DANMARKS OG GRØNLANDS GEOLOGISKE UNDERSØGELSE RAPPORT 2008/40

Geophysical investigation in Horns Rev windfarm transformer region

Zyad K. Al-Hamdani & Steen Lomholt

GEOLOGICAL SURVEY OF DENMARK AND GREENLAND
MINISTRY OF CLIMATE AND ENERGY

G E U S

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Released 01.06.2013

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G E U S

Introduction

GEUS has conducted a seismic and bathymetric survey in 2006 in the windmill farm region in Horns Rev for Dong Energy. In connection with this work GEUS has performed bathymetric analysis around the transformer platform position for EnergiNet/Denmark. This year GEUS was approached again by EnergiNet/Danmark for conducting a survey in the area surrounding the transformer location as well as the area covering part of the outgoing cable from the same region, Fig.(1). The results of this survey are presented in this report.

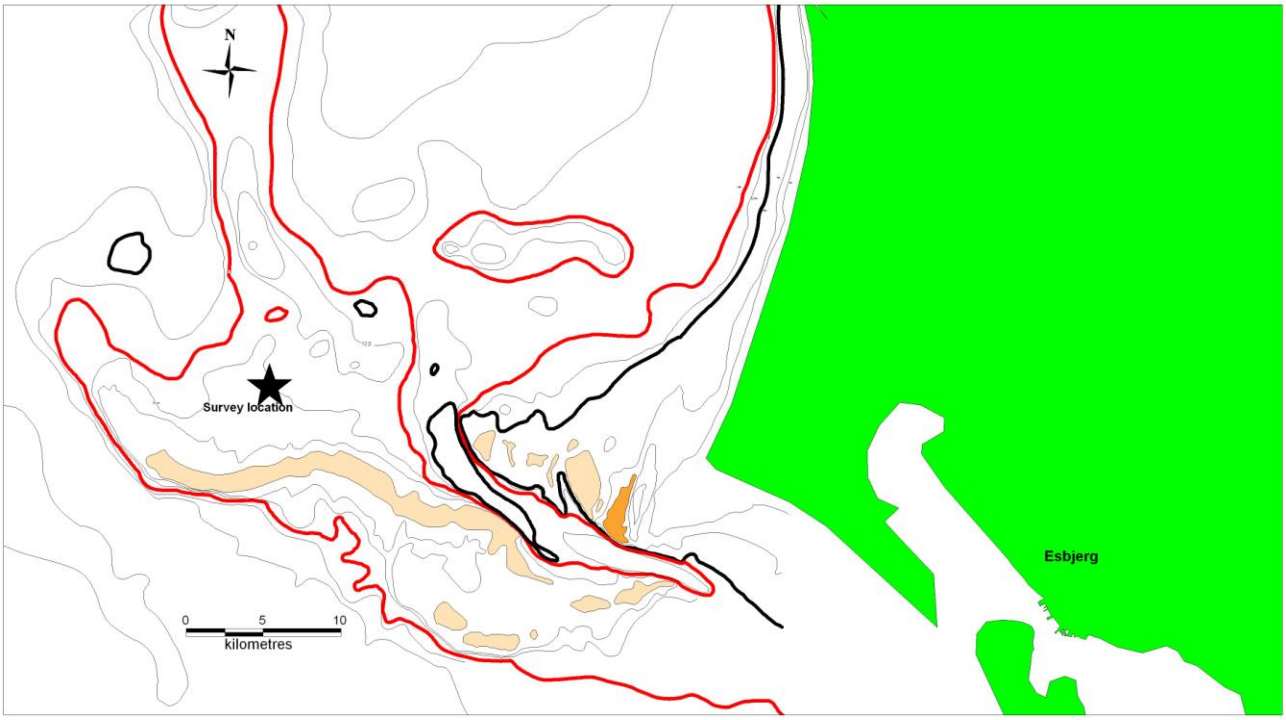

Figure 1. Survey area location in the North sea.

The survey consists of three parts:

1. the Bathymetry part
2. the Magnetic part.
3. the sidescan mosaicing part.

All parts were conducted simultaneously in the same survey vessel.

The survey

The survey was conducted at the 15th and 16th of May 2008 using the survey ship Madog from Nord-Marine company, Fig 2, to cover the area of 650m side and the cable route beside it as shown in Fig 3. The surveyed region is located at about 55km from Esbjerg harbour.
The 650m area was surveyed at 25m interval with a North South survey lines, the cable route region was also surveyed at 25m so all the area was completely covered during the survey.
A cross line was made to pass through the 650m area and on top of the SUB locations for the detail analysis of the four legs on the transformer position.

Figure 2. The survey ship Madog.

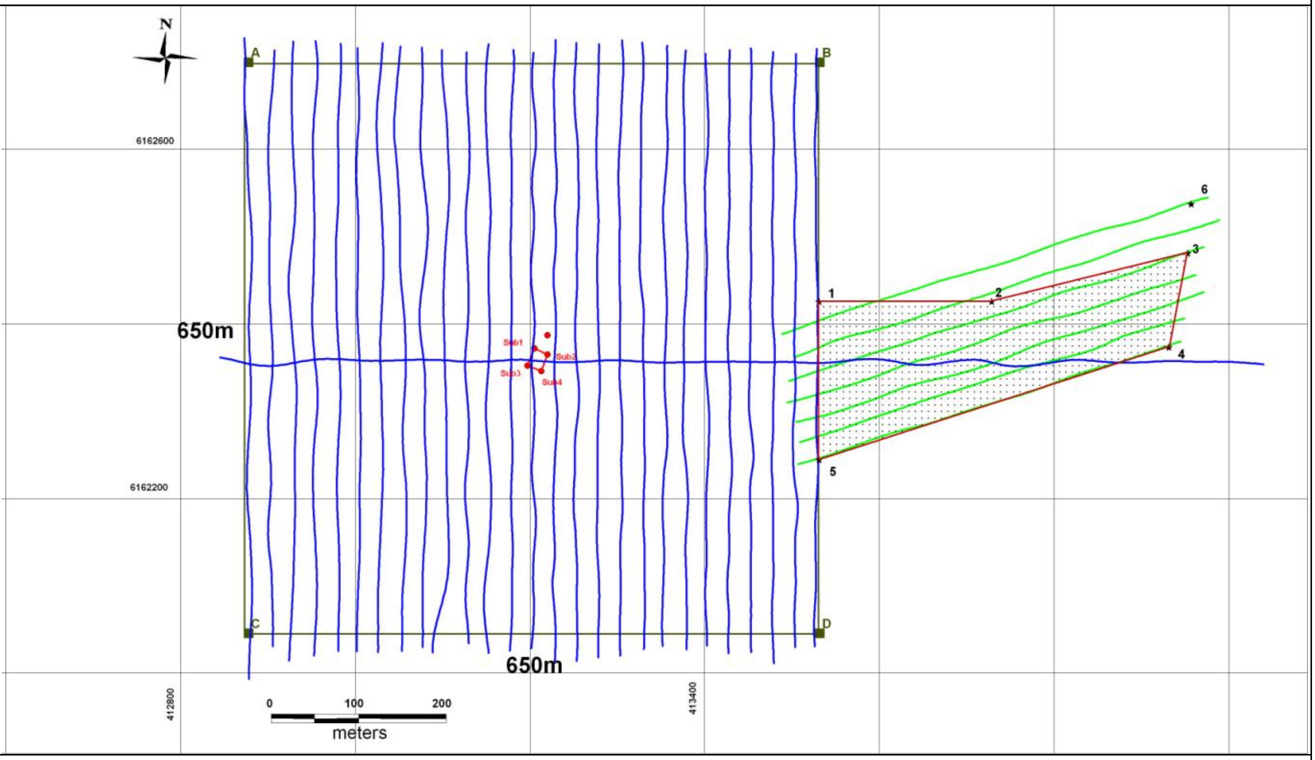

Figure 3. The two survey regions with survey lines indicated.

The equipment

To conduct such a survey three types of instruments were deployed:

1. The Kongsberg EM3002 D Multibeam echosounder.
2. The Geometrics G882 magnetometer.
3. The Teledyne Benthos SIS-1625 Seafloor imaging system.

The technical description of these instruments is found in Annex III.
An RTK navigation system was installed by Dansurvey A/S for high positioning and navigation. The MRU motion sensor was also used during the survey. The sound velocity profiler was used at different stages of the survey and during the calibration for the velocity profile measurement of the water column.

Results

The bathymetry data

The EM3002D is a high resolution multibeam echosounder with a spatial accuracy depending on the RTK signal. In this area the accuracy is about a decimetre in depth. The system was calibrated near the survey sites and several sound velocity profiles were taken before, during and after the survey for exact water column velocity structure measurement. After acquiring the data, it was cleaned from spikes and artefacts and converted to 1m grid. The system calibration and processing is found in Annex I. The results of the surveyed area bathymetry (the Main 650m area and the cable route, is shown in Fig 4.

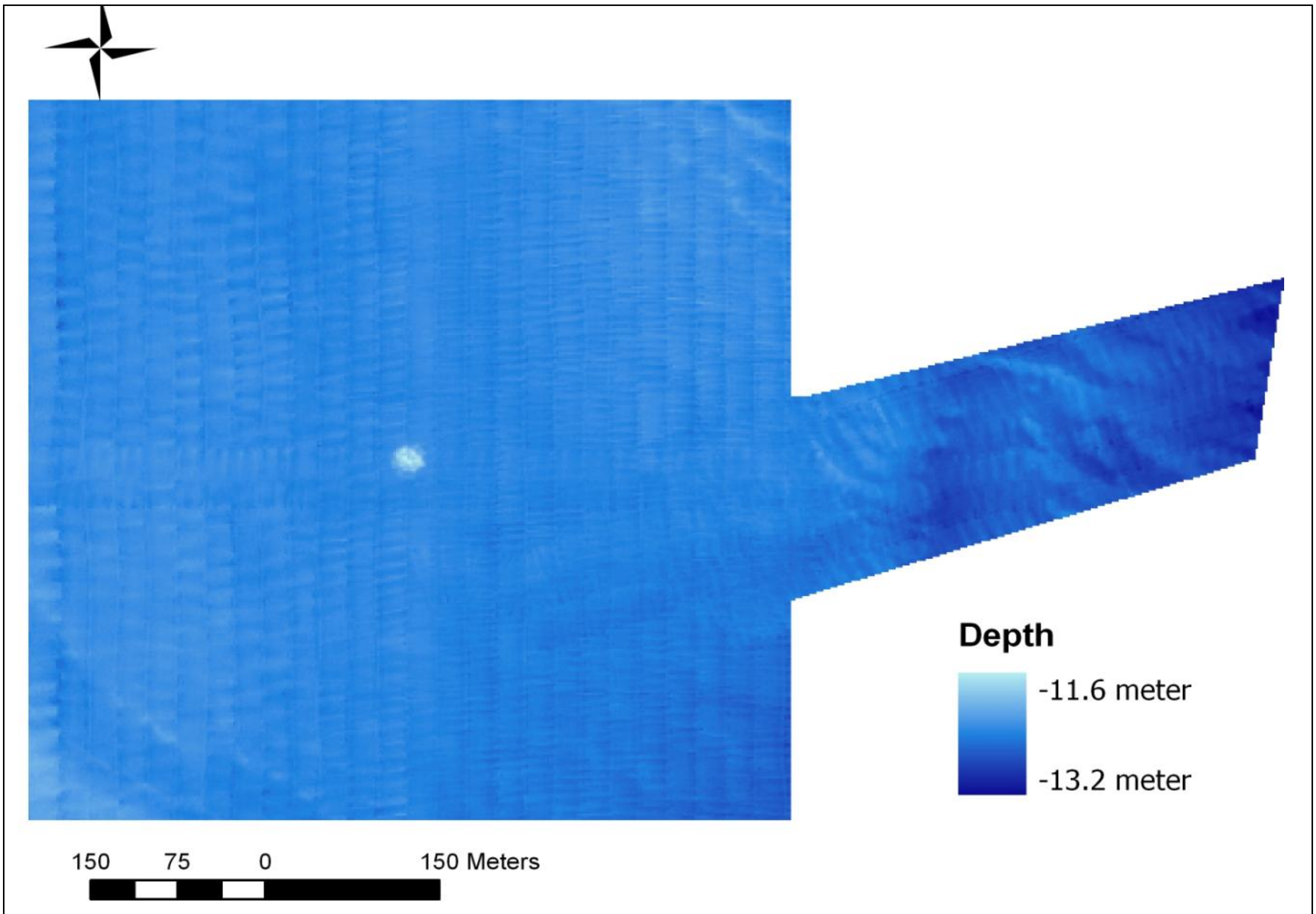

Figure 4. The bathymetry map of the surveyed area.

The detailed contour map of the same area is shown in Fig 5.

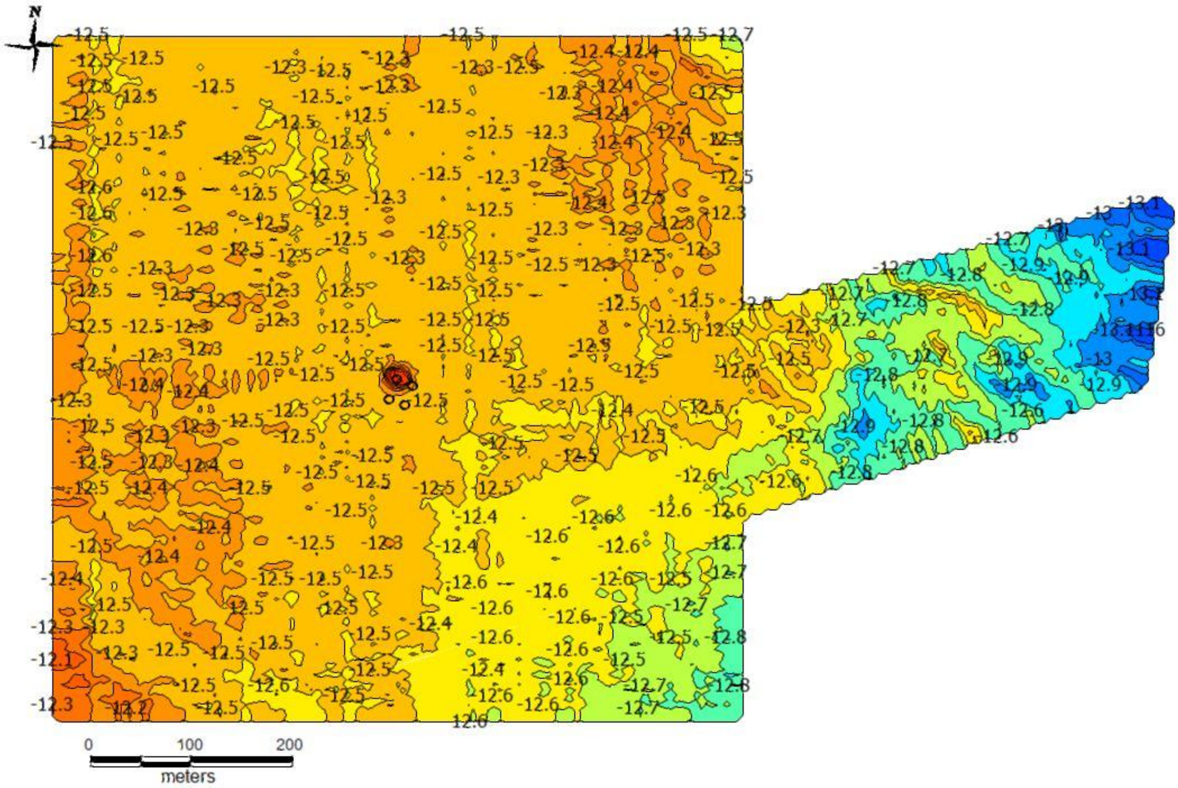

Figure 5. Depth contour map of the survey area. The circles in the middle are the Sub positions.

The Sub positions is shown in Fig 6, they are plotted over the gridded bathymetry map with the numbers indicating the depth at each grid point.

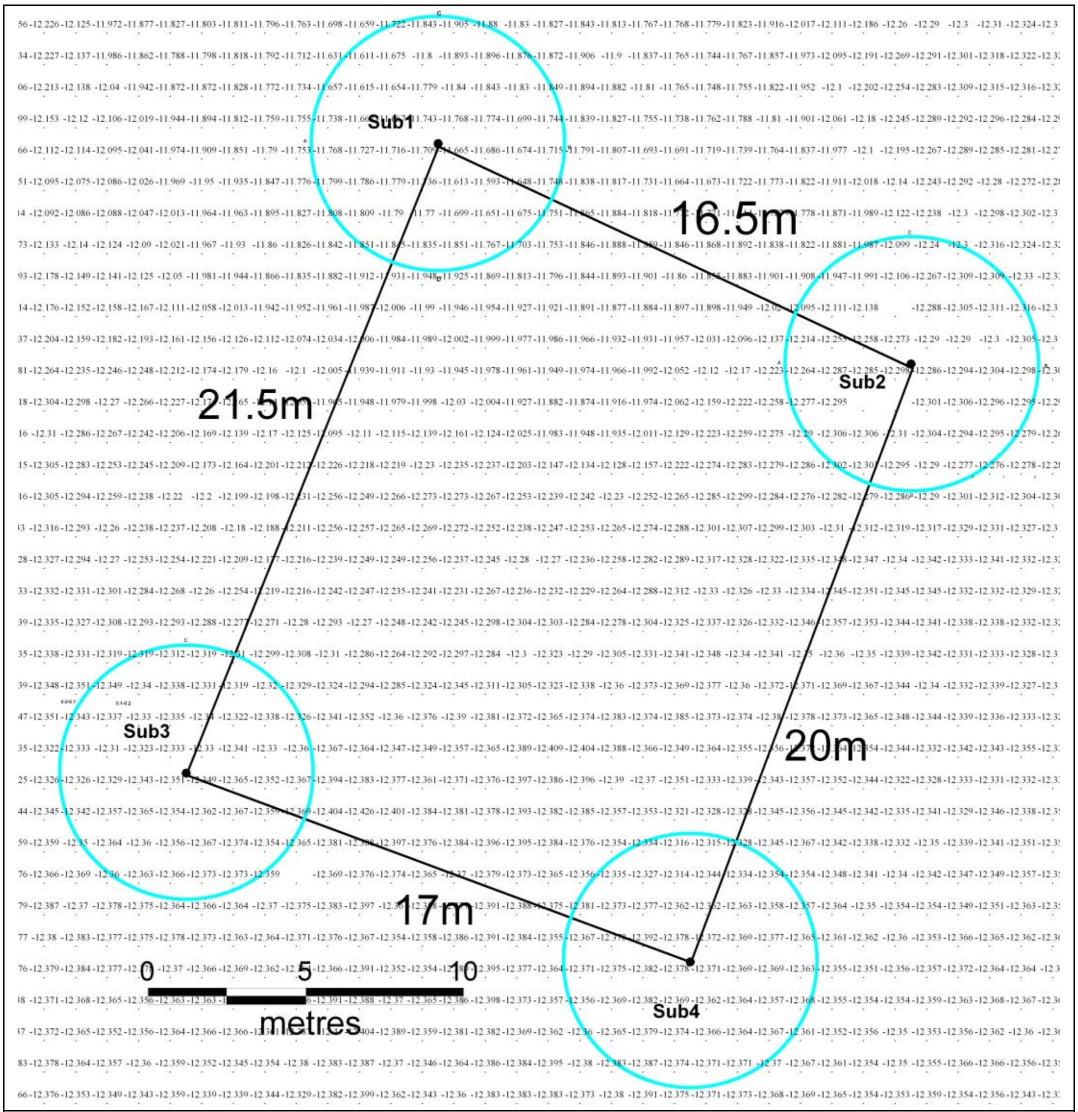

Figure 6. The Sub positions on a 1m grid bathymetry map.

An 8 meter diameter circle was drawn around each Sub position.

The bathymetry map shown in Fig. 5 is compared with the bathymetry map produced earlier by GEUS during the 2006 survey in order to see whether there is a significant change in seabed depth. The difference between the two maps was calculated and presented in Fig. 7. The figure shows the contour values of the depth differences.

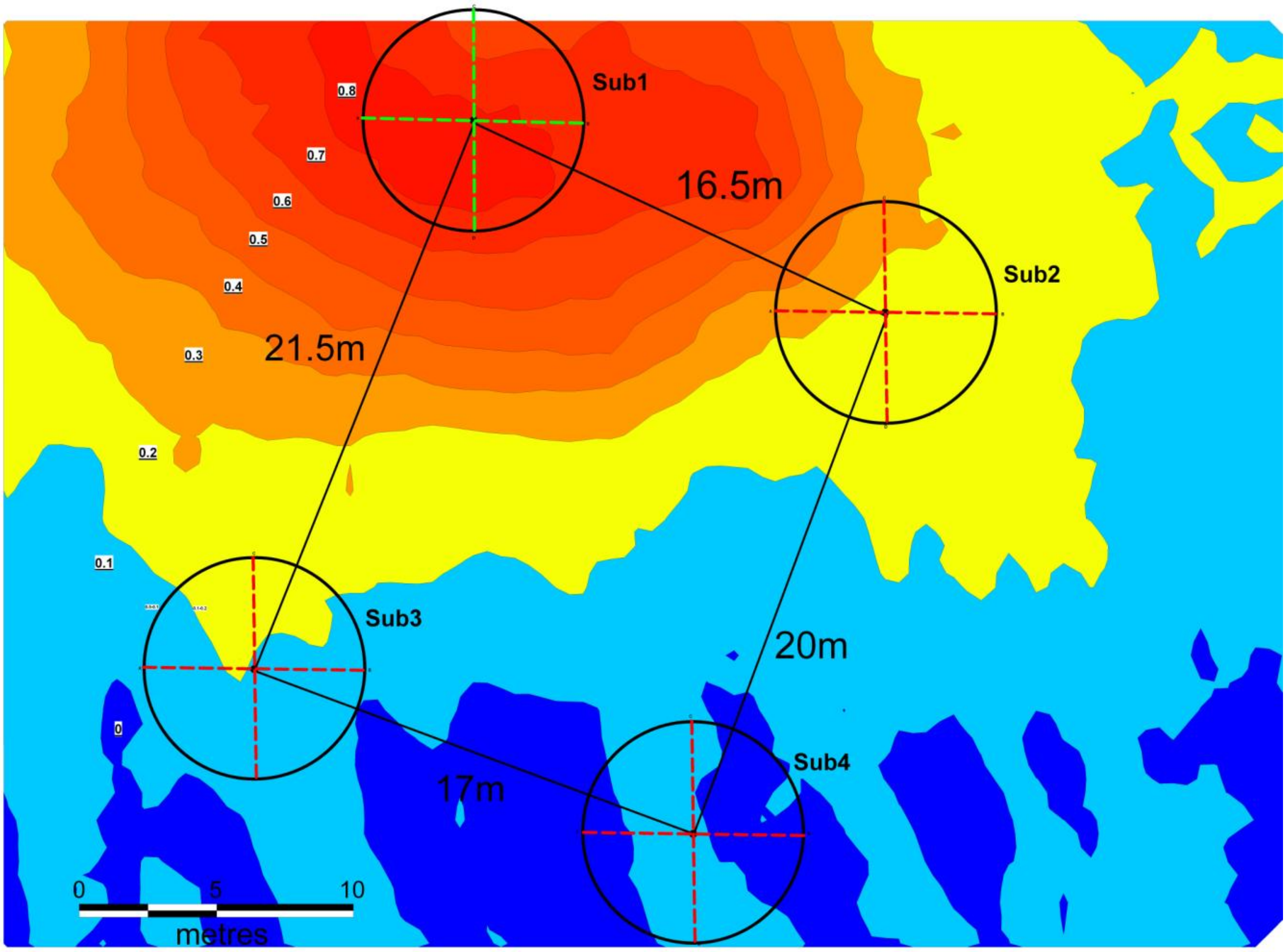

Figure 7. Contour map showing difference in depth (meter) between this year survey and 2006 survey. Notice the large difference in SUB 1 area (about 0.8m)

Each SUB position was looked at separately and two sections were plotted for the depth measured during the last survey. Also shown is the contour map for the difference in depth.

1. Sub 1.

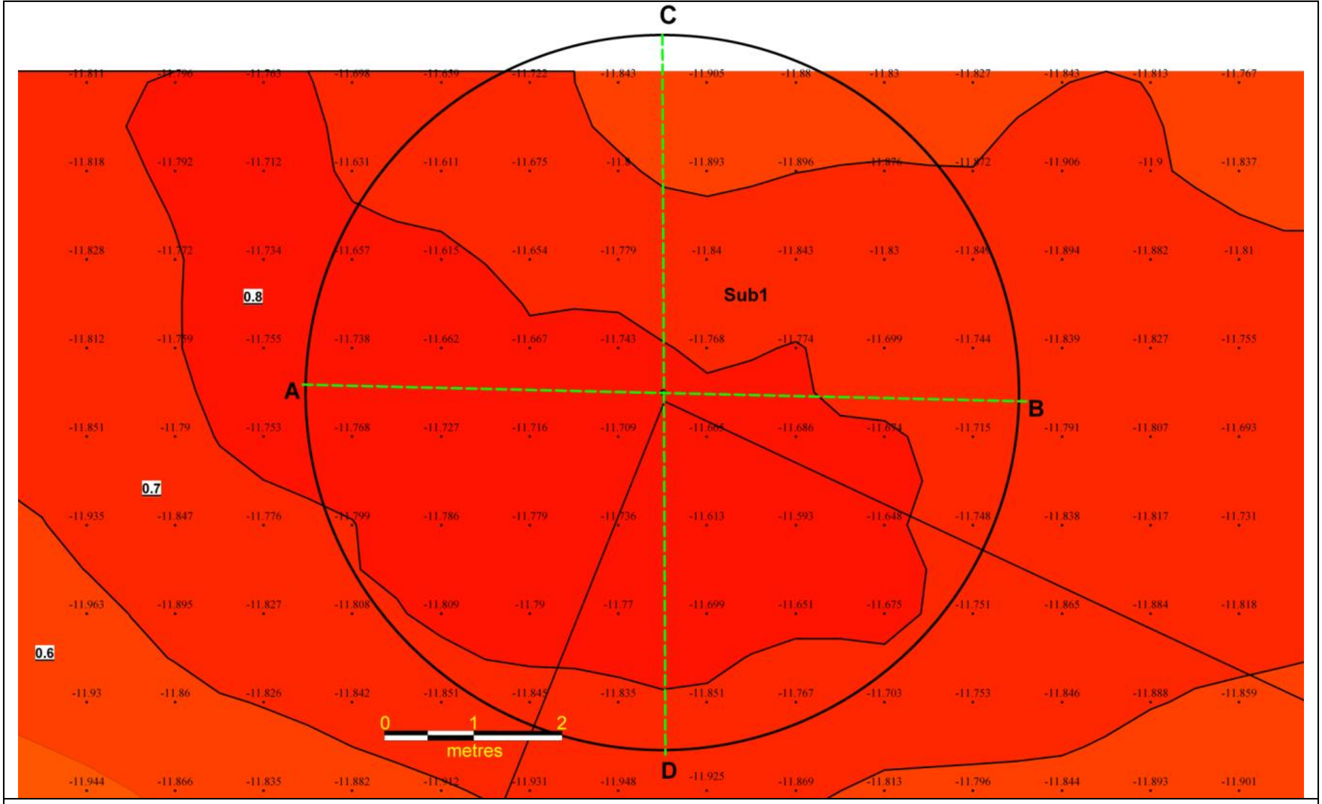

Figure 8. SUB 1 with 8m circle. The grid shows the bathymetry, the contour shows the difference in depth compared with 2006 survey.

It can be noticed in the figure that the seabed depth within the 8m diameter circle ranges from -11.6 to -11.9 m.

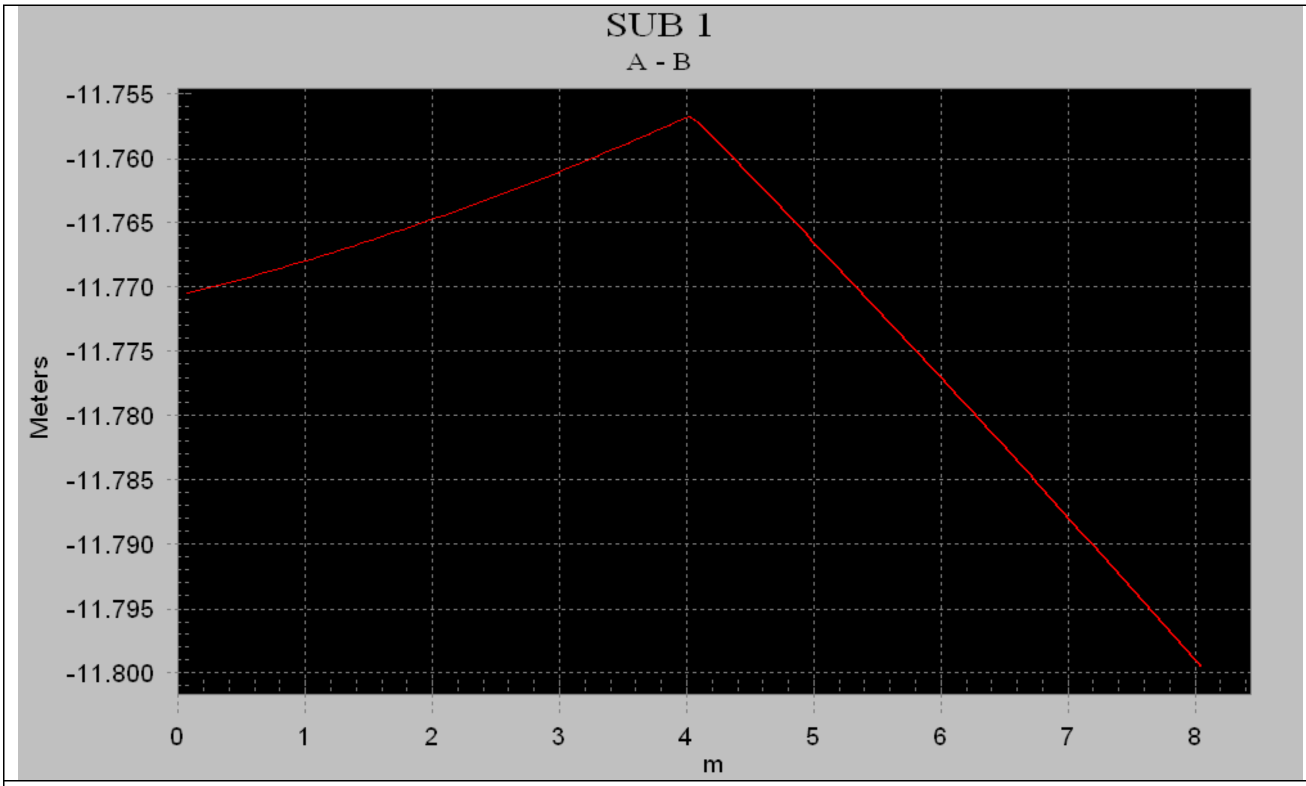

Figure 9. A section in the bathymetry gridded data of SUB1 between point A and B shown in Fig. 8.

Figure 10. A section in the bathymetry gridded data in SUB1 between point C and D shown in Fig. 8.

2. Sub 2

It is shown in Fig 11. The depth ranges within the 8m diameter circle between -11.9m at the north-western part to about -12.3m in most of the area inside the circle.

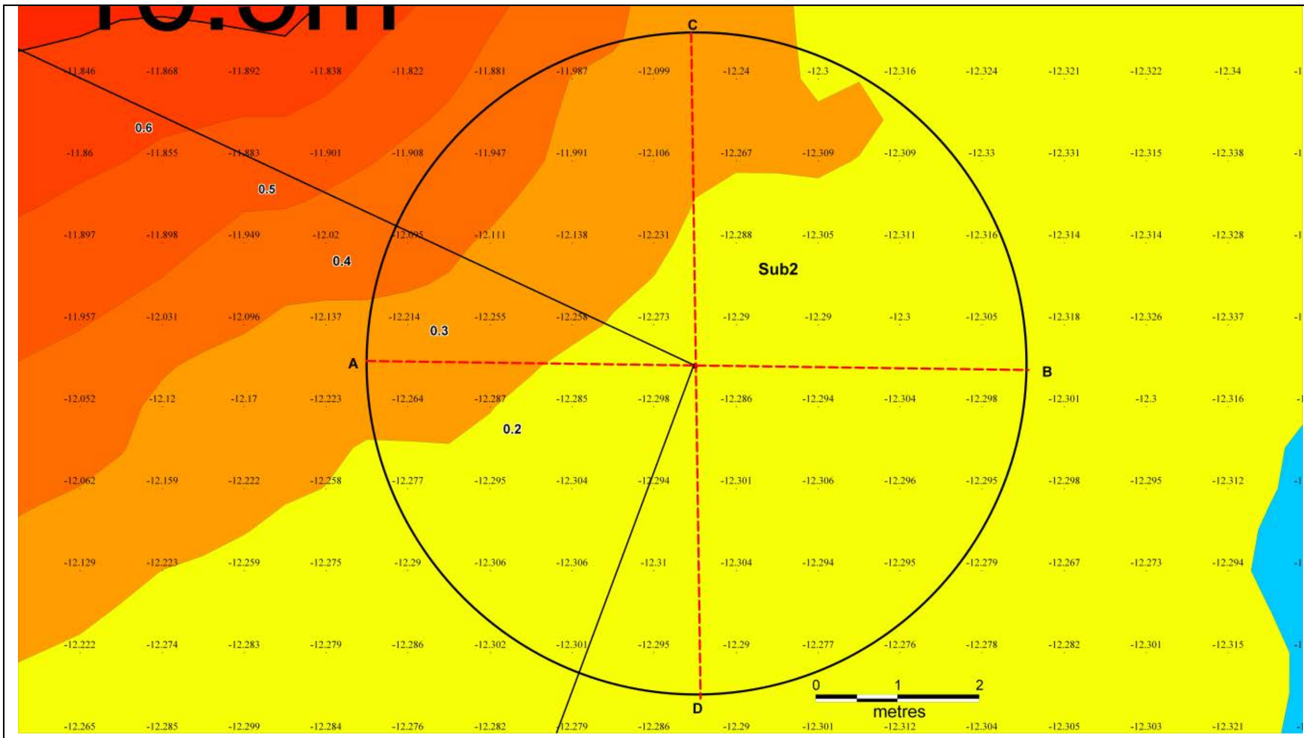

Figure 11. SUB 2 with 8m circle. The grid shows the bathymetry, the contour shows the difference in depth compared with 2006 survey.

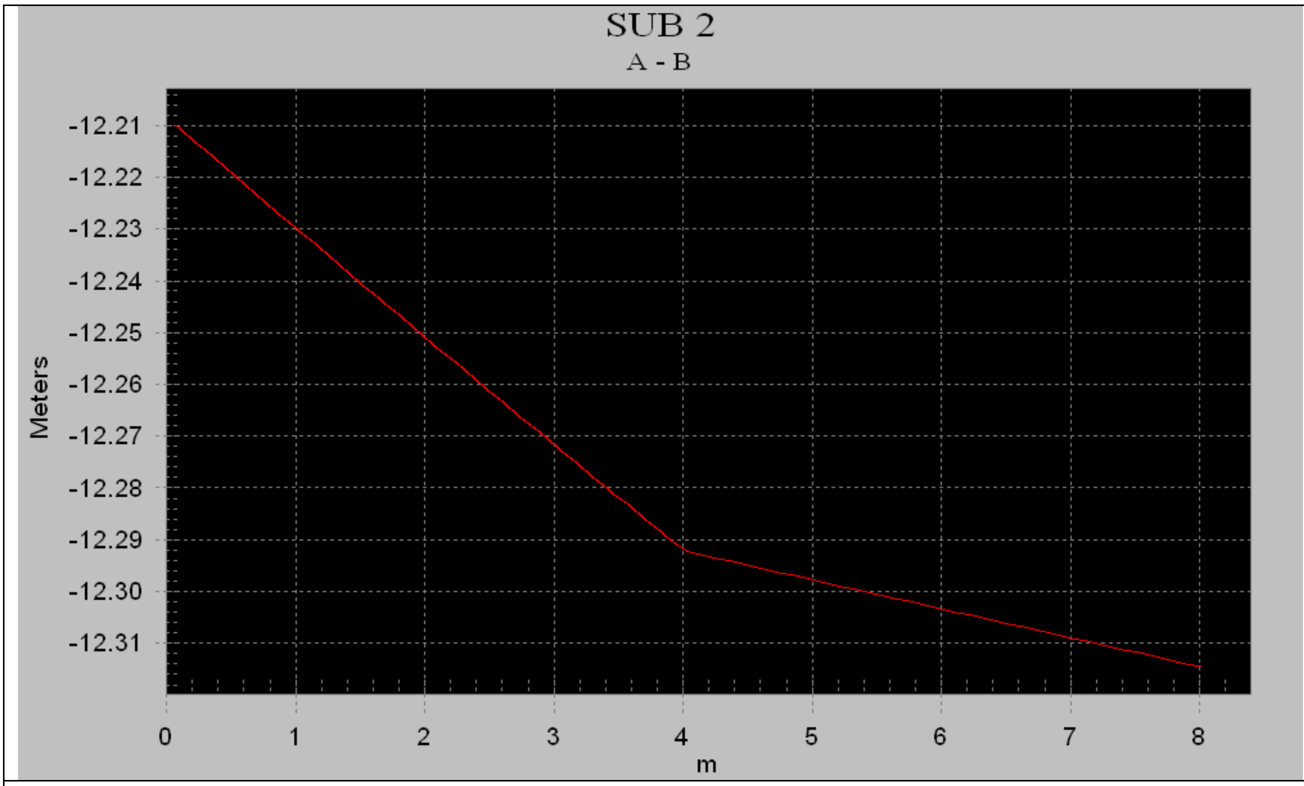

Figure 12. A section in the bathymetry gridded data in SUB2 between point A and B shown in Fig. 11.

Figure 13. A section in the bathymetry gridded data in SUB2 between point C and D shown in Fig. 11.

3. Sub 3.
The Sub3 position and a surrounding 8m circle are shown in Fig 14.
The depth values inside the circle are within -12.3m.

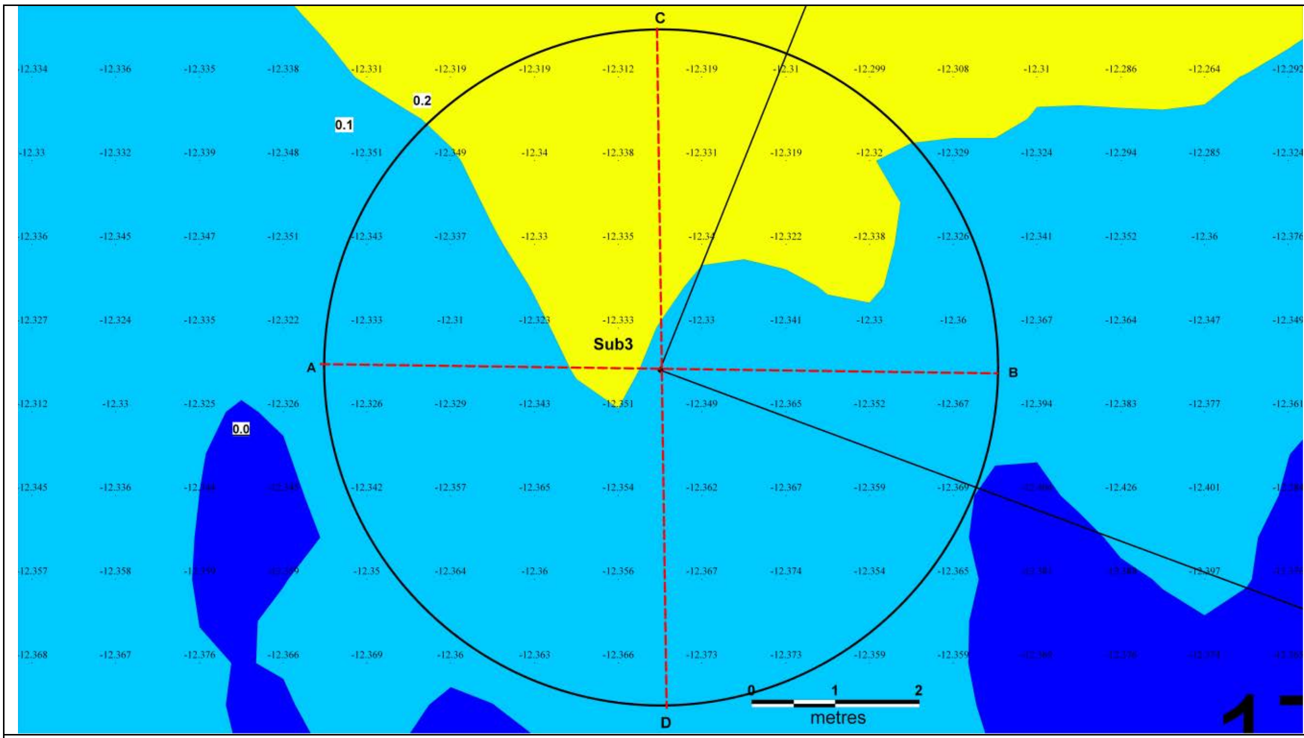

Figure 14. SUB 3 with 8m circle. The grid shows the bathymetry, the contour shows the difference in depth compared with 2006 survey.

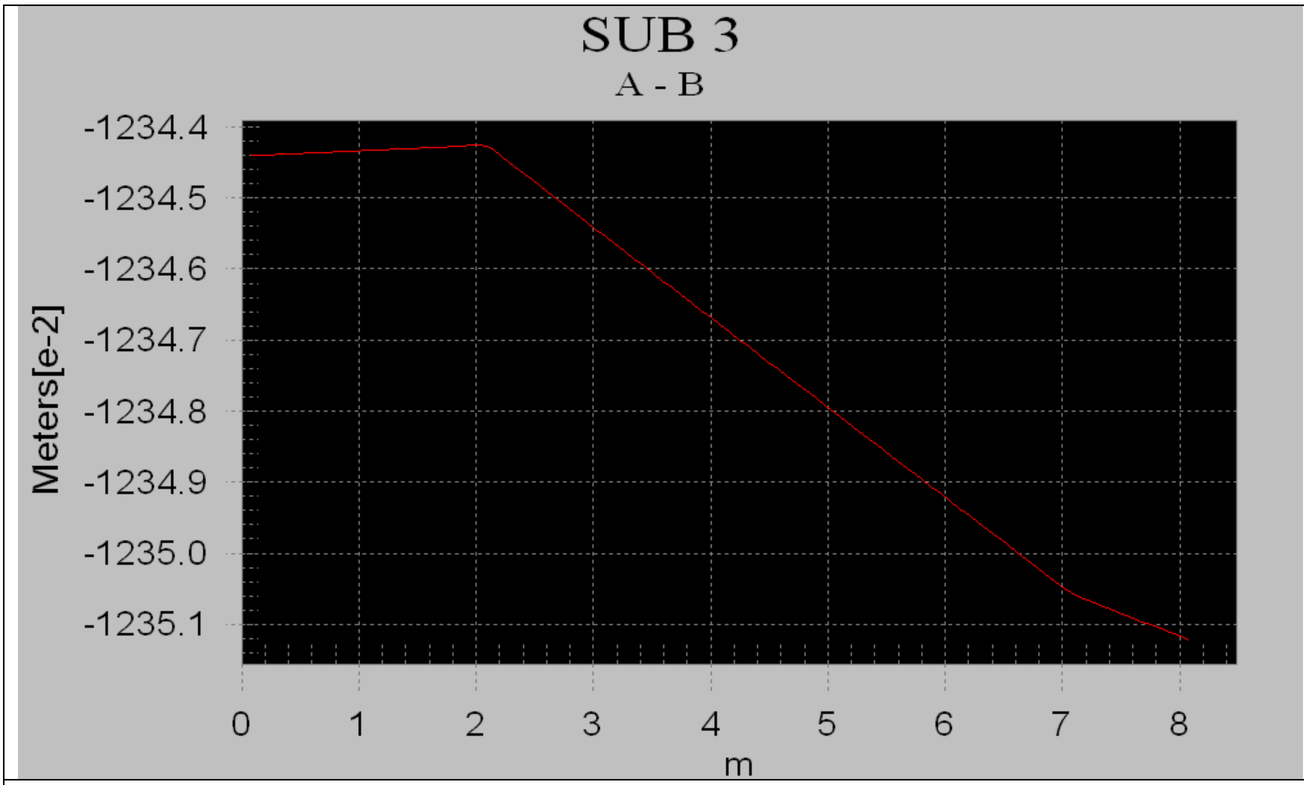

Figure 15. A section in the bathymetry gridded data in SUB3 between point A and B shown in Fig. 14. The difference values are very small so the Y axis is multiplied by 100.

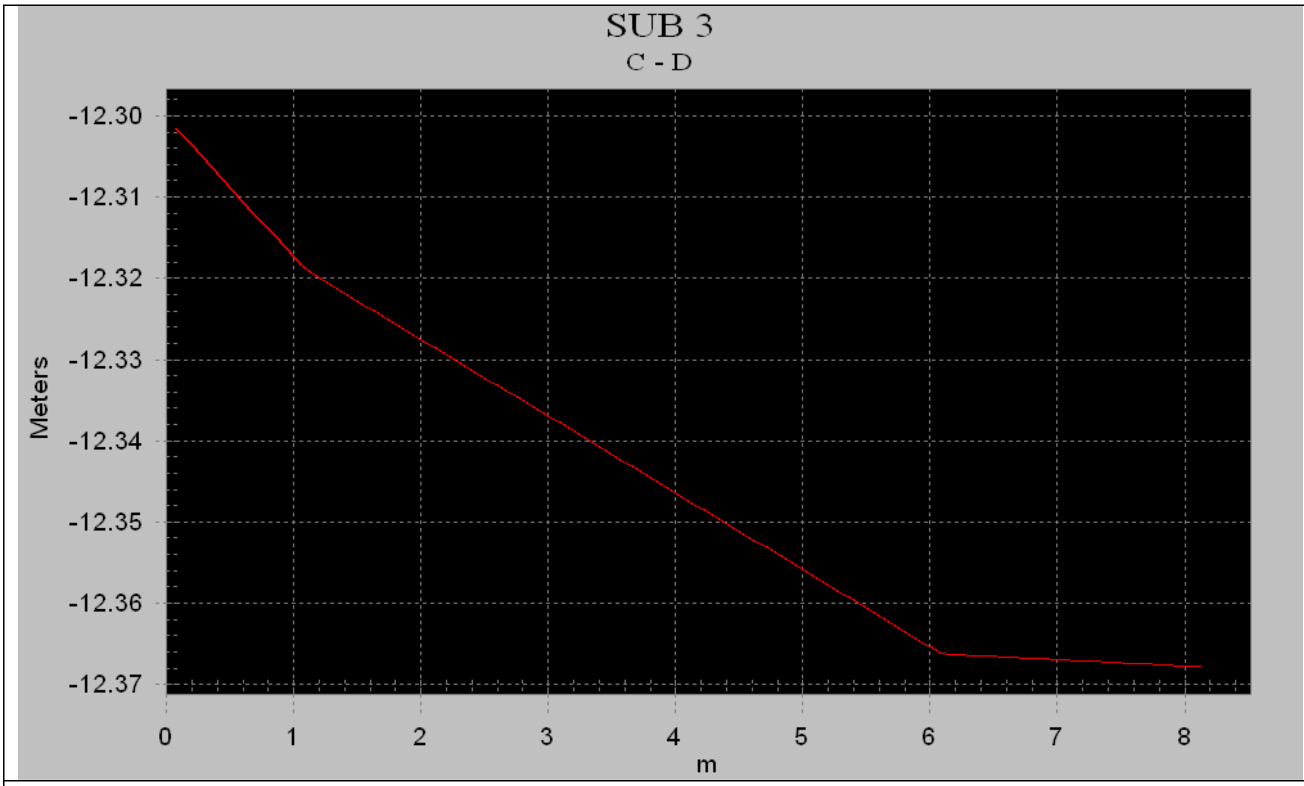

Figure 16. A section in the bathymetry gridded data in SUB3 between point C and D shown in Fig. 14.

4. Sub 4.

The Sub4 position and a surrounding 8m diameter circle are shown in Fig 17. The depth values inside the circle are within -12.3m.

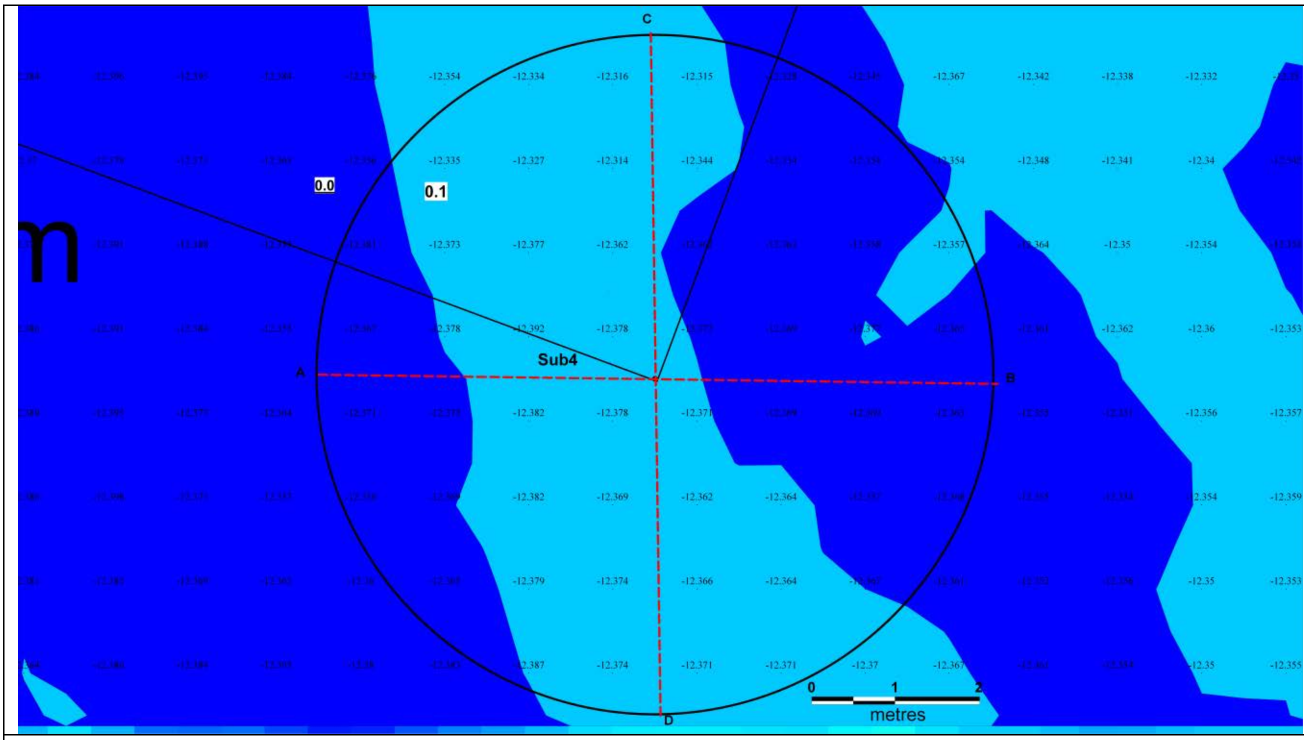

Figure 17. SUB 4 with 8m circle. The grid shows the bathymetry, the contour shows the difference in depth compared with 2006 survey.

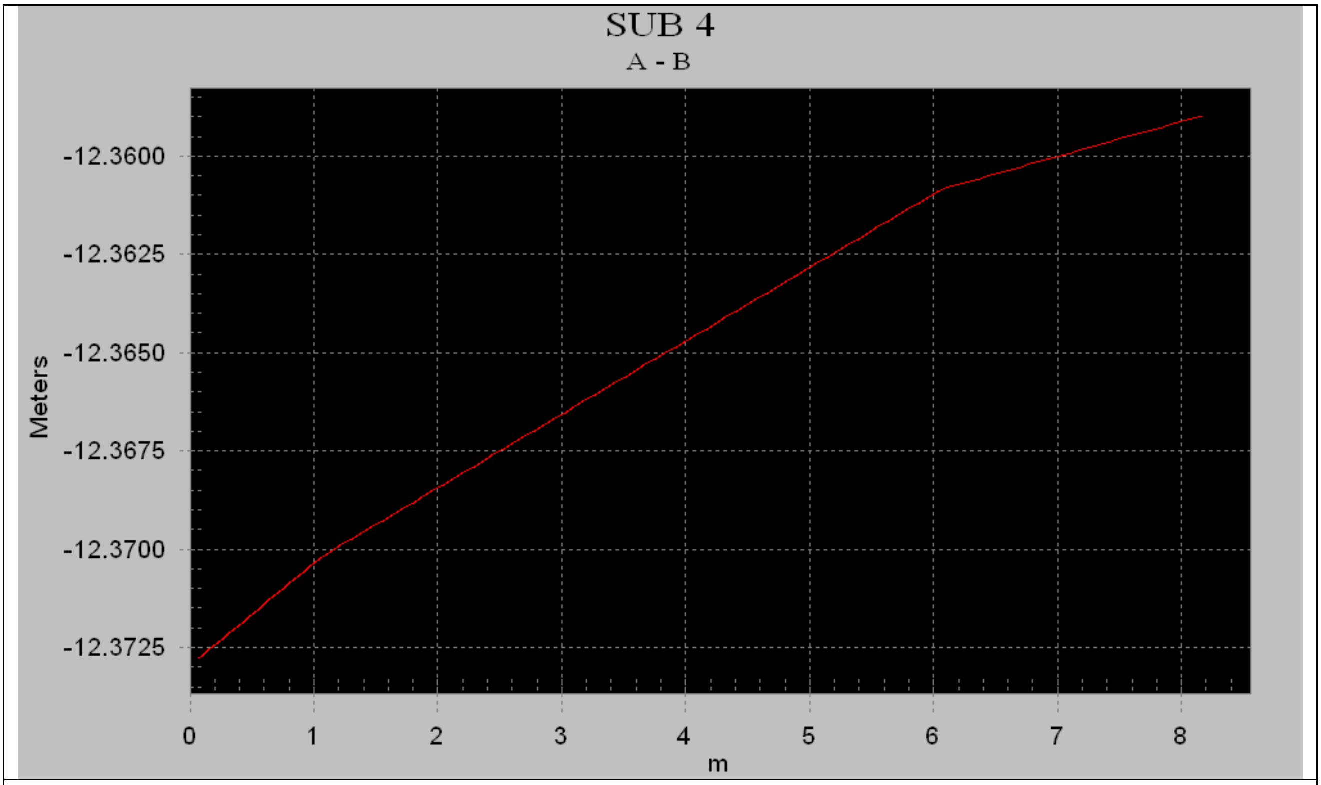

Figure 18. A section in the bathymetry gridded data in SUB4 between point A and B shown in Fig. 17.

Figure 19. A section in the bathymetry gridded data in SUB4 between point C and D shown in Fig. 17.

It is worth mentioning here again that the accuracy shown in the cross-sections (several decimals) are due to mathematical calculations, the real accuracy of the bathymetric system is in decimetres. Looking at these cross-sections and the difference bathymetry map, one can realise the presence of a discrepancy in the area surrounding SUB 1. If we plot the sidescan picture, Fig. 20, of the same location we can clearly notice a change in the sediment type at that area. Also looking at the overall bathymetry map of the areas a shallower depth is also noticed in the same region. It could be something was dumped in the area.

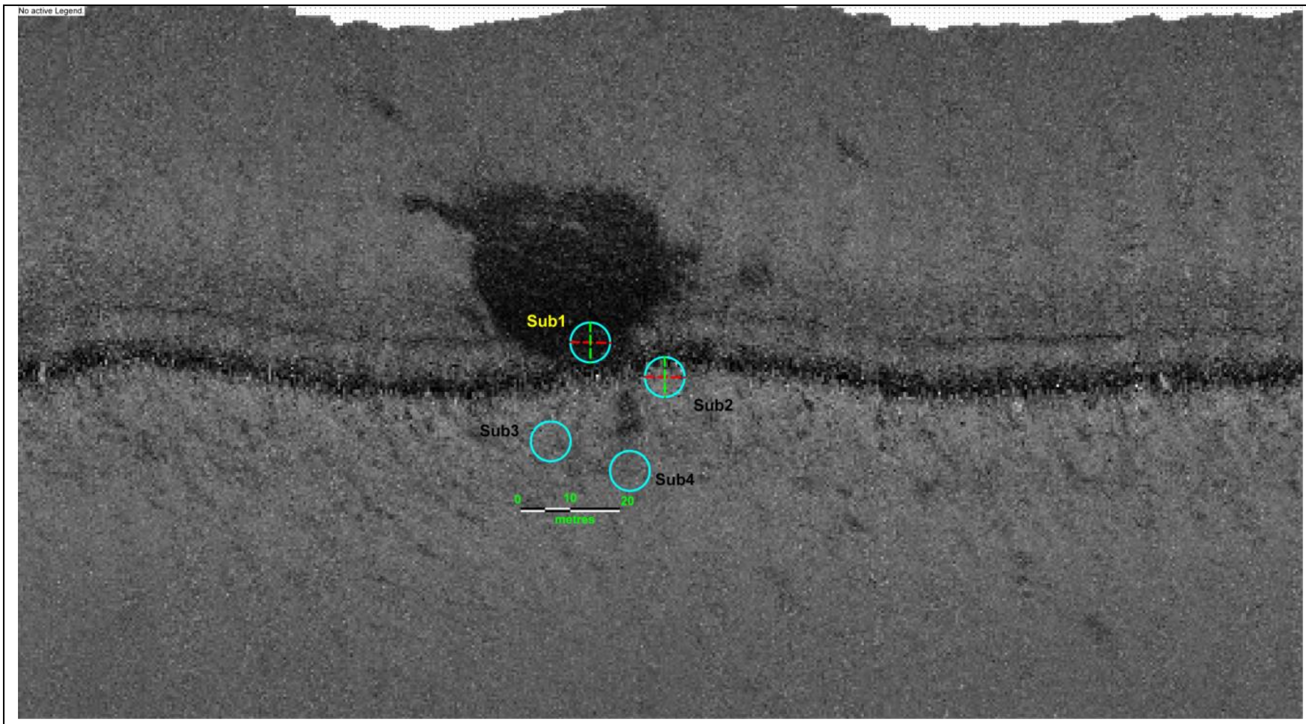

Figure 20. A sidescan image from a cross line showing the area where high bathymetric difference is noticed near SUB 1.

The magnetic survey data

The magnetic data was processed and cleaned first from artefacts and spikes and then the running difference (ΔnT) was taken for each line to find the local anomalies.
The resulting magnetic distribution map was gridded and shown in Fig 21. On the map the probable target positions were shown. Also shown on the map is the position of the four Sub stations.
The magnetic values ranges from 49860 to 49790nT and the target's running difference at each line have values between 2.5 to 3.2nT.
A spread sheet with target positions and values are given in Annex II.
For each target position a sidescan image was presented to show the seabed features at that position. These pictures can be seen in Annex II.

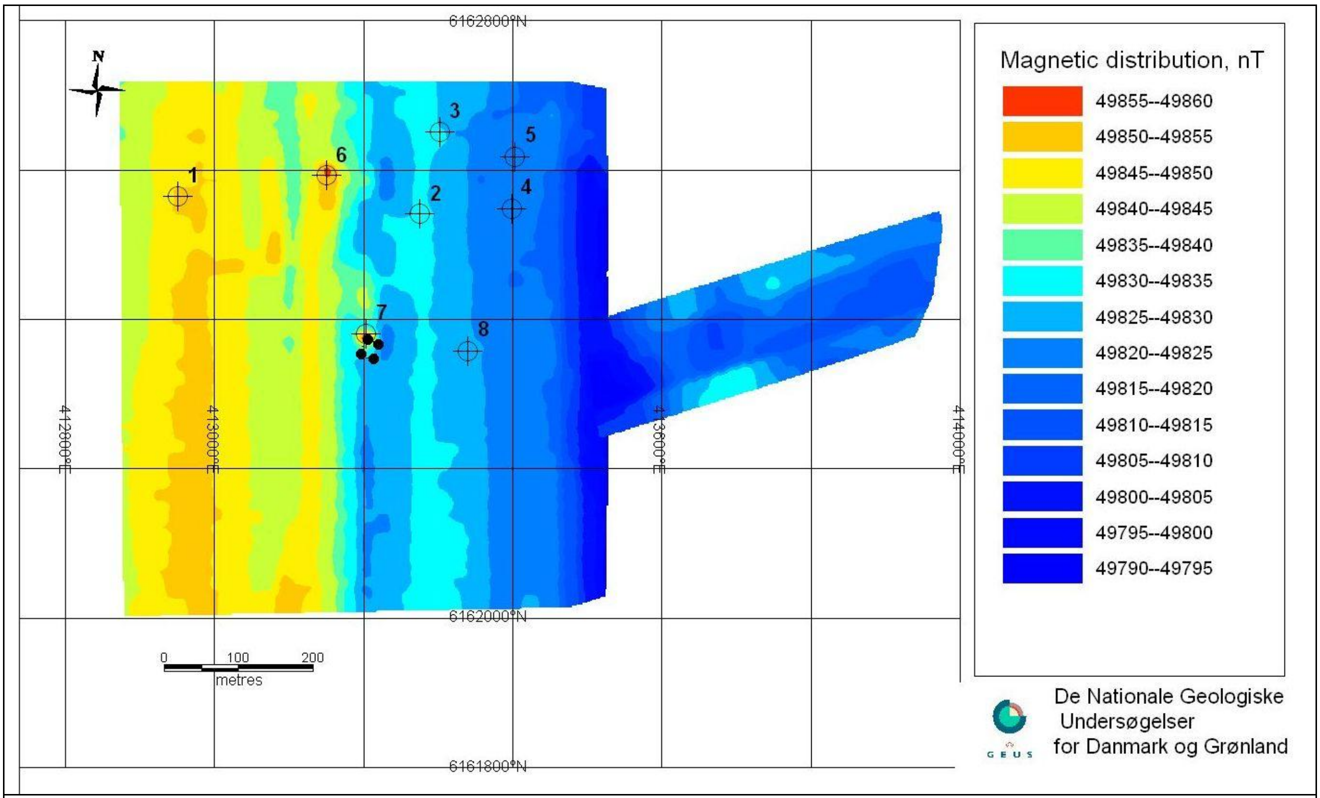

Figure 21. The magnetic distribution map of the surveyed area. The black dots represent the four Sub stations position, and the cross hair circles are target positions and numbers.

The sidescan survey data

The backscatter data from the seabed was processed, mosaiced and presented in Fig 22.
The seabed looks almost flat with sand cover and some ripples, no major structures can be seen in the data except for the lower depth area near SUB1.

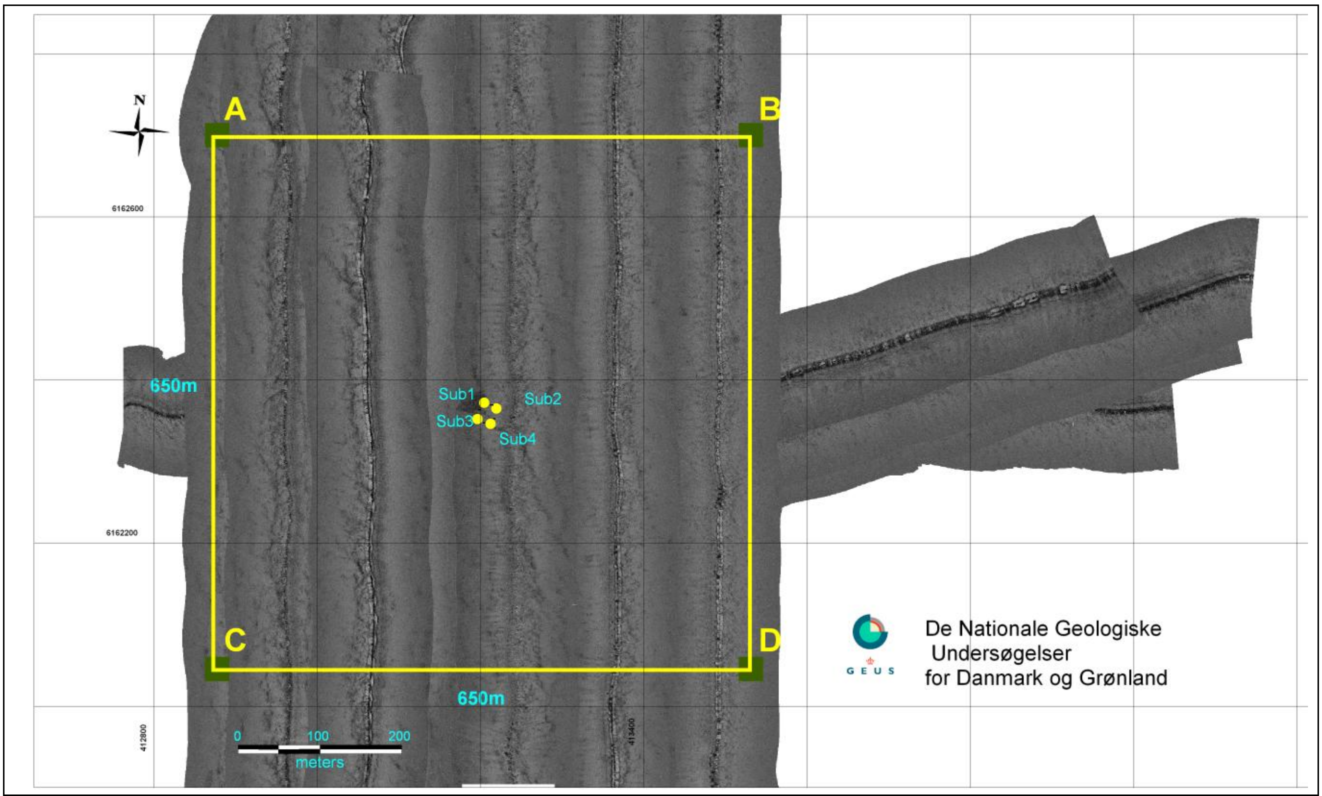

Figure 22. The sidescan mosaic of the survey area.

Annex I

Multibeam system calibration and bathymetry data processing

PATCH TEST

Calibration of EM 3002D system for

GEUS

Horns Rev Wind Farm

15. May 2008

Initial setting of transducer mounting angles

The patch test was mainly carried out as a confidence and confirmation calibration on previously conducted calibration.

Initial settings:	PORT transducer	STBD transducer
Latency	0 ms	0 ms
Roll	40.110 º	-39.930 º
Pitch	-2.860 º	-3.340 º
Yaw	-3.480 º	-3.150 º

Final settings:	PORT transducer	STBD transducer
Latency	0 ms	0 ms
Roll	39.290 º	-40.460 º
Pitch	0.770 º	0.390 º
Yaw	-1.010 º	0.380 º

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Calibration of EM3002D Port Head

Latency Check PORT:

As the system is synchronized with PPS and time interface from the GPS receiver the latency is expected to be negligible and hence this part of the patch test is mainly as confirmation of the time synchronisation.

Latency Lines	**0001 – PATCH - 0002**	**5.0 kt**
	0007 – PATCH - 0001	**9.0 kt**

By measuring the variation between the “fast” and ”slow” line the latency appeared to be negligible.

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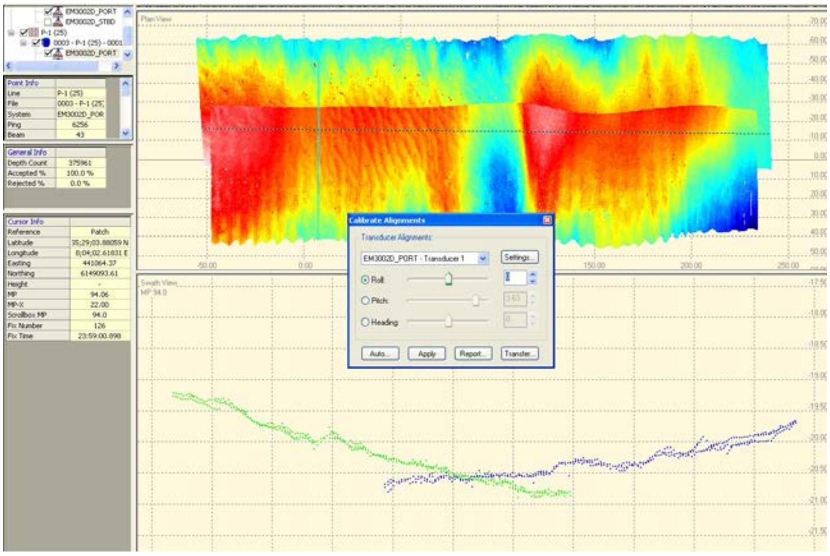
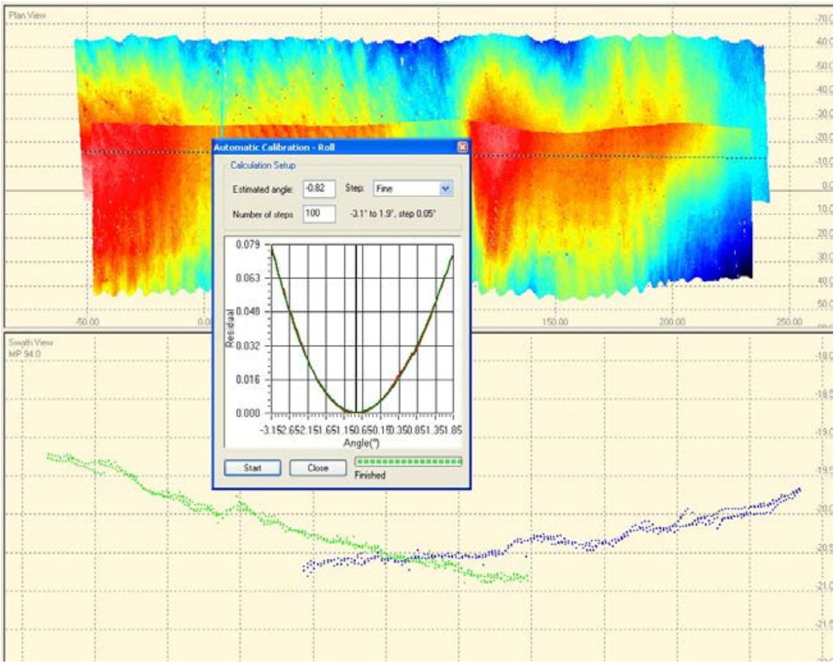
Roll Lines **0002 - PATCH - 0002**
0003 - P-1(25) - 0001

Roll = -0.82 º



Before Calculation



Automatic Calculation routine (-0.82)

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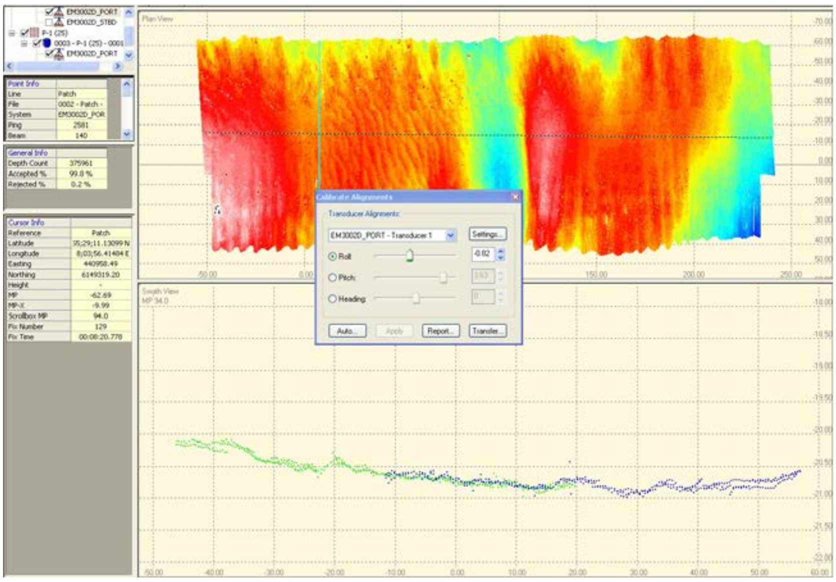
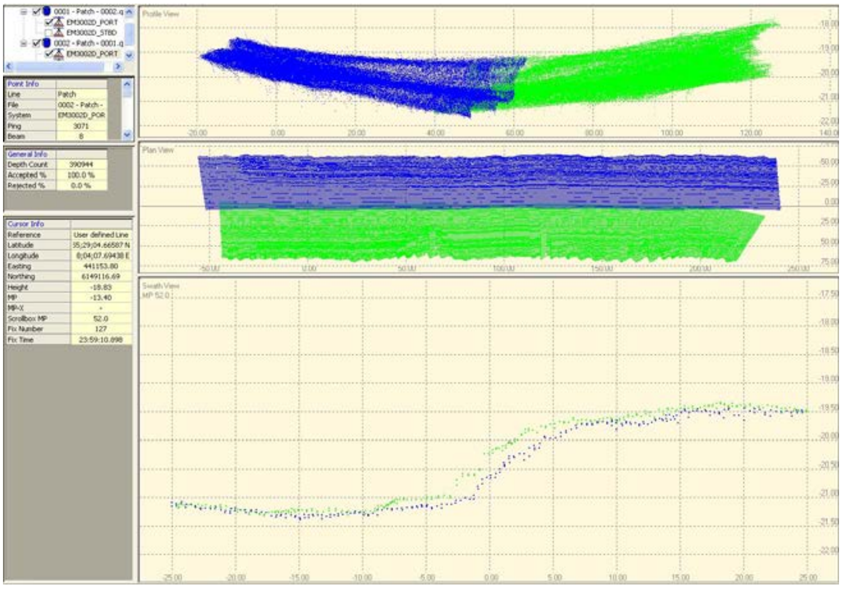


Correction Applied to Port Roll (-0.82)

Pitch Lines 0001 - PATCH - 0002
0002 - PATCH - 0001

Pitch = +3.63



Before Calculation

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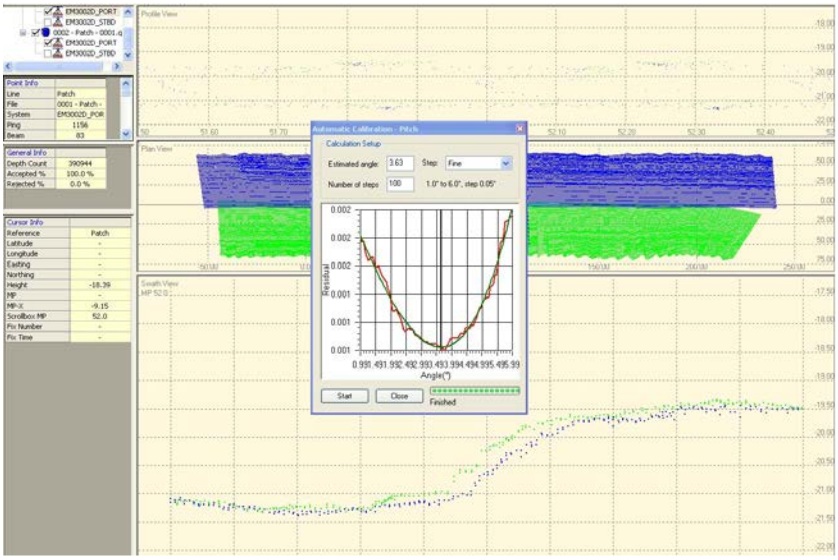
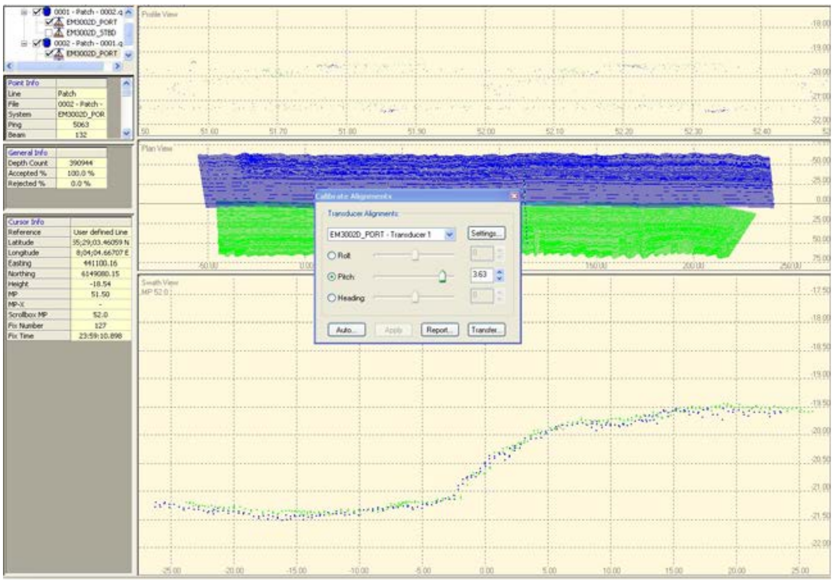
mail: info@scansurvey.dk Web www.scansurvey.dk



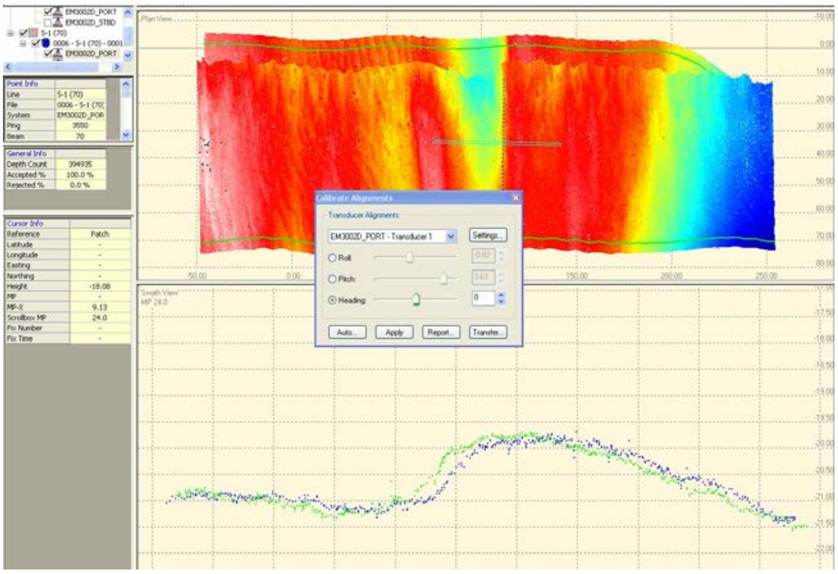
Automatic Calculation routine (+3.63)



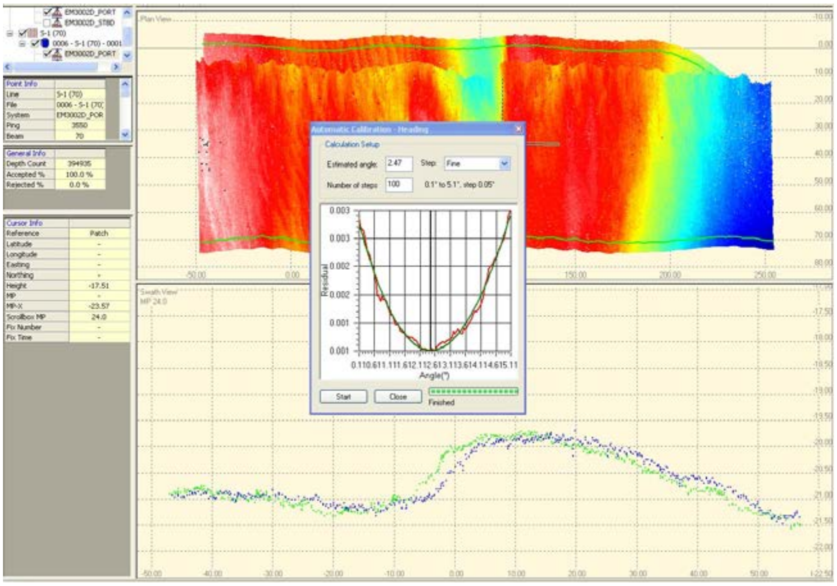
Correction Applied to Port Pitch (+3.63)

Yaw Lines 0001 - PATCH - 0002
0006 - S-1(70)-0001

Yaw = +2.47



Before Calculation



Automatic Calculation routine (+2.47)

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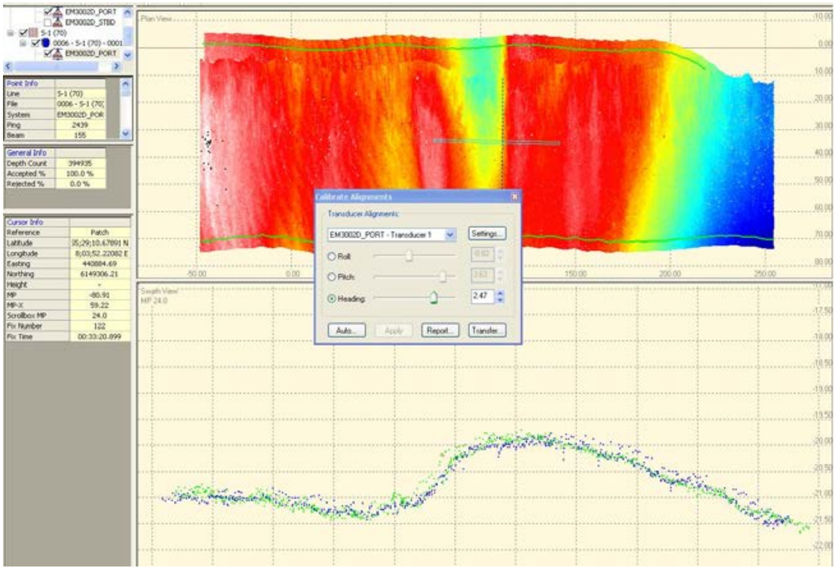


Correction Applied to Port Yaw (+2.47)

Final result PORT Head: **Roll = -0.82 º Pitch = +3.63 º Yaw = +2.47 º**

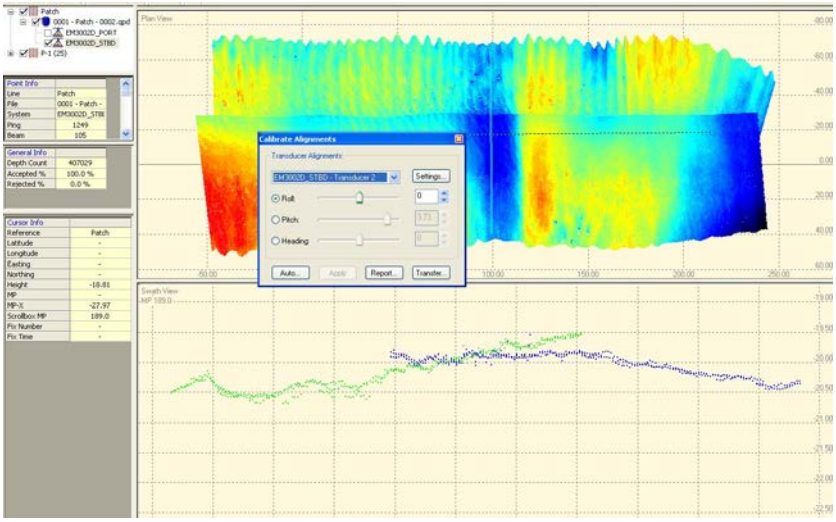
Latency Check STBD:

As the system is synchronized with PPS and time interface from the GPS receiver the latency is expected to be negligible and hence this part of the patch test is mainly as confirmation of the time synchronisation.

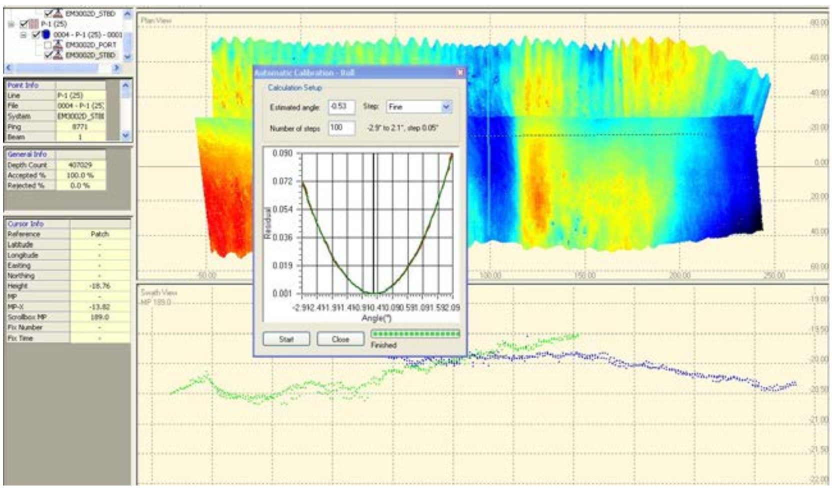
Latency Lines	**0001 – PATCH - 0002**	**5.0 kt**
	0007 – PATCH - 0001	**9.0 kt**

By measuring the variation between the “fast” and ”slow” line the latency appeared to be negligible.

Roll Lines	**0001 - PATCH - 0002**	
	0004 - P-1(25)-0001	Roll = -0.53 º



Before Calculation



Automatic Calculation routine (-0.53)

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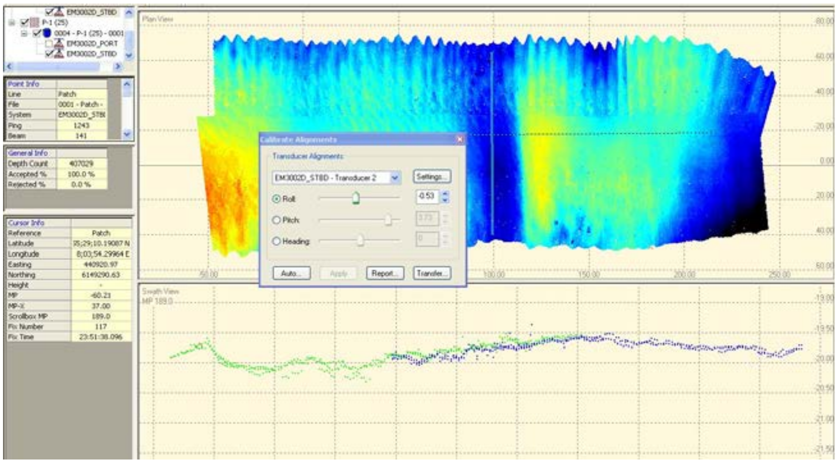
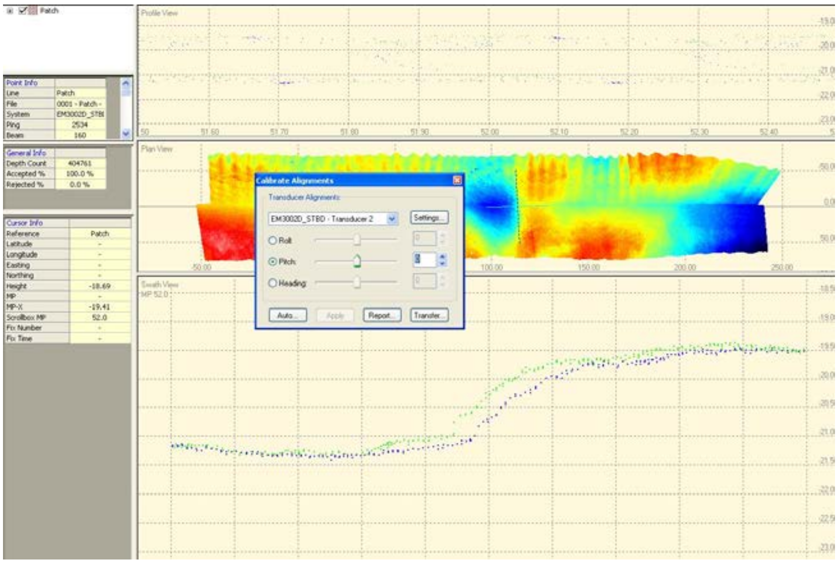


Correction Applied to STBD ROLL (-0.53)

Pitch lines 0001 - PATCH - 0002
0002 - PATCH - 0001

Pitch = +3.63



Before Calculation

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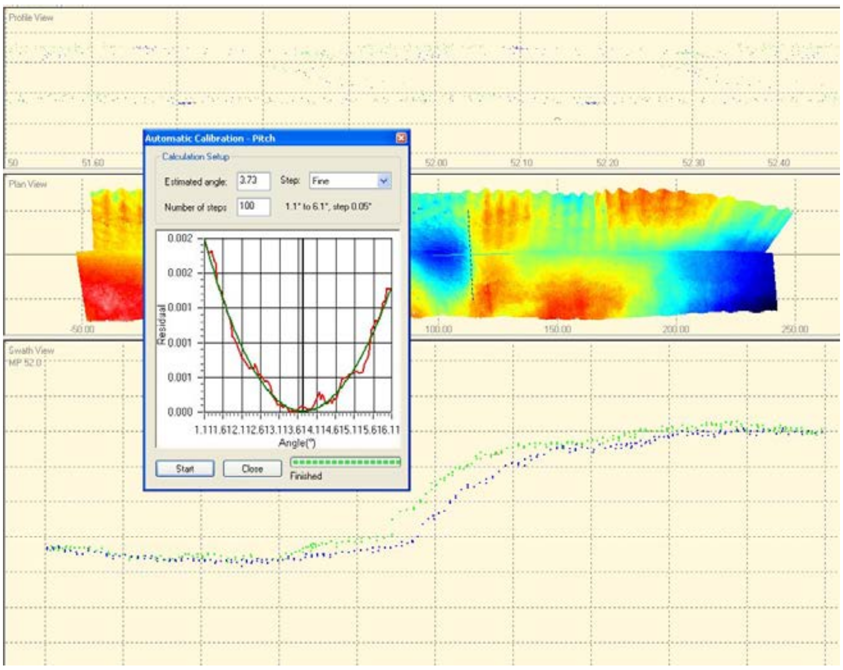
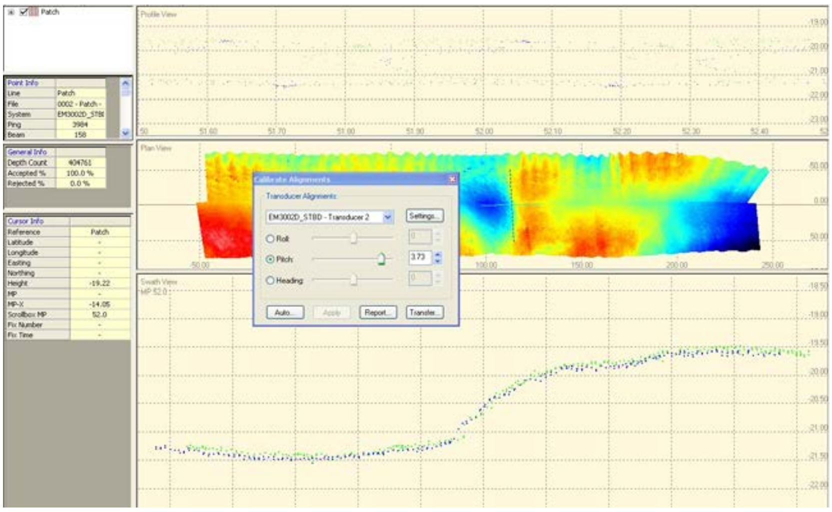


Automatic Calculation routine (+3.73)



Correction Applied to STBD PITCH (+3.73)

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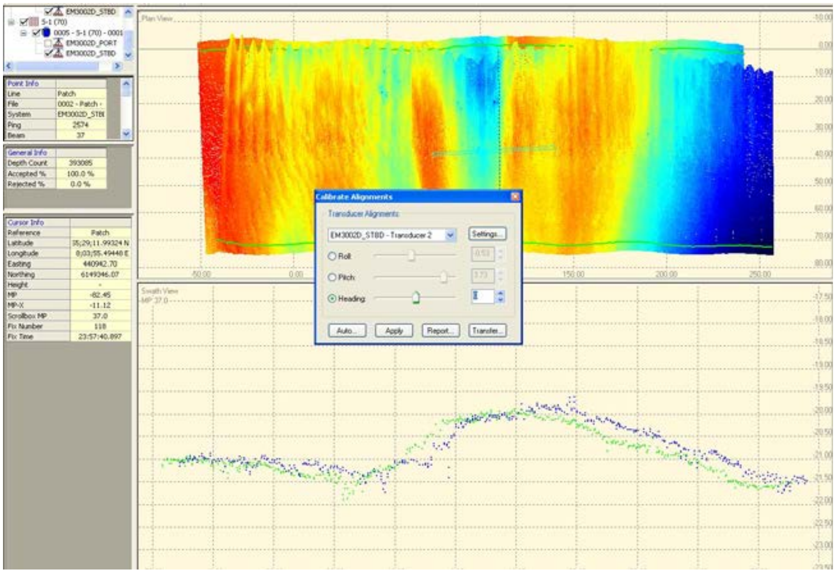
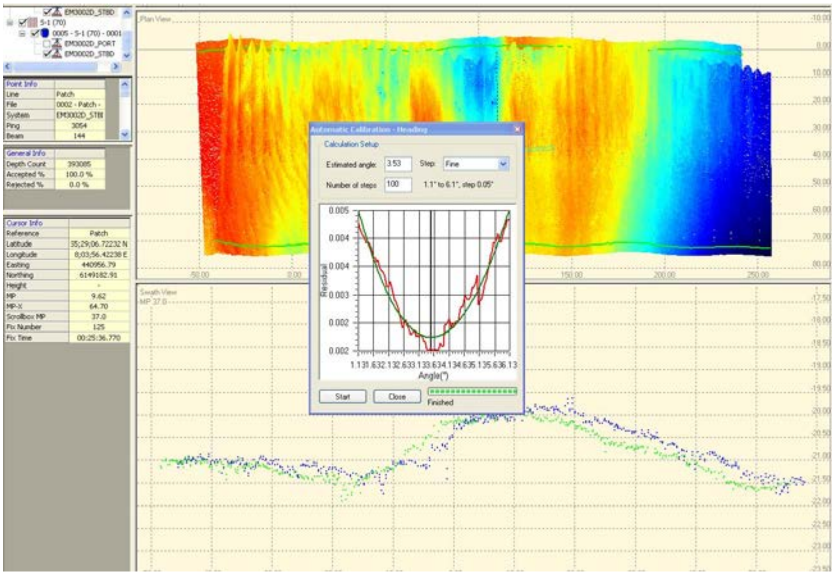
Yaw Lines **0002 - PATCH - 0001**
0005 - S-1(70)-0001

Yaw = 3.53



Before Calculation



Automatic Calculation routine (+3.53)

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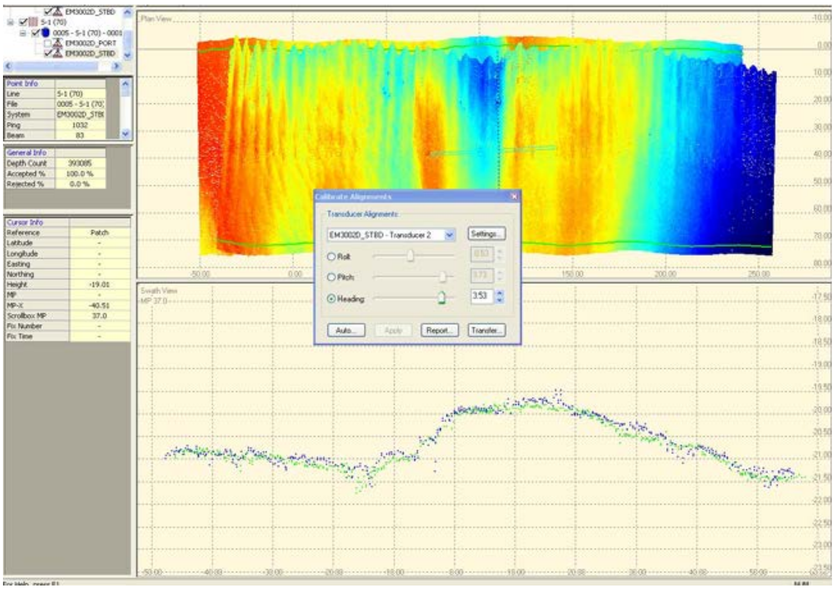

Correction Applied to STBD YAW (+3.53)

Result of Patch test of GEUS EM3002D multibeam system on board M/S MADOG on the 15th of May 2008.

Final result PORT Head: **Roll = -0.82º Pitch = 3.63 º Yaw = 2.47 º**
Final result STBD Head: **Roll = -0.53 º Pitch = 3.73 º Yaw = 3.53 º**

Final settings:	**PORT transducer**	**STBD transducer**
Latency	**0 ms**	**0 ms**
Roll	**39.290 º**	**-40.460 º**
Pitch	**0.770 º**	**0.390 º**
Yaw	**-1.010 º**	**0.380 º**

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Position Check

Position check of AD Navigation 201 RTK system for

GEUS

Performed over known geodetic point in Esbjerg

14. May 2008

Known Coordinates (WGS 84/UTM 32 - DVR-90):

KmsTrans
Transformation from utm32Heuref89_h_dvr90 to utm32Eeuref89

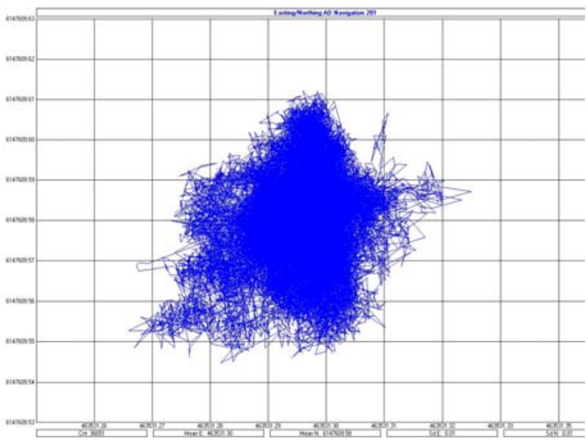
1001
Input 6 147 609.58 m 463 531.31 m 3.37 m
Output: 6 147 609.580 m 463 531.310 m 44.148 m

Antenna Height (Measured on Point 1001): 0.995 m

Calculated Geoidal Height: 45.143

Measuring time: $2^h\ 09^m$ Number of Samples: 36651

Mean Easting:	463531.27	Variation:	0.06 metres
Mean Northing:	6147609.61	Variation:	0.07 metres
Mean Height:	45.14 metres	Variation:	0.14 metres



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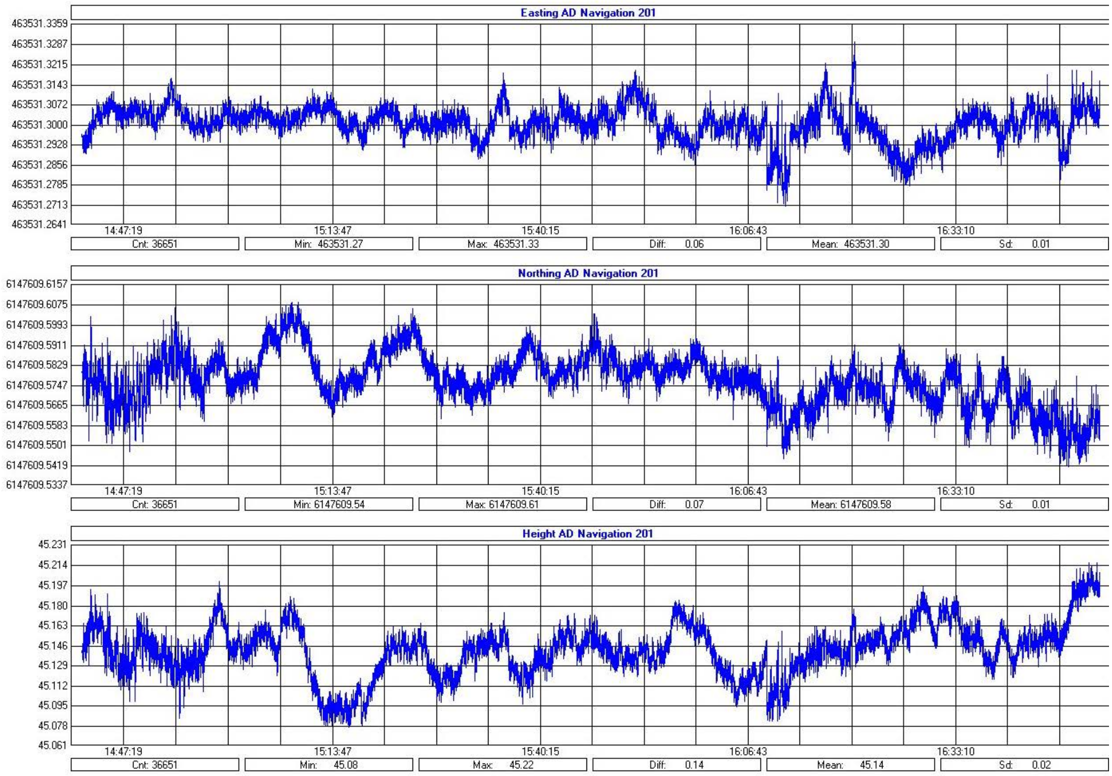
Distribution of samples:



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Gyro/Heading Check

Gyro/Heading check carried out for
Primary GPS Gyro SeaPath 20
and
Secondary Gyro Madog Sperry

for

GEUS

Performed by RTK measurments of fore and aft point of vessel central plane.

14. May 2008

Measured Coordinates (WGS 84/UTM 32 - DVR-90):

Fore:	Easting:	463512.70	Northing:	6147632.60
Aft:	Easting:	463526.77	Northing:	6147608.03

Grid Bearing: 330.29
Convergence: - 0.65

True Bearing: 329.74

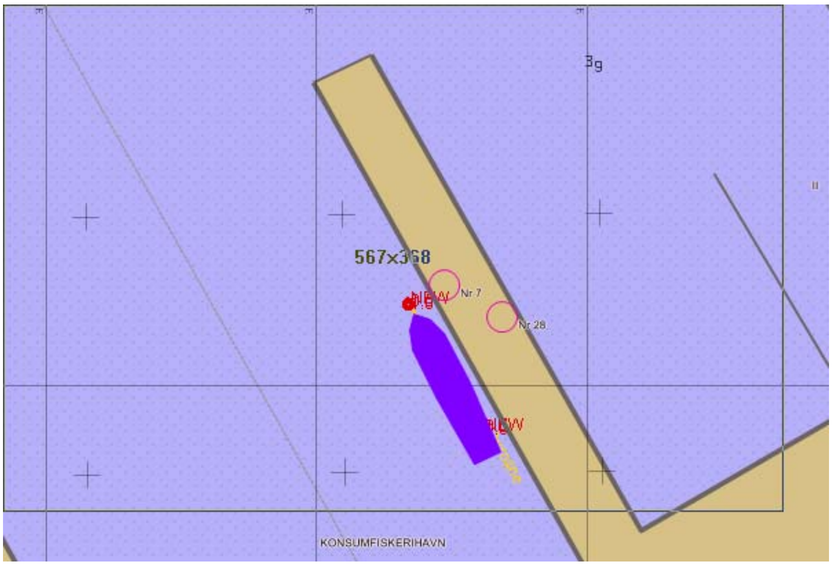
Measured Heading:

SeaPath 20:	329.37	Correction = +0.37
Madog Gyro:	333.46	Correction = -3.17

The SeaPath 20 has been Delta Corrected by injected positioning, and speed data from internal GPS.

The Madog (secondary) gyro has not been Delta Corrected (not important for the heading test as the speed was zero).

Logging time gyro/heading data: 1^{h} 02^{m} in Port of Esbjerg along quay.



(Alignment in this exampel by Madog Gyro).

Annex II

Magnetic targets and sidescan images of target positions

	Line	Pnt#	X	Y	Mag	Anomaly
1	080516C008_HRII_009	2135	412952	6162562	49857.3	3.15nT
2	080516C009_HRII_010	4117	413277	6162539	49837	3.22nT
3	080516C011_HRII_012	1647	413304	6162648	49833.83	3.36nT
4	080516C019_HRII_020	3999	413400	6162546	49821.32	3.11nT
5	080516C019_HRII_020	4177	413404	6162615	49823.2	3.22nT
6	080516C024_HRII_025	2981	413151	6162590	49860	1.2nT
7	080516C029_HRII_030	4715	413204	6162378	49862.41	2.6nT
8	080516C031_HRII_032	1273	413340.2	6162355.36	49819.78	2.5nT

Table 1. Magnetic target positions and values.

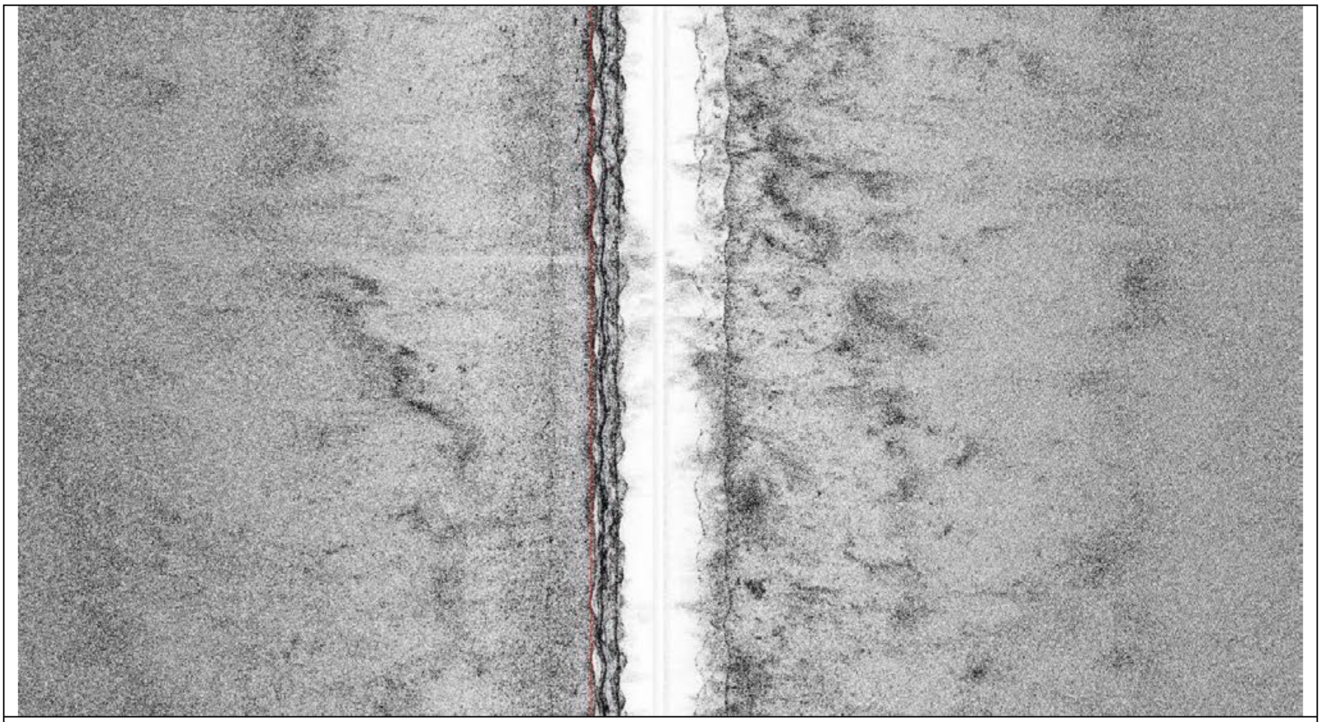


Figure AnxII.1 Sidescan image of target1.

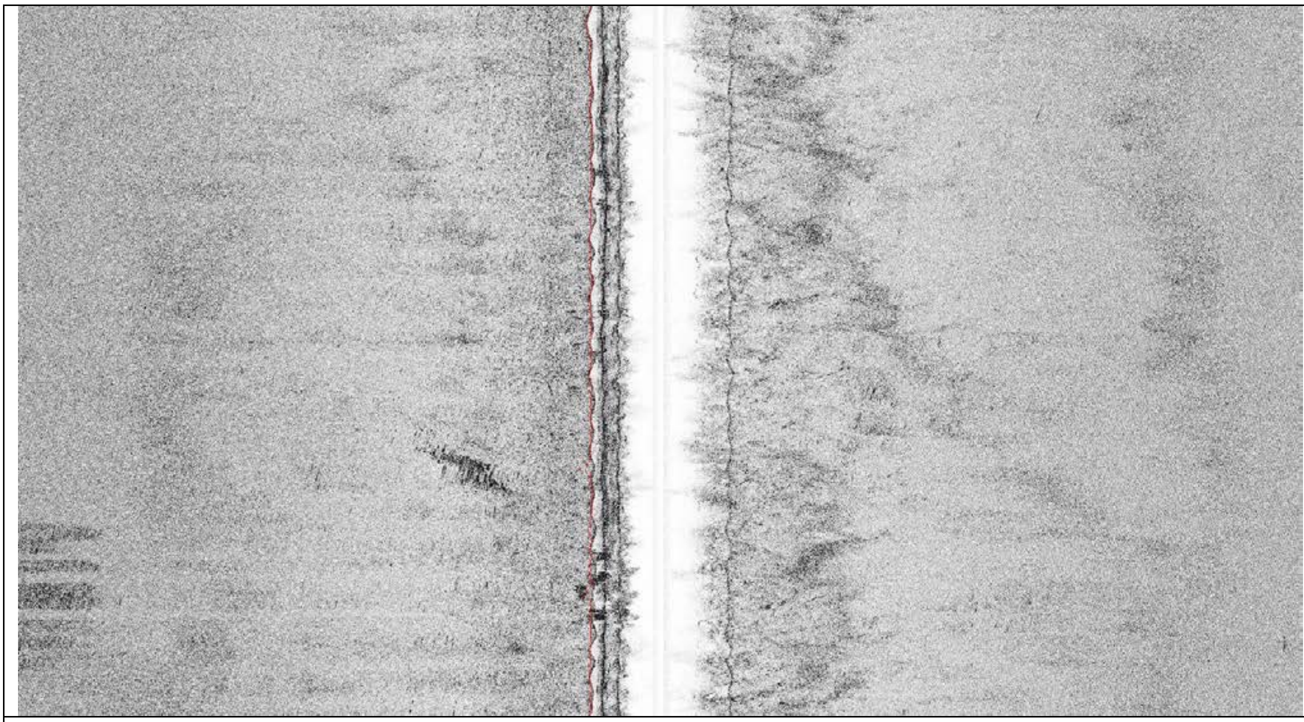


Figure AnxII.2 Sidescan image of target2.

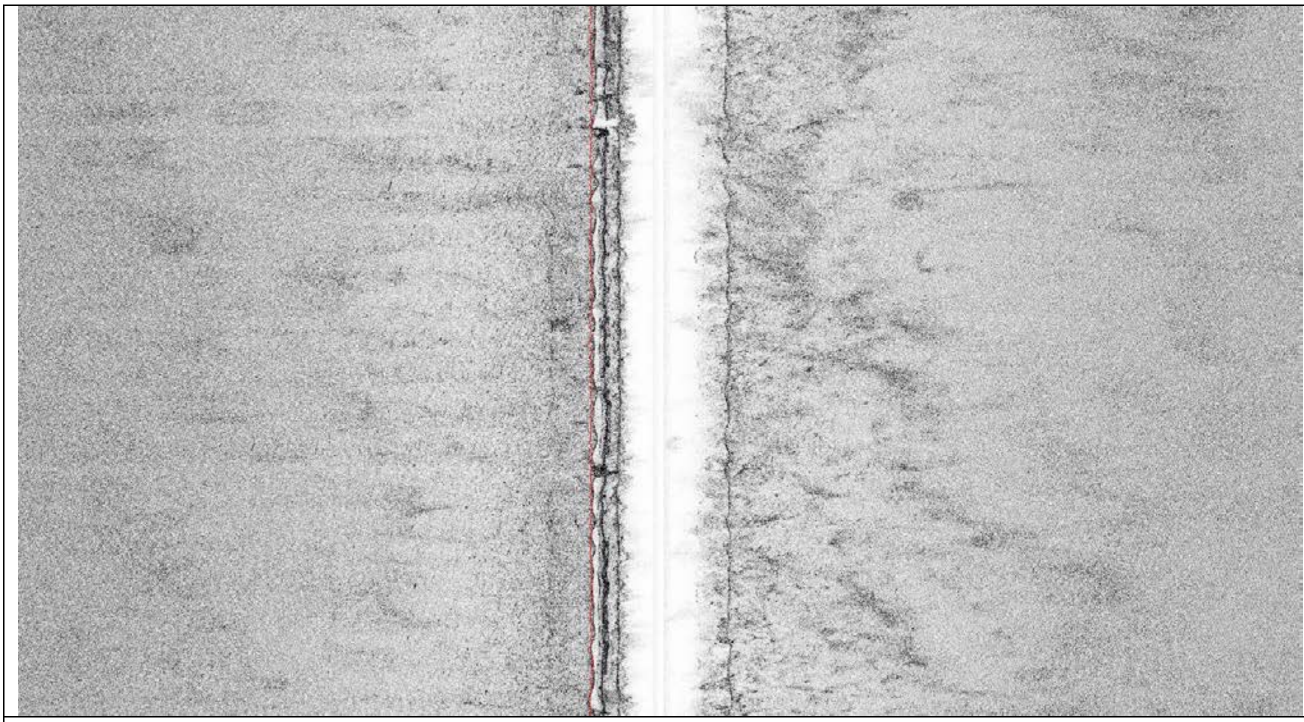


Figure AnxII.3 Sidescan image of target3.

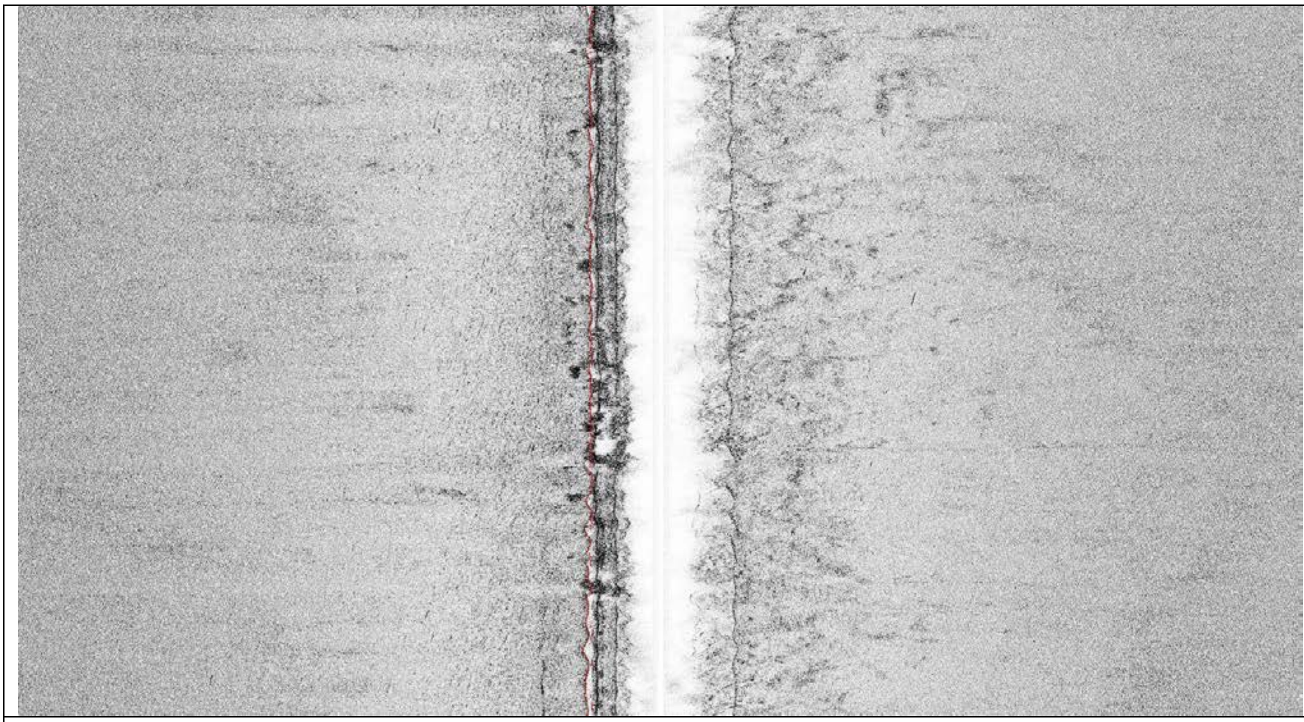


Figure AnxII.4 Sidescan image of target4.

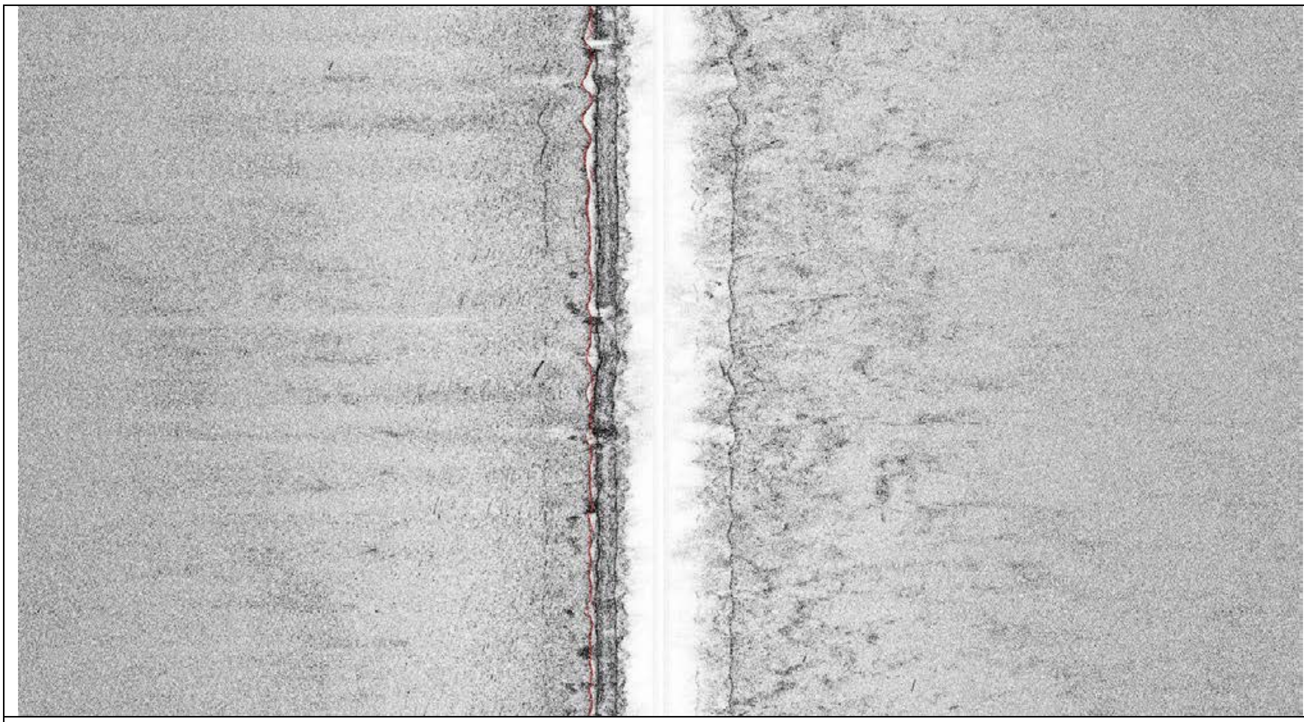


Figure AnxII.5 Sidescan image of target5.

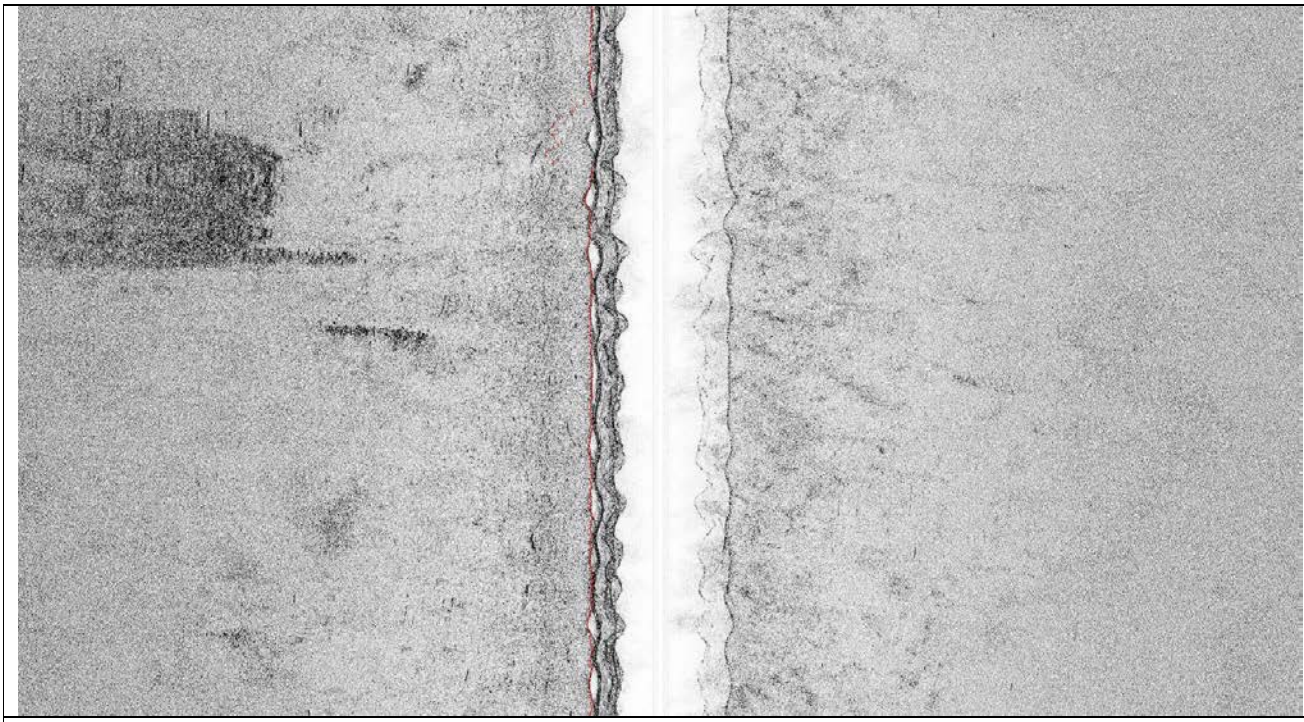


Figure AnxII.6 Sidescan image of target6.

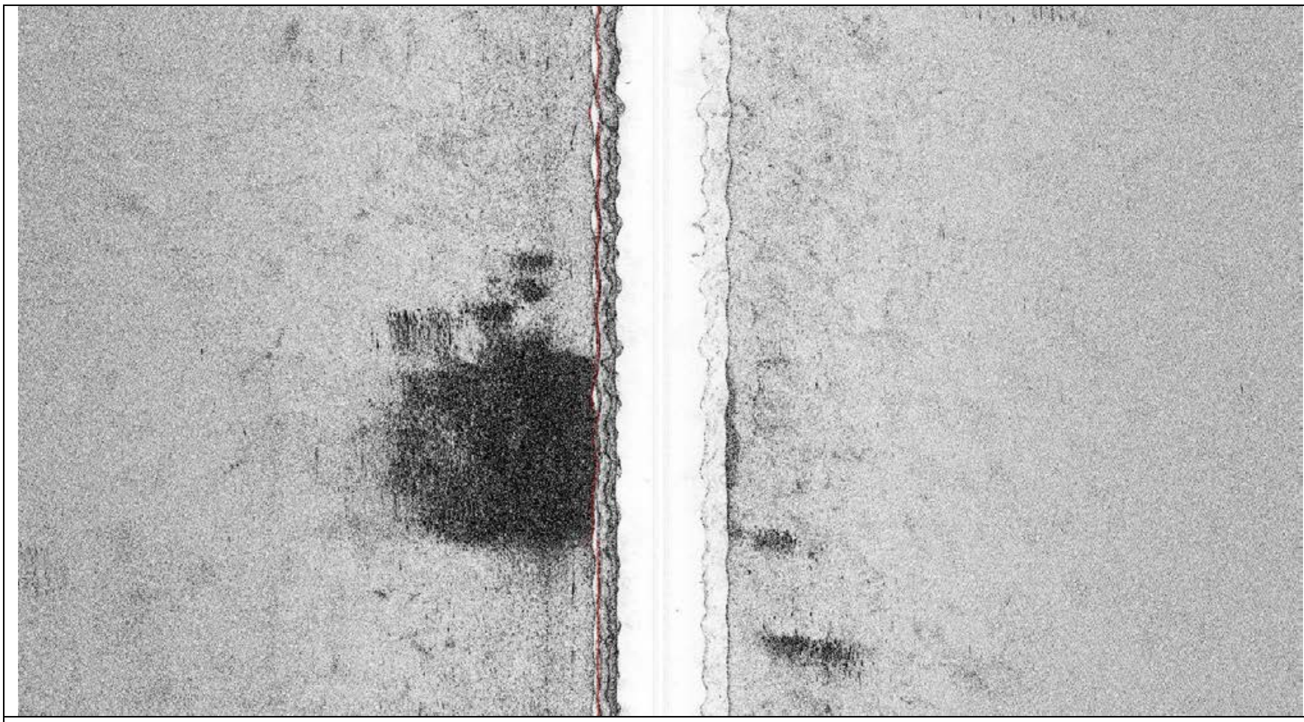


Figure AnxII.7 Sidescan image of target7.

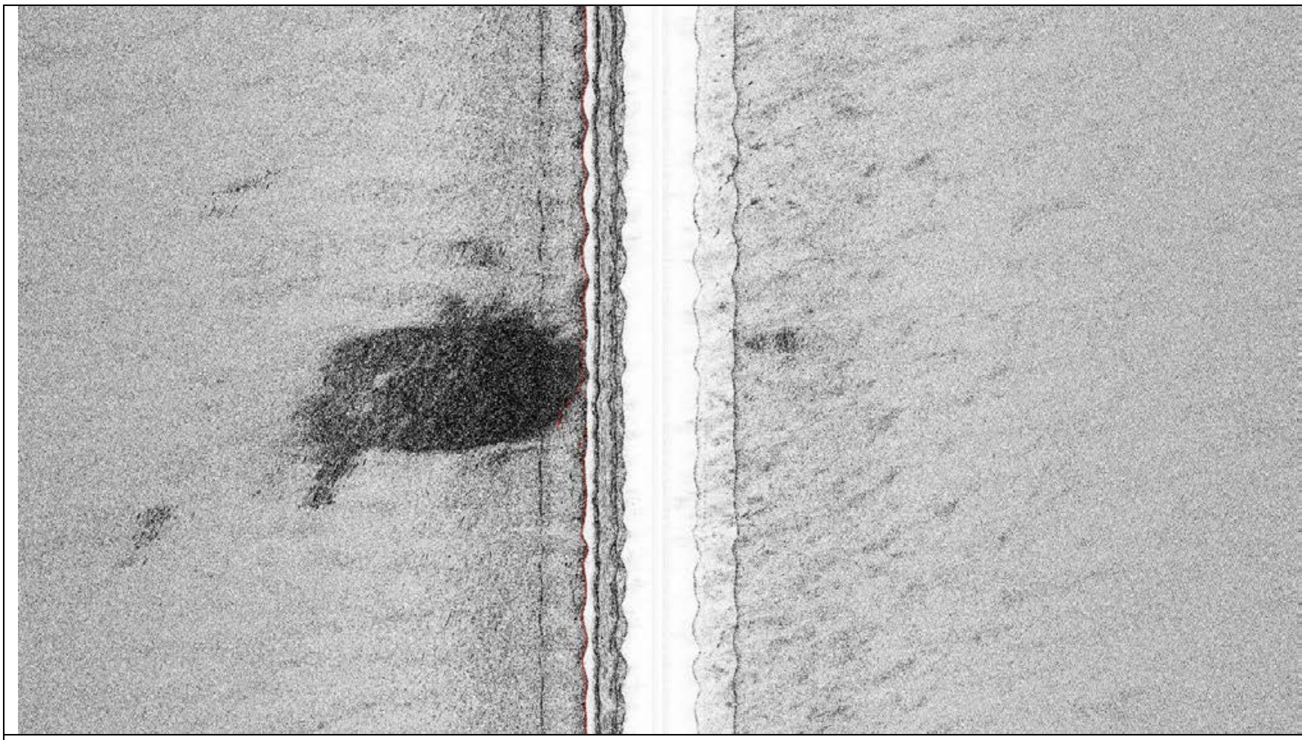


Figure AnxII.8 Sidescan image of target8.

Annex III

Equipment specifications

1. The Seafloor imaging system, SIS1625

SIS-1625 Seafloor Imaging System

SIDE SCAN SONAR/ PROFILER

Combined Chirp/CW Side Scan Sonar/ Sub-bottom Profiling System

The SIS-1625 Seafloor Imaging System has quickly become the industry standard for shallow water (<2000M) seafloor survey operations. This field proven, highly versatile survey tool offers a fully digital platform capable of collecting high resolution chirp side scan/sub-bottom data, as well as a full suite of customer selected sensor data. The high resolution, extended range chirp data and multiple data sensor capability provide the surveyor with a significant savings in instrument cost and survey time.

One Workstation

Topside system consists of:

- Chirp DSP based side scan sonar, operating at 100/400 kHz simultaneously, allows a full 1000 meter swath, with resolution equivalent to much higher frequency systems.
- Chirp DSP/CW based sub-bottom profiling, operating in the 1 to 10 kHz region, allows maximum sediment penetration with greatly improved resolution.
- Gain, TVG, image correction, color palette, and other programmable parameters are under trackball control.
- Digital interface provided for thermal graphic recorders.

One Tow Vehicle—TTV-290

The TTV-290 is a fully digital platform with standard Chirp side scan/sub-bottom transducer arrays, digital multiplexor, subsea electronics, and RS-232 ports for optional sensors.

- Hydrodynamically stable tow vehicle includes pitch, roll and heading sensors, optional position responder/ transponder, and other customer selected sensors.
- 0.5° side scan sonar horizontal radiation pattern,combined with broad band Chirp DSP match filter processing, provides optimal cross-track and along track resolution.
- Tow vehicle operates in depths up to 2000 meters.

- ACOUSTICS
- FLOTATION
- GEOPHYSICAL
- HYDROPHONES
- MODEMS
- LOCATOR
- ROBOTICS

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SIS-1625 Seafloor Imaging System

One Cable—CL-160 Communications Link

The comm link was designed through a program to develop a full ocean depth telemetry module for a multisensor seafloor mapping system.

- Two-way communication with tow vehicle over single coax with digital high speed multiplexor. Standard cable length—up to 10,000 meters.
- Digital multiplexor for single coaxial tow cables. Communication rates: sonar data—up to 5 megabit/sec; uplink status—9600 bits/sec; downlink command—9600 bits/sec.

SPECIFICATIONS

CL-160 Shipboard Sub-System	
Chirp Processing:	Sonar/status control PC based workstation; 5-DSP based sonar matched filter processing channels.
Display:	High resolution video display.
Recording:	Large capacity hard drive, DVD writable, other..
Status Display:	Vehicle pitch, roll, heading (standard); speed, altitude, and depth (optional). Customer input ship position, vehicle position, event marks; all status data recorded.
Sonar Display:	Side scan port, starb; dual channel sub-bottom; all sonar data recorded.
Corrections:	Slant range and speed; beam angle/grazing angle.
Multiplexor:	Digital MUX for coaxial cables (ADSL).
Sonar Data:	up to 5 megabit/sec.
Uplink Status:	9600 bit/sec.
Downlink Command:	9600 bits/sec.
Power Supply:	110/220 VAC autosensing.
Side Scan	
Side Scan Transducers:	Multi-element array, dual channel 100/400 kHz 0.5° horizontal beam; 60° vertical beam.
Frequency:	100/400 kHz band swept FM; 4.5 cm resolution.
Processing:	Calibrated transmit waveform stored in ROM; match filter FFT digital signal processing.
Swath Selection:	25 meters to ±500 meters.
Sub-Bottom	
Transducer:	Transmit projector array; line array receiving hydrophone; 30° conical radiation pattern.
Frequency:	1 kHz to 10 kHz swept FM (4 KW output), synchronous with side scan.
Resolution:	5 cm.
Processing:	Calibrated transmit waveform stored in ROM; matched filter FFT digital signal processing.
Scale Selection:	25 meters to 500 meters full scale.
TTV-290 Tow Vehicle Sub-System	
Depth rating:	2000 meters.
Vehicle Dimensions:	18 inches (45 cm) OD x 64 inches (162.6 cm) long.
Weight:	In air: 300 lbs (136 Kg); in water: 170 lbs (77 Kg).

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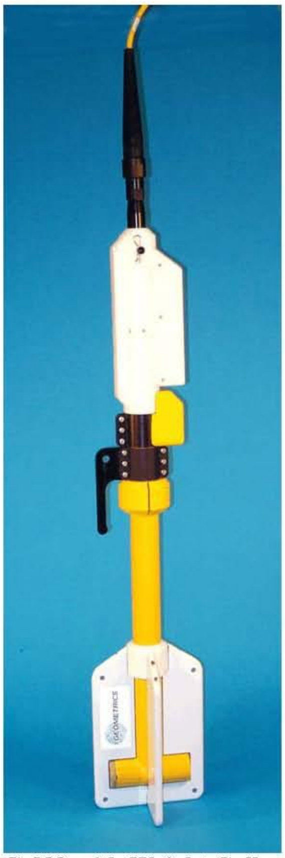
2. The G882 marine magnetometer

GEOMETRICS

G-882 MARINE MAGNETOMETER

- ***CESIUM VAPOR HIGH PERFORMANCE – Highest detection range and probability of detecting all sized ferrous targets***
- ***NEW STREAMLINED DESIGN FOR TOW SAFETY – Low probability of fouling in lines or rocks***
- ***NEW QUICK CONVERSION FROM NOSE TOW TO CG TOW – Simply remove an aluminum locking pin, move tow point and reinsert. New built in easy carry handle!***
- ***NEW INTERNAL CM-221 COUNTER MODULE – Provides Flash Memory for storage of default parameters set by user***
- ***NEW ECHOSOUNDER / ALTIMETER OPTION***
- ***NEW DEPTH RATING – 4,000 psi !***
- ***HIGHEST SENSITIVITY IN THE INDUSTRY – 0.004 nT/Hz RMS with the internal CM-221 Mini-Counter***
- ***EASY PORTABILITY & HANDLING – no winch required, single man operation, only 44 lbs with 200 ft cable (without weights)***
- ***COMBINE TWO SYSTEMS FOR INCREASED COVERAGE – Internal CM-221 Mini-Counter provides multi-sensor data concatenation allowing side by side coverage which maximizes detection of small targets and reduces noise***



G-882 with Weight Collar Depth Option & Altimeter

Very high resolution Cesium Vapor performance is now available in a low cost, small size system for professional surveys in shallow or deep water. High sensitivity and sample rates are maintained for all applications. The well proven Cesium sensor is combined with a unique and new CM-221 Larmor counter and ruggedly packaged for small or large boat operation. Use your computer and standard printer with our MagLogLite™ software to log, display and print GPS position and magnetic field data. The G–882 is the lowest priced high performance full range marine magnetometer system ever offered.

The G-882 offers flexibility for operation from small boat, shallow water surveys as well as deep tow applications (4,000 psi rating, telemetry over steel coax available to 10Km). The G-882 also directly interfaces to all major Side Scan manufacturers for tandem tow configurations. Being small and lightweight (44 lbs net, without weights) it is easily deployed and operated by one person. But add several streamlined weight collars and the system can quickly weigh more than 100 lbs. for deep tow applications. Power may be supplied from a 24 to 30 VDC battery power or the included 110/220 VAC power supply. The tow cable employs high strength Kevlar strain member with a standard length of 200 ft (61 m) and optional cable length up to 500m with no telemetry required.

A rugged fiber-wound fiberglass housing is designed for operation is all parts of the world allowing sensor rotation for work in equatorial regions. The shipboard end of the tow cable is attached to an included junction box or optional on-board cable for quick and simple hookup to power and output of data into any Windows 98, ME, NT, 2000 or XP computer equipped with RS-232 serial ports.

The G-882 Cesium magnetometer provides the same operating sensitivity and sample rates as the larger deep tow model G-880. MagLogLite™ Logging Software is offered with each magnetometer and allows recording and display of data and position with Automatic Anomaly Detection and automatic anomaly printing on Windows™ printer! Additional options include: MagMap2000 plotting and contouring software and post acquisition processing software MagPick™ (free from our website.)

The G-882 system is particularly well suited for the detection and mapping of all sizes of ferrous objects. This includes anchors, chains, cables, pipelines, ballast stone and other scattered shipwreck debris, munitions of all sizes (UXO), aircraft, engines and any other object with magnetic expression. Objects as small as a 5 inch screwdriver are readily detected provided that the sensor is close to the seafloor and within practical detection range. (Refer to table at right).

The design of this high sensitivity G-882 marine unit is directed toward the largest number of user needs. It is intended to meet all marine requirements such as shallow survey, deep tow through long cables, integration with Side Scan Sonar systems and monitoring of fish depth and altitude.

Typical Detection Range For Common Objects

Ship 1000 tons	0.5 to 1 nT at 800 ft (244 m)
Anchor 20 tons	0.8 to 1.25 nT at 400 ft (120 m)
Automobile	1 to 2 nT at 100 ft (30 m)
Light Aircraft	0.5 to 2 nT at 40 ft (12 m)
Pipeline (12 inch)	1 to 2 nT at 200 ft (60 m)
Pipeline (6 inch)	1 to 2 nT at 100 ft (30 m)
100 KG of iron	1 to 2 nT at 50 ft (15 m)
100 lbs of iron	0.5 to 1 nT at 30 ft (9 m)
10 lbs of iron	0.5 to 1 nT at 20 ft (6 m)
1 lb of iron	0.5 to 1 nT at 10 ft (3 m)
Screwdriver 5 inch	0.5 to 2 nT at 12 ft (4 m)
1000 lb bomb	1 to 5 nT at 100 ft (30 m)
500 lb bomb	0.5 to 5 nT at 50 ft (16 m)
Grenade	0.5 to 2 nT at 10 ft (3 m)
20 mm shell	0.5 to 2 nT at 5 ft (1.8 m)

MODEL G-882 CESIUM MARINE MAGNETOMETER SYSTEM SPECIFICATIONS

OPERATING PRINCIPLE:	Self-oscillating split-beam Cesium Vapor (non-radioactive)
OPERATING RANGE:	20,000 to 100,000 nT
OPERATING ZONES:	The earth's field vector should be at an angle greater than 6° from the sensor's equator and greater than 6° away from the sensor's long axis. Automatic hemisphere switching.
CM-221 COUNTER SENSITIVITY:	<0.004 nT/ √Hz rms. Up to 20 samples per second
HEADING ERROR:	±1 nT (over entire 360° spin)
ABSOLUTE ACCURACY:	<2 nT throughout range
OUTPUT:	RS-232 at 1,200 to 19,200 Baud
MECHANICAL:	
Sensor Fish:	Body 2.75 in. (7 cm) dia., 4.5 ft (1.37 m) long with fin assembly (11 in. cross width), 40 lbs. (18 kg) Includes Sensor and Electronics and 1 main weight. Additional collar weights are 14lbs (6.4kg) each, total of 5 capable
Tow Cable:	Kevlar Reinforced multiconductor tow cable. Breaking strength 3,600 lbs, 0.48 in OD, 200 ft maximum. Weighs 17 lbs (7.7 kg) with terminations.
OPERATING TEMPERATURE:	-30°F to +122°F (-35°C to +50°C)
STORAGE TEMPERATURE:	-48°F to +158°F (-45°C to +70°C)
ALTITUDE:	Up to 30,000 ft (9,000 m)
WATER TIGHT:	O-Ring sealed for up to 4,000 psi (9000 ft or 2750 m) depth operation
POWER:	24 to 32 VDC, 0.75 amp at turn-on and 0.5 amp thereafter
ACCESSORIES:	
Standard:	View201 Utility Software operation manual and ship kit
Optional:	Telemetry to 10Km coax, gradiometer (longitudinal or transverse), reusable shipping case
MagLog Lite™ Software:	Logs, displays and prints Mag and GPS data at 10 Hz sample rate. Automatic anomaly detection and single sheet Windows printer support

SPECIFICATIONS SUBJECT TO CHANGE WITHOUT NOTICE ***12/03***

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GEOMETRICS Europe Manor Farm Cottage, Galley Lane, Great Brickhill, Bucks, England MK179AB □ 44-1525-261874 □ Fax 44-1525-261867

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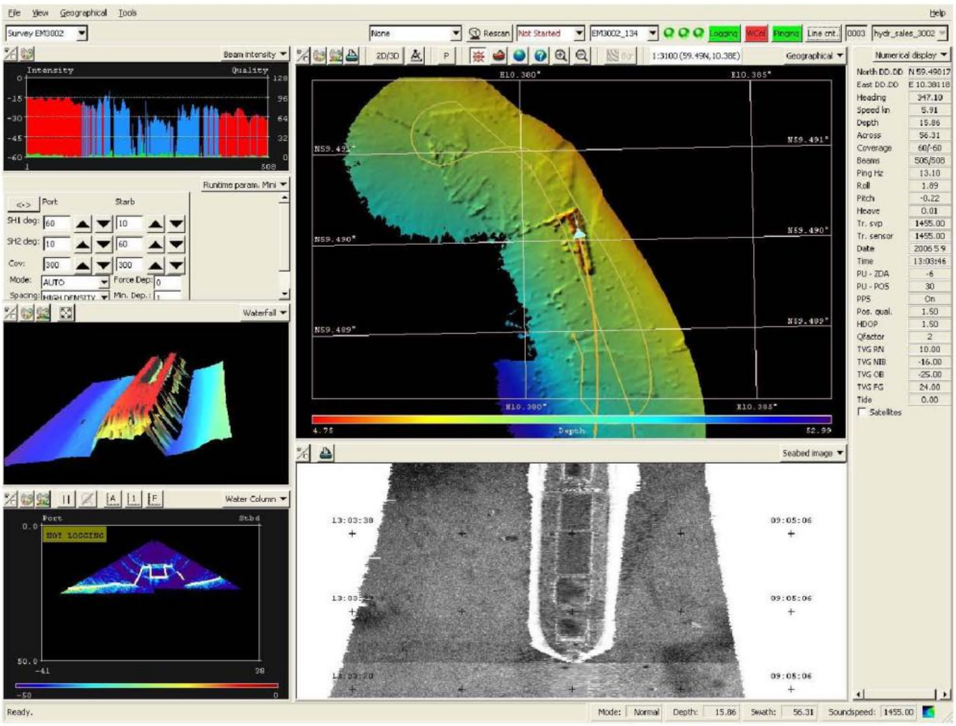
3. The Kongsberg EM3002D Multibeam system

EM 3002

KONGSBERG

Multibeam echo sounder

The new generation high performance shallow water multibeam



System description

Key facts

The **EM 3002** is a new advanced multibeam echo sounder with extremely high resolution and dynamically focused beams. It is very well suited for detailed seafloor mapping and inspection with water depths from less than 1 meter up to typically 200 meters in cold oceanic conditions. Maximum depth capability is strongly dependant on water temperature and salinity - up to 300 meters is possible under favorable conditions. Due to its electronic pitch compensation system and roll stabilized beams, the system performance is stable also in foul weather conditions.

The spacing between soundings as well as the acoustic footprints can be set nearly constant over the swath in order to provide a uniform and high detection and mapping performance. Dynamic focusing of all receive beams optimizes the system performance and resolution for short range applications such as underwater inspections.

Typical applications

- Mapping of harbours, inland waterways and shipping channels with critical keel clearance
- Inspection of underwater infrastructure
- Detection and mapping of debris and other underwater objects
- Detailed surveys related to underwater construction work or dredging
- Environmental seabed and habitat mapping
- Mapping of biomass in the water column

Features

The EM 3002 system uses frequencies in the 300 kHz band. This is an ideal frequency for shallow water applications, as the high frequency ensures narrow beams with small physical dimensions. At the same time, 300 kHz secures a high maximum range capability and robustness under conditions with high contents of particles in the water.

EM 3002 uses a powerful sonar processor unit in combination with 1 or 2 compact sonar heads. The high computing power of the EM 3002 sonar processor makes it possible to apply sophisticated and exact signal processing algorithms for beamforming, beam stabilisation, and bottom detection. In High Density processing mode the system has close to uniform acoustic footprints and resolution over the whole swath width, and therefore a much improved capability to detect objects and other details on the bottom.

EM 3002 will in addition to bathymetric soundings, produce an acoustic image of the seabed. The image is obtained by combining the acoustic return signals inside each beam, thus improving signal to noise ratio considerably, as well as eliminating several artifacts related to conventional sidescan sonars. The acoustic image is compensated for the transmission source level, receiver sensitivity and signal attenuation in the water column, so that reliable bottom backscatter levels in dB are obtained. The image is also compensated for acoustic ray bending, and thus completely geo-referenced, so that preparation of a sonar mosaic for a survey area based upon data from several survey lines is easy. Objects observed on the seabed image are correctly located and their positions can be readily derived.

List of options

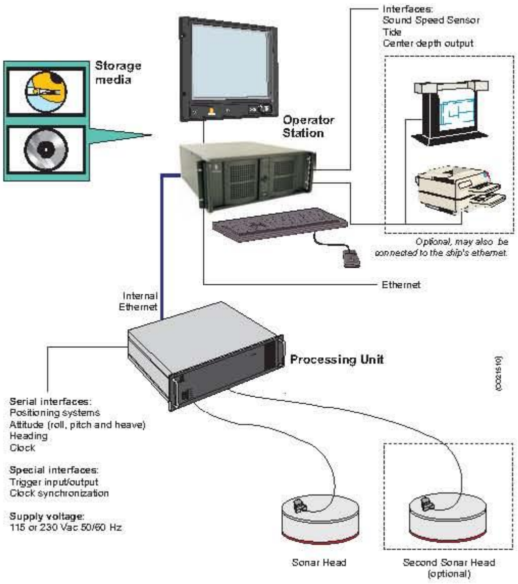
- Dual sonar heads - EM 3002D
- Logging of water column data
- Software for Automatic Calibration
- CUBE terrain modeling SW
- Extended depth raiting for transducer(s): 1500 m
- Extended length of transducer cable: 30 or 45 m
- Bracket for portable mounting of sonar head(s)
- Flight case for safe transportation of 1 sonar head w/cable
- Flight case for processing unit and operators workstation

- Full swath width accuracy to the latest IHO standard
- Swath width up to 10 x water depth (EM 3002D) or 200 m (cold oceanic water)
- Depth range from < 1 meter to > 200 meters
- Bottom detection by phase or amplitude
- 100% bottom coverage even at more than 10 knots vessel speed
- Real-time ray bending and attitude compensation
- Seabed image (sidescan) data output
- Sonar heads for 500 or 1500 meters depth rating
- Water column data display window + logging (optional)

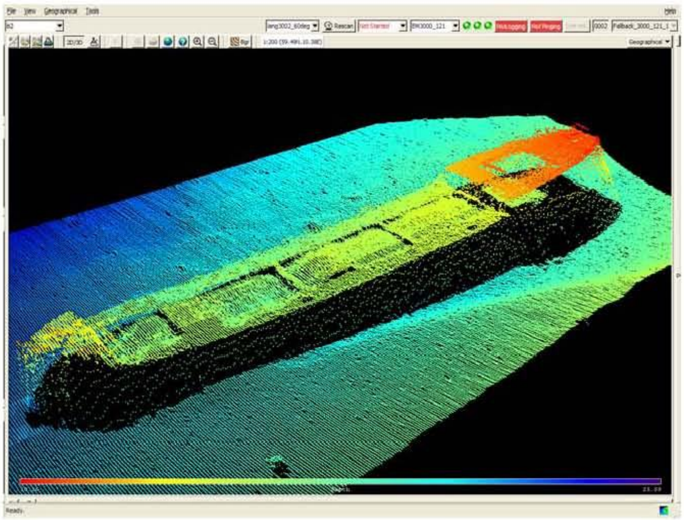
Operator Station

The Operator Station is a rugged zed PC workstation running on either Linux® or Microsoft Windows XP®. The Operator Station software, SIS, has extensive functionality such as 3D graphics, real-time data cleaning and electronic map background.

The EM 3002 can be set up to use other operational software than SIS, for example "QINCy®" or Costal Oceanographics "HYPACK® Max", and is also supported by software from Triton Elics International, EIVA and others.



Typical system configuration with desktop Operator Station, Processing Unit and one or two Sonar Heads.



The image of a sunken wreck at 20 m depth.

Note that Kongsberg Maritime AS does not take any responsibility for system malfunction caused by third-party software.

Advanced functions

- Bottom detection uses a combination of amplitude and phase processing in order to provide a high sounding accuracy over the whole swath width.
- All beams are stabilized for pitch and roll movements of the survey vessel, by electronically steering the transmit beam as well as the receive beams.
- Dynamic focusing of the receive beams is applied in order to obtain improved resolution inside the acoustic near-field of the transducer.
- Swath coverage with one sonar head reaches 130 degrees, but can be manually limited while still maintaining all beams inside the active swath. For deeper waters the swath width will be reduced due to reduced signal-to-noise margin. The system will automatically re-locate all beams to be within the active swath.
- With two sonar heads the swath width will reach 200 degrees to allow for inspection of constructions up to the water surface, as well as for efficient mapping of beaches, rivers and canals. On a flat shallow seabed the swath-width can be about 10 x depth.
- Operator controlled equidistant or equiangular beam spacing.

Technical specifications

Operational specifications

Frequencies .... 293, 300, 307 kHz
Number of soundings per ping:
- Single sonar head .... Max 254
- Dual sonar heads .... Max 508

Maximum ping rate .... 40 Hz
Maximum angular coverage:
- Single sonar head .... 130 degrees
- Dual sonar heads .... 200 degrees

Pitch stabilisation .... Yes
Roll stabilisation .... Yes
Heave compensation .... Yes
Pulse length .... 150 μs
Range sampling rate .... 14, 14.3, 14.6 kHz
Depth resolution .... 1 cm
Transducer geometry .... Mills cross
Beam spacing .... Equidistant or equiangular
Beamforming:
- Time delay with shading
- Dynamically focused receive beams

Seabed image data

- Composed from beamformed signal amplitudes
- Range resolution 5 cm.
- Compensated for source level and receiver sensitivity, as well as attenuation and spherical spreading in the water column.
- Amplitude resolution: 0.5 dB.

External sensors

- Position
- Heading
- Motion sensor (Pitch, roll and heave)
- Sound velocity profile
- Sound velocity at transducer.
- Clock synchronisation (1 PPS)

Environmental and EMC specifications

The system meets all requirements of the IACS E10 specification. The Operator Station, LCD monitor and Processing Unit are all IP22 rated.

Dimensions and weights

Sonar head:
- Shape .... Cylindrical
- Housing material .... Titanium
- Diameter .... 332 mm
- Height .... 119 mm
- Weight .... 25 kg in air, 15 kg in water
- Pressure rating .... 500 m (1500 m option)
- transducer cable length .... 15 m

Sonar Processing Unit:
- Width .... 427 mm
- Depth .... 392 mm
- Height .... 177 mm
- Weight .... 14.5 kg

Operator Station:
- Width .... 427 mm
- Depth .... 480 mm
- Height .... 127 mm
- Weight .... 20 kg

19" industrial LCD monitor:
- Width 483mm
- Depth .... 68 mm
- Height .... 444 mm
- Weight .... 12 kg
- Resolution .... 1280 x 1024 pixels

All surface units are rack mountable. Dimensions exclude handles and brackets.

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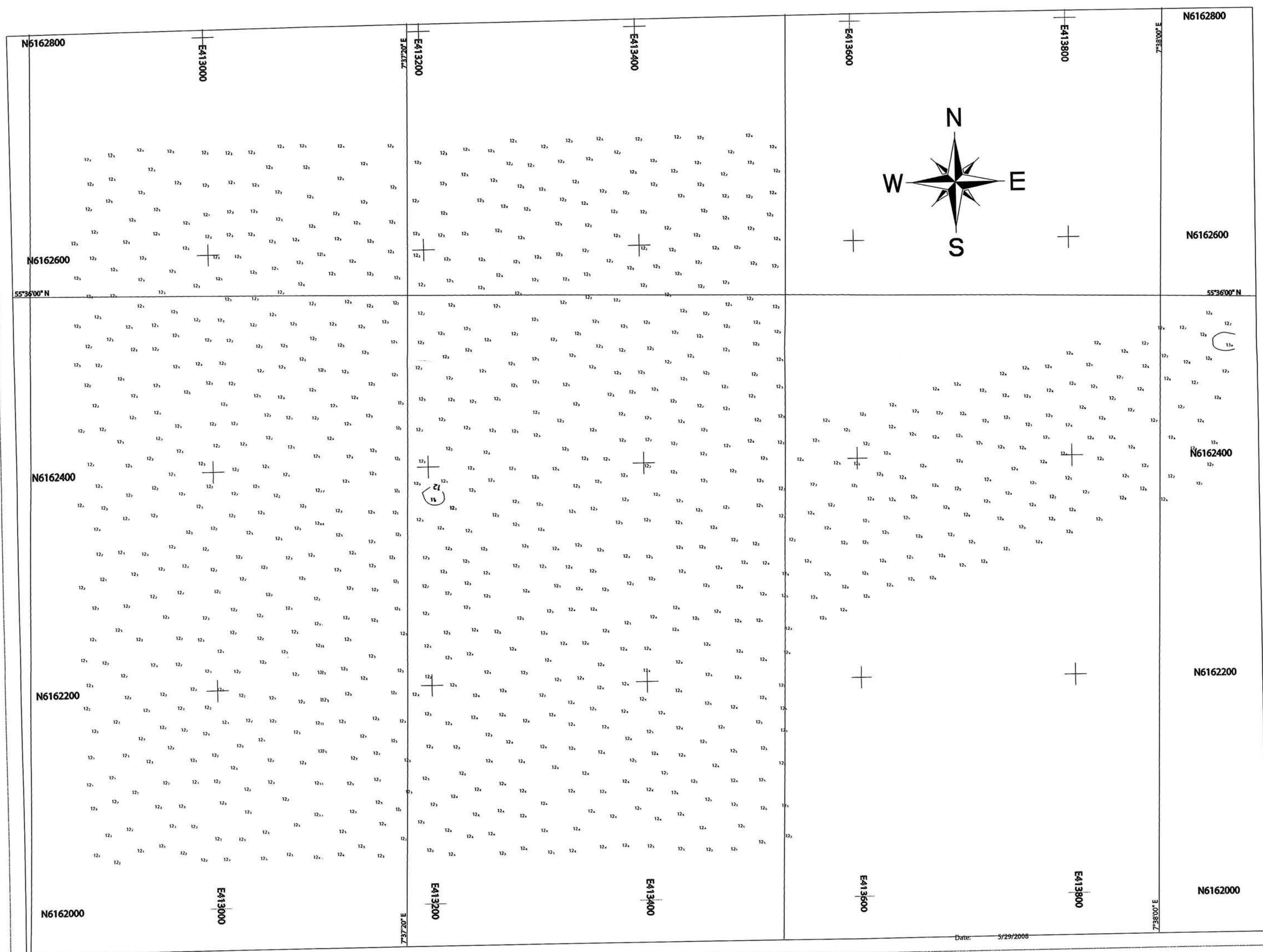
KONGSBERG

WIND FARM HORNS REV II 2008



GEODETIC INFORMATION	
Datum	WGS 84
Projection	UTM
Central Meridian	9 EAST
Zone	UTM 32 N
False Easting	500000
False Northing	0
Scale Factor	0.9996
Sounding Datum	DVR-90

SURVEY SYSTEM	
Multibeam	EM 3002D
Positioning	AD 201 RTK
Motion sensor	Kongsberg MRU 5
Heading/Gyro	SeaPath 20/MADOG Gyro
MB SV/ sensor	AML Micro SV
SV Profiler	AML SV PLUS
Data Aquisition	QINSy 8.0
MB Postprocessing	QLOUD 2.1

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G E U S
Report File no.
27163
Enclosure (1/1)