Vedlegg 5

Gandsfjorden Geophysical and Geotechnical Survey

Statnett

Marine Survey Report

Gandsfjorden Geophysical and Geotechnical Survey

Statnett

May 2014

Document No:101755-STN-MMT-SUR-SURVEYRE
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Final Report
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Survey Report

Gandsfjorden Geophysical and Geotechnical Survey

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ABBREVIATIONS

DPR	Daily Progress Report
DTM	Digital Terrain Model
DVL	Doppler Velocity Log
GC	Gravity Core
GNSS	Global Navigation Satellite Systems
DTU10	Global Ocean tide model derived at Danmarks Tekniske Universitet Space in 2010
HiPAP	High Precision Acoustic Positioning
HSEQ	Health, Safety, Environment and Quality
INS	Inertial Navigation System
KP	Kilometer Post
m	Metre
MAC	Mobilisation and Calibration
MBES	Multibeam Echo Sounder
MDK	Sjøforsvarets Minedykkerkommando
MOM	Minutes of Meetings
MSL	Mean Sea Level
PPS	Pulse Per Second
PC	Push Corer
QA	Quality Assurance
QC	Quality Control
RMS	Root Mean Square
ROV	Remotely Operated Vehicle
SBET	Smoothed Best Estimated Trajectory
SBP	Sub Bottom Profiler
SK4	Skagerrak 4 cable
SOW	Scope of Work
SSBL	Super Short Baseline System
SSS	Side Scan Sonar
SVP	Sound Velocity Profile
UTC	Universal Time Coordinated
UTM	Universal Transverse Mercator
WGS84	World Geodetic System 1984

1. EXECUTIVE SUMMARY

MMT was contracted by Statnett SF to conduct a geophysical and geotechnical survey in Gandsfjorden, Norway, for a probable future cable corridor suitable for 9 single core cables separated by approximately at least 5 to 10 m.

The results from the geophysical and geotechnical survey are presented in this text report including appendices, together with alignment charts and digital deliveries. The digital delivery comprises raw data and GIS (TSG). This report provides a summary of the survey performance, instrumentation and the results from the geophysical and geotechnical survey performed in May 2014.

The survey operation commenced on the 26th of May 2014 with the calibration of additional survey equipment and finished on the 29th of May 2014 upon completing the work. In total, four working days were logged in the project.

The geophysical survey spread included remotely operated vehicle mounted multibeam echo sounder, side scan sonar, sub bottom profiler and video and the geotechnical included gravity corer and push corer sampling. The geophysical data was interpreted onboard the vessel and in the Gothenburg office while the geotechnical and chemical testing of the samples was performed at laboratories.

The Statnett Gandsfjorden project was performed in a safe manner with no personal injury or major Health, Safety, Environment and Quality issues.

The surveyed area is constituted by a narrow fjord with very steep slopes, >15°, occasionally up to 40°. The water depth range from approximately 10 m in the westernmost part to maximum depth of 243 m in the central part. BEDROCK and coarse sediments outcrops on the slopes, which occasionally are covered by a thin layer of soft CLAY. Especially in the eastern slope, BEDROCK outcrops extensively. In the central, deeper part, the seabed sediments comprise thick beds of very soft CLAYS. The very soft CLAYS in some locations contain a significant amount of organic content and occasionally also smelling of sulphur, indicating anoxia.

The geotechnical-tested sediments are generally very to extremely soft. Three of the samples have thermal resistivity above 1 and three below. Three samples, i.e. push corer samples, were sent to ALS laboratory for testing of chemical contents. They show a slight increase in heavy metals and organic contaminants.

The area appears to be heavily trawled, this is concluded from the amount of seabed scars. Wrecks and different kinds of debris are present in the whole area, with a concentration in the central part.

Remotely operated vehicle target inspections were made on eleven contacts whereof nine were proved wrecks, one a concrete block and one a crane.

2. INTRODUCTION

2.1. Project Information

MMT was contracted by Statnett SF to conduct a geophysical and geotechnical survey in Gandsfjorden, Norway.

Client:	Statnett SF
Project:	Gandsfjorden Geophysical and Geotechnical Survey
MMT Project Number:	101755
Survey Type:	Geophysical and Geotechnical Survey
Area:	Gandsfjorden, Stavanger, Norway.
Survey Period:	May 2014
Survey Vessel:	M/V Stril Explorer
MMT Project Manager:	Ola Svensson

2.2. Survey Area

The proposed cable corridor in Gandsfjorden is located between Sandviga and Mariero, (Figure 1).

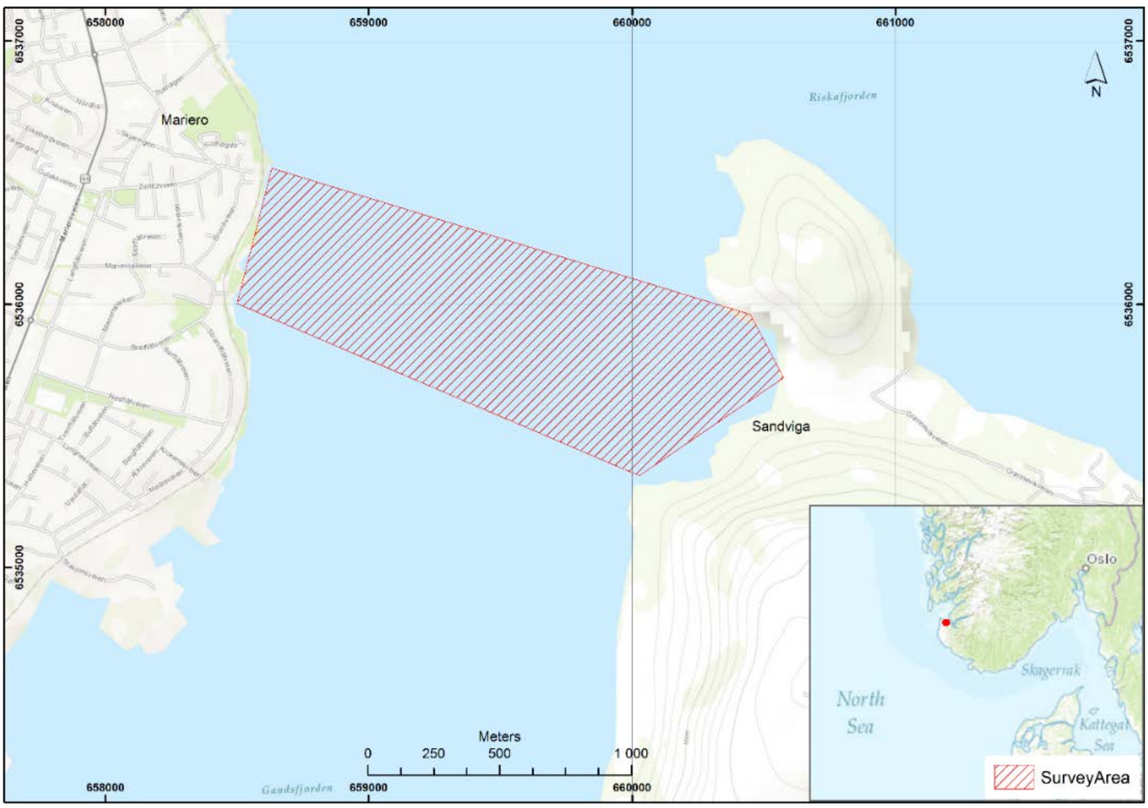


Figure 1 Overview image of Gandsfjorden.

2.3. Scope of Work (SOW)

MMT performed a detailed high-resolution offshore remotely operated vehicle (ROV) survey of the proposed Gandsfjorden cable route corridor, approximately 2 km long and 0.7 km wide. The purpose of the survey was to map the area to enable finding suitable routes for nine single core cables, separated by 5-10 m. For reference see Statnett document SN2014_02_03_Inquiry Exhibit A - Scope of Work.

The survey spread comprised a dual-head multibeam echo sounder (MBES), side scan sonar (SSS), sub-bottom profiler (SBP), video cameras and Gravity Corer (GC) capable of recovering a maximum of 3 m long sediment samples and Push Corer (PC).

2.3.1. Deviations to SOW

The following deviations were made to the SOW during the survey in Gandsfjorden.

- The survey corridor was extended south of the original corridor in order to investigate alternative cable routes.
- A total of 2 cross lines were surveyed, one on each side of the fjord.
- The chemical sampling was conducted using a push corer from the ROV instead of the gravity corer.

2.4. Purpose of Document

This report presents the results from the geophysical and geotechnical survey performed in Gandsfjorden by M/V Stril Explorer. In addition, a summary is given for the survey operations and equipment used.

This report aims to provide an overview of the bathymetric and geological conditions present along the corridor, based on interpretations of the geophysical and geotechnical data obtained.

Objects and wrecks detected within the corridor are also presented.

2.5. Report Structure

The results from the geophysical and geotechnical survey performed in Gandsfjorden are presented in this text report with appendices and alignment charts. The data can also be found in the provided GIS database (TSG). Raw data is included in the digital delivery for the report. The report and charts are delivered in digital format only.

2.5.1. Text Report

This report summarises the survey performance, equipment used and all processing stages within the project, together with summaries of the survey results.

2.5.2. Charts

The charts in this report illustrate and describe the results from the survey and are intended to assist in further planning and evaluation. Three charts are produced: two area charts, where one presents the bathymetry results while the other presents the surface geology and features, and one chart presenting the interpreted profiles for three of the surveyed lines. The horizontal scale is 1:2 000 and the vertical scale 1:800. A list of all the produced charts is presented in Table 1.

Table 1 Produced Charts

Document Number	Content
101755-STN-MMT-SUR-DWG-SIGAFB001	Bathymetry
101755-STN-MMT-SUR-DWG-SIGAFG001	Surface Geology
101755-STN-MMT-SUR-DWG-SIGAFP001	Profiles
101755-STN-MMT-SUR-DWG-NSGAFB001	Nearshore Bathymetry (western side)
101755-STN-MMT-SUR-DWG-NSGAFB002	Nearshore Bathymetry (eastern side)

Bathymetry Chart

The bathymetry is presented with 1 m and 5 m contour lines, with labels and colour identification. A colour relief is presented with a 16 m colour interval. The lines also presented as interpreted profiles are indicated.

Surface Geology Chart

Interpreted seabed sediment is presented with colour coding. Surface features, such as a heavily trawled area and an area covered with much debris are indicated with patterns. Indicated are identified linear features (pipelines), contacts identified from SSS with ID (wrecks are presented with specific symbol) and geotechnical sampling sites. The lines also presented as interpreted profiles are indicated.

Longitudinal Profile Chart

This section illustrates the seabed profile and interpreted geology along three of the survey lines. The lines are chosen to be representative of the area. Geotechnical sampling results are presented.

2.5.3. Digital Delivery

In Table 2 the data sets that are a part of the digital report delivery are presented.

Table 2 Data sets included in the digital draft report deliveries.

Data Type	File Extension	Comment	Delivery
MBES	.db	QINSY raw database files	On HD
	.xyz	Accepted soundings	On HD
	.xyz	DTM	On HD
	.tiff	Images	On HD
	.nmp	Navimodel project	On HD
SSS	.jsf	Raw	On HD
	.png	Mosaic stripes	On HD
	.xlsx and pdf	Contact report	On HD
SBP	.sgy	Raw	On HD
	.jpg	Images	On HD
Video	.mov	Raw	On HD
Still Images	.jpg	Images	On HD
GC/PC	.pdf	Lab results	On HD

Data Type	File Extension	Comment	Delivery
GIS (TSG)	.gdb		On HD
Charts	.pdf e-transmittal		On HD and ftp
Draft Survey Report	.pdf	Text report including appendices	On HD and ftp

2.6. Reference Documents

Table 3 Reference documents

Document Number	Title	Author
101655-STN-MMT-QAC-PRO-PMQAPLAN-A	Project Manual	MMT
101655-STN-MMT-MAC-PRO-STRIL-02	Mobilisation and Calibration Procedures	MMT
101655-STN-MMT-MAC-REP-STRIL-A	Mobilisation and Calibration Report	MMT
101655-STN-MMT-SUR-REP-DSTUDY01	Desktop Study	MMT
SN2014_02_03_Inquiry Exhibit A - Scope of Work	Scope of Work	Statnett

3. HEALTH, SAFETY, ENVIRONMENT AND QUALITY (HSEQ)

3.1. HSEQ Summary

The Statnett Gandsfjorden project was performed in a safe manner with no personal injury or major HSEQ issues.

3.2. HSEQ Objectives

MMT had six project specific HSEQ-objectives in the project:

- Zero fatalities
- Zero injuries
- To ensure that there is emergency preparedness in case of an incident.
- To reduce the risk of environmental impacts.
- To fulfil all national and international requirements.
- To fulfil all customer and internal demands.

All of the six objectives were fulfilled.

3.3. HSE Statistics

The HSE-statistics and the major HSE related activities for the interval 26 May to 29 May are presented in Table 4 and Table 5.

Table 4 HSE statistics

HSE Issue	No.
Man Hours	1212 H
Survey Induction SJA, (Safe Job Analysis)	1
SOC (Safety Observation Card)	0
HIRA	1
MINCS	0
Work Place Inspection	0
Safety Drill	0
Toolbox Meetings	11

Table 5 Major HSE related activities

Activity	Hours
Downtime Vessel	0
Downtime Equipment	0
Downtime ROV	0

4. SURVEY PARAMETERS

4.1. Geodetic Datum and Grid Coordinate System

Table 6 Geodetic parameters

Datum Parameters WGS84	
Ellipsoid	WGS84
Semi Major Axis	6378137.000m
Semi Minor Axis	6356752.314m
Inverse Flattening	1/298.257223563
Eccentricity Squared	0.0066943801

Table 7 Projection parameters

Projection Parameters	
Projection	UTM
Zone	32 N
Central Meridian	09° 00' 00'' E
Latitude origin	0
False Northing	0 m
False Easting	500 000 m
Central Scale Factor	0.9996
Units	metres

4.2. Vertical Datum

Global Navigation Satellite System (GNSS) - tide is used to correct the bathymetry data to the defined vertical datum, MSL. The GNSS-tide is obtained by post-processing GNSS-data collected by an Applanix PosMV 320 system. The GNSS-data is post-processed in the software POSPac MMS. Both the POS MV and POSPac MMS are developed by Applanix. The output from POSPac is ellipsoidal heights with accuracies of 5 cm RMS and are corrected for motion and referenced to the multibeam reference point. By incorporating the DTU10 model into the process the heights will be referenced to MSL. The DTU10 model is developed by the Danish National Space Center and has accuracy within a decimetre. Comparisons with the closest water-level station will be done to ensure that the data is levelled correctly.

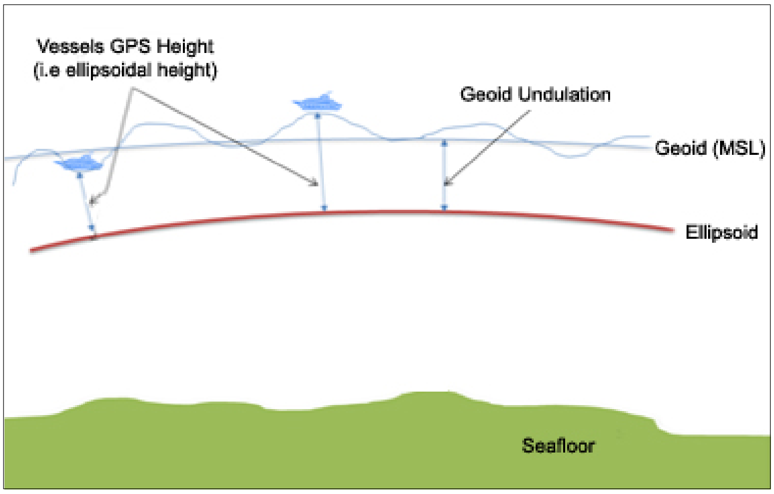


Figure 2 Overview of the tide methodology

This tidal reduction methodology encompasses all vertical movement of the vessel, including tidal effect and vessel movement due to waves and currents. The short variations in height are identified as heave and the long variations as tide.

This methodology is very robust since it is not limited by the filter settings defined online and provides very good results in complicated mixed wave and swell patterns. The vessel navigation is exported into a post processed format, Smoothed Best Estimated Trajectory (SBET) that is then applied onto the MBES-data.

The methodology has proven to be very accurate as it accounts for any changes in height caused by changes in atmospheric pressure, storm surge, squat, loading or any other effect not accounted for in a tidal prediction.

4.3. Time Datum

Coordinated universal time (UTC) is used on all survey systems on board the vessel. The synchronisation of the vessel's onboard system is governed by the Pulse Per Second (PPS) issued by the primary positioning system. All displays, overlays and logbooks are annotated in UTC. The DPR refers to UTC.

4.4. KP Protocol

KP for the survey lines were calculated with KP 0 in west, increasing eastwards but no reference to actual cable routes have been made.

5. OPERATIONAL HISTORY

The survey operations commenced on the 26th of May 2014 with the calibration of additional survey equipment on M/V Stril Explorer in Stavanger, Norway and finished on the 29th of May 2014 upon completing the work. In total, 4 working days were logged in the project.

A summary of M/V Stril Explorer's hours in Gandsfjorden is presented in Figure 3 and in Table 8 showing the distribution of all logged time during the Gandsfjorden geophysical and geotechnical survey. All involved personnel are listed in Appendix C – List of Personnel.

Upon completion of mobilisation and calibration (MAC) of additional equipment, M/V Stril Explorer started the geophysical survey in Gandsfjorden on the 26th of May. The survey was continued until the morning of the 28th of May for transit to Stavanger and crew change. Preparations for the geotechnical and video inspection survey continued throughout the morning and afternoon after which M/V Stril Explorer headed back to finish the SOW.

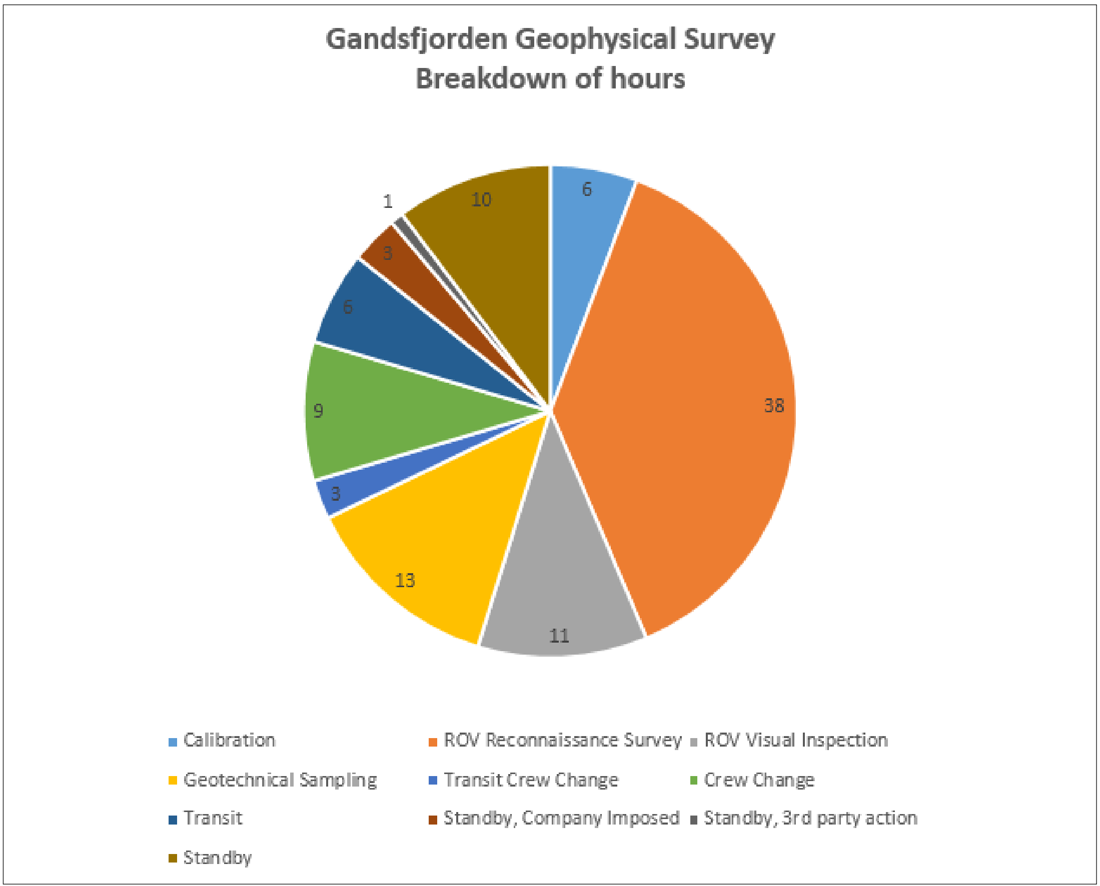


Figure 3 Breakdown of hours

Table 8 Breakdown of hours

Breakdown of hours	Total hours	Total %
Mobilisation	00:00	0
Calibration	05:00	6
ROV Reconnaissance Survey	33:15	38
ROV Visual Inspection	09:45	11
Geotechnical Sampling	11:30	13
Transit Crew change	02:15	3
Waiting on weather	00:00	0
Crew change	08:00	9
Maintenance Survey	00:00	0
Transit	05:25	6
Standby, Company Imposed	02:45	3
Standby, 3rd party action	00:45	1
Standby	09:00	10
Resurvey	00:00	0
Downtime Vessel	00:00	0
Downtime Equipment	00:00	0
Downtime ROV	00:00	0
TOTAL	**87:40**	**100**

6. SURVEY PERFORMANCE

6.1. Survey Tasks

The survey tasks are presented in Table 9. Project documentations are presented in Appendix A – Daily Progress Reports and Appendix B – Minutes of Meetings.

Table 9 Survey tasks

Task	Date	Description
6.2	2014-05-03-2014-05-10 and 2014-05-26	Mobilisation and Calibration
6.3	2014-05-26-2014-05-28	ROV Reconnaissance Survey
6.4	2014-05-28-2014-05-29	Geotechnical Survey
6.5	2014-05-29	ROV Visual Inspection

6.2. Daily Narrative

A summary of the Daily Narrative Report is given in Table 10. DPR's are presented in full in Appendix A.

Table 10 Daily Narrative

Date	Activities
2014-05-26	Arrived at the test site outside Stavanger at 08:20 and made some calibrations for the Chirp and SSS as well as verification of MBES. The trials was ready at 13:00 and Stril Explorer continued the transit in to Gandsfjorden and arrived at start position at 17:00. Starting up with a toolbox talk and survey continuing the rest of the day. Several wrecks were observed in the area.
2014-05-27	Continued the survey of main lines and finished the main lines in the afternoon. Trying to relocate the telecom cable from sss data, however only an old water pipe was found, broken and going back and forward over the area. The area was also extended south with a few lines. We also made some additional main lines in the south and some infills at the rocky area at the east landfall before midnight.
2014-05-28	Completed some infills and the cross lines in the morning. Remobilised the ROV for inspection. Changing light setup, adding cutting tools and removing the Chirp. Starting target inspection, however the ROV got entangled with a rope in one thruster and needed to be recovered to deck. The disentanglement took 1.5 hour and there was no pint to launch the ROV again before the crew change, Stril Explorer headed for the crew change and service of the crane. The geotechnical equipment was mobilised during the day. At 19:00 UTC we left the pier and headed for the survey area, arriving at 20.00. Started the gravity corer scope and continued to midnight.

Date	Activities
2014-05-29	Finished the geotechnical sampling in the morning and reriggd for inspection of targets. The target inspection did not reveal any UXO threat, at least not from the point doing cross section of the worst debris areas, i.e. the north parts. The debris seemed to be super structures and twisted steel as well as more than 10 wrecks. A possible explanation/speculation for the wrecks could be that they were deliberately scuttled by their owners and slinked at the deep part of the fjord. Possibly some rests from a cement barge that went down before (Cemcon accident) The inspection was finished at 13:30. Stril Explorer were not able to get a pier until the evening and waited on site until 16:15 and then headed for the pier, alongside 18.00 at Dusavik.

6.3. Personnel

The personnel onboard M/V Stril Explorer during the geophysical and geotechnical survey in Gandsfjorden are listed in Appendix C.

6.4. Mobilisation and Calibrations Test

Mobilisation and Calibration (MAC) tests were performed in the fjord out of Kristiansand, Norway between the 3rd and 10th of May 2014. The mobilisation was successful and the performance of the equipment was accepted. Result of the MAC is presented in document 101655-STN-MMT-MAC-REP-STRIL. The MAC tests were conducted prior to start of the previous project, the protection survey for the Skagerrak 4 cable (MMT project ID 101655). Prior to start of Gandsfjorden survey a calibration was conducted for chirp and SSS as well as verification of MBES. The results of this calibration and verification were checked and accepted onboard.

The MAC test procedures are presented in a separate document 101655-STN-MMT-MAC-PRO-STRIL-02. This document details the calibrations and verifications performed on the equipment used in the project. The verification of the SSS and the SBP is presented in Appendix J.

The MAC procedure is considered a quality calibration test of all survey instruments, according to ISO 9001:2008 (SS-EN ISO 9001:2008 - section 7.6 - Control of monitoring and measuring equipment).

6.5. Geophysical Survey

The geophysical survey included MBES, SSS, SBP (Chirp) and visual target inspection.

The initial processing and interpretation of the results were performed on board M/V Stril Explorer while remaining processing and finalising of the report and deliverables were performed at MMT office, Sweden.

6.5.1. Survey Parameters

The survey parameters that were used during the Gandsfjorden geophysical survey are presented in Table 11.

Table 11 Survey Parameters

Item	Setting
Survey speed	0.5-1.5 knots
No. Of survey lines	14 main lines, 2 cross lines
Line spacing	50 m
Total Survey length	24 km
Side scan sonar range	75 m
ROV Altitude	10 m
MBES data coverage	Minimum 100 %. 0.2 m grid size
Visual	On selected SSS contacts

6.5.2. Multibeam Echo Sounder

A dual head R2Sonic 2024 (200-400 kHz) MBES was mounted on the ROV. This was mobilised and verified prior to the previous project. The survey was performed to cover the survey area with minimum 100% overlap between the MBES survey lines and to make a grid with 0.2 m grid size. Due to the seabed morphology of the area full coverage was not achieved over some of the major bedrock outcrops. This was deemed acceptable by the client, based on the purpose of the survey.

6.5.3. Side Scan Sonar

Prior to start of the geophysical survey in Gandsfjorden an Edgetech 4200 (300/600 kHz) SSS was mobilised, mounted on the ROV, and the function verified. The survey was performed to achieve full cover of the survey area and the range was set to 75 m to achieve full overlap of data. The data was used for verifying the seabed sediment and for detection of objects and other obstructions. The SSS provided detailed high resolution data throughout the surveyed area.

6.5.4. Sub-bottom Profiler (Chirp)

An Edgetech DW106 (1-6kHz) chirp was mobilised and mounted on the ROV before commencing the geophysical survey in Gandsfjorden. Data was collected along all survey lines to achieve an understanding of the sub seabed conditions. The focus was to map the upper 10 m of sediment. The chirp provides high resolution data of the upper portion of the sub bottom sediment.

6.5.5. Camera and Light

The camera set up in the original scope was three wide angle (85º (H) x 50º (W) x 95° (D)) Deep Sea power multi cam HD cameras, one mounted in the centre and one on each boom arm. One of the cameras was broken and in order to keep the symmetry the centre cam was replaced by a 70° HD camera.

The additional light set up was three APHOS 16 LED lights, 28000 lumen and 5700 K. One of the light covers the centre and the other two are directed for best use of the boom cameras. The strong lights caused occasional spots bleaching out the image. However the scattered light with the combination of wide angle lens gives a possibility to observe objects on the side of the bleached out regions for most parts of the survey. Diffusors were added on the LED lights, which improved the lightning somewhat. Gas lights were also added to the ROV during suvey to be used simultaneously with the original light set up to decrease the bleached out areas and to increase the visibility.

6.6. Geotechnical Survey

The geological samples were collected using a 3 m long gravity corer and a ROV push corer. The sample sites were selected based on the geophysical survey results and in agreement with the Client.

The samples from the gravity corer were sent to the NGI laboratory for geotechnical analyses while the samples achieved with push corer was sent to ALS laboratory for chemical analyses.

6.7. ROV Visual Inspection

A visual target inspection was performed on selected contacts from the SSS and MBES data.

7. VESSEL

The vessel M/V Stril Explorer is shown in Figure 4 and a short summary of vessel specification are given here.

Figure 4 M/V Stril Explorer

Port of Registry:	Douglas
Flag:	Isle of Man
Call sign:	2EBI9
Class:	Det Norske Veritas + 1A1 General cargo Carrier EO-HELDK-S-DYNPROS-AUTR
Builder:	Westcon, Norway
Date of build:	2010
LOA:	76.4 m
Draught:	4.75 m
Machinery:	4xCat 3516
Service speed:	10-12 knots

For detailed vessel specifications, see Appendix D.

8. EQUIPMENT

Below is a summary of the vessel equipment and the instruments used during the geophysical and the geotechnical survey.

Navigation and Positioning

- Primary Positioning: Applanix POS MV 320 with C&C C-Nav 3050 using RTG corrections
- Secondary Positioning: Fugro Starpack with Starfix XP and HP corrections
- Primary Gyro and INS Applanix POS MV
- Secondary Gyro and INS CDL MiniPOS 3
- Underwater positioning Kongsberg HiPAP 501
- QPS QINSy navigation survey system

Sound Velocity

- Sound Velocity Valeport Mini SVS, hull-mounted at transducer
- Sound Velocity Valeport Mini SVS, mounted on ROV
- MMT Moving Sound Velocity Profiler - Valeport SVX2

Geophysical Hull Mounted Equipment (Optional)

- Multibeam Echo sounder - Kongsberg EM2040D (200, 300, 400 kHz)

ROV Equipment Work-Class ROV Kystdesign Supporter

- Primary Gyro and INS IXSEA ROV INS
- Sound Velocity Sensor - Valeport miniSVS
- CTD probes - Valeport miniCT
- Pressure gauges – Valeport IPS 0.001 %
- Obstacle Avoidance Sonar Blueview P900-130
- Altimeter – Tritech PA500 (500 kHz)
- DVL - LinkQuest NavQuest microDVL (600 kHz)
- Multibeam Echo sounder – Dual R2Sonic 2024 (200-400 kHz)
- Side scan sonar - Edgetech 4200 (300/600 kHz)
- Sub-bottom profiler Chirp Edgetech DW-106 (1-6kHz)
- Underwater lasers for dimensioning of objects dual Sealaser 100 with bracket
- Manipulators – Schilling T4 and Rigmaster
- Boom Arms
- Cameras – 3x DSPL HD Multi SeaCam
- LED flood lights – 4x CATHX APHOS 16, 28000 lumen
- LED flood light - - 2x ROS Q-LED III 3500 Lux
- LED spot light – 4x ROS MV LED 890 Lumen
- SSBL transponders Kongsberg MST319

Geotechnical Sampling

- Gravity corer 3 m
- ROV Push corer – Elkins EE-PC-2 0.48 m

For full specifications and details, refer to Appendix E.

9. METHODOLOGY

9.1. Positioning and Navigation

The primary positioning system is Applanix PosMV320 with multiple reference sources. C&C C-Nav 3050 providing Real-Time “Gipsy” (RTG) corrections with an accuracy of 0.1 m RMS in the horizontal plane is the primary source.

The Applanix POS MV also collects raw observables, which can be post-processed with POSPac and generate accuracy of 0.05 m RMS. As a summary three different methods are used by the primary positioning system to ensure the quality of the position data:

- C-Nav 3050 (RTG)
- DGPS
- POSPac post-processed positioning.

The secondary positioning system is Fugro Starpack using XP and HP corrections, which provides a horizontal accuracy of 0.1 m RMS.

Both positioning systems are operated according to the IMCA-OGP 'Guidelines for GNSS positioning in the offshore Oil & Gas Industry'.

9.1.1. Primary Positioning System Pos MV 320 with C-Nav Corrections

Applanix POSMV 320 systems are installed on all of the MMT vessels. The POS MV 320 system represents the state of the art in precise, real time, dynamic positioning and orientation technology. POS MV is a user friendly, turnkey solution that fully integrates Inertial and GPS sensors to provide an accurate reference for attitude, heading, heave, position, and velocity. POS technology was originally developed and rigorously tested as part of an extensive helicopter navigation project. The performance of POS MV 320 has been proven in trials with various national hydrographic offices and commercial survey organisations.

MMT have developed techniques using the Applanix POS MV system, which has meant that the actual water line on the vessel can be almost dispensed with. The distance from the waterline to the transducer is required so that the post processing software applies the sound velocity refraction correction properly, but beyond that, the techniques that we use can be used in the same way on an aircraft. The Applanix POS MV records all data with a height above the ellipsoid. The Applanix POSPAC MMS software creates a smoothed best estimate (SBET) file that is accurate to approximately 5 cm in x, y and z. This is then applied to the MBES data and the depths reduced to chart datum by applying a height model.

The C-Nav 3050 is a dual frequency GNSS receiver with 66 channels, which tracks all GPS, GLONASS and Galileo satellites in view. For corrections, the C-NavC¹ and C-NavC² services are utilised.

9.1.2. Secondary Positioning System Fugro Starpack

The GNSS dual frequency receiver has 72 channels capable of tracing all GPS, GLONASS and Galileo satellites in view. In order to achieve an accuracy of 0.1 m RMS the receivers uses the XP Skyfix XP and HP corrections. The status of the positioning solution is monitored both by the QINSy (Quality Integrated Navigation System) navigation software and through the web interface of the receiver, which provides extensive control and QC functionality.

9.1.3. QINSy Navigation Software

QINSy is a hydrographic data acquisition, navigation and processing software package. The suite of applications can be used for various types of surveys, ranging from simple single beam surveys up to complex offshore construction works.

An array of real-time quality assurance tools and displays are available to the online surveyor who is constantly monitoring the performance and validity of the connected sensors. Different examples of automated checks are detailed below:

- Time synchronisation
- Time out of incoming data
- Comparison between positioning systems, gyros, MRU:s etc.
- Positing status e.g. Fixed RTK, Float RTK, aided GPS etc.
- Difference between sound velocity (SV) sensor at sensor carrier and SV profile

9.2. Underwater Positioning

The underwater position of the ROV is obtained by a full INS system combining and weighting the input from various types and sources.

A schematic view of the underwater positioning system is shown in Figure 5. The iXSEA ROV INS as a central unit receives and records data from a number of sources. Each individual data type is there after stored within one binary file, which through post processing in the iXSEA Delph INS software may be individually prioritized depending on observed accuracy.

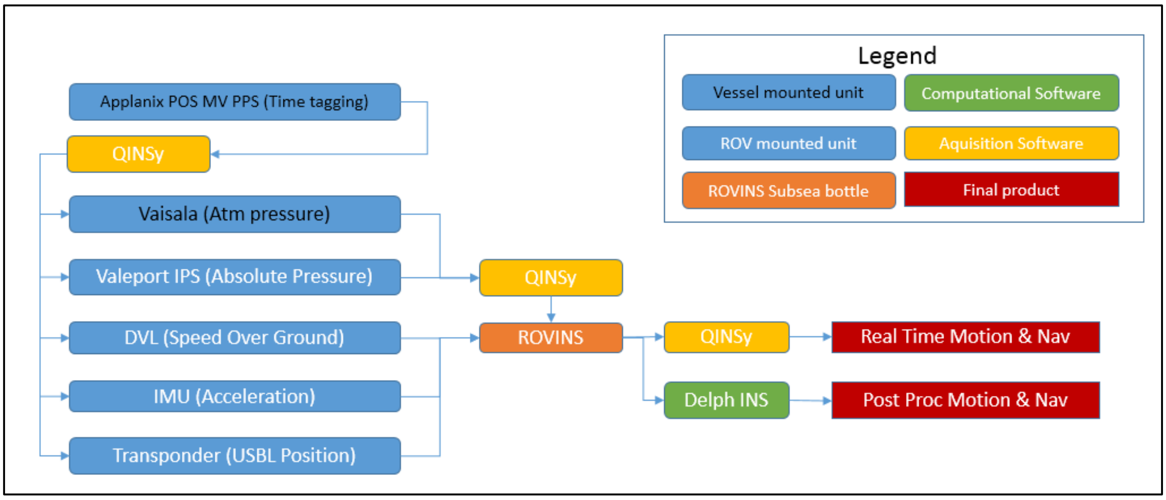


Figure 5 Schematic view of the underwater positioning integration.

The components integrated into the INS system are the following.

- Underwater positioning Kongsberg HiPAP 501
- Primary Gyro and INS IXSEA ROV INS
- Pressure gauge – Valeport IPS
- DVL - LinkQuest NavQuest microDVL (600 kHz)

In addition, a vessel mounted Vaisala Weather station continuously monitors the atmospheric pressure. This is then subtracted from the continuous pressure readings made by the Valeport IPS on the ROV, and thereby a correct pressure at the depth of the ROV is obtained. This is converted to depth and fed to the ROVINS system.

9.3. Time Synchronisation

UTC is used on all survey systems on board the vessel. All systems are synchronised to this time reference system. The synchronisation of the vessel's onboard system is governed by the Pulse Per Second (PPS) and the time tag provided in the ZDA-message which are both sent from the primary positioning system Applanix PosMV320. Synchronisation is checked by the QPS QINSy navigational software. The system alerts if the clock times are unsynchronised. The assigned surveyor is responsible for monitoring the alarms.

9.4. WROV Kystdesign Supporter

The WROV system is equipped and designed to meet all requirements for subsea construction and intervention services, in addition to full survey interface and capabilities. From the delivery of the first Installer in 2002 the number of operating Installers and Supporters has reached 25 systems. A majority of the systems are operating in the North Sea. The ROV technology is refined from years of operational and “hands-on” experience by the designers at Kystdesign.

The ROV, operations and personnel are fully compliant with NORSOK Standard U-102 ROV Class IIB.

The Supporter ROV has an excellent track record as a stable system.

The LARS system is a Sepro HPL 15.

9.4.1. Short specifications - Supporter WROV

Depth rating	2000 msw
Mass	2450 kg
Length	2500 mm
Width	1700 mm
Height	1650 mm
Through-frame lift	3000 kg
Payload in seawater	220 kg
Power	125 Hp
Thrusters	4 x horizontal, 3 x vertical
Speed forward	3 knots

Figure 6 Supporter ROV

9.5. R2Sonic 2024

The Sonic Broadband / Wideband Multibeam Echo Sounders are the world's first true wideband high resolution shallow water MBESs. With proven results and unmatched performance, the Sonic systems produce reliable and remarkably clean data with maximum user flexibility through all range settings. The unprecedented 60 kHz signal bandwidth offers twice the resolution of any other commercial sonar in both data accuracy and imagery.

With over 20x selectable operating frequencies to choose from within the 200 to 400 kHz band, the user is not limited by two or three operating frequencies and thus can trade off resolution and range and effectively control interference from other active acoustic systems.

In addition to the selectable operating frequencies, Sonic systems provide variable swath coverage selections from 10° to 160° on the fly, in real-time and across all frequencies from 200 to 400 kHz. The operator may also rotate the sector to precise location either port or starboard side of the survey platform.

9.6. Video and Lights

MMT are experienced in using HD cameras on ROVs and in order to achieve the best results the complete chain must be considered. A number of critical items have been identified and addressed:

- Camera quality and settings
- Sufficient and evenly distributed illumination
- Digital transfer of the signal
- HD-recording with optimal settings

The wide angle HD cameras are mounted on separate pan and tilt units in the ROV frame in order to be able to adjust the view independently. It is critical to achieve an evenly distributed high intensity illumination this is performed by using a combination 4+2 LED flood lights and 4 LED spot lights all of which are can be controlled independently. The total continuous light power output of the lights are in excesses of 100 000 lumen. The signal is transferred by HD-SDI to a Visualsoft HD recorder.

9.7. Side Scan Sonar

The SSS images are used for mapping the seafloor morphology and detection of obstacles.

The SSS have been used to detect and position obstacles and structures on the seafloor as well as geological conditions. The seabed is interpreted into units and colour-coded in the survey charts for easy recognition during the planning and installation phases.

An Edgetech 4200 dual frequency (300/600 kHz) MP was used during the project.

9.8. Sub-bottom Profiler

The SBP data is used for interpretation of the geology below seabed surface. The Edgetech DW-106 (1-6 kHz) chirp sub-bottom profiler is very well suited for the purpose of the project, which was to map the upper meters of sediment.

9.9. Geotechnical Sampling

A 3 m long gravity corer based on the Kullenberg principle was used for geological sampling. When sample recovery was less than 70 % of core barrel length a second attempt was made at the same location.

10. DATA PROCESSING

Within the MMT Quality Assurance system, there are workflows for all processes in an MMT project. The flows explain the process, show where the QC will be done and are easy to follow. Together with the MMT Quality Control System (QCS), the process flow makes it easier for the project personnel to keep track of the data and the quality checks along the flow line.

MMT procedures will guarantee that all collected data are QC checked and that data processing and evaluation is conducted with the experience gained during previous surveys. First priority for the off-line personnel during the field operation is to check data quality and survey coverage for the incoming data.

After completion of fieldwork, the final processing and chart production is performed at MMT office in Gothenburg, Sweden. This work includes finalisation of charts and the production of the Final reports.

10.1. INS Data

On the occasions where the realtime solution as provided by the IXSEA ROV INS does not fulfil the required specification or if for any other reason the need for post processed subsea navigation should arise, the IXSEA provided software Delph INS may be used.

The data acquired by the INS (Inertial Navigation System) is logged at all times during subsea activity. By using an integrated solution where each sensor is logged with the same timestamp in one file but with separate handles, it is possible through post processing to alter the weight of each individual input parameter as per need.

Data Analysis and Processing

The ROV INS logged data is imported into Delph INS where each of the input sensors are plotted over time. By comparison between the MBES data based on the realtime solution and the sensor data as seen in Delph INS, deviations and biases are confirmed. The reason for the navigation drift decides what action to take prior to processing the data again.

With the findings from the analysis, the USBL input is assigned a temporary higher standard deviation during the periods of biased real time data. The Delph INS software is then set to perform a combined process where a forward and a backward process are both combined into an integrated solution.

This final post-processed solution is then exported using the common format of SBET.

Application

The final post-processed solution (SBET) is applied to the data in QINSy (ROV track) and in Caris HIPS (MBES). The MBES data receives the updated navigation within the Caris HIPS software without loss of previously executed data cleaning for example. The updated ROV track data is exported from QINSy and imported as .etr and .pip into the terrain model in NaviModel. The Video events are thereafter updated by applying the new ROV track onto the eventing program Visual Soft.

10.2. Bathymetry Data

The MBES system shall include full quality control and data processing facilities capable of statistical analysis, production of Digital Terrain Models (DTM). Soundings are corrected and compensated for the variations in sound velocity, tide, ray bending, and other environmental / atmospheric effects and referenced to the survey vertical datum. Figure 7 displays the workflow and quality check procedures during the MBES-data processing for both hull mounted and ROV-mounted MBES units.

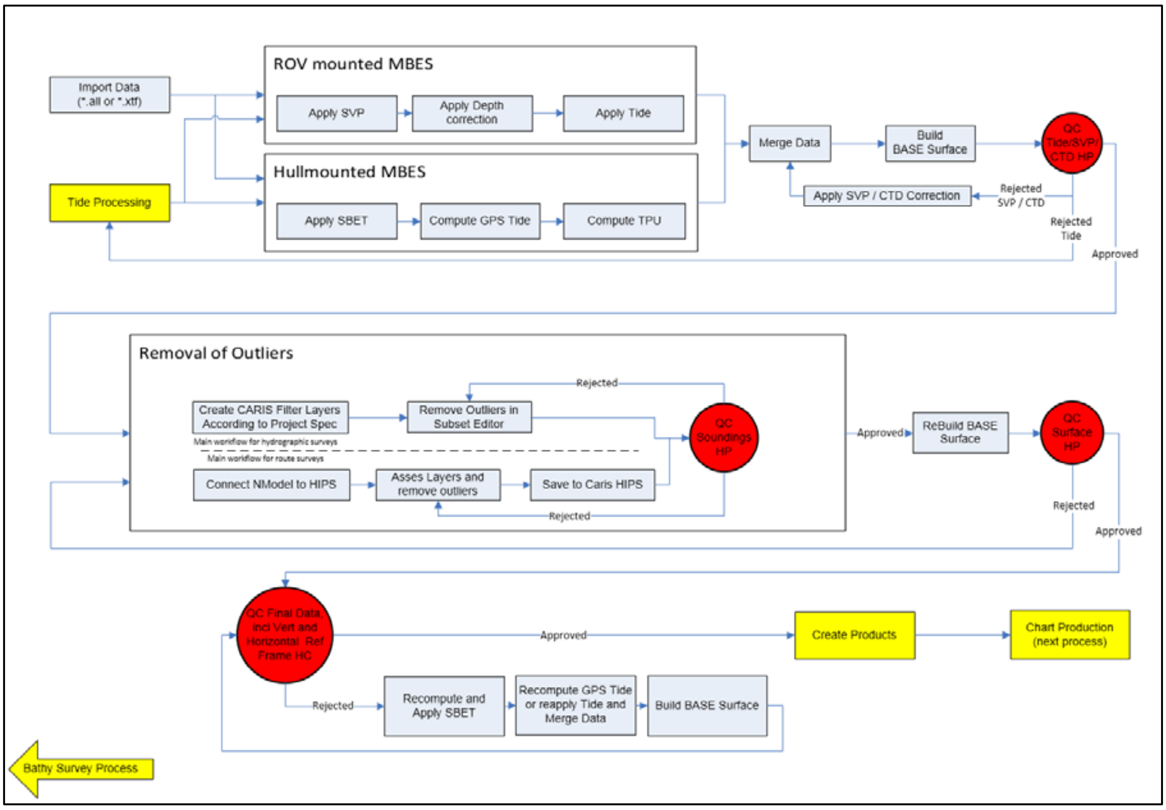


Figure 7 Workflow and QC during MBES data processing
The steps are valid for hull- and ROV- mounted MBES

The red circles indicate a QC check during a MMT MBES survey. The Project Manager has the overall responsibility to assure that the Quality checks will be performed with the right intervals and with a high reliability.

Post processing will be performed using three different software packages, Caris HIPS, Eiva NaviModel and QPS/IVS Fledermaus.

CARIS HIPS & SIPS is used for:

- Application of sensor and vessel altitude correction
- Application of SBET for a height derived heave
- Sound velocity and CTD correction
- Tidal reduction
- Peripheral sensor editing
- Computation of TPU (Total Propagated Uncertainty)
- Creating Base surfaces for initial visual QC

Eiva NaviModel is used for:

- Final assembly of data
- Sounding validation, de-spiking and data editing
- Verification of sounding accuracy and data density
- Applying corrections back into HDCS files

- Creating contours and Geotiffs
- Pipeline digitizing (if applicable)
- 8 point list

QPS/IVS Fledermaus is used for:

- Processing of backscatter data (FMGT)

Data Cleaning

The primary methods for cleaning the data will is NaviModel where the point editing, histogram cleaning and SCALGO filter may be implemented on the dataset, and in Caris HIPS where the CUBE filter algorithm may be used when applicable as well as manual point editing.

The depths of bins over wrecks and shoals are manually forced to the shoalest soundings if applicable. A shoal-biased grid is also created and the two surfaces shall be checked for conformity.

Quality Control

Both Caris HIPS & SIPS and Elva NaviModel allows the surface to be coloured by a number of different attributes such as standard deviation, sounding density, uncertainty, checked status and modified status. The colouring can be tailored to specific tolerances to ensure, instantaneously, whether the specifications have been met.

Re-application of Tidal Data, Sound Velocity and System Offsets

The data logged by the acquisition system is completely raw. This allows the surveyors to be able to change system offsets, apply new sound velocities and tidal correct the data. Sound velocity is applied on a nearest time basis unless there is spatial as well as temporal distribution, in which case it will be applied on a nearest distance constrained within a certain time basis.

10.3. Side Scan Sonar Data

The SSS processing is made with the following main objectives:

- Detection of contacts (in this project 0.25 m x 0.25 m and bigger)
- Detection of cables and pipelines
- Identify man made features, such as trawl scars, interventions, ropes, wires or other debris.

General Processing and Creating Mosaics in SonarWiz

- The .jsf files are continuously loaded into SonarWiz5 with appropriate file type specific settings (TVG retrieved from Discover). The appropriate settings are determined during the mobilisation and calibrations.
- The data quality is checked. If the data quality is not accepted, OM is alerted.
- The navigation is checked and, where necessary, smoothed and spikes are removed. The check includes verification against the MBES data to conclude consistency.
- The bottom track is automatically tracked and then, if needed, adjusted manually.
- The coverage is checked for navigation gaps, overlap and data loss. If any, OM is alerted. QC of this step is performed by another geologist than the one performing the original task.
- Offset from survey line is checked.
- The settings are fine-tuned to optimise for mosaicing and contact identification.

- Each file is exported as geoPNG.
- Tracklines are exported as .shp (single polyline per file).

Classification of Contact Identification

The following criteria are used:

- Wrecks
- Man-made objects
- Boulders >0.25 in any dimension

Selecting Contacts in SonarWiz

- The .jsf files are run in digitising mode and contacts are selected according to specifications. The contact is measured, classified and zoomed appropriately. Special attention is made to wrecks/cables or archaeologically interesting objects. Cables and linear features are also digitised on screen.
- The contacts are correlated to bathymetry on screen.
- QC of the contacts and correlation to bathymetry is performed by another geologist than the one performing original processing.
- A contact list of all accepted contacts is created.
- QC of the contact list is performed by the Report Coordinator or Senior Geologist.

Digitising Seabed Sediment Classifciation and Features in SonarWiz and AutoCAD

- Mosaics are created. The mosaic geoPNGs and, if any, .dxfs are inserted into AutoCAD.
- The seabed sediment type and features are interpreted and digitised on screen from the mosaic geoPNGs in AutoCAD.
- Seabed features, such as ripples and dunes, are identified and approximate size and transport direction are recorded.
- The seabed features are correlated to bathymetry, sub-bottom data and seabed sampling results.
- QC of the interpretations is performed by Report Coordinator or Senior Geologist.

10.4. Sub-bottom Profiler Data

Processing in SonarWiz

- The .jsf files are loaded into SonarWiz5 with appropriate file type specific settings (TVG retrieved from Discover). The appropriate settings are determined during the mobilisation and calibrations.
- The navigation is checked and, where necessary, smoothed and spikes are removed.
- The bottom track is automatically tracked and then, if needed, adjusted manually.
- The coverage is checked for navigation gaps, overlap and data loss. QC of this step is performed by another geologist than the one performing the original task.
- The settings are fine-tuned to optimise display for digitising.
- All visible horizons are digitised and interpreted on screen, after which they are correlated to the adjacent files for consistency in interpretation.
- Correlation is made to surface interpretations and seabed sampling results.

- The data curtains, with appropriate gain settings and resolution, are exported into a PNG format for use in the GIS database.

10.5. ROV Visual Data

General Processing

All video files are continuously being auto-copied from the online system to an offline server which is accessible from the VisualSuite computer. Positioning, video overlay and quality are checked. Accepted data is then being reviewed. A project specific VisualSuite script is run to recalculate event positions and KP’s if necessary.

Inspected contacts are described and images are exported for the contact list.

If required the survey track along with events are exported as ACSII files for further visualisation in either NaviModel or/and AutoCad.

11. RESULTS

Gandsfjorden is a silled fjord between Sandnes and Hillesvågneset. The surveyed area of the fjord has a maximum water depth of 243 m. The sill restricts the exchange and renewal of deep waters.

The seabed on the western side of the fjord slopes very steep (> 15°) down towards East with water depths ranging from approximately 9 m to 237 m. The seabed sediments in this interval comprises mainly silty, sandy CLAY. BEDROCK outcrops are observed, often surrounded by DIAMICTON. The soft sediment cover, where present, is often less than 1 m thick, but pockets with thicker layers occur. Several scars are observed on the western slope, inferred to be anchor scars.

In the bottom of the fjord, the seabed is flat and smooth with water depths ranging around 235 – 243 m. The seabed sediments comprises thick beds, up to 40 m, of silty CLAY and in the central parts, a large area with numerous wrecks and other debris are observed. Multiple scars, probably trawl scars, are observed on the seabed in this section.

On the eastern slope of the fjord, the seabed generally slopes very steeply with water depths ranging from approximately 230 to 17 m. The seabed sediments comprises silty, sandy CLAY with high frequency of BEDROCK outcrops, especially along survey line M250, where almost the entire section is a large BEDROCK outcrop. The sediment cover, where present, is generally less than 1 m thick.

11.1. Data Quality and Interpretation Accuracy

At times positioning drift was detected in the data during the survey this was a result of a drifting C-Nav solution due to a malfunctioning C-Nav receiver. By assigning the USBL input a lower weight than the live weight, the solution could be improved.

The survey lines were separated by 40 m and if full coverage was not achieved by either the SSS or the MBES, often due to the steep slopes and bedrock outcrops which made the survey at some sections complicated, extra infill lines were run. There are small data gaps in the MBES data in these steep sections, but it was decided onboard the vessel that there was sufficient data and it was not worthwhile time wise.

The coverage and resolution of the acquired MBES data allowed producing a 0.2 m DTM, with a mean of 14 soundings per grid cell. The MBES footprint is illustrated in Figure 8. Multiple wrecks and man-made objects as well as many scars in the seabed are visible in good detail. Steep slopes in the eastern part of the fjord presented a challenge for steady flight of the ROV and affected the stability of the acquired data. Thanks to several infill passes recorded from a higher altitude, gaps in the crucial areas were filled in.

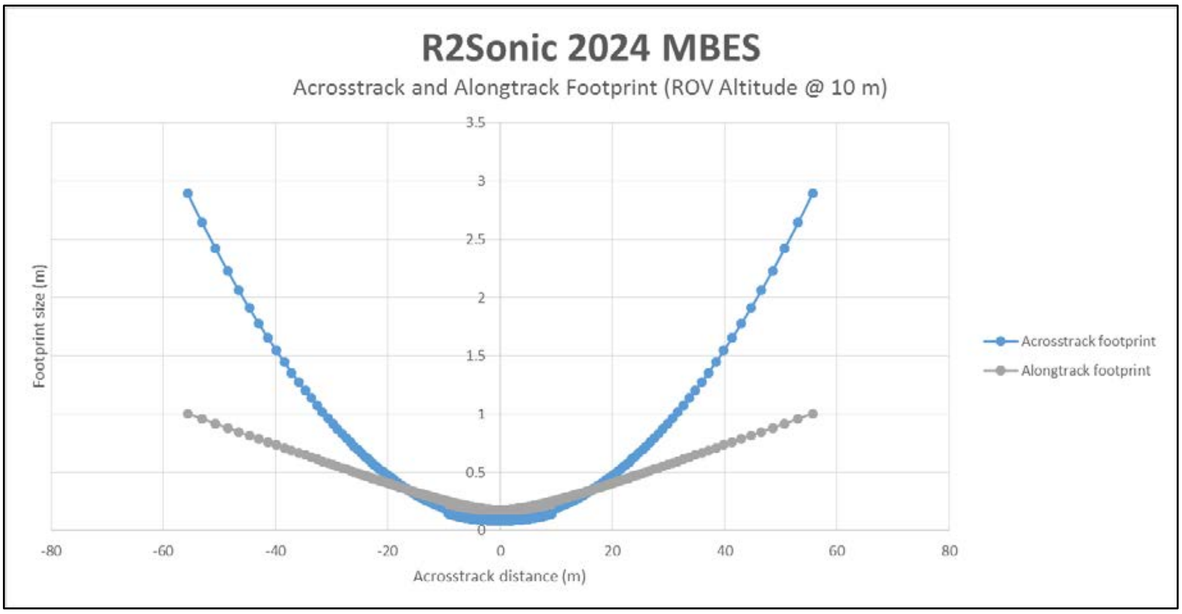


Figure 8 The MBES footprint at a height of 10 m above seabed.

The SSS data was of good quality, however the difficulties of survey operations within fjords, resulting from almost vertical fjord walls, did present themselves in the SSS data. Protruding outcrops causes shadows to obscure portions of the data, however in these instances the information is present in the adjacent survey lines. The correlation between SSS and MBES is very good, however at some instances objects and wrecks may seem to be offset between the data sets. This is considered to be due to the differences in methodology, as with the SSS the angle with which the signal is reflected from an object influences the imagery. In these instances the MBES positions are considered to be the most relevant. The SSS coverage in the survey corridor is illustrated in Figure 9.

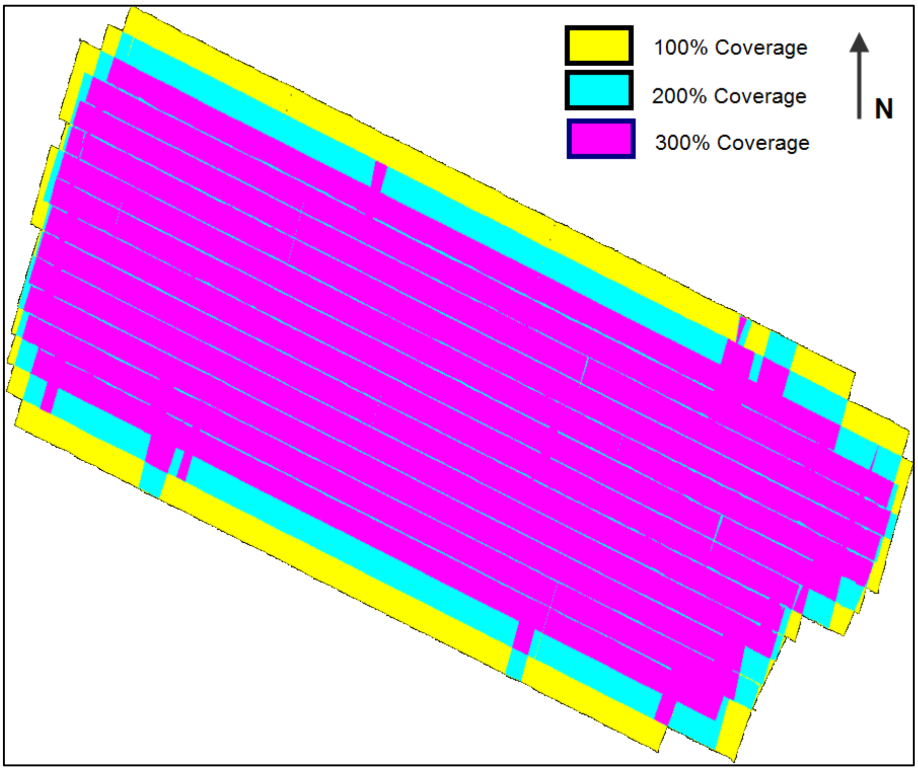


Figure 9 The SSS coverage in the survey corridor

The SBP data was generally good and achieved excellent penetration, up to 40 m in clay sediments. The theoretic resolution for the SBP used is approximately 0.2 m. The seabed reflection and the uppermost portion of the data is somewhat diffuse due to the extremely soft sediment.

The quality of the video during visual target inspection was dependent on several factors; the nature of the seabed, the light from the ROV and the clarity of the water column. When good conditions were present the quality of the video was good.

Gravity corer operations were relatively successful however it was challenging to fulfill core length recoveries of over 2 m. A second attempt was performed at four of six locations. The push core sampling from the ROV was successful.

11.2. Geophysical Survey

11.2.1. Sound Velocity Profiles

In total four sound velocity profiles (SVP) were acquired during survey operations in Gandsfjorden. The diagram below indicates a relatively well mixed water column with a pycnocline visible at a depth of approximately 30 to 40 m.

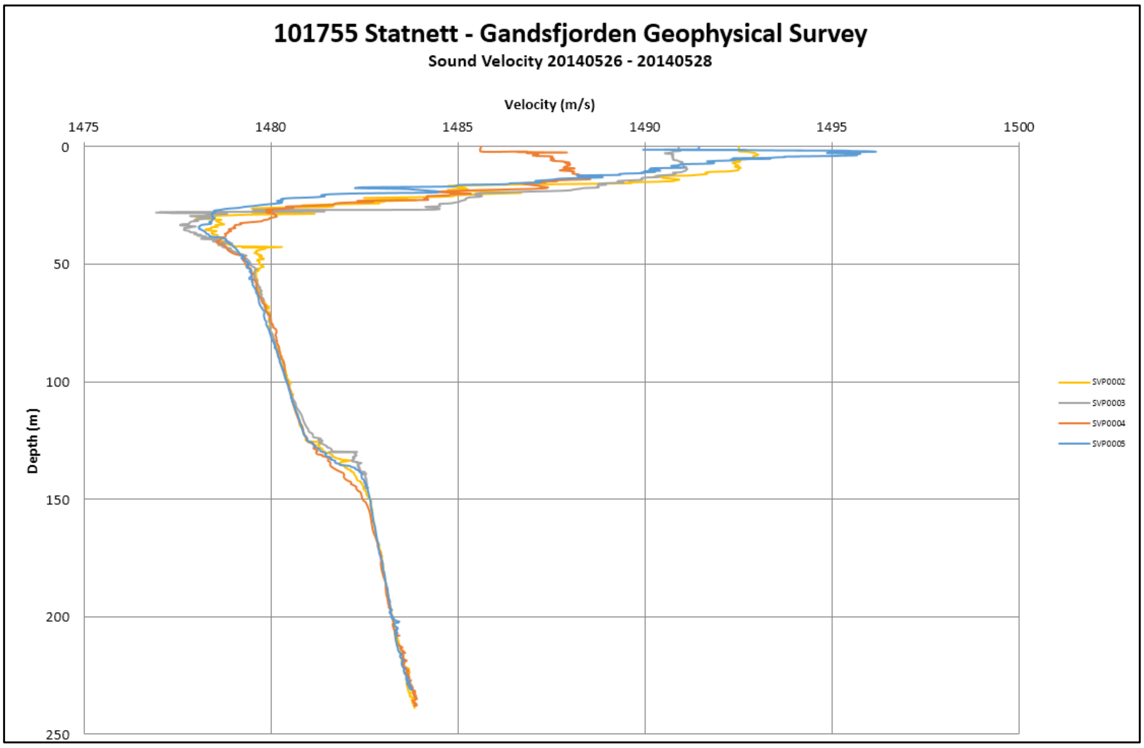


Figure 10 Sound velocity diagram displaying SVPs acquired in Gandsfjorden

11.2.2. Bathymetry

The water depth in the surveyed area of Gandsfjorden spans from 10 m on the western and eastern edges of the fjord, to a maximum of 243 m in the middle part. Slopes on both sides reach steepness of up to 40 degrees. The western side descends at a more even rate with a flat plateau present at approximately 50 m water depth. On the east side, multiple rock outcrops are visible. Figure 11 shows a bathymetry overview of the surveyed area.

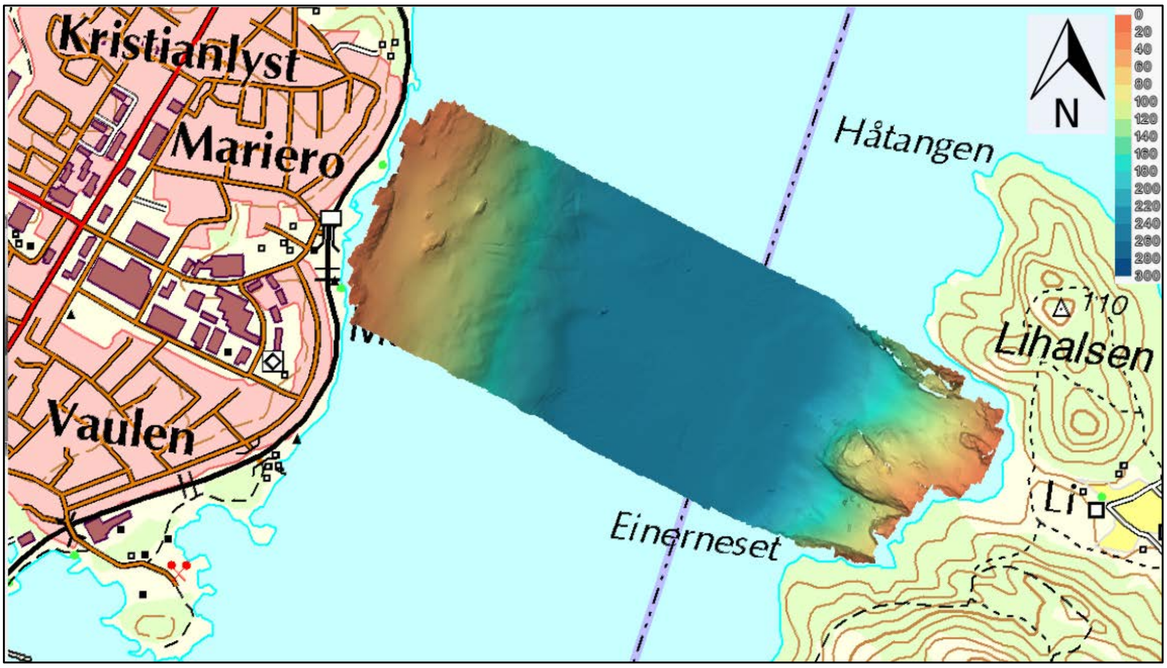


Figure 11 Overview of the bathymetry in the survey area in Gandsfjorden

Along the western extent of the surveyed area, rough seabed due to outcropping bedrock is dominating out to approximately 50 to 100 m from the shore at a water depth of 10 to 40 m, however in between outcrops smoother seabed surface with gentler slope is present (Figure 12). The southwest shows smoother surface and gentler slope than the northwest and has numerous of pronounced seabed scars, probably caused by anchoring. (Figure 13). The central part of the fjord is very flat with depths around 240 m. The eastern slope is generally rougher. A very pronounced outcrop dominates in the central of the eastern extent of the survey area (Figure 14); however, on the sides of this outcrop gentler slopes towards the shore are present.

In the deepest part of Gandsfjorden seabed scars and an area of debris are visible. Some of these objects consist of longitudinal shaped poles sticking straight up from the seafloor (Figure 15 and Figure 16). In addition some rectangular shaped seafloor depressions can be seen in this area (Figure 17 and Figure 18).

Furthermore a total of 11 wrecks and/or larger objects have been detected and confirmed by visual inspection, see section 0.

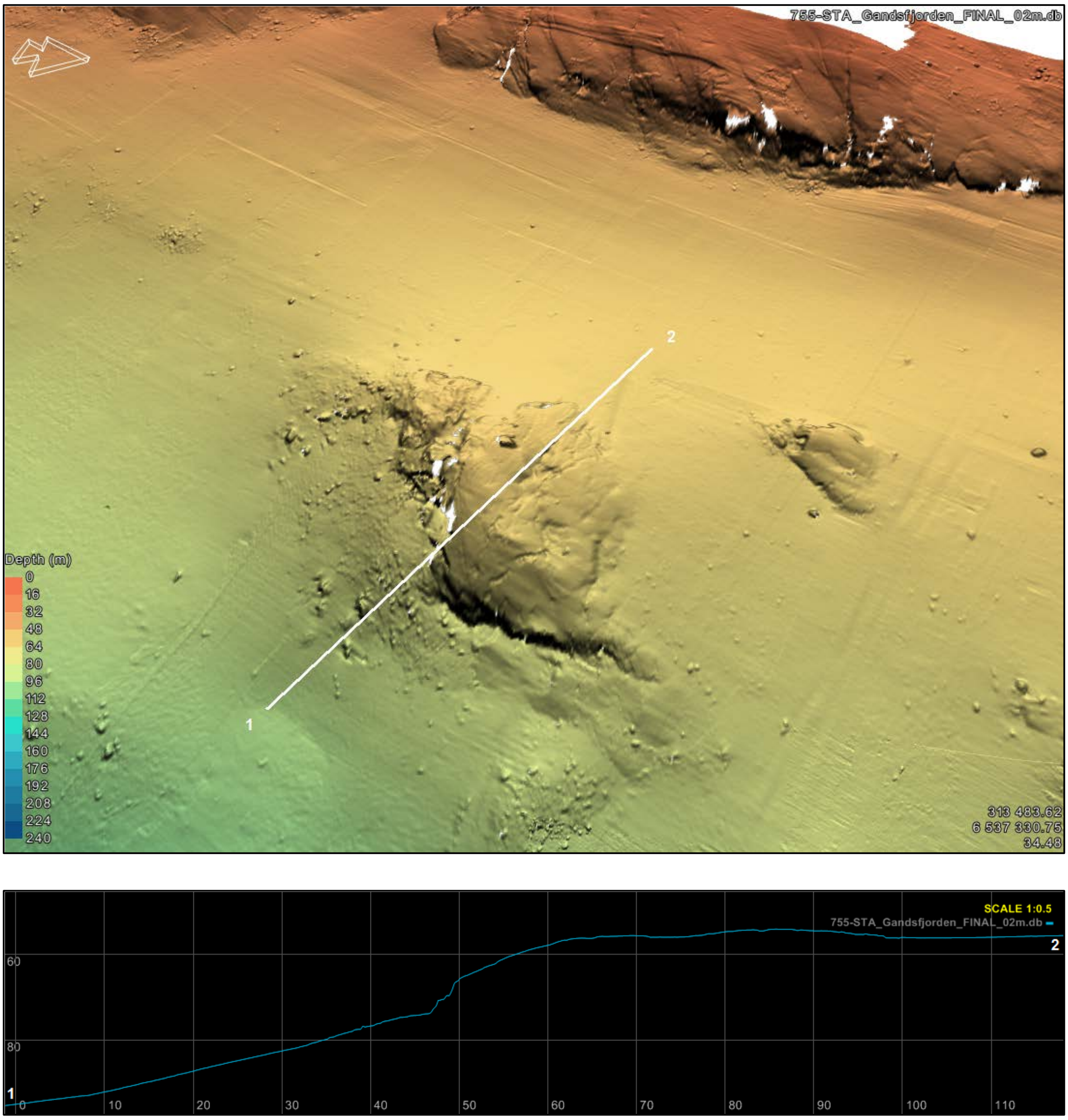


Figure 12 Bathymetric image and profile across rock outcrop on western slope (Heading 258 deg, Pitch 47 deg).

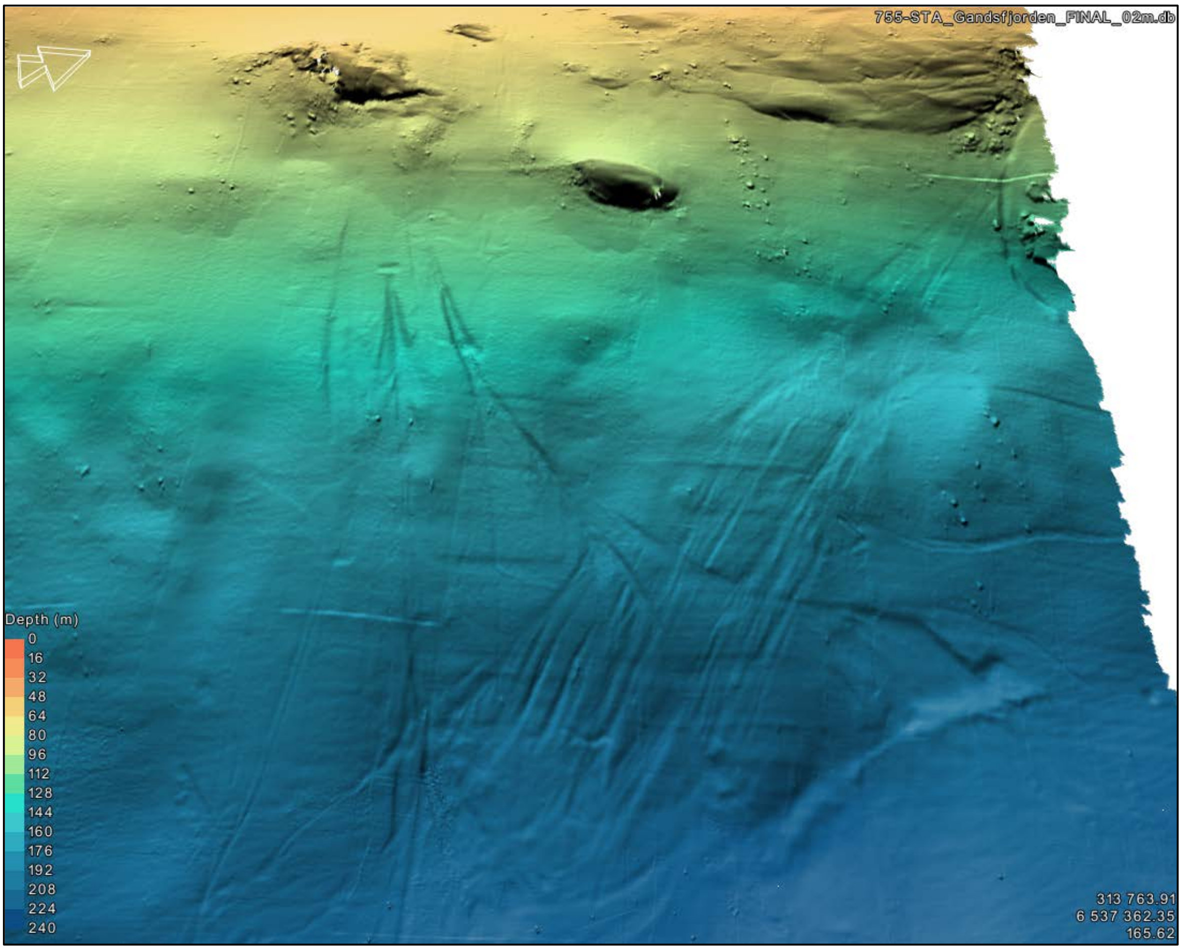


Figure 13 Bathymetric image showing scars on the western slope.
The scars are believed to be caused by anchors.

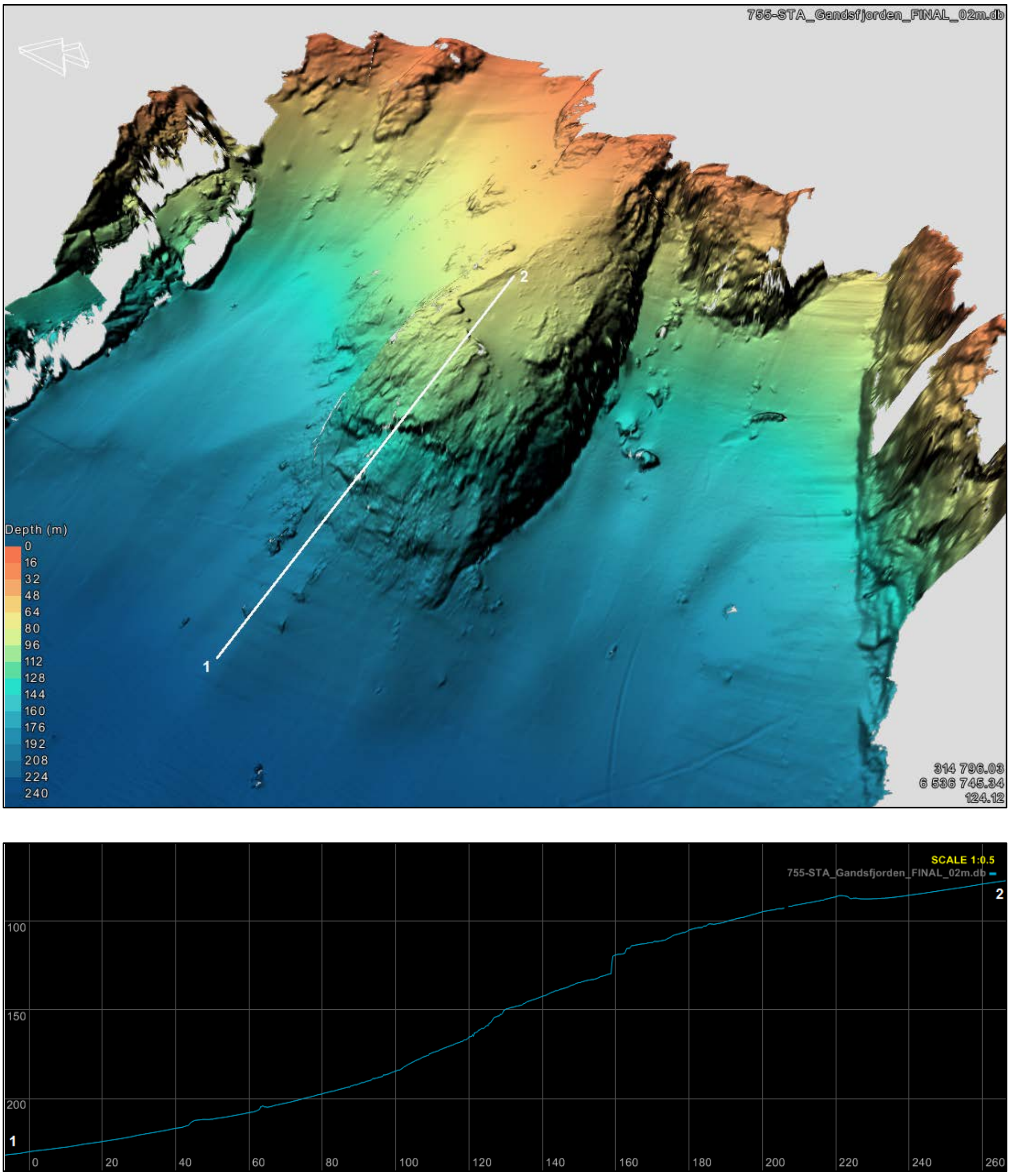


Figure 14 Bathymetric image and profile across rock outcrop on eastern slope (Heading 85 deg, Pitch 54 deg).

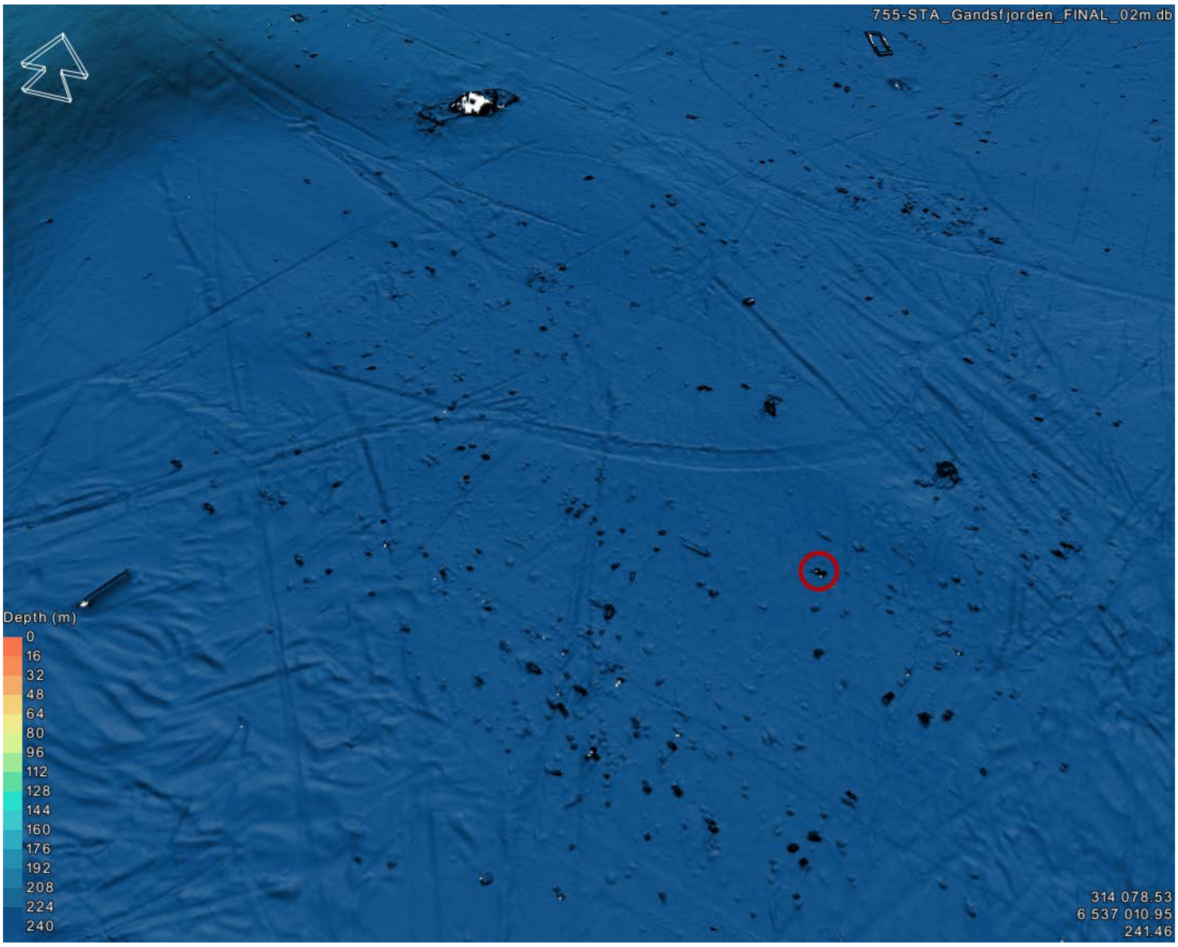


Figure 15 Bathymetric image of debris field in Gandsfjorden.
The red circle indicates the location of the contact shown in Figure 16.

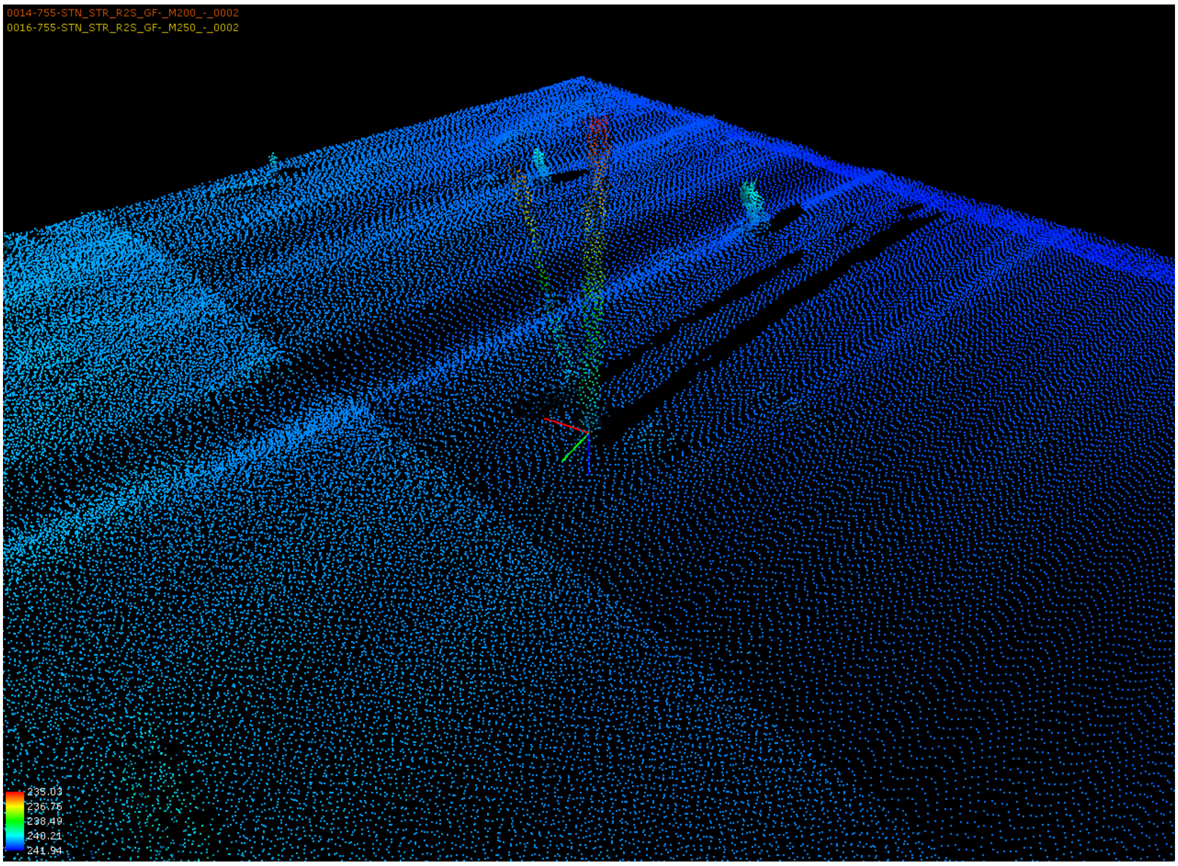


Figure 16 Example of poles/objects sticking up from the seafloor.
In this example the objects have a height of approximately 6 m above the seafloor.

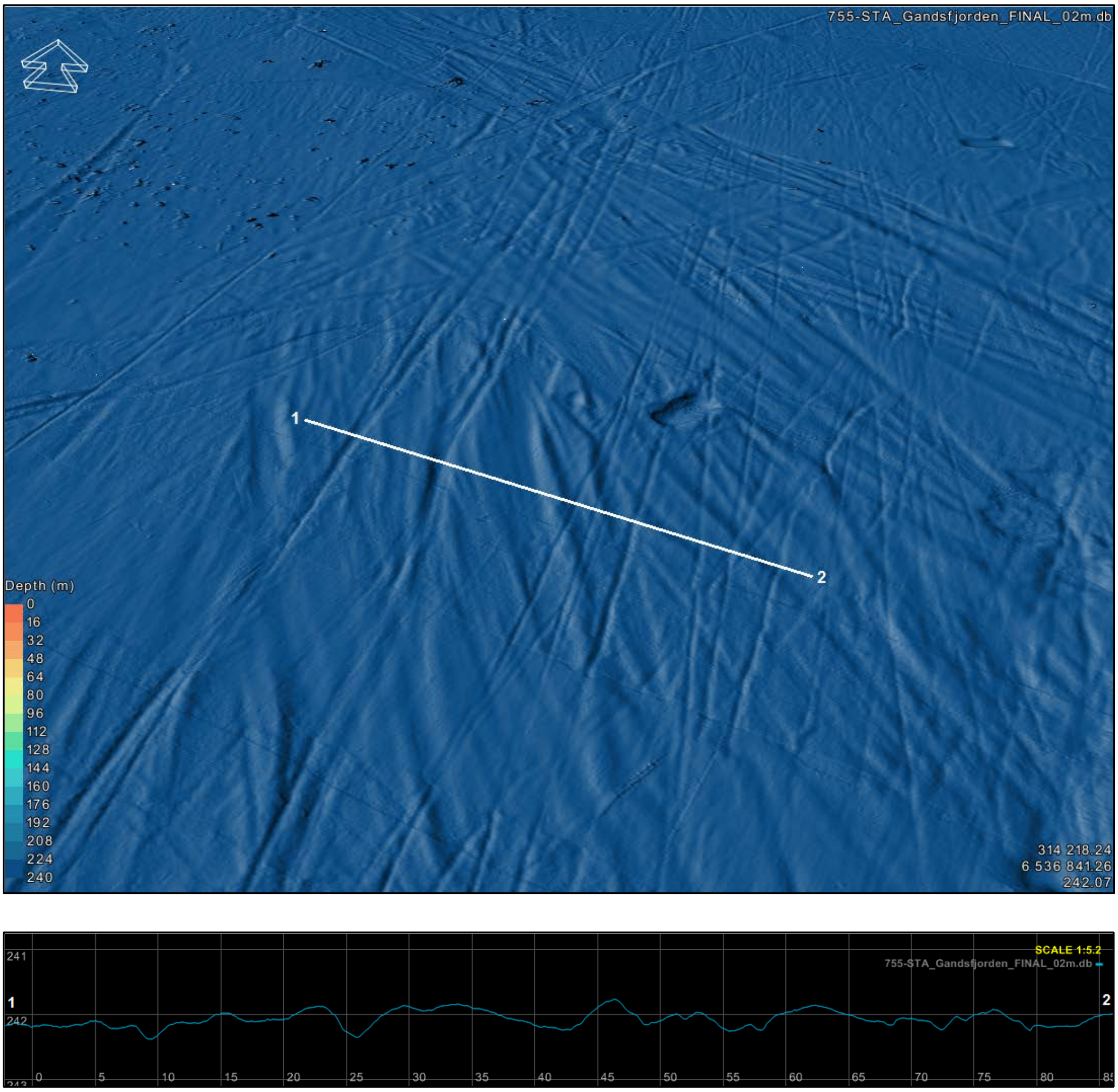


Figure 17 Bathymetric image and profile across seafloor scars in the central deep section of the fjord. The scars are approximately 20-40 cm in depth. (Heading 354 deg, Pitch 55 deg)

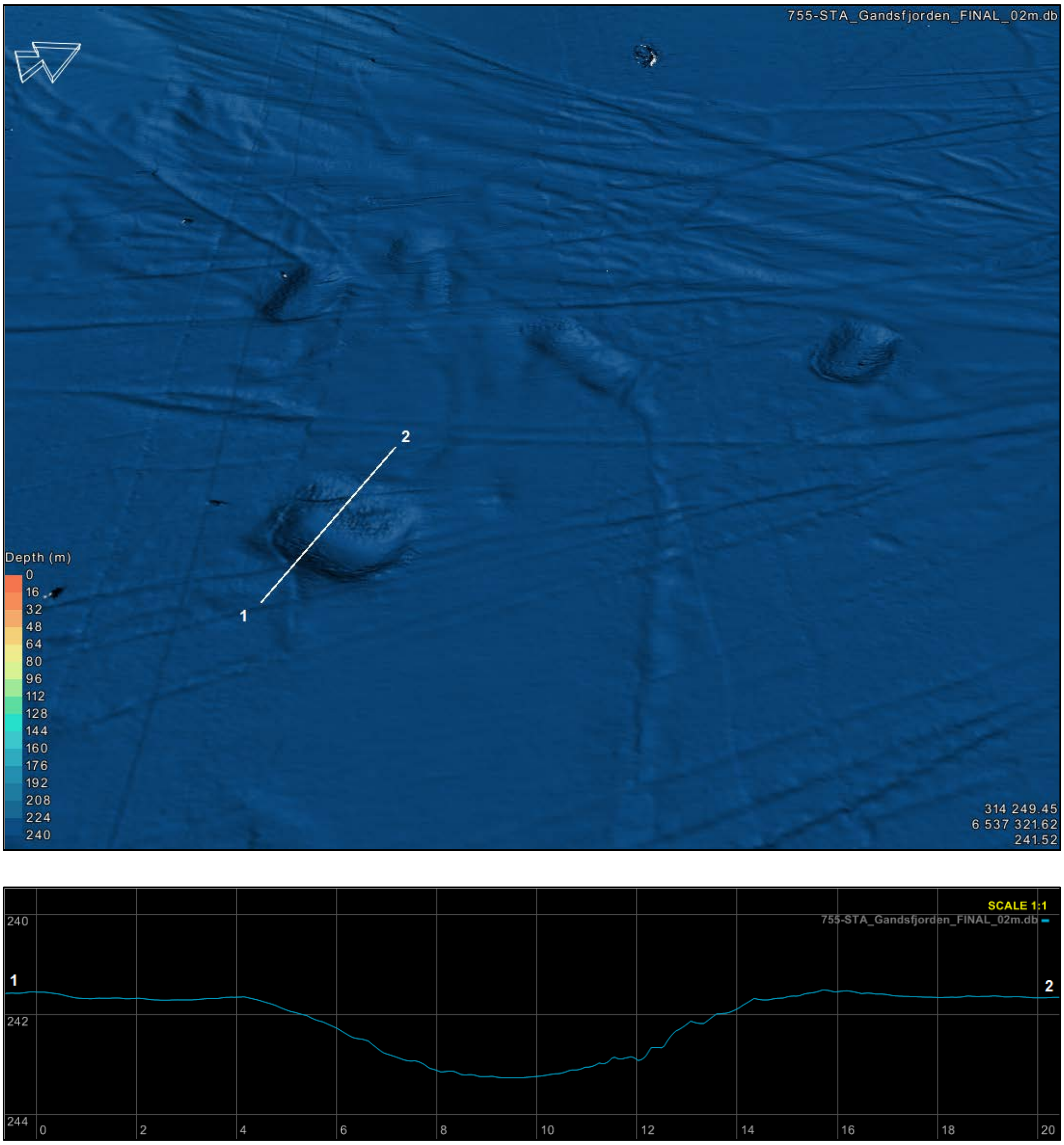


Figure 18 Bathymetric image and profile across seafloor scars in the central deep section of the fjord. The depression is approximately 1.5 m deep and 10 m across. (Heading 295 deg, Pitch 51 deg)

11.2.3. Surficial Geology

In general, the surficial geology of Gandsfjorden is dominated by deposits of silty CLAY throughout the deep section and by outcropping or sub-cropping BEDROCK and areas of coarser sediment, in the shallow and steep sections.

Along the western extent of the surveyed area, BEDROCK is outcropping at seabed surface out to approximately 50 to 100 m from the shore, except for in the north and a small section more south where silty sandy CLAY is present. In the north western part BEDROCK is present as outcrops until approximately 400 m from the shore. The bedrock is often associated with DIAMICTON, comprising coarser deposits (Figure 19). In between the outcrops silty sandy CLAY is present at seabed surface. In the south western part of the survey area areas of DIAMICTON is present surrounded by silty sandy CLAY.

In the central part of the fjord, from approximately 600 m from the western shore, until approximately 500 m from the eastern shore, very soft CLAY is present at the seabed surface.

Along the eastern slope towards shore, large BEDROCK outcrops are present in the north middle and south, while in between those silty sandy CLAY is present. Less DIAMICTON is visible in the eastern part than in the west.

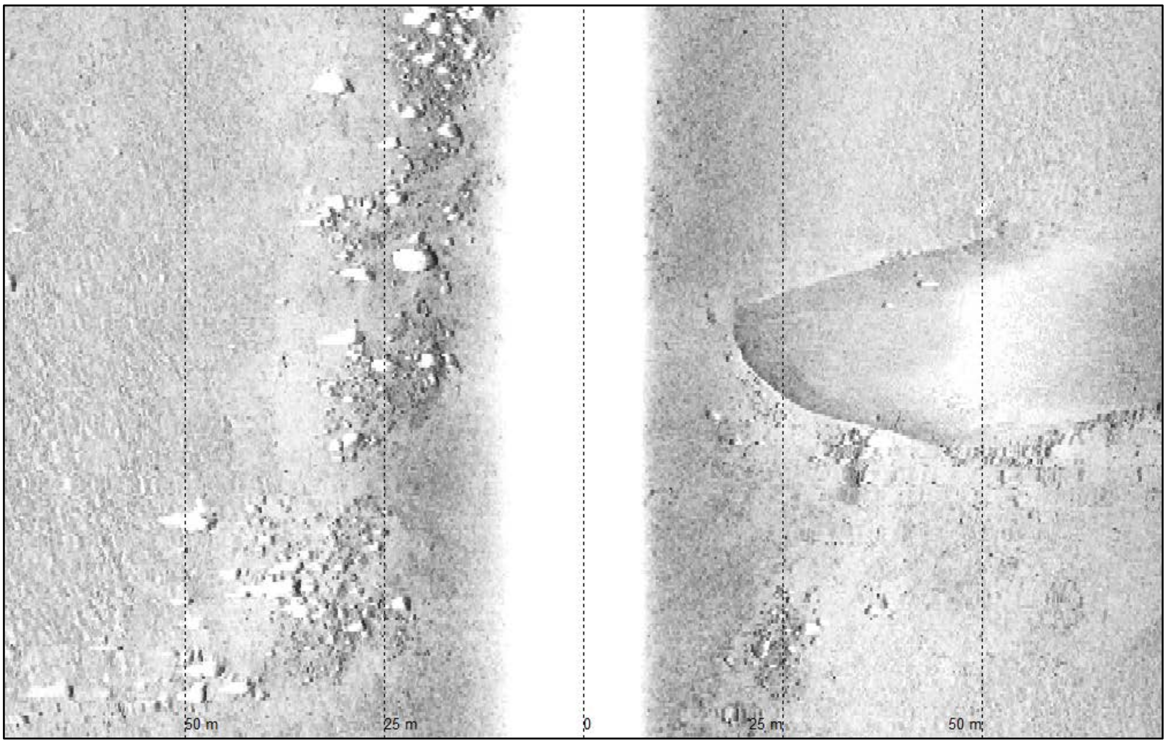


Figure 19 Side scan sonar data example.
Outcropping bedrock with diamicton and silty sand.

Seabed Features

Large areas of debris were detected in Gandsfjorden, mostly in the northern part of the survey area. In total eight SSS contacts and one MBES contact were confirmed as wrecks during the visual inspection, see section 0. One SSS contact was interpreted as possible wreck but was not confirmed with visual inspection. In the very central part of the survey area the intensity of debris is very high. Instead of picking all debris as contacts from the data an area of approximately 500 m in diameter has been marked as debris area in the charts and as shown in Figure 20. South and north of this area is somewhat less debris.

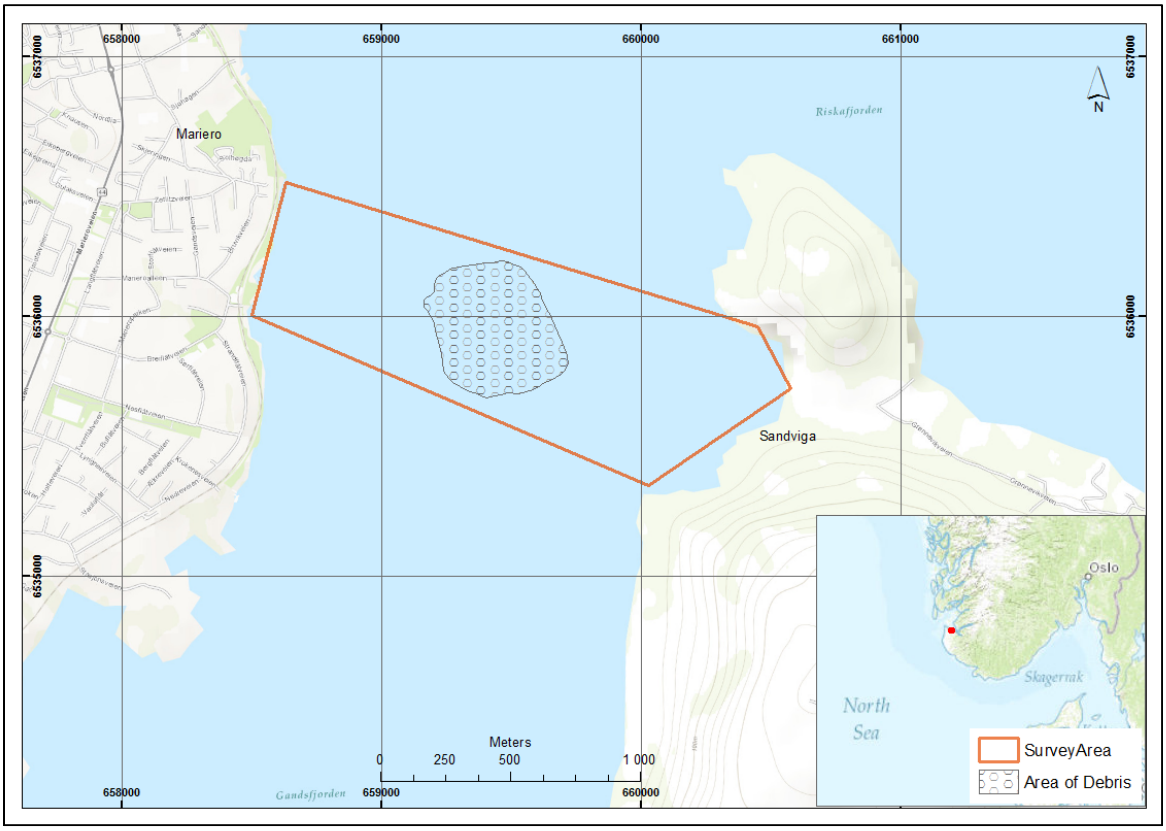


Figure 20 Location of the debris area.

There is a group of SSS features that can indicate the presence of gas charged sediments in the sub-laying sediment unit, these have been interpreted as pockmarks in the SSS data (Figure 22). They appear as higher reflectance areas within the otherwise low reflectance clay seabed, and are typically found at a water depth of approximately 230 m in the eastern part of the fjord. Trawl marks often pass through the features with no discernable effect on depth of scar, suggesting no significant lithological change. These possible pockmarks are however not clearly visible in the sub-bottom data or in the bathymetric data.

Seabed scars, possibly trawl marks and anchor scars, are frequently occurring in the deep middle part of the fjord (Figure 21). Seabed scars are also present along the slopes and are often associated with wrecks or debris.

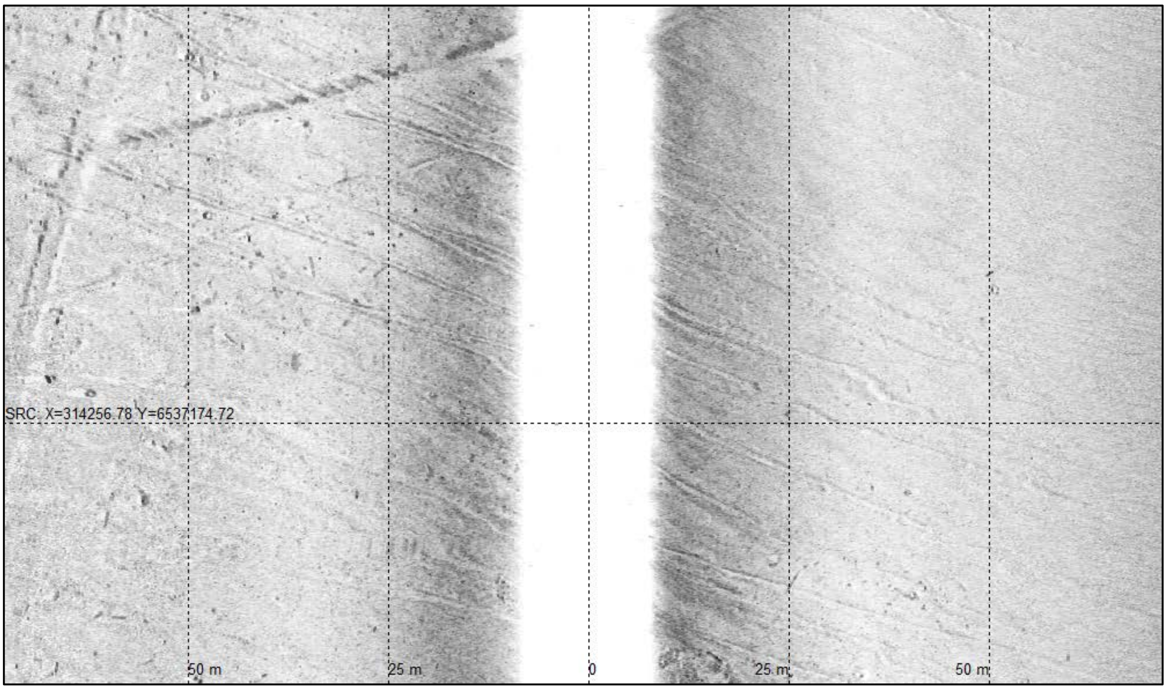


Figure 21 Side scan sonar data example.
Seabed scars, probably from trawling and anchoring.

One broken pipeline was detected in the SSS data in the south western part of the area. The pipeline follows the slope from the shore line and changes direction approximately 300 m from shore to go south, perpendicular to the slope.

For full SSS contact list refer to Appendix F.

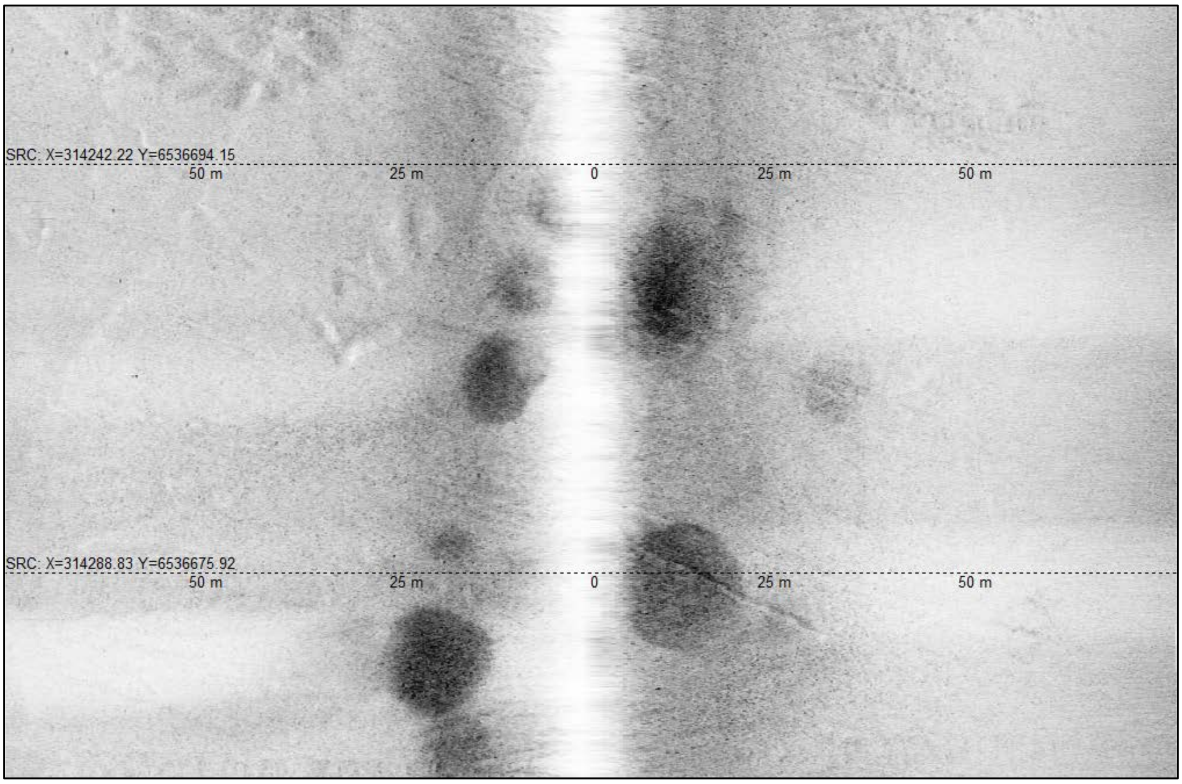


Figure 22 Possible pockmarks or gas charged sediments in the sub-laying sediment unit visible in the SSS data.

11.2.4. Shallow Geology

The shallow geology along the slopes is characterised by BEDROCK and DIAMICTON with a very thin cover of very soft sandy silty CLAY, while in the central part of the area the sediment thickness of CLAY is greater. For the majority of the slopes the cover of very soft sandy silty CLAY is less than a metre, but there are pockets of up to two metres in thickness.

In the north western part the slope is characterised by BEDROCK outcropping at surface surrounded by sediment pockets of up to two metres in thickness, while in the south western part DIAMICTON is present at or close to the surface and where covered, the CLAY unit is very thin, mostly less than a metre.

In the central part of the fjord, from approximately 600 m from the western shore, until approximately 500 m from the eastern shore, CLAY is present as a thick deposit, at least 40 m thick in the deepest part. The sediment consist of very soft CLAY with high organic content. Laminations of SILT are visible and the sediment contains shell fragments and scattered whole shells and drop stones of the size of 3 cm.

On the eastern slope the cover of sandy silty CLAY is generally very thin, mostly less than a metre in thickness and BEDROCK is commonly outcropping at surface.

It is difficult to distinguish between the DIAMICTON and BEDROCK in the acoustic data; however, the DIAMICTON is not believed to be thick, generally two metre or less along the slopes.

Data examples are shown in Figure 23 to Figure 25.

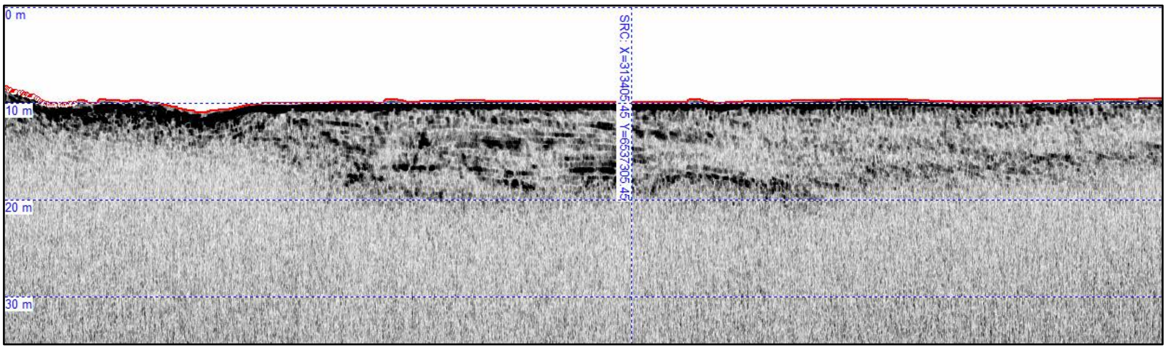


Figure 23 Example image of shallow geology in Gandsfjorden.
Pocket of silty sandy clay over diamicton.

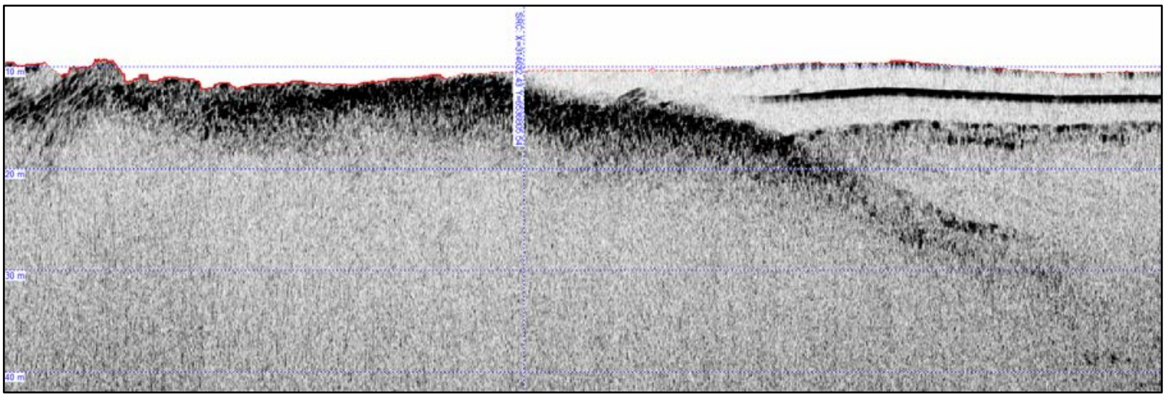


Figure 24 Example image of shallow geology in Gandsfjorden.
Lower part of slope, bedrock covered by a thin layer of diamicton and to the right in the image clay.

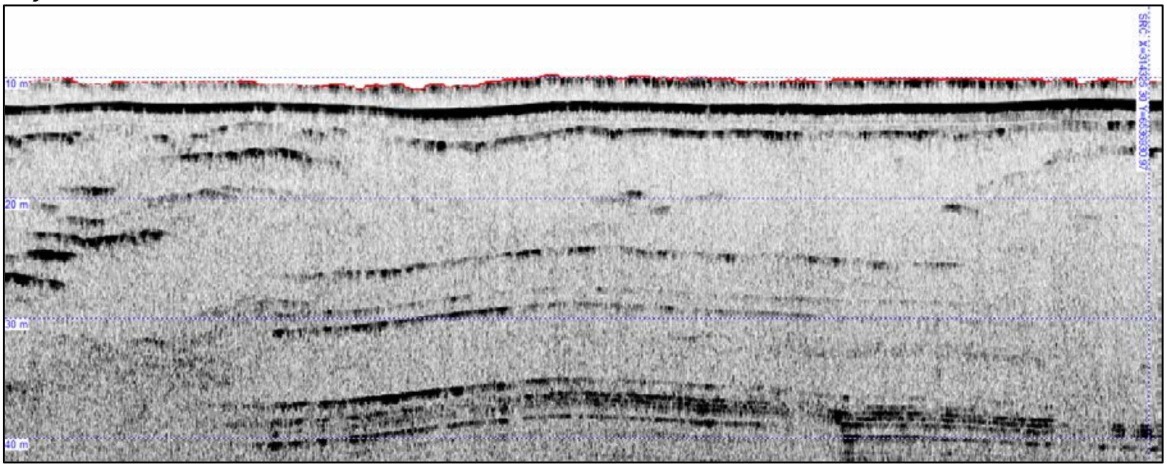


Figure 25 Example image of shallow geology in Gandsfjorden.
Laminated clay is visible at approximately 40 m sediment depth.

11.3. Geotechnical Survey

Gravity corer (GC) sampling was performed at six locations, Figure 26 and Table 12. The sediment recovery varied from 1.8 to 2.6 m. The sediments were very soft to soft and dominated by silty clay with organic content. Shells and shell fragments are common and sand and drop stones are occasionally present within the clay. Sulphuric smell at three locations, sample 01, 03 and 06, indicates anoxia in deeper parts of the fjord. Samples 02, 04 and 05 have thermal conductivity values above 1 W/mK, while the rest has values around 0.8 W/mK.

The area has previously received large amounts of wastewater from both industry and from the municipal sewer system (http://www.miljostatus.no/). As Gandsfjorden is a popular recreational area large attentions has been given Gandsfjorden the last 50 years to decrease the environmental constraints. Previously large amounts of ooze and heavy metals in the sediment as well as in the benthic fauna have been reduced. However, Mercury is still present in both fish and mussels fished in Gandsfjorden (http://www.environment.no/).

Sampling for chemical analysis were achieved with a push corer (PC), operated by the ROV. In total three samples were collected and sent to laboratory for analysis. The chemical content in all three samples generally showed concentrations above average of heavy metal and organic contaminants, generally klasse II and III, (Weideborg, et al., 2013). Two of the samples showed significant increase in Copper (Cu) concentration (klasse IV). (Weideborg, et al., 2013).

Field logs for all sampling are found in Appendix G, geotechnical laboratory results in Appendix H and chemical laboratory results in Appendix I.

Table 12 Positions for gravity cores and push cores

Sampling Sites	Sampling Equipment	Easting (m)	Northing (m)	Recovery (m)
755-GC-01	Gravity Corer	314383	6536637	1.95
755-GC-02	Gravity Corer	314812	6536947	2.40
755-GC-03	Gravity Corer	313909	6536938	2.55
755-GC-04	Gravity Corer	313613	6537221	1.90
755-GC-05	Gravity Corer	313416	653730	1.80
755-GC-06	Gravity Corer	314510	6536801	2.22
755-PC-07	Push Corer	314046	6536847	0.25
755-PC-08	Push Corer	314331	6536742	0.20
755-PC-11	Push Corer	314822	6536978	0.30

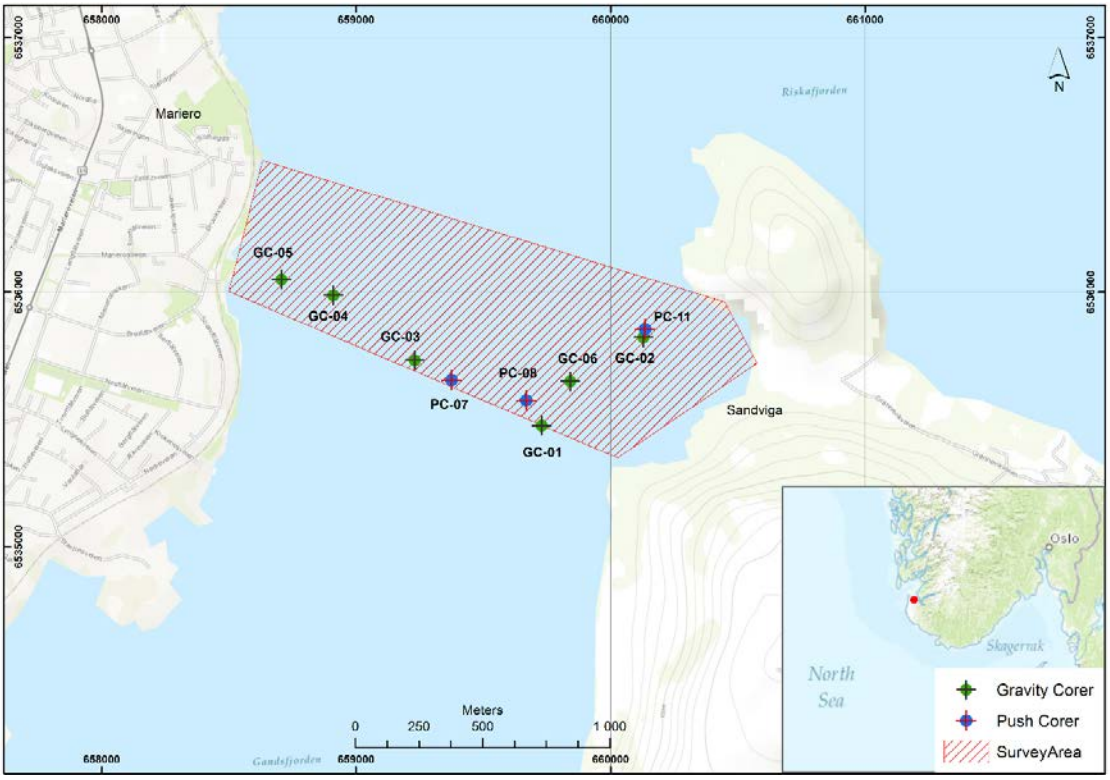


Figure 26 Overview of sampling sites in Gandsfjorden.

11.3.1. 755-GC-01

This Gravity Corer sample (Figure 27) consisted of extremely soft, generally very slightly sandy, silty GYTTJA CLAY and CLAY with sulphuric odour, indicating anoxia. Shell fragments are present in the upper metre of the sample. The mean thermal resistivity in this sample was 0.81 W/mK.

For full geotechnical laboratory results, please see Appendix H.

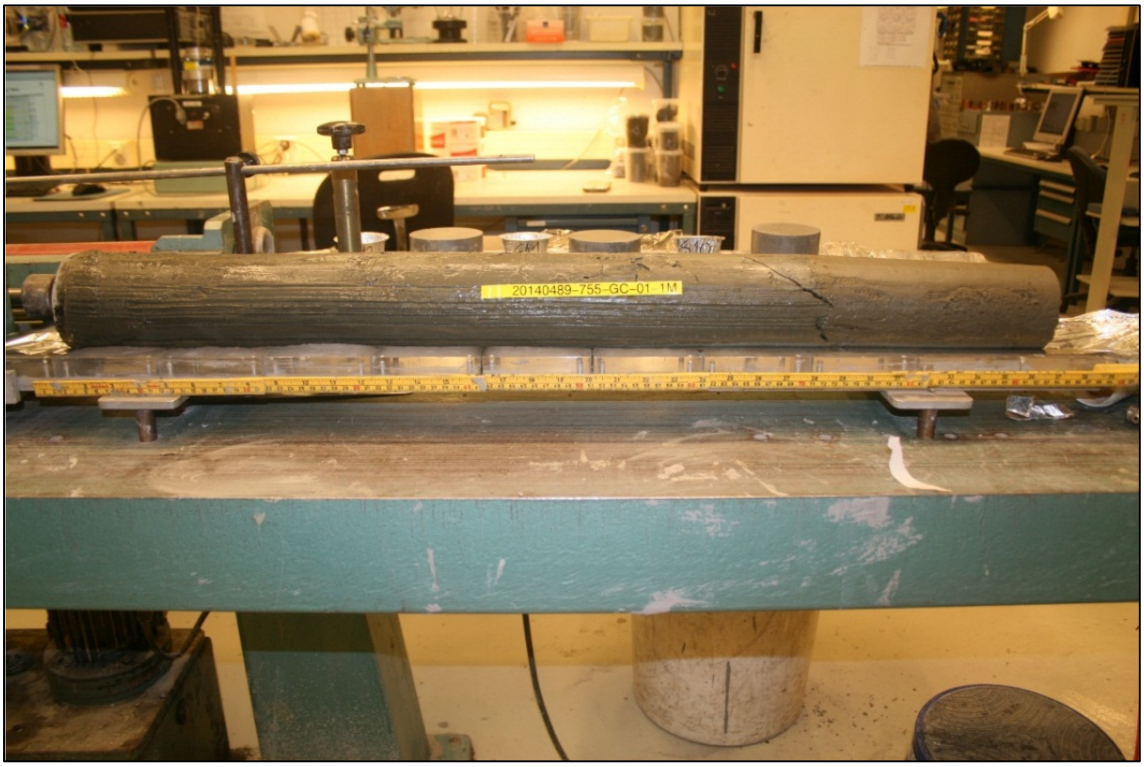


Figure 27 Gravity corer sample 755-GC-01 at the laboratory.

11.3.2. 755-GC-02

This Gravity Corer sample (Figure 28) consisted of silty sandy CLAY on top of extremely soft very slightly sandy, silty CLAY. In the top metre organic content, cobbles and pebbles were observed. Shell fragments were present between 1-2 m. The mean thermal resistivity in this sample was 1.01 W/mK.

For full geotechnical laboratory results, please see Appendix H.

Figure 28 Gravity corer sample 755-GC-02 at the laboratory.

11.3.3. 755-GC-03

This Gravity Corer sample (Figure 29) consisted of primarily very soft silty CLAY with some sandy, silty GYTTJA in the uppermost part. The sample had a sulphuric odour indicating an anoxic environment. The mean thermal resistivity in the sample was 0.84 W/mK.

For full geotechnical laboratory results, please see Appendix H.

Figure 29 Gravity corer sample 755-GC-03 at the laboratory.

11.3.4. 755-GC-04

This Gravity Corer sample (Figure 30) consisted of very soft sandy, silty CLAY with sandy, clayey SILT with stones and shell fragments in the uppermost part. The mean thermal resistivity in this sample was 1.06 W/mK.

For full geotechnical laboratory results, please see Appendix H.

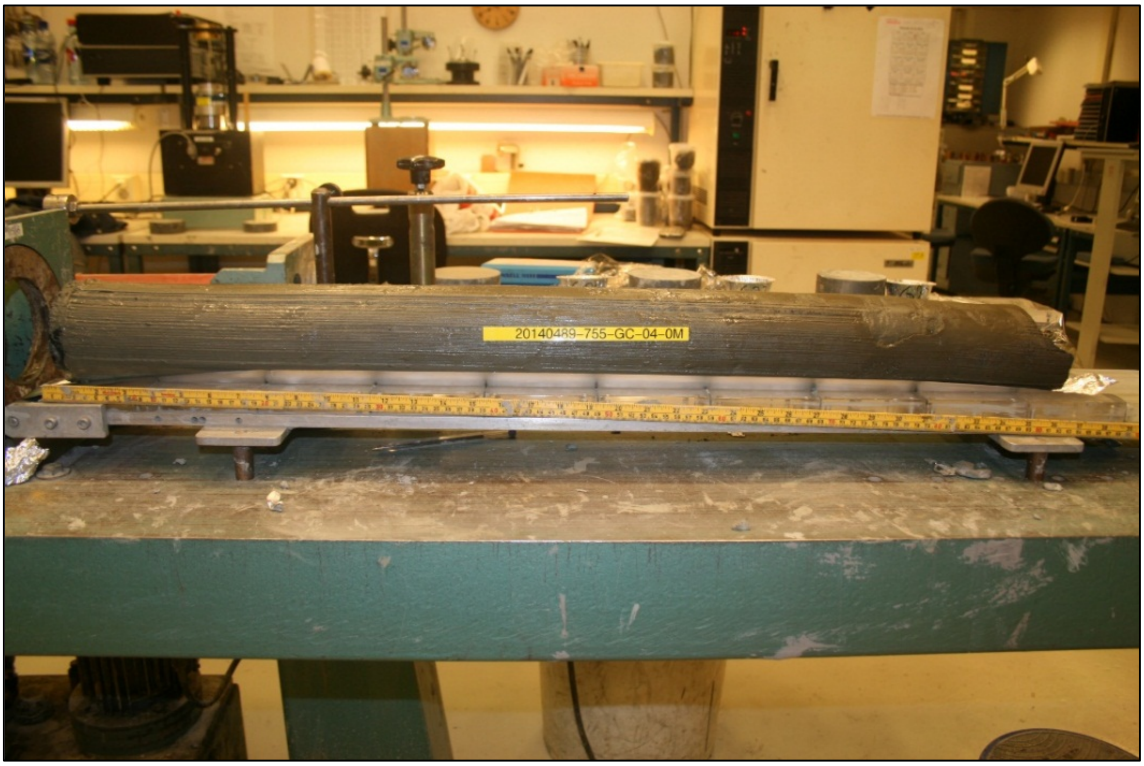


Figure 30 Gravity corer sample 755-GC-04 at the laboratory.

11.3.5. 755-GC-05

This Gravity Corer sample (Figure 31) consisted of slightly sandy, silty CLAY with gravelly, silty sandy CLAY in the uppermost part, where also Cobbles, SAND pockets and shell fragments were observed. The mean thermal resistivity in this sample was 1.60 W/mK.

For full geotechnical laboratory results, please see Appendix H.

Figure 31 Gravity corer sample 755-GC-05 at the laboratory.

11.3.6. 755-GC-06

This Gravity Corer sample (Figure 32) consisted of very soft, silty CLAY with very soft GYTTJA in the uppermost part. The entire sample has a sulphuric odour indicating anoxia. The thermal resistivity in the sample was 0.79 W/mK.

For full geotechnical laboratory results, please see Appendix H.

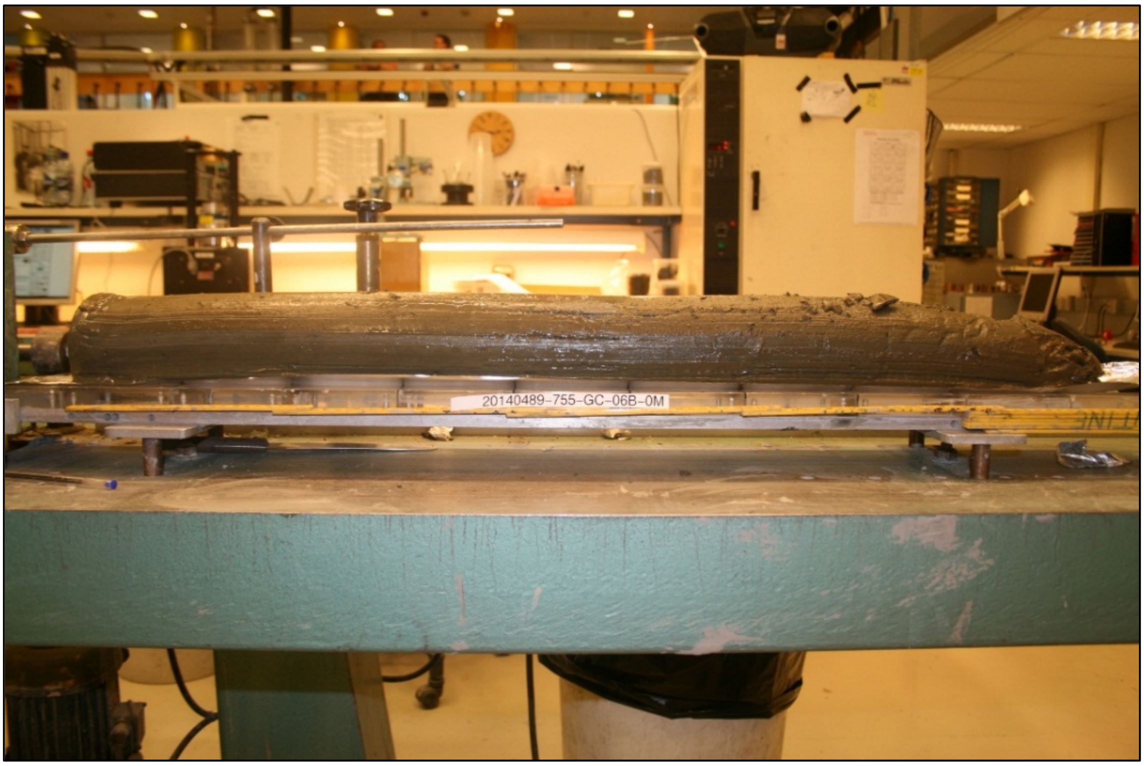


Figure 32 Gravity corer sample 755-GC-06 at the laboratory.

11.3.7. 755-PC-07

This Push Corer sample (Figure 33) consisted of slightly clayey, slightly sandy SILT. It was tested for chemical content at ALS laboratory and generally showed concentrations above average of heavy metal and organic contaminants, generally klasse II and III, (Weideborg, et al., 2013). The sample showed significant increase in Copper (Cu) concentration (klasse IV). (Weideborg, et al., 2013).

For full laboratory test results, please see Appendix I.

Figure 33 Push corer sample 755-PC-07 in field.

Sampling for chemical analysis were achieved with a push corer (PC), operated by the ROV. In total three samples were collected and sent to laboratory for analysis. The chemical content in all three samples generally showed concentrations above average of heavy metal and organic contaminants, generally klasse II and III, (Weideborg, et al., 2013). Two of the samples showed significant increase in Copper (Cu) concentration (klasse IV). (Weideborg, et al., 2013).

11.3.8. 755-PC-08

This push corer sample (Figure 34) consisted of very slightly clayey, slightly sandy SILT. It was tested for chemical content at ALS laboratory and generally showed concentrations above average of heavy metal and organic contaminants, generally klasse II and III, (Weideborg, et al., 2013). The sample showed significant increase in Copper (Cu) concentration (klasse IV). (Weideborg, et al., 2013)

For full laboratory test results, please see Appendix I.

Figure 34 Push corer sample 755-PC-08 in field.

11.3.9. 755-PC-11

This push corer sample (Figure 35) consisted of very slightly clayey, sandy SILT. It was tested for chemical content at ALS laboratory and generally showed concentrations above average of heavy metal and organic contaminants, generally klasse II and III, (Weideborg, et al., 2013).

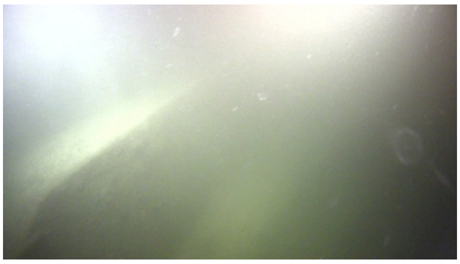
For full laboratory test results, please see Appendix I.

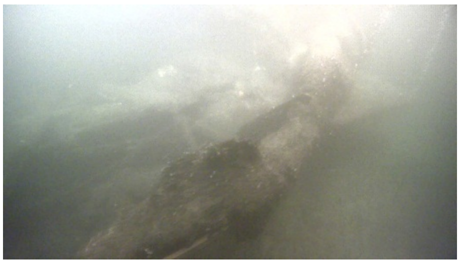
Figure 35 Push corer sample 755-PC-11 in field.

11.4. Visual Inspections

A total number of 11 contacts were inspected within Gandsfjorden survey area, Table 13 and Figure 36.

Table 13 Visual inspected contacts within Gandsfjorden.

Contact ID	Easting	Northing	Comment	Image
GF-R-0116	313977	6536954	Concrete Block	
GF-R-0393	314168	6537028	Possible crane	
GF-MB-0001	314804	6536573	Wooden Wreck	
GF-R-0064	314662	6536670	Wooden sailboat	
GF-R-0002	314555	6536668	Wooden Wreck	

Contact ID	Easting	Northing	Comment	Image
GF-R-0113	314584	6536868	Small fishing boat	
GF-R-0394	314476	6536895	Small Boat	
GF-R-0112	314003	6537154	Possible tug boat	
GF-R-0381	314138	537231	Metallic wreck	
GF-R-0389	314113	6537265	Modern small boat	
GF-R-0346	314171	6537379	Small craft	

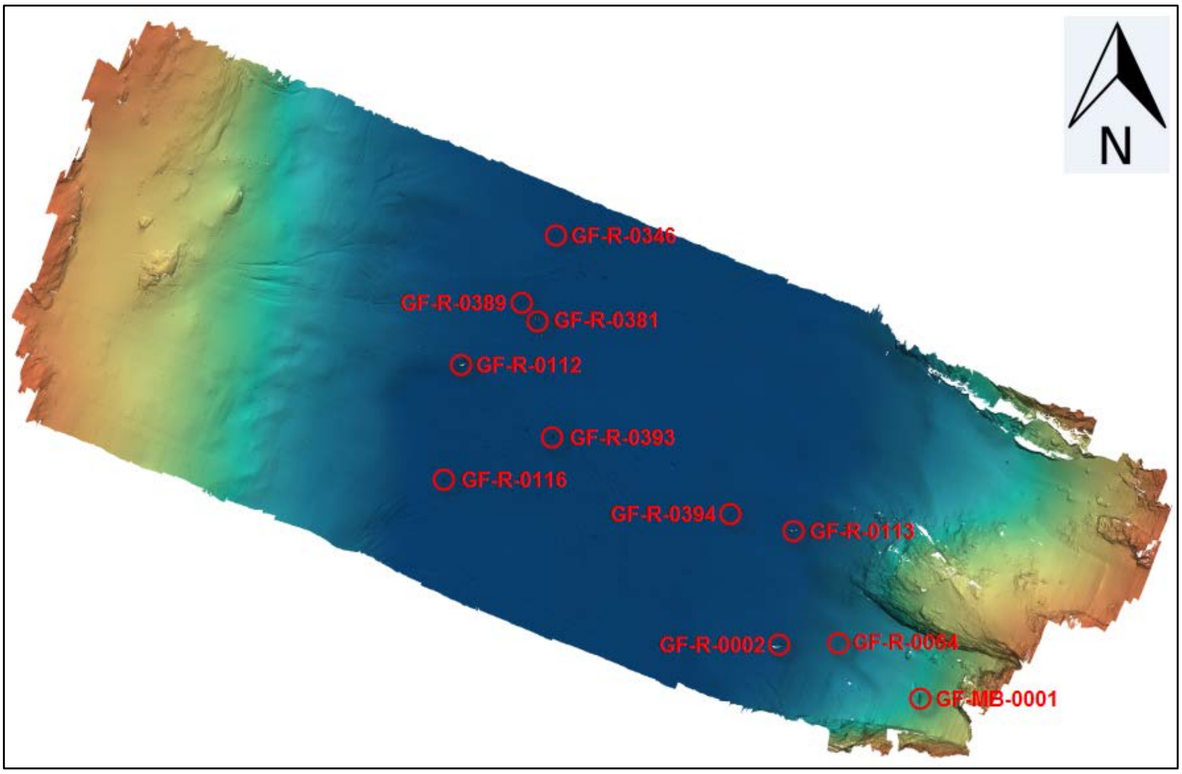


Figure 36 Locations where visual contact inspection was performed

11.4.1. GF-R-0116

Visual inspection revealed a concrete block on contact location GF-R-0116, with approximate dimensions 10 x 2 x 0.5 m and an average water depth of 242 m. Figure 37 shows bathymetric data for the location.

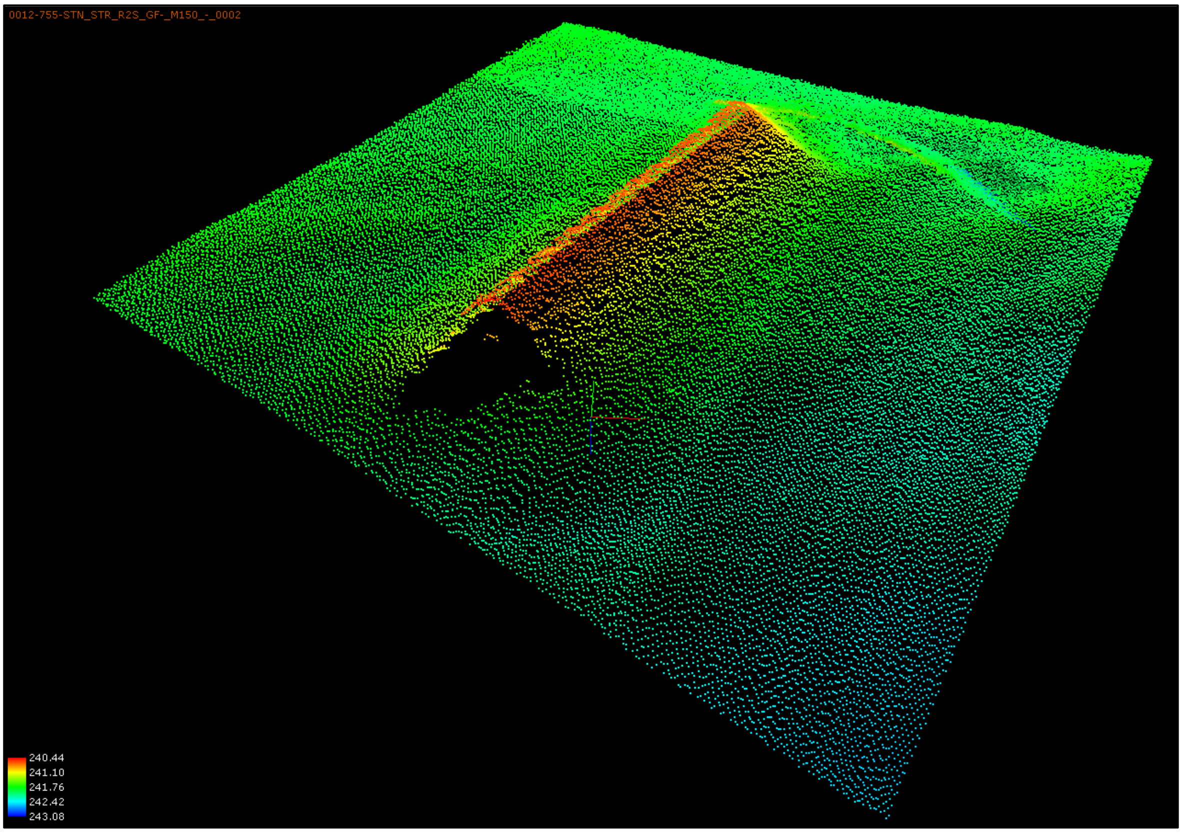


Figure 37 Bathymetric image of object GF-R-0116

11.4.2. GF-R-0393

Visual inspection revealed a possible crane on contact location GF-R-0393, with approximate dimensions 11.5 x 6.1 x 3.9 m. The average water depth is 240 m. Figure 38 shows bathymetric data for the location.

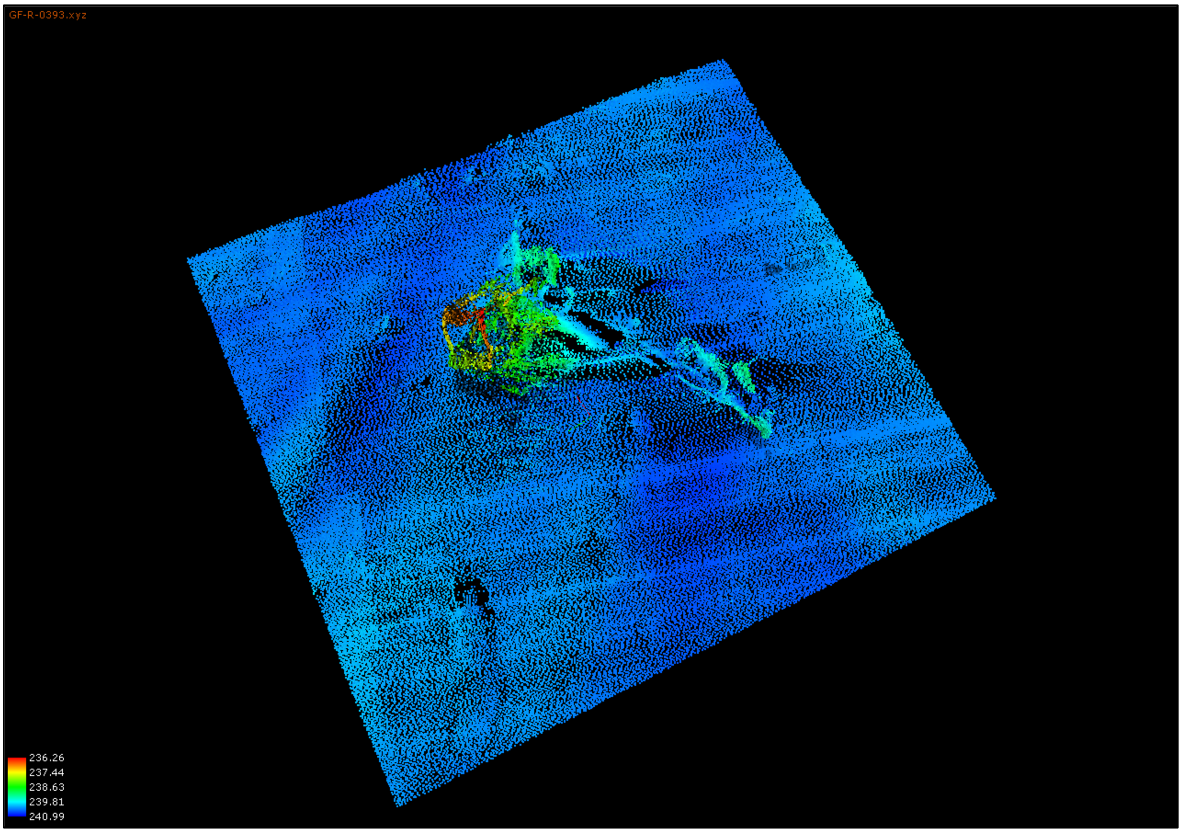


Figure 38 Bathymetric image of object GF-R-0393

11.4.3. GF-MB-0001

Visual inspection revealed a wooden wreck heeling to its port side on contact location GF-MB-0001, with approximate dimensions 20 x 4 m, sticking about 4 m above the seafloor. The average water depth is between 125 and 130 m. Figure 39 shows bathymetric data for the location.

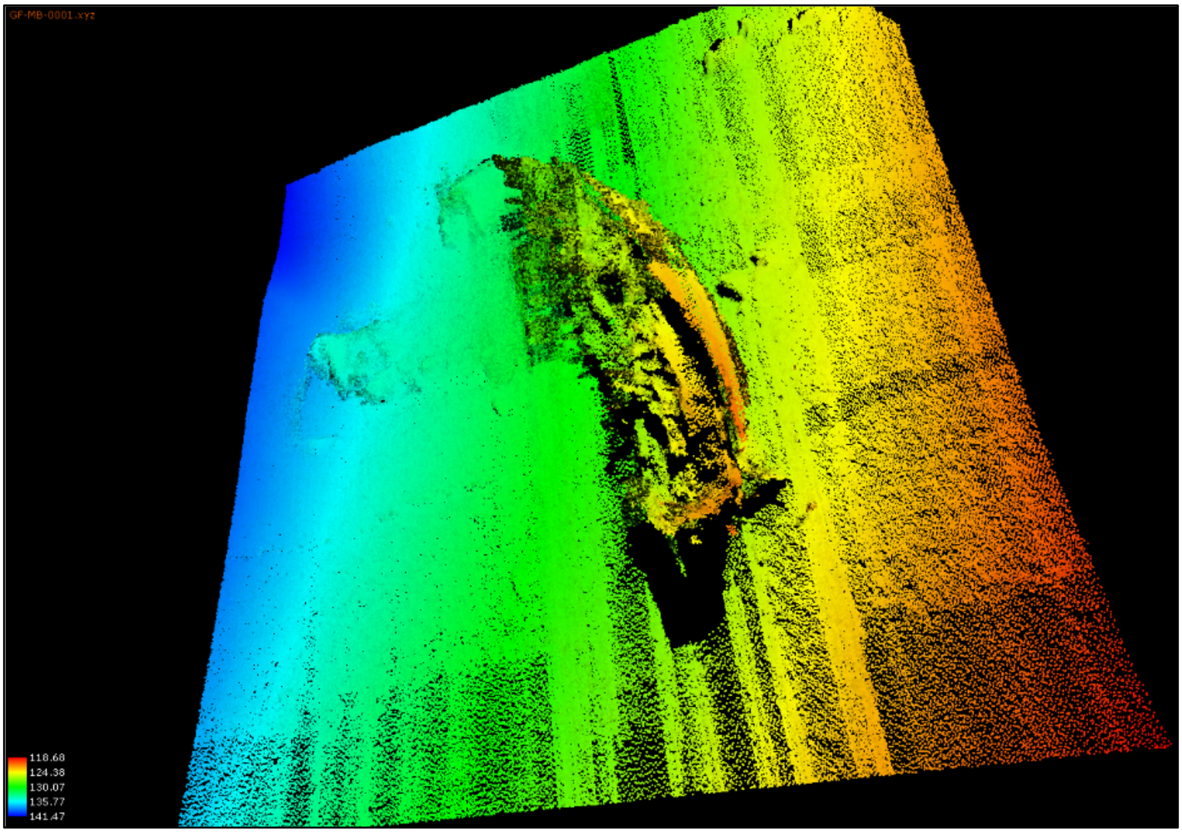


Figure 39 Bathymetric image of object GF-MB-0001

11.4.4. GF-R-0064

Visual inspection revealed a wooden sailboat on contact location GF-R-0064, with approximate dimensions 10 x 2.6 m, sticking about 1 m above the seafloor. Clearly visible is a scar mark resulting from the wreck sliding down the slope. The average water depth is between 200 and 205 m. Figure 40 shows bathymetric data for the location.

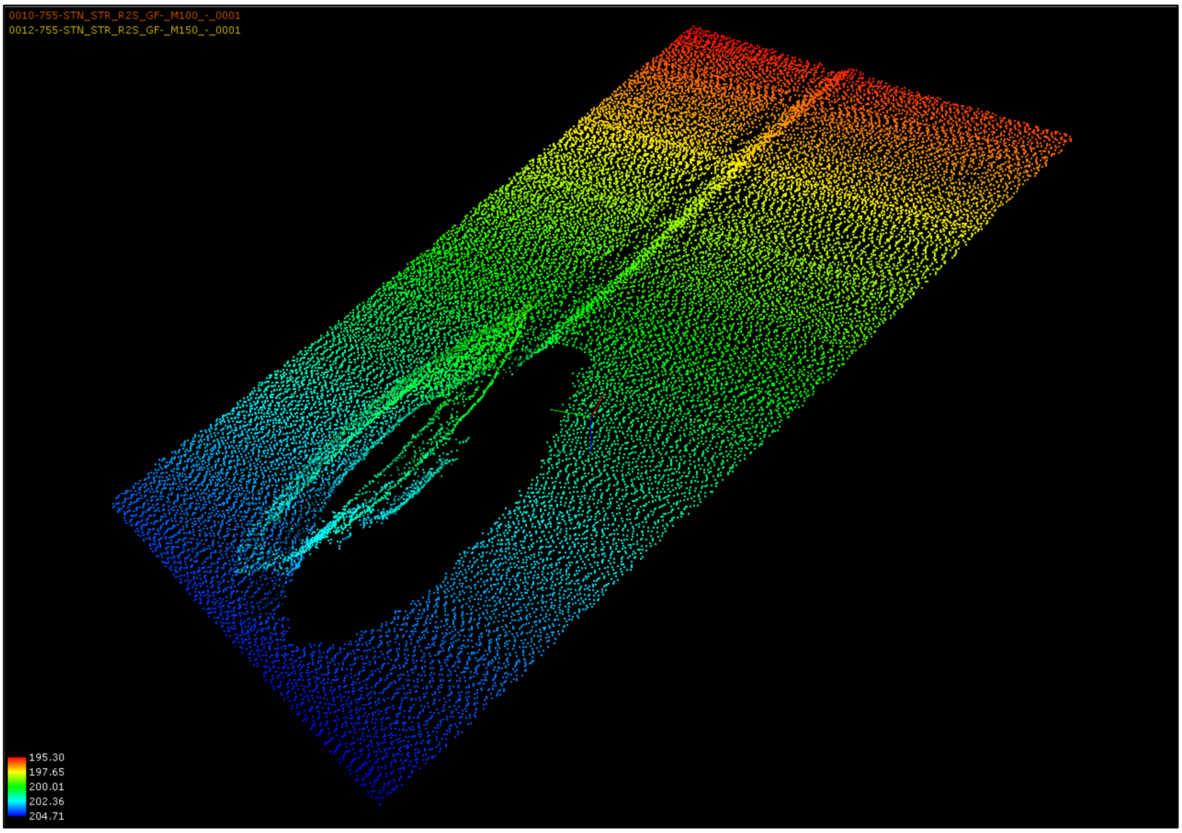


Figure 40 Bathymetric image of object GF-R-0064.
Scar mark on slope clearly visible.

11.4.5. GF-R-0002

Visual inspection revealed a wooden wreck on contact location GF-R-0002, with approximate dimensions 17.3 x 5.7 m. The highest part of the wreck is about 4 m above the seafloor. Clearly visible is a scar mark resulting from the wreck sling down the slope. The average water depth is between 130 and 133 m. Figure 41 shows bathymetric data for the location.

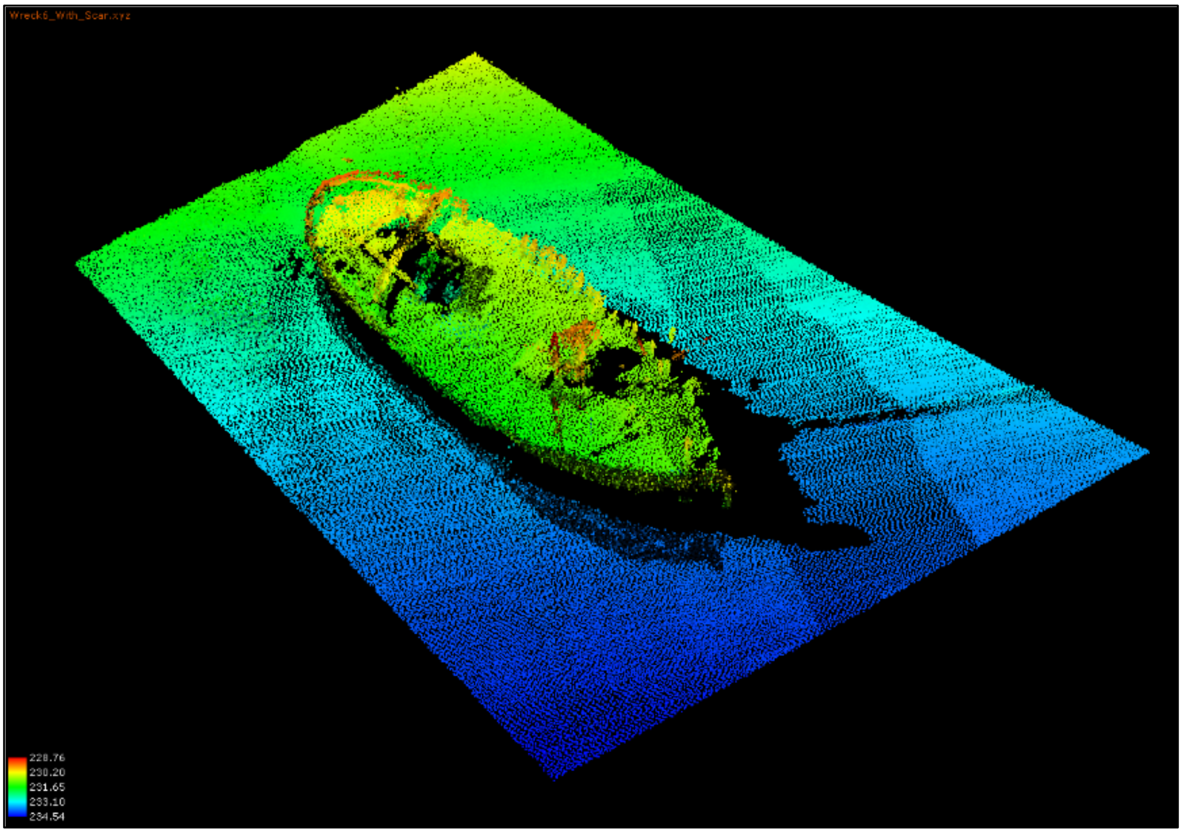


Figure 41 Bathymetric image of object GF-R-0002

11.4.6. GF-R-0113

Visual inspection revealed a small fishing boat on contact location GF-R-0113, with approximate dimensions 13.7 x 3.6 m. The wreck is standing upright on the seafloor and all masts are intact, with the highest protruding point about 6.5 m above the seafloor. The average water depth is 235 m. Figure 42 shows bathymetric data for the location.

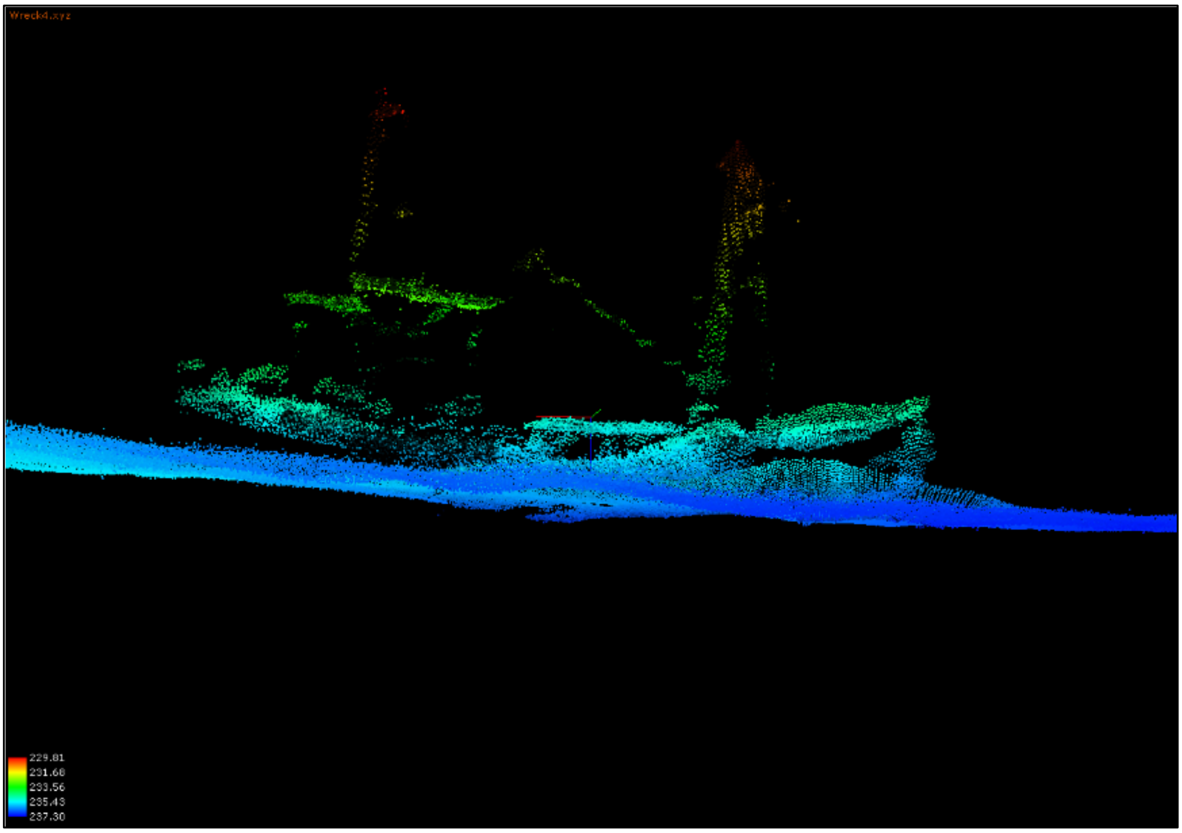


Figure 42 Bathymetric image of object GF-R-0113

11.4.7. GF-R-0394

Visual inspection revealed a small boat on contact location GF-R-0394, with approximate dimensions 6.2 x 1.8 m. The highest part of the wreck is about 1.8 m above the seafloor. The average water depth is 237 m. Figure 43 shows bathymetric data for the location.

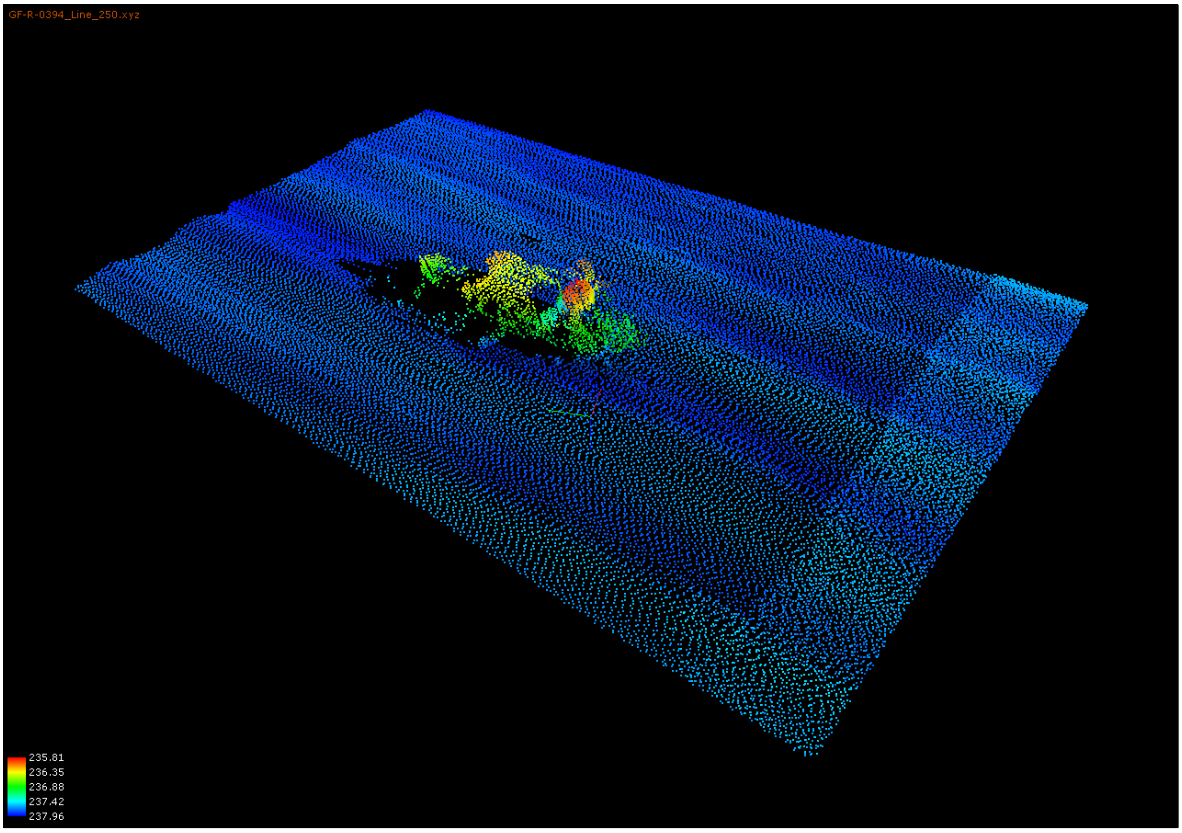


Figure 43 Bathymetric image of object GF-R-0394

11.4.8. GF-R-0112

Visual inspection revealed a possible tug boat on contact location GF-R-0112, with approximate dimensions 34 x 7 m. The wreck is standing upright on the seafloor and the superstructure is partly intact, with the highest protruding point about 11 m above the seafloor. The average water depth is 237 m. Figure 44 shows bathymetric data for the location.

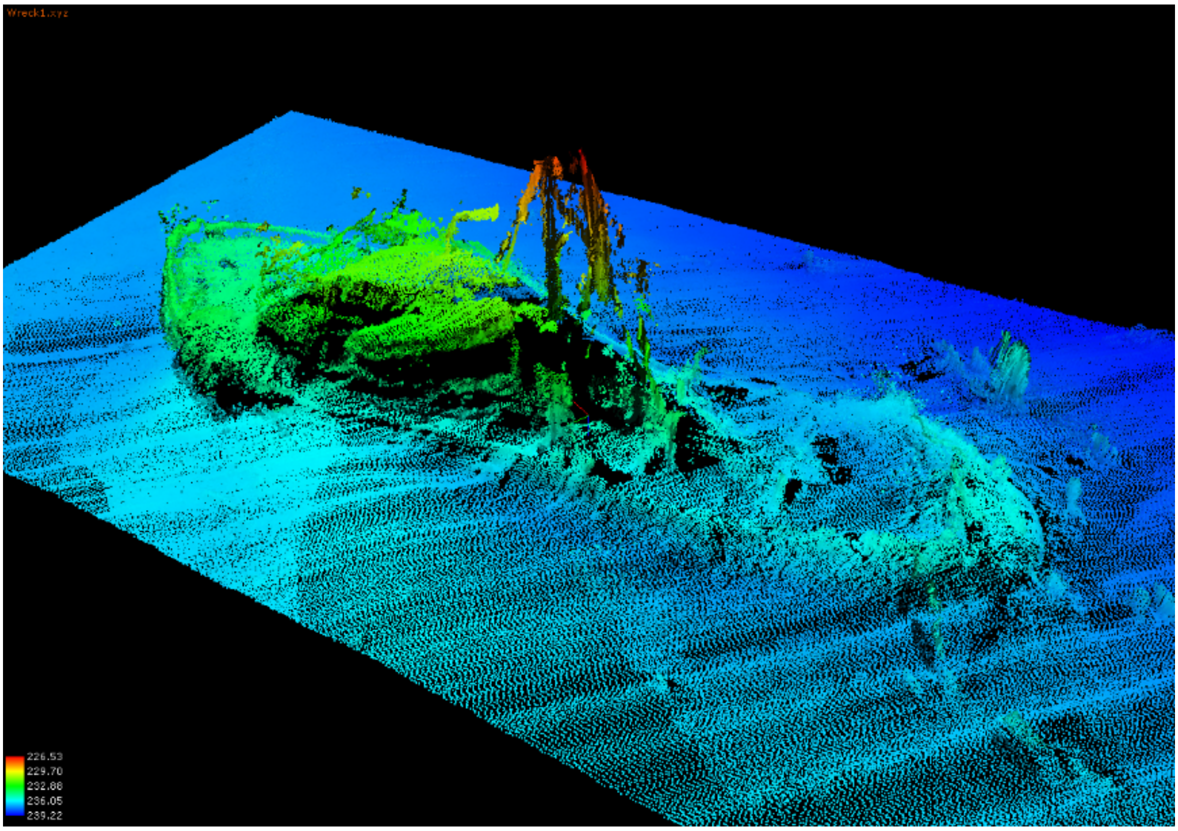


Figure 44 Bathymetric image of object GF-R-0112

11.4.9. GF-R-0381

Visual inspection revealed a metal wreck on contact location GF-R-0381, with approximate dimensions 16 x 5 m. The wreck is sticking about 1 m above the seafloor in an average water depth of 240 m. Figure 45 shows bathymetric data for the location.

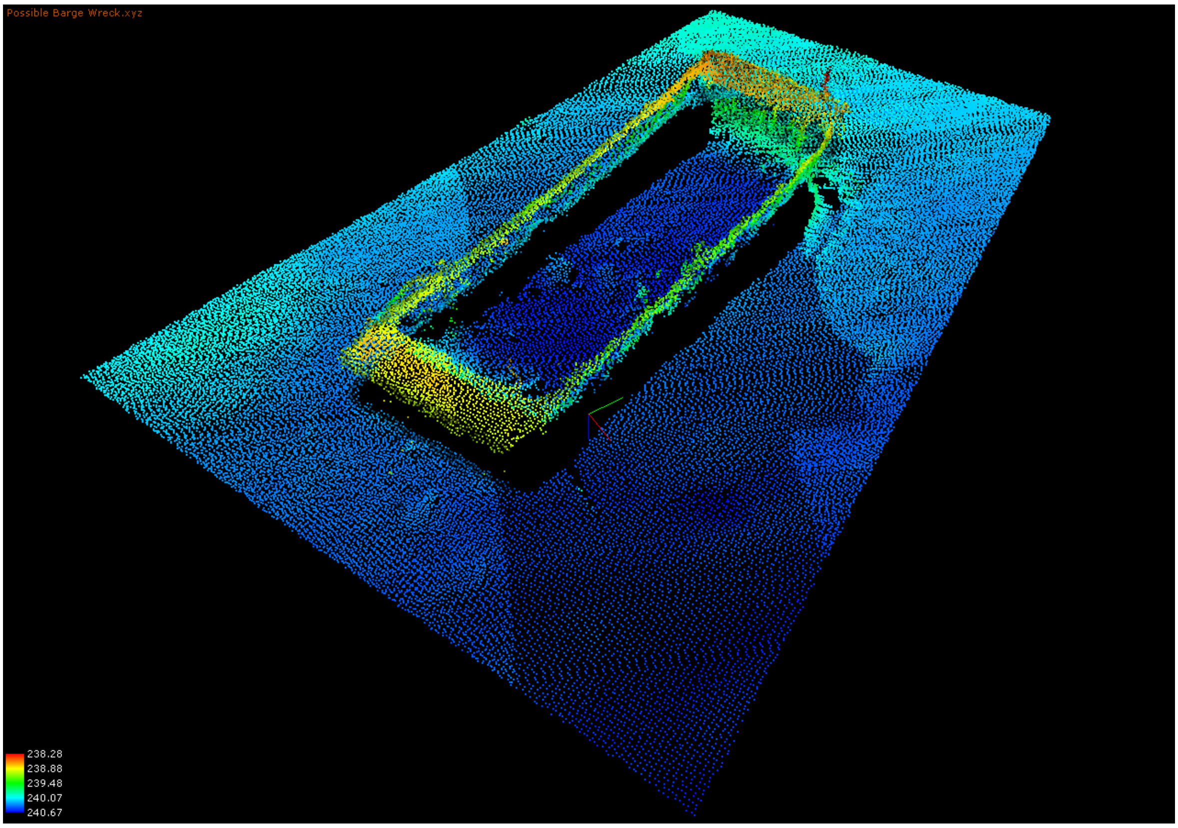


Figure 45 Bathymetric image of object GF-R-0381

11.4.10. GF-R-0389

Visual inspection revealed a modern small boat on contact location GF-R-0389, with approximate dimensions 8 x 2.4 m. The wreck is standing upright and is only partly intact, the highest point being about 1 m above the seafloor. The average water depth is 239 m. Figure 46 shows bathymetric data for the location.

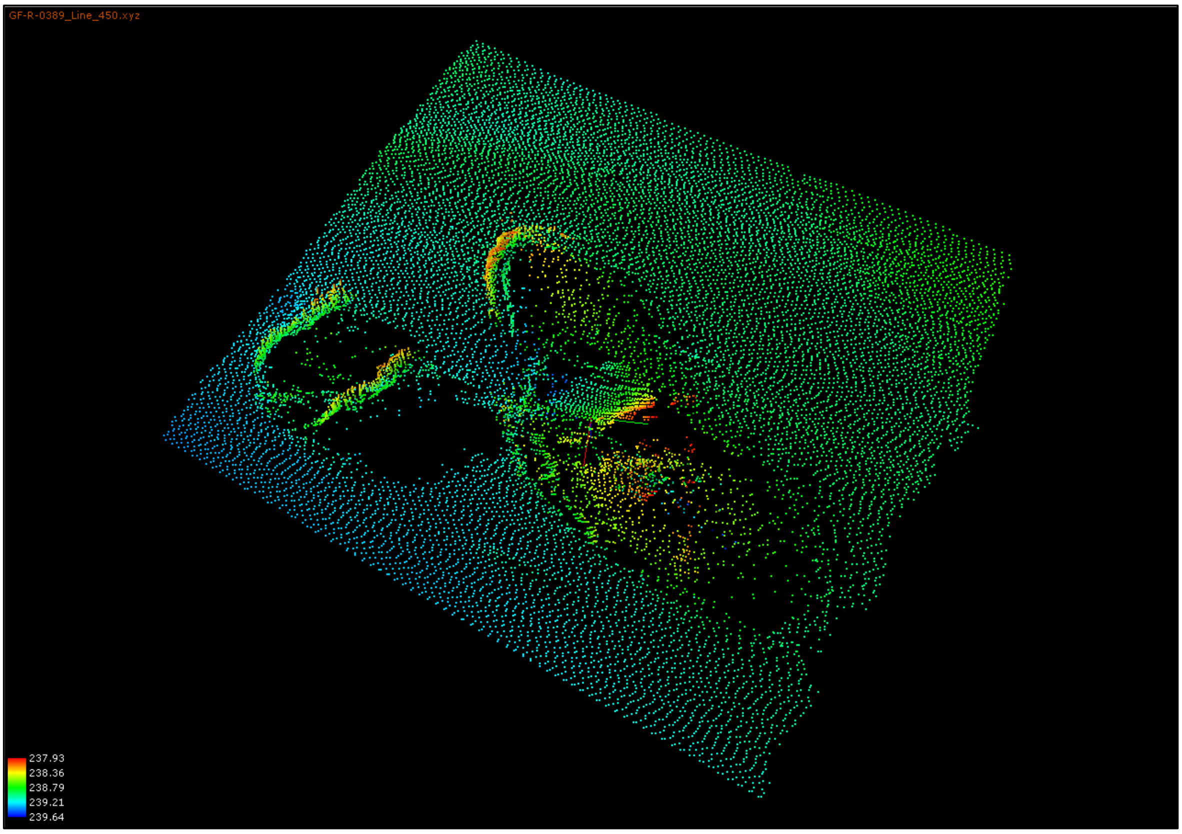


Figure 46 Bathymetric image of object GF-R-0389

11.4.11. GF-R-0346

Visual inspection revealed a small craft on contact location GF-R-0346, with approximate dimensions 8.7 x 2.9 m and its highest point sticking about 1 m above the seafloor. The average water depth is 239 meters. Figure 47 shows bathymetric data for the location.

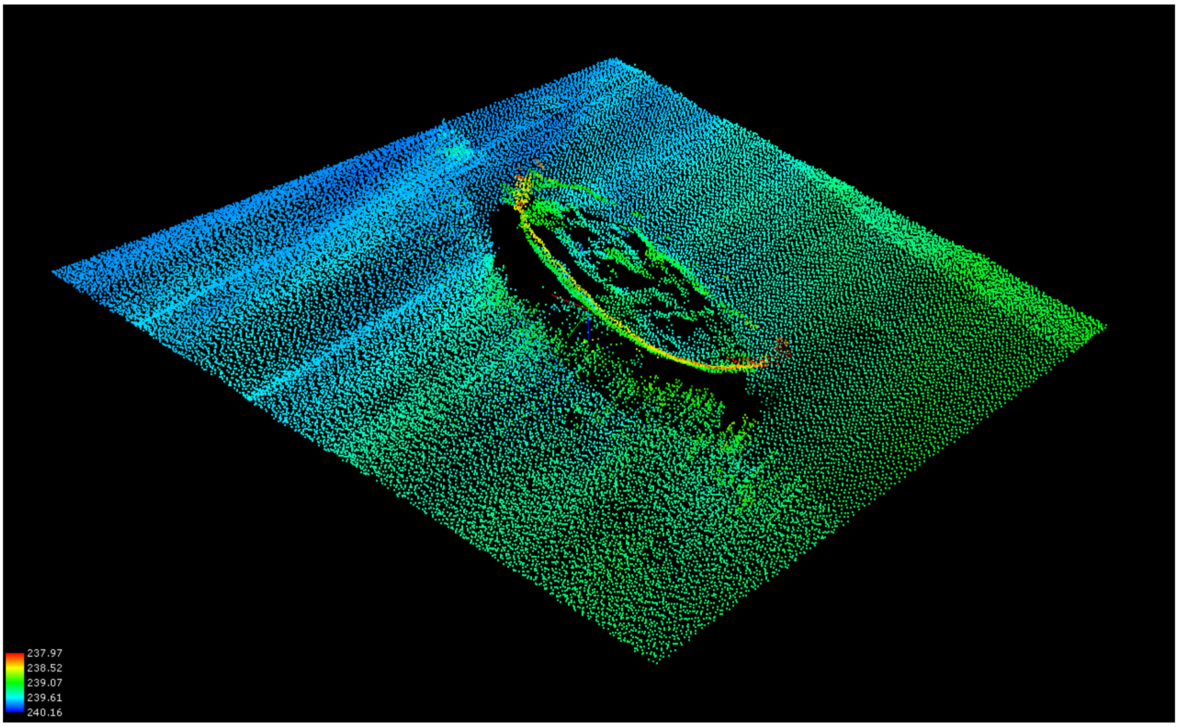


Figure 47 Bathymetric image of object GF-R-0346

12. CONCLUSIONS

The surveyed area is constituted by a narrow fjord, with steep slopes on either side. BEDROCK and coarse sediment is to a large extent outcropping on the sides while the central, deeper part of the fjord, comprises very soft sediment.

The softer sediments tends to be very soft to extremely soft CLAYS, generally with SILT content and occasionally with gravel, shell fragments or organic content. A few sampling sites had a distinct sulphuric odour, indicating anoxia. The three sites selected for chemical testing showed generally slightly increased concentrations of heavy metals and organic contaminants. Two of the sites (007 and 008) showed significant increase in Copper (Cu) concentration.

The geotechnical samples showed generally extremely low shear strength. The thermal resistivity is <1 W/mK in three samples and > 1 W/mK in three.

The area seems to be heavily trawled, concluded from the amount of seabed scars.

Wrecks and different kinds of debris are present in the whole area, with a higher concentration in the central part.

13. RECOMMENDATIONS

The current survey do not cover up to the shore. It is recommended to perform a nearshore survey to obtain a complete data set for the area.

The extremely soft sediment may be challenging for cable installation and further geotechnical testing is recommended.

In October 2012, Island Offshore detected 10 - 15 torpedoes, each containing about 300 kg explosives, during a ROV test. They were dismantled by blasting in March 2014 by Sjøforsvarets Minedykkerkommando (MDK). (Aftenbladet.no, 2014) However, it is not impossible that further UXO is present in Gandsfjorden and due to this and to the amount of debris observed in the survey area, UXO/buried objects screening and visual inspection along the entire decided route is recommended before cable is installed.

The sediment in the fjord show indications of being contaminated by heavy metals and organic contents. It is therefore recommended that a detailed study of the sediment composition is evaluated prior to any cable laying operations commences that could lead to sediment disturbance and therefore releasing contamination into the water column.

A detailed desktop study and risk assessment for the area is recommended where issues like UXO, chemical contamination of the sediment and the consequences of this if cable laying operations are commenced, an object and wreck inventory, the central parts of the surveyed fjord is littered with old wrecks, cranes, concrete dumping's and other debris, which all will complicate the cable installations.

14. REFERENCES

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(http://www.environment.no/

Aftenbladet.no, 2014. *Tonnevis med tysk sprengstoff i Gandsfjorden.* [Online] Available at: www.aftenbladet.no [Accessed 04 08 2014].

Weideborg, M. et al., 2013. Utkast til Bakgrunnsdokument for utarbeidelse av miljøkvalitetsstandarder og klassifisering av miljøgifter i vann, sediment og biota, Oslo: Klif.