



**British
Geological Survey**

NATURAL ENVIRONMENT RESEARCH COUNCIL

Multibeam trials on the Northern Lighthouse Board vessel, Polestar, 2011/2.

Internal Report OR/11/044

Multibeam trials on the Northern Lighthouse Board vessel, Polestar, 2011/2.

Nick Smart, Rhys Cooper

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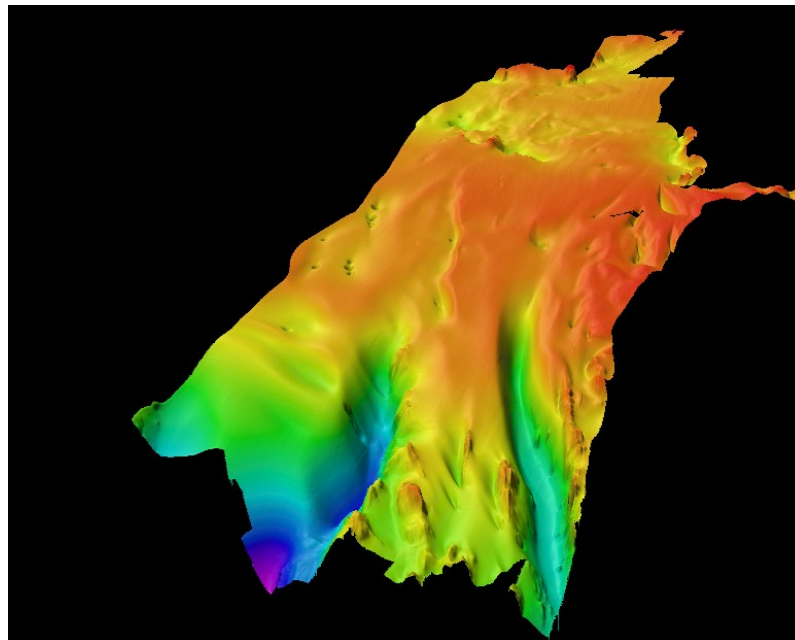
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Foreword

The British Geological Survey (BGS) and the Northern Lighthouse Board (NLB) are part of a joint venture to collect multibeam bathymetric data. Two BGS Hydrographic Surveyors, Nick Smart and Rhys Cooper, were assigned to the Northern Lighthouse Board (NLB) in Oban, to assess the Kongsberg EM3002D multibeam system installed on board the Northern Lighthouse Board (NLB) vessel Polestar. An initial three day period between the 15th February and 18th February 2011 was used to review the system and identify any faults. The system has previously had very little use or expert maintenance.

A test bathymetric survey was undertaken between the 24th February and the 5th March 2011 at the north end of the Firth of Lorne, Oban Bay. This area was selected due to relevance for the NLB and potential use in future INNIS Hydro and Marine Coastguard Agency (MCA) surveys. It was also ideally situated close to the installed tide gauge.

A number of issues were identified and solved during the initial three day set-up and subsequent survey. This report describes the survey procedures undertaken and details the issues encountered, equipment used and final results.

Acknowledgements

A number of individuals in the Northern Lighthouse Board and BGS have contributed to the project. This assistance has been received at all stages of the study. In addition to the collection of data, many individuals have freely given their advice, and provided local knowledge.

Of the many individuals who have contributed to the project we would particularly like to thank the following:

Mike Spain (NLB)

Stuart Ross (NLB)

NLB Polestar crew members, officers and mates.

Mark Field (Applanix)

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1 Introduction

The British Geological Survey (BGS) and The Northern Lighthouse Board (NLB) are part of a joint venture to collect multibeam bathymetry. Part of this partnership was to ensure the correct functioning of the installed Kongsberg EM3002D multibeam system on board the NLB vessel Polestar and provide the NLB crew members with an insight into multibeam survey operations. Two BGS hydrographic surveyors, Nick Smart and Rhys Cooper boarded the Polestar over two separate periods. The initial period, from the 15th of February to 18th February 2011, was used to test equipment and gain familiarity with the ship. The second period, from the 24th February to the 5th of March 2011 enabled further fault finding and a test survey to be completed in an area at the northern tip of the Firth of Lorne, Oban Bay.

The Polestar is a Medium Buoy Tender and has served the Board since 2000. It has an overall length of 51.52m, width of 12 meters whilst only drawing 3.46m. The Polestar has Dynamic Positioning capabilities (DP), allowing precise and accurate manoeuvres (nlb.org.uk 2009)



Figure 1: NLB Polestar (NLB 2009).

Numerous technical problems were encountered and solved by the BGS surveyors during the initial set-up and subsequent survey. These issues will be outlined and discussed in detail throughout this report.

A full path test calibration was completed and a total of 131 lines were run over a 10 day period, a total of nine Shipek grab samples were also taken.

1.1 SURVEY AREA

The test area was chosen due to its close proximity to the BGS installed tide gauge at the NLB quay in Oban. This area was also selected due to relevance for the NLB and potential use in future INNIS Hydro and Marine Coastguard Agency (MCA) surveys. Transit routes in an out of

Oban were recorded; the main survey area extended from the west side of Kerrera to the east side of Lismore, north, up to Ardmucknish Bay and the entrance of the Lynn of Lorn.



Figure 2: Test survey area. Firth of Lorne, nr Oban

2 Mobilisation and Survey

Mobilisation and system testing commenced on the 15/02/11 til 18/2/11 and continued during the second survey period from the 24/2/11 – 5/03/11. Many issues were encountered that were mainly due to the system remaining dormant for so long and re routing all the electrical wiring to move the survey processing units to a different deck. Full details are provided below.

A tide gauge was installed prior to the test survey at the NLB jetty and a full patch test was carried out to calibrate the dual sonar heads for latency, pitch, roll and yaw. The patch test lines used by Kongsberg during the initial systems installation back in 2008 were still stored and were re-ran to test for any significant changes. Full patch test details can be found in Appendix 4.

2.1 SYSTEM ISSUES

The following table gives a summary of the issues encountered. Full details of all faults found and solutions applied can be found in the Daily Log, Appendix 8.

Issues encountered	Solution	Reasoning
TNC connectors on POS MV GPS cables were broken, a crimp device within the connector fell apart upon inspection.	New cables were sent out by Applanix with pre-terminated ends as existing cables were out of date, connector repair kits were no longer available, these were fitted by the NLB electrician.	A previous cable refit could be responsible for breakage, the cables appeared to be under tension at the back of the POS MV unit.
No RTCM corrections from SeaStar unit received by POS MV	HyperTerminal was used to prove absence of correction at the POS MV. The NLB electrician solved the issue through rewiring, putting the problem down to a power supply.	Issue likely to have occurred during cable refit.
AML SVP probe losing charge	The device was charged between deployments. New batteries were recommended.	Current batteries are several years old.
POS MV not tracking satellites	Software and firmware upgrades to POS View V5.05 and Trimble BD960 GNSS V4.02	Software and firmware had not been updated since the unit was purchased; Applanix suggested the upgrade which required a maintenance agreement to be taken out.
SIS acquisition software update V3.8.2 producing licensing issues.	Reverted to V3.6.5	This was a known issue to Kongsberg.

2.2 TIDE GAUGE SET-UP

A Valeport TideMaster tide gauge was hired from Geophysical Equipment Rentals (GSE) in Aberdeen. Accurate tidal information is critical for multibeam survey operations. The Valeport tide gauge is small with a long battery life making it ideal for use in Oban. Tide was measured in 15 second burst and logged every minute to a text file providing a continuous record during all survey operations.

The quayside at the NLB proved the ideal location to install the tide gauge as it was secure, stable, easily accessible, and importantly did not dry out at low tide.

It was possible to measure the tide gauge height and reference this to chart datum. The Admiralty chart for this area notes that Chart Datum for Oban is 2.10m below Ordnance Datum Newlyn.

2.2.1 Tide gauge set-up

Tide gauge height relative to chart datum was determined using a Leica GPS500 system, Leica Geo Office software and the freely available RINEX data from the Ordnance Survey website.

The tide gauge was deployed from the NLB quay. To maintain its position a 56lb weight was used, to which the transducer was attached. Nylon rope was tied to the weight to aid in deployment and recovery. Using the rope meant that the weight was not lowered using the transducer cable. The cable-rope assembly ran up to the logging unit at the top of jetty, where the rope was tied off. The offset of the gauge to the top of the jetty was measured using a standard 20m roll of measuring tape. Five metre intervals were marked out on the rope to allow exact final measurement to quayside.

The GPS antenna was positioned on the quayside using a level tripod and tribach and position logged for 1 hour. The same process was repeated during the crew change day as further validation of height. Position was logged for 3 hours on this occasion.

The logged data was then downloaded into Leica GeoOffice to allow the application of RINEX differential corrections freely available from the Ordnance Survey Active GPS network RINEX data server website (<http://gps.ordnancesurvey.co.uk/active.asp>). Web access was possible using the vessels satellite communications.

For more information on the National GPS Network follow this link.

http://www.ordnancesurvey.co.uk/oswebsite/gps/osnetfreeservices/about/overview_osnet.html



Figure 8: Leica GPS setup on NLB quayside.

The logged data could then be corrected to provide an accurate position and height to approximately 1cm accuracy.

The height of the tide gauge was determined to be 1.8739m below Chart Datum. The table below shows position and height difference from the two logging periods.

Date/Time	Easting	Northing	Ellipsoid Height	Position + height quality	Orthogonal Height	Comments
02/25/2011 08:32:45	185311.7	729837.7	58.7469	0.0091	3.806	Initial level - logged for 1 hour due to time constraints.
03/01/2011 15:41	185311.8	729837.7	58.7645	0.0069	3.823	Level Check - logged for 3 hours during crew change - 2cm difference

Table 2: Position and height data from two separate logging periods.

A 2cm height difference was noted between observations; however, this difference is negligible for the purpose of this exercise.

Below is a schematic summarising the heights from the first period's observations:

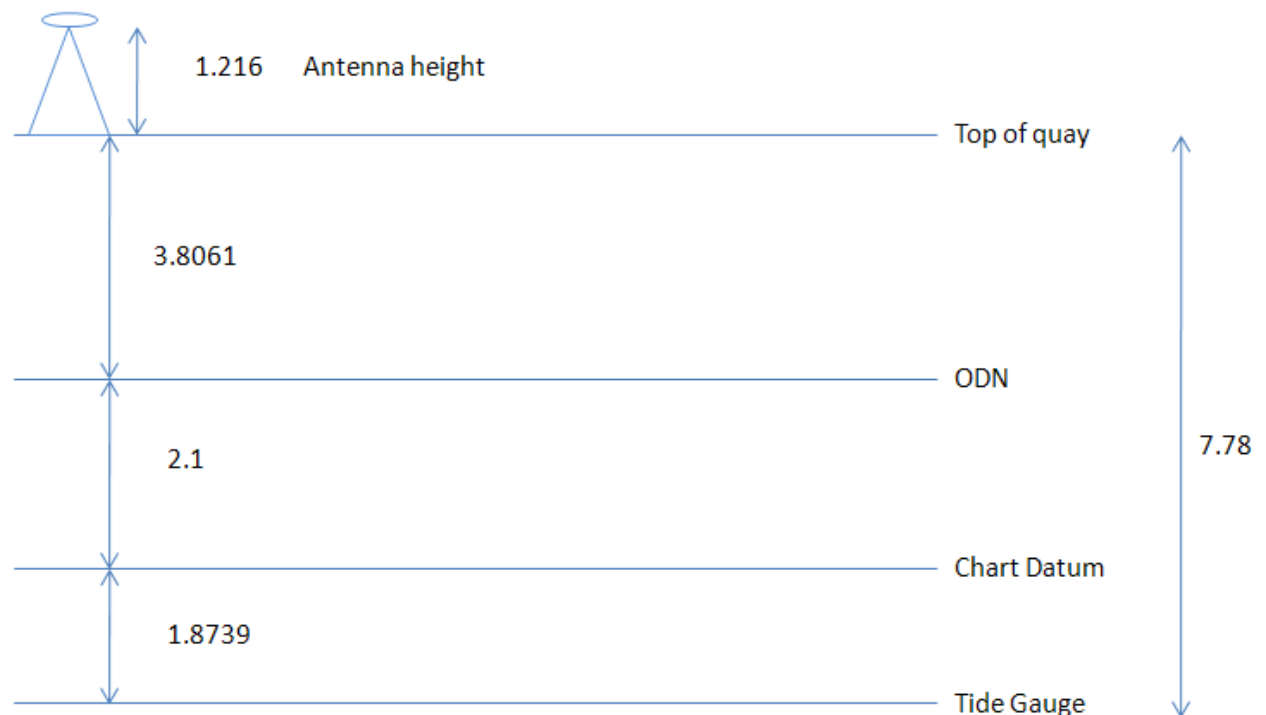


Figure 9: Height level diagram in meters for NLB quayside. The antenna height, chart datum/ODN difference and top of quay to tide gauge measurements were already known. Leica Geo Office was used to convert ellipsoid heights to ODN heights, a level below chart datum could then be determined.

2.3 SURVEY OPERATIONS

Offshore operations ran from 0800 – 1700 to fit in with crew scheduling and daylight hours; during this time a total of 131 lines were recorded with 9 Shipek grab samples taken for ground-truthing purposes.

No fixed survey plan was created and the lines were ran ‘free-style’ with an approximate 25% overlap of each adjacent lines swath width. This was more than adequate for the relatively shallow survey depths of test area. This also allowed the ship’s crew to get used to running lines and multibeam operations.

Sound velocity profiles were taken at least once a day or whenever the SIS warning light indicated values were out of range.

The Shipek grab was deployed using 10mm cable from the main deck winch. The operation of the grab was demonstrated to the crew, after which they took control of the deployment and recovery. A BGS surveyor was present to retrieve the sample and watch over the operation. Samples that were collected were bagged and labelled with a site name, date, vessel name, a position and water depth. Further details can be found in Appendix 9.

Tide gauge data was collected at the end of each day and downloaded to the CARIS processing machine along with the lines ran that day. Data was processed the following day; allowing gaps and interesting features to be highlighted for future lines.

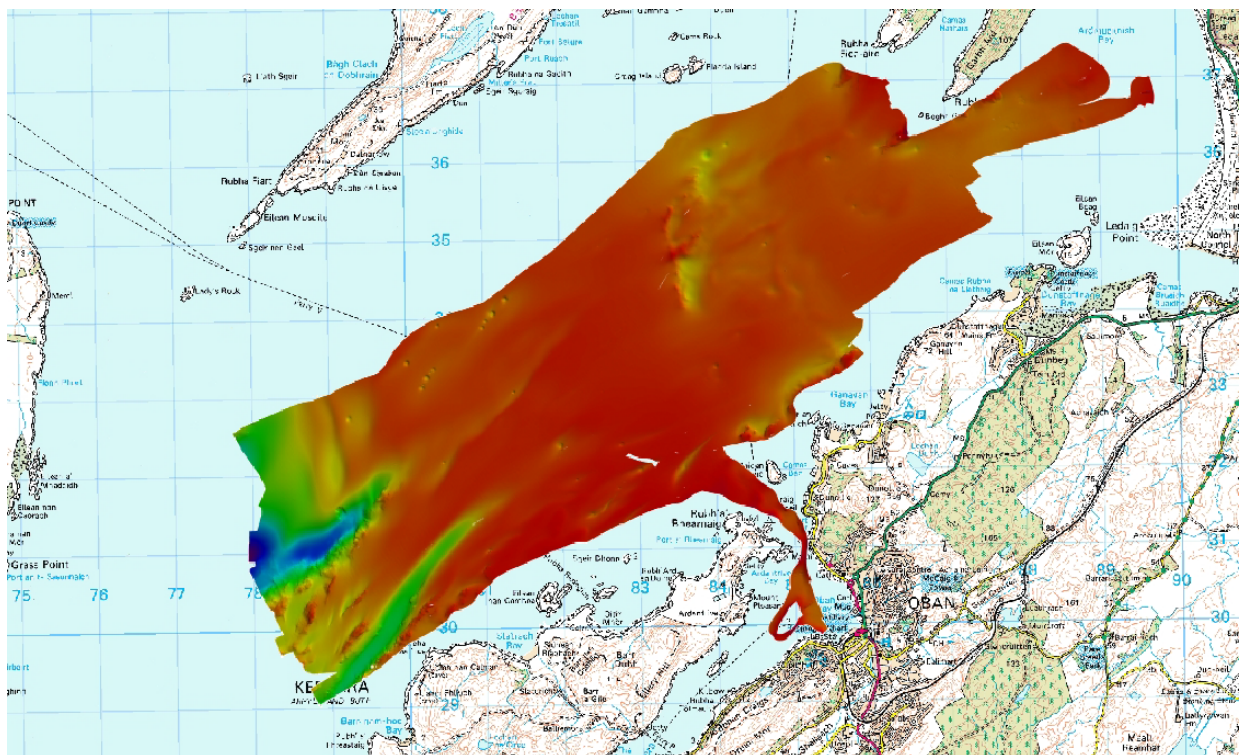


Figure 4: highlights the survey area completed during the second period.

2.4 DATA PROCESSING

Insert stuff on processing log

2.5 DE-MOBILISATION

Demobilisation occurred during the afternoon of the 05/03/11, the tide gauge was recovered from the NLB quay and equipment was loaded into a BGS vehicle. BGS staff departed NLB Polestar at 1500 05/03/11.

3 Survey Equipment

3.1 NAVIGATION

Navigation was provided by an Applanix POS MV 320 with DGPS corrections from a Fugro SeaSTAR receiver. Associated antennas were at the top of the main mast, the SeaSTAR receiver was placed on the bridge, with the POS MV unit placed in the level one office.

3.1.1 POS MV 320

The POS MV 320 system is a GPS aided inertial navigation system which provides accurate attitude, heading, heave, position and velocity data with the aid of inertial GPS. The unit was running with POS View V5.05 software and firmware with Trimble BD960 GNSS V4.02 firmware.



Figure 5: POS MV PCS and Inertial Measurement Unit (Applanix 2009).

The POS MV consists of the above components, the POS computer system (PCS) and the Inertial Measurement Unit (IMU). The processor software functions include the Strapdown Inertial Navigation Algorithm to compute velocity, roll, pitch and true heading from the accelerometer and gyro outputs, a Kalman filter that estimates long term drift in the inertial solution using GPS aiding measurements, and an error corrector that applies the Kalman Filter estimates to the strap-down navigator to continually calibrate the inertial sensor. The PCS also contains a GPS Azimuth Measurement Subsystem for computing true heading from carrier phase measurements output by the dual GPS receivers. The processor firmware and software provide sensor calibration, and also fault detection, isolation and automatic reconfiguration (Applanix 2008).

The POS MV was receiving RTCM type 1/9 corrections from the Fugro SeaSTAR 3510R receiver over a D type 9 pin serial connection. The POS MV output an \$INGPGGA string to the EM3002D PU plus Kongsberg proprietary data string for attitude data. A PPS was also utilised between the POS MV and the PU to synchronise timing.

The table below shows expected accuracies:

Table 1: Accuracies of the POSMV 320 (Applanix 2009).

PERFORMANCE SUMMARY - POS MV Accuracy

POS MV 320	DGPS	RTK	GPS Outage
Position	0.5 - 2 m ¹	0.02 - 0.10 m ¹	<2.5 m for 30 s outages, <6 m for 60 s outages
Roll & Pitch	0.020°	0.010°	0.020°
True Heading	0.020° with 2 m baseline 0.010° with 4 m baseline	-	Drift less than 1° per hour (negligible for outages <60 s)
Heave	5 cm or 5% ²	5 cm or 5% ²	5 cm or 5% ²

3.1.2 SeaSTAR 3510r

This receiver will output a range of Fugro raw data options and calculates RTCM corrections for the user's location; it is designed for use with an external GPS receiver.



Figure 6: SeaSTAR 3510R, image courtesy of (SeaSTAR 2004).

Further spec details of both SeaSTAR and POSMV can be found at ReportAndDeliverables\Documents\SeaSTAR 3510_nov04.

3.2 GEOPHYSICAL SURVEY EQUIPMENT

3.2.1 Kongsberg EM3002D Multibeam Echo sounder

The EM3002D is a dual-headed system capable of producing up to 508 dynamically focused beams; this produces a swath width of up to 200° operable in depths of up to 150 m. The system operates in the 300 kHz frequency range, which ensures narrow beams and a small acoustic footprint, and is also robust under conditions with high particle content in the water column.

The EM3002D uses a powerful processing unit and two compact sonar heads. The processing unit applies sophisticated processing algorithms for beam forming, beam stabilisation and bottom detection.

Information from the processing unit is sent to an operator station running Windows XP, from where the surveyor can operate the system and adjust settings accordingly within the Seafloor Information System (SIS). SIS has extensive functionality such as 3D graphics and real-time data cleaning.

Position and attitude information for the EM3002D is provided via the Seapath 200. This incorporates a motion reference unit and position antennae, a combination of which positions and measures the attitude of the vessel. All of this information is tagged to the data to provide a real-world position.

3.3 CABLE LAYOUT

Below is a schematic showing cable runs between the equipment involved:

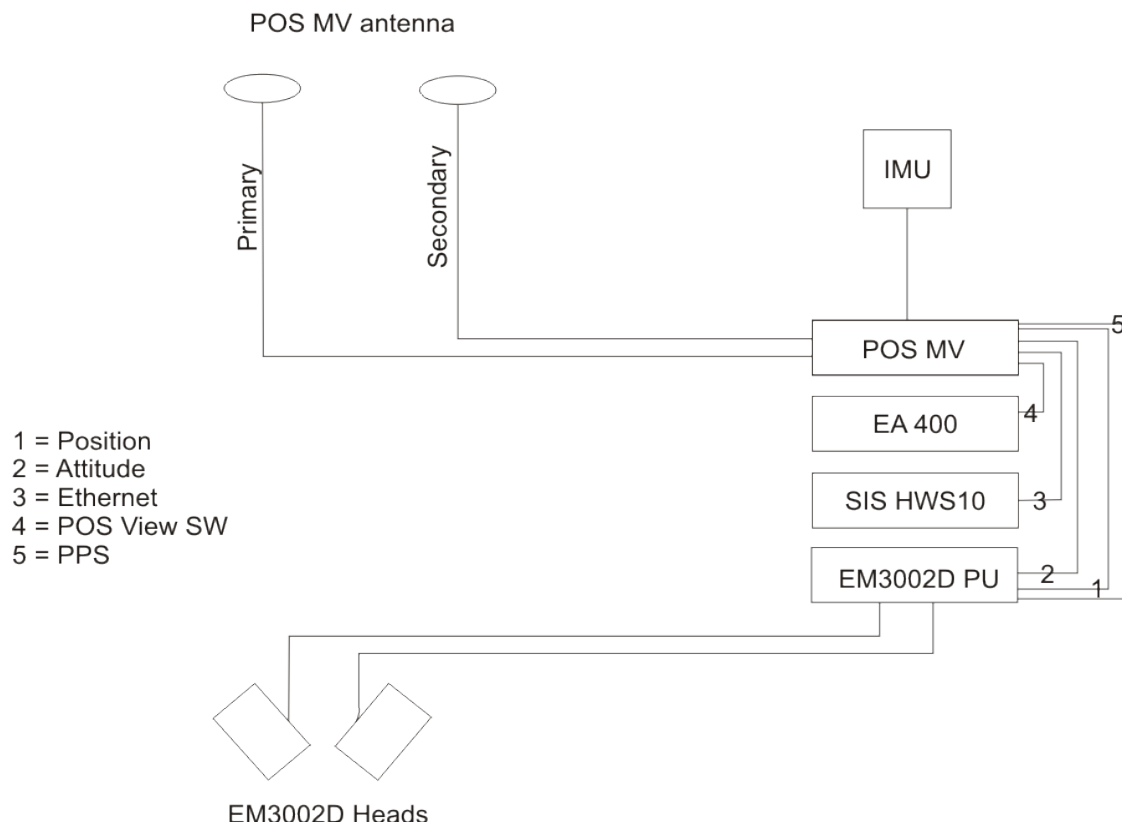


Figure 3: Schematic showing multibeam cable layout.

3.4 SAMPLING EQUIPMENT

3.4.1 SHIPek grab

A BGS Shippek grab was used to collect samples throughout the survey, the grab was used with the vessels main winch and a support crane. Details on the method of use can be found in Appendix 7.



Figure 7: BGS Shippek grab.

Appendix 1 Personnel

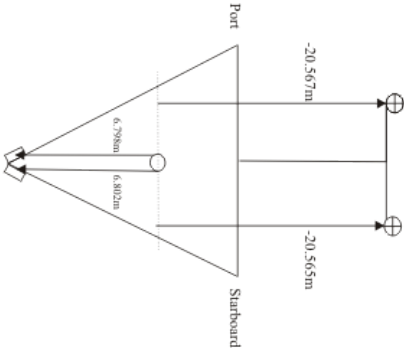
BGS personnel: Nick Smart and Rhys Cooper.

Appendix 2 Equipment Offset Diagram

- KEY
- ⊕

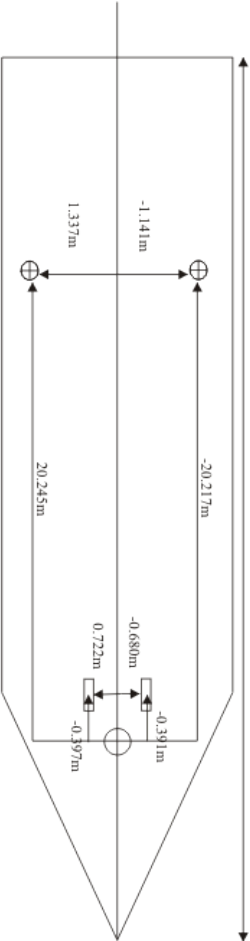
 POS MV antenna
- IMU = CRP
- ▭

 EM3002D sonar heads



NLB Polestar Offset Diagram

+ve = forwards, down and starboard



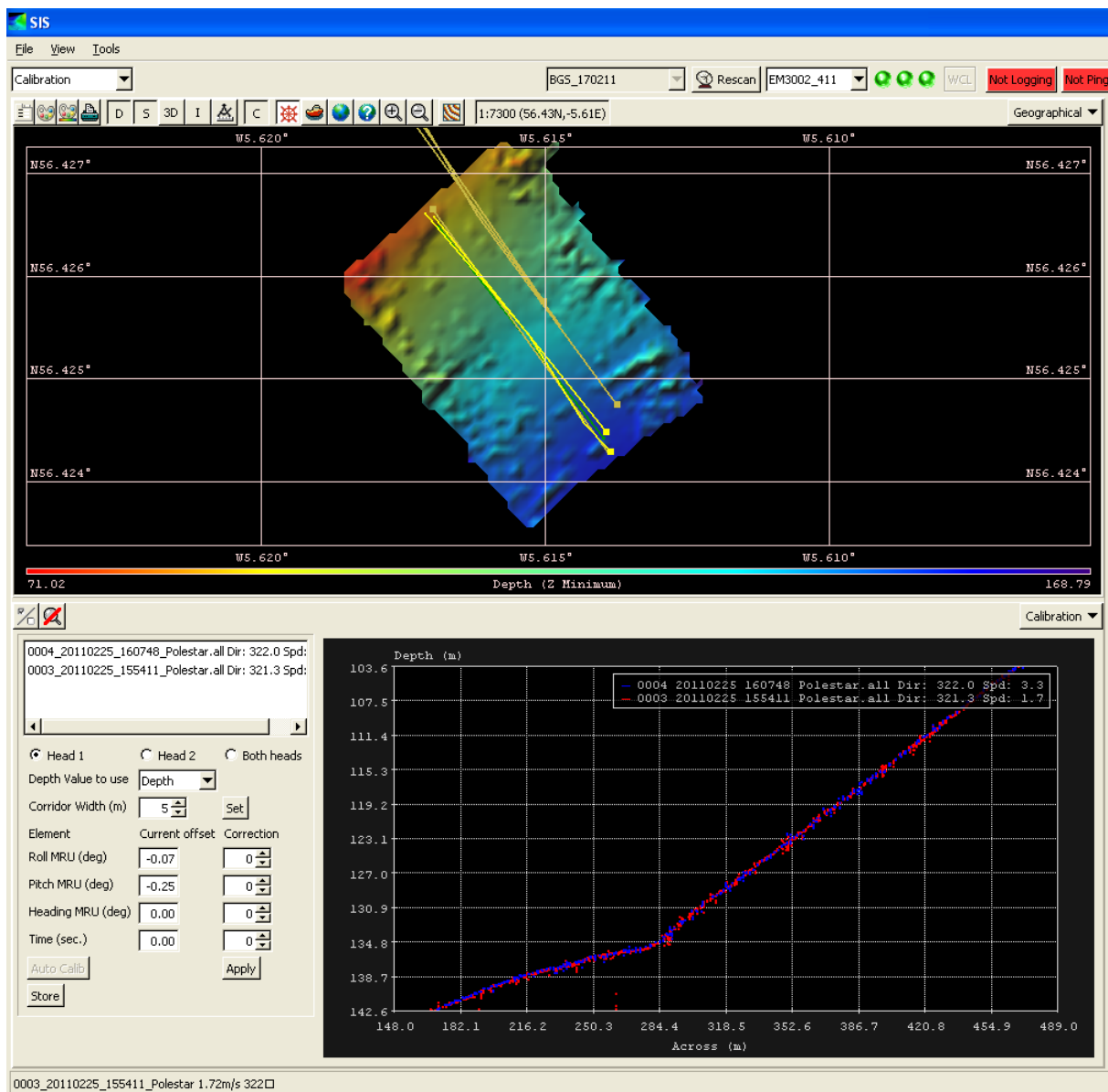
Appendix 3 Patch test

Patch test for NLB Polestar.

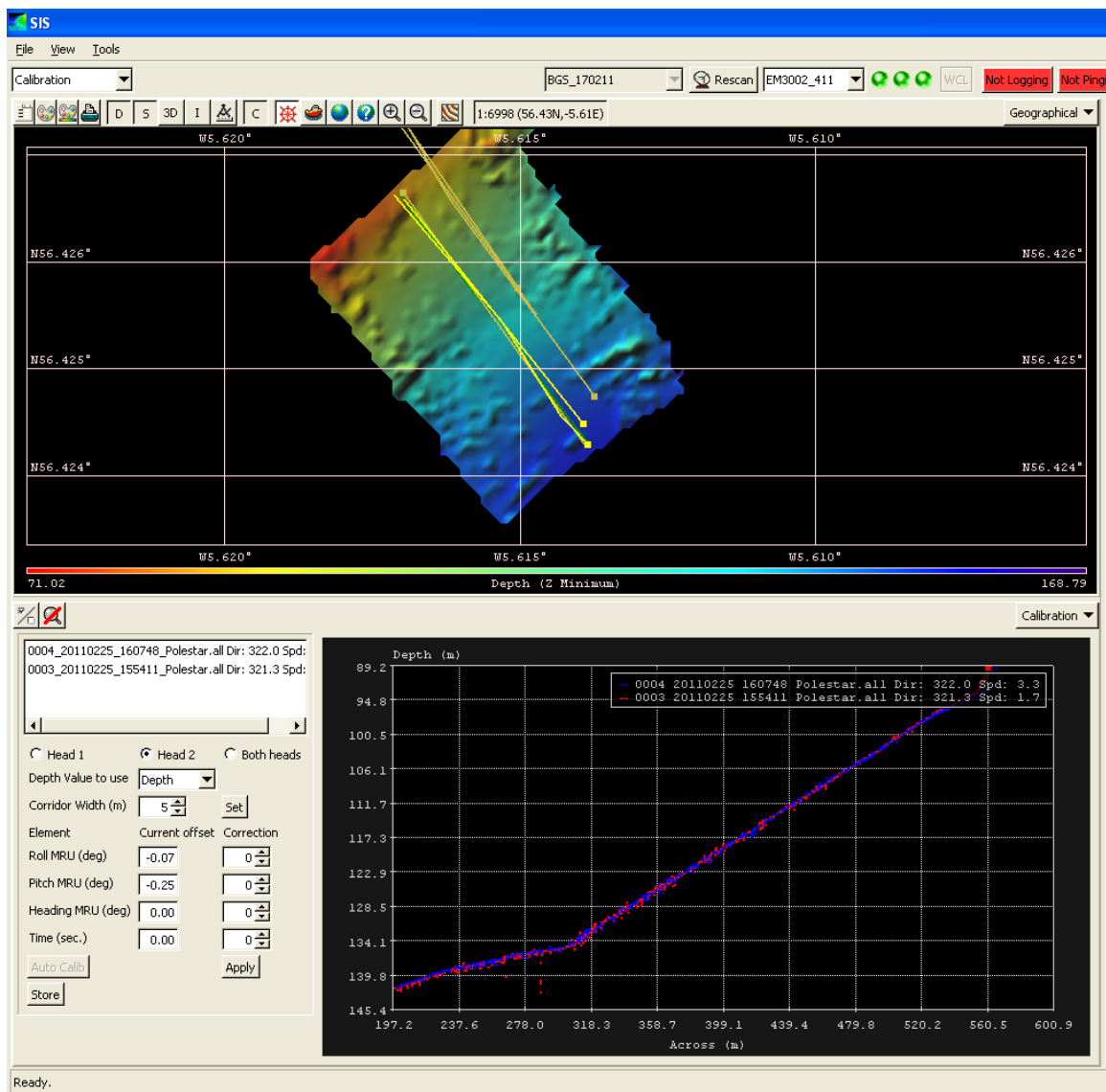
A patch test was carried out on board the NLB vessel Polestar on the 25/02/11 by BGS surveyors.

The results can be seen below. Roll was the only parameter that needed an offset corrected for.

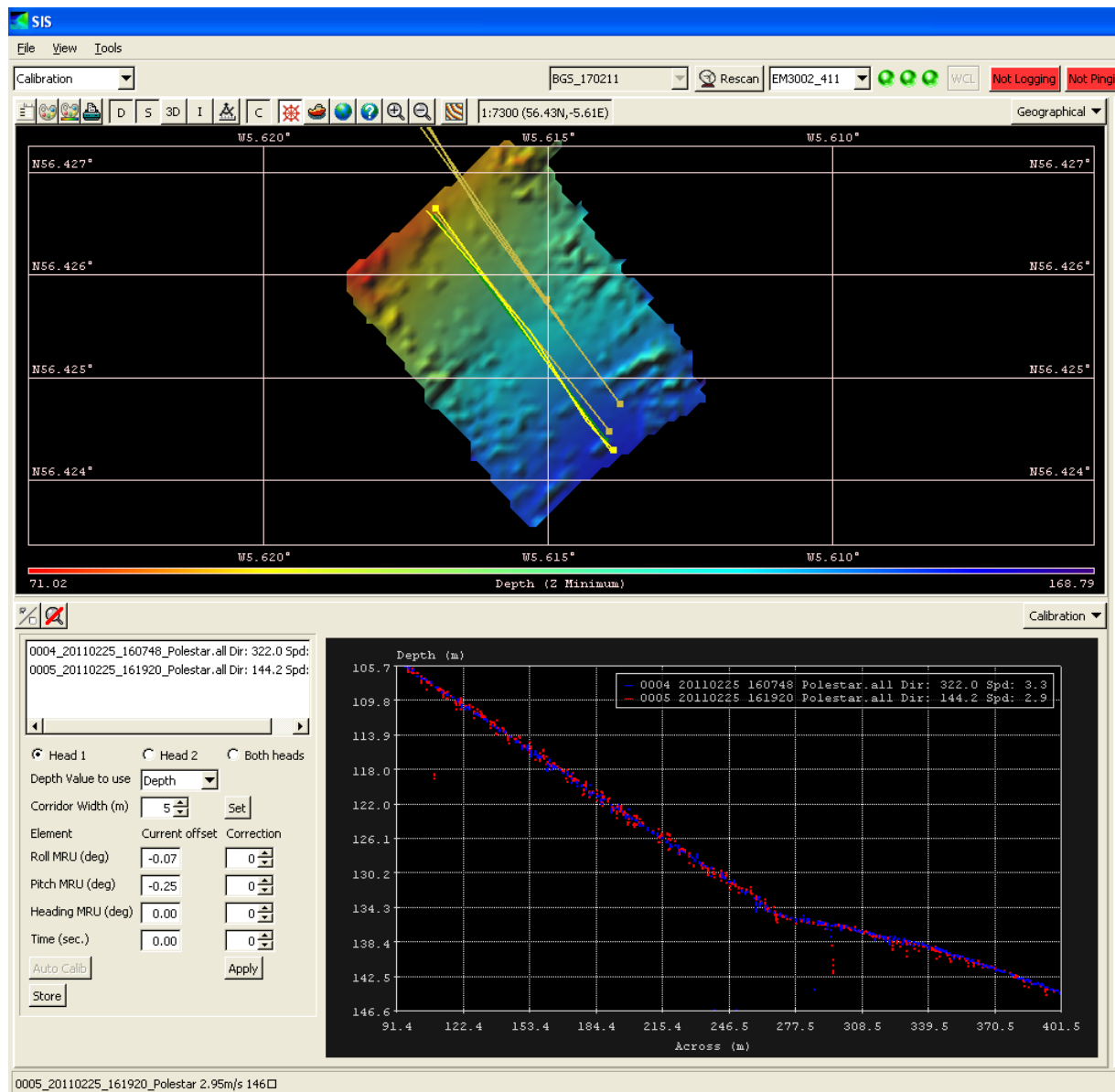
Latency – Head 1



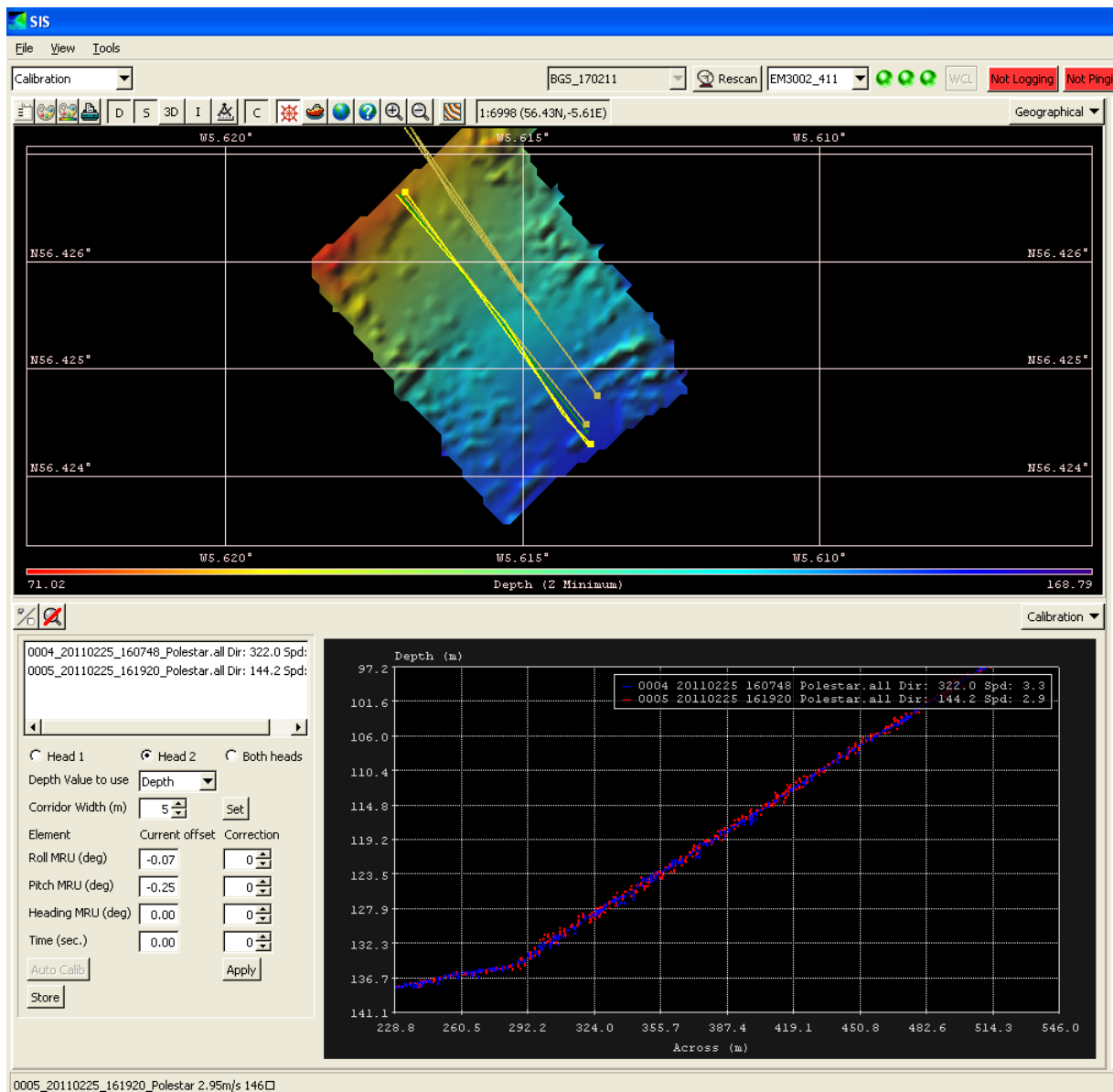
Latency – Head 2



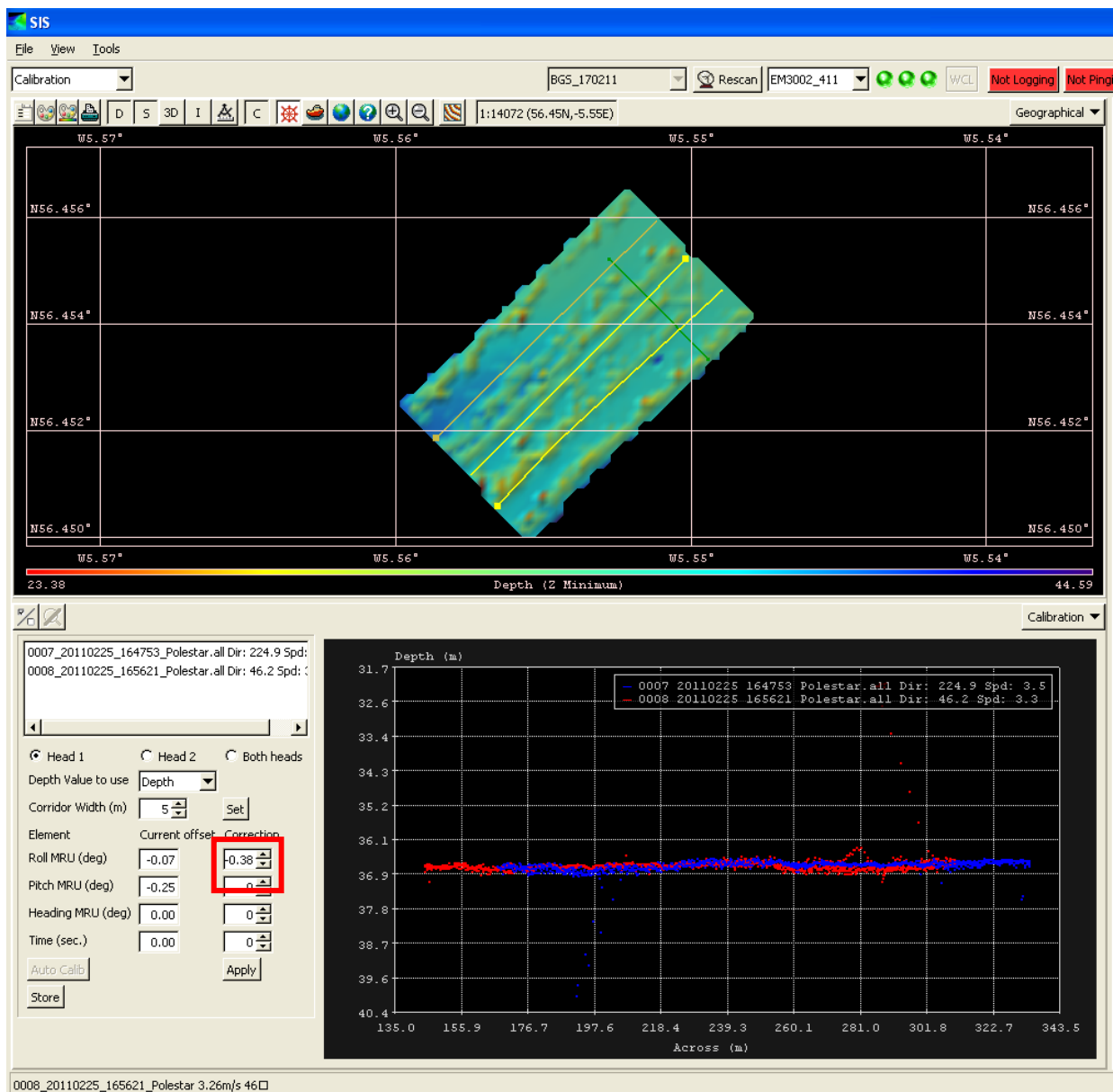
Pitch – Head 1



Pitch – Head 2



Roll - Head 1



Head 1 correction needed:

Head 1 correction needed:

Head 1 ☒ Head 2 ☐ Both heads ☐

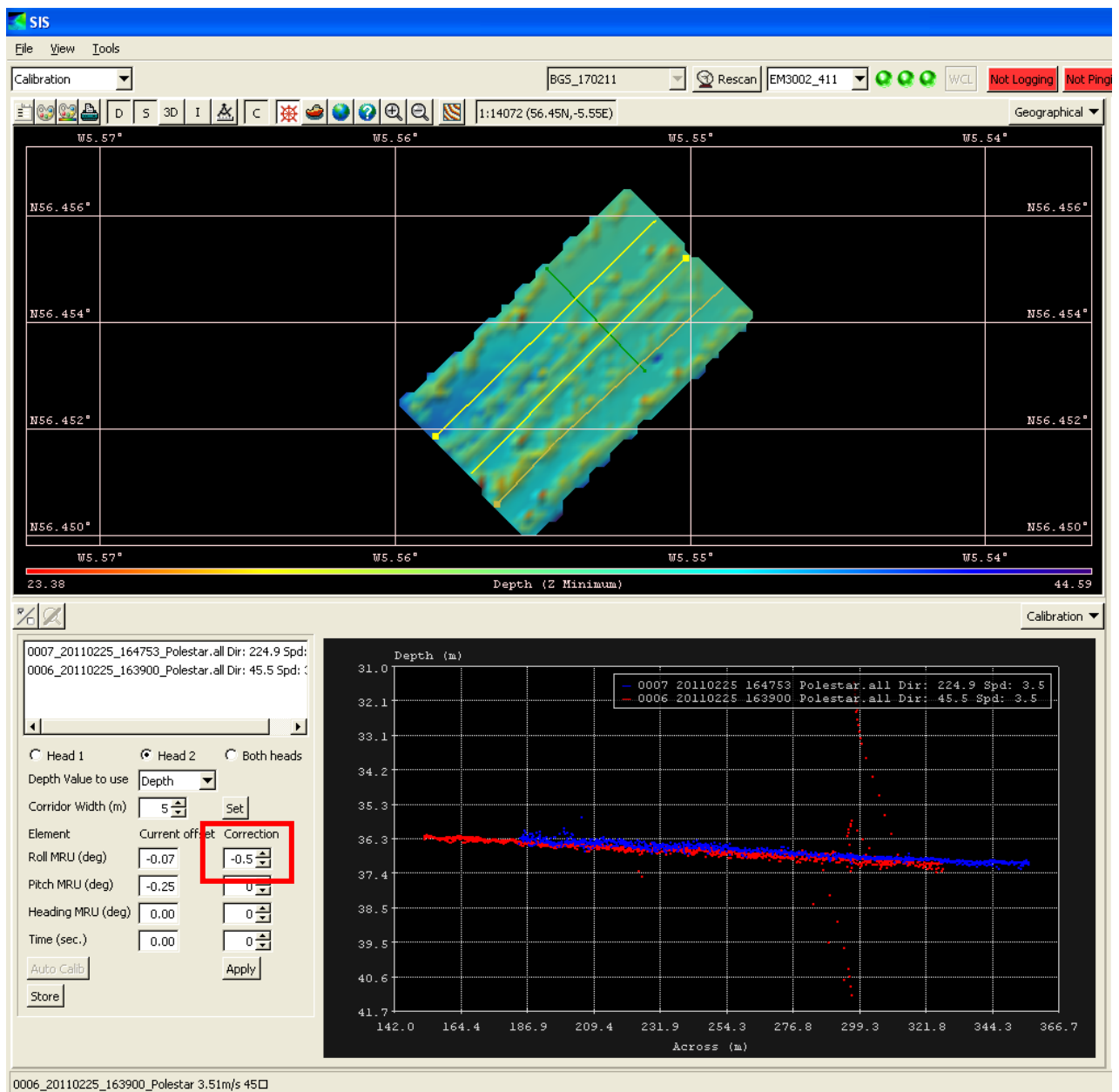
Depth Value to use: Depth

Corridor Width (m): 5 Set

Element: Roll MRU (deg) -0.07 -0.38 Pitch MRU (deg) -0.25 Heading MRU (deg) 0.00 Time (sec.) 0.00

Auto Calib Store Apply

Roll - Head 2



Head 2 correction needed:

☐ Head 1
 ☒ Head 2
 ☐ Both heads

Depth Value to use: Depth

Corridor Width (m): 5

Element: Current offset Correction

Roll MRU (deg): -0.07

Pitch MRU (deg): -0.25

Heading MRU (deg): 0.00

Time (sec.): 0.00

Auto Calib

Store

Apply

Roll correction application:

Head 1 = -0.38

Head 2 = -0.5

Common Error (CE) = $(-0.38 + -0.5) / 2 = -0.44$

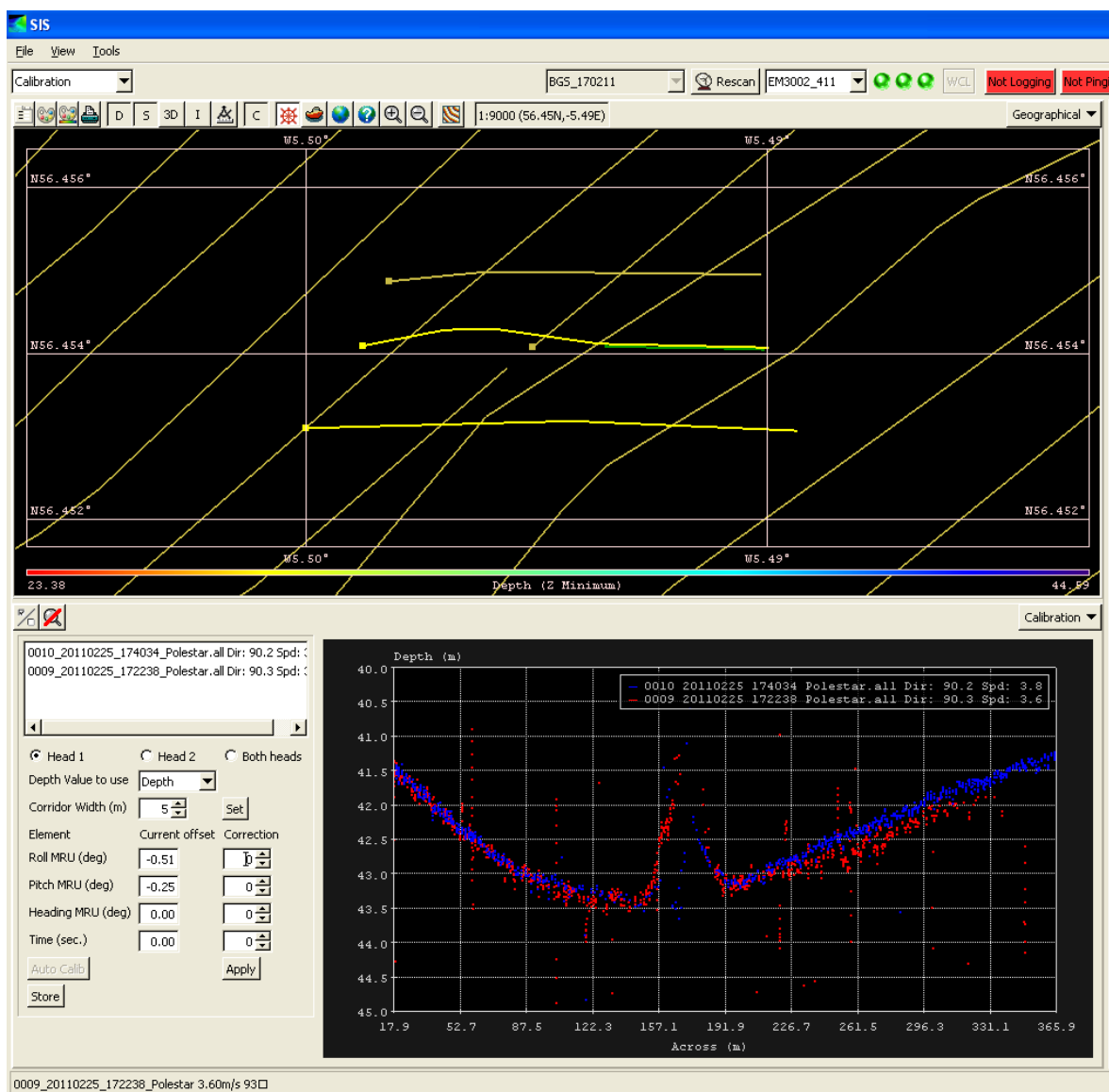
Head 1 correction = +0.06

Head 2 correction = -0.06

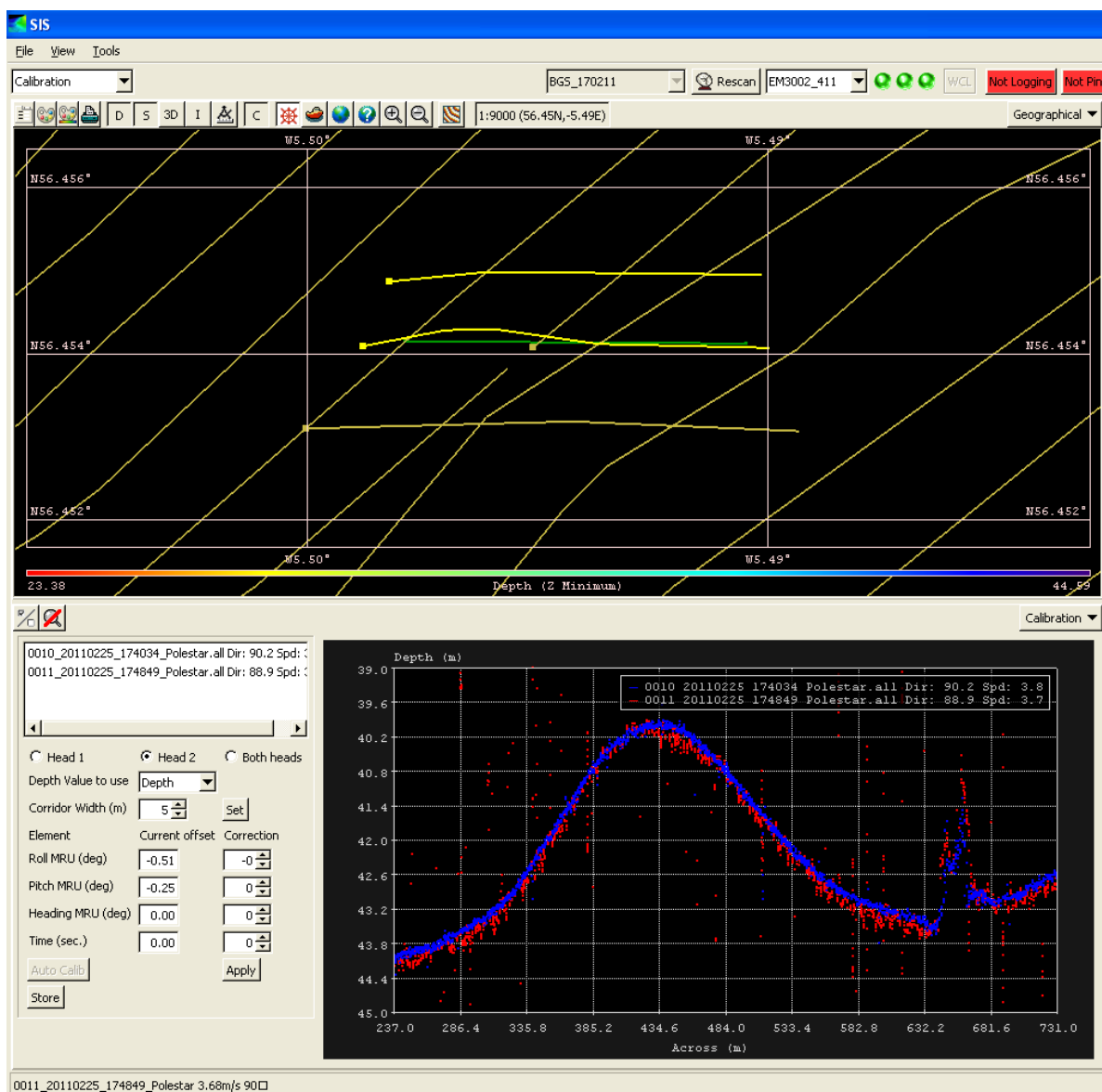
Head 1 installation = 39.345

Head 2 installation = -38.515

Heading – Head 1



Heading – Head 2



There were no corrections required for latency, pitch or heading.

Appendix 4 Swath images

The following images are screen captures from visualisation software, Fledermaus V.7; the data is subject to 6m height exaggeration to extenuate features. Here the data has been gridded at 5m, although 1m grids are available on request.

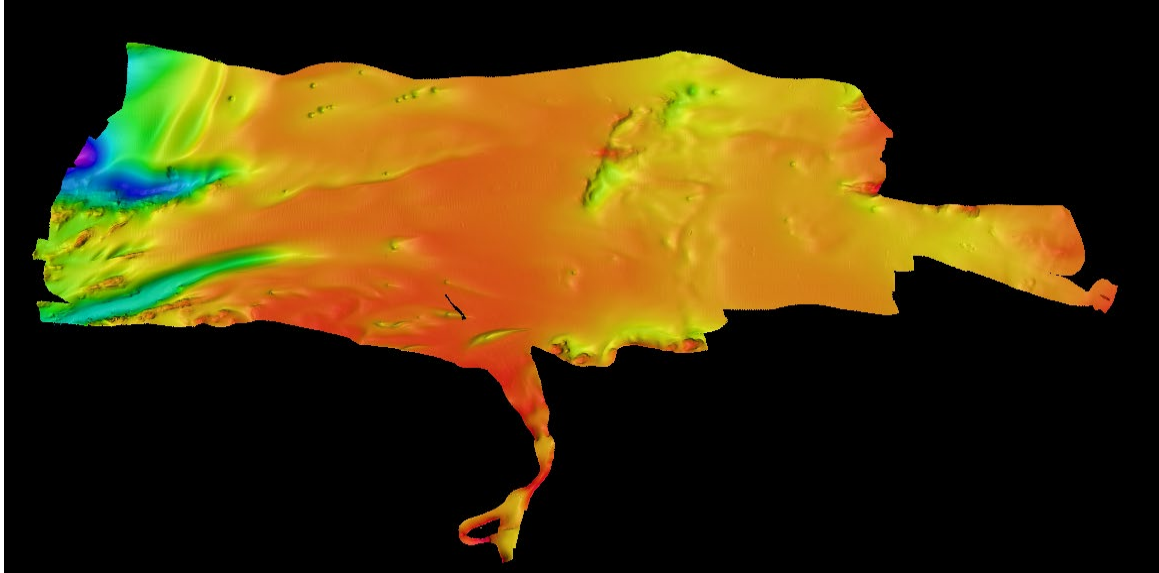


Figure 10: General overview of survey area

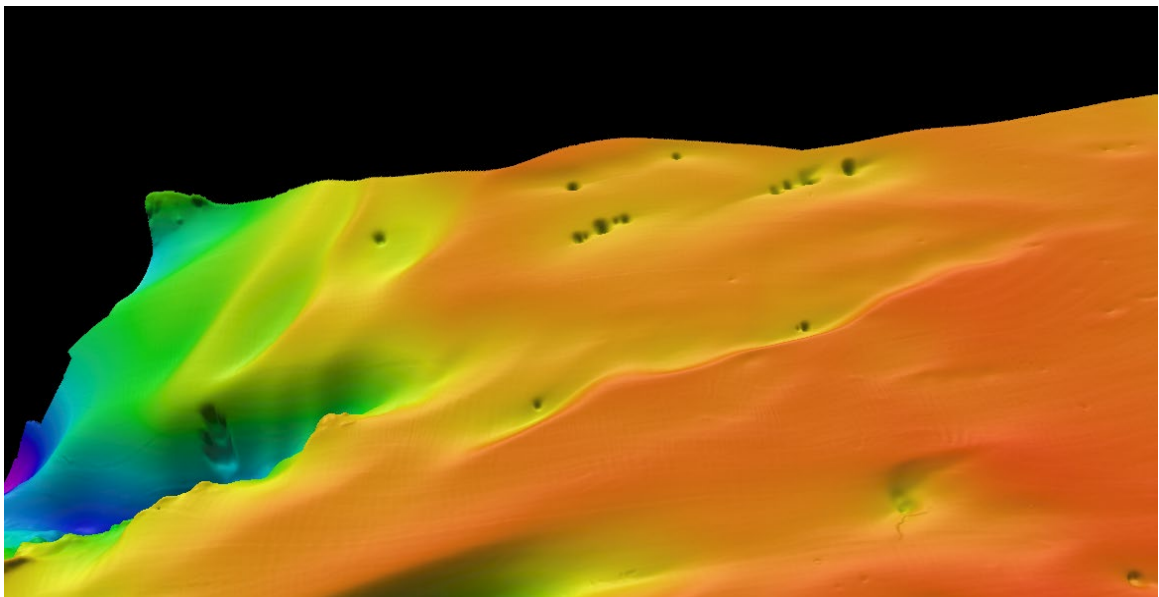


Figure 11: Easterly view of pock marks

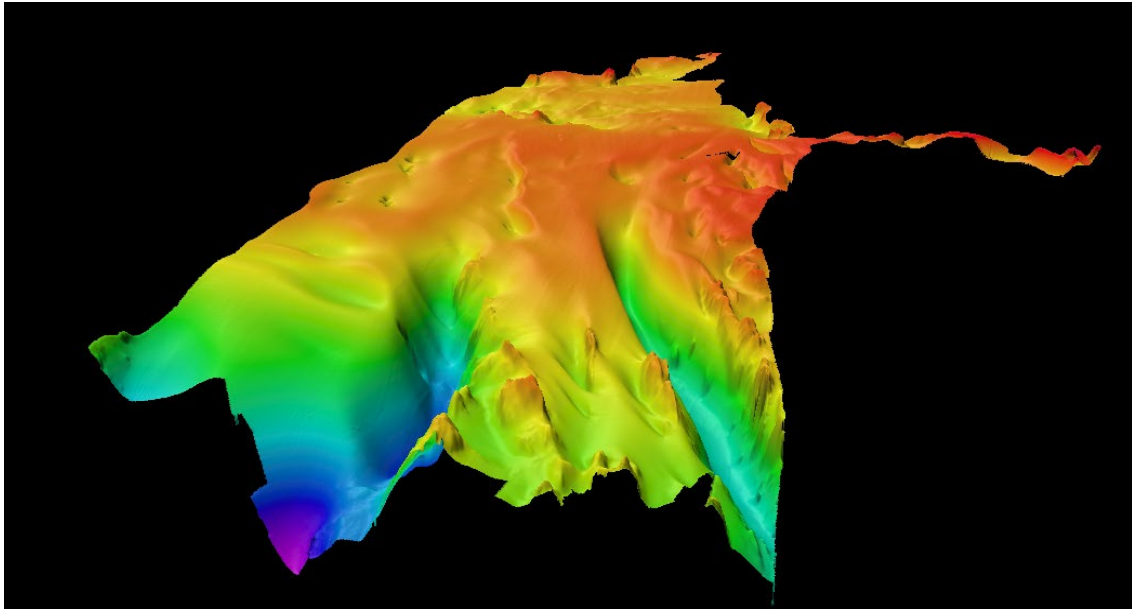


Figure 12: Northerly view of survey data highlighting 200m deep trenches.

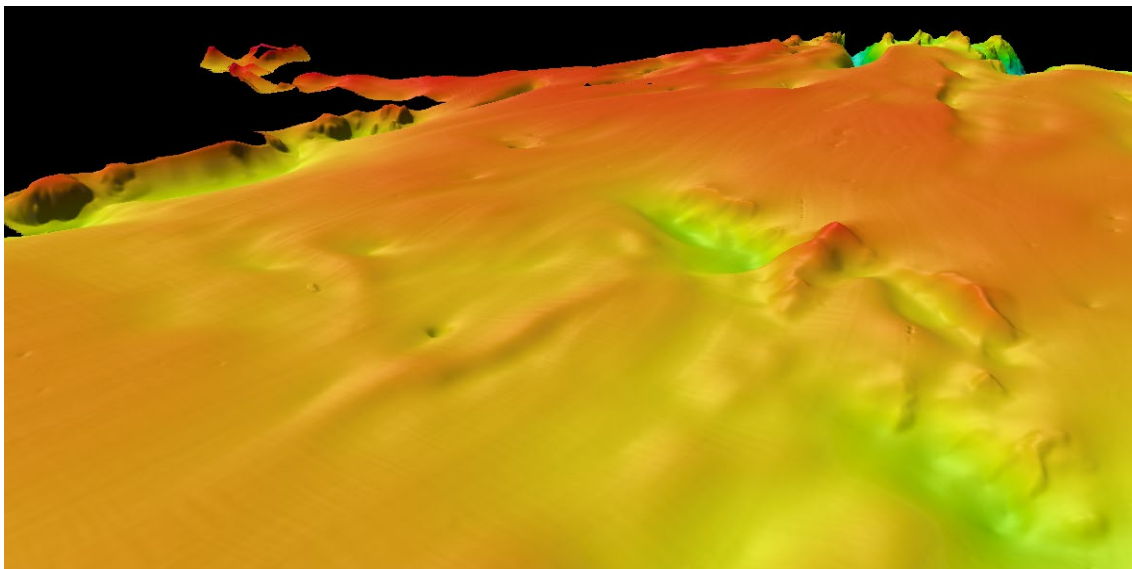


Figure 13: Southerly view of 19m pinnacle.

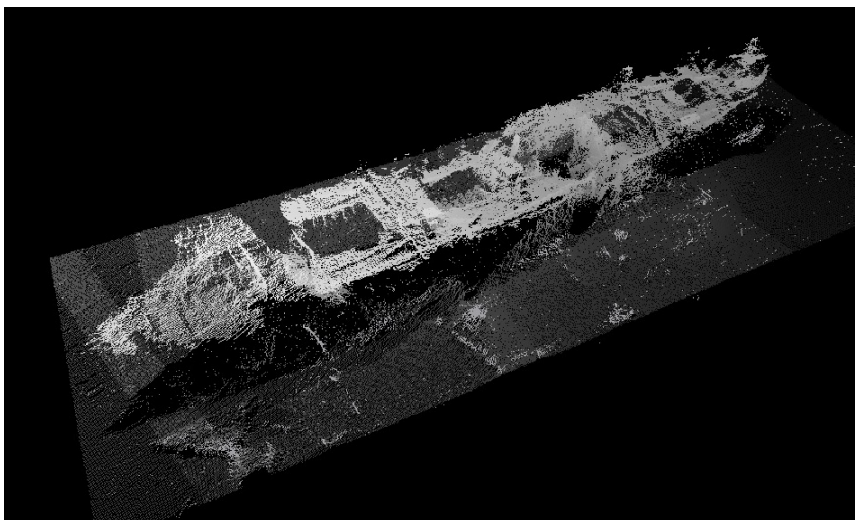


Figure 14: Breda wreck in Ardmucknish Bay at the north end of the survey area.

Appendix 5 Shipek grab method

Set up the grab on the steel frame provided, this aids in setting up the bucket.

The red pins either side of the grab need to be pulled out to allow bucket placement.

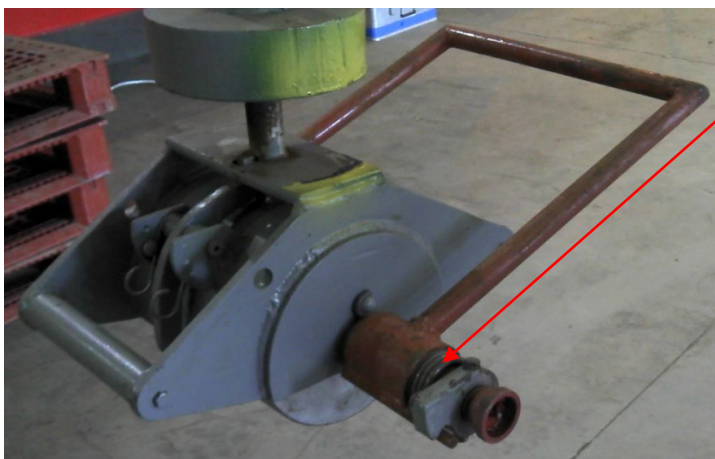
Attach the bucket to the underside of the grab with the base of the bucket facing down; align the grooves in the bucket with those on the grab, release the red pins and manoeuvre until they click into place; they should be flush if in place properly.



Figure 15: This shows the red pins flush to their mounting, this suggests the bucket is securely in place.

Once the bucket is in place, the grab needs to be 'loaded'. To do this use the handle best fitting for the coil size.

The handle sits on the coils with the pin locking into the necessary groove, ensure this is facing away from you.



Handle attached with brackets facing up and locking pin in place.

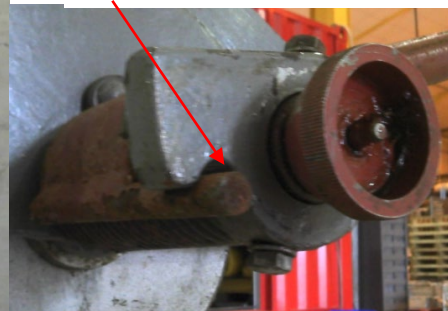


Figure 16: Correct handle placement for loading the coils.

The handle should be push downwards until tension is felt, then whilst keeping hold of the handle, spin the whole grab through 180° and pull the handle upwards until the pawl engages, this method saves working under the loaded bucket.

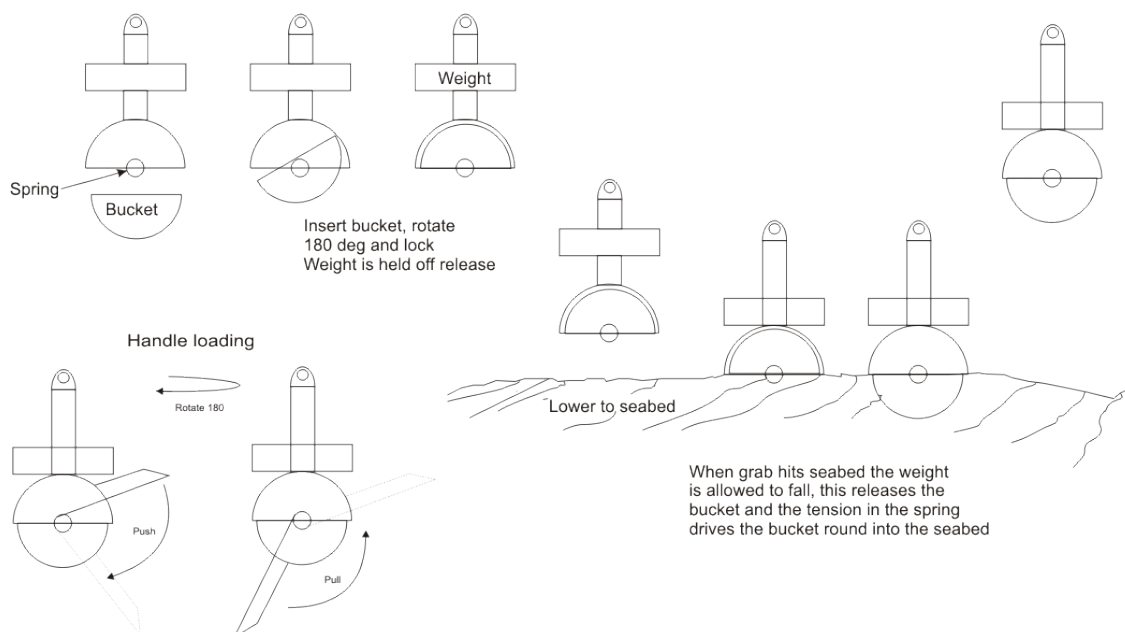


This shows the pawl engaged, therefore the bucket is loaded. Engagement is indicated by a click as the pawl fits through the hole.

Figure 17: This shows the pawl engagement, locking the bucket in place.

When the grab is lowered to the sea bed, the whole grab is pushed upwards where it meets a stop weight; this weight pushes against the pawl and releases the loaded coils, causing the bucket to spin round, collecting a sample.

The grab is then recovered, to remove the bucket 2 people are required, one person should hold the bucket whilst the other pulls out the red pins. Using two people means the bucket won't spill its contents when the red pins are released.



Basic Principle of the Shipek Grab

Appendix 6 Setup issues in detail

During 17/02/11 the POS MV failed to track GPS satellites throughout the day; POS View software was opened and revealed that neither the primary or secondary receivers were tracking satellites, they would drop out intermittently either simultaneously or one at a time, no real pattern was observed. The primary receiver is used for position, whilst the secondary receiver is used for a heading solution in combination with the IMU.

Once satellites were lost the position would go from ~0.5m accuracy up to several meters, the POS MV would switch to dead reckoning mode (DR) where the position and heading would degrade further, rendering any multibeam data collected during this period useless.

This prompted an inspection of the cables that ran from the POS MV antenna to the POS MV unit. At the back of the unit the TNC connectors were attached but sitting loose. They were therefore unscrewed and disconnected, upon doing so the connector fell apart. The electrician was called in to see if a repair could be made and Applanix were contacted to discuss replacement options.

Upon inspection of the antenna, it was discovered that one of the antennas was cracked, but still functioning, Applanix sent out a temporary replacement, however, this was not used.

The POS View software also revealed that RTCM corrections were not being received from the Fugro SeaSTAR receiver. The RTCM string was tested at the POS MV unit via HyperTerminal, no incoming data string was observed. By navigating the SeaSTAR menus, this revealed that corrections were being output; the Polestar's DP system also relies on corrections from this source, this was working as expected. Therefore it was suggested that there may be a cable or splitter issue between the SeaSTAR and the POS MV. Notes on this were left with the crew for their electrician to solve.

After contact with Applanix, their view was that the cables currently in place were out of date, and no longer preferred, hence no connector repair kits were available. Therefore to repair; connectors needed to be sourced from an external supplier or, both cables needed replacing.

The electrician revealed that it was a crimp device that had broken within the connector, he modified the connector with a temporary fix, ultimately this did not solve the problem due to issues with earthing.

A possible explanation for the crimp failure on the connector could be due to the cables and connectors being under unnecessary strain, there appeared to be little cable slack behind the POS MV unit, which over a period of time could have caused the failure. This could have occurred during a cable refit in the past.

It was decided by NLB that the best solution was for the cables to be fully replaced, they were provided pre terminated by Applanix; these were fitted by the electrician.

Upon arrival for the completion of the second period on the 24/02/11, the cables were being fitted. This was completed by the 25/02/11 and the POS MV appeared to be functioning correctly; satellites were being tracked and RTCM corrections were being received. The route of the problem concerning the RTCM corrections was a change in power supplies and earthing during a cable refit.

On the 25/02/11, the tide gauge was set up and a patch test was completed, the POS MV appeared to be working fine. Upon return to Oban, the POS MV lost GPS satellites once again; Applanix were contacted and various solutions were discussed and tested. These included determining the type of RTCM corrections being provided to the POS MV; it has been known that if anything more than a simple RTCM type 1 or 9 message was sent, the POS MV position would degrade as it struggles to read anything other than RTCM. The SeaSTAR menu revealed

that the AOREH satellite was being tracked, with VBS corrections being output to the POSMV, this suggested that corrections were not the issue.

The next stage was to systematically unplug the communication cables between the POS MV and the SIS/EM3002D PU; the POS View software was monitored to see if one of the cables was causing the error. There was no unexpected occurrence; ruling out the possibility of input/output cables causing any interference.

Recorded POS MV data was then sent to the Applanix; however there was not enough appropriate data to resolve anything conclusive; as the error had not been isolated in the recording. More files were recorded with the aim of capturing the point at which the POSMV failed, this proved difficult however due to the unpredictable nature of the error and the restriction the vessel had on file size.

The error was resolved by Applanix looking back through previous release notes of old software (SW) and firmware (FW) releases. It was found that in the past the POS MV would fail and switch the DR mode if more than 10-12 satellites were being tracked, this had been fixed in previous releases. Because the POS MV was not under any maintenance contract, the system had not been updated since its purchase; this therefore seemed the most likely solution as it fitted the problems that were encountered. To gain access to these updates a maintenance contract was required, verbal agreement from NLB allowed the setup of new FW and SW for the POS MV, plus a once yearly visit from and Applanix engineer for \$1865.

The new SW and FW were applied to the POS MV and GNSS receivers by BGS surveyors solving the issue, the system remained stable and accurate throughout the remainder of the survey.

SIS was several versions out of date; after the POS MV upgrade was completed an attempt was made to upgrade SIS to the latest version, 3.8.2. However, upon opening the software, a license server error occurred. This happen intermittently, therefore Kongsberg were contacted and it was one of several customer reports describing the same error. Therefore SIS was reverted back to version 3.6.5; this was a BGS copy and was still an upgrade from what NLB SIS was running.

There were ongoing issues with the AML SVP probe, the unit appeared to struggle to hold its charge, there was also concern over the USB connector cable, it was advised that the batteries get replaced.

Appendix 7 Sample locations

Table 3: Sample locations and descriptions.

Sample No.	Time	Lat (N)	Long (W)	Comments
Sample 1	1450	56.44560000000	5.52653000000	clay/mud
Sample 2	1340	56.44260000000	5.50580000000	hole - clay/mud
Sample 3	0913	56.41384000000	5.59343000000	rocky
Sample 4	1354	56.47323000000	5.47721000000	clay
sample 5	-	56.45344000000	5.51143000000	clay
Sample 6	0830	56.44513000000	5.52521000000	clay, mud
sample 7	-	56.42958000000	5.59934000000	clay
Sample 8	0900	56.43035000000	5.52092000000	clay muddy sand
Sample 9	0930	56.43830000000	5.54695000000	smelly mud



Figure 18: Most samples retrieved consisted of clay/mud.

Appendix 8 Summary

BGS surveyors joined the NLB vessel, the Polestar, to get the Kongsberg EM3002D multibeam system functioning and familiarise NLB staff with its operation. This was achieved successfully; whilst a number of issues were encountered, the system is now fully operational, with the potential to run accurate IHO standard surveys. There are a few outstanding issues that need to be resolved prior to any survey work for outside organisations can be completed; the POS MV antenna arms needs to be fixed in place, as present it relies on the stiffness of the hinge to keep the antenna in place, this has been reported to have moved during ship operations, plus there is no guarantee that when the arms are retracted and extended, that they are going back in the same place every time; any change in position will start to degrade heading accuracy.

The cracked antenna that is currently in place needs to be monitored, this should be taken down and checked for damage; any possible repairs to the outer casing should be made.

Further maintenance contracts could be considered for both the multibeam and POS MV for both the Polestar and the Pharos.

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