

B.3.5. Compute GPSTide and Merge

To assist with initial cleaning and QC, the “Compute GPS Tide” utility in HIPS was run on each line to provide tide corrections. During field processing, the options for “Apply Dynamic Heave” and “Apply Waterline Offset” were chosen. For sounding datum, a preliminary model file was selected which accounted for the varying changes in the ellipsoid to MLLW separation across the survey area. The model file was a text file containing positions and their datum separation in a CARIS-compatible format.

This separation was initially established by JOA at each tide station using short-term tide data series tied to GPS benchmarks. To provide non-step transitions between tide sites a linear relationship was assumed to exist between stations for the purpose of modeling. Note that this preliminary model was replaced in office processing when the final model—built from longer data series and more data points—was loaded and GPSTide recomputed prior to final surface creation.

In field processing GPSTide was frequently computed prior to the application of navigation and GPS height from SBET. This was possible because most real-time GPS heights were RTK corrected with good accuracies, and usually necessary because of the lag time associated with PPK processing and lack of predicted tidal data for the area. However, the accuracy of the real-time GPS heights was a function of quality of RTK reception aboard the vessel, which varied from excellent to spotty or non-existent. SBETs were therefore loaded into each line as soon as they were available, and GPSTide recomputed. It is important to note that without exception, all real-time altitudes and positions were replaced with PPK from SBETs.

After computation of GPSTide, all lines were merged with HIPS' "Merge" utility. The option to "Apply GPS tide" was selected.

B.3.6. Post-processed Kinematics

Vertical accuracy of positioning was critical for this project due to the dependence on ellipsoid-based surveying for tide reduction. For this reason as well as the lack of dependable DGPS coverage, the project made extensive use of RTK positioning in real-time. However, the RTK radio link was highly susceptible to interruption and interference. Therefore post-processed kinematic (PPK) data was applied to all survey lines, replacing the real-time positions.

PPK processing utilized Applanix POSPac MMS software. POSPac makes use of dual-frequency GPS data logged at nearby shore base stations (".DAT" format, converted from ".T01") and dual-frequency GPS and inertial data logged on the vessel (".POS" format) to produce a smooth best estimate of trajectory (".SBET") file. The SBET file was directly readable by CARIS HIPS.

This process produced a result superior to RTK for the following reasons:

- Uninterrupted overlapping rover / base data
- A backwards-in-time processing step not available in real-time
- A solution that is tightly coupled with inertial data versus loosely coupled in real-time, therefore more tolerant of PDOP spikes and loss of satellite lock
- The ability to select closest or better base stations when incorrect station may have been used in real-time.

RTK and PPK positions compared well (< 0.03 m vertically) only when RTK was operating in its higher accuracy, "narrow-lane" mode.

To produce an SBET file, a project was setup in POSPac with the same name as the POS file being processed. The POS file was imported, and extracted by the software into component sensors. By examining the time extents and position of the logged POS data, the processor would select a base station to import, as a general rule using the closest with overlapping time extents. Trimble DAT files or Rinex files belonging to the selected base would be then imported. DAT files that contained more than two or three days of base station data usually could not be read properly by POSPac and required splicing into 24-hour pieces and converted into Rinex (*.10o) generic format.

After import of the base data, the POSPac "Coordinate Manager" was used to enter the critical information concerning the base station deployment. This included non-varying parameters such as benchmark coordinates, and deployment-specific settings taken from the base station deployment logsheet which consisted of antenna type, antenna height, and antenna measurement method. Base station and deployment used was tracked on the PPK processing logsheet, which is available in each Descriptive Report's *Separate I*.

After correct information was entered for base station parameters, the "GNSS Inertial Processor" utility was used in single base mode. This processed the inertial and GPS data forwards in time, backwards in time, and then combined the solution into an SBET file.

POSPac constantly computes error estimates and provides a number of plots and tables to QC the post-processed position quality. "Smoothed Performance Metrics" were examined for every POSPac project at a minimum to ensure RMS error was low with no unusual spikes or high uncertainties. An example is shown below.

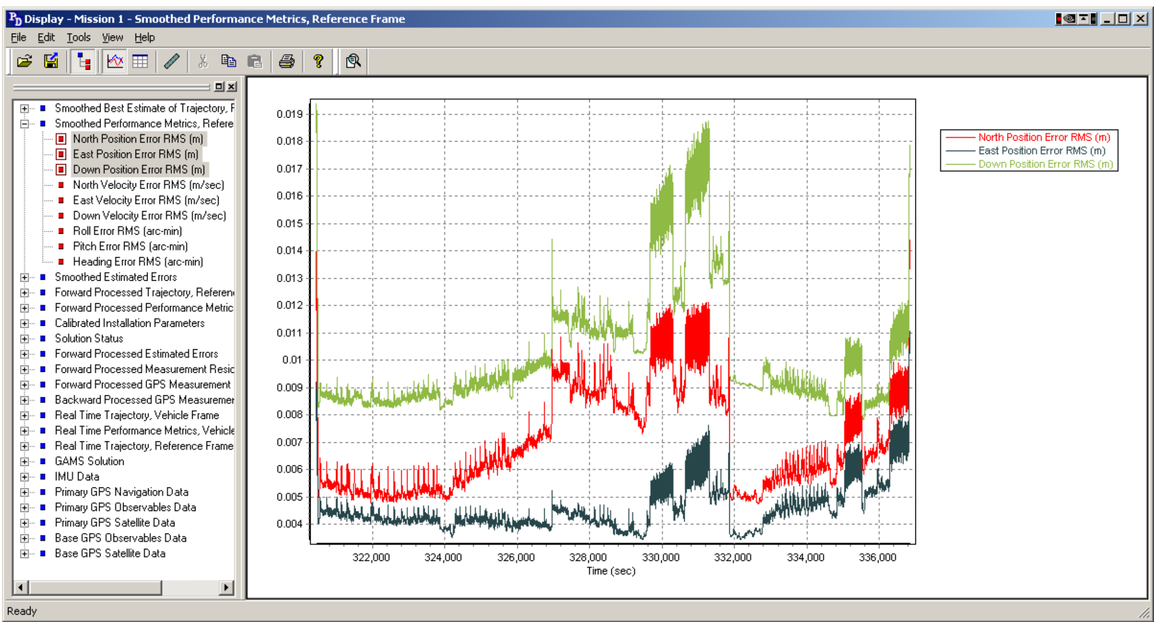


Figure 6 – Example of POSPac estimated RMS errors of positioning of an SBET file

When spikes or periods of unusually large uncertainty were encountered they were noted in the POS processing logsheet and further investigated. Spikes in RMS error were checked against computed altitude to determine if the error carried through to altitude. Spikes usually corresponded to periods of high-speed transit or periods of satellite masking when the survey vessel was alongside the mother-ship, the *M/V Dream Catcher*. If altitude was negatively affected the time of the spike was compared to actual survey times. If the vessel was not surveying at the time of the spike, which was usually the case, the SBET would be applied as is. If vessel was surveying the corresponding lines were marked for further examination and were sometimes rejected and rerun.

After QC was complete on the solution status, the SBET was copied and renamed to match the POS file and was ready to load in to CARIS HIPS. The RMS error values in tabular and graphical format were also exported in order to allow quick future QC without requiring POSPac. The following flow chart outlines the PPK process with POSPac.

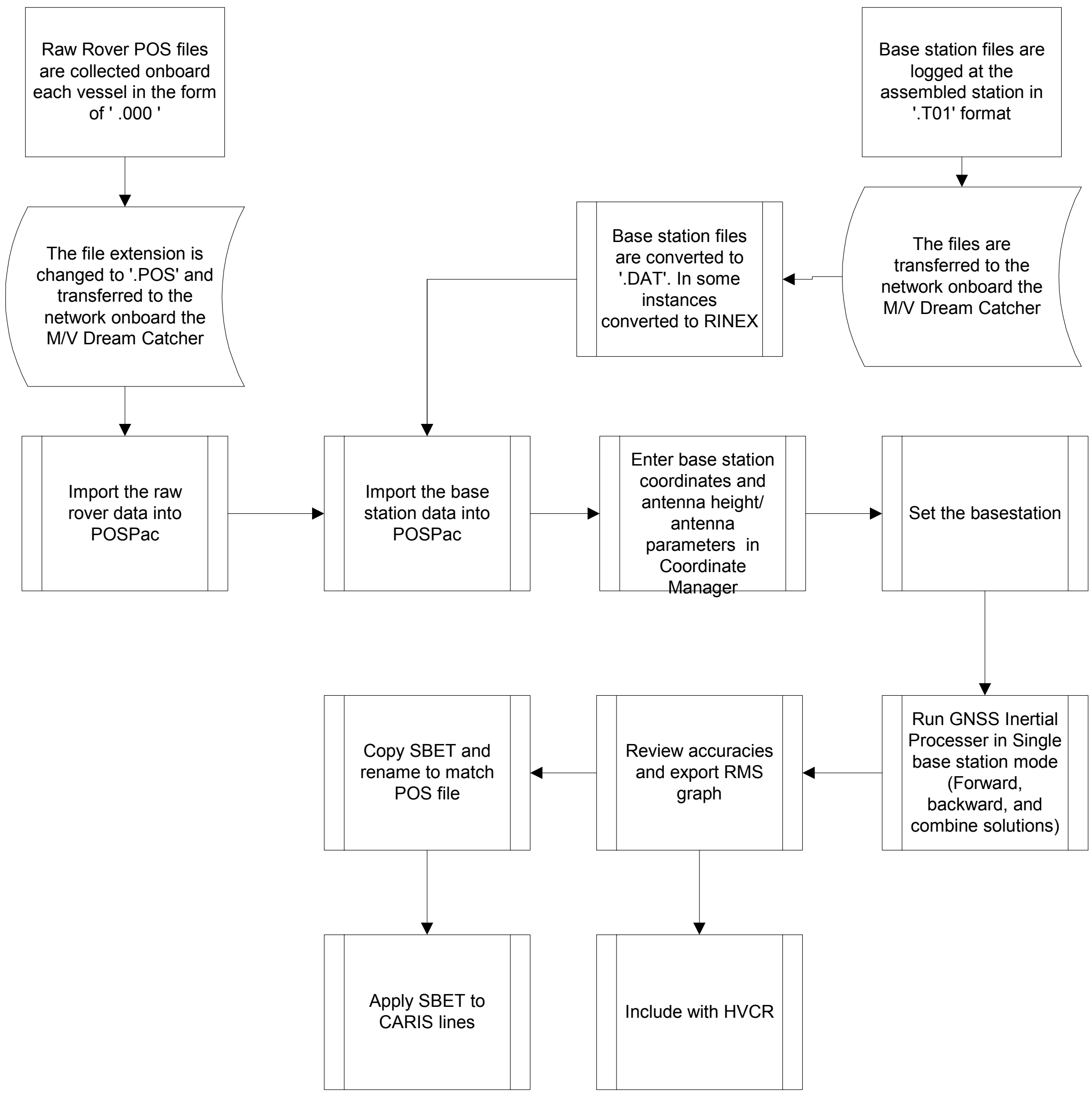


Figure 7 – PPK Processing flow overview

The settings used in POSPac for producing the SBET were checked at least twice to ensure correct parameters were used for benchmark position, antenna height and type, and antenna measurement method. Any errors found were corrected and the PPK processing procedure repeated producing a new SBET which was applied to the applicable lines.

More information concerning base stations as well as the RMS error graphs and tabular RMS data are available with the project HVCR.

B.3.7. *Load Navigation and GPS Height*

The HIPS "Load Attitude/Navigation" utility was used to import PPK navigation and GPS height records into each survey line. This utility replaced the real-time positioning data with more accurate data from the SBET files. Gyro, Pitch, and Roll sensors were not loaded into the survey lines due to the inconsequential difference between their real time and PPK versions. After loading, HIPS output window was checked to confirm application and any application errors reconciled. GPSTide was then recomputed to use the new heights.

Note that SBET files were available only after PPK processing, which usually lagged behind acquisition by two to seven days, depending on the availability of base station data.

B.3.8. *Navigation and Attitude Sensor Checks*

Navigation data were reviewed using the CARIS "Navigation Editor". The review consisted of a visual inspection of plotted fixes noting any gaps in the data or unusual jumps in vessel position. Discrepancies were rare and were handled on a case-by-case basis. Unusable data were rejected with interpolation using a loose Bezier curve. Fixes were queried for time, position, delta time, speed and status and, if necessary, the status of the data was changed from accepted to rejected.

Attitude data was reviewed for every line in HIPS "Attitude Editor". This involved checking for gaps or spikes in the gyro, pitch, roll, heave, and TrueHeave sensor fields. Like navigation, spikes and gaps in the attitude data was extremely uncommon but were addressed when found, typically by rejection of incorrect data points. Any large drop outs in the attitude data would prompt rejection of the affected data and re-run.

Checks done on the sensors were tracked in the line logsheets, available in each Descriptive Report's *Separate 1: Acquisition and Processing Logs*.

B.3.9. Single-Beam Editing

Single-beam data was cleaned using HIPS "Single-Beam Editor". Erroneous soundings exceeding error tolerances outlined in the 2010 Hydrographic Surveys Specifications and Deliverables (HSSD) were rejected.

The digital bottom trace recorded to DSO files was used extensively and was critical to edit the single-beam data to accurately represent the river bottom. Single-beam editing in HIPS was done in the context of the bottom trace simultaneously displayed in Odom eChart software. eChart was run alongside HIPS on the same processing PC and DSO files that corresponded to the HIPS line being cleaned were loaded. Time tick marks in HIPS were used to correlate the data being viewed with the event marks recorded in the DSO file. The following example illustrates some commonly encountered situations.

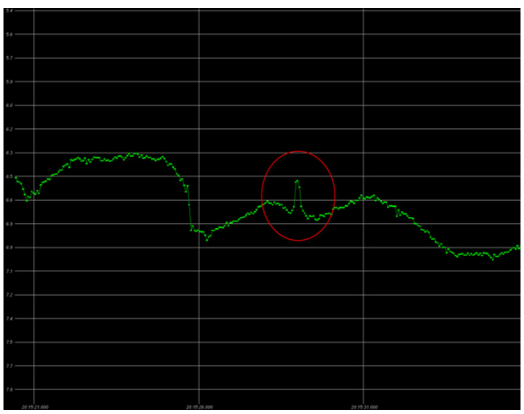
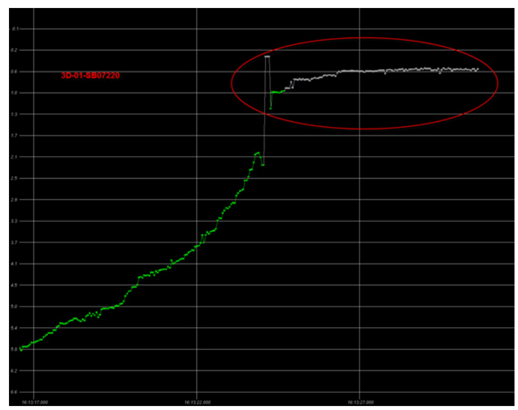
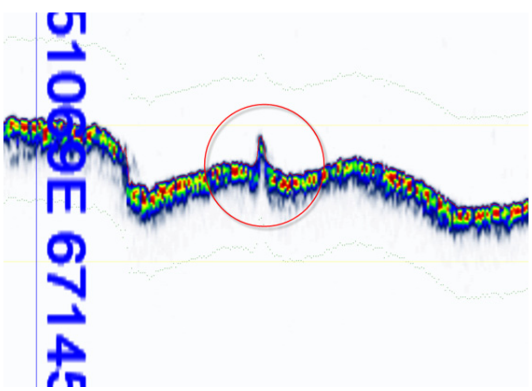
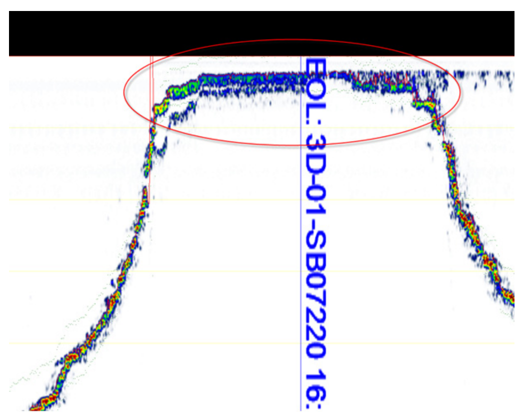
Data in HIPS SBES Editor		
Data in eChart Digital Trace		
	Questionable soundings in SBES editor are an obvious feature in digital trace. Soundings are not edited.	Questionable soundings in SBES editor are obvious noise in digital trace (due to vessel maneuvering at EOL). Soundings are gray (rejected) in HIPS SBES editor.

Figure 8 – Example of use of digital bottom trace in SBES editing

To ensure the single-beam data was thoroughly cleaned with all erroneous soundings rejected, this process was done twice – once in the field, and again in the office prior to deliverable production.

As a final check on the SBES data for gross fliers, a 4-meter uncertainty surface was created in HIPS and soundings generated at a 20 meter interval based on the shoal layer. Soundings were colored to emphasize change, and any soundings that indicated potential fliers were examined again in SBES editor.

B.3.10. Multibeam Editing

Prior to manual editing, multibeam data was filtered in CARIS HIPS. Optimal filter settings were determined for the project area which eliminated low quality and outer beam data. These settings were stored in a HIPS filter file (60_01.HFF, provided with the survey deliverables) and reused for all lines. The filter automatically rejected beams greater than 60° from nadir and beams flagged by the Reson system as quality “0” and quality “1”. However, filtered beams were sometimes reaccepted by processing to fill gaps or better define a feature when necessary.

The multibeam data was examined and edited in HIPS subset mode at least three times over the course of the survey. These phases of editing are as follows:

1. Course cleaning: Initial cleaning of a vessel’s full shift of data using RTK-derived tides. This was completed within 12 hours of the end of the acquisition shift. Allowed for immediate feedback on data quality to acquisition crew and identification of definite data gaps which could be re-run the next shift.

2. Fine cleaning: Sheet-wide cleaning using PPK-derived tides. Began when PPK SBETs available and applied to all lines; usually began and completed within 7-10 days of last day of acquisition in a sheet. Allowed for gaps or coverage issues to be identified and sent back to acquisition for rerun as necessary.

3. Final review: Sheet-wide reviews, re-edits, and designate soundings. Done after all final correctors are applied, prior to deliverable production.

In all phases HIPS was used to create a BASE surface using the CUBE algorithm. CUBE parameters and resolutions for depth ranges were compliant with the 2010 HSSD.

Data was reviewed in HIPS 2D-Subset and 3D-Subset modes in a surface-based editing approach, whereby soundings were rejected ONLY when they adversely affected the surface greater than the allowable error budget for depth. It is important to note that this approach means noisy soundings are still evident in the data set. However, gross fliers were also rejected regardless of their effect on the surface to ensure they did not contribute to the final BASE surfaces.

Designated soundings were selected during the final review. These were selected in accordance with the 2010 HSSD, whereby soundings that were shoaler then the BASE surface by ½ of the allowable error budget for depths less than 20 m (and equal to the error budget for deeper depths) were designated.

Per the HSSD survey scale was considered during the designation process as well. Soundings were generally NOT designated if a shoaler part of the BASE surface existed within 2mm at survey scale (20 meters ground distance), even if the sounding was shoaler by greater then ½ the error specification for the depth from the BASE surface. This situation was commonly encountered in this project on slopes or near the river bank.

The following table illustrates the difference between the three multibeam cleaning phases.

Course Cleaning	Fine Cleaning	Final Review
Tides:	Tides:	Tides:
☐ PPK-derived tides applied	☒ PPK-derived tides applied	☒ PPK-derived tides applied
Surface Data Source:	Surface Data Source:	Surface Data Source:
☒ Single shift MBES data	☐ Single shift MBES data	☐ Single shift MBES data
☐ All MBES data in sheet	☒ All MBES data in sheet	☒ All MBES data in sheet
Corrections and Reductions:	Corrections and Reductions:	Corrections and Reductions:
☒ Preliminary Applied	☒ Preliminary Applied	☐ Preliminary Applied
☐ Final Applied	☐ Final Applied	☒ Final Applied
Edits:	Edits:	Edits:
☒ Reject gross fliers	☒ Reject gross fliers	☒ Reject gross fliers
☒ Reject fliers that exceed error budget	☒ Reject fliers that exceed error budget	☒ Reject fliers that exceed error budget
☒ Check for busts or artifacts, note and investigate	☒ Check for busts or artifacts, note and investigate	☒ Check for busts or artifacts, note and investigate
☐ Designate soundings	☐ Designate soundings	☒ Designate soundings

Table 22 – Multibeam editing phases

B.3.11. Final BASE Surfaces

The final depth information for this survey is submitted as a collection of CARIS BASE surfaces (HIPS 7.0 CSAR format), which best represent the seafloor at the time of survey.

Multibeam surfaces were created at 1-meter resolution, and 2-meter when necessary, as CUBE surfaces. “Density and Locale” was chosen as the disambiguity method and NOAA CUBE parameter .XML based on resolution as the advanced CUBE parameters. The CUBE parameters used meet the 2010 HSSD. These parameters are included with the CARIS digital data deliverables.

Single-beam surfaces were created at 4-meter resolutions as Uncertainty surfaces. Uncertainty was chosen over CUBE for SBES data because CUBE does not produce a shoal layer.

All surfaces are projected to UTM Zone 3 North (NAD83) except H12170 which is projected in Zone 4 North (NAD83). For specific grid resolutions, depths and naming conventions refer to the Descriptive Reports.

Each surface was finalized prior to submittal. During this process, final uncertainty was determined using the “Greater of the two” (Uncertainty or Std. Dev at 95% C.I.) option. Designated soundings were applied. For multibeam surfaces, depth thresholds were applied based on resolution when warranted.

A data set containing a single S-57 (.000) file and supporting files was submitted in conjunction with each 2010 survey deliverable. The S-57 file contains information on objects not represented in the depth grid, including nature of the seabed (bottom samples), sand-wave areas, and meta-data objects. For survey H12170 shoreline detail is also included. Each feature object includes the mandatory S-57 attributes and additional attributes that may be useful in chart compilation.

B.3.12. Crossline Analysis

The crossline analysis was conducted using CARIS HIPS’ QC Report routine. Each crossline was selected and run through the process, which calculated the difference between each accepted crossline sounding and a 1m resolution or 4m resolution BASE surface (depending on data type – 1m for multibeam, 4m for single beam) created from the mainscheme data.

The differences in depth were grouped by beam number and statistics computed, which included the percentage of soundings compared whose differences from the BASE surface fall within IHO survey Order 1. Beams where at least 95% of the soundings exceed IHO Order 1 were considered to “pass”, while beams where less than 95% of the soundings compare within IHO Order 1 were considered to “fail”.

Crossline acquisition and processing on this project was unconventional in that single-beam mainscheme lines, which transect the river channel, served as crosslines for the multibeam lines, which parallel the channel. Likewise, multibeam mainscheme lines served as crosslines for the single-beam data. However, since large temporal changes in depth were being observed due to the dynamic nature of the river bottom, as an additional check a small number of conventional crosslines were also run.

A discussion concerning the methodology of crossline selection, as well as a summary of results for each sheet, is available in the relevant Descriptive Report. The QC Reports are included in each DR's *Separate IV: Crossline Comparisons.*

B.3.13. Processing Workflow Diagram

The following diagram outlines the processing flow.

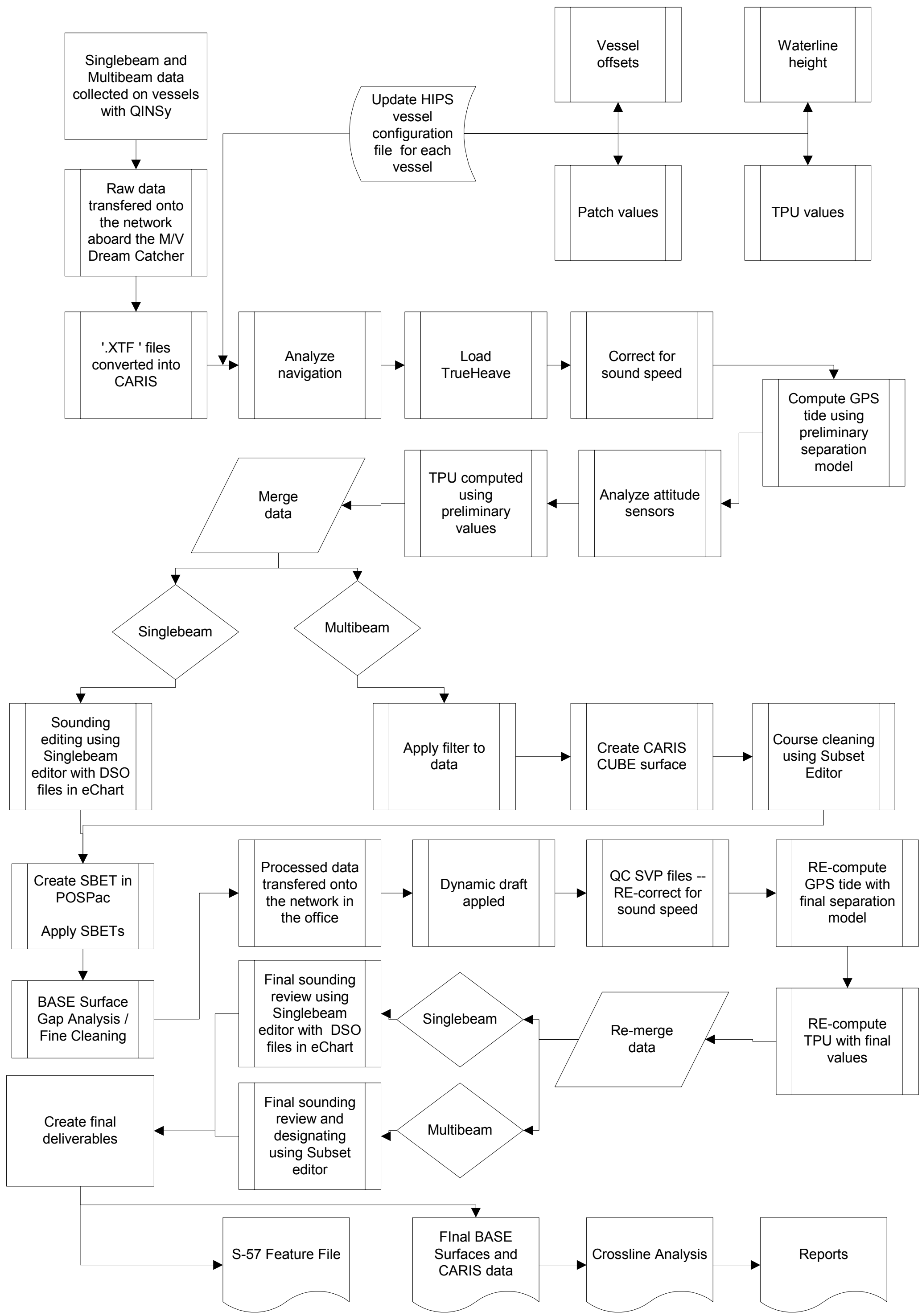


Figure 9 – Processing flow overview

B.4. Confidence Checks

In addition to the QC steps relating to acquisition and processing procedure outlined in the above sections, frequent formal confidence checks were undertaken throughout the survey to ensure the best possible accuracy and precision was achieved. These were designed to exceed the minimum requirements outlined in the 2010 HSSD.

The following table summarizes the formal confidence checks.

Confidence Check	Purpose	Normal Frequency
Bar checks	Ensure echo sounder accuracy Determine and refine Z offsets	1-3 times over survey depending on vessel and sounder
Echo sounder Comparison	Overall check of consistency between survey systems and platforms	Weekly
SVP Comparison	Check SVP sensors for consistency	Weekly
Base station position check	Ensure consistent base station position	Weekly, or at least once per deployment
Base station site confirmation	Confirm base station position accuracy	Once
Vessel position confidence check	Check for consistent vessel positioning	Weekly
Staff Shots	Check of tide gauge stability	Weekly to bi-weekly

Table 23 – Summary of confidence checks

B.4.1. Bar Checks

For this survey bar-checks were employed to determine or refine Z offsets and to check the absolute accuracy of both the MBES and SBES systems.

For SBES bar checks an aluminum tube, roughly six inches in diameter and a length equivalent to the vessel beam, was hung by chains from guide points on the vessel's gunwale. For MBES bar checks a steel grating of approximately 1 meter width hung with steel cable was used. The bar chain or cable was marked at an interval of 1 meter from the bar, measured by tape.

A sound velocity profile was collected and the average velocity entered into the echosounder. Static draft was measured.

With QPS Qinsy logging and the sonar tuned to track the bar instead of the bottom, the bar was lowered by 1 meter increments directly below the vessel's transducer while bar depth and time was noted in the log. Bar check max depth – which ranged from 1 to 5 meters on this survey – was determined by ability to maintain a sonar lock on the bar (usually a function of the current) and depth in the area.

The bar depth was read relative to the waterline for later comparison to the HIPS results, as well as relative to the gunwale measure down points for determining or checking the acoustic center offset. Bar depth versus HIPS results always compared to better then 0.10 m, but usually better than 0.03 m.

In addition to confidence checks, bar checks were critical to establish acoustic center offsets on the Odom single-beam systems. Unlike the Reson multibeam which has a fixed acoustic center which can be determined with vessel survey, the Odom single-beam systems have an acoustic center position that can vary from the transducer face due to electronic delays between the processor, transducer, and interconnecting cable. Odom refers to this offset from the transducer face as the "index value". For example, on JD198 the Echotrac CVM on the *M/V Jella Sea* was switched out with an Echotrac CV100. The bar check done immediately after revealed the acoustic center had changed by 0.085 m despite the fact that the same transducer and cable were still used. Once determined for a particular layout, however, the value remains fixed.

Bar check processing logs are available in *Separate I* of each project DR.

B.4.2. Echo Sounder Comparison

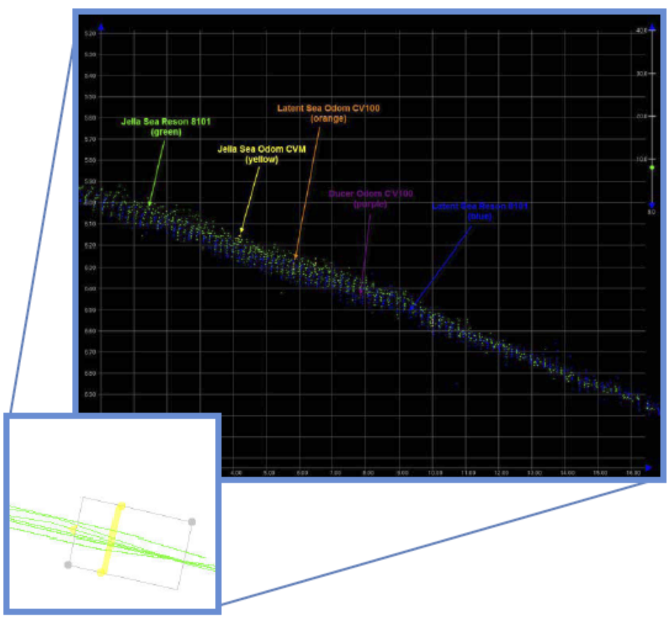
Direct comparisons were normally completed weekly between the echo sounders installed on the vessels. The echo sounder comparison served as a confidence check on the total survey system, involving two multibeam sonars and three single-beam sonars installed on three vessels, each with separate configurations and offsets.

A survey line was established in an area of mixed bottom topography and each vessel would in turn run the line in both directions at an average survey speed. The *M/V Jella Sea* and *M/V Latent Sea* would log simultaneous multibeam and single-beam data while the *M/V Ducer* would log single-beam data only.

After standard processing including application of PPK-derived tide corrections the agreement between all systems was examined in HIPS subset editor and the results noted in an echo sounder comparison logsheet (see example below). On any given day, all systems agreed to within 0.10 m of each other, but agreement was typically better than 0.05 m. The echo sounder comparison logs are available in *Separate I: Acquisition and Processing Logs* of the project DR's. Line data is also available for examination in CARIS HIPS data included with the project deliverables, in the "Data_Checks" project.

Examples of changes in bottom topography observed week to week during the confidence checks are available in the project DRs.

Echo Sounder Comparison
2010-192



Date:
2010-192

Files used in comparison:
Jella Sea
1-2010-192-MBTest01.xtf
1-2010-192-MBTest02.xtf
Ducer
2B-01-192-SBTest01.xtf
2B-01-192-SBTest02.xtf
Latent Sea
3-2010-192-MBtest01.xtf
3-2010-192-MBtest02.xtf

Altitude Source:
PPK

Comments:
All systems agree within 5 cm

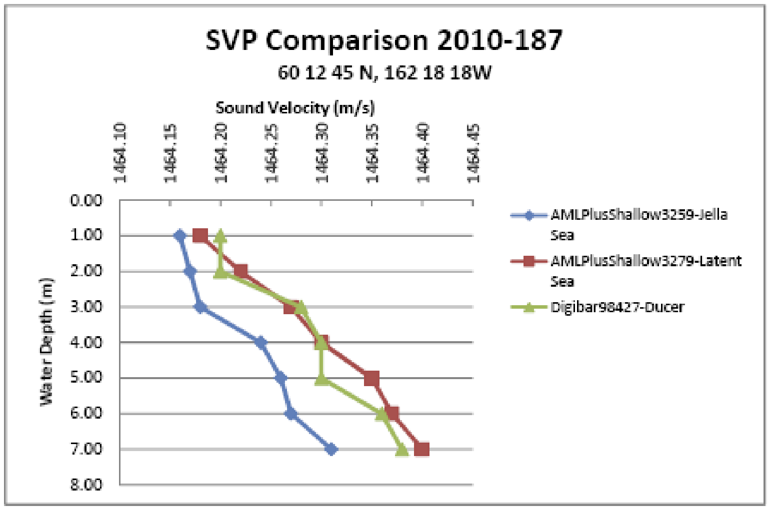
(Figure 1- All instruments viewed in CARIS 7.0 subset editor)

Figure 10 – Example of typical echo sounder comparison results. JD192 comparison.

B.4.3. SVP Comparison

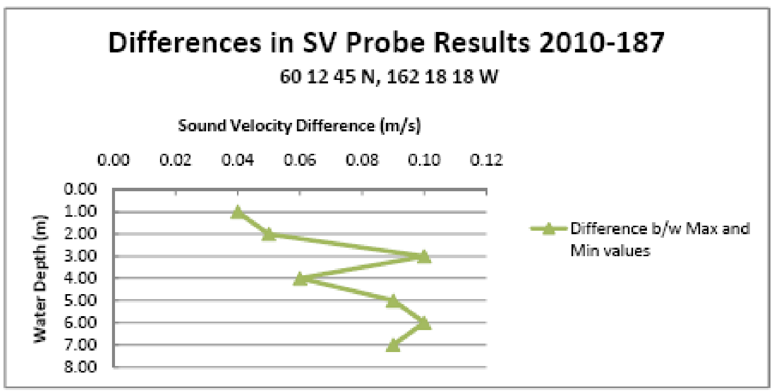
Direct comparisons were normally completed weekly between the sound-speed sensors in use on the project. This was usually done coincidentally with the echosounder comparisons. A cast was taken with each sensor in the area within the same time frame. The data underwent standard processing and was then compared depth-by-depth in an SVP comparison logsheet (see example below). Results were good between sensors, with all data comparing to better then 0.85 m/s but usually to better then 0.20 m/s. Individual test results are available in *Separate I* of each Descriptive Report.

SV Probe Results			
S/N	3259	3279	98427
Date/time:	187/15:11	187/15:15	187/15:22
Depth	Sound Velocity (m/s)		
1.00	1464.16	1464.18	1464.20
2.00	1464.17	1464.22	1464.20
3.00	1464.18	1464.27	1464.28
4.00	1464.24	1464.30	1464.30
5.00	1464.26	1464.35	1464.30
6.00	1464.27	1464.37	1464.36
7.00	1464.31	1464.40	1464.38



(Figure 1- Sound velocity from each Sound velocity Probe)

Statistics on the SV Probe results			
	Sound Velocity (m/s)		
Depth	Max	Min	Difference
1.00	1464.20	1464.16	0.04
2.00	1464.22	1464.17	0.05
3.00	1464.28	1464.18	0.10
4.00	1464.30	1464.24	0.06
5.00	1464.35	1464.26	0.09
6.00	1464.37	1464.27	0.10
7.00	1464.40	1464.31	0.09



(Figure 2- Differences between the Maximum and Minimum Sound Velocity of the three casts)

Figure 11 – Example of typical SVP comparison results. JD187 SVP comparison.

B.4.4. *Base Station Position Checks*

Positions of base station benchmarks were established using NOAA NGS' OPUS (Online Positioning User Service) by upload of the first 24-hour GPS static session from each initial base station deployment. This position became the accepted, surveyed position.

To ensure that the benchmark did not subsequently shift over the course of the survey and to check repeatability of the surveyed position, a static session from each reoccupation of the benchmark was uploaded to OPUS and the results compared in an Excel spreadsheet to the surveyed position. If a reoccupation of a benchmark lasted longer than a week, more than one check was done during the occupation.

Results were good, with subsequent occupations and checks always comparing to better then 0.05 m (both horizontally and vertically) but usually better than 0.01 m. See the HVCR for more information regarding specific results and the base station position check logsheet.

B.4.5. *Base Station Site Confirmation*

As an additional check of base position accuracy and to ensure no site specific issues existed, a site confirmation was done once for each base station. For this check, an established CORS (Continually Operating Reference System) base station was used as the "rover" and each project base station used as the "base". The selected rover was the CORS site in Bethel (BET1). Rinex data downloaded for BET1 was imported into Applanix POSPac and processed using the project base station. The resulting computed position for BET1 was then compared to the CORS published position of BET1.

Results were good, with computed position of BET1 comparing to actual position of BET1 to better then 0.03 m for most base stations (both horizontally and vertically), with some degradation using the more distant base stations. See the HVCR for more information and specific site confirmation results.

B.4.6. *Vessel Positioning Confidence Check*

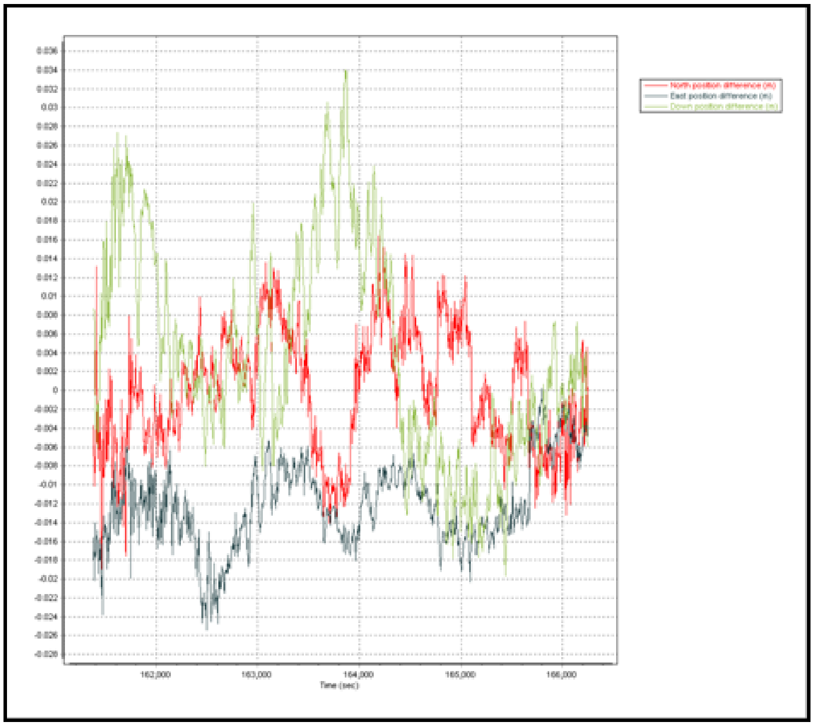
To ensure that vessel positioning was consistent regardless of the base station in use – and as independent check of vessel positioning – vessel position confidence checks were done normally on a weekly basis, for each survey vessel.

To complete this check, for each vessel a random POS file was selected from the week and processed as normal with the closest base station, producing an SBET file. The POS file was then re-processed with an independent but usually more distant secondary base station, producing a second SBET. Due to the lack of nearby CORS sites in the area, the secondary station was typically another project base station, although the CORS site in Bethel (BET1) was used whenever possible.

The two SBETs were differenced using the "NavDif" utility available in Applanix POSPac. This produced a difference plot, which was reported on a vessel positioning confidence check form. Results were good, usually returning differences better than 0.05 m (both horizontally and vertically). See the vessel positioning confidence check logs in *Separate I* of each DR for specific results. An example is shown below.

Positioning Confidence Check

POS file: 2010-221-2049-3G.POS **Date:** 2010-221 **Vessel:** Latent Sea



(Figure 1- Position difference between 2010-221-2049-3G.POS processed with station RTK01 versus CORS station BET1.)

Base Station

Base Station Name	**Approx. Min. Baseline Distance (m)**	**Max. Baseline Distance (m)**
RTK01	11700	13500
BET1	9900	10620

(Table 1- Baseline minimum and maximum distance)

Statistics

Position	**Approx. Min. Difference (m)**	**Approx. Max. Difference (m)**
North	-0.019	0.016
East	-0.025	0.000
Down	-0.020	0.034

(Table 2-Approximate minimum and maximum difference)

Figure 12 – Example positioning confidence check. M/V Latent Sea JD221.

B.4.7. Tide Station Staff Shots

To check the stability of tide gauge orifices and to collect data to assist with establishing MLLW to ellipsoid ties, staff shots consistent with requirements of the 2010 HSSD were done at each tide station. These were typically completely weekly but occasionally bi-weekly due to environmental constraints.

Standard leveling procedures were used to determine the difference in elevation between a tide station benchmark and the water surface. At least one hour of observations were collected at each visit, at a six minute interval that started on the hour. The staff-shot readings were timed to coincide with data collected by the Seabird or WaterLOG tide gauges which were synced to UTC.

Results were logged and compared to the values recorded by the tide gauge to compute a staff shot constant. The staff shot form along with downloaded gauge data was sent by email normally within 24-hours of collection to TerraSond's tide subcontractor, John Oswald and Associates (JOA). JOA would then QC the data and send requests to the field for gauge maintenance or other tasks when necessary. See the HVCR for more information concerning tide operations and JOA's tide station reports (included with HVCR) which include the staff shot forms.

C. *Corrections to Echo Soundings*

The following methods were used to determine, evaluate and apply corrections to instruments and soundings.

C.1. Vessel Offsets

Sensor locations were established with a pre-season survey of each vessel using conventional survey instruments. Acoustic center offsets were determined through bar check method for the SBES systems and refined for the MBES systems. For each vessel, the top center of the POSMV's IMU was selected as the center reference point (CRP) – or point from which all offsets were referenced. The IMU was mounted as close as practical to the estimated center of gravity on each vessel.

All vessel-related offsets were applied in CARIS HIPS by means of the HVF except the primary GPS antenna to reference point offset. This offset was entered into each POSMV at the start of the project as a lever arm offset and was required for optimal POSMV performance. This resulted in the POSMV outputting positions already corrected to the CRP. The POSMV also computed the primary to secondary antenna separation during GAMS calibration and used the value internally during heading calculations.

All offsets received numerous checks including total station and reality test by survey tape and bar check. Checks reveal an offset uncertainty of 0.020 horizontally and 0.025 vertically. POSPac was also utilized to check lever arm offsets through its lever arm calibration plots.

Vessel outlines and offset descriptions are provided below.

C.1.1.1. *M/V Latent Sea Vessel Survey*

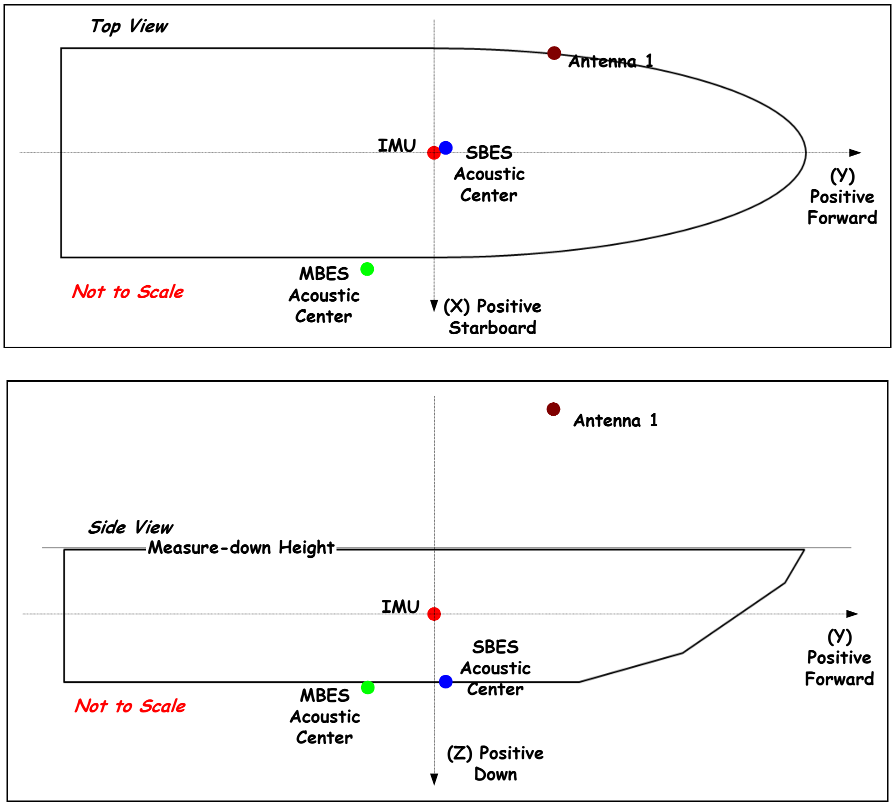
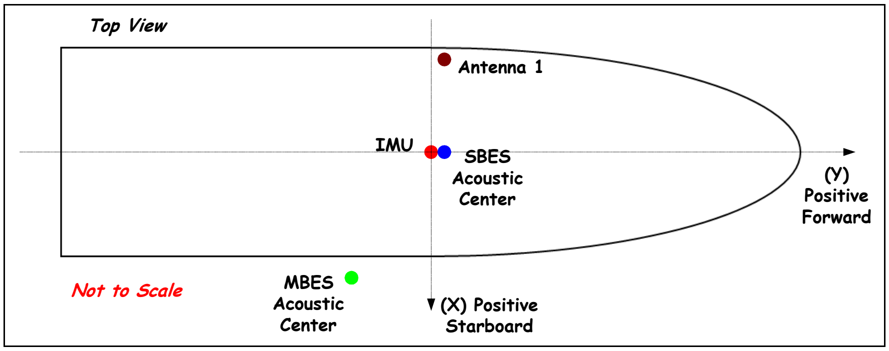


Figure 13 – M/V Latent Sea vessel survey showing the relative positions of the installed survey equipment.

Equipment	Offset from CRP (m) based on CARIS Convention		
	X	Y	Z
IMU	0.000	0.000	0.000
MBES Acoustic Center	0.933	-0.659	0.703
SBES Acoustic Center	-0.027	0.070	0.463
GPS1 (Primary/Port)	-1.111	1.367	-2.067
Draft Measure-down Point	n/a	n/a	-0.837

Table 24 – M/V Latent Sea offset measurements determined during vessel survey. The CARIS convention of + down (z), + starboard (x) and + forward (y) was used for all measurements.

C.1.1.2. *M/V Jella Sea Vessel Survey*



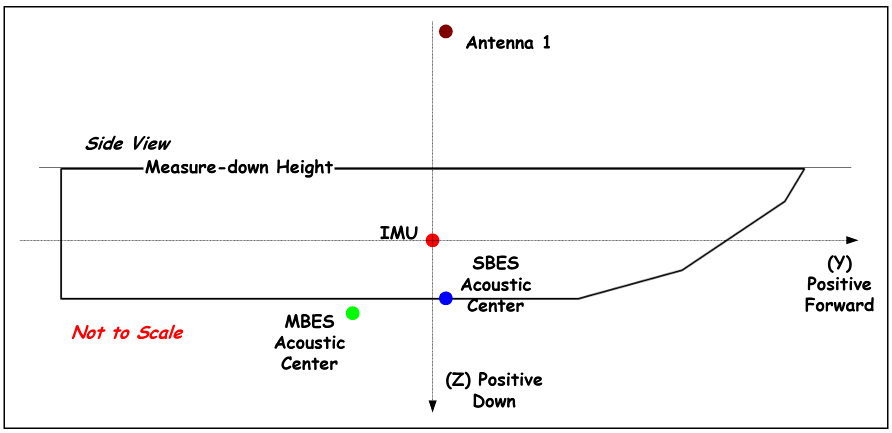
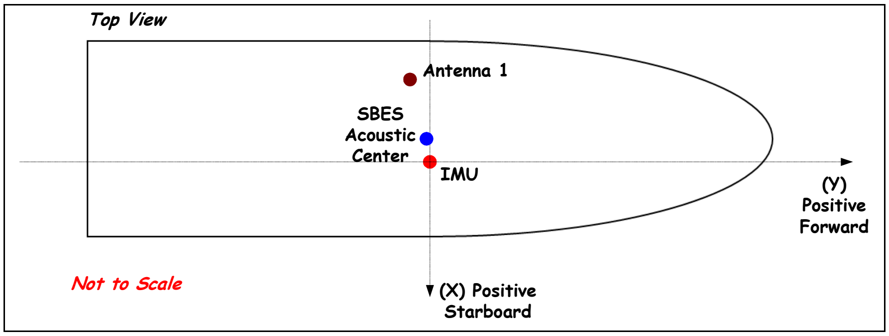


Figure 14 – M/V Jella Sea vessel survey showing the relative positions of the installed survey equipment.

Equipment	**Offset from CRP (m) based on CARIS Convention**		
	X	**Y**	**Z**
IMU	0.000	0.000	0.000
MBES Acoustic Center	1.147	-0.890	0.721
SBES Acoustic Center (to JD198)	0.001	0.098	0.508
SBES Acoustic Center (JD198 +)	0.001	0.098	0.423
GPS1 (Primary/Port)	-0.974	0.098	-2.180
Draft Measure-down Point	n/a	n/a	-0.722

Table 25 – M/V Jella Sea offset measurements determined during the vessel survey. The CARIS convention of + down (z), + starboard (x) and + forward (y) was used for all measurements.

C.1.1.3. *M/V Ducer Vessel Survey*



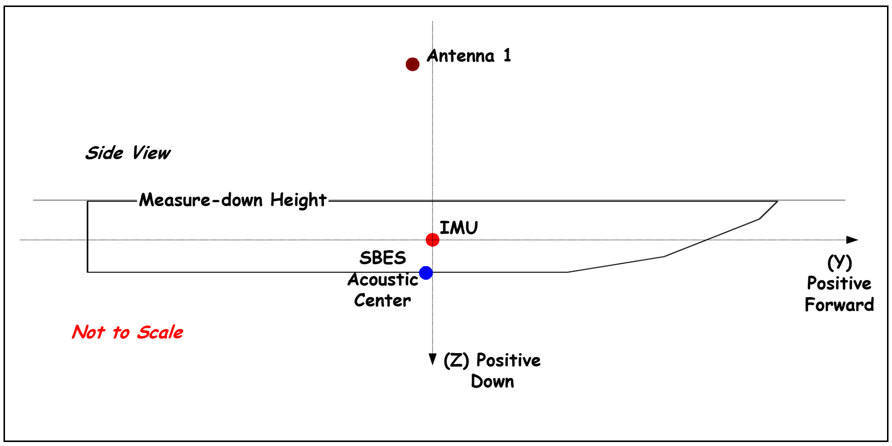


Figure 15 – M/V Ducer vessel survey showing the relative positions of the installed survey equipment.

Equipment	Offset from CRP (m) based on CARIS Convention		
	X	Y	Z
IMU	0.000	0.000	0.000
SBES Acoustic Center	-0.340	-0.050	0.403
GPS1 (Primary/Port)	-0.882	-0.206	-1.796
Draft Measure-down Point	n/a	n/a	-0.507

Table 26 – M/V Ducer offset measurements determined during the vessel survey. The CARIS convention of + down (z), + starboard (x) and + forward (y) was used for all measurements.

C.1.2. Attitude and Positioning

As described in previous sections of this report, heave, roll, pitch, heading, and positioning data for the three vessels were measured using Applanix POSMV. The system provided output as a binary data string via RS-232 serial cable to the QINSy acquisition software at 50Hz. The data was also logged to POS file for post-processing of positions and application of TrueHeave. Heave (or TrueHeave), roll and pitch corrections were applied during the sound velocity correction process in CARIS HIPS. Uncertainty associated with these measurements is discussed in section B of this report.

C.1.3. Patch Test Data

For multibeam data, patch tests were performed on the vessels to determine any offset angles (roll, pitch and azimuth) and latency between the transducer and motion sensors. Single-beam systems were tested for latency only. These tests were done over a stable sand wave feature near the seawall in Bethel, AK. The patch test data is available for review with the CARIS deliverables in the "Calibrations" project.

C.1.3.1. ***Navigation Latency***

To determine latency, a survey line was run twice – in the same direction – at different speeds over a distinct feature. The data was examined in HIPS "Calibration" mode. Any horizontal offset of corresponding nadir beams on the feature indicated latency between the positioning and sounding systems. A value (in seconds) that improved the matchup was determined and entered into the HVF.

C.1.3.2. ***Pitch***

After determining and correcting for any latency, pitch offset was determined. The same survey line run twice over a distinct feature, in opposite directions, was examined in Calibration mode. Any horizontal offset of corresponding nadir beams indicated a pitch offset between the sounder and motion sensor reference frames. A value that improved matchup was determined and entered into the HVF.

C.1.3.3. ***Azimuth (Yaw)***

After determining and correcting for any latency and pitch, the azimuth (yaw) offset was determined. Survey lines run in opposite directions with outer beams overlapping on a distinct feature were examined in Calibration mode. Any horizontal offset of corresponding nadir beams indicated a yaw offset between the sounder and motion sensor reference frames. A value that improved matchup was determined and entered into the HVF.

C.1.3.4. *Roll*

The roll offset was determined after the latency, pitch, and yaw offsets had been determined and corrected. The same survey line run twice over flat bottom topography, in opposite directions, was examined in Calibration mode. Any vertical offset of outer beams indicated a roll offset between the sounder and motion sensor reference frames. A value that improved matchup was determined and entered into the HVF.

C.1.3.5. *Patch Test Results*

Patch test values and latency corrections were applied to the raw sounding data during the merge process in CARIS HIPS. Refer to section B of this report for uncertainties associated with patch test results. The following table summarizes the patch tests and the results.

Vessel	Echo Sounder	Time (sec)	Pitch (deg)	Roll (deg)	Yaw (deg)	Patch Test Date
M/V Latent Sea	Reson MBES	0.00	0.30	-2.50	-0.50	June 20th, 2010 (JD171)
	Odom SBES	0.00	n/a	n/a	n/a	
M/V Jella Sea	Reson MBES	0.00	-0.31	0.30	2.00	June 20th, 2010 (JD171)
	Odom SBES	0.20	n/a	n/a	n/a	
M/V Ducer	Odom SBES	0.10	n/a	n/a	n/a	June 21st, 2010 (JD172)

Table 27 – Patch tests performed for instrument calibration during OPR-R341-KR-10.

C.2. Speed of Sound Corrections

Sound-speed profile data for OPR-R341-KR-10 was collected using two AML SV Plus sensors and two Odom Digibar sensors.

Profiles were collected by acquisition normally on a 12-hour interval during SBES operations and 4-hour interval during MBES operations. They were processed in TerraSond's SimpleSVP software which produced a CARIS compatible format at 1-meter depth intervals. The output was appended to the master HIPS SVP file by vessel and sheet.

Sound-speed corrections were applied in processing to the raw sounding data through HIPS sound velocity correction. Nearest in distance within time was selected for the correction method, with 12-hours used for SBES data and 4-hours used for MBES data. The DR, *Separate II* contains sound-speed comparisons and calibration reports. Individual cast data can be found in the ".SVP" file submitted with the digital CARIS data for each survey.

Note concerning speed of sound correction for single-beam lines run prior to JD184:

> On July 3rd, 2010 (JD184) it was discovered that QINSy was writing incorrect travel times for Odom data to XTF. QINSy was not writing raw travel time output by the Odom to XTF as assumed. QINSy was instead using the digitized depth output by the Odom in conjunction with a QINSy sound-speed setting to determine the travel time. After SV correction in HIPS this resulted in an incorrect depth for all SBES soundings whereby they were 0.05 to 0.20 m shallower then actual depth. This affected all survey sheets except H12164.
>
> This was alleviated from JD184 onwards by modification of the acquisition procedure, whereby during SBES ops the survey crew would ensure QINSy and the Odom had the same sound speed entered resulting in correct travel times written to XTF. Pre-JD184 lines were temporarily fixed in the field by applying modified SVP files in HIPS.
>
> However during office processing all pre-JD184 lines were repaired so that application of the normal sound velocity correction file resulted in correct depths. This was done by exporting new XTFs with correct travel time out of QINSy, reconverting into CARIS HIPS, and transferring edits from the existing lines. This was possible because all necessary data was stored in the QINSy DB files, and in-use Odom sound-speed settings were available from the eChart DSO files.
>
> *It is important to note that all affected single-beam data included with the survey deliverables have been corrected for this issue. This includes all raw XTFs and all CARIS data.*
>
> Raw XTFs included with the deliverables for SBES lines run prior to JD184 will show a post-survey data modified because of the XTF export process.

C.3. Static Draft

Static draft was measured at least once daily on each vessel with an uncertainty of 0.01 m. Static draft was determined by measuring from a measure-down point on the gunwale of the port and starboard side of each survey vessel to the waterline. The measure-down values were recorded in the daily acquisition logsheets.

HIPS vessel files (HVF) were then updated by processing with a new waterline value. The port and starboard measure-downs recorded in the daily acquisition logsheet were averaged and reduced to the vessel's reference point using the surveyed vessel offsets to determine the static draft. This value was entered as a new waterline value in each vessel's HVF and checked to confirm the values fell within the normal range for the vessel.

The waterline correction was applied to the soundings by HIPS during sound velocity correction. The waterline correction was also applied to GPS altitudes during the compute GPS tide process. Static draft tables are available in each HVF available with the CARIS deliverables.

C.4. Dynamic Draft Corrections

Dynamic draft corrections were determined using PPK GPS methods for all vessels. The *M/V Ducer* and *M/V Latent Sea* values were computed from squat-settlement tests while the *M/V Jella Sea* values were derived from its PPK altitudes. Corrections were determined for a range that covered normal survey speeds and engine RPMs.

C.4.1. Squat Settlement Tests

During squat-settlement tests, the vessel logged position data to POS file while a nearby shore base station logged dual frequency GPS data. A survey line was setup in the direction of the current and run up-current and then down-current at incrementing engine RPM ranges. Between each set as well as at the start and end of the test a "static" was collected whereby the vessel would sit with engines in idle, and log for a minimum of two minutes. The survey crew would note in the acquisition logsheet the precise time and average engine RPM of each event. The entire test was repeated with the multibeam sonar deployed to account for different vessel response due to the increased drag.

The POS file was later processed with the nearby base station data in Applanix POSPac to produce an SBET. The SBET was examined to determine vessel speeds for each RPM range. Altitudes were extracted from the SBET and imported into Microsoft Excel.

In Excel the altitude records were separated and grouped according to RPM range or static. Each range was averaged to remove heave and motion. A 4^{th} to 5^{th} order polynomial equation was computed that best fit the static periods and used to remove the tide component from the RPM ranges. The residual result was the difference from static or dynamic draft. The up-current and down-current results were then averaged to eliminate any affect from current. Interpolated RPM ranges were inserted when necessary to eliminate steps.

This resulted in a table of corrections for draft as a function of engine RPM for multibeam deployed (head down) and a separate set for multibeam in stowed position (head up) situations.

C.4.2. Application of Dynamic Draft

Dynamic draft corrections for this project were primarily engine RPM based. Speed-based corrections were not used except in a relatively few cases where RPM data was not logged. Due to the strong river and tidal currents, typically averaging 3 kts, RPM-based corrections more accurately captured vessel vertical response.

Excel was used to process the logged RPM data to produce a dynamic draft correction file. In Excel, the RPM data that had been time tagged and logged continually during survey operations was imported and a lookup table used to exchange RPM with the appropriate dynamic draft correction determined for that vessel (and status of multibeam sonar deployment).

A CARIS-compatible output was produced. Two versions were created: one used the “head down” squat settlement table while the other used the “head up” squat settlement table. The appropriate file was then loaded into CARIS lines in processing – lines run when the multibeam sonar was in the deployed position were loaded using HIPS “Load Delta Draft” utility with “head down” corrections file while lines run when the multibeam sonar was in the up or stowed position were loaded with “head up” corrections file. The dynamic draft files are available with the CARIS survey deliverables in the “tide” directory.

On rare occasions RPM files were not logged or logged without time stamps. Lines without overlapping RPM data were identified and a speed-to-draft correction table setup in each HVF for their benefit. Note that the vast majority of lines have the delta draft corrections loaded, which override speed-based corrections in the HVF. Lines without dynamic draft loaded are itemized in the appropriate DR.

Subsequently all lines were sound-speed corrected again and GPSTide re-computed in HIPS to apply the correctors.

C.4.3. M/V Latent Sea

A squat-settlement test was completed on the *M/V Latent Sea* on August 14th, 2010 (JD226). The test was done with the multibeam transducer in the deployed position, and repeated with the multibeam in the stowed or up position. The *M/V Latent Sea* typically surveyed at engine RPMs below 3200. The results are shown below.

M/V Latent Sea Settlement Table

RPM	Head-Down Speed (kts)	Head-Down Settlement (m) (+ down)	Head-Up Speed (kts)	Head-Up Settlement (m) (+ down)
0	0.0	0.000	0.000	0.000
650	2.9	0.007	2.9	0.009
1000	3.5	-0.001	4.2	-0.012
1200	3.7	0.015	4.9	-0.027
1400	4.4	-0.009	5.6	-0.002
1600	5.2	-0.005	6.3	0.016
1800	6.0	0.000	6.7	0.012
2000	6.5	0.000	7.2	0.008
2200	6.9	-0.002	7.5	0.006
2400	7.4	-0.022	7.8	-0.020
2600	7.7	-0.037	8.1	-0.043
2700	n/a	n/a	8.2	-0.057
2800	7.8	-0.054	8.3	-0.070
2850	n/a	n/a	8.5	-0.081
2900	n/a	n/a	8.6	-0.092
2950	n/a	n/a	8.8	-0.103
3000	8.0	-0.066	8.9	-0.114
3200	8.3	-0.064	n/a	n/a
	20.0	-0.064	20	-0.114

- Results in **blue** were interpolated from adjacent values to smooth steps
- 20 kts "max" speed entered in HVF to ensure correction of all lines continuing last computed speed value

Table 28 – M/V Latent Sea Settlement Results

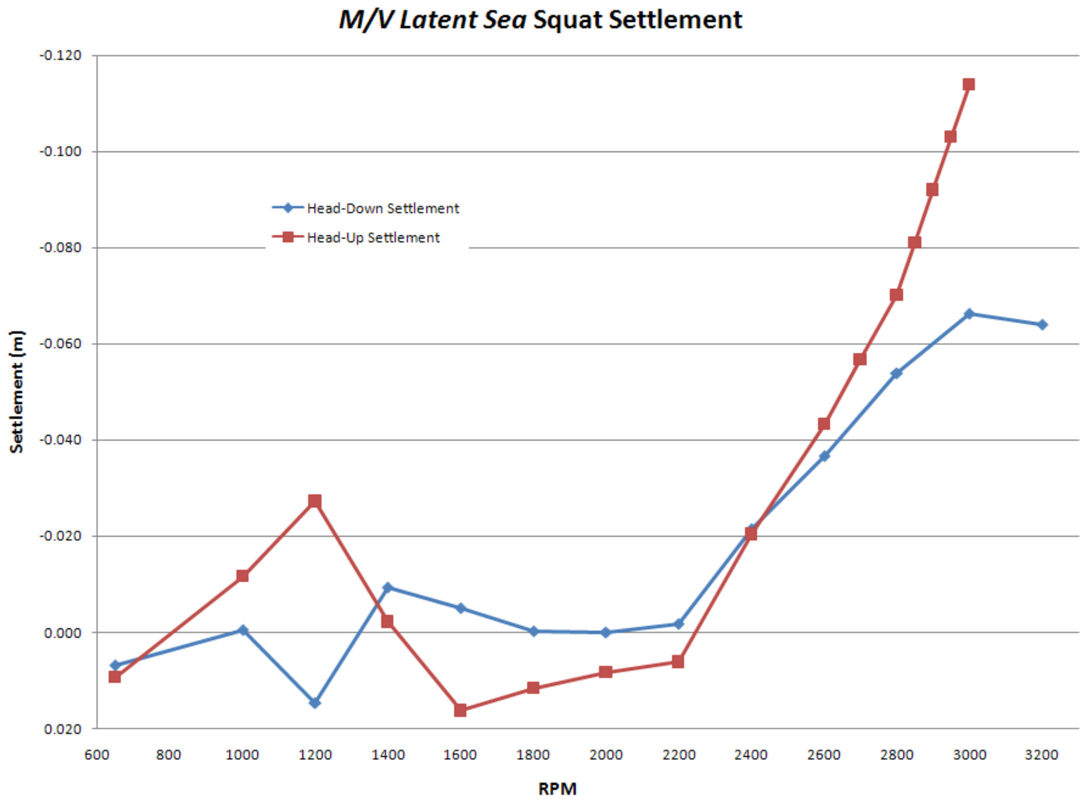


Figure 16 – M/V Latent Sea Settlement Results

C.4.4. M/V Ducer

A squat-settlement test was completed on the *M/V Ducer* on July 22nd, 2010 (JD203). The *M/V Ducer* typically surveyed at engine RPMs below 3000. Results are shown below.

***M/V Ducer* Settlement Table**

RPM	Speed (kts)	Settlement (m) (+ down)
0	0.0	0.000
800	0.0	0.000
1200	3.7	0.015
1300	4.0	0.016
1400	4.3	0.017
1500	4.6	0.024
1600	4.9	0.031

RPM	Speed (kts)	Settlement (m) (+ down)
1700	5.2	0.037
1800	5.5	0.042
1900	5.7	0.046
2000	5.9	0.050
2100	6.0	0.051
2200	6.0	0.052
2300	6.3	0.052
2400	6.6	0.052
2500	6.8	0.051
2600	6.9	0.050
2700	7.0	0.048
2800	7.0	0.047
2900	7.4	0.041
3000	7.8	0.035
	20.0	0.035

- Results in **blue** were interpolated from adjacent values to smooth steps
- 20 kts "max" speed entered in HVF to ensure correction of all lines continuing last computed speed value
- Duplicate speed values omitted from HVF

Table 29 – M/V Ducer Settlement Results

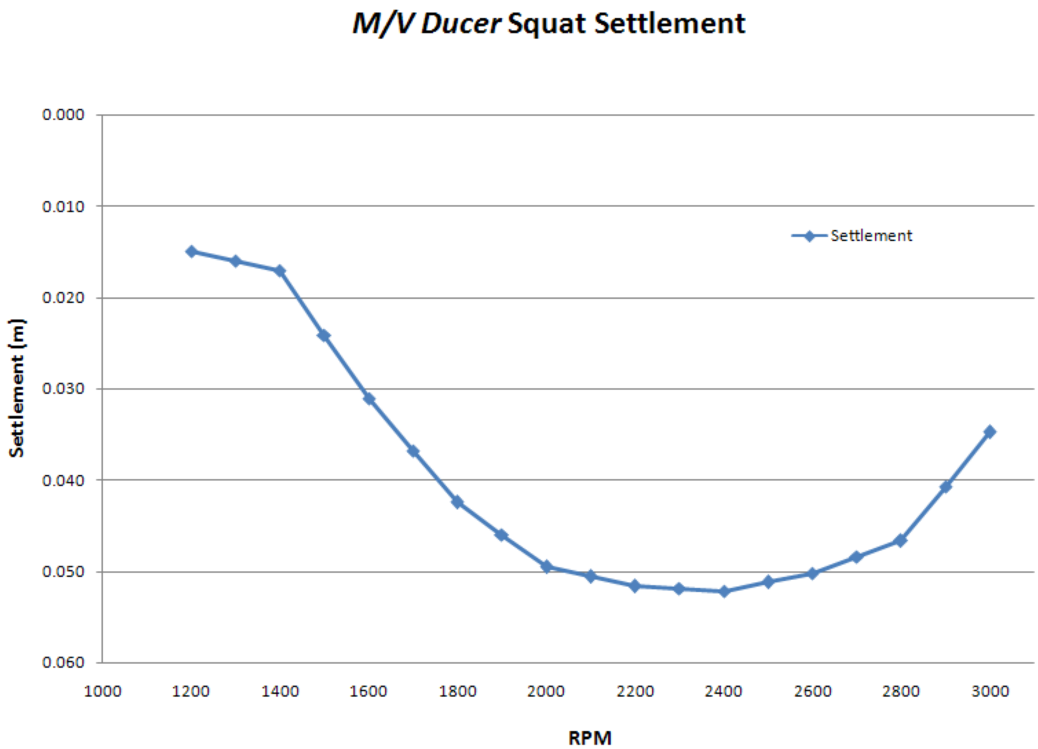


Figure 17 – M/V Ducer Settlement Results

C.4.5. M/V Jella Sea

A formal squat-settlement test was not accomplished on the *M/V Jella Sea*.

As noted in the vessel section, the *M/V Jella Sea* was removed from the project prematurely on July 27th (JD208) when the vessel sank during the night. The vessel was successfully re-floated the same day and equipment recovered. However the decision was made to remove the vessel from the project to allow for remediation. This incident occurred before a formal squat-settlement test could be done.

However, sufficient data existed in the survey records to derive squat-settlement. This was possible because RPM data had been logged continuously during the survey with concurrent PPK data. In processing, RPM values were correlated with PPK altitude by time stamp. Static periods were identified and used to compute tide correction curves which were used to remove tide. Results were averaged to smooth noise, producing a settlement curve. The process was repeated for both "head-down" and "head-up" conditions.

The *M/V Jella Sea* typically surveyed at engine RPMs below 3800. Results are shown below.

***M/V Jella Sea* Settlement Table**

RPM	Head-Down Speed (kts)	Head-Down Settlement (m) (+ down)	Head-Up Speed (kts)	Head-Up Settlement (m) (+ down)
0	0.0	0.000	0.0	0.000
800	0.0	0.000	0.0	0.000
850	n/a	0.031	n/a	n/a
900	n/a	0.047	n/a	0.003
1000	4.0	0.049	3.5	0.010
1100	n/a	0.060	n/a	0.009
1150	n/a	0.037	n/a	n/a
1200	4.4	0.020	4.3	0.011
1250	n/a	0.039	n/a	n/a
1300	n/a	0.052	n/a	0.017
1400	4.8	0.034	4.9	0.012
1500	n/a	0.040	n/a	0.017
1600	5.2	0.055	5.5	0.019
1700	n/a	0.051	n/a	0.028
1800	5.7	0.032	6.0	0.035
1900	n/a	0.024	n/a	0.034
1950	n/a	0.036	n/a	n/a
2000	6.1	0.057	6.5	0.032
2050	n/a	0.058	n/a	n/a
2100	n/a	0.083	n/a	0.026
2200	6.5	0.064	6.9	0.034
2300	n/a	0.048	n/a	0.022
2400	6.9	0.038	7.2	0.018
2500	n/a	0.029	n/a	0.017
2600	7.4	0.027	7.5	0.018
2700	n/a	0.012	n/a	0.008
2750	n/a	n/a	n/a	-0.007
2800	7.8	0.033	7.7	-0.019
2900	n/a	0.008	n/a	-0.007
3000	8.2	0.000	7.8	-0.016

RPM	Head-Down Speed (kts)	Head-Down Settlement (m) (+ down)	Head-Up Speed (kts)	Head-Up Settlement (m) (+ down)
3050	n/a	-0.032	n/a	n/a
3100	n/a	-0.052	n/a	-0.065
3200	8.6	-0.051	n/a	-0.112
3300	n/a	-0.034	n/a	-0.155
3400	9.0	-0.055	n/a	-0.208
3500	n/a	-0.063	n/a	-0.231
3600	n/a	-0.082	n/a	n/a
3700	n/a	-0.111	n/a	n/a
3800	n/a	-0.116	n/a	n/a
	20.0	-0.055	20.0	-0.016

- Speed values computed to correlate to 200-rpm increments
- 20 kts "max" speed entered in HVF to ensure correction of all lines continuing last computed speed value

Table 30 – M/V Latent Sea Settlement Results

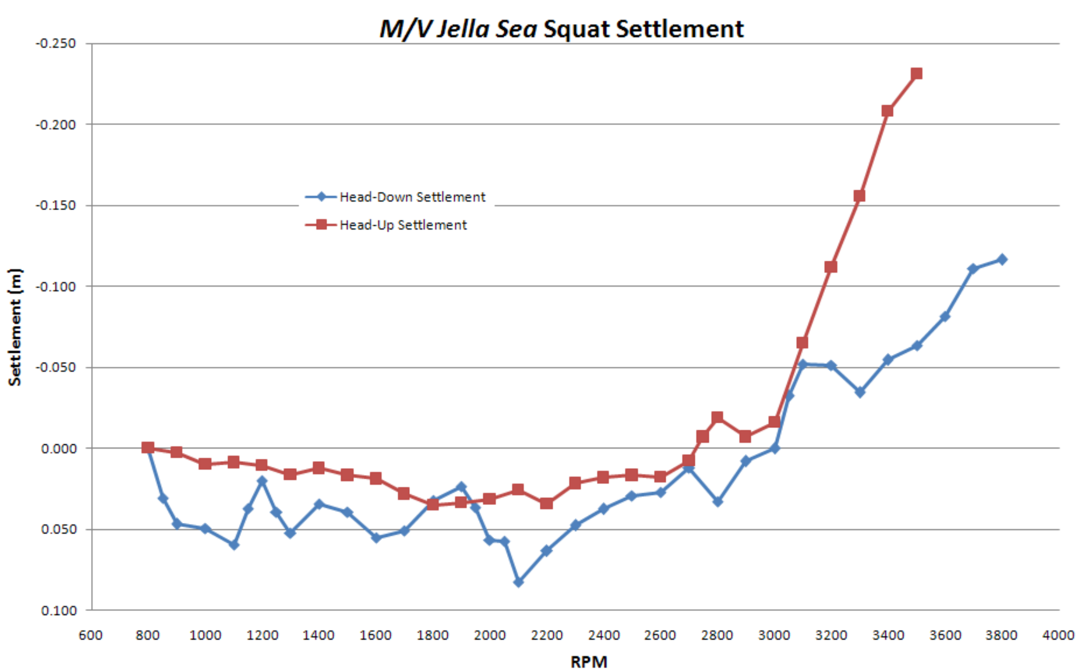


Figure 19 – M/V Jella Sea Settlement Results

C.5. Tide Correctors and Project Wide Tide Correction Methodology.

Ellipsoid Referenced Surveying (ERS) methods were used for tide correction on this project. All survey lines were loaded with an accurate NAD83 ellipsoid height from SBET file as outlined previously in this document. To reduce the ellipsoid heights to MLLW, a separation model was developed by JOA and applied to the lines in CARIS HIPS. The model utilized the GPS to MLLW datum separations computed for installed tide stations at Quinhagak, AK (946-5831) and Popokamute, AK (946-6057) and new stations at Bethel, AK (946-6477), Lomavik Slough, AK (946-6328) and Helmick Point, AK (946-6153). Additionally, short duration tide gauges were installed at the project RTK sites and their separation values computed and utilized in the model as well. See the project HVCR for more information regarding the MLLW separation values and the separation model.

APPROVAL SHEET

For

H12164 through H12170

This report and the accompanying digital data are respectfully submitted.

Field operations contributing to the completion of this project were conducted under my direct supervision with frequent personal checks of progress and adequacy. This report, digital data, and accompanying records have been closely reviewed and are considered complete and adequate per the *Statement of Work*. Other reports submitted with this survey include the Descriptive Report (one for each survey sheet) and the Horizontal and Vertical Control Report.

This survey is complete and adequate for its intended purpose.

Andrew Orthmann

Digitally signed by Andrew Orthmann
DN: CN = Andrew Orthmann, C = US, O = TerraSond Ltd
Reason: I attest to the accuracy and integrity of this document
Date: 2010.12.20 19:32:43 -09'00'

Andrew Orthmann (ACSM Certified)
Lead Hydrographer
TerraSond Ltd.

Date: December 20th, 2010