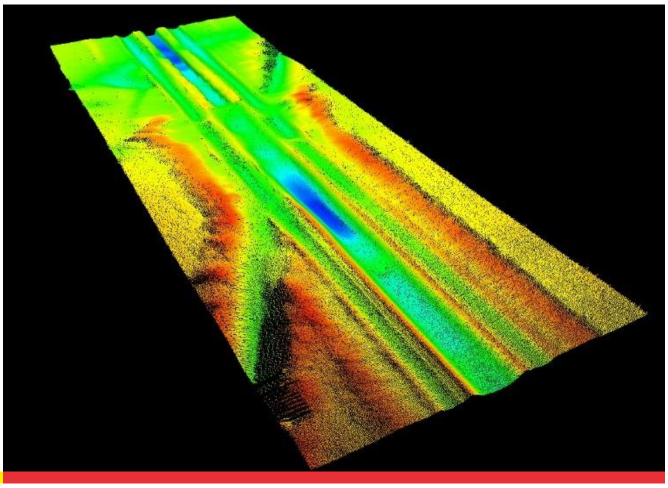
GEOPHYSICAL SURVEY REPORT

103282-ENN-MMT-SUR-REP-SURVLOT2
REVISION B | FOR USE
MAY 2020

ENERGINET



THOR OFFSHORE WIND FARM EXPORT CABLE ROUTE INVESTIGATIONS
LOT 2

DANISH NORTH SEA
AUGUST-DECEMBER 2019

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MMT

EXECUTIVE SUMMARY

THOR OFFSHORE WIND FARM AND EXPORT CABLE ROUTES OVERVIEW

Energinet are developing the proposed Thor Offshore Wind Farm in the Danish sector of the North Sea (Figure 3). MMT have been contracted to provide geophysical and geotechnical surveys covering the Offshore Wind Farm (OWF) and four export cable route options to two potential landfall locations in Jutland, Denmark. The OWF survey area is referred to as Lot 1, while the export cable route surveys are referred to as Lot 2. Aerial drone surveys were conducted at both landfall areas. This report covers the four export cable route survey corridors together with the two landfall locations for Lot 2, presenting the integrated results of the geophysical and geotechnical surveys and encompassing seabed and sub-seabed conditions, obstructions and installation constraints.

An overview image of routes R2 and R3 are presented in Figure 1 and for routes R4 and R5 in Figure 2.

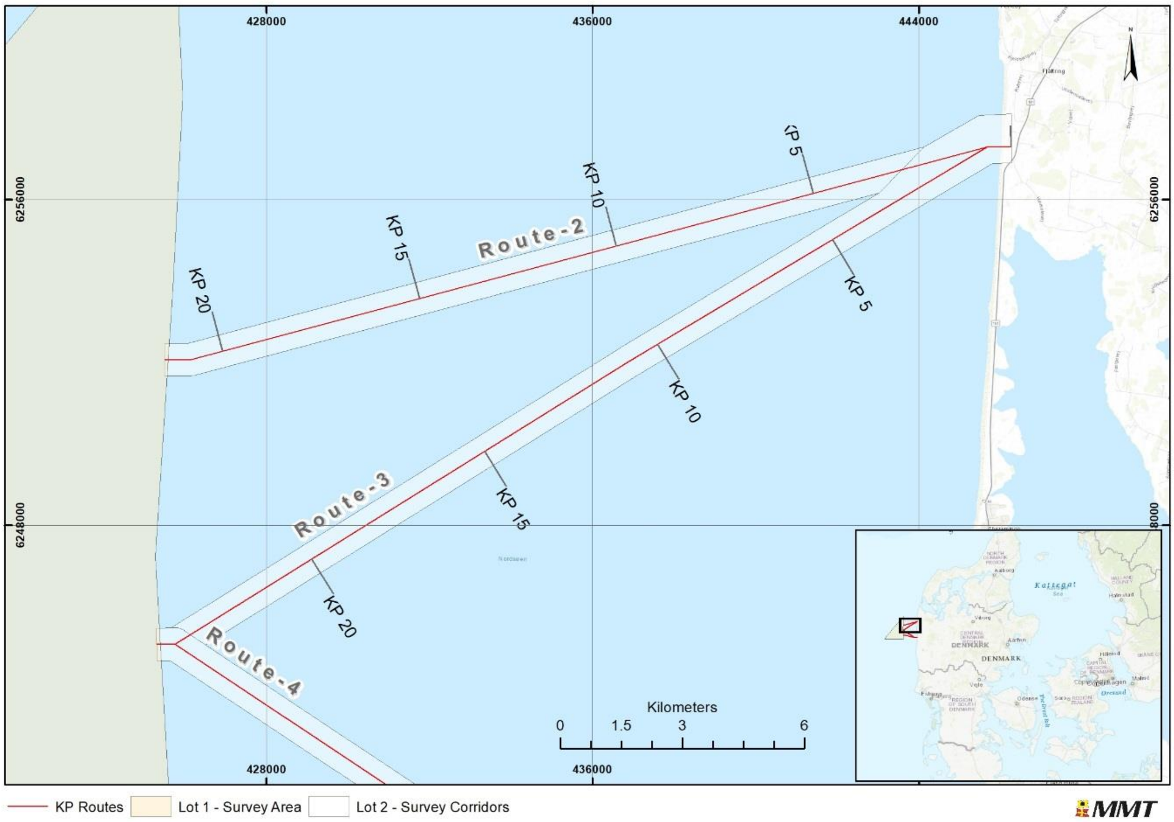


Figure 1 Overview of routes R2 and R3.

THOR OFFSHORE WIND FARM AND EXPORT CABLE ROUTES OVERVIEW

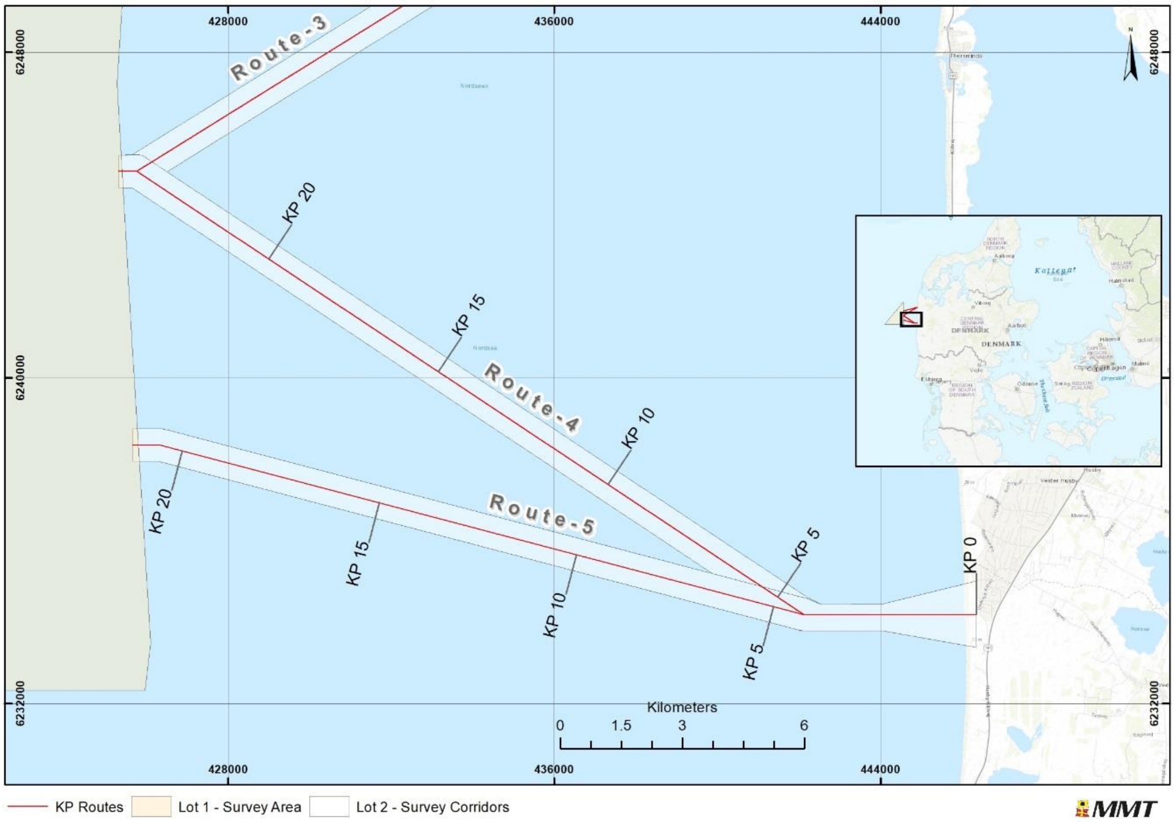


Figure 2 Overview of routes R4 and R5.

PRINCIPAL ROUTE POINTS – ROUTE 2					
Geodetic Datum & Projection: ETRS89 UTM Zone 32N (EPSG 25832)					
Point	KP	Latitude (dd.dddd)	Longitude (dd.dddd)	Easting (m)	Northing (m)
Start: Landfall 1	0.000	56.4571	8.1281	446263	6257296
End: OWF Entry 2	21.444	56.4072	7.7928	425504	6252058

BATHYMETRY AND SEABED MORPHOLOGY

From KP 0.00 to KP 0.83 the route crosses a level but generally undulating field after which it crosses a 135 m wide sand dune. The maximum elevation of +13.92 m is on the crest of the dune at KP 0.156. The maximum slope value is 37.4°, which is located on the landward (east) side of the dune. The base of the dune has an elevation of +1.67 m at KP 0.229 and, from here, the route generally slopes down to the edge of the drone coverage at KP 0.280 where the minimum elevation is +0.76 m.

The bathymetry in Route 2 is highly variable. The bathymetry data indicate several deep channels and shallow sandbanks along the proposed cable route. The seabed exhibits an initial gentle gradient as the water depth drops below DTU15 MSL benchmark to -5 m. Throughout the remainder of Route 2, the seabed shoals and deepens with very gentle slopes to a maximum depth of -29.3 m. The steepest prolonged slopes occur at the beginning of the block surrounding KP 2.00. Maximum & minimum depths of -29.26 m & -1.77 m occur at KP 21.442 and KP 0.486, respectively.

SEABED SEDIMENTS AND FEATURES

Within Route 2 survey corridor, the seabed surface alternates between SAND and Gravelly SAND to Sandy GRAVEL areas, associated with occasional discrete areas of DIAMICTON; a major band of DIAMICTON crosses the survey corridor from KP 20.854 to the end of the route at KP 21.444.

Ripples are observed throughout the survey area, mainly as discrete bands and small patches that frequently cross the width of the corridor. Boulder fields, both occasional and numerous are observed between approximately KP 6.000 and KP 14.500. Most are discrete bands and patches but occasionally form wider areas that cross the survey corridor.

Occasional areas of depressions, likely caused by changes in seabed current regime rather than shallow biogenic gas, are observed as discrete areas from KP 14.000 until the end of the route.

Some man-made features of importance were observed in the intertidal zone; these include two military bunkers and an area of concrete blocks forming a coastal erosion defence structure. An additional 735 contacts were detected, with the majority interpreted as boulders (721) and 8 as debris.

SHALLOW GEOLOGICAL CONDITIONS

The Innomar sub-bottom profiler (SBP) results show good performance in terms of penetration and resolution, with a maximum penetration of approximately 8.6 m below seabed. The upper unit along the survey route consists of SAND which often show internal variations of silt and gravel. The SAND unit extends from seabed to 3.4 m below seabed. The base of this unit has been defined by a fairly continuous, irregular horizon (H1). Often horizon H1 rests upon channel infill sediments that are defined by an underlying discontinuous, erosional surface (H2) which represents the base of palaeo-channels.

Along the route, the base of these channels reach a maximum of 8.6 m below seabed, as observed on the SBP data. These channel features are characterised by a range of sediment types from Silty SAND and Gravel to CLAY with occasional PEAT and organic matter that infill these features.

POTENTIAL INSTALLATION CONSTRAINTS
Factors that could be of consideration when laying a cable in Route 2 is the corridor wide DIAMICTON that crosses the survey corridor from KP 20.859 to KP 21.444. Boulder fields are frequent within the route corridor. The majority of boulder fields crossing the survey route occur between KP 6.011 to KP 10.238 and KP 12.051 to KP 14.784. Outside of these ranges boulder field areas are observed mainly adjacent to the corridor boundary. Two military bunkers from WWII and coastal defence blocks were located in the intertidal zone area of the route. It is likely that other items of debris could be buried under the mobile sediments that define this dynamic area. Minor organic content traces were identified in two vibrocore samples: 282-VC-R2-013 indicate minor peat laminae within SAND at 0.70 m, 1.50 m and 1.71 m BSB at KP 6.786; 282-VC-R2-010 indicate CLAY has some organic content at 0.85 m and 282-VC-R2-009 shows organic CLAY from 1.34 m at KP 11.136. On review of the draft VC logs very soft clays (extremely low to low strength) are present in VC sample 282-VC-R2-004 at 1.0 m and 1.5 m. However, this will be reviewed on receipt of the final geotechnical report. During the survey campaign a number of fishing vessels were contacted in order to remove fishing gear and therefore it must be assumed that fishing activity is present within Route 2.

PRINCIPAL ROUTE POINTS – ROUTE 3					
Geodetic Datum & Projection: ETRS89 UTM Zone 32N (EPSG 25832)					
Point	KP	Latitude (dd.dddd)	Longitude (dd.dddd)	Easting (m)	Northing (m)
Start: Landfall 1	0.000	56.4549	8.1129	446263	6257296
End: OWF Entry 3	24.400	56.3444	7.7915	425304	6245071

BATHYMETRY AND SEABED MORPHOLOGY

From KP 0.00 to KP 0.83 the route crosses a level but generally undulating field after which it crosses a 135 m wide sand dune. The maximum elevation of +13.92 m is on the crest of the dune at KP 0.156. The maximum slope value is 37.4°, which is located on the landward (east) side of the dune. The base of the dune has an elevation of +1.67 m at KP 0.229 and, from here, the route generally slopes down to the edge of the drone coverage at KP 0.280 where the minimum elevation is +0.76 m.

The bathymetry in Route 3 is highly variable. The seabed exhibits an initial gentle gradient as the water depth drops below DTU15 MSL benchmark to -6.0 m. Throughout the remainder of Route 3, the seabed shoals and deepens with very gentle slopes to a maximum depth of -29.67 m. The steepest prolonged slopes occur at the beginning of the route from KP 0.000 to KP 6.000. The maximum sub-sea slope angle is 9.0° at KP 9.767. Maximum and minimum depths of -29.67 m and -1.77 m occur at KP 24.272 and KP 0.486, respectively.

SEABED SEDIMENTS AND FEATURES

Within Route 3 survey corridor, the surficial sediments are dominated by SAND and GRAVEL with smaller discrete areas and bands of Gravelly SAND to Sandy GRAVEL. Occasional, discrete areas of DIAMICTON are observed mainly between KP 6.754 to KP 11.000. Boulder fields, both occasional and numerous are observed within a similar KP range, stretching across the survey corridor. South west of KP 11.000 that form more isolated, discrete bands that occasionally cross the survey centre line but are more often observed adjacent to the survey boundary.

Areas of ripples are observed throughout the corridor and generally form either thin bands or discrete areas that occasionally cross the survey corridor.

A large area of depressions, likely caused by changes in seabed current regime rather than shallow biogenic gas, are observed crossing the route from KP 14.976 to KP 16.533.

In total 1135 contacts were identified in the corridor the majority being boulders, however two potential wrecks or wreck debris were located at KP 5.391 (S_R3_0002) and KP 5.370 (S_R3_0108).

SHALLOW GEOLOGICAL CONDITIONS

The Innomar sub-bottom profiler (SBP) results show good performance in terms of penetration and resolution, with a maximum penetration of approximately 7.8 m below seabed. The upper unit along the survey route consists almost entirely of SAND which often show internal variations of silty SAND and GRAVEL. Localised areas of GRAVEL and CLAY are also observed along the route. The SAND unit extends from seabed to 3.1 m below seabed. The base of this unit has been defined by a fairly continuous, irregular horizon (H1). Often horizon H1 rests upon channel infill sediments that are defined by an underlying discontinuous, erosional surface (H2) which represents the base of palaeo-channels.

Along the route, the base of these channels reach a maximum of 7.8 m below seabed, as observed on the SBP data. These channel features are characterised by a range of sediment types from uniform

PRINCIPAL ROUTE POINTS – ROUTE 3
thick SAND to more laminated Silty SAND and GRAVEL to CLAY with occasional PEAT and organic matter that infill these features.
POTENTIAL INSTALLATION CONSTRAINTS
Factors that could be of consideration when laying a cable in Route 2 is the presence of DIAMICTON. Small discrete areas are also observed close to or crossing the survey centre line between KP 8.327 to KP 11.049. Boulder fields are frequently observed within the route corridor. They are particularly concentrated between KP 2.980 to KP 4.628, KP 7.923 to KP 11.148 and KP 20.682 to KP 21.861. A large area of depressions was observed crossing the survey corridor between KP 14.976 and KP 16.533. These are likely due to changes in seabed currents rather than shallow biogenic gas. During the survey campaign a number of fishing vessels were contacted in order to remove fishing gear and therefore it must be assumed that fishing activity is present within Route 3.

PRINCIPAL ROUTE POINTS – ROUTE 4					
Geodetic Datum & Projection: ETRS89 UTM Zone 32N (EPSG 25832)					
Point	KP	Latitude (dd.dddd)	Longitude (dd.dddd)	Easting (m)	Northing (m)
Start: Landfall 2	0.000	56.2494	8.1180	446349	6234187
End: OWF Entry 3	24.335	56.3444	7.7915	425304	6245071

BATHYMETRY AND SEABED MORPHOLOGY

From KP 0.00 to KP 0.134 the route crosses the undulating dune system and reaches a maximum elevation of +19.16 m at this point. The western extent of the dune is reached at KP 0.205. From here, the beach generally slopes gently towards the sea with the minimum elevation on route being +1.26 m at KP 0.245. The maximum slope for the landfall section of the Route is 43.0° at KP 0.167.

The bathymetry in Route 4 is less variable than Routes 2 and 3, with the seabed exhibiting an initially gentle gradient as the water depth drops below 0.0 m DTU15 MSL to -19 m. Throughout the remainder of Route 4, the seabed shoals and deepens with very gentle slopes to a maximum depth of -29.67 m. The steepest prolonged slopes occur at the beginning of the route from KP 0.000 to KP 4.000; however, the maximum sub-sea slope for Route 4 is 6.0° at KP 17.155. Maximum and minimum depths of -29.67 m and -3.75 m occur at KP 24.207 and KP 0.477, respectively.

SEABED SEDIMENTS AND FEATURES

In Route 4, the surficial geology is mainly characterised by SAND with occasional areas of gravelly SAND to sandy GRAVEL. Discrete GRAVEL patches are observed within the intertidal zone and from KP 12.000 to the end of the route at KP 24.335.

DIAMICTON forms small, numerous discrete areas near the start of the route between KP 1.303 to KP 1.942 crossing the corridor.

Areas of depressions are also seen along R4. These features are visible as numerous depressions scattered across the seabed and are likely caused by changes in seabed current regime rather than shallow biogenic gas. The lack of gas blanking / turbidity in the upper layers of the SBP data suggests gas is unlikely to be the provenance for these features but cannot be discounted.

Possible fishing gear, forming possible clump weight and rope was observed approximately 93 m N-W from the route at KP 8.347.

SHALLOW GEOLOGICAL CONDITIONS

The Innomar sub-bottom profiler (SBP) results show good performance in terms of penetration and resolution, with a maximum penetration of approximately 7.7 m below seabed. The upper unit along the survey route consists almost entirely of SAND which often show internal variations of silty SAND and gravel. Localised areas of GRAVEL and CLAY are observed along the route. The SAND unit extends from seabed to 3.0 m below seabed. The base of this unit is defined by a fairly continuous, irregular horizon (H1). Often, horizon H1 rests upon channel infill sediments that are defined by an underlying discontinuous, erosional surface (H2) which represents the base of palaeo-channels.

Along the route, the base of these channels reach a maximum of 7.7 m below seabed, as observed on the SBP data. These channel features are characterised by a range of sediment types, from Silty SAND and GRAVEL mixed to CLAY and organic matter.

PRINCIPAL ROUTE POINTS – ROUTE 4
POTENTIAL INSTALLATION CONSTRAINTS
A large area of depressions was observed crossing the survey corridor between KP 10.541 and KP 11.368, KP 13.204 and KP 14.461, KP 14.655 and KP 16.732 and KP 22.240 and KP 23.002. Two contacts (S_R3_0002 and S_R3_0108) are possible wreck debris and have also been correlated to MAG anomalies. Two items interpreted as fishing gear were observed within Route 5 (S_R4_0075, DCC 105 m and S_R4_0076, DCC 93 m). These items are thought to comprise a possible clump weight and rope. As such it must be assumed that fishing activity is active within Route 4. Low strength soils were identified in the draft geotechnical report with very soft clays (low strength) present in VC sample 282-VC-R4-037 at 1.0 m, 2.0 and 2.5 m.

PRINCIPAL ROUTE POINTS – ROUTE 5					
Geodetic Datum & Projection: ETRS89 UTM Zone 32N (EPSG 25832)					
Point	KP	Latitude (dd.dddd)	Longitude (dd.dddd)	Easting (m)	Northing (m)
Start: Landfall 2	0.000	56.2495	8.1342	446349	6234187
End: OWF Entry 4	21.237	56.2841	7.7990	425651	6238350

BATHYMETRY AND SEABED MORPHOLOGY

From KP 0.00 to KP 0.134 the route crosses the undulating dune system and reaches a maximum elevation of +19.16 m at this point. The western extent of the dune is reached at KP 0.205. From here, the beach generally slopes gently towards the sea with the minimum elevation on route being +1.26 m at KP 0.245. The maximum slope for the landfall section of the Route is 43.0° at KP 0.167.

The bathymetry in Route 5 exhibits an initially gentle gradient as the water depth drops below DTU15 MSL benchmark to -6 m. Throughout the remainder of Route 5, the seabed shoals and deepens with very gentle slopes to a maximum depth of -27.22 m. The steepest prolonged slopes occur at the beginning of the route from KP 0.000 to KP 5.000; however, the maximum sub-sea slope for Route 5 is 5.0° at KP 15.655. Maximum and minimum depths of -27.22 m DTU15 MSL at KP 19.041 and -3.75 m DTU15 MSL at KP 0.477, respectively.

SEABED SEDIMENTS AND FEATURES

In Route 5, the surficial geology is largely SAND with occasional, discrete areas of Gravelly SAND to Sandy GRAVEL and GRAVEL. The latter sediments are observed in the nearshore section and towards the end of the route between approximately KP 18.500 and KP 20.000.

DIAMICTON forms small, numerous discrete areas near the start of the route between KP 1.303 to KP 1.942 crossing the full survey corridor.

Ripples are also observed in areas where Gravelly SAND to Sandy GRAVEL are present. A sand bank and channel is also observed crossing the route at KP 20.670.

Areas of depressions are also seen in areas in R5. These features are visible as numerous depressions scattered across the seabed and are likely caused by changes in seabed current regime rather than shallow biogenic gas. The lack of gas blanking / turbidity in the upper layers of the SBP data suggests gas is unlikely to be the provenance for these features, but cannot be discounted.

SHALLOW GEOLOGICAL CONDITIONS

The Innomar sub-bottom profiler (SBP) results show good performance in terms of penetration and resolution, with a maximum penetration of approximately 9.8 m below seabed. The upper unit along the survey route consists almost entirely of SAND which often show internal variations of silty SAND and gravel. The SAND unit extends from seabed to 3.2 m below seabed. The base of this unit is defined by a fairly continuous, irregular horizon (H1). Often, horizon H1 rests upon channel infill sediments that are defined by an underlying discontinuous, erosional surface (H2) which represents the base of palaeo-channels.

Along the route, the base of these channels reach a maximum of 9.8 m below seabed, as observed on the SBP data. These channel features are characterised by a range of sediment types, from Silty SAND and Gravel mixed to CLAY, PEAT and organic matter.

PRINCIPAL ROUTE POINTS – ROUTE 5
POTENTIAL INSTALLATION CONSTRAINTS
Occasional DIAMICTON patches were found on Route 5 mainly located between KP 1.000 and KP 2.000. These areas are commonly surrounded by occasional boulder fields Two large area of depressions was observed crossing the survey corridor between KP 10.757 and KP 14.697 and KP 15.634 and KP 18.145. No areas of acoustic blanking were observed within the SBP data. Active gas release was also not observed in the water column. These areas of depressions evident in the surficial geology, are more likely associated with changes in seabed current regime rather than shallow biogenic gas. One possible wreck was identified on Route 5 at KP 4.226. In addition, two other items classified as potential debris were also observed within 50 m of the route centre line. During the survey campaign a number of fishing vessels were contacted in order to remove fishing gear and therefore it must be assumed that fishing activity is present within Route 5. On review of the draft VC logs very soft clay (extremely low strength) are present in VC sample 282-VC-R5-064 at 2.0 m; 282-VC-R5-060 at 1.0 m and low strength CLAY at 1.5 m. However these will be subject to review once the final geotechnical report has been received.

REVISION HISTORY

REVISION	DATE	STATUS	CHECK	APPROVAL	CLIENT APPROVAL
B	2020-05-06	For Use	DO	KG	
A	2020-03-27	For Use	DO	KG	
03	2020-03-06	Issue for Client Review	DO	KG	
02	2020-01-17	Issue for Client Review	DO	KG	
01	2020-01-13	Issue for Internal Review			

REVISION LOG

DATE	SECTION	CHANGE
2020-05-06	Various	As per client comment sheet Deliverable register ECR

DOCUMENT CONTROL

RESPONSIBILITY	POSITION	NAME
Content	Senior Data Processor	Andrew Stanley
Content	Senior Geophysicist	Hanna Milver
Content, Check	Project Report Coordinator	David Oakley/Darryl Pickworth
Check	Document Controller	Sofie Mellander
Approval	Project Manager	Karin Gunnesson/Martin Godfrey

TABLE OF CONTENTS

APPENDICES

LIST OF FIGURES

LIST OF TABLES

ABBREVIATIONS AND DEFINITIONS

BP	Before Present
BS	Backscatter
BSB	Below Seabed
CAD	Computer Aided Design
CPT	Cone Penetration Test
DCC	Distance Cross Course
DPR	Daily Progress Report
DTM	Digital Terrain Model
DTU	Technical University of Denmark
EEZ	Exclusive Economic Zone
EPSG	European Petroleum Survey Group
ETRS	European Terrestrial Reference System
GIS	Geographic Information System
GNSS	Global Navigation Satellite Systems

GRS	Geodetic Reference System
GS	Grab Sample
IHO	International Hydrographic Organization
INS	Inertial Navigation System
ISO	International Organization for Standardization
ITRF	International Terrestrial Reference Frame
KP	Kilometre Post
LGM	Last Glacial Maximum
M/V	Motorised Vessel
MAG	Magnetometer
MBBS	Multibeam Backscatter
MBES	Multibeam Echo Sounder
MMO	Man Made Object
MSL	Mean Sea Level
nT	Nanotesla
OWF	Offshore Wind Farm
PPS	Pulse Per Second
QC	Quality Control
ROTV	Remotely Operated Towed Vehicle
ROV	Remotely Operated Vehicle
RPL	Route Position List
RTK	Real-time Kinematic
SBET	Smoothed Best Estimated Trajectory
SBP	Sub-Bottom Profiler
SOW	Scope of Work
SSS	Side Scan Sonar
SVS	Sound Velocity Sensor
TPU	Total Propagated Uncertainty
TVU	Total Vertical Uncertainty
UAS	Unmanned Aircraft System
USBL	Ultra Short Baseline
UTC	Coordinated Universal Time
UTM	Universal Transverse Mercator
UXO	Unexploded Ordnance
VC	Vibrocore

1| INTRODUCTION

1.1| PROJECT INFORMATION

Energinet are developing the proposed Thor Offshore Wind Farm in the Danish sector of the North Sea. MMT have been contracted to provide geophysical surveys and geotechnical sampling covering the Offshore Wind Farm (OWF) and four export cable route options to two potential landfall locations in Jutland, Denmark. The OWF survey area is referred to as Lot 1, while the export cable route surveys are referred to as Lot 2. Topographic surveys were conducted at both landfall areas.

This report covers the four export cable route survey corridors and two landfall locations for Lot 2. A summary of project details is presented in Table 1.

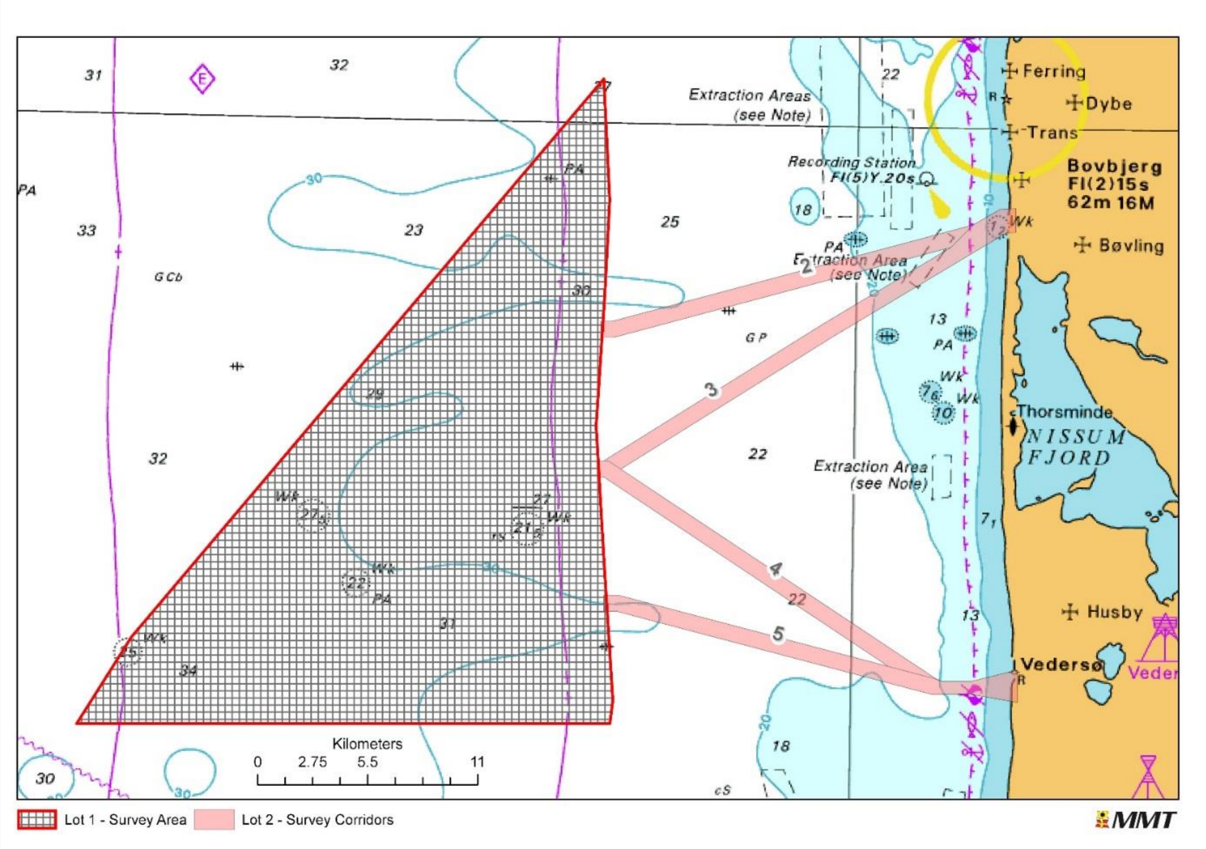


Figure 3 Thor Offshore Wind Farm and Export Cable Routes area overview.

Table 1 Project details.

CLIENT:	Energinet
PROJECT:	Thor Offshore Wind Farm Investigations Lot 1 & Lot 2
MMT SWEDEN AB (MMT) PROJECT NUMBER:	103282
SURVEY TYPE:	Geophysical and geotechnical cable route survey
AREA:	Danish North Sea
SURVEY PERIOD:	August – December 2019
SURVEY VESSELS:	M/V Franklin, M/V Deep Helder, M/V Stril Explorer, M/V Ping, UAS SenseFly eBee
MMT PROJECT MANAGER:	Karin Gunnesson / Martin Godfrey
CLIENT PROJECT MANAGER:	Jens Colberg-Larsen

1.2| SURVEY INFORMATION – LOT 2

The Lot 2 work scope comprises several tasks including:

- Project Management and Administration
- Geophysical surveys
- Geotechnical survey
- Landfall Topographic survey

The Lot 2 export cable route surveys cover four export routes numbered 2 to 5 from Jutland, Denmark to the proposed Thor Offshore Wind Farm location in the Danish sector of the North Sea. This also consists of two landfall areas, Landfall 1 and Landfall 2, which are located north and south respectively of the coastal town of Thorsminde (Figure 3). Export route 2 runs from the Landfall 1 location to the OWF Entry 2 point. Export route 3 runs from the Landfall 1 location to the OWF Entry 3 point. Export route 4 runs from the Landfall 2 location to the OWF Entry 3 point. Export route 5 runs from the Landfall 2 location to the OWF Entry 4 point. Route extents are shown in Table 2.

The two landfall topographic surveys were sub-contracted and were conducted using a SenseFly eBee unmanned aircraft system (UAS). The surveys extended 400 m from the high water mark at each cable export route landfall location (0 m MSL to 400 m inland). In addition, three benchmarks were established at each of the two landfalls for future construction works during the construction phase of the wind farm development. These benchmarks are expected to have a life span of at least 5 years.

The nearshore (< 10 m water depth) geophysical survey was conducted by the M/V Ping.

The offshore geophysical surveys were completed by the M/V Franklin. The offshore grab sampling and geotechnical investigations were completed by both the M/V Franklin and M/V Stril Explorer respectively.

The nearshore and offshore geophysical survey operations in Lot 2 comprised acquisition of multibeam echo sounder (MBES), sub bottom profiler (SBP), side scan sonar (SSS) and magnetometer (MAG) data. The landfall topographic survey used photogrammetry from an UAS.

This report covers the landfall and export cable route survey works acquired by MMT with integrated geotechnical survey (Appendix D|) results.

Table 2 Export cable route extents.

Number	Start KP	End KP
Route 2	0.000	21.444
Route 3	0.000	24.401
Route 4	0.000	24.335
Route 5	0.000	21.237

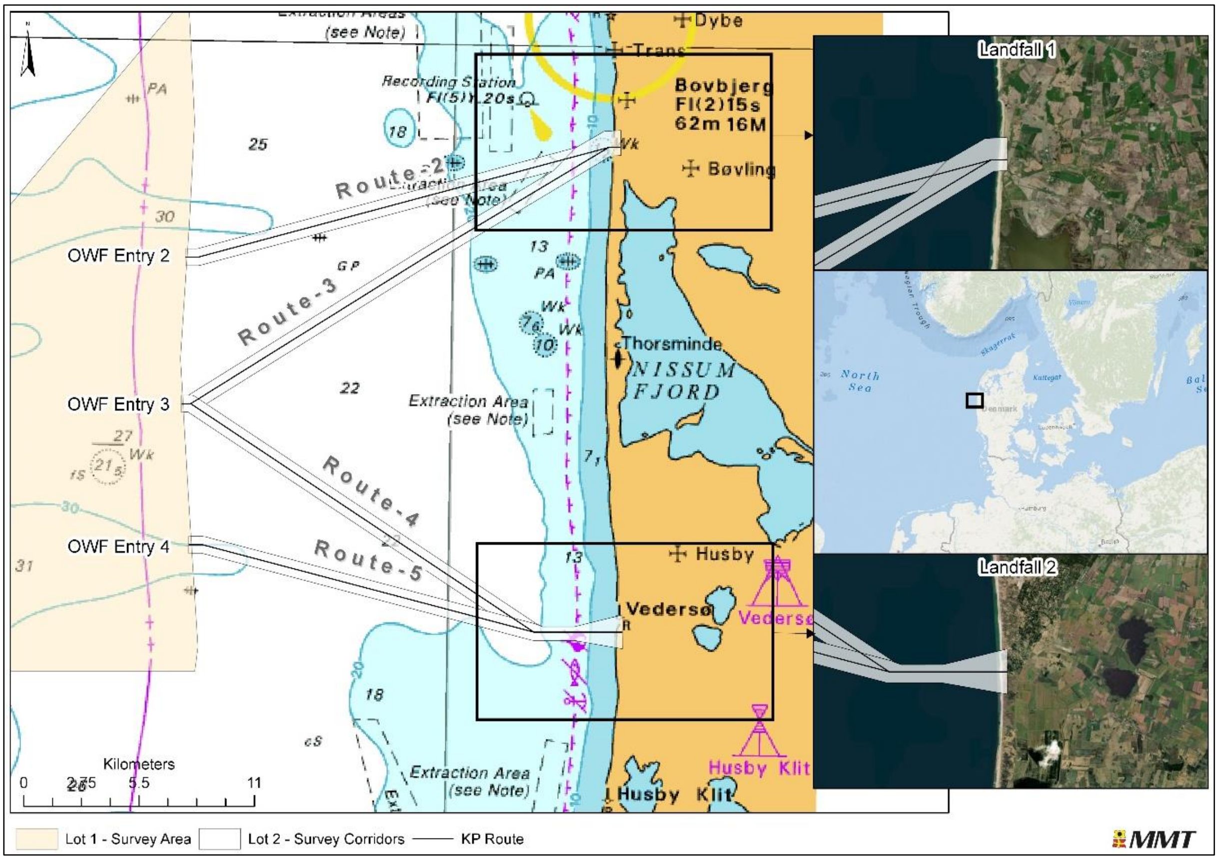


Figure 4 Overview of the Lot 2 export cable routes and Denmark nearshore.

1.3| SURVEY OBJECTIVES

The survey objectives for this project were to acquire bathymetric soundings, magnetometer, seabed imagery and sub-seabed geological information along the four surveyed route corridors (nominally 800 m wide) between the Landfall 1 and 2 locations on the Danish coast and the Entry points 2 to 4 at the proposed Thor Offshore Wind Farm. Acquisition of these data sets was conducted in order to provide comprehensive bathymetric soundings, seabed features maps including contact listings and shallow geological information to inform a ground model and mapping of magnetic anomalies. The interpretation of the datasets was charted and reported to inform cable route micro-routing and subsequent engineering.

The main objectives of the surveys were to:

- Acquire and interpret high quality seabed and sub-seabed data for project planning and execution. As a minimum, this includes local bathymetry, seabed sediment distribution, seabed features, seabed obstructions, wrecks and archaeological sites, crossing cables and pipelines and evaluation of possible mobile sediments
- Sub-bottom profiling along the survey centre line and wing-lines to map shallow geological units.
- Mapping of magnetic targets and to identify infrastructure crossings and large metallic debris.
- Seabed sampling and testing to provide in-situ geological data to support the interpretation of the shallow geophysical survey data.
- Ground truthing grab samples acquisition where necessary to inform potential environmentally sensitive habitats.

1.4| SCOPE OF WORK

For Lot 2 the following work packages are included in the scope of work (SOW):

- Work Package A – Offshore Cable Route Survey > 10 m Water Depth
  A full geophysical seabed survey of the entire cable route corridor to the 10 m water-line to map; bathymetry, seabed features, geology and upper soil stratifications.

- Work Package B – Nearshore and Landfall Survey < 10 m Water Depth
  A full geophysical seabed survey of the entire cable route corridor from the 10 m water-line to landfall to map; bathymetry, seabed features, geology and upper soil stratifications. In addition, a number of 3 geodetic benchmark points must be established in the area of the landfall site.

- Work Package C – Geotechnical investigations
  Upon completion and interpretation of the Work Packages A and B, a geotechnical campaign to provide the soil parameters of the interpreted soil strata.

- Work Package E – Reporting and data delivery
  The results of the investigations shall be processed, interpreted and supplied as a number of reports, charts and a set of digital deliverables.

1.4.1| DEVIATIONS TO SCOPE OF WORK

OFFSHORE CABLE ROUTE SURVEY (M/V FRANKLIN)

During the offshore cable route survey there were four deviations from the original SOW (Table 3).

Table 3 Deviations from the Lot 2 SOW during offshore cable route survey.

DATE	DESCRIPTION	CAUSE
2019-11-11	Locations of Lot 2 geophysical crosslines moved to coincide with VC locations	In order to add value to crossline data
2019-11-11	Lot 2 crosslines surveyed with MBES/SBP only, no SSS and Mag	SSS/Mag not required and not towing ROTV increases efficiency when running crosslines
2019-11-13	Lot 2 Export cable route line spacing changed from 80 m to 70 m. TQ-025 issued in this regard.	Narrower line spacing improves data overlap
2019-11-24	Lot 2 R4 data gap in SSS and SBP (~KP 17.5)	Fishing gear present, fisherman would not remove despite several requests

NEARSHORE AND LANDFALL SURVEY (M/V PING AND UAS SENSEFLY EBEE)

During the nearshore survey there was one deviation from the original SOW (Table 4).

Table 4 Deviations from the Lot 2 SOW during nearshore and landfall surveys.

DATE	DESCRIPTION	CAUSE
2019-08-02	Nearshore line plan changed to have survey lines parallel to depth contours.	Vessel safety and magnetometer survey altitude consistency

GEOTECHNICAL INVESTIGATIONS (M/V FRANKLIN AND M/V STRIL EXPLORER)

During the geotechnical investigations there were two deviations from the original SOW (Table 5).

Table 5 Deviations from the Lot 2 SOW during geotechnical investigations.

DATE	DESCRIPTION	CAUSE
2019-10-19	282-CPT-R2-016, 016A and 016B tests carried out in error inside an archaeological avoidance zone	Refer to MINCS report 2070
2019-10-23	282-VC-R2-016 and 016A samples taken in error inside an archaeological avoidance zone	Refer to MINCS report 2070

1.5| PURPOSE OF DOCUMENT

This report details the interpretation of the geophysical and geotechnical results from the landfall and offshore wind farm export cable route surveys.

The report summarises the conditions within the Lot 2 survey area with regards to; bathymetry, surficial geology and seabed features, contacts and anomalies, existing infrastructure, and subsurface geology. Geo-hazard identification and interpretation has also been considered.

All data obtained from the geophysical and geotechnical surveys have been correlated with each other and compared against the existing background information, in order to ground truth, the survey results.

Separate reports include the Offshore Wind Farm survey, Geotechnical survey results, and Operations reports. A full list of reports is given in Table 6 (Reference Documents).

1.6| REPORT STRUCTURE

The results from the Lot 2 survey campaign are presented in two separate reports.

- Operations Report
- Geophysical Survey Report (this report)

The Geophysical Survey Report, includes an alignment chart series and north up charts. A full chart list is provided within Appendix B|.

1.6.1| GEOPHYSICAL SURVEY REPORT

This report presents the Lot 2 Geophysical Survey results.

Attached to the report are the following appendices:

- Appendix A| Route Position Lists

- Appendix B| List of Produced Charts
- Appendix C| Contact and Anomaly List
- Appendix D| Geotechnical Report
- Appendix E| Geodetic Benchmarks
- Appendix F| Boulder Field Images

1.6.2| CHARTS

The MMT Charts describe and illustrate the results from the survey. The charts include an overview chart with a scale of 1:50 000, north up charts at a scale of 1:10 000 and alignment charts with a horizontal scale of 1:10 000, vertical scale of 1:100 and vertical exaggeration of 1:100.

The charts contain background data (existing infrastructure, EEZ, 12 nautical mile zone and wreck database) alongside survey results.

A list of all produced charts is presented in Appendix B|.

OVERVIEW CHART

Shows coastlines, EEZ, routes, survey corridor and planned survey lines. The chart also includes the bathymetry presented as a shaded relief colour image with 5 m interval.

ALIGNMENT CHARTS

The alignment charts show the following:

- **Bathymetry** presented as a shaded relief colour image with 1 m colour interval, overlaid with contour lines (1 m (minor) and 2 m (major)) with depth labels;
- **Surface geology and seabed features** presented as solid hatches (geologic classifications include: clay, silt, sand, gravelly sand to sandy gravel, gravel, diamicton, bedrock and very coarse sediment); surface morphology presented as solid hatches (morphologic classifications);
- SSS and magnetic contacts and linear features; seabed features divided into eight different classes (ripples, megaripples, sand waves, occasional boulders, numerous boulders, trawl mark areas, areas of marine growth and scars, pockmarks and scours.) and are presented as hatches with patterns;
- **Backscatter data and trackline**: Backscatter image overlain by the tracklines from the survey.
- **Depth below seabed:** Horizon (H1) gridded overlain with contours (1m)
- **Longitudinal Profile with shallow geology**: sub-seabed geology profiles with interpreted horizons related to seabed level and geotechnical sample results.

1.7| REFERENCE DOCUMENTS

The documents used as references to this report are presented in Table 6.

Table 6 Reference documents

Document Number	Title	Author
THOR_OWF_REPORT_1	Geological Desktop Study – Geoarchaeology	From Client
THOR_OWF_REPORT_2	Geological Desktop Study – Geological Model	From Client
103282-ENN-MMT-QAC-PRO-CADGIS	CAD and GIS Specification	MMT

Document Number	Title	Author
103282-ENN-MMT-MAC-REP-PING	Mobilisation and Calibration Report – Ping	MMT
103282-ENN-MMT-MAC-REP-FRANKLIN	Mobilisation and Calibration Report – Franklin	MMT
103282-ENN-MMT-MAC-REP-STRILEXP	Mobilisation and Calibration Report – MV Stril Explorer	MMT
103282-ENN-MMT-SUR-REP-OPEREPL2	Operations Report Lot 2	MMT
103282-ENN-MMT-SUR-GEOTEC-LOT2	Geotechnical Report Lot 2	InSitu
103282-ENN-MMT-SUR-REP-BSREPL2	Benthic Scope Report Lot 2	MMT
103282-ENN-MMT-Data-Examples	103282-ENN-MMT-Data-Examples presentation	MMT

1.8 | CORRIDOR LINE PLAN

The Lot 2 survey line spacing and minimum parameters are detailed in Table 7.

A breakdown of the survey lines is provided in Table 8.

Table 7 Survey line parameters.

Geophysical Survey Settings	Scope
Route 2	Length 21.444 km
Route 3	Length 24.401 km
Route 4	Length 24.335 km
Route 5	Length 21.237 km
Line spacing offshore geophysical Main Lines	70 m
Line spacing offshore geophysical Cross Lines	1 km
Line spacing nearshore geophysical Main Lines	25 m
Line spacing nearshore geophysical Cross Lines	225 m

Table 8 Survey line breakdown.

Survey Line Breakdown	Scope
Offshore geophysical Main Lines	5539.0 km/338 Lines
Offshore geophysical Cross Lines	446.3 km/32 Lines
Nearshore geophysical Main Lines	107.0 km/106 Lines
Nearshore geophysical Cross Lines	6.6 km/6 Lines

2| SURVEY PARAMETERS

2.1| GEODETIC DATUM AND GRID COORDINATE SYSTEM

2.1.1| ACQUISITION

The geodetic datum used for survey equipment during acquisition is presented in Table 9.

Table 9 Geodetic parameters used during acquisition.

HORIZONTAL DATUM: ITRF2014	
Datum	ITRF2014
ESPG Datum code	1165
Spheroid	GRS80
Semi-major axis	6 378 137.000m
Semi-minor axis	6 356 752.314m
Inverse Flattening (1/f)	298.257222101

2.1.2| PROCESSING

The geodetic datum used during processing and reporting is presented in Table 10.

Table 10 Geodetic parameters used during processing.

HORIZONTAL DATUM: ETRS89	
Datum	ETRS89
ESPG Datum Code	4936
Spheroid	GRS80
Semi-major axis	6 378 137.000m
Semi-minor axis	6 356 752.314m
Inverse Flattening (1/f)	298.257222101

2.1.3| TRANSFORMATION PARAMETERS

The transformation parameters used to convert from acquisition datum (ITRF2014) to processing/reporting datum (ETRS89) are presented in Table 11.

Table 11 Transformation parameters.

DATUM SHIFT FROM ITRF2014 TO ETRS89 (RIGHT-HANDED CONVENTION FOR ROTATION - COORDINATE FRAME ROTATION)	
PARAMETERS	**EPOCH 2019.5**
Shift dX (m)	+0.099440
Shift dY (m)	+0.064160
Shift dZ (m)	-0.120400
Rotation rX (“)	-0.00313900

DATUM SHIFT FROM ITRF2014 TO ETRS89 (RIGHT-HANDED CONVENTION FOR ROTATION - COORDINATE FRAME ROTATION)	
Rotation rY (“)	-0.01334000
Rotation rZ (“)	+0.02369500
Scale Factor (ppm)	+0.0030100000

Table 12 Test coordinate for datum shift.

UTM Zone	Datum	Easting (m)	Northing (m)	Latitude	Longitude	Location
32	ITRF 2014	399264.77	6232328.08	56° 13' 30,608" N	7° 22' 31,004" E	Point 1
	ETRS 89	399264.28	6232327.54	56° 13' 30.590" N	7° 22' 30.975" E	
32	ITRF 2014	425649.00	6264590.00	56° 31' 11.332" N	7° 47' 29.609" E	Point 2
	ETRS 89	425648.51	6264589.4654	56° 31' 11.314" N	7° 47' 29.581" E	
32	ITRF 2014	446353.50	6233387.15	56° 14' 32.370" N	8° 8' 3.841" E	Point 3
	ETRS 89	446353.01	6233386.6169	56° 14' 32.352" N	8° 8' 3.813" E	

2.1.4 | PROJECTION PARAMETERS

The projection parameters used for processing and reporting are presented in Table 13.

Table 13 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

2.1.5 | VERTICAL REFERENCE

The vertical reference parameters used for processing and reporting are presented in Table 14.

Table 14 Vertical reference.

VERTICAL REFERENCE PARAMETERS	
Vertical reference	MSL
Height model	DTU15

2.2| VERTICAL DATUM

Global navigation satellite system (GNSS) tide was used to reduce the bathymetry data to Mean Sea Level (MSL) the defined vertical reference level (Figure 5). The vertical datum for all depth and/or height measurements was MSL via DTU15 MSL Reduction from WGS84-based ellipsoid heights.

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, SBET (Smoothed Best Estimated Trajectory) that is then applied onto the multibeam echo sounder (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.

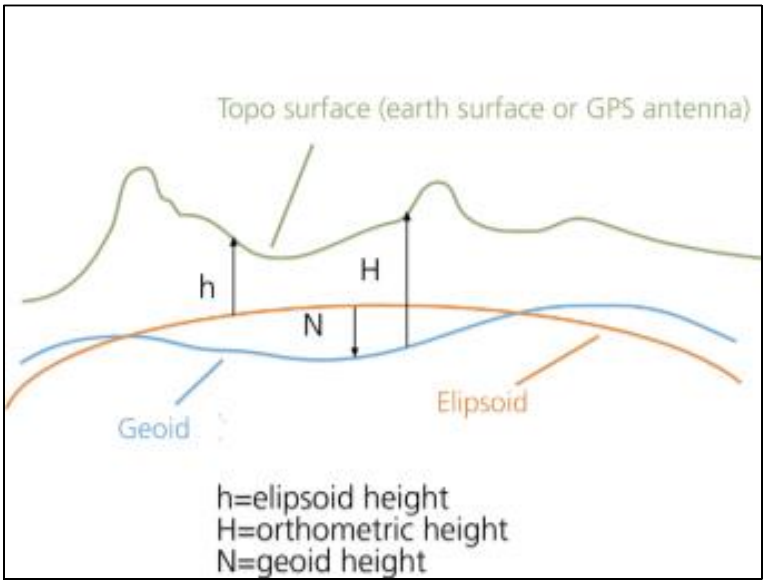


Figure 5 Overview of the relation between different vertical references.

2.3| TIME DATUM

Coordinated universal time (UTC) is used on all survey systems on board the vessel. The synchronisation of the vessels on board system is governed by the pulse per second (PPS) issued by the primary positioning system. All displays, overlays and logbooks are annotated in UTC as well as the daily progress report (DPR) that is referred to UTC.

2.4| KP PROTOCOL

For the export cable routes, the routes are based off the client supplied RPL REV04.

KP 0.000 is located at the two landfalls (Landfall 1 in north, Landfall 2 in south). KP values increase towards the OWF survey area entry points 2, 3 and 4.

KPs were calculated based upon the relevant UTM mapping projection zone and were at all times related to the selected route. The KP databases used, provided by the client were:

- REV04_LF1-ENTRY2_20190603_JCO – Route 2
- REV04_LF1-ENTRY3_20190603_JCO – Route 3
- REV04_LF2-ENTRY3_20190603_JCO – Route 4
- REV04_LF2-ENTRY4_20190603_JCO – Route 5

3| SURVEY VESSELS

3.1| M/V FRANKLIN

GEOPHYSICAL SURVEY OFFSHORE

The offshore geophysical survey operation was conducted by the survey vessel M/V Franklin (Figure 6). The vessel equipment is shown in Table 15.

Figure 6 M/V Franklin.

Table 15 M/V Franklin equipment.

INSTRUMENT	NAME
Primary Positioning System	Applanix POS MV 320 with C-Nav 3050 with C-NavC^2 corrections on the SF2 service
Secondary Positioning System	C-Nav 3050 using C-NavC^2 corrections on the SF1 service Hemisphere R110 using IALA and SBAS corrections
Primary Gyro and INS System	Applanix POS MV 320
Secondary Gyro and INS System	CDL Minipos3
Underwater Positioning System	IXBLUE GAPS
Survey Navigation System	QPS QINSy
Surface Pressure Sensor	Vaisala Pressure Sensor
Multibeam Echo Sounder (Medium to Shallow Water)	Kongsberg EM2040D (200-400 kHz)
Side Scan Sonar	EdgeTech 2200-CSS (300/600 kHz) and Focus II ROTV
Sub-Bottom Profiler	Innomar SES2000
Magnetometer	Geometrics G882
Sound Velocity Sensor	Valeport SVX2, deployed over the side Real-time SVS Valeport miniSVS, hull-mounted at the MBES transducers
Grab Sampler	Van Veen Grab

3.2| M/V PING

GEOPHYSICAL SURVEY NEARSHORE

The nearshore geophysical survey operation was conducted by the survey vessel Ping (Figure 7). The vessel equipment is shown in Table 16.

Figure 7 M/V Ping.

Table 16 M/V Ping equipment.

INSTRUMENT	NAME
Primary Positioning System	Applanix POS MV 320 with C-Nav 3050 using C2 corrections
Secondary Positioning System	Hemisphere R110 using IALA and SBAS corrections
Primary Gyro and INS System	Applanix POS MV 320
Underwater Positioning System	Pole-mounted IXBLUE GAPS
Survey Navigation System	QPS QINSy
Multibeam Echo Sounder (Medium to Shallow Water)	Dual Head Reson 7125D (200, 400 kHz)
Side Scan Sonar	Pole-mounted EdgeTech 4200 (300/600 kHz)
Sub-Bottom Profiler	Pole-mounted Innomar SES2000 Standard
Magnetometer	Geometrics G882
Sound Velocity Sensor	Valeport miniSVS, deployed over the side Real-time SVS Valeport miniSVS, hull-mounted at the MBES transducers

3.3| M/V STRIL EXPLORER

GEOTECHNICAL SURVEY OFFSHORE

The offshore geotechnical survey operation was conducted by the survey vessel M/V Stril Explorer (Figure 8). The vessel equipment is shown in Table 17.

Figure 8 M/V Stril Explorer.

Table 17 M/V Stril Explorer equipment.

INSTRUMENT	NAME
Primary Positioning System	Applanix POS MV 320 with C-Nav 3050 with C-NavC^2 corrections on the SF2 service
Secondary Positioning System	C-Nav 3050 using C-NavC^2 corrections on the SF1 service
Primary Gyro and INS System	Applanix POS MV 320
Secondary Gyro and INS System	Sonardyne Lodestar 300
Underwater Positioning System	Kongsberg HiPAP 501
Survey Navigation System	QPS QINSy
Vibrocorer	6 metre CMS HPMV (High Power Marine Vibrocorer, CMS-Geotech Ltd)
PCPT	ROSON 100

3.4| UAS SENSEFLY EBEE

LANDFALL TOPOGRAPHIC SURVEY

The two landfall topographic surveys were sub-contracted and were conducted using an UAS (Figure 8). The equipment is shown in Table 17.

Figure 9 UAS SenseFly eBee.

Table 18 UAS equipment.

INSTRUMENT	NAME
Primary Positioning System	Trimble SPS750 RTK GNSS system

4| DATA PROCESSING AND INTERPRETATION METHODS

4.1| BATHYMETRY

The objective of the processing workflow is to create a Digital Terrain Model (DTM) that provides the most realistic representation of the seabed with the highest possible detail. The processing scheme for MBES data comprised two main scopes: horizontal and vertical levelling in order to homogenise the dataset and data cleaning in order to remove outliers.

The MBES data is initially imported into Caris HIPS to check that the coverage and density requirements have been achieved. It then has a post-processed navigation solution applied in the form of a SBET. The SBET is created by using post-processed navigation and attitude derived primarily from the POS M/V Inertial Measurement Unit (IMU) data records. This data is processed in POSPac MMS and then applied to the project in Caris HIPS.

In addition to the updated position data, a file containing the positional error data for each SBET is also applied to the associated MBES data. The positional error data exported from POSPac MMS contributes to the Total Propagated Uncertainty (TPU) which is computed for the DTM grid nodes. These surfaces are generated in Caris HIPS and are checked for deviations from the Total Horizontal Uncertainty (THU) and Total Vertical Uncertainty (TVU) thresholds as specified by the client. This is discussed in further detail in Section 5.1|.

After the post-processed position and error data is applied, a Global Positioning System (GNSS) tide is calculated from the SBET altitude data which vertically corrects the bathymetry using the DTU15 MSL ellipsoidal separation model within Caris HIPS. The bathymetry data for each survey block is then merged together to create a homogenised surface which can be reviewed for both standard deviation and sounding density. Once that data has passed these checks it is taken into NaviModel.

Data has been cleaned in both Caris and NaviModel. In Caris, statistical cleaning using Cube surfaces has been performed, while in NaviModel the data is turned into a 3D model, which undergoes further checks and data cleaning processes. Typically, an S-CAN filter is applied to the data to remove any outliers although some manual cleaning may also take place. This data cleaning is then written back to the data in the Caris HIPS project ready for QC.

In Caris HIPS the QC surfaces are recalculated to integrate any sounding flag editing that has occurred in NaviModel and examined to check that the dataset complies with the project specification. If the dataset passes this QC check then products (DTMs, contours and rasters) can be exported from NaviModel for delivery or for further internal use.

The work flow diagram for MBES processing is shown in Figure 10.

Offshore the bathymetry data was vertically reduced to the DTU15 MSL datum. This data was used to create subsequent data products as well as calculating surface gradients (slope). These vertical transformations and slope values were calculated using the file manipulation software FME. This software was also used to create 1 km x 1 km tiles of the gridded bathymetry deliverables following the client approved schema and all other MBES products were clipped to the same extents in order to provide a standardised naming scheme. Figure 11 show how the tile grid overlies the route data.

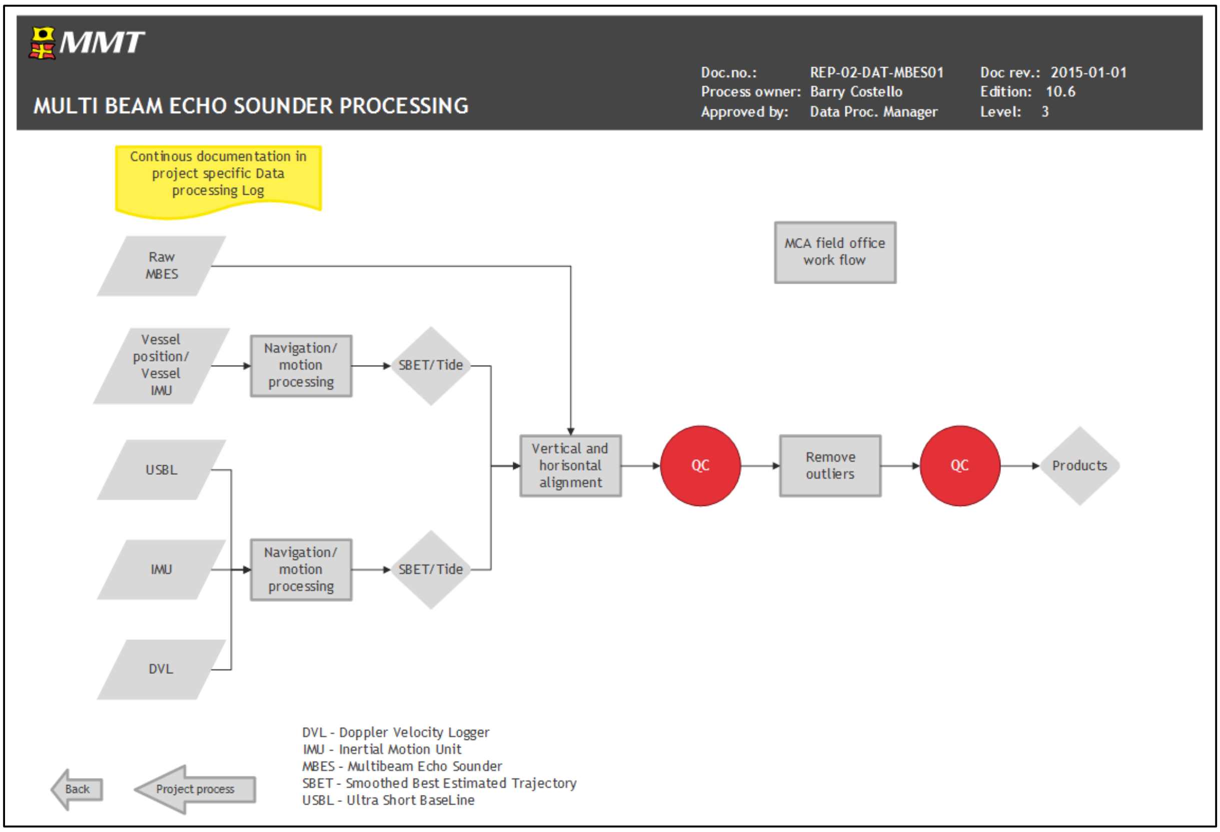


Figure 10 Workflow MBES processing.

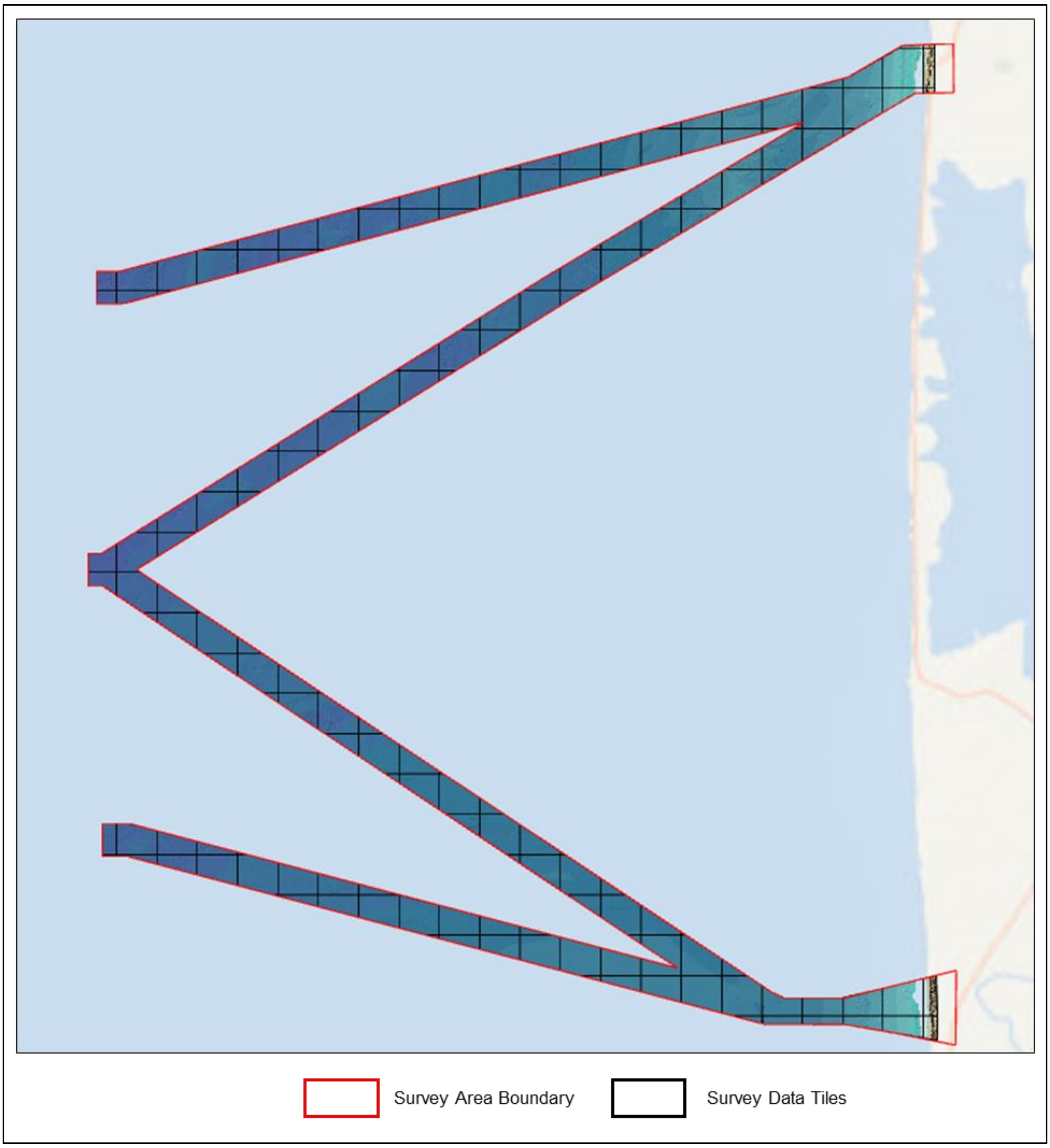


Figure 11 Overview of bathymetry data tiles scheme.

4.2| BACKSCATTER

MBES backscatter mosaics, in GeoTIFF and ASCII XY-Intensity formats, were generated using QPS Fledermaus GeoCoder Toolbox (FMGT).

FMGT reads the intensity of each returned ping and applies a sequence of normalising algorithms to account for the variations in intensity generated by vessel motion, beam angle and high frequency along track variability. In addition, FMGT effectively back-calculates other intensity changes generated by any automatic changes to the EM2040D (MBES) operating settings and results in a homogenous grayscale backscatter mosaic that accurately represents the spatial variations in seafloor sediments.

The raw MBES files for each survey route (R2 to R5) are processed in individual FMGT projects in order to manage extents of the project scope in terms of computer processing power. Despite each survey route being processed separately the colour scales of the final exported mosaics can be adjusted to present the same overall intensity range so that each sediment type is represented by the same colour tone across the separate routes.

The nearshore backscatter data, was collected using a Reson Seabat 7125. This data was processed separately in FMGT from the offshore data and was then merged in to the EM2040D data.

These individual route datasets were combined in the file management software FME where the merged dataset was divided into a series of tiles based on the schema outlined in section 4.1|. Figure 12 shows an example of backscatter tile R2_445_6257_MBES_BS_100CM, the data/image covers an area measuring 1 km x 1 km. For all survey areas the backscatter mosaics have been exported at 1 m resolution.

Figure 12 Example backscatter mosaic Tile R2_445_6257_MBES_BS_100CM.
Image is presented north-up. Areas with high acoustic reflectivity show up as lighter shades of grey.

4.3| SIDE SCAN SONAR

SSS processing and interpretation was conducted within SonarWiz. Prior to importing raw SSS JSF files the water sound velocity at towing depth was confirmed and updated within the SonarWiz import settings. The raw SSS data was then imported into SonarWiz (which automatically creates a mosaic window) without the application of any gains, and the following QC/processes were conducted:

1. Navigation data QC'd and any sporadic spikes removed
2. Seabed auto tracked, QC'd and manually adjusted if necessary
3. User controlled gains applied to the data and manually adjusted to enhance seabed sediment contrasts and seabed features
4. SSS data QC'd against MBES data by locating features/contacts clearly distinguishable in both data sets and comparing appearance and position
5. Coverage QC'd and any gaps flagged and infilled in order to meet client coverage requirements

The SSS processing workflow is outlined in Figure 13 and Figure 14.

The processing was conducted with the following objectives:

- To classify seabed surface sediments
- To classify mobile bedforms and other potential hazards
- To identify natural and anthropogenic seabed features
- To detect contacts
- To detect cables and pipelines

The interpretation of SSS geo-boundaries was conducted within SonarWiz and AutoCAD software. Within SonarWiz geo-boundaries were digitised as features within the mosaic window and exported as DXF files. For digitisation in AutoCAD, SSS mosaics were exported from SonarWiz (as geotiff files) loaded into AutoCAD and line and polygon features mapped.

The geo-boundaries were reviewed against backscatter, MBES and MAG grid data so an integrated interpretation was obtained based upon all available data. Seabed sediment classifications were also reconciled against the geotechnical GS results. Interpretations were QC'd and finalised by a Senior Geologist.

The interpretation of SSS contacts was conducted within SonarWiz. The SSS data was viewed in digitising mode and contacts were selected according to specifications. Contacts were digitised alongside MBES data so that associations with a visible MBES feature could be included within the comments, and to ensure that all contacts visible on the MBES data were identified by the SSS. The interpreted contacts were QC'd and correlation/assessment against MBES data repeated and a list of accepted contacts created. The contacts list was then correlated to MAG anomalies and a final QC conducted by a Senior Geologist.

Before the mosaic is exported as a geotiff, the files are arranged so the best available data is uppermost. The nadir is made transparent in order for data in overlapping files that cover the nadir gap to be seen. This process is conducted for both HF and LF data sets.

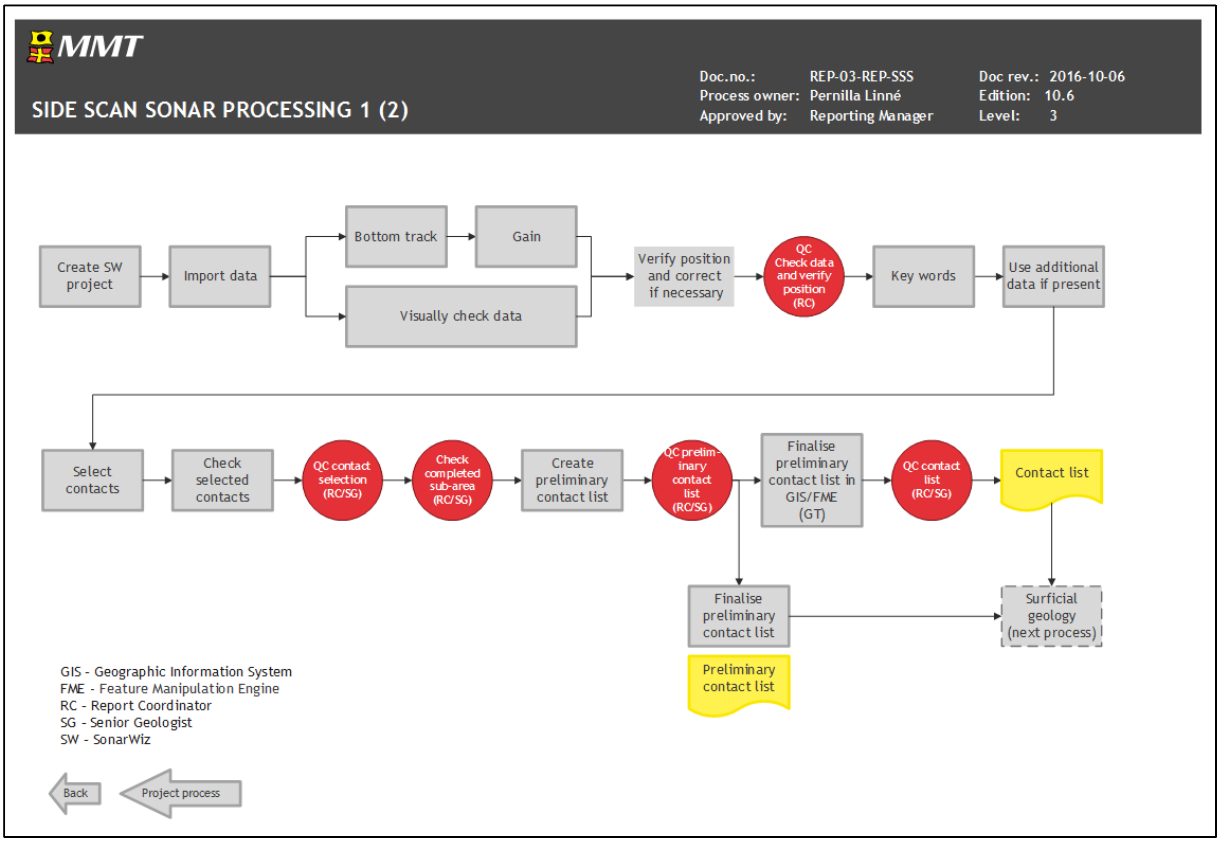


Figure 13 Workflow side scan sonar processing (1 of 2).

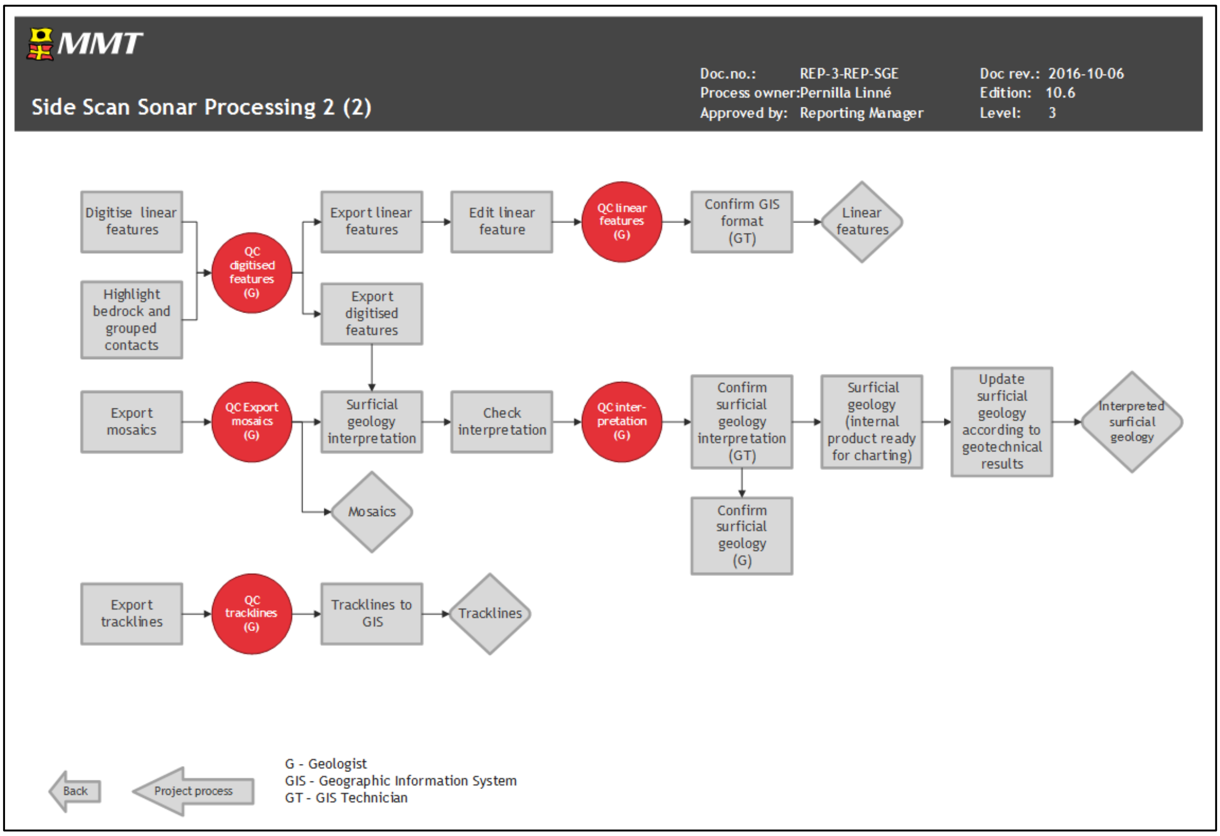


Figure 14 Workflow side scan sonar processing (2 of 2).

4.4| MAGNETOMETER

MAG data was processed and interpreted within Oasis Montaj software.

Navigation is despiked removing outliers through a set distance from the navigational trend, after a manual check is performed and additional spikes are removed as needed. Small gaps of 1-2 meters are interpolated and bigger navigational gaps are flagged for infill. Once the navigation has been despiked a small rolling statistic smoothing filter is applied.

Altitude, depth and motion is despiked removing outliers through a set value that incorporates real data for each sensor but excludes spikes as these vastly differ from the real data, after a manual check is perfomed and additional spikes removed as needed. Once despiked a small rolling statistic smoothing filter is applied for each sensor.

Each file was individually studied for anomalies. Once an anomaly was identified a comparison was carried out between the different sensor information available (altitude, depth, motion and quality) to determine if the anomaly is real or induced by low quality data or rapid changes in MAG movement. Once an anomaly was confirmed to be real the location was added to a database and the anomaly's amplitude and wavelength were manually measured. Once completed, each picked anomaly was individually Quality Checked to confirm stored values.

OFFSHORE MAG DATA SETTINGS

The raw MAG data was de-spiked using a pre-set cut off value of 49500 nT and 51000 nT to remove occasional spikes. To generate the regional background field, a series of four filters were used. The regional background field was then subtracted from the total field to generate the residual field.

Applied filters to generate background offshore data:

- Non-linear filter 1; Width = 150, Tolerance = 1.2
- Non-linear filter 2; Width = 75, Tolerance = 0.5
- Non-linear filter 3; Width = 67.5, Tolerance = 0.25
- Non-linear filter 4; Width = 32, Tolerance = 0.125

Example of the result can be seen in Figure 15

NEARSHORE MAG DATA SETTINGS

The raw MAG data was de-spiked using a pre-set cut off value of 47000 nT and 70000 nT to remove occasional spikes. To generate the regional background field, a series of four filters were used. The regional background field was then subtracted from the total field to generate the residual field

Applied filters to generate background nearshore data:

- Non-linear filter 1; Width = 100, Tolerance = 10
- Non-linear filter 2; Width = 50, Tolerance = 1.0
- Non-linear filter 3; Width = 10 Tolerance = 0.25
- Non-linear filter 4; Width = 5, Tolerance = 0.125

Example of the result can be seen in Figure 15.

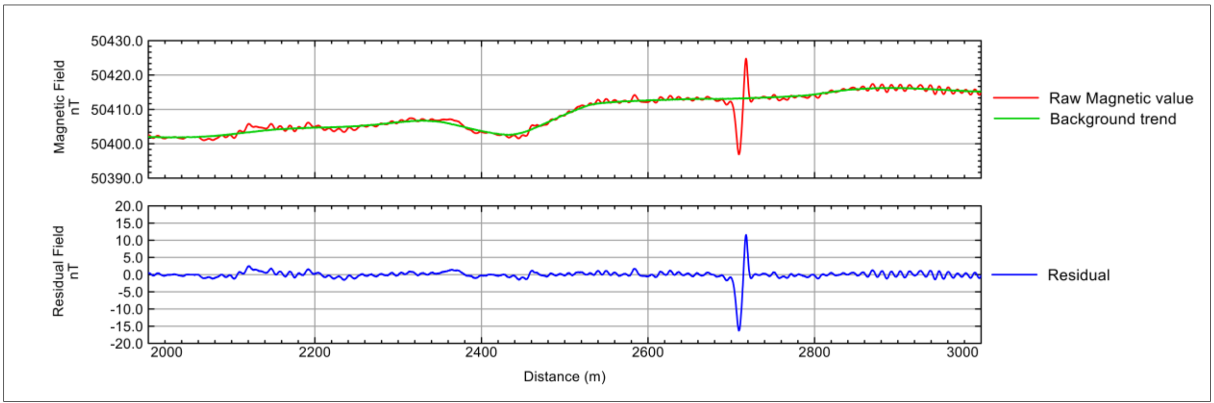


Figure 15 MAG Data example from R4.
Indicates raw, processed, background trend and the resulting residual signal of the magnetometer data over 1000 m with range of 40 nT.

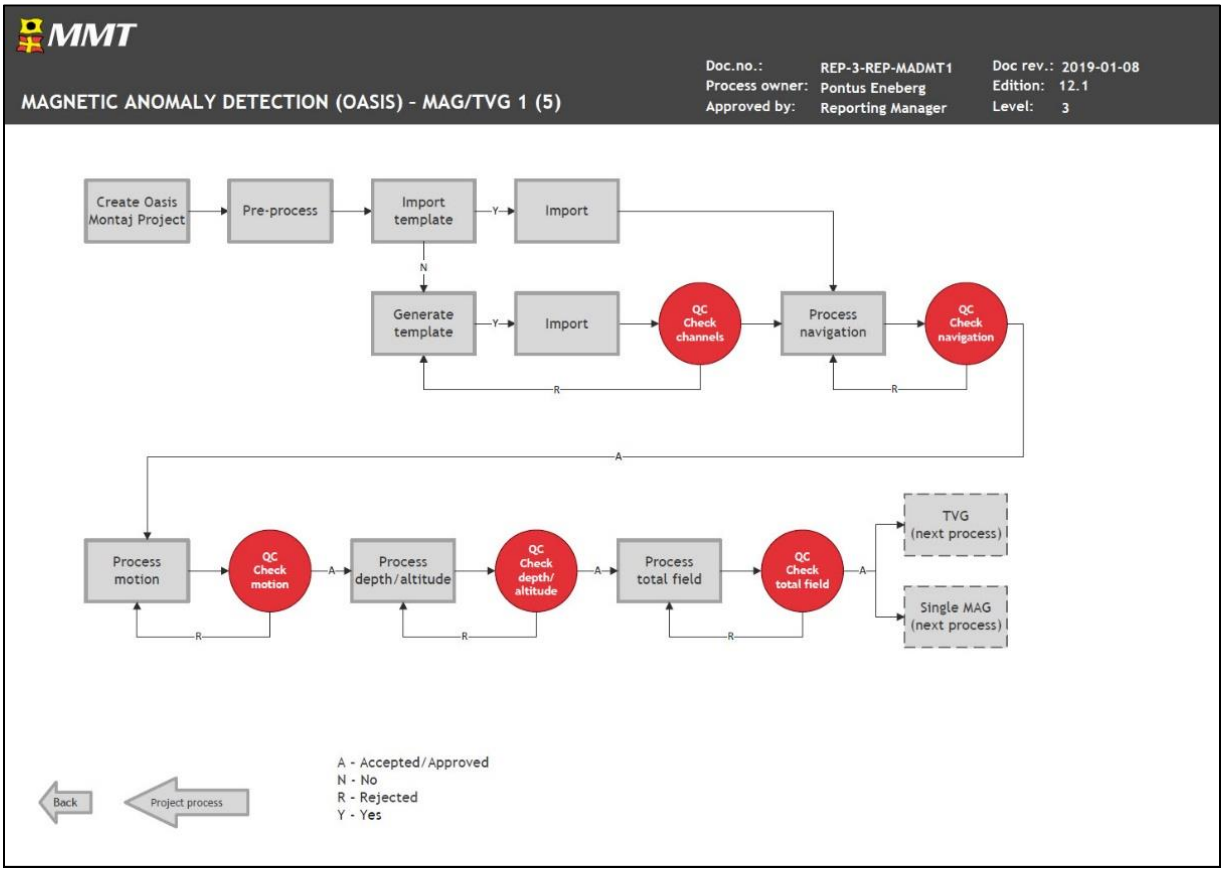


Figure 16 Workflow MAG processing (1 of 2).

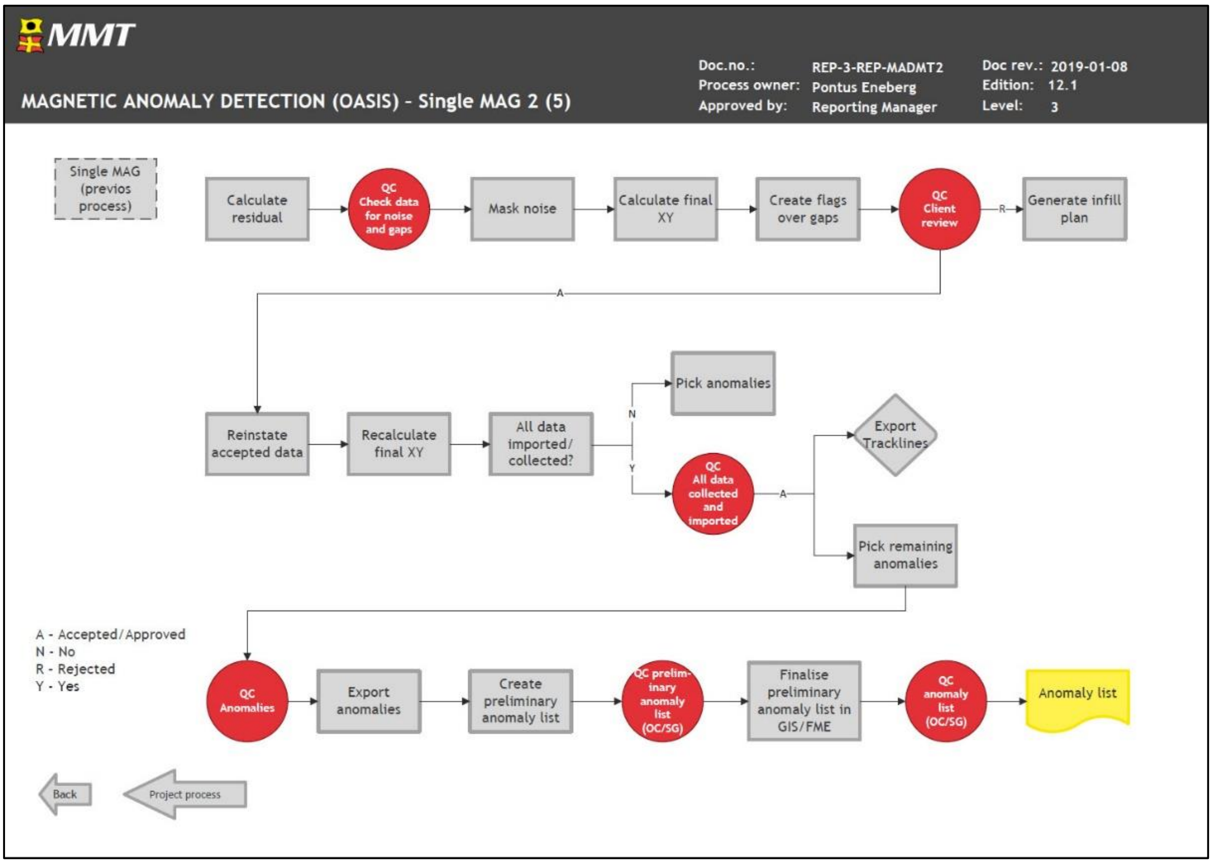


Figure 17 Workflow MAG processing (2 of 2).

4.5| SUB-BOTTOM PROFILER - INNOMAR

Prior to import, the SBP data files were converted from SES3 format to SGY format using the Innomar software module SESConvert64. The SBP files were then imported into SonarWiz where navigation was checked and files were bottom tracked. The seabed was initially auto tracked and then quality checked and manually adjusted if required. Position was verified using MBES data by locating features clearly visible in both data sets and comparing the position. The coverage was assessed and any gaps or unacceptable data quality was flagged.

The SBP data was imported into Kingdom via Seismic Direct. In the beginning of the survey, a few filters were tried, but it didn’t increase the resolution of the data. It was therefore decided to apply dynamic amplitude gains (overall gain) where required to enhance reflectors. These are not applied to all files in a global setting but rather adjusted on a file by file basis for interpretation purposes only. In periods were the motion of the vessel was evident due to weather conditions, the data was temporarily flattened to the seabed to aid the digitising of reflectors.

Along the centrelines of each of the surveyed routes, all reflectors were digitized. The distance from the seabed to the digitized reflectors was calculated using the sound velocity of 1600 m/s. The interpretation was continuously correlated with the results from the geotechnical campaign. This was done by comparison with the geotechnical logs during interpretation in Kingdom and the final correlation was done during the interpretation in ACAD. The reflectors and the geotechnical results are presented in profile charts delivered along with this report.

In addition to this, the only coherent surface, defined by the reflector H1, was digitized on all lines. A grid showing the depth below seabed to this reflector were created, using the flex gridding algorithm with the fit set to 0 and the smoothness set to 6. The grid cell size was 10 m. The distance from data was limited to 80 m to ensure coverage of the survey corridor.

Datum alignment to MSL was performed on the gridded surface (H1) by applying the MSL corrected seabed grid to the isochore surface.

For the survey centreline, additional reflectors within the data such as the laterally discontinuous H2 and internals were also digitised to enhance the information displayed in the profile charts. As the internals represent minor lithological changes within a defined unit and the H2 reflector was not laterally continuous enough to form an isochore, these have not been digitised on the survey winglines.

The general workflow of the SBP processing is outlined in Figure 18 and Figure 19.

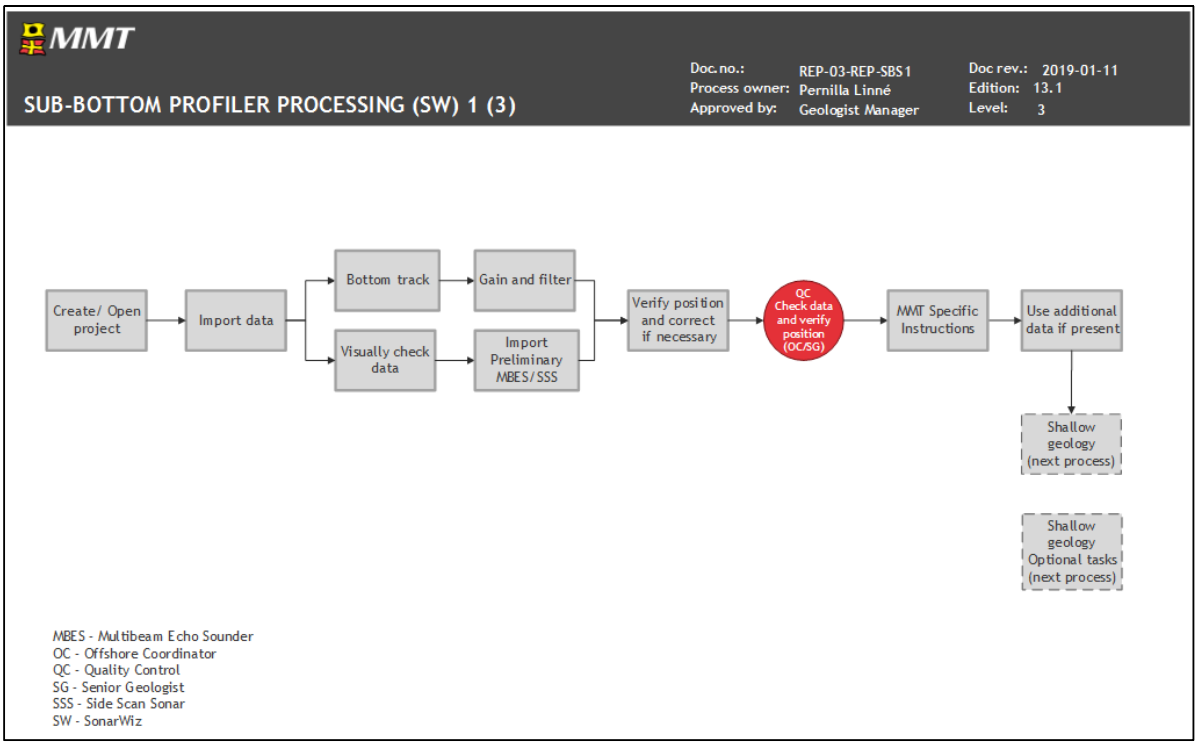


Figure 18 Workflow SBP processing (1 of 2).

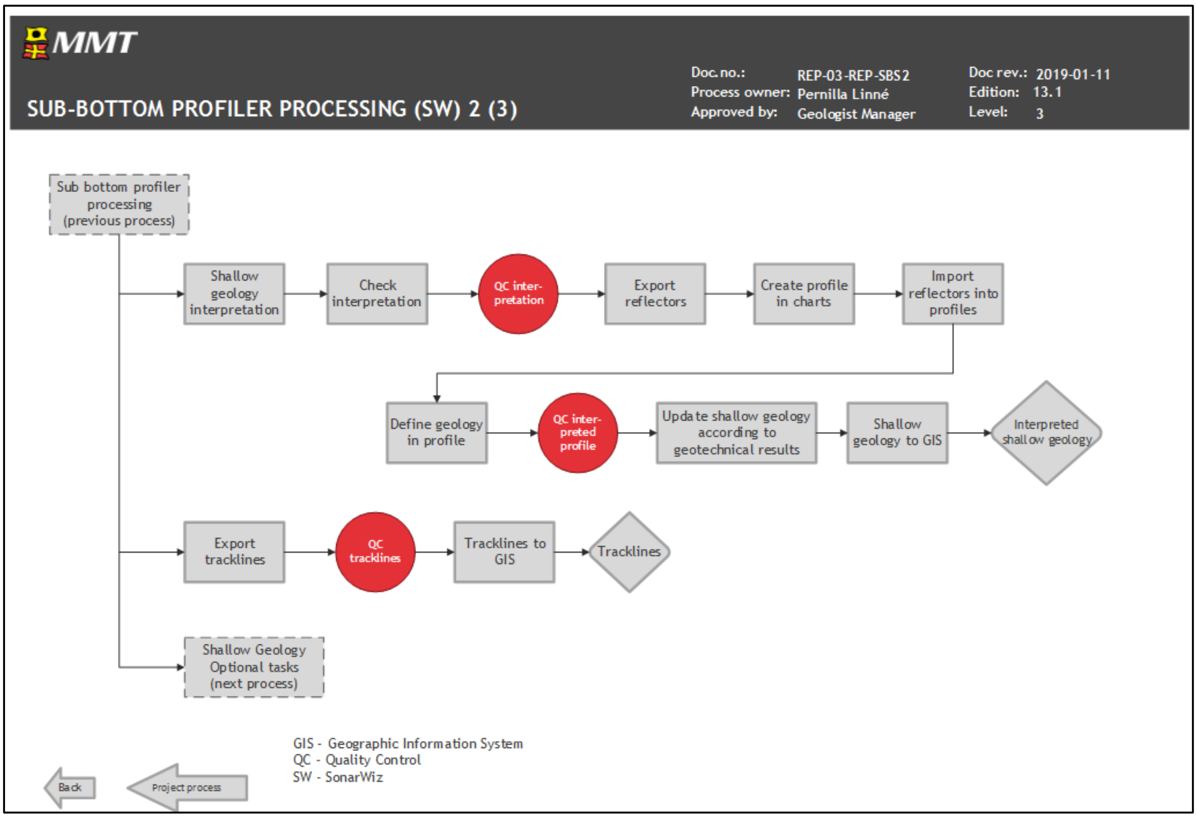


Figure 19 Workflow SBP processing (2 of 2).

5| PROCESSED DATA QUALITY

5.1| BATHYMETRY DATA

The horizontal and vertical uncertainty of the soundings data were, for the vast majority of the survey area, within the 0.5 m threshold as specified by the client. Sounding density across the routes generally conformed to the revised specification of 16 soundings per 100 cm cell (Figure 20). Density and gap checking was performed on gridded surfaces in Caris HIPS during survey operations for MV Franklin. Some data gaps exist in the final dataset, these correspond to areas that did not meet the infill threshold criteria (i.e. 4 or more missing 1 m cells that shared a long side) and areas that were flagged as rejected during office data cleaning after both vessels had left the survey area.

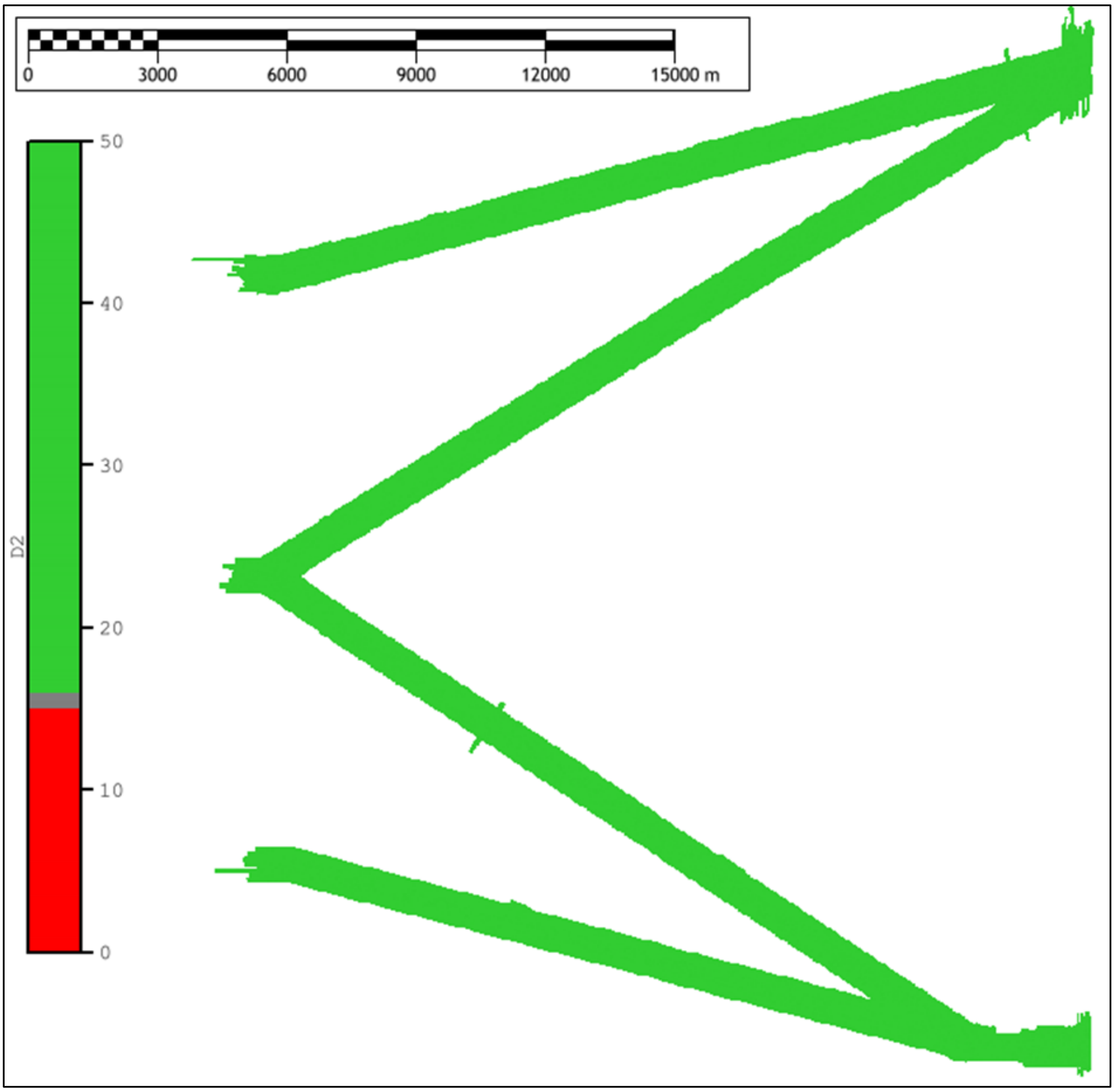


Figure 20 Overview of the sounding density surface for Lot 2.

Density checks for MV Ping data were performed in the QPS software Qimera using the same 16 soundings per 1 m cell. Data gaps found during survey operations were forwarded to the online survey team from the field office where data processing was performed.

Caris HIPS QC surfaces were generated for all the MV Franklin MBES data within the Lot 2 survey area. A range of properties are computed for each surface and these are checked systematically to ensure the data falls within specification. The Standard Deviation at 95% confidence interval is checked in order to highlight areas where the vertical spread of soundings within a DTM grid node is high and checks can be made to determine the cause. If necessary, action can be taken to bring the soundings into closer alignment. Regions that have high standard deviations can occur where there are sound velocity errors, errors in the post-processed navigation, where data is acquired in heavy weather and where there are steep slopes such as boulder fields.

Standard deviation surfaces were also checked in Qimera to check the vertical alignment of the MV Ping data.

Figure 21 shows an overview of the Lot 2 Standard Deviation surface for MV Franklin, which presents regions as having low, medium and high standard deviations in green, orange and red, respectively. Regions where there are numerous boulders are present on all routes but more prevalent on routes 2 and 3. These show up as clusters of orange and red points. These features are not indicative of poor quality data but represent areas that have a greater vertical spread of soundings within a cell relating to the natural roughness of the seabed. Linear artefacts that follow the survey line direction are visible in the standard deviation surface which are the result of minor systematic errors within the data. Such errors relate to small misalignments in vertical position of the vessel and typical differences in sound velocity. An example of such an error can be seen in Figure 22.

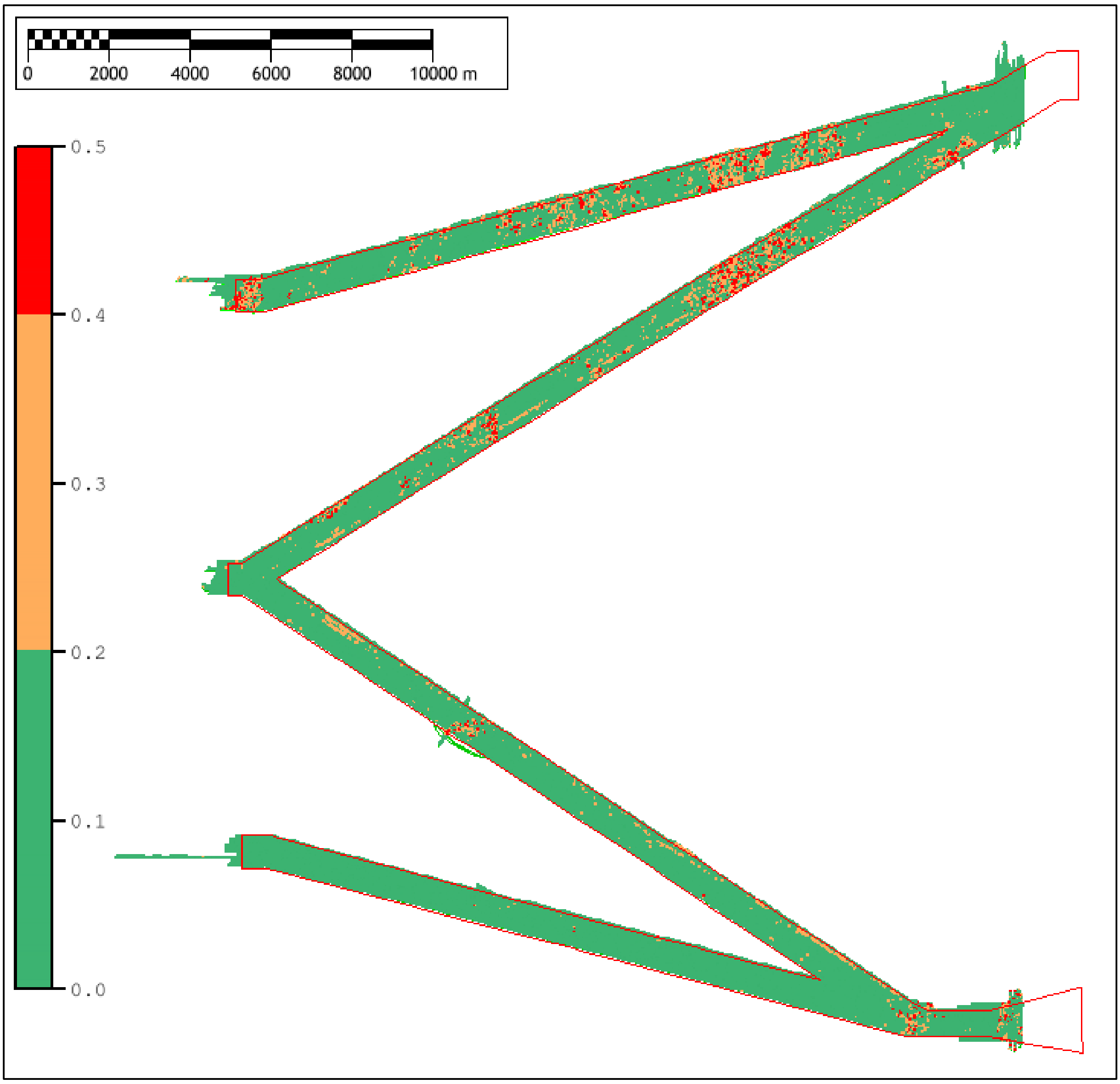


Figure 21 Overview of the Standard Deviation surface for Lot 2.

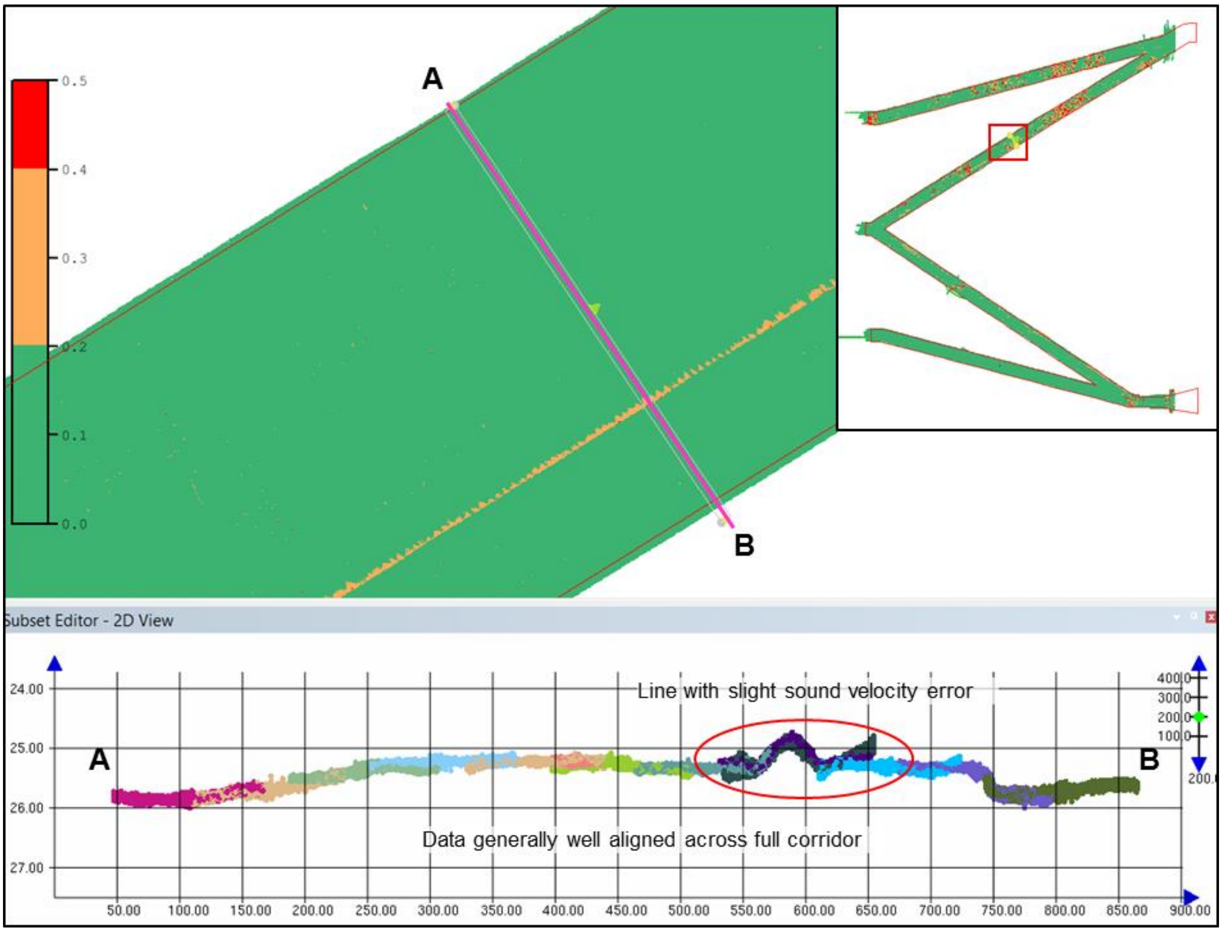


Figure 22 Example of good and poor data along Route 3.
Depth convention in Caris HIPS is positive down; vertical exaggeration of cross section is x200. Pink line marks position of cross section.

QC surfaces were computed to show the vertical separation between the mean seabed position and the positions of the shallowest and deepest soundings within a cell. The QC surfaces are used to target both systematic error correction and data cleaning. However, seabed features, such as boulders, are highlighted by these surfaces as well as the outlying soundings. Careful assessment is made of all areas flagged as requiring data cleaning to ensure that real features are not removed from the dataset.

An example of these QC surfaces is shown in Figure 23. Contacts within the boulder area are highlighted in pink and blue since the sounding data deviates from the mean surface by an amount greater than the chosen threshold value for that depth. The surfaces are coloured to indicate the direction of the deviation. Cells where soundings are shallower than the mean surface are highlighted in pink and cells where soundings are deeper than the mean surface are highlighted in blue.

Since the MV Ping survey areas were much smaller than those covered by MV Franklin it was feasible to visually assess the data and use the automatic filters and manual cleaning tools in Qimera to remove outlying soundings.

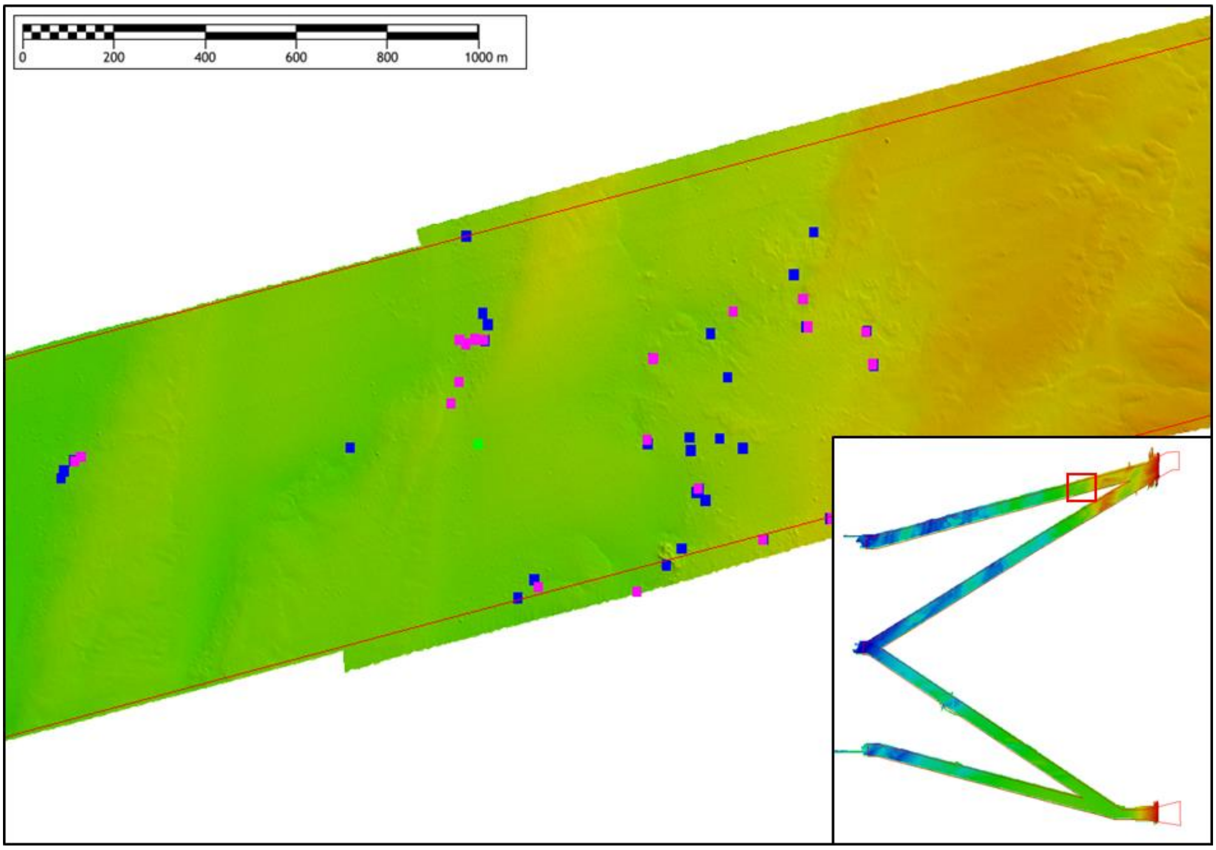


Figure 23 QC surfaces (pink and blue cells) highlighting boulders along Route 2.

Figure 24 shows the combined vessel TVU surface for Lot 2. The colour scale represents areas where the TVU is low as green, medium as orange, and above the 0.5 m threshold as red. The results show that the TVU values are below the 0.5 m threshold across the full Lot 2 survey area.

An overview of the THU results is shown in Figure 25. The range of values has been restricted to show areas with low THU as blue-green, medium THU as orange and higher THU as red. The overview shows that the values associated with the MV Ping data are relatively higher than those generated by MV Franklin, however all are within the 0.5 m threshold for positional uncertainty. The differences arise as the datasets from MV Franklin and MV Ping are not directly equivalent. Different MBES equipment was used and the data was processed using different software packages (following the same workflow principles). Most importantly though the sizes of the vessels is very different with the smaller vessel, MV Ping, being subjected to larger ranges of motion during the survey of the more dynamic nearshore areas of Route 2 and 5. Faster changes in position resulting from wave motion could lead to elevated uncertainty values for the MV Ping dataset. A close up view of the Route 5 nearshore region is shown in Figure 26. The same pattern is observed in the Route 2 nearshore area.

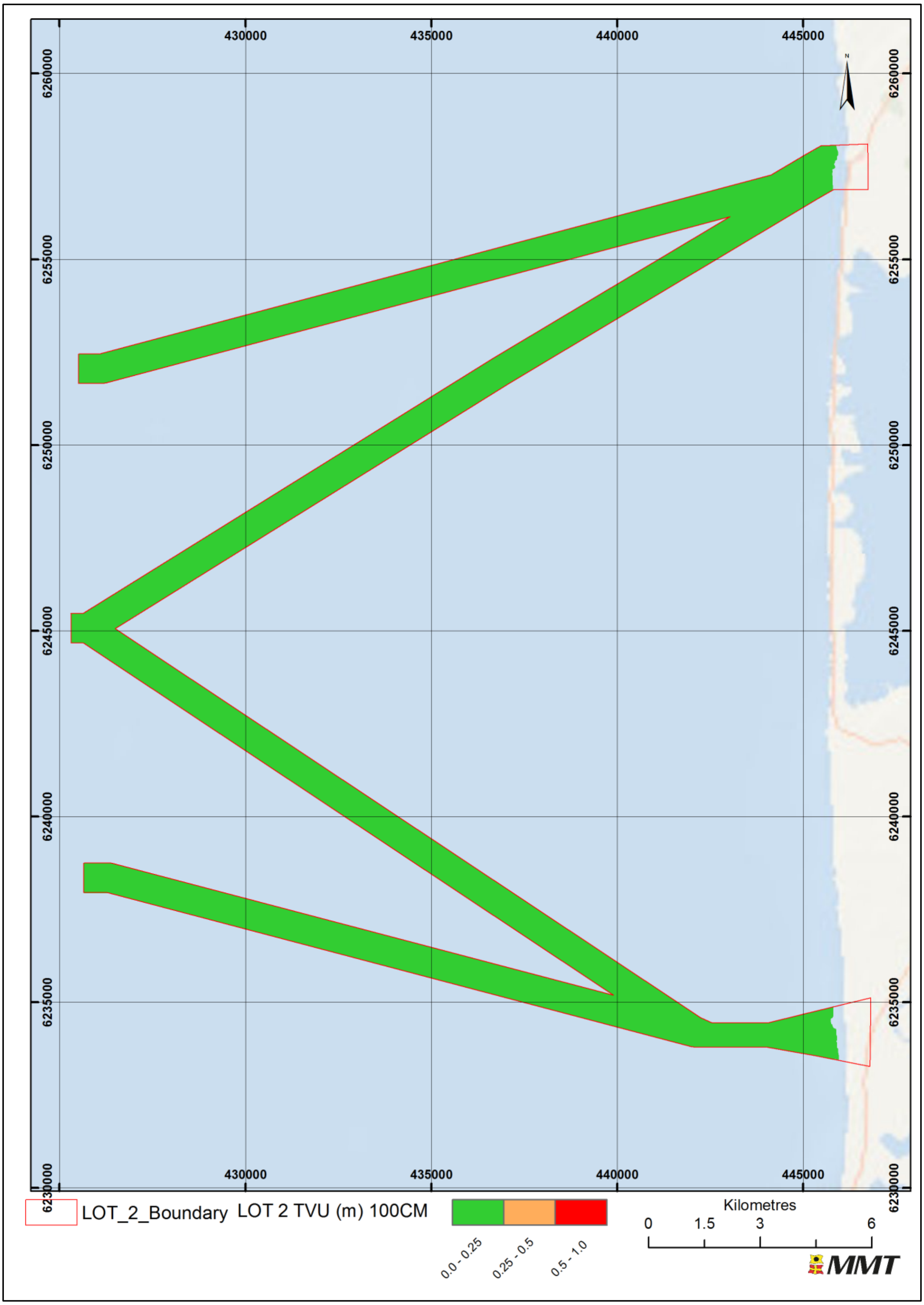


Figure 24 Overview of the Total Vertical Uncertainty (TVU) surface for Lot 2.

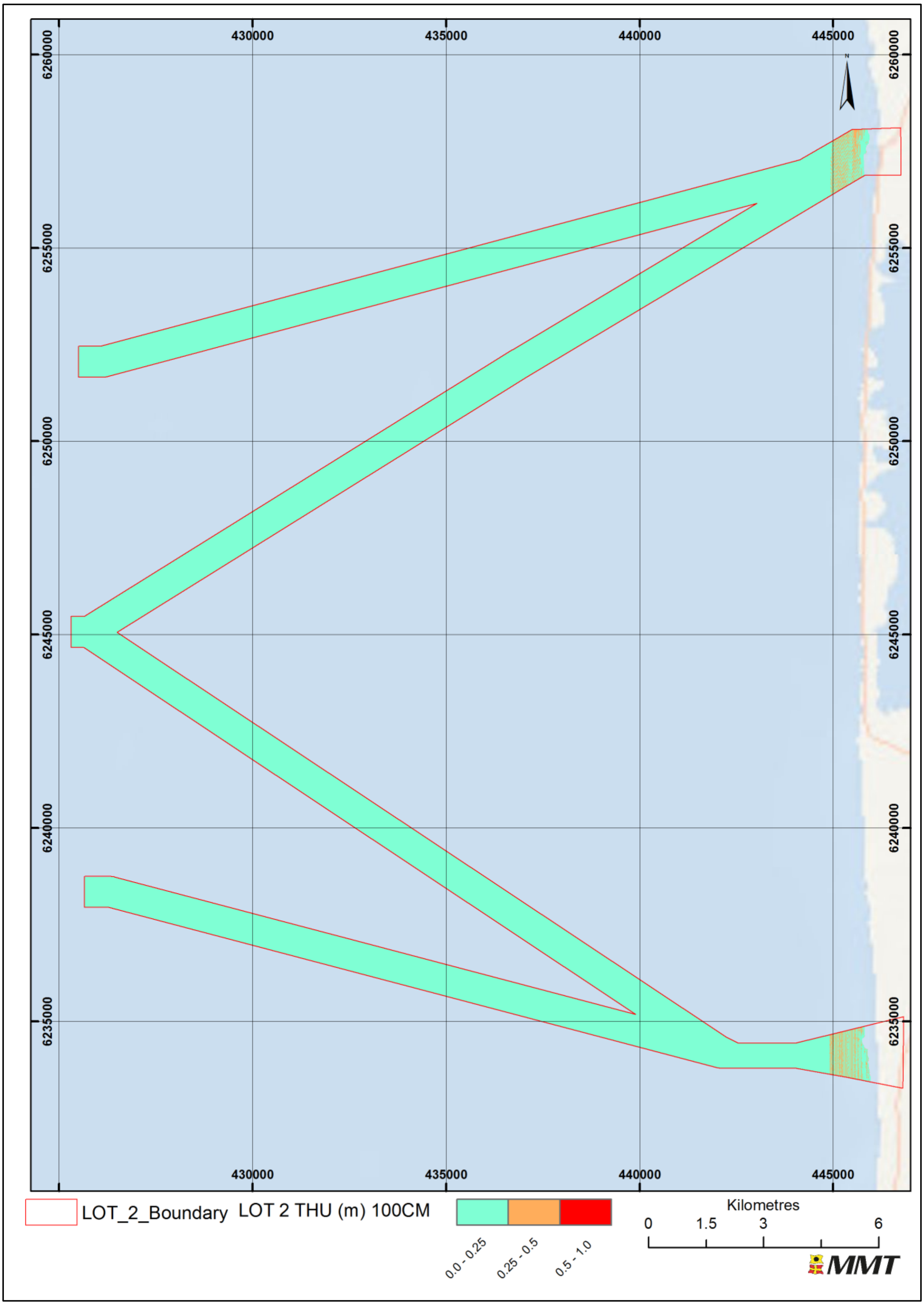


Figure 25 Overview of the Total Horizontal Uncertainty (THU) surface for Lot 2.

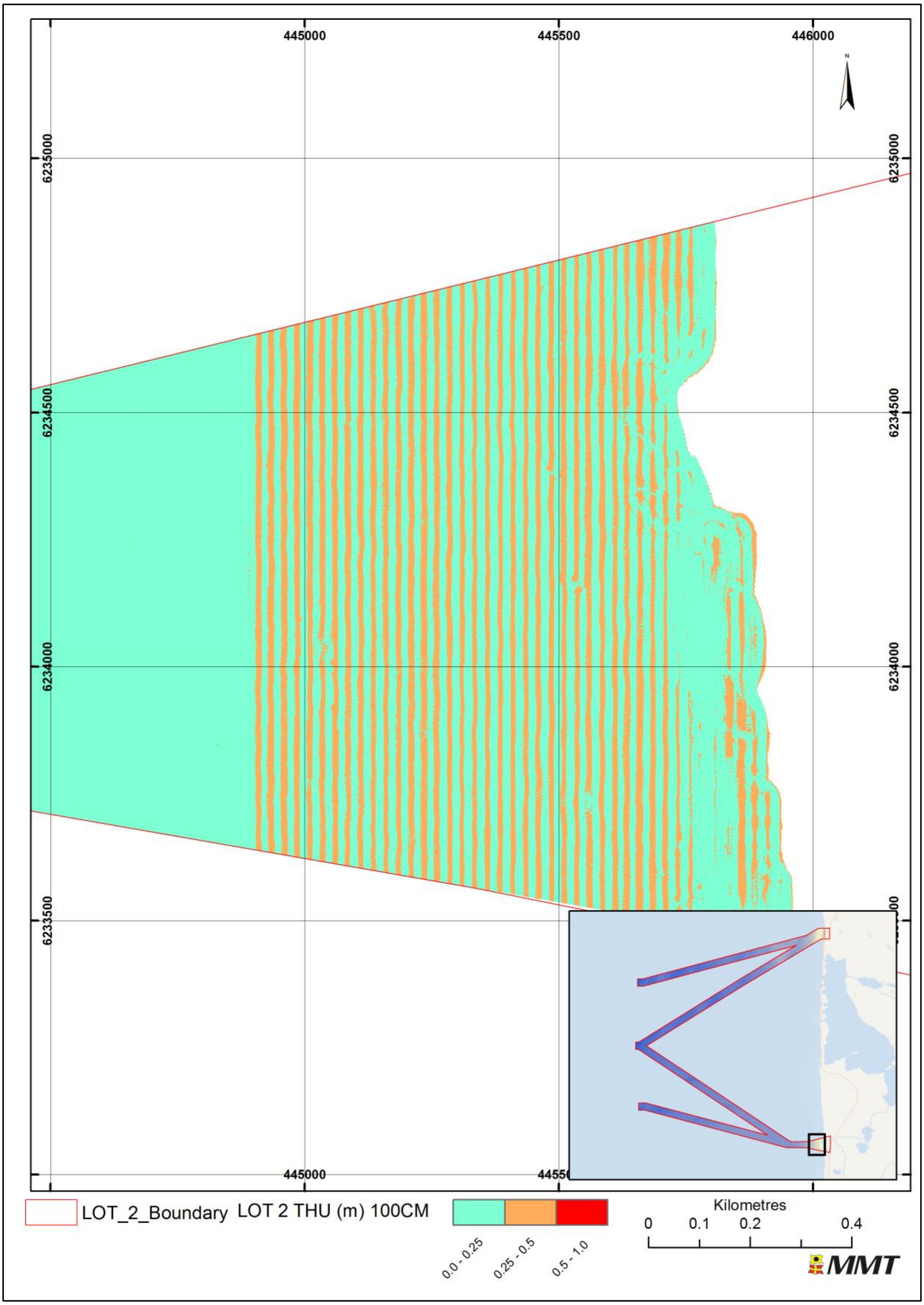


Figure 26 THU surface at the Nearshore end of Route 5.

5.2| BACKSCATTER DATA

The MBES backscatter data quality was of a high standard throughout the project. The backscatter intensity data was obtained via processing of the raw bathymetry files in FMGT. For purposes of data management, the route data was divided in to 6 FMGT projects split by route and survey vessel. Once the backscatter mosaics had been generated these were exported from each project in ASCII XY+Intensity format. These files were clipped into 1 km tiles using the SN2019_009 shapefile and imported to ArcGIS where rasters were generated for each tile. The colour scales for all tiles were homogenised so that when viewed in combination they would appear as a single backscatter mosaic for the full survey site (Figure 27).

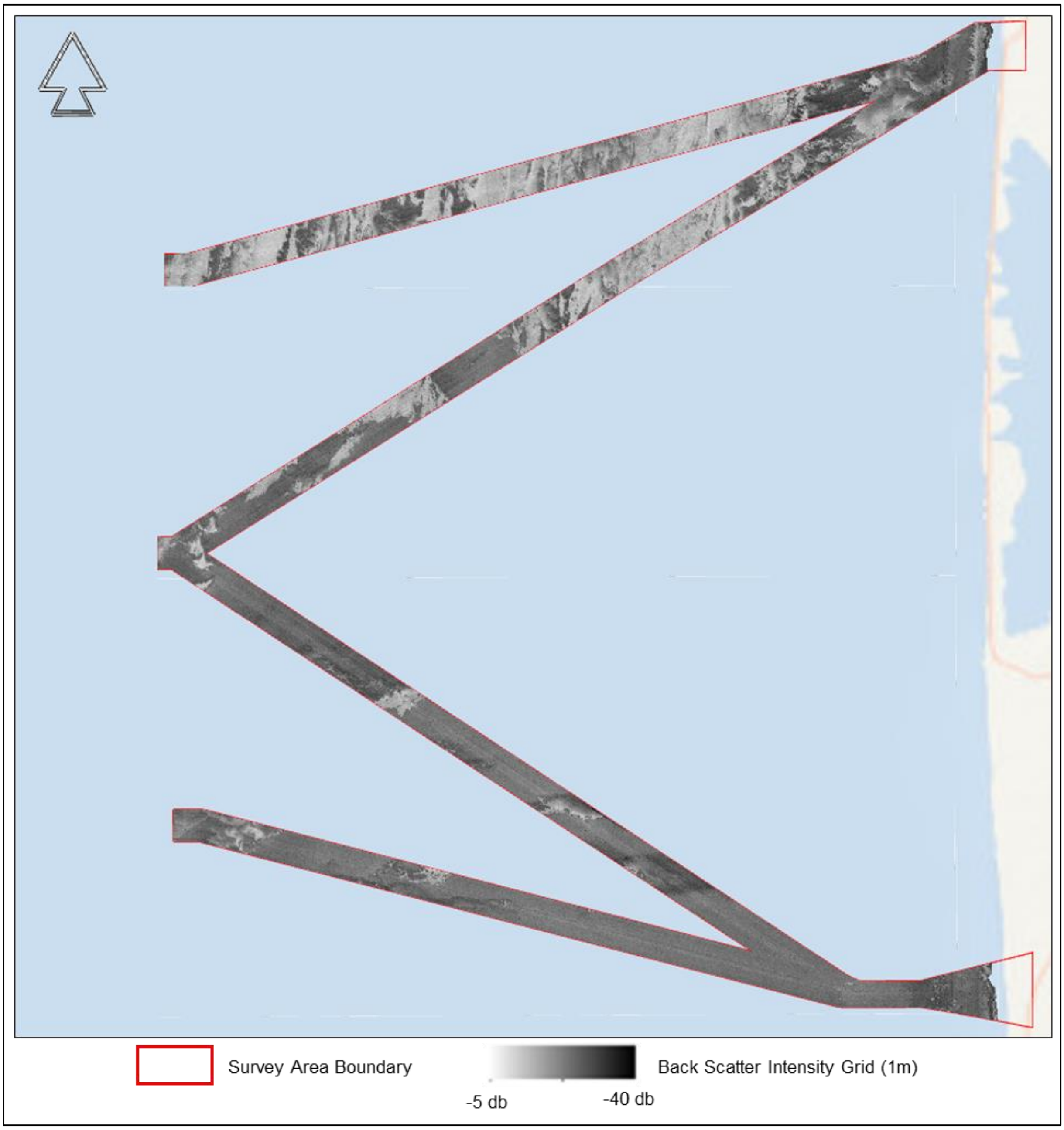


Figure 27 Overview of the combined vessel backscatter intensity grid for Lot 2.

The backscatter mosaics are generally high quality and enable an accurate interpretation of the seafloor sediment boundaries. An example a region where the mosaic is free of artefacts is shown in Figure 28, which shows part of Route 4 with homogenous sediment that is liberally scattered with boulders. Towards the south are patches of a different sediment type that generate a higher backscatter amplitude and therefore appear brighter than their surroundings.

The backscatter dataset contains some artefacts that FMGT is not able to remove from the mosaics during processing. These are quite typical in MBES backscatter mosaics and are mainly derived from the motion of the vessel or the occurrence of bubble-wash over the MBES transducers.

Figure 29 shows an artefact that is derived from excessive motion in the MV Franklin mosaic. This oscillation between light and dark tones occurs where FMGT fails to determine the fluctuations of backscatter intensity as vessel motion and this becomes presented as differences in sediment properties.

Bubble-wash occurs when air bubbles are dragged across the sonar face as the vessel encounters white-water or pitches heavily. These bubble-wash effects manifest as black lines that run across the MBES swath (perpendicular to the survey line direction). These artefacts are present in the mosaics from MV Franklin but more common in the area surveyed by MV Ping. Ping is a small vessel operating in a dynamic nearshore environment, experiencing a greater range of motion and more likely to encounter white-water. Examples of these are shown in Figure 30 in the nearshore survey of Route 5.

Other artefacts can arise from the survey line orientation in relation to the sediment area boundaries. When the vessel is travelling normal to the sediment boundary a "smearing" artefact can sometimes arise. This occurs as FMGT attempts to normalise along track variations in order to produce mosaics that have reduced noise. This is achieved by normalising the backscatter intensity for a moving window of pings. When this window crosses a sharp sediment boundary the apparent clarity gets reduced due to differences in intensity being averaged out. Examples of these effects are present near the eastern edge of Figure 30.

The presence of these artefacts is visually distracting but does not affect the results of the seabed interpretation. Experienced marine geologists are able to see beyond the artefacts and use multiple layers of data (bathymetry, bathymetric hillshade, gradients and side-scan-sonar mosaics) to determine whether these variations arise from real features of the seabed.

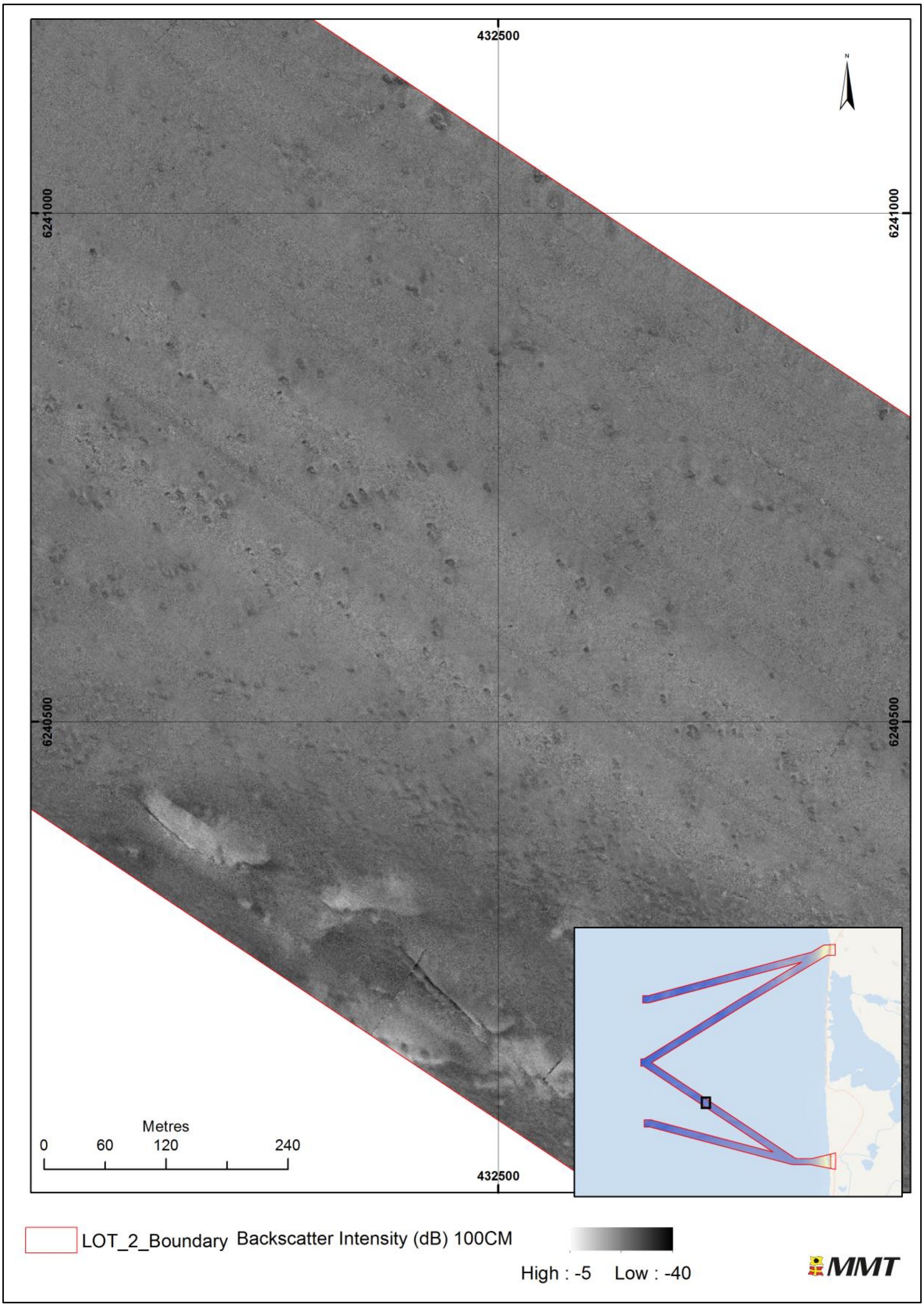


Figure 28 Area of good quality backscatter data along Route 4.

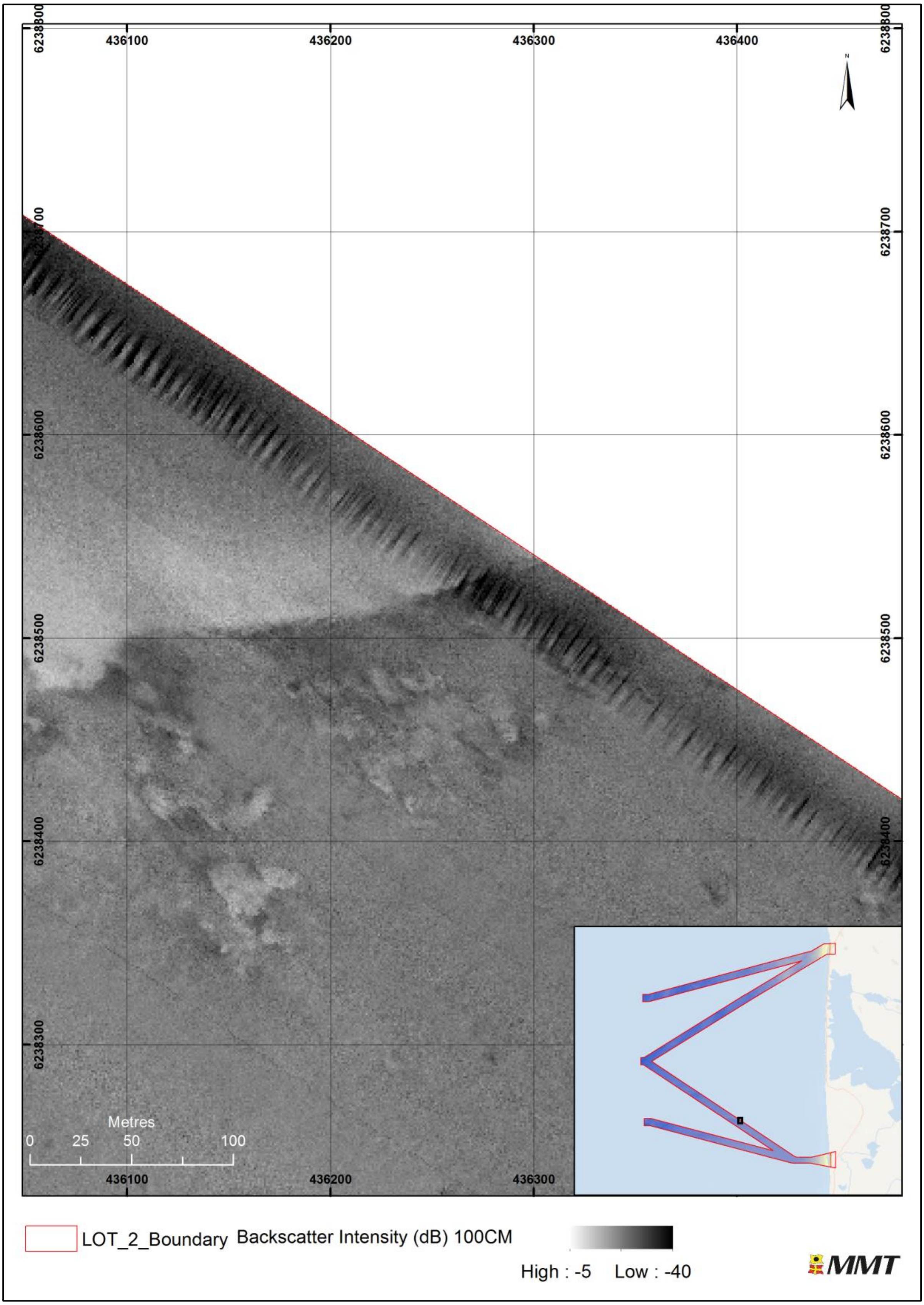


Figure 29 Motion artefact in MV Franklin backscatter mosaic in Route 4.

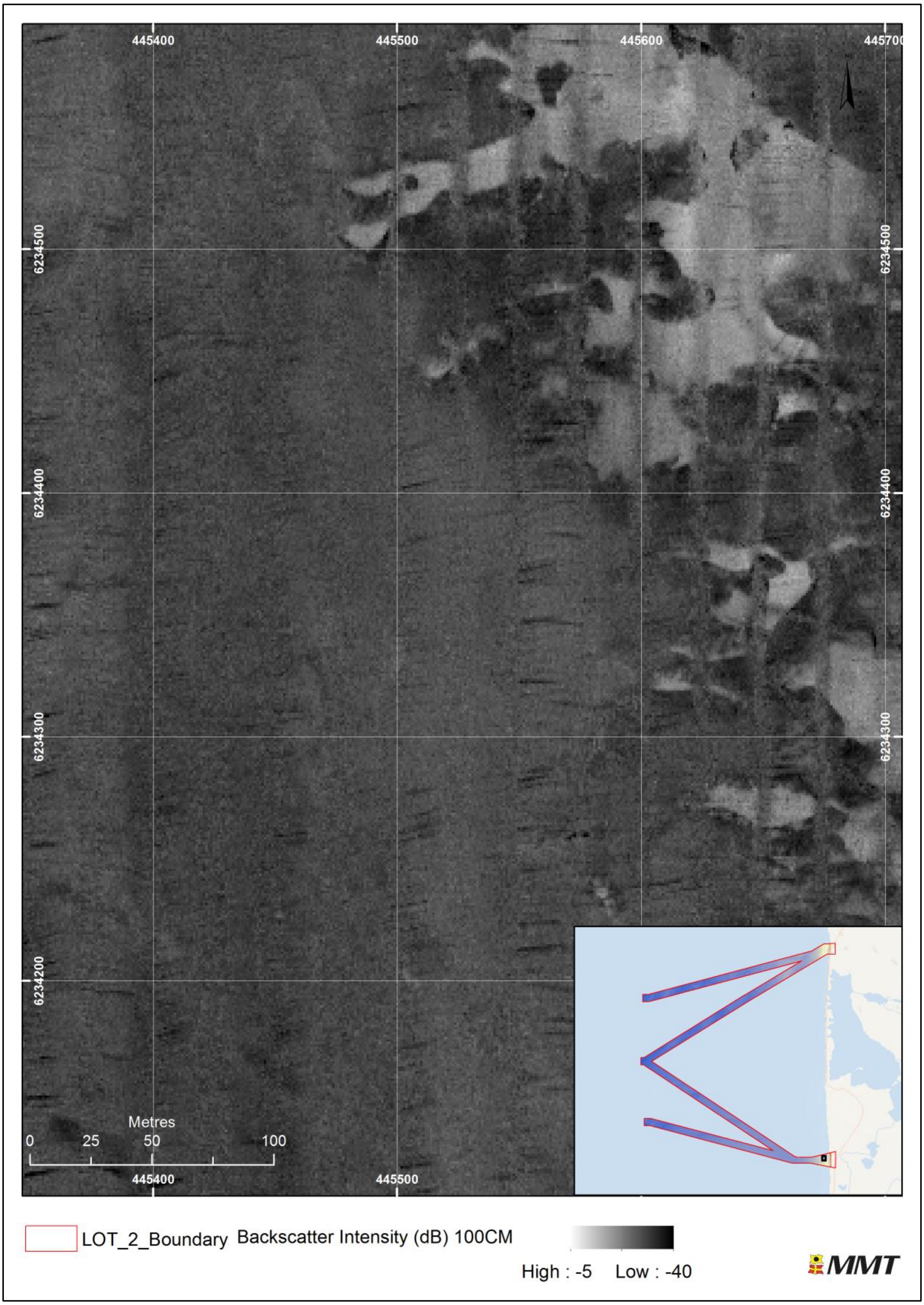


Figure 30 Backscatter artefacts within the R5 nearshore mosaic.

5.3| SIDE SCAN SONAR DATA

As detailed by the clients SOW, the SSS data were to provide a 100 m range data with a 300/600kHz sonar. The altitude of the SSS was to be kept at 10-15% of the range. 200% coverage was to be achieved in order to ensure overlap with the nadir of adjacent lines. Object detection was specified as >0.5 m for individual targets.

The SSS data quality varied and very much depended on the prevailing weather conditions and a strong pycnocline that was observed on all routes, affecting the data in the outer ranges; in some sections up to 40% of the data was affected (Figure 31). This noise varies along the routes and in most cases it was possible to cover the areas of poor data with adjacent lines, achieving full coverage. However, some areas have small sections were coverage was marginal and in such cases (particularly on the outer 30 m to the corridor boundary), these have been correlated against the MBES and Backscatter data to support the interpretation and description of the routes.

A number of fish shoals were observed in the data as medium to high reflectivity ‘smudges’. The fish shoals could be readily identified and disregarded as noise when checking against adjacent lines.

The infills made for the SSS data were related to software crashes in the main logging system and losing USBL tracking of the equipment for short periods of time. The total amount of infills for the SSS data was near 3700 m representing around 0.4 % of the total length of Lot 2 survey area.

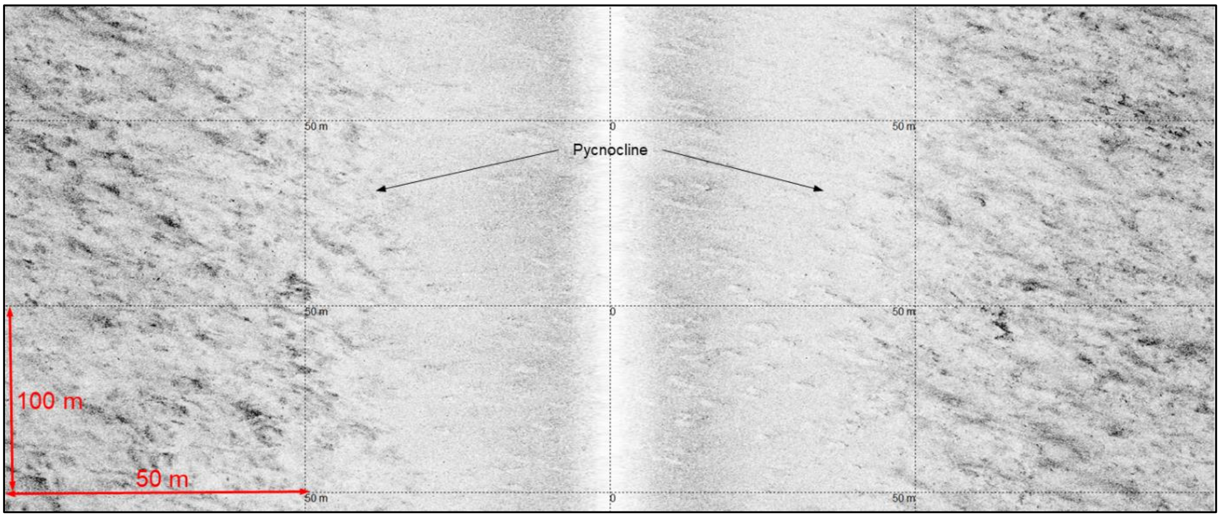


Figure 31 Pycnocline as observed on Route 3 at ~KP15.

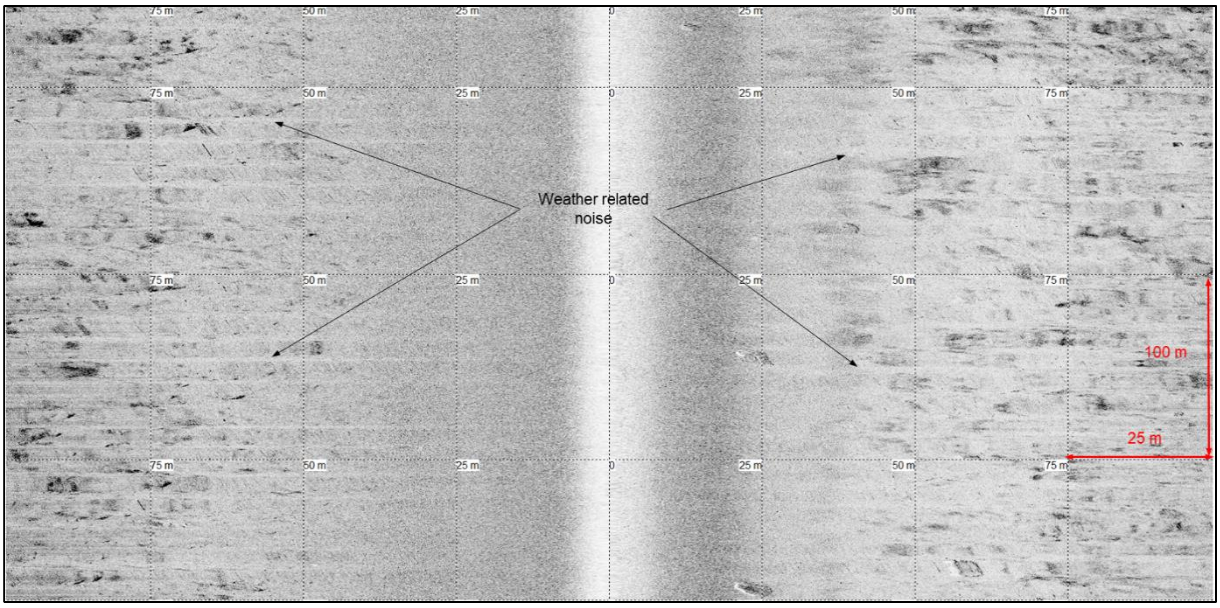


Figure 32 Weather related noise (Striping) as observed on Route 5 at ~KP18.

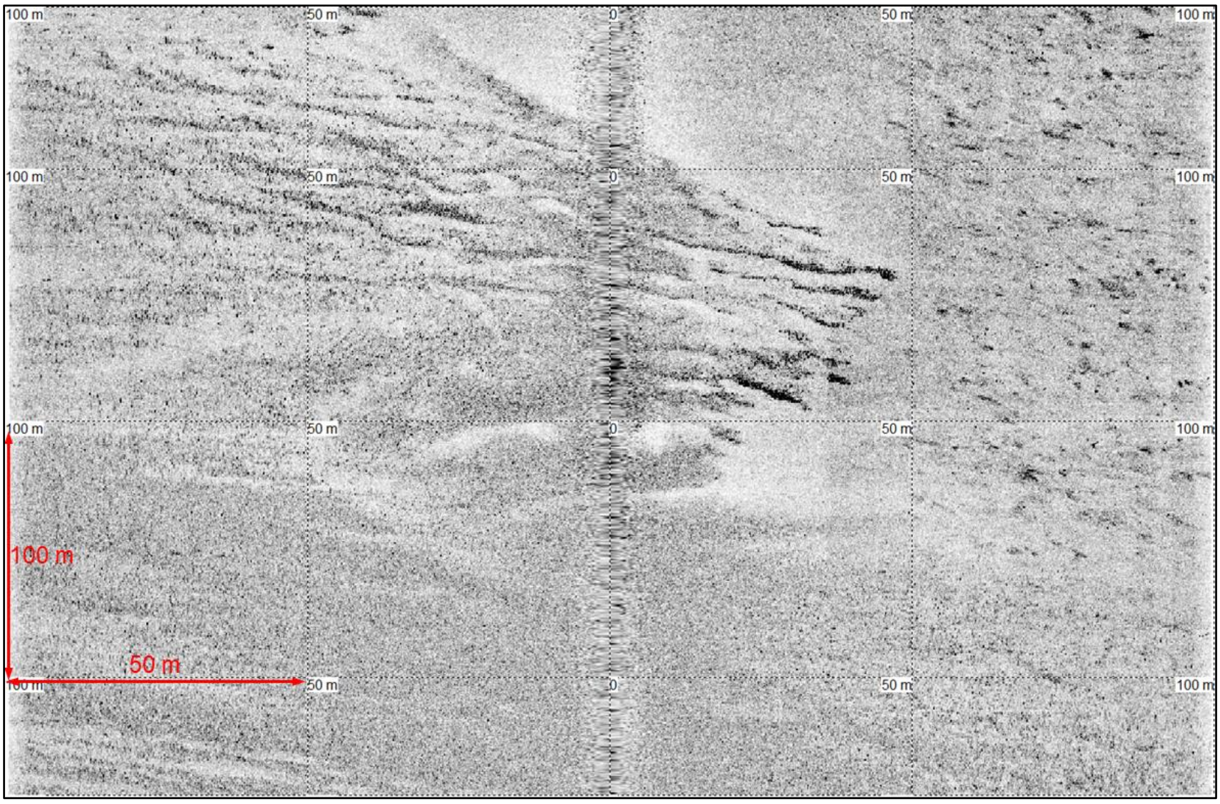


Figure 33 Example of good LF data from Route 2 at ~KP20.

5.4| MAGNETOMETER DATA

The MAG was piggy backed behind the SSS tow fish.

The aim of the MAG was to be able to pick large anomalies as well as linear features such as cables and pipelines. Due to these arguments the client relaxed the altitude requirement of the Mag from 5 m to 8 m. The MAG data was deemed lower priority, with focus on collecting high quality SSS data and thus flying altitude was dictated by the SSS requirement. In some sections of the route, the altitude of the MAG was therefore higher than 8 m.

The MAG data quality was generally good. Background noise level varies from +/- 2 nT to +/- 10 nT (Figure 34). Some files had increased noise levels due to poor weather conditions or electrical interference, these were rejected and rerun where deemed appropriate. Another main issue of rejected files was the failure of the online logging system (QINSy) and equipment malfunction, such as loss of USBL tracking. In general, the areas affected by these issues, did not extend for more than 4000 m of the whole line plan for Lot 2, approximately 0.4% of the original line plan.

The altitude averaged 5.7 m across the export routes and the signal strength was good with a mean of approximately 800.

Magnetic anomalies were identified with a 20 nT detection (peak to peak) threshold. Where the data allowed, anomalies between 10-20 nT (peak to peak) have been picked. An assessment of quality was completed for each survey line and a decision was taken on the picking threshold to be used, this was dependant on weather conditions and seafloor topography, and varied between routes.

Infills were acquired in all sections where noise levels where too high. Altitude was generally equal or below 8 m and no infills were generally required. When the increase in altitude was momentary and not significantly above 8 m no infills were made. The decision to run infills was made onboard the vessel together with the client representative onboard.

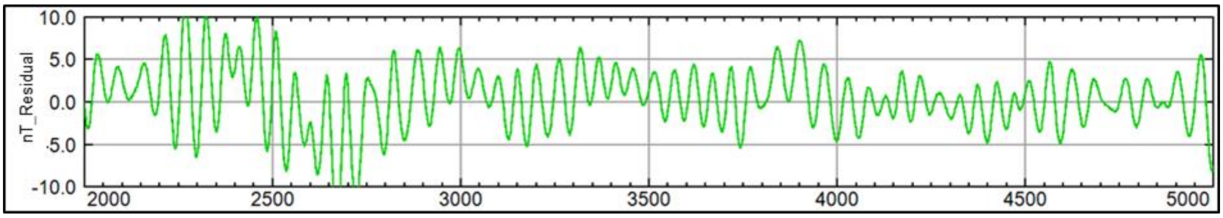


Figure 34 Example of background noise oscillation, on Route 2.

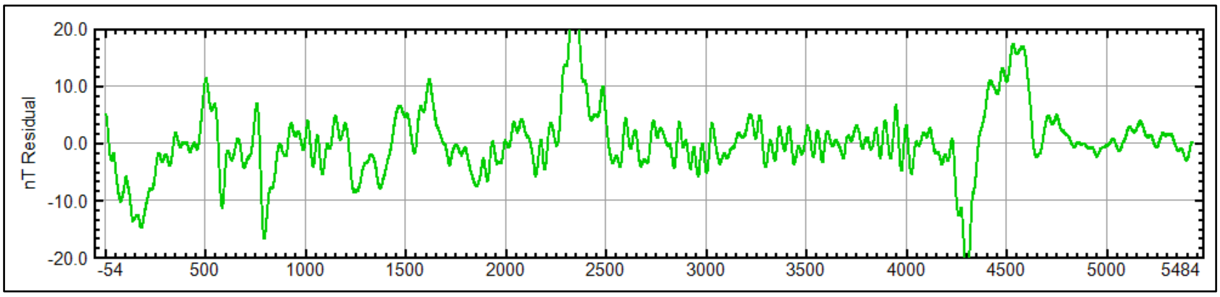


Figure 35 Example of bad mag data from Route 5.

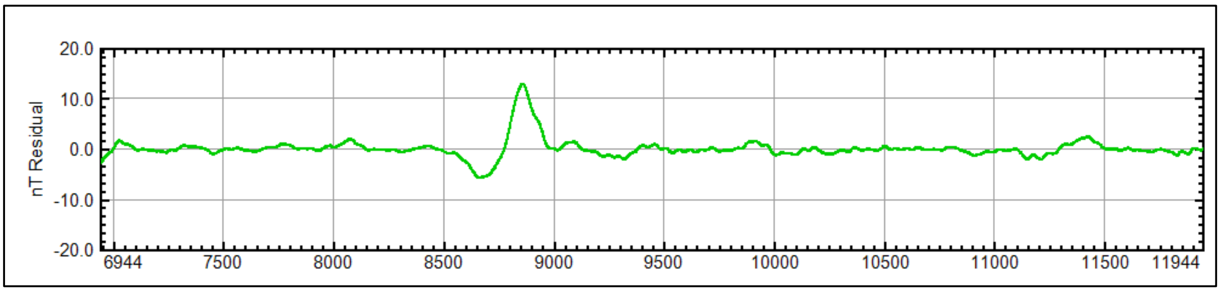


Figure 36 Example of good mag data from Route 4.

5.5| SUB-BOTTOM PROFILER DATA

The requirement for the Innomar data was primarily focused on gathering good resolution in the upper 10 m of the seabed. The settings of the Innomar were adjusted to achieve this such that vertical resolution achieved the 0.3 m specification.

The penetration of the Innomar data is dependent on the sediment properties in the seabed units. During this project, the Innomar data was of good quality with penetration generally between 2 and 5 m. Occasionally the penetration surpasses 10 m, mainly in some areas along R5. The penetration is usually limited by the interpreted H2 horizon; below which it is rare to see additional reflectors. Occasionally, the shallower interpreted horizon H1 also masks the reflectors below, limiting the penetration even further.

The data was highly resolute allowing several parallel reflectors within the 1 m to be defined. Data was occasionally affected by the weather, causing cavitation along the profile to occur (Figure 37). However, drop outs were rare and always less than 10 m along track. As a result, interpretation could still be conducted with confidence. To aid interpretation the section was flattened using the seabed horizon, in Kingdom, which removed the effects of heave and motion resulting in a cleaner data set.

A few infills were necessary to acquire due to wrong seabed track of the data, after the acquisition software tracked a multiple as the seabed, windowing out part of the data. Other infills were related with crashes in the main survey software. The total distance of infills related for all these issues was around 5600 m, representing circa 0.5 % of the total survey length in Lot 2.

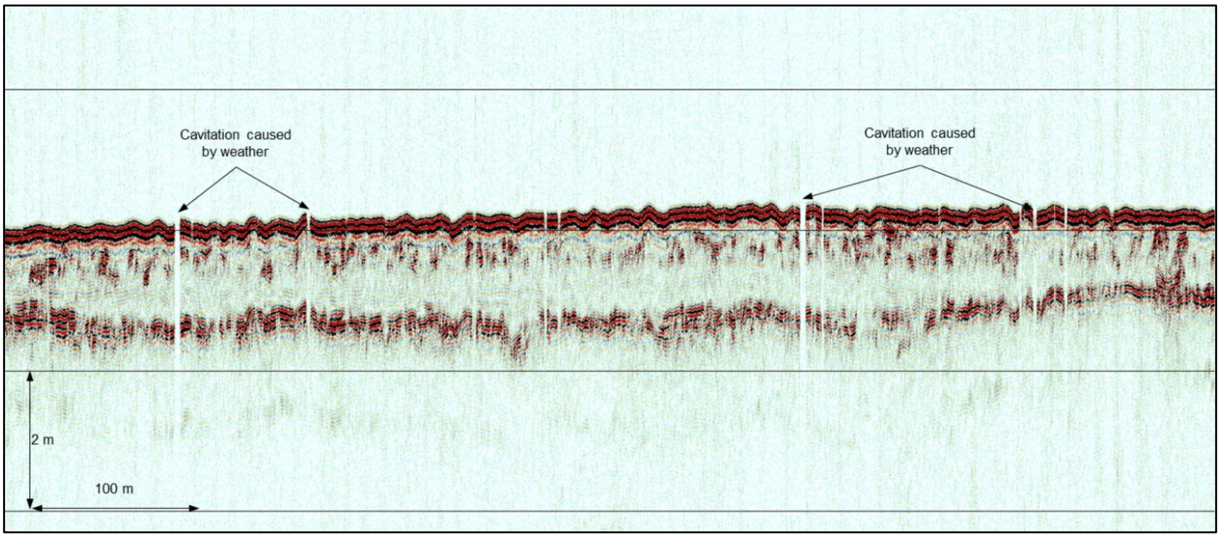


Figure 37 Cavitation caused by weather. Route 3 at ~KP19.

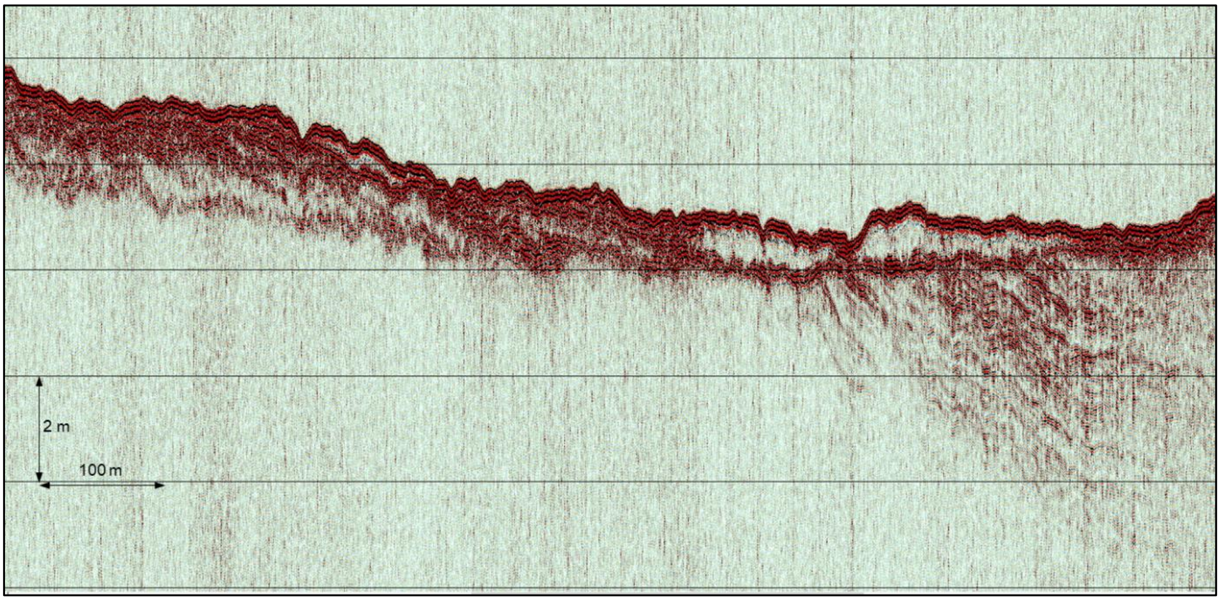


Figure 38 Example of good data from Route 2 at ~KP 18.5.

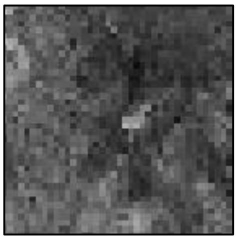
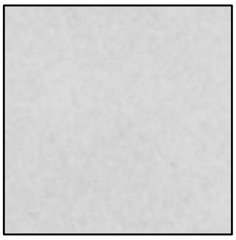
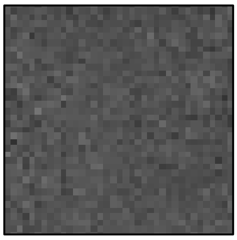
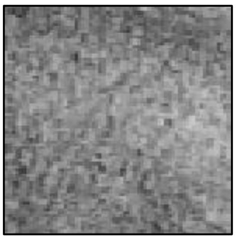
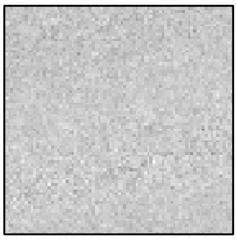
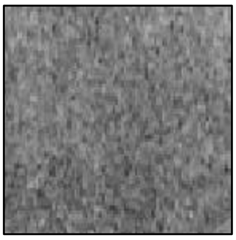
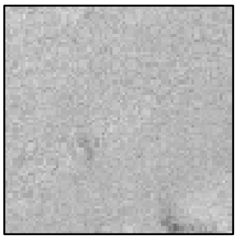
6| SEABED CLASSIFICATION AND STRATIGRAPHY

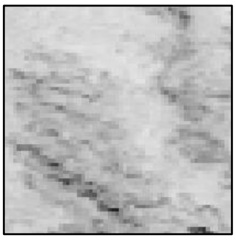
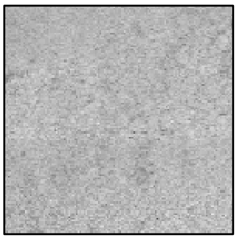
6.1| SEABED SEDIMENT CLASSIFICATION

The interpretation of surficial sediment types was derived from the acoustic character of the low frequency side scan sonar (SSS) data, and the interpretation was aided by multibeam echo sounder (MBES) bathymetric 3D surfaces, multibeam backscatter (MBBS) and sub-bottom profiler (SBP) data. In addition to this, the results from the grab sampling campaign was also used to ground truth the interpretation. During the review of the SSS survey data, higher intensity sonar returns (darker grey to black colours) were interpreted as relatively coarser grained sediments, and lower intensity sonar returns (lighter grey colours) were interpreted as relatively finer grained sediments. Bathymetric data was used to assist in boulder field interpretation and to correct for the effects of seabed slope on sonar returns.

The ID column in Table 19 defines the colour in the charts for the specific sediment type mapped along the survey corridor. All particle sizes refer to the soil classification in ISO 14688-1 (2002).

Table 19 Seabed sediment classification.

ID	SSS Image	BS Image	Acoustic Description	Lithological Interpretation
			Low acoustic reflectivity. No texture. Texture indicates wave and stream working of the sediment.	**CLAY** May contain silt, sand and/or gravel**.**
			Medium acoustic reflectivity, slightly grainy texture.	**SAND** Predominantly sand, may have minor fractions of clay, silt and/or gravel.
			Medium to high acoustic reflectivity. Slightly grainy to grainy texture, coarse texture in places.	**GRAVELLY SAND TO SANDY GRAVEL** Predominantly gravelly sand, may contain silt. The ratio between sand and gravel can vary within this sediment type.
			High acoustic reflectivity. Grain, coarse texture.	**GRAVEL** Predominantly gravel. May contain minor fractions of silt or clay. Ranges from slightly to very sandy. May also contain gravel sized shell fragments. May include cobbles.

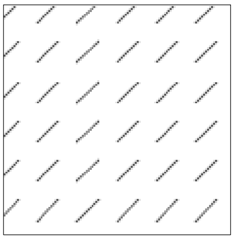
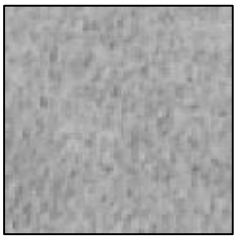
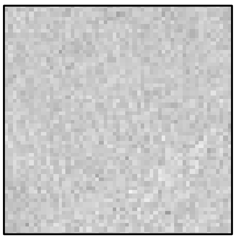
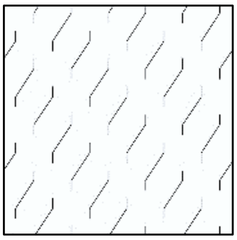
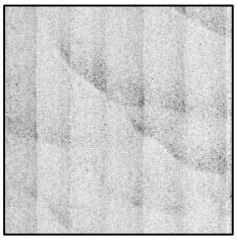
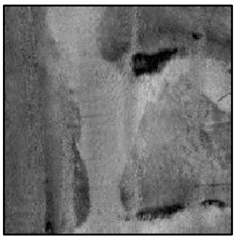
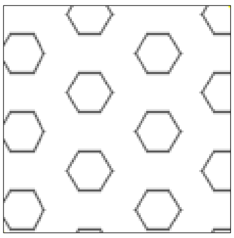
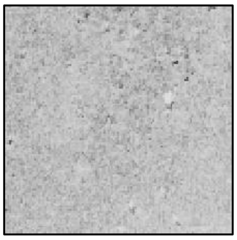
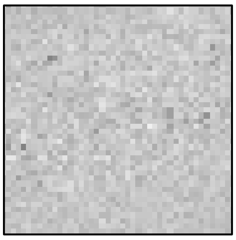
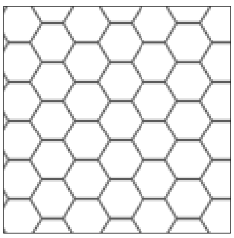
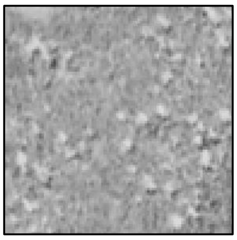
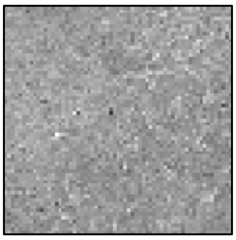
ID	SSS Image	BS Image	Acoustic Description	Lithological Interpretation
			Low to high acoustic reflectivity. Bands of high reflectivity interspersed with pockets of low reflectivity. Occasional grainy texture.	**DIAMICTON** Predominantly gravelly sand. Constituents range between clay and boulders.

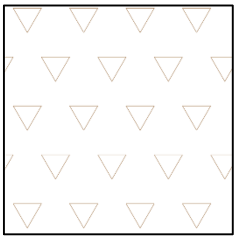
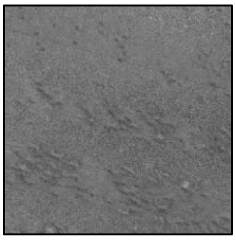
6.2| SEABED FEATURE/BEDFORM CLASSIFICATION

The ID column in Table 20 defines the pattern in the charts for the specific seabed feature type.

SSS, MBES and MBBS data have been used for interpretation of the seabed feature boundaries.

Table 20 Seabed features classification.

ID	SSS Image	BS Image	Seabed Feature	Criteria
			Ripples	Wave length <5 m Height <1.0 m
			Sand Waves	Wave length >25 m Height 1.5 – 25 m
			Boulder Field Occasional boulders All >0.5 m	>10 and <20 boulders per 50x50 m.
			Boulder Field Numerous boulders All >0.5 m	>20 boulders per 50x50 m.

ID	SSS Image	BS Image	Seabed Feature	Criteria
			Area of depressions	No detection of gas in underlying sediments indicates the likely cause to be changes in seabed current regime rather than shallow biogenic gas

6.3| SEABED SEDIMENT CLASSIFICATION BASED ON GRAIN SIZE

The seabed sample soil classifications are based on ISO 14688-1 (Table 21).

Table 21 Geotechnical soils classification based on grain sizes (after ISO 14688-1).

SOIL GROUP	Very Coarse Soils			Coarse Soils						Fine Soils				
PRINCIPAL SOIL TYPE	**BOULDERS**		**COBBLES**	**GRAVEL**			**SAND**			**SILT**			**CLAY**	
Particle Size (mm)	Large boulder	Boulder	Cobble	Coarse	Medium	Fine	Coarse	Medium	Fine	Coarse	Medium	Fine		
	>630	630 - 200	200 - 63	63 - 20	30 - 6.3	6.3 - 2.0	2.0 - 0.63	0.63 - 0.2	0.2 - 0.063	0.063 - 0.02	0.02 - 0.0063	0.0063 - 0.002	<0.002	
Secondary Constituents	Note 1			Terms in coarse soils	slightly (sandy) Note 2	(sandy) Note 2	very (sandy) Note 2	SAND AND GRAVEL		Terms in fine soils	slightly (sandy) Note 4	(sandy) Note 5	very (sandy) Note 5	Silty CLAY Clayey SILT As needed
				Proportion secondary Note 1	<5% Note 3	5-20% Note 3	>20% Note 3	About 50% Note 3		Proportion secondary Note 1	<35%	36-65% Note 6	>65% Note 6	

Notes:			
	1 Typically not recovered in conventional marine samplers. Percentage of coarse or fine soils constituents excludes cobbles and boulders	2 gravelly or sandy and/or silty or clayey	3 Or described as fine soil depending on mass behaviour
	4 gravelly and/or sandy	5 gravelly or sandy	6 Or described as coarse soil depending on mass behaviour

6.4| CLASSIFICATION OF CONTACTS AND ANOMALIES

The SSS and MBES contacts were classified according to the following criteria:

- Boulder
- Man-made object (MMO) (Debris, fishing gear, man-made structures etc.)
- Wreck
- Other

Boulders were grouped into boulder fields based on their spatial density:

- Occasional boulder field: >10 and <20 boulders per 50x50 m
- Numerous boulder field: > 20 boulders per 50x50 m

Boulders were not interpreted within boulder fields or within areas of diamicton.

When contacts were observed on the SSS and MBES they were included in the SSS contact list, and when contacts were only observed in the MBES they were included in the MBES contact list.

In the GIS database all MAG anomalies are categorized as MMO, due to the inherent uncertainties of magnetic anomaly interpretation.

In the combined contact listings, the MAG contacts were classified as

- MMO (includes all anomalies that correlate to SSS or MBES contact, linear contacts and wrecks)
- Discrete Anomaly (includes all anomalies with no further comment)
- Geology (includes all anomalies that is inferred to be of a geological nature)

All MAG anomalies were compared to all MBES and SSS contacts. If a MAG anomaly was within 5 m of any contact detected in either MBES or SSS, it was deemed a correlation. A note was then made in the combined contact listing, as well as in the GIS database.

Anomalies forming a linear pattern were commented as such and these could indicate the presence of fishing gear, cables, wire/chain or anything of a ferrous linear nature. Some anomalies were inferred to be of a geological nature and these were also commented as such.

Discrete anomalies are all anomalies detected in the MAG data lacking any additional information to aid the interpretation.

SBP contacts are selected when diffraction hyperbolas are present and can be clearly related to a single object. No hyperbolas were deemed sufficiently defined to be attributed to contacts.

6.5| SUB-SEABED GEOLOGY CLASSIFICATION

The classifications of the shallow geology have been derived through a combination of analysis and interpretation of the acoustic character of the SBP data and geotechnical results. Only one reflector (H1) was laterally continuous with a well-defined amplitude (indicating a high impedance contrast), separating different sediment units. this was mapped across all survey lines in order to create a gridded surface to the base of the unit. The other main unit (H2) was not as continuous and well defined and was therefore only digitized on the centre lines. Within each sedimentary unit, if reflectors were present indicating minor variations in sediment type, these were digitised as internal reflectors, this was completed only on the centreline for the purpose of the alignment charts.

It was possible to correlate the base of H1 with the geotechnical results and it was seen to delineate the base of a unit which varied spatially with varying density of GRAVEL and/or CLAY, but was consistently and predominantly comprised of SAND. It was possible to assume that sediment variation between localised channels, was minimal, and therefore vibrocores from a single channel, could be used to provide an accurate interpretation of the subsurface between mapped units.

Unit H2 is interpreted to comprise mainly SAND with varying content of SILT and GRAVEL. The reflector of the top of unit H2 was commonly very vague and was only visible sparsely in the SBP data due to variations in penetration depth and the properties of overlying layers.

Major sediment types along the route are present in (Table 22), sediments types were derived from a combination of grab samples and vibrocores; as well as interpretive experience of North Sea post LGM depositional environments.

Major sediment types along the route are present in (Table 22).

Table 22 Shallow geology soil types and lithology summary.

SEDIMENT TYPE	ACOUSTIC CHARACTERISTICS	LITHOLOGICAL VARIATION
CLAY	Homogeneous to layered, transparent to high amplitude recent sediments lying from at or near the seabed to base of record and/or filling palaeo-channels.	Very soft to very stiff, slightly silty to very silty, slightly sandy to very sandy, slightly gravelly to very gravelly CLAY. Massive to layered to pockets. May locally contain shells, pebbles, cobbles and pockets of SILT, SAND and GRAVEL.
SILT	Acoustically layered, low to medium amplitude recent sediments lying from at or near the seabed to base of record and/or filling palaeo-channels.	Slightly sandy to very sandy, slightly clayey to very clayey SILT. Generally present as laminations and pockets and occasionally as a coherent unit.
SAND	Acoustically homogeneous to layered, low to medium amplitude recent sediments lying from at or near the seabed to base of record and/or filling palaeo-channels.	Slightly clayey to very clayey, slightly silty to very silty, slightly gravelly to very gravelly SAND. Laminations of CLAY and SILT. May locally contain shells, pebbles, cobbles and pockets of SILT, CLAY and GRAVEL. Commonly forming mobile sediment.
GRAVEL	Medium to high amplitude recent sediments lying from at or near the seabed to base of record and/or filling palaeo-channels.	Slightly clayey to very clayey, slightly silty to very silty, slightly sandy to very sandy GRAVEL. Predominantly comprising shell fragments, Generally present as pockets and internal layers and commonly a surface veneer. Locally mobile. May locally contain pebbles, cobbles.
PEAT	High amplitude layers/bands and/or filling palaeo channels.	Soft to firm PEAT. Present as thin layer/band, pockets or reworked.

6.6| SEABED GRADIENT CLASSIFICATION

The seabed gradient is classified according to Table 23.

Table 23 Seabed gradient classification.

Classification	Gradient
Very Gentle	<1°
Gentle	1° - 4.9°
Moderate	5° - 9.9°
Steep	10° - 14.9°
Very Steep	>15°

6.7| GEOLOGICAL FRAMEWORK

The Danish sector of the North Sea basin is connected to the east sector by the Scandinavian Shield and by the WNW-ESE striking Sorgenfrei-Tornquist fault zone, Figure 39. The Ringkøbing-Fyn High, located further south, emerged during the Late Permian (Pre-Zechstein) as a result of tectonic subsidence (Vejbæk, 1997; Vejbæk et al., 2007). This structural feature divides the Danish sector of the North Sea basin into the North German Basin, located south of the Ringkøbing-Fyn High, and the Danish-Norwegian Basin, north of Ringkøbing-Fyn High. During the Zechstein (Late Permian) four to five cycles of evaporites were deposited, infilling the structural lows (Sorgenfrei and Buch, 1964; Vejbæk et al., 2007). Further deepening of the North Sea basin resulted in thousands of meters of Mesozoic sediment deposition over the evaporites. The thick Mesozoic deposits activated diapirism of the underlying evaporites. Subsequently, several cycles of glaciations resulted in further loading inducing reactivation and upward migration of the salt diapirs (Nielsen et al., 2008). This halokinesis is likely to be ongoing in modern times.

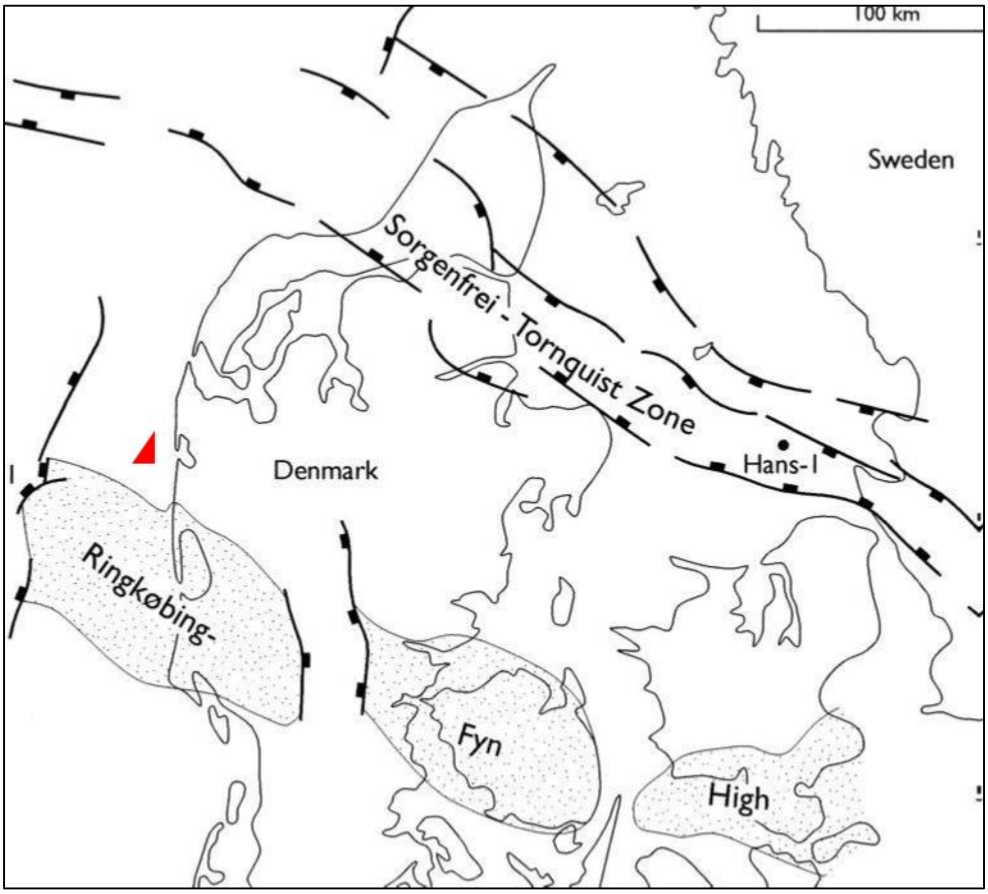


Figure 39 – Major Danish structural elements, site location in red.
(After Stemmerik et al., 2000)

During the Late Cretaceous a major tectonic inversion episode, associated with initiation of the Alpine Orogeny, affected the North Sea region (Clausen and Huuse, 1999; Japsen, 2000). Cretaceous tectonism was followed by sequential episodes of uplift and major sea level fluctuations from the Palaeogene to Neogene. These events resulted in variable rates and types of sediment deposition. The top of the Palaeogene-Neogene succession is represented as an important unconformity in Denmark. The same unconformity corresponds to the base of the Quaternary as defined in Rasmussen et al. (2010). The pre-Quaternary deposits are successively younger moving from the rim of the basin at the Sorgenfrei-Tornquist Zone towards the central North Sea Basin. The depositional systems (mostly deltaic) show a general shift moving from east to west. The Miocene succession is hundreds of metres thick in the Danish sector of the North Sea. A major regional unconformity occurs between the Upper Eocene and lower Upper Oligocene, Brejning Fm. (Mica Clay) (Rasmussen et al., 2010).

A large-scale glaciotectonic thrust complex has been identified in the Danish sector of the North Sea and it is bounded at is base by a weak décollement surface (Larsen and Andersen, 2005). The décollement surface is located in the early Miocene Arnum Formation (Andersen, 2004). It is interpreted as being of glaciotectonic origin (Huuse and Lykke-Andersen, 2000b; Andersen, 2004). The deformed sequence located above this structure comprises sediments from the Miocene to the Quaternary. Correlation with onshore areas suggest that the deformation took place during a westward advance stage of the Late Saalian (Warthe) ice sheet (Andersen, 2004). Based on the glacial stratigraphy outside the deformed areas (away from the deformation front), it is suggested that the same ice sheet advance that caused the glaciotectonic deformation eroded the top of the thrust sheets (Larsen and Andersen, 2005).

Nielsen et al. (2008) states that Quaternary sequences rest conformably on Pliocene deltaic sediments west of a transitional zone in the North Sea (Figure 40). East of the transition zone, the base of the Quaternary rises, becoming an unconformity along the coast from north of Thyborøn to south of the Danish-German border (e.g. Japsen, 2000; Nielsen et al., 2008). Generally, this unconformity (base of Quaternary) occurs at depths of a few hundred meters within valley structures to just below the seabed along the Danish west coast (Andersen, 2004; Huuse and Lykke-Andersen, 2000b; Leth et al., 2004, Novak et al., 2015). Across the wider region this surface is characterized by strong undulation controlled by variable-scale structures in the pre-Quaternary basement.

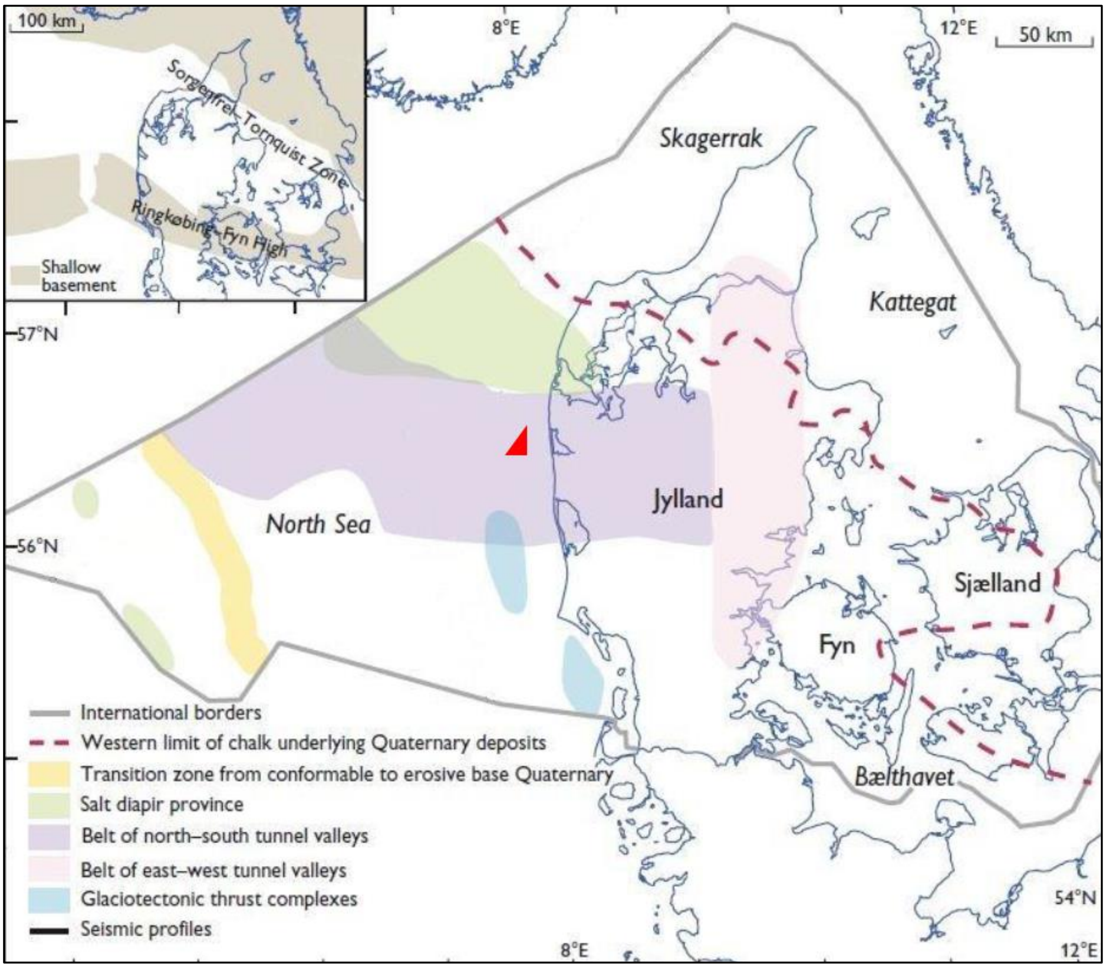


Figure 40 – Map overview of some geological elements in the region; site location in red. (After Nielsen et al., 2008)

Only a few studies have been performed on the Quaternary deposits in the Danish North Sea. However, onshore studies provide a decent foundation for outlining the regional geology in the eastern North Sea (Sjørring and Frederiksen, 1980; Sandersen and Jørgensen, 2003; Pedersen, 2005; Jørgensen and Sandersen, 2006; Jacobsen, 2003; Høyer A-S et al., 2013; Houmark-Nielsen, 2007).

The Elster and Saale ice sheets extended across the entire North Sea (Figure 41). Glaciation came from the northwest, northeast and from the Baltic region (Sjørring and Frederiksen, 1980; Ehlers, 1990). The Weichselian ice sheet extended north and east of the main stationary line which was located from inland Jutland towards the northwest into the North Sea. Morphological elements such as moraine ridges and elongated boulder reefs, occurring perpendicular to the main stationary line, indicate the location of the ice boundary on the seabed (Nicolaisen, 2010). The maximum extent of the ice extended further than the site during the Elsterian and Saalian glacial periods, being the site in a sub glacial setting for those periods. For the Weichselian glacial period, the maximum extent of the ice sheet was close to the site, however the available references do not have it extending over the site. Therefore, it was presumably in a proglacial environment for the Last Glacial Maximum (LGM).

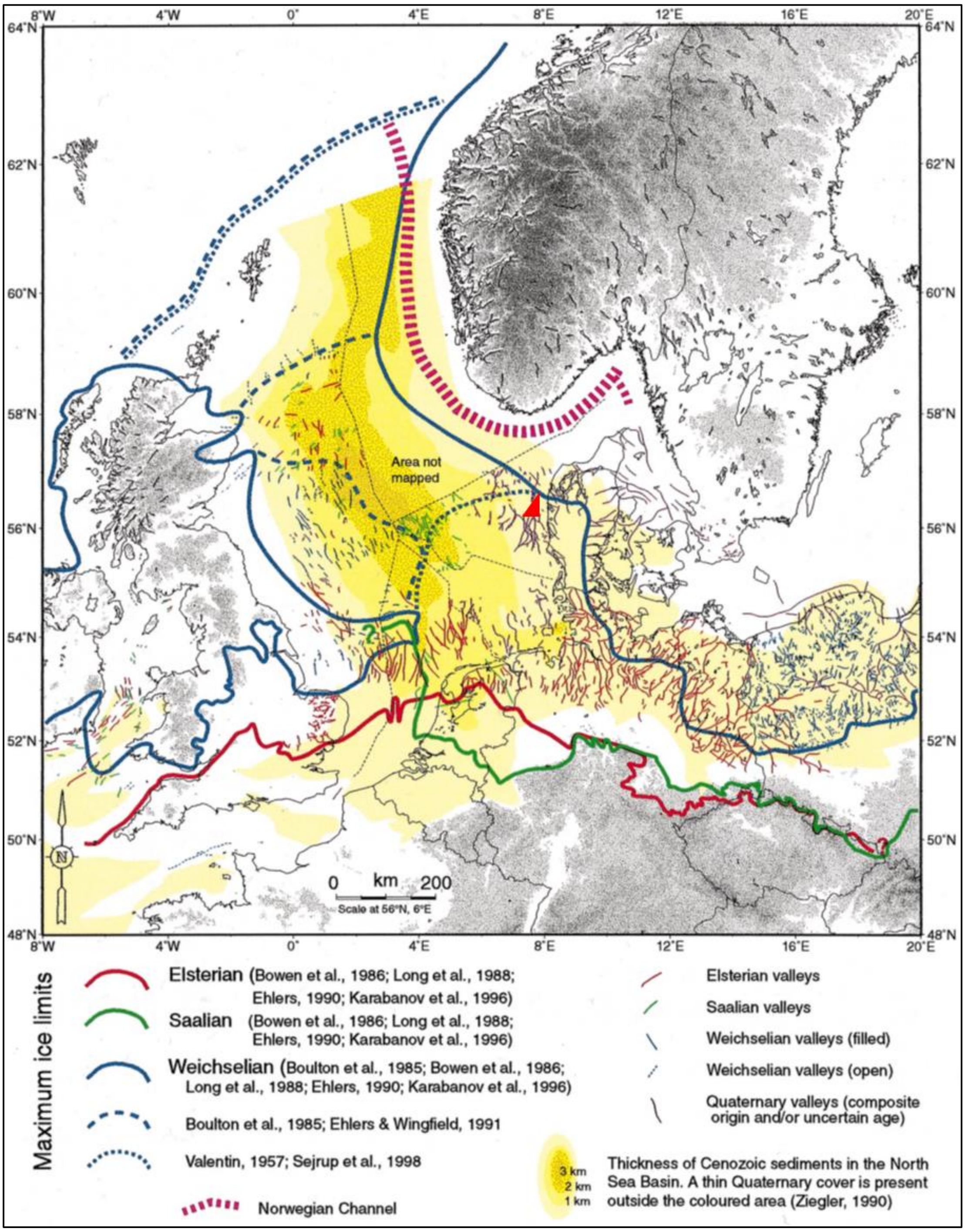


Figure 41 – The quaternary glaciations and an overview of Quaternary valleys in northwest Europe (Huuse, M., and Lykke-Andersen, H. 2000); site location in red.

In general, the Quaternary sequence thins from the central North Sea towards the Danish mainland (from thousands to tens of metres thick). A system of buried shelf valleys, 100-300m deep and several tens of kilometres long, are present in this area (Andersen, 2004; Huuse and Lykke-Andersen, 2000b; Novak et al., 2015). The submarine valleys are correlatable to onshore valleys and are considered to be of the Elster and Saale ages. Younger, reactivated Saale valleys have been found north and east of the Weichselian main stationary line (Smed 1979, 1981a; Jørgensen et al., 2005). Repeated episodes of glacial advance and catastrophic outbursts of melt water are believed to be the processes that generated these valleys.

Pre-Weichselian glaciations are not well documented offshore along the Danish west coast. However, it is known that the Elster and Saale ice sheets covered the Danish North Sea and extended further to the south (Ehlers, 1990). The formation of glacial tectonic complexes found to the west and south of the Weichselian ice sheet at the LGM boundary are believed to be attributable to the Saalian ice cover (Andersen, 2004; Huuse and Lykke-Andersen, 2000b; Novak et al., 2015; Vaughan-Hirsch and Phillips, 2017). In the Holmsland Thrust Complex (Novak et al., 2015) Saale till was found in a borehole at approximately 60 meters below sea level (Fugro 2014).

Onshore, the so called "hill islands" (Dalgas, 1867), which outline the Saalian landscape, are found to extend into the North Sea (Larsen, 2003; Larsen & Andersen, 2006, Leth et al., 2001; Anthony, 2001; Leth, 2003). Morphological remnants are absent on the seabed due to marine erosion. However, seismic profiles reveal horizons that have been interpreted to represent this same landscape.

During the Eemian period the palaeo-North Sea extended across the region. Related sediment deposits occur both on and offshore in the southwest (Konradi et al., 2005). Eem deposits representing valley infill were found in a borehole in the Vesterhav South survey area (Fugro 2014).

During the Weichselian glaciations, Figure 42, tills alternate with mixed sediment units comprised of glaciofluvial gravel, glaciolacustrine clay, silt and sand that were deposited to the north and east of the MSL (main stationary line). Towards the west and south of the main stationary line, glaciofluvial sand and gravel were deposited in morphological lows within the older Saale landscape (Houmark-Nielsen, 2007). The glaciation maximum occurred in the region around 22ka BP. The glaciers' subsequent retreat generated accommodation space close to the ice front where deposition of the glaciolacustrine Yoldia Clay occurred around 16-15ka BP. Also, as Weichselian ice melted, the deep-valleys were filled with laminated clay, silt and fine sand deposits, Figure 42.

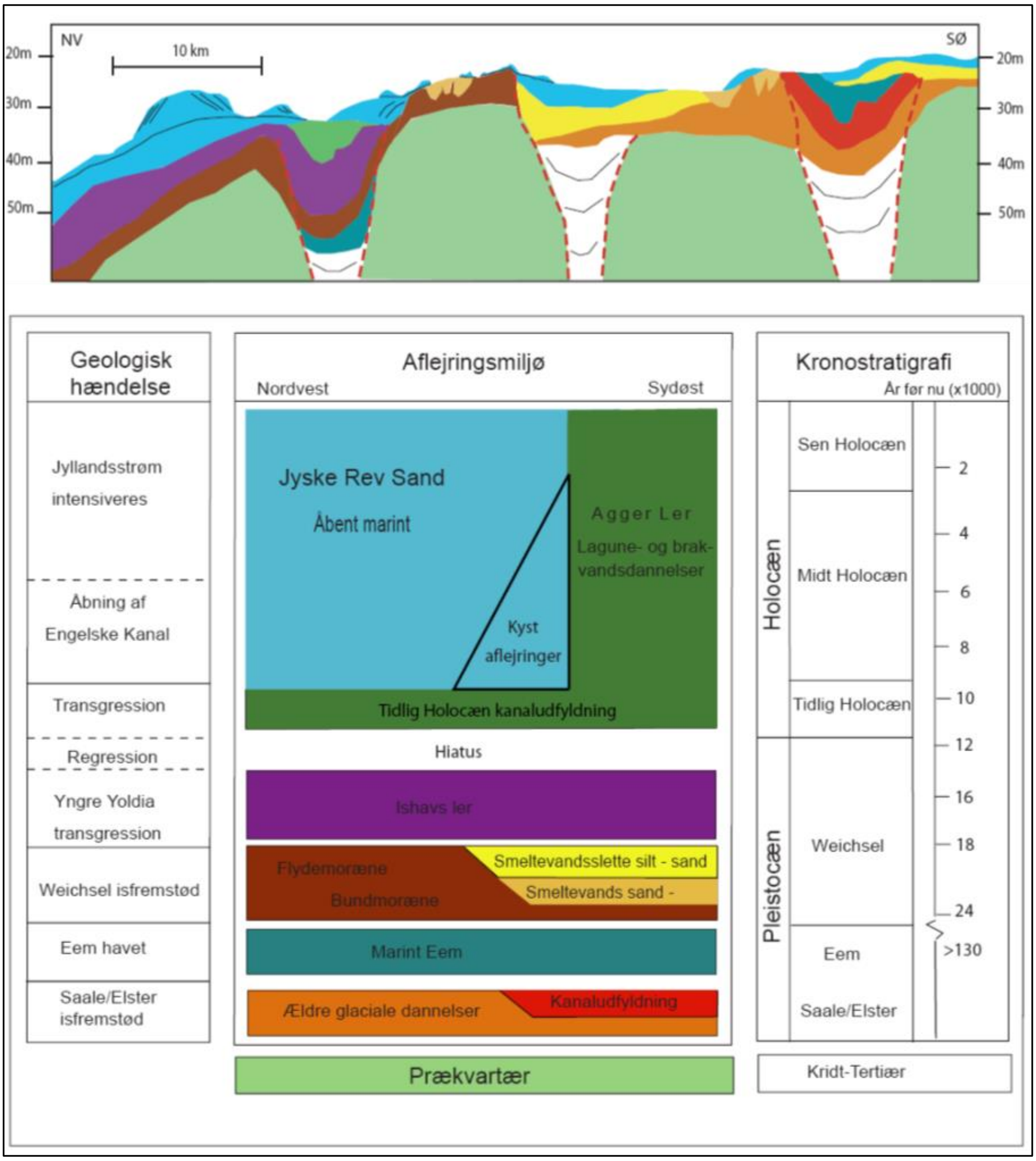


Figure 42 - General stratigraphy model of the geology in the eastern Danish North Sea. Above: A composite profile from NW towards SE representing approximately 50 km from Jyske Rev and towards the shore. Below: Stratigraphic unit names and their relative age. Same colour code used above and below. (After Nicolaisen, 2010).

The removal of the glacial load triggered isostatic rebound which drove a regression that took place until 11ka BP. During this timeframe, relative sea level was, at a minimum, 50 to 45 meters lower than present thus maintaining the eastern Danish shelf above sea level. Terrestrial conditions and rising temperatures increased organic material production resulting in peat accumulations. This marker horizon has been found in many survey areas across Danish waters (Leth, 1996; Bennike et al., 1998, 2000; Novak and Björck, 2002; Novak and Pedersen, 2000). In the eastern Danish North Sea fine-grained material was deposited in sheltered areas between till "islands", e.g, the Agger Clay unit (Leth, 1996). During the Holocene transgression, from 11ka BP to 6 ka BP, the Agger Clay depocenter shifted coastward and offshore low-lying islands were submerged. At the same time, coastal processes overtook the glaciogenic landscape where it was exposed to waves and currents. The result was the formation of spit/platform/lagoon deposits throughout the region (Nielsen and Johannesen, 2004; Johannesen et al., 2008; Novak and Pedersen, 2000).

In the eastern North Sea, metre-thick fossil sand waves were present at Jyske Rev. These current- and wave-generated structures have often been formed around sandy-gravelly fossil beach ridges. Seismic data depict multiple generations of these events. After 6 ka BP sea level was at its highest and the North Sea tidal system and coast parallel Jylland current developed.

A recent mobile sediment unit is the latest deposit and is found to cover major areas of the eastern North Sea seabed. Coast-parallel strong currents and waves generate the active bedforms, i.e., mobile sand waves and dunes. The Danish Coast Agency has documented bedform migrations of up to 20-50m per year; the dunes and waves are organized in kilometre-wide areas migrating across an apron of relict gravelly sand (Anthony and Møller, 2003; Anthony and Leth, 2001; Leth et al., 2004).

7| RESULTS

The results from the geophysical and geotechnical surveys are presented in this report together with associated alignment charts. The charts are presented in Appendix B|.

The results are presented by route (Table 24), including a section describing the survey findings in general in the route and tables with detailed results in KP intervals. Descriptive images and data examples are incorporated after the detailed sections.

Table 24 Export cable routes results.

NUMBER	START KP	END KP	RESULTS	INSTALLATION CONSTRAINTS
Route 02	0.000	21.444	Section 7.5|	Section 8.2|
Route 03	0.000	24.401	Section 7.6|	Section 8.3|
Route 04	0.000	24.335	Section 7.7|	Section 8.4|
Route 05	0.000	21.237	Section 7.8|	Section 8.5|

The results focus on bathymetry, surficial geology, and shallow geology. A summary of all contacts, anomalies and features is also presented.

The Offshore Wind Farm survey results, Geotechnical survey results and Operations reports are presented in separate standalone reports (Table 6).

All reports, appendices, and charts refer to the client supplied RPL REV04 (Appendix A|) unless otherwise stated.

The terms *elevation* and *depth* have been used throughout the report. Although referring to the same parameter, the vertical position relative to the DTU15 MSL datum, it is standard within the industry to refer to those in the marine environment (i.e. below Mean Sea Level) as *depths* and those in the terrestrial environment (i.e. above Mean Sea Level) as *elevations*. These descriptive terms are used in conjunction with the numerical value for each vertical position and these values will use the correct sign convention as requested for delivery. In this case elevations have positive values and depths negative values.

Additionally, report imagery obtained from the EIVA NaviModel software inherently stores DTMs with depth conventions of positive down. Examples of such images include Figure 44, Figure 45 and Figure 68. For all images from NaviModel there will be captions to indicate the reversed depth convention.

7.1| CABLE AND PIPELINE CROSSINGS

There are no known crossings by the planned Thor OWF cable routes.

7.2| BENTHIC SCOPE

The geophysical interpretation and the geotechnical findings were used as the basis for a benthic scope proposal.

Benthic data acquisition was proposed to include sediment sampling, for fauna and physico-chemical analyses, photography with continuous video recording aiming to map and describe existing habitats and species present. The survey was recommended to be conducted using a towed High Definition camera, a Dual Van Veen grab, and a Hamon grab.

The results of the benthic scope were as follows:

- A total of 9 grab sample sites together with three video transects were successfully executed for benthic investigations along the R2 route.
- A total of 12 grab sample sites, together with two video transects, were successfully executed for benthic investigations along the R3 route.
- A total of 5 grab sample sites, together with one video transect, were successfully executed for benthic investigations along the R4 route.
- A total of 6 grab sample sites, together with one video transect, were successfully executed for benthic investigations along the R5 route.

The proposed benthic scope is presented in detail in 103282-ENN-MMT-SUR-REP-BSREPL2

7.3| GEOTECHNICAL SUMMARY

The geotechnical locations were selected by MMT based upon a full review of the geophysical sub-bottom profiler data to ensure that all representative shallow sediments were targeted. The locations were subsequently approved by Energinet. The coordinates and water depths, shown on the records, were obtained by MMT during the fieldwork.

The geotechnical survey consisted of vibrocore samples (VC), cone penetration tests (CPT) and grab sampling (GS).

For more detailed information, check Appendix D|.

7.3.1| ROUTE 2

From the start of the route to KP 4.430 the encountered ground conditions are almost entirely granular with the material being typically described as silty to very silty, to silty gravelly SAND. Cohesive content appears to increase with depth.

Across the remainder of route 2, the ground conditions are slightly more variable. Granular material is typically encountered from the seabed, comprising silty, locally gravelly SAND to coarse grained material, locally slightly silty, sandy to very sandy GRAVEL. The thickness of granular material is variable across the route section. The seabed grab samples taken along the route are also all granular, being slightly silty to silty slightly gravelly SAND to GRAVEL. At several locations the granular material overlies high strength cohesive material, being firm to stiff sandy gravelly CLAY TILL. The depth at which CLAY TILL is encountered is variable, from only 0.11 m to 1.49 m.

The presence of organic-rich CLAY and PEAT along a cable route must also be taken into consideration. Significant PEAT has not been identified at any locations along the survey route, although its potential presence, especially close to the landfalls, should not be discounted.

The CPT data obtained from the survey is generally of high quality, application classes 1 and 2, with good cone response in all the penetrated sediment types. In general, the correlation between the interpreted strata and material parameters, to that ascertained from the vibrocores is good.

7.3.2| ROUTE 3

From the start of the route to KP 10.995 granular material is typically encountered from the seabed, comprising SAND, locally silty or gravelly. The thickness of granular material is variable across the route.

Along route 3, GRAVEL deposits are sporadically present at several locations, particularly in the upper 1 m of recovered material, with thickest stratum of 0.92 m.

At most locations the granular material overlies high strength cohesive material, being firm to stiff sandy gravelly CLAY TILL. The depth at which CLAY TILL is encountered is variable, from only 0.09 m to 3.00 m.

From KP 12.342 to KP 17.541, the encountered ground conditions are almost entirely granular. The majority of the recovered sediment is silty to very silty, locally gravelly, SAND.

From KP 18.892 to KP 23.949, granular material is typically encountered from the seabed, comprising slightly silty to very silty, locally slightly gravelly, SAND.

Cohesive material is seen at all locations, with very sandy slightly gravelly CLAY TILL being identified at locations VC-021, VC-020B and VC-019, underlying GRAVEL. CLAY at the other locations is silty, sandy.

The CPT data obtained from the survey is generally of high quality, application classes 1 and 2, with good cone response in all the penetrated sediment types. In general, the correlation between the interpreted strata and material parameters, to that ascertained from the vibrocores is good.

7.3.3| ROUTE 4

The encountered ground conditions across route 4 are a variety of both granular and cohesive material. Granular material is encountered from the seabed and varies from SAND through to silty gravelly SAND. In the upper 0.5 m of material, the sediment is generally slightly silty to silty, locally slightly gravelly to very gravelly SAND. GRAVEL is generally sandy to very sandy, locally silty/clayey and has a maximum thickness of only 0.27 m (VC-045).

CLAY is encountered across the route. CLAY TILL, typically very sandy slightly gravelly CLAY is seen at several locations. Other cohesive material seen across the route are sandy CLAY, often thinly laminated and some minor sandy SILT strata.

GRAVEL deposits are sporadically present at several locations, particularly in the upper 1 m of recovered material, the thickest stratum is only 0.27 m.

The CPT data obtained from the survey is generally of high quality, application classes 1 and 2, with good cone response in all the penetrated sediment types. In general, the correlation between the interpreted strata and material parameters, to that ascertained from the vibrocores is good.

7.3.4| ROUTE 5

The encountered ground conditions across route 5 are a variety of both granular and cohesive material. Granular material is encountered from the seabed and typically varies from very silty SAND through to silty gravelly SAND.

The thickness of granular deposits is variable. At four locations, VC-061A, VC-058A, VC-057 and VC-054, the entire recovered material to a depth of 4.30 m (VC-057) is SAND, silty to very silty, locally slightly gravelly to very gravelly.

SILT can also be seen at several locations as thin layers up to 2.18 m. The SILT is slightly sandy to very sandy.

CLAY is encountered across the route. CLAY TILL, locally very sandy slightly gravelly, is seen at most locations. The depth to the CLAY TILL varies, from 0.2 m to 3.9 m. Other cohesive material seen across the route are silty to very sandy CLAY, often thinly laminated.

GRAVEL is almost absent from the recovered material

The CPT data obtained from the survey is generally of high quality, application classes 1 and 2, with good cone response in all the penetrated sediment types. In general, the correlation between the interpreted strata and material parameters, to that ascertained from the vibrocores is good.

7.4| DESCRIPTION OF DATA INTERPRETATION

The interpretation in the area utilised all of the collected data sets throughout the interpretation process.

From the drone survey an orthophoto and DTM data sets were exported for interpretation of terrestrial features. These were brought into Auto CAD and features such as dunes, agricultural areas, buildings and roads etc. were digitised. Once completed the data was brought in to GIS for hatching and merging with the marine data set.

The SSS data was the main data set used when interpreting the surficial geology, but was at all times compared and correlated with both the MBES and the MBBS data to give the most accurate and confident interpretation. Along with this, the results from the geotechnical campaign, including GS, VC and CPT was used to ground truth the interpretation.

The SBP data was interpreted using the data from the Innomar system correlated to the surficial interpretation. The results from the geotechnical campaign was also used to ground truth the interpretation.

The topographical features were digitized using both the MBES and the SSS data sets simultaneously.

The contacts were mainly detected on the SSS data. To ensure all contacts were picked, the data set was gone through and additional contacts were also picked in the MBES data. The contacts are picked as either a SSS contact or a MBES contact. The same contact never has both a SSS and a MBES ID.

Magnetometer records collected during the survey are used to identify cables/pipelines and ferrous objects on the seafloor within the survey corridors. Note that due to line spacing and data acquisition height above seabed, data acquired for the offshore survey does not constitute an unexploded ordnance (UXO) survey.

All magnetic anomalies were manually picked in the data set. These were correlated to the SSS and MBES contacts, using a 5 m radius. If the contacts and the anomalies are within 5 m from each other, they are considered to be correlating, and additional correlation information was added in the contact information.

7.5| ROUTE 2: KP 0.000 TO KP 21.444

7.5.1| OVERVIEW

Route 2 covers the Landfall 1 survey area and the 800 m wide route corridor out to OWF Entry 2.

BATHYMETRY

The topographical survey, conducted by aerial drone, covered a section of the landfall zone that measured 280 m long at the route and spanned the full width of the survey corridor. Where the route crosses the landfall and bathymetry data there is a 205 m gap which resulted from poor coverage of the beach by the aerial drone survey. Towards the north of the route the coverage is improved, with a minimum gap of 93 m. From KP 0.00 to KP 0.83 the route crosses a level but generally undulating field after which it crosses a large sand dune. This dune spans 135 m of the route and has a maximum elevation of +13.92 m and stands 12.5 m higher than the beach. The maximum slope value is 37.4° which is located on the landward (east) side of the dune. The western (seaward side) has a maximum slope angle of 30.4°. The dune gradually tapers off to the base at an elevation of +1.67 m at KP 0.229

where the beach gradually rises again to an elevation of +2.27 m at KP 0.264. From here the beach falls away more steeply to the edge of the drone coverage at KP 0.280 where the elevation is +0.76 m.

North of the route position the topography is largely similar with the exception of a complex two buildings (TUSKAER, Kulinarisk Kunst and Kulturcentre) centred on 446220 E and 6257559 N with access road. A vehicular access route to the beach crosses the dune at 446147 E, 6257148 N. South of the route the topography is also similar, however the dune narrows towards the route boundary and, on the landward side, there is a curving ridge, possibly associated with the road (181) located on its eastern side.

The bathymetry along Route 2 is highly variable. The variation is due to several deep channels and sand banks observed along the proposed cable route. Nevertheless, slopes throughout the survey corridor tend to be gentle, mainly between 1 and 2°.

Between KP 0.488 (start of the MBES data along the route) and KP 6.000, the cable route deepens westward. The maximum depth is -7.50 m DTU15 MSL, at 440449.96 E and 6255862.99 N at KP 6.000. The shallowest point is -1.83 m MSL is at 445909.35 E, 6257766.90 N at KP 0.340.

Between KP 6.500 and KP 16.000, the seabed deepens and crosses parallel seabed formations orientated in a N-E/ S-W direction. The maximum depth is -27.28 m DTU15 MSL, at 432556.99 E and 6254152.28 N at KP 14.069 (DCC 362 m). The minimum depth is -19.28 m 439812.63 E and 6255712.89 N at KP 6.656.

At KP 11.700 the cable route crosses a shallow channel orientated N-S with a width of 104 m. At the northern part of this channel at KP 11.746 (DCC 175 m) there is an isolated raised feature with a NE-SW orientation, approximately 41 m long and 13 m wide. This feature (S_R2_3047) at 434850.23 E and 6254567.98 N appears to be an elongated mound similar to a rock dump.

Between KP 13.700 and KP 14.000 the cable route crosses a depression with a maximum depth of -26.65 m DTU15 MSL at 432802.90 E and 6253882.80 N.

Between KP 15.000 and 16.000 the seabed shoals to -24.72 m DTU15 MSL at MSL at 431058.88 E 6253329.31 N before deepening at its SW edge as it delineates the eastern edge of a N-S trending channel that cuts in to the underlying sediments.

Between KP 16.000 and KP 18.000 the seabed begins to level with the bathymetry generally -27 m DTU15 MSL.

Between KP 18.300 and KP 19.200 the seabed shoals to a minimum depth of -23.26 m DTU15 MSL. The cable route passes over a potential sandbank orientated NE-SW that crosses the survey corridor with a width of 762 m.

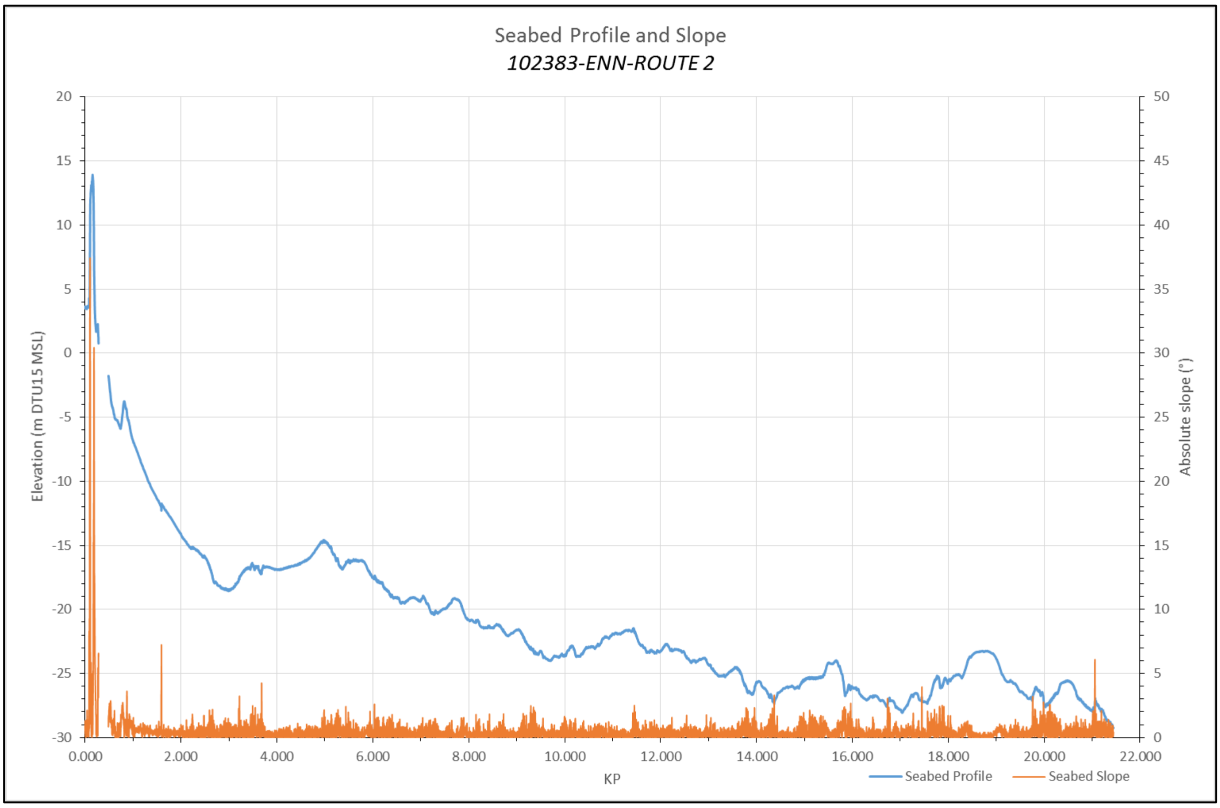


Figure 43 Route 2 longitudinal profile and slope.
Elevation is in metres (with bathymetric depths negative below MSL datum) and slope is in degrees (absolute value for visualisation). Vertical exaggeration x 250.

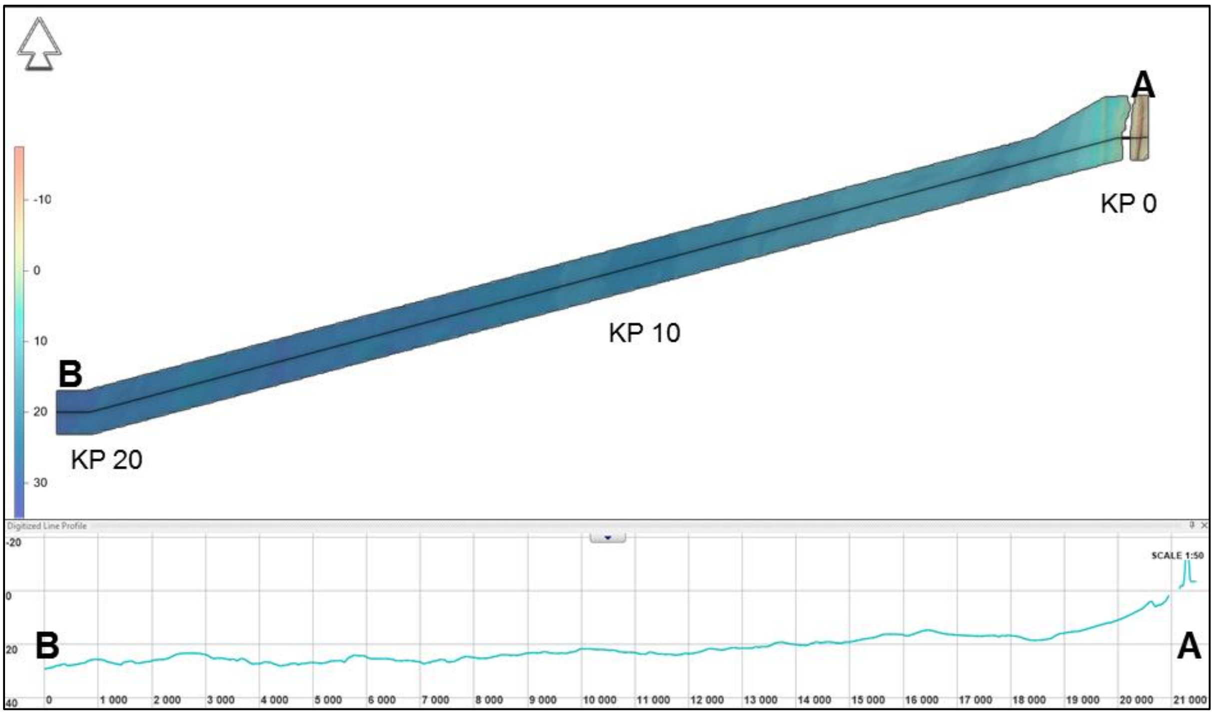


Figure 44 Overview image of Route 2.
The scale on the profile is in metres with distance given along the x-axis. NaviModel depth convention is positive down, vertical exaggeration of profile x50.

SURFICIAL GEOLOGY

The seabed surface predominantly comprises SAND with frequent patches and bands of gravelly SAND to sandy GRAVEL oriented mostly NNE-SSW. These sections are commonly associated with areas of ripples which display the same orientation. The general direction of sediment transport in the area is N-S close to shore with a slight rotation toward NE-SW further out.

Areas of depressions, often associated with SAND, are present from KP 14.000 to the end of the route at KP 21.444. These features are likely caused by changes in seabed current regime rather than shallow biogenic gas. The lack of gas blanking / turbidity in the SBP data suggests gas is unlikely to be the provenance for such features.

Occasional and numerous boulders are observed along the route as patches, with occasional boulders being more common (Appendix F|). Discrete areas of DIAMICTON are observed within the survey corridor, with a major band extending crossing the corridor from KP 20.854 to the end of the route at KP 21.444.

Minor discrete areas of CLAY were observed at the beginning of the survey route only, at KP 1.610.

Some man-made features of importance were observed in the intertidal zone; these include two military bunkers and an area of concrete blocks forming a coastal erosion defence structure. An additional 735 contacts were detected, with the majority interpreted as boulders (721) and 8 as debris.

Detailed description of the surficial geology is presented in Table 25.

SHALLOW GEOLOGY

A detailed description of the shallow geologic changes observed along the proposed Route 2 can be found in the Route 2 seabed details table presented in Table 25.

A number of sedimentary units were identified in the sub-surface geology down to a maximum depth of 8.6 m below the seabed (-35.7 m DTU15 MSL). The upper unit along the majority of the route has been confirmed to be SAND based on the geotechnical sampling results. These sediments are often laminated and acoustically transparent internally. Distinct and highly reflective layers are common within this section of the stratigraphy, varying in length, vertical placement, and amplitude (Figure 65). These were interpreted as internal layers within the Unit.

The upper SAND unit varies from silty SAND to SAND and GRAVEL. More localised areas of GRAVEL and CLAY, were also observed along the route. The SAND unit extends along the entire route at variable depths ranging from the seafloor to 3.4 m below seabed. The base horizon for this unit (H1) is often undulating in character.

From KP 1.944 to KP 21.440, the upper SAND unit, bounded by horizon H1, lies atop an erosional discontinuous surface named as H2 which represent the base of palaeo-channels of varying depths and extents. Based on the SBP penetration limit, the deepest channel structure reached was 8.6 m below the seabed.

The infill of these channels is variable, consisting of laminated and homogenous sediments which characterise the channel infill along the route. In some channels the infill sediments form a uniform thick unit while others have a strong upper boundary reflector indicating a change in sediment characteristics. Based on geotechnical results, sediments recovered ranged from Silty SAND and GRAVEL to CLAY with PEAT and organic matter.

From KP 1.944 and heading nearshore, the SAND unit lies atop a thick unit of gravelly SAND to SAND. The base of this unit is detectable from KP 1.009 to KP 1.944 and presented as nearshore internal.

A grid was created to map the base of the upper SAND unit (H1) detected from SBP data related to depth below seabed and related to the MSL datum.

7.5.2| DETAILED DESCRIPTION

A detailed presentation of the conditions and features on Route 2 are shown in Table 25.

Table 25 Route 2 seabed details.

KP	ASSOCIATED CHART	DESCRIPTION (INCLUDING MIN/MAX DEPTH BSB TO BASE OF UNIT)	REMARK
0.000 – 5.145	103282-ENN-MMT-SUR-DWG-ALR20001	**Bathymetry:** Initially flat field then crosses a dune between KP 0.083 to KP 0.229. The dune stands 12.5 m above the level of the beach at KP 0.229. The beach slopes gently down towards the surf zone. Maximum elevation +13.92 m at KP 0.156. Minimum elevation +0.76 m at KP 0.280 Moderately deepening seafloor from the beach outwards with shallow channels and sandbank/sandwave. Minimum depth -1.77 m at KP 0.486. Maximum depth -18.57 m at KP 2.987	Subaerial: Very steep slopes on east and west sides of the dune, with a maximum value of 37.4° on the eastern side. Maximum elevation on the dune crest is +13.92 m. Subsea: Very gentle to gentle slopes with a maximum value of 2° at landfall. Total elevation/depth range = 32.5 m. Maximum slope of 37.4° at KP 0.103 (Figure 45).
		Surficial Geology: SSS coverage starts at KP 0.464. This section is dominated by SAND with occasional areas of sediment comprising gravelly SAND to sandy GRAVEL. Ripples and areas of occasional boulders are also seen, commonly in association with the gravelly areas (Figure 46). A nearshore sandbank/sandwave area is present between KP 0.465 and KP 0.900 (Figure 45).	Several man-made objects are located in the nearshore area. • KP 0.371 (DCC 637.3): S_R2_3012- Man made structure interpreted as military bunker* (Figure 51, Figure 52, Figure 53) • KP 0.386 (DCC 571.2): S_R2_3015- Man made structure interpreted as military bunker* (Figure 51, Figure 52, Figure 53) These features have clear correlating MAG responses. (Figure 53) • KP 0.404 to KP 0.606: Several contacts believed to be square-shaped blocks used as coastal defence** structures (Figure 54, Figure 55). These features are detected in both the SSS and MBES data. • KP 0.622 (DCC 87.6) to KP 0.951 (DCC 177.6): Magnetic anomalies display a linear pattern (Figure 56) that could be interpreted as a buried cable/pipe.

KP	ASSOCIATED CHART	DESCRIPTION (INCLUDING MIN/MAX DEPTH BSB TO BASE OF UNIT)	REMARK
			This feature is not seen in the SSS or MBES data and it is not present in the background data. Field of occasional boulders crossing the route between: • KP 3.601 to KP 3.685 *A photo taken from the beach confirms the presence of bunkers along the coastline. (103282-ENN-MMT-Data-Examples presentation) **Photo taken from information board near site showing coastline in 1970, before defences were installed, confirm this interpretation, (103282-ENN-MMT-Data-Examples presentation)
		Shallow Geology: SBP coverage begins at KP 0.493. KP 0.493 to KP 1.944: SAND, fine to coarse (0.25 – 3.4 m BSB) overlaying a thick unit of gravelly SAND to SAND (0.2 – 5.8 m BSB). The base of the gravelly SAND unit is named on the charts as nearshore internal and it can be detected up to KP 1.009. KP 1.944 to KP 3.170: Silty SAND (0.5 – 2.2 m BSB) overlaying channel infills, SAND (1.9 – 4.0 m BSB). KP 3.170 to KP 3.680: Gravelly SAND (0.0 – 1.5 m BSB) overlaying channel infills, SAND (0.0 – 4.0 m BSB). KP 3.680 to KP 5.145: Silty SAND unit with internals of gravelly SAND at the base (0.0 – 2.8 m BSB) overlaying silty SAND.	(Figure 57), (Figure 58) and (Figure 59)
5.145 – 9.441	103282-ENN-MMT-SUR-DWG-ALR20001 103282-ENN-MMT-SUR-DWG-ALR20002	**Bathymetry:** Relatively flat seabed with areas of shallow channels and sandbanks. Minimum depth -15.48 m at KP 5.147. Maximum depth -23.53 m at KP 9.441.	Very gentle to gentle slopes with a maximum value of 0.9°. Depth range 8 m. Maximum slope of 2.6° at KP 6.034.

KP	ASSOCIATED CHART	DESCRIPTION (INCLUDING MIN/MAX DEPTH BSB TO BASE OF UNIT)	REMARK
		Surficial Geology: In this section, sediments predominantly comprise gravelly SAND to sandy GRAVEL, intermixed with areas of SAND. Ripples and occasional boulders are common. An area of numerous boulders is present between KP 8.570 to KP 8.805 (Figure 47).	Fields of occasional boulders crossing the route between: • KP 6.073 and KP 6.109 • KP 6.188 and KP 6.237 • KP 6.376 and KP 6.389 • KP 6.515 and KP 6.557 • KP 6.600 and KP 6.690 • KP 6.941 and KP 6.957 • KP 7.109 and KP 7.180 • KP 7.243 and KP 7.337 • KP 7.831 and KP 8.352 • KP 8.502 and KP 8.529 • KP 9.023 and KP 9.380 Fields of numerous boulders crossing the route between: • KP 8.570 and KP 8.585 • KP 8.604 and KP 8.805 See Appendix F| for images.
		Shallow Geology: KP 5.145 to KP 5.880: Gravelly SAND (0.0 – 2.0 m BSB) overlaying SAND to silty SAND. KP 5.880 to KP 9.441: Gravelly SAND (0.0 – 0.9 m BSB) overlaying either channel infills, silty SAND (0.7 – 4.8 m BSB) or sandy gravelly CLAY which outcrops at seabed between KP 8.589 to KP 9.441.	(Figure 59) and (Figure 60) Vibrocore results (282-VC-R2-013) indicate minor peat laminae within SAND at 0.70 m, 1.50 m and 1.71 m BSB.
9.441 – 11.402	103282-ENN-MMT-SUR-DWG-ALR20002	**Bathymetry:** Relatively flat seabed with areas of shallow channels and sandbanks. Minimum depth -21.59 m at KP 11.327. Maximum depth -24.02 m at KP 9.700.	Very gentle to gentle slopes with a maximum value of 0.4°. Depth range 2.4 m. Maximum slope of 1.6° at KP 9.996.

KP	ASSOCIATED CHART	DESCRIPTION (INCLUDING MIN/MAX DEPTH BSB TO BASE OF UNIT)	REMARK
		Surficial geology: This area is classified as predominately SAND, with occasional. discrete patches of gravelly SAND to sandy GRAVEL (Figure 47 and Figure 48). Areas with occasional boulders are also present in this section.	Fields of occasional boulders crossing the route between: • KP 9.527 and KP 9.557 • KP 9.858 and KP 10.018 • KP 10.179 and KP 10.237 See Appendix F| for images.
		Shallow Geology: KP 9.441 to KP 10.128: Silty SAND (0.3– 0.8 m BSB) overlaying silty SAND with clay. KP 10.128 to KP 11.245: Gravelly SAND (0.2 – 1.0 m BSB) overlaying either channel infills, silty SAND (0.9 – 4.8 m BSB) or silty SAND with clay. KP 11.245 to KP 11.402: Gravelly SAND (0.2 m BSB) overlaying silty SAND.	(Figure 61) Vibrocore results (282-VC-R2-010) indicate CLAY has some organic content. Vibrocore results (282-VC-R2-009) indicate SAND has some organic content.
11.402 – 14.890	103282-ENN-MMT-SUR-DWG-ALR20002	**Bathymetry**: Relatively flat seabed with areas of shallow channels and sandbanks. Minimum depth -21.47 m at KP 11.434. Maximum depth -27.37 m at KP 14.369.	Very gentle to gentle slopes with a maximum value of 0.8°. Depth range = 5.9 m. Maximum slope 3.3° at KP 14.370.
		Surficial geology: Gravelly SAND to sandy GRAVEL dominate this section with minor sections of SAND (Figure 48). Ripples are common and are mostly present as elongated bands orientated NNE-SSW which cross the survey corridor. (Figure 48). Isolated raised feature with a NE-SW orientation, approximately 41 m long and 13 m wide. This feature (S_R2_3047) at 434850.23 E and 6254567.98 N appears to be an elongated mound similar to a rock dump?	Fields of occasional boulders cross the route between: • KP 12.090 and KP 12.197 • KP 12.360 and KP 12.552 • KP 12.921 and KP 13.216 • KP 13.701 and KP 13.829 • KP 13.897 and KP 13.948 See Appendix F| for images. Areas of depressions cross the route between:

KP	ASSOCIATED CHART	DESCRIPTION (INCLUDING MIN/MAX DEPTH BSB TO BASE OF UNIT)	REMARK
		Areas of occasional boulders are observed within this section; a single discrete and minor area of numerous boulders, less than 40 m wide cross the route at KP 14.337. Areas of depressions are also present.	• KP 13.960 and KP 13.994 • KP 14.890 and KP 15.422
		Shallow Geology: KP 11.402 to KP 12.152: Gravelly SAND (0.3 – 0.7 m BSB) overlaying silty SAND with clay. KP 12.152 to KP 12.715: Gravelly SAND (0.2 – 0.7 m BSB) overlaying channel infills, silty SAND (1.1 – 6.0 m BSB). Overlies silty SAND with clay. KP 12.715 to KP 13.265: Gravelly SAND (0.4 – 0.6 m BSB) overlaying silty SAND with clay, which outcrops to seabed between KP 12.935 to KP 13.265. KP 13.265 to KP 14.890: Gravelly SAND (0.2 – 0.8 m BSB) overlaying channel infills, silty SAND (0.3 – 4.5 m BSB). Overlies silty SAND with clay.	(Figure 62)
14.890 – 16.114	103282-ENN-MMT-SUR-DWG-ALR20002 103282-ENN-MMT-SUR-DWG-ALR20003	**Bathymetry:** Relatively flat seabed with areas of shallow channels and sandbanks. Minimum depth -23.98 m at KP 15.664. Maximum depth -26.76 m at KP 15.844.	Very gentle to gentle slopes with a maximum value of 1.7°. Depths range = 2.8 m. Maximum Slope of 2.7° at KP 15.966.
		Surficial geology: This section is dominated by SAND. First half of the section characterised by an area of depressions in the northern part of the corridor (Figure 48)	Several MAG anomalies (6 in total) concentrated between KP 15.715 (DCC -138.6) and KP 16.052 (DCC -209.9)
			(Figure 63)

KP	ASSOCIATED CHART	DESCRIPTION (INCLUDING MIN/MAX DEPTH BSB TO BASE OF UNIT)	REMARK
		Shallow Geology: KP 14.890 to KP 15.130: Gravelly SAND (0.6 – 0.9 m BSB) overlaying channel infills, silty SAND (1.5 – 3.0 m BSB). KP 15.130 to KP 16.114: Silty SAND (0.7 – 2.5 m BSB) overlaying channel infills, silty gravelly SAND (1.1 – 3.4 m BSB). Overlies sandy gravelly CLAY.	
16.114 – 21.444	103282-ENN-MMT-SUR-DWG-ALR20003	**Bathymetry:** Relatively flat seabed with areas of shallow channel systems and sandbanks. Minimum depth -23.24 m at KP 18.707. Maximum depth -29.26 m at KP 21.442.	Very gentle to gentle slopes with a maximum value of 0.8°. Depth range = 6 m. Maximum slope of 6.1° at KP 21.057.
		Surficial geology: The section is dominated by gravelly SAND to sandy GRAVEL with alternating bands and patches of SAND (Figure 49). From KP 20.859 until the end of the route, the surface geology is interpreted as DIAMICTON (Figure 50). Areas of depressions are common around KP 18.000 and KP 20.000. Minor areas of occasional boulders are also present at KP 16.875 and KP 17.436.	Fields of occasional boulders crossing the route between: • KP 16.875 and KP 16.953 • KP 17.436 and KP 17.477 Field of numerous boulders crossing the route between: • KP 14.337 and KP 14.376 See Appendix F| for images. Areas of depressions cross the route between: • KP 16.725 and KP 16.785 • KP 17.834 and KP 17.907 • KP 19.757 and KP 19.988 • KP 20.046 and KP 20.269
		Shallow Geology: KP 16.114 to KP 17.054: Gravelly SAND (0.3 – 1.4 m BSB) overlaying channel infills, silty SAND with laminated clay (0.8 – 8.6 m BSB). Overlies sandy gravelly CLAY.	(Figure 64) and (Figure 65)

KP	ASSOCIATED CHART	DESCRIPTION (INCLUDING MIN/MAX DEPTH BSB TO BASE OF UNIT)	REMARK
		KP 17.054 to KP 17.234: Silty SAND (0.3 – 1.3 m BSB) overlaying channel infills, silty SAND with laminated clay (Beyond penetration limit). KP 17.234 to KP 17.575: Silty SAND (0.3 – 1.3 m BSB) overlaying channel infills, silty SAND with laminated clay (4.9 – 6.4 m BSB). KP 17.575 to KP 18.436: Silty SAND with internals of gravel (0.4 – 2.7 m BSB) overlaying silty SAND (Up to penetration limit). KP 18.436 to KP 19.590: Sandy GRAVEL (0.3 – 2.7 m BSB) overlaying silty SAND (Up to penetration limit). KP 19.590 to KP 20.340: Silty SAND (0.3 – 2.4 m BSB) overlaying either channel infills, silty SAND (1.0 – 5.9 m BSB) or sandy gravelly CLAY. KP 20.340 to KP 20.809: Gravelly SAND (0.5 – 1.6 m BSB) overlaying channel infills, silty SAND (1.6 – 4.0 m BSB). Overlies sandy gravelly CLAY. KP 20.809 to KP 21.440: limited penetration, sandy gravelly CLAY outcropping at surface.	

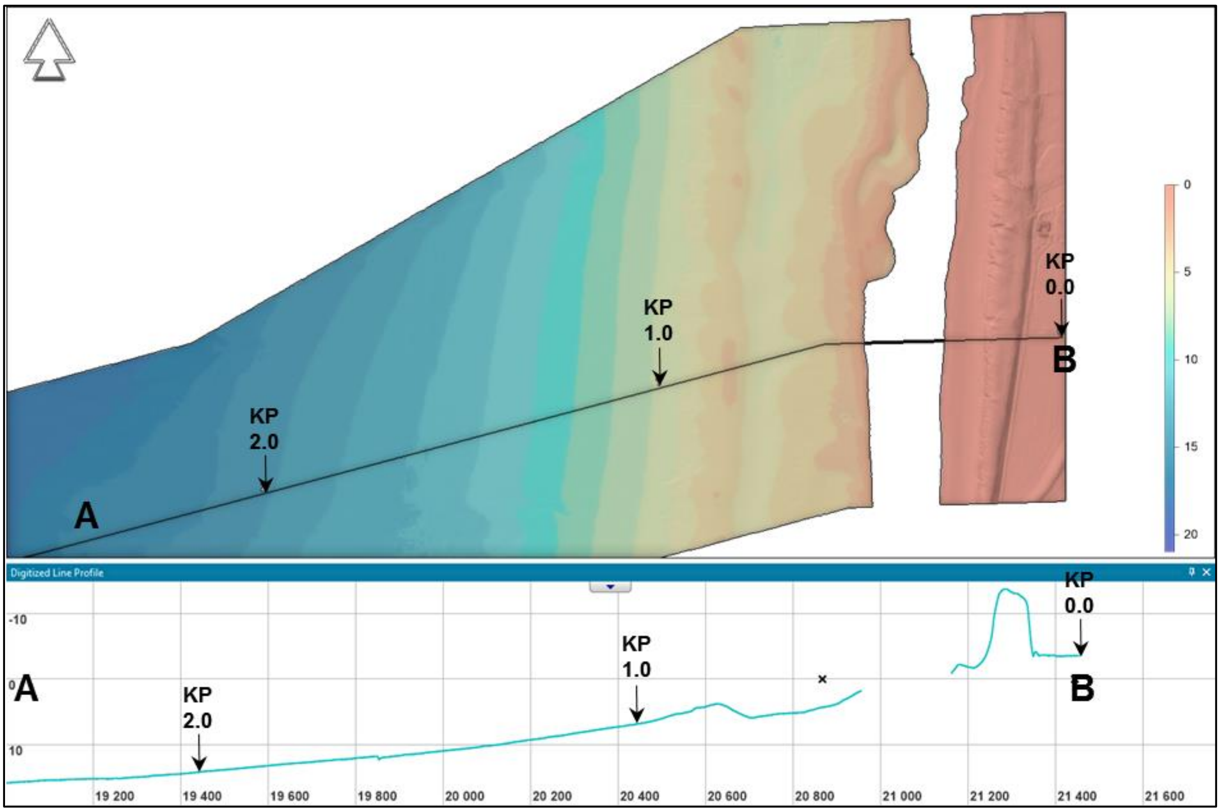


Figure 45 Inshore section of Route 2 showing UAS data and nearshore bathymetry. Horizontal scale is distance in metres from western end of the route. Depths in NaviModel presented positive down; Vertical exaggeration of profile x15.

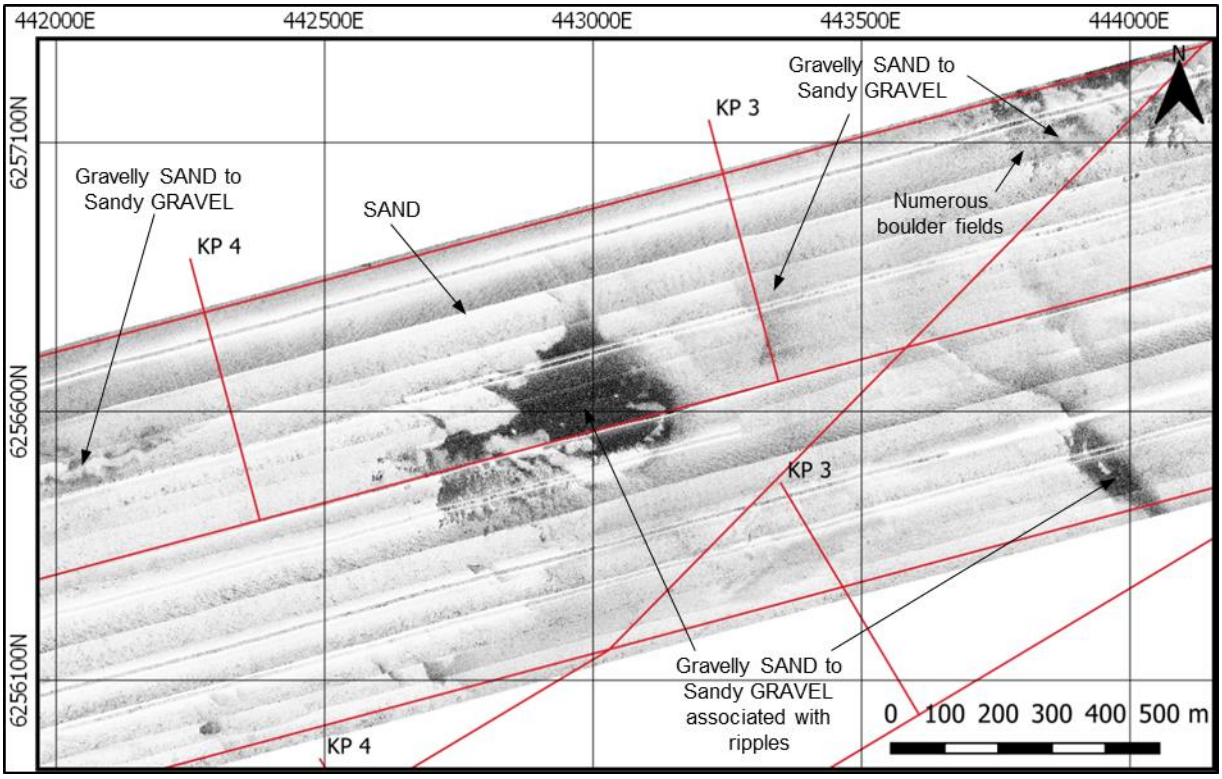


Figure 46 Overview of surficial geology from KP 2.1 to KP 4.3 as seen on SSS.

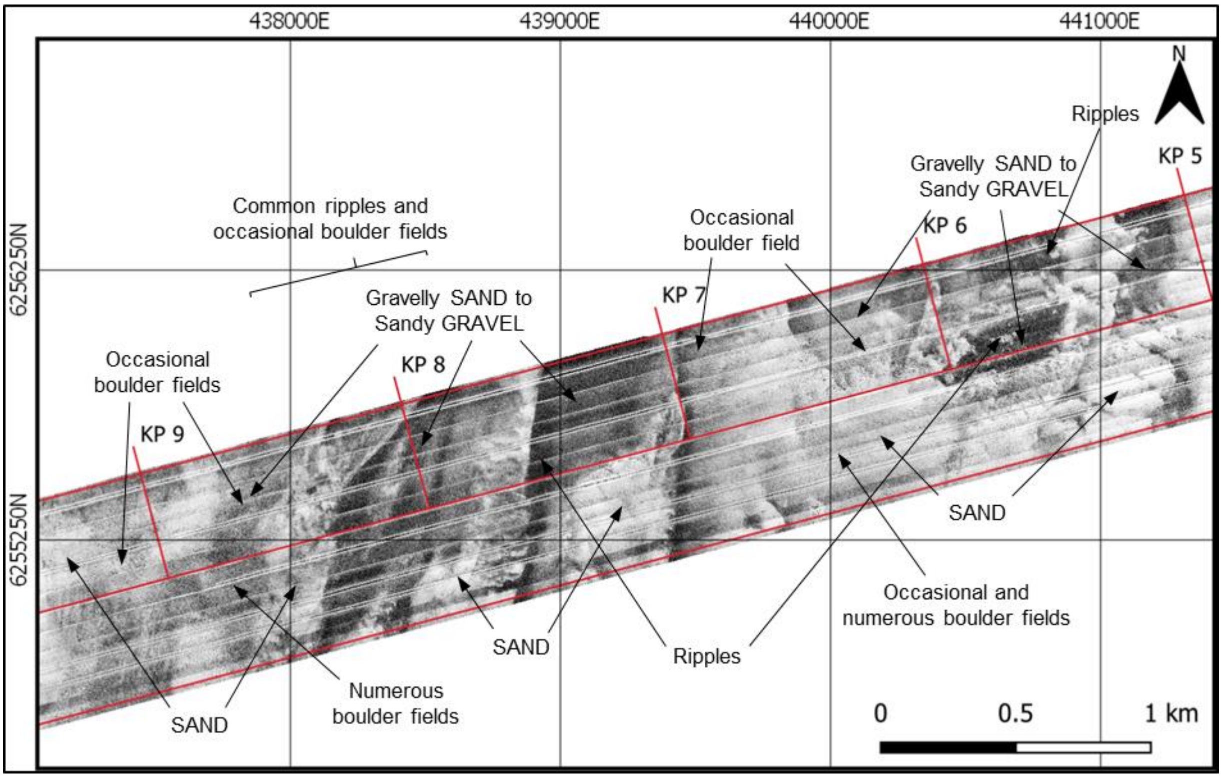


Figure 47 Overview of surficial geology from KP 5.0 to KP 9.5 as seen on SSS.

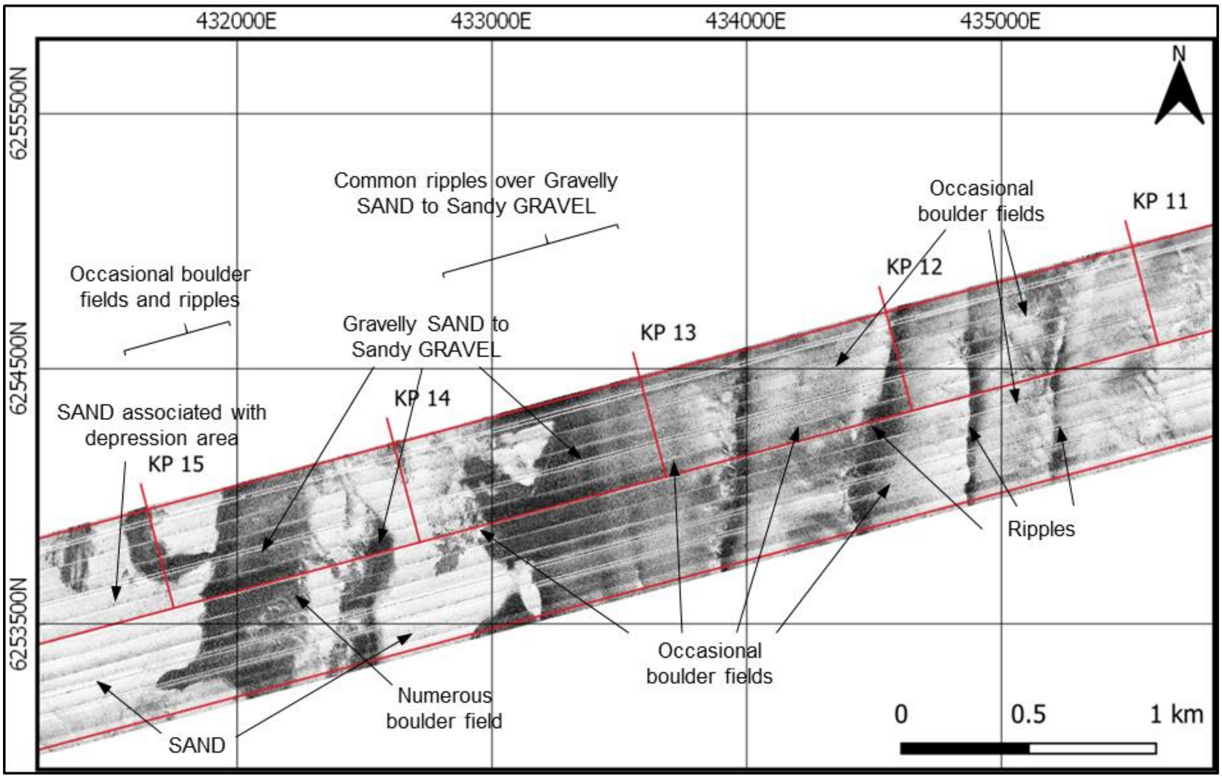


Figure 48 Overview of surficial geology from KP 10.7 to KP 15.5 as seen on SSS.

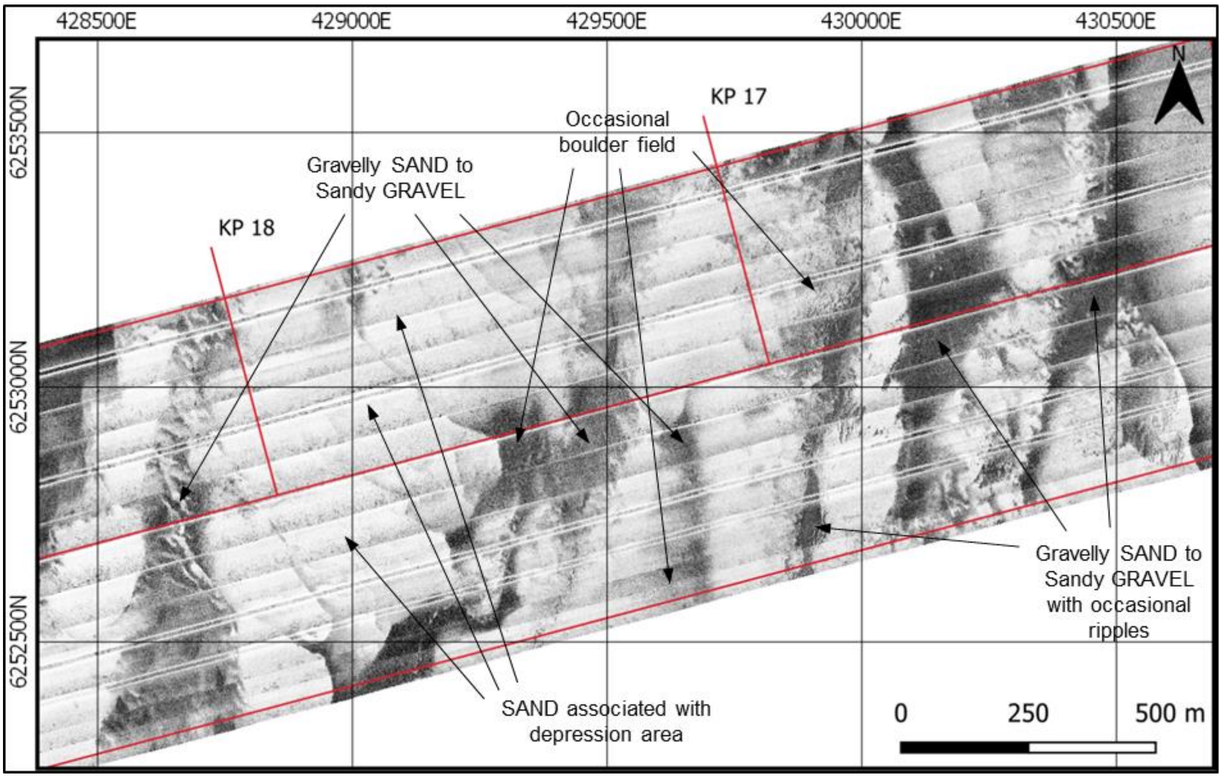


Figure 49 Overview of surficial geology from KP 16.1 to KP 18.5 as seen on SSS.

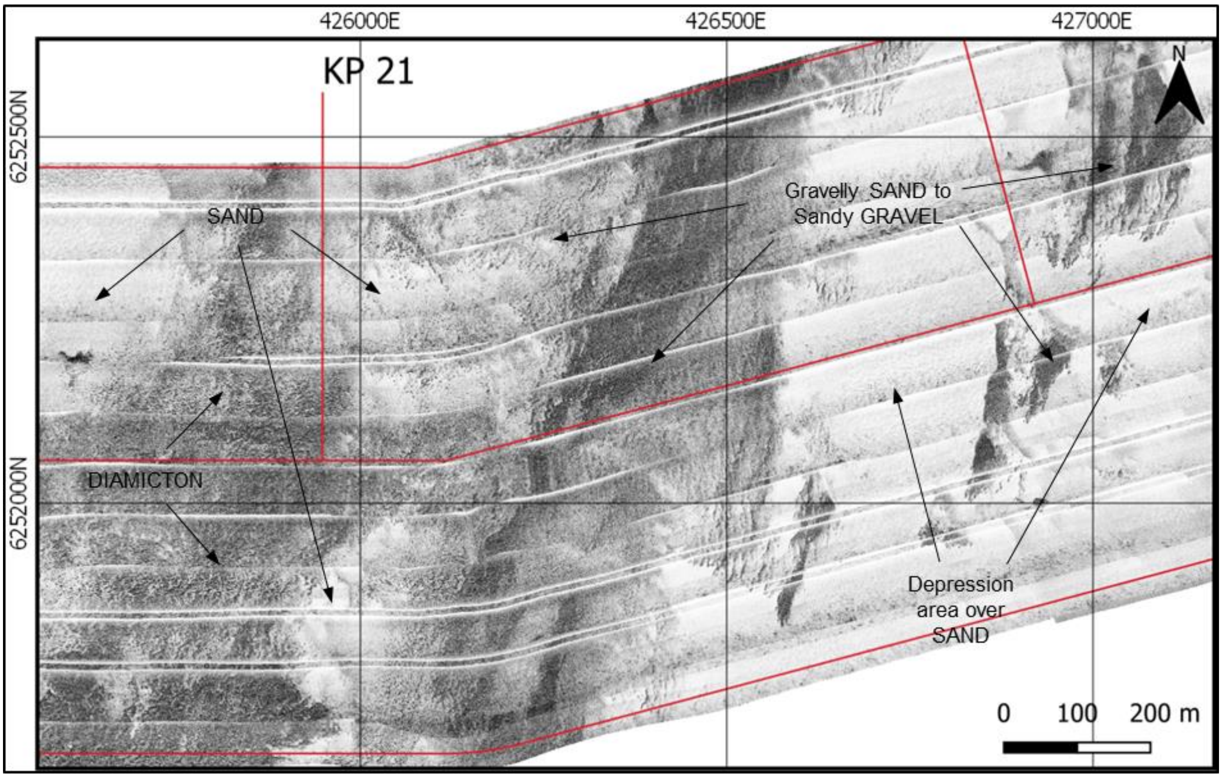


Figure 50 Overview of surficial geology from KP 19.7 to KP 21.4 as seen on SSS.

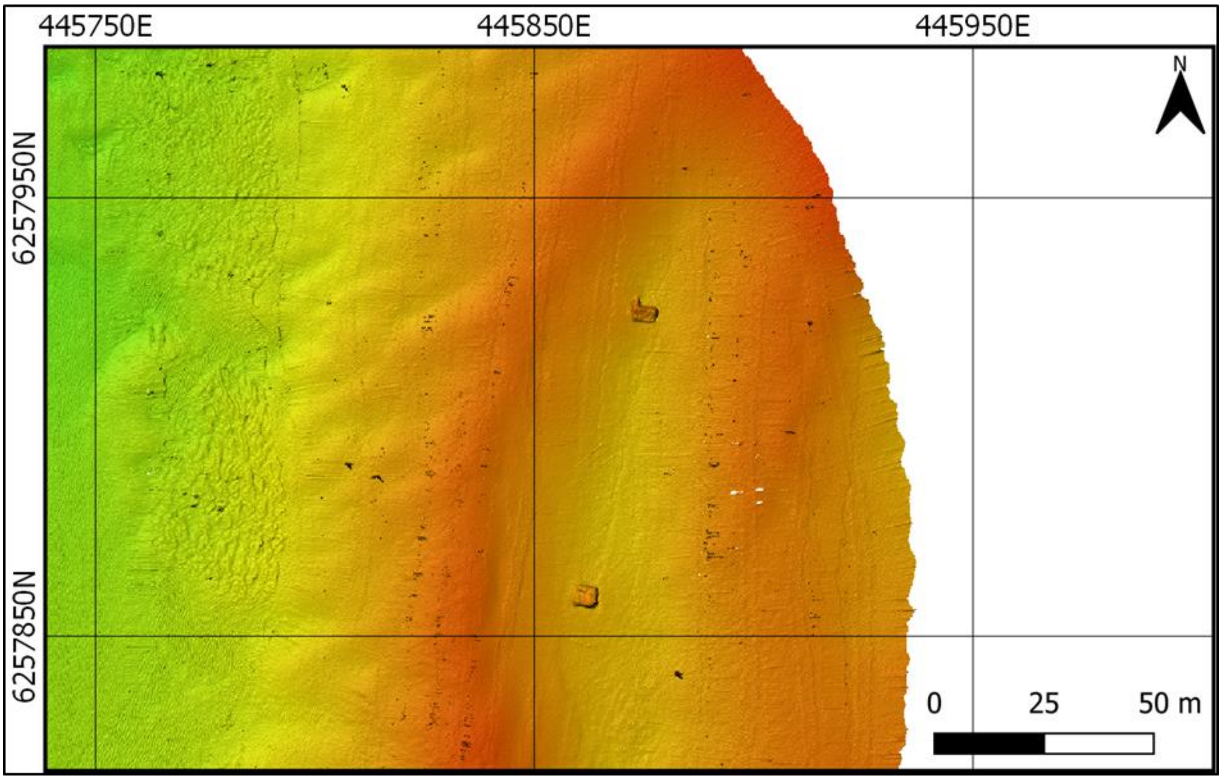


Figure 51 MBES image at KP 0.371 and KP 0.386
Military bunkers sitting between two sandbanks.

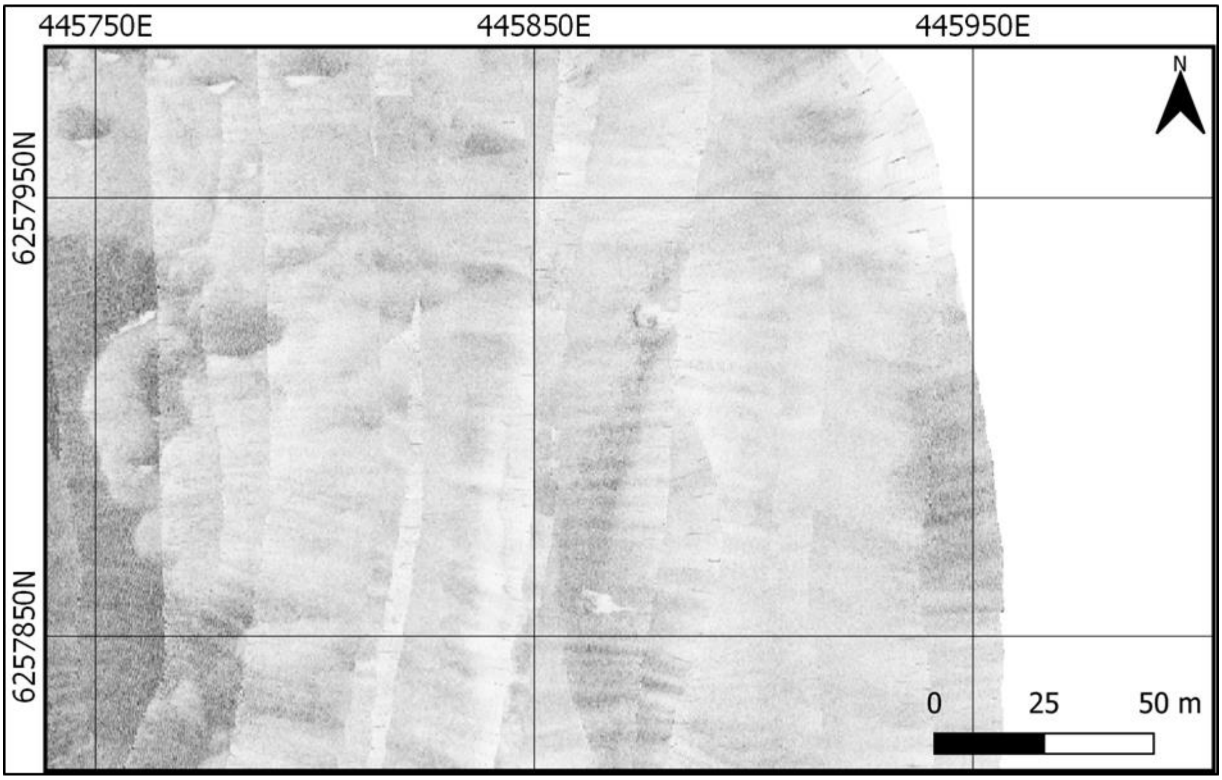


Figure 52 Side scan sonar image at KP 0.371 and KP 0.386
Military bunkers over SAND sediments and in-between Gravelly SAND to Sandy GRAVEL banks.

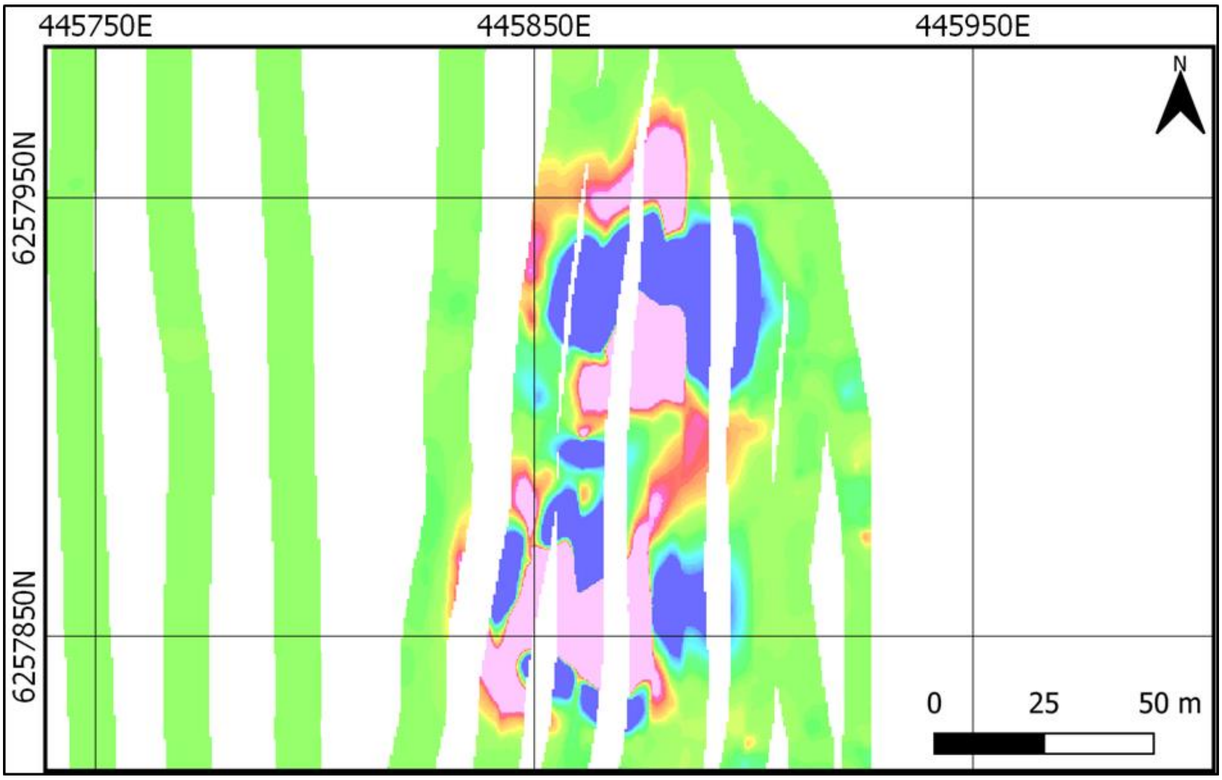


Figure 53 MAG grid KP 0.371 and KP 0.386
Magnetic response (max 11871.8 nT) for military bunkers at KP 0.371 and KP 0.386.

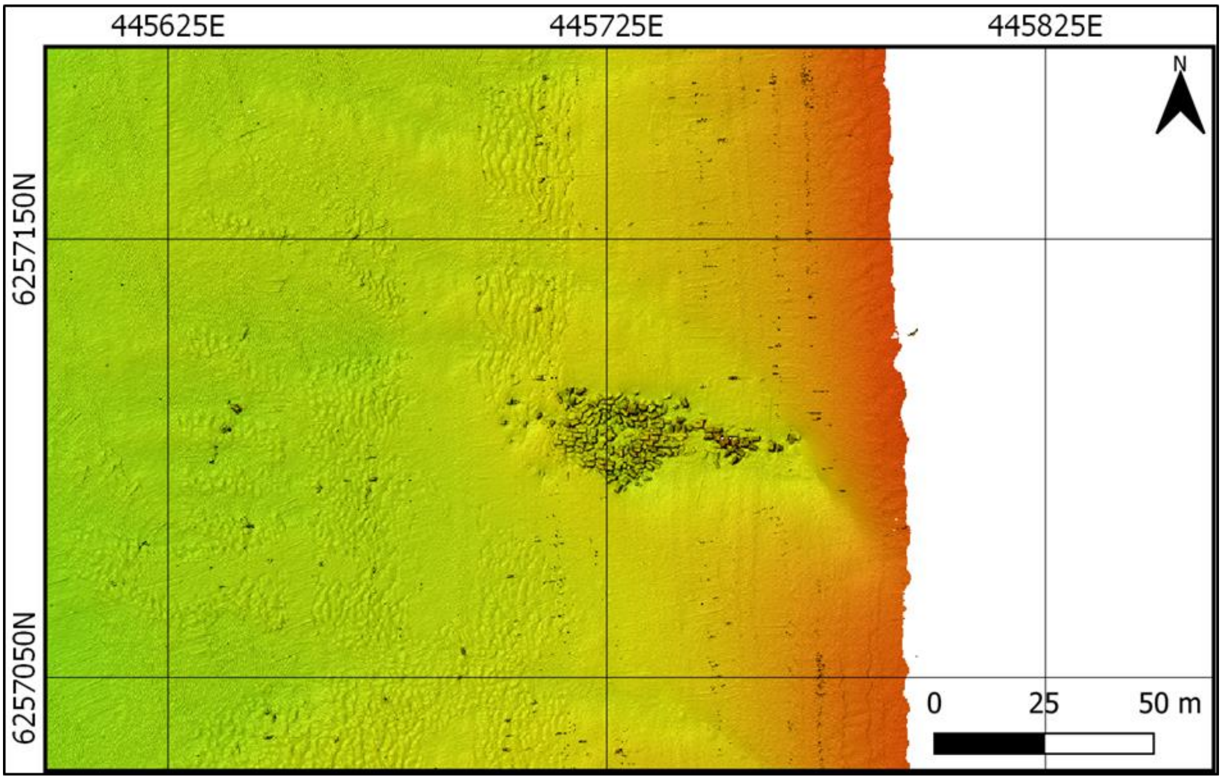


Figure 54 MBES image at KP 0.541 (DCC -177.9)
Coastal defence blocks.

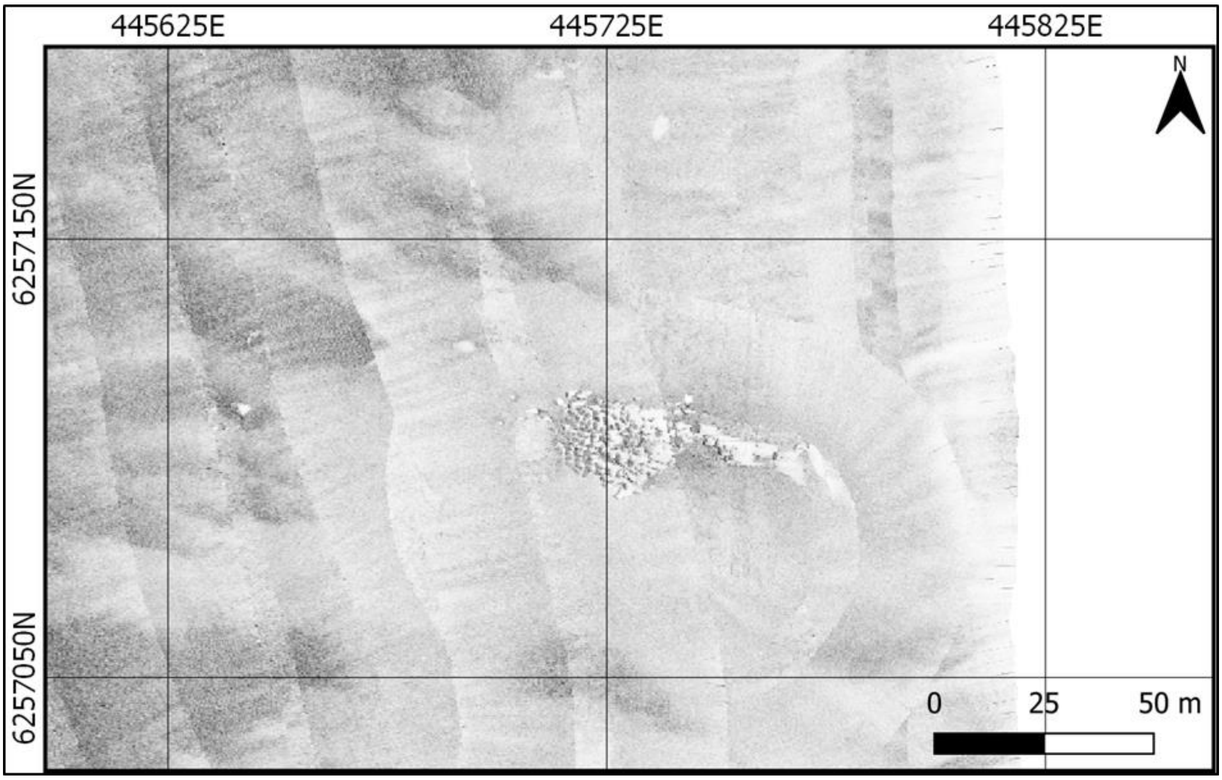


Figure 55 Side scan sonar image at KP 0.541 (DCC -177.9)
Coastal defence blocks over SAND sediments.

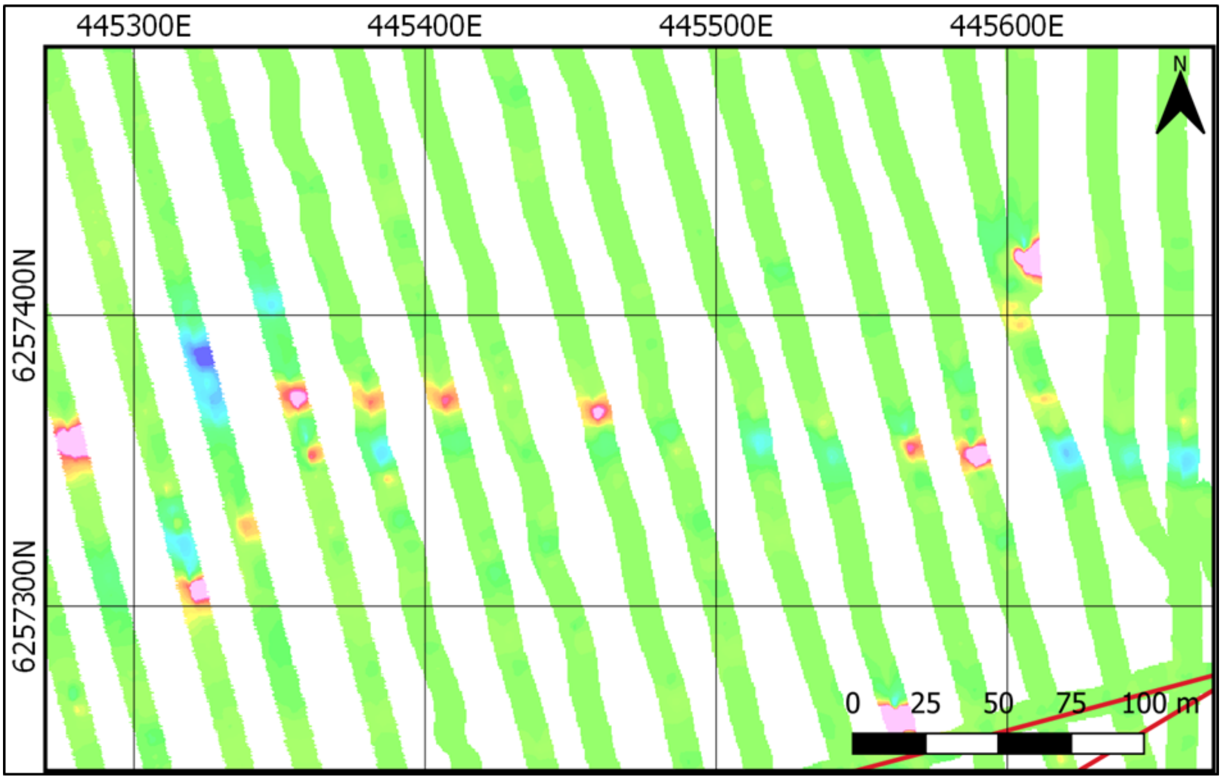


Figure 56 MAG grid from KP 0.622 (DCC 87.6) to KP 0.951 (DCC 177.6)
Possible linear feature.

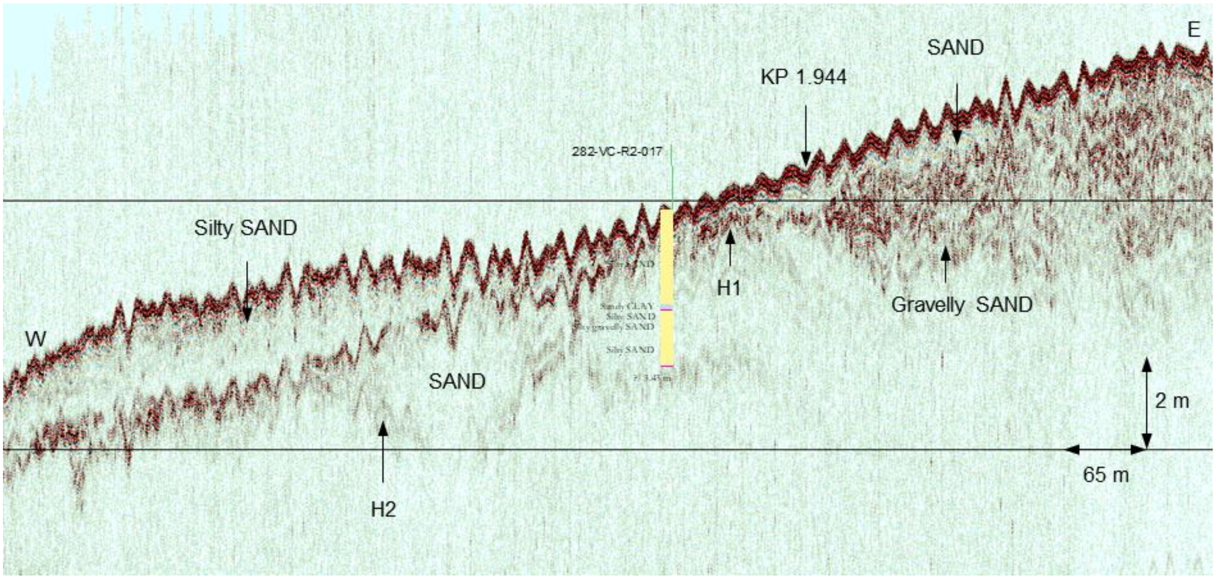


Figure 57 Innomar SBP data example from KP 1.653 (E) to KP 2.636 (W).
Showing SAND and silty SAND overlying either gravelly SAND or channel infill comprised of SAND.

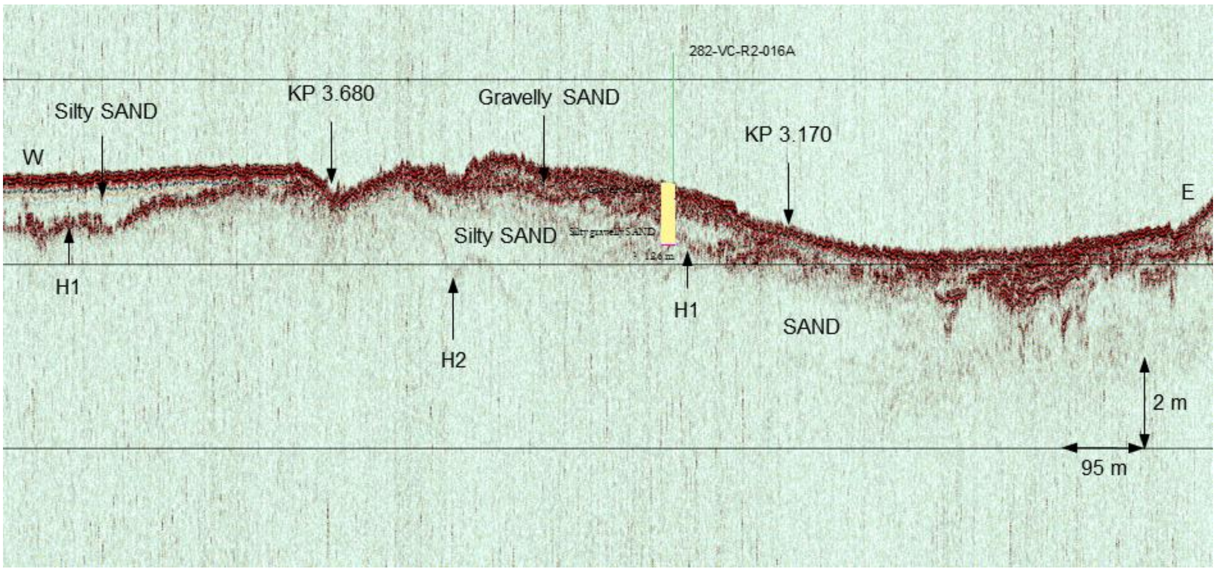


*Figure 58 Innomar SBP data example from KP 2.645 (E) to KP 4.047 (W).
Showing gravelly SAND and silty SAND overlying channel infills, silty SAND.*

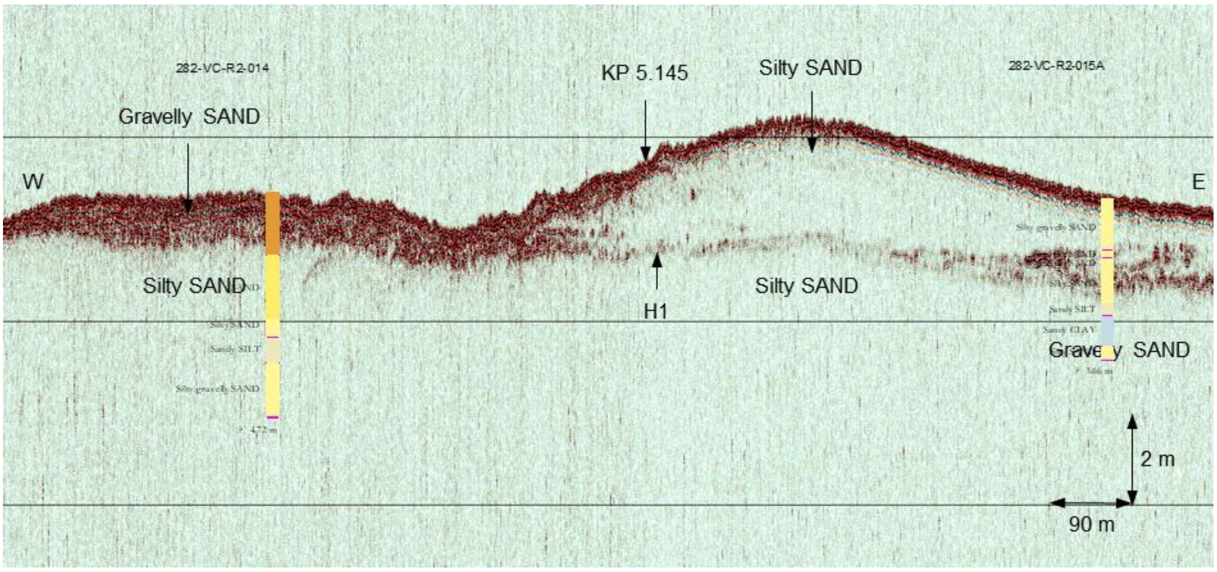


*Figure 59 Innomar SBP data example from KP 4.508 (E) to KP 5.880 (W).
Showing silty SAND and gravelly SAND overlying silty SAND.*

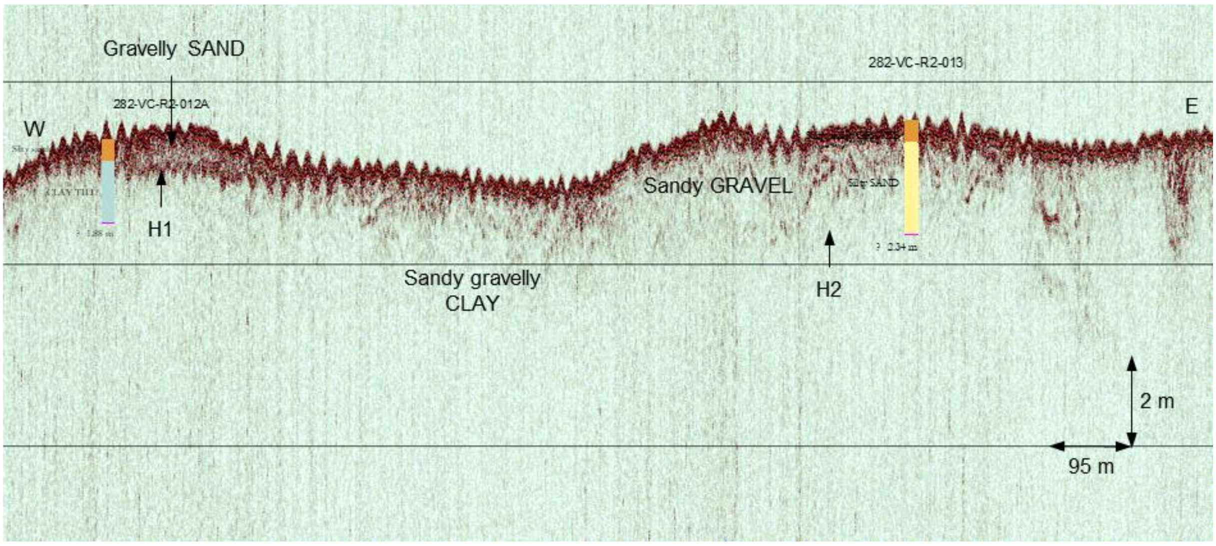


Figure 60 Innomar SBP data example from KP 6.470 (E) to KP 7.888 (W).
Showing gravelly SAND overlying either channel infills sandy gravelly CLAY.

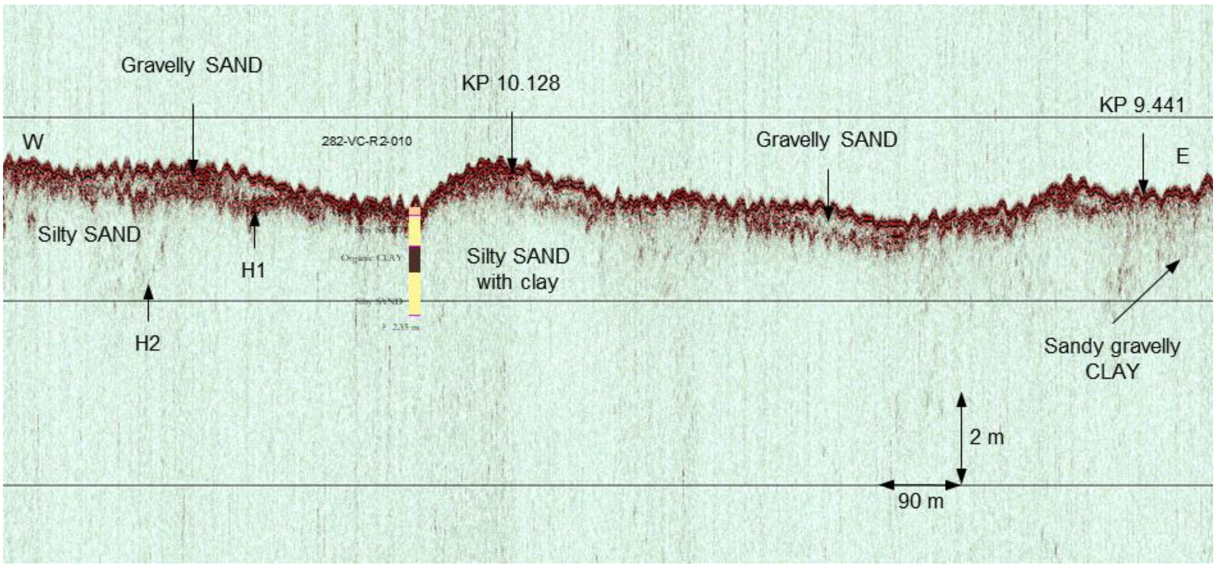


Figure 61 Innomar SBP data example from KP 9.337 (E) to KP 10.715 (W).
Showing gravelly SAND overlying either silty SAND with clay. Sandy gravelly CLAY outcrops to seabed.

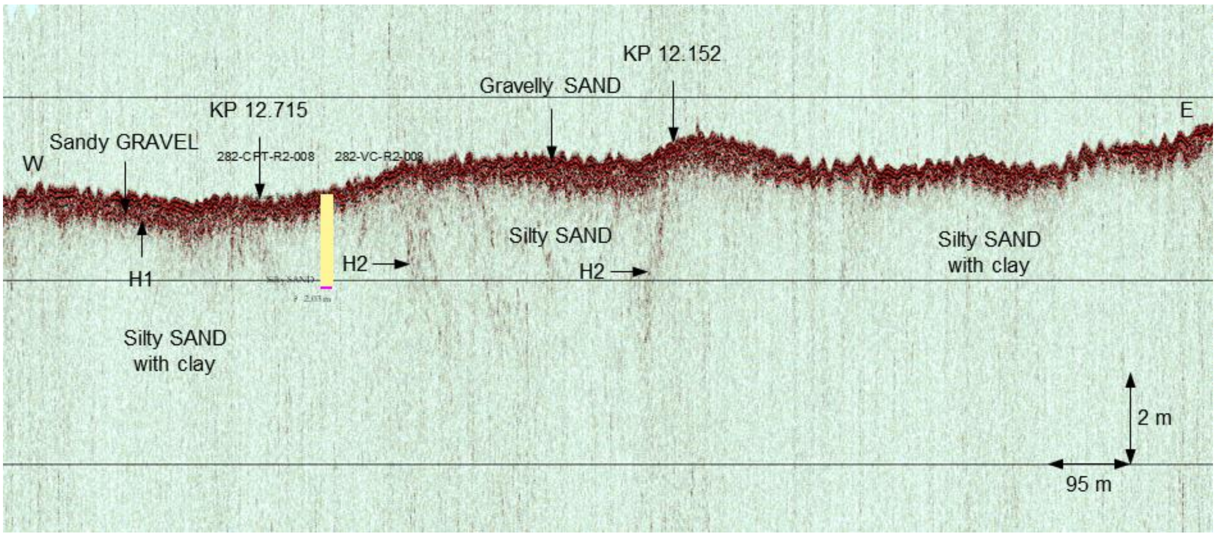


*Figure 62 Innomar SBP data example from KP 11.523 (E) to KP 12.966 (W).
Showing gravelly SAND or Sandy GRAVEL overlying either channel infills, silty SAND or silty SAND with clay.*

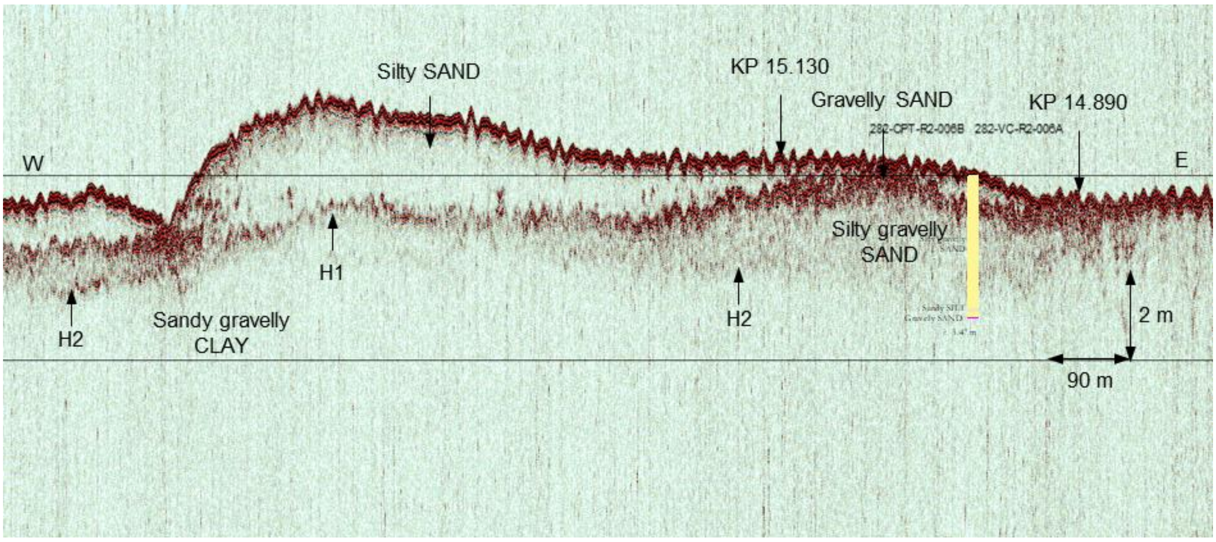


*Figure 63 Innomar SBP data example from KP 14.679 (E) to KP 16.046 (W).
Showing silty SAND and gravelly SAND overlying channel infills, silty gravelly SAND. Overlies sandy gravelly CLAY.*

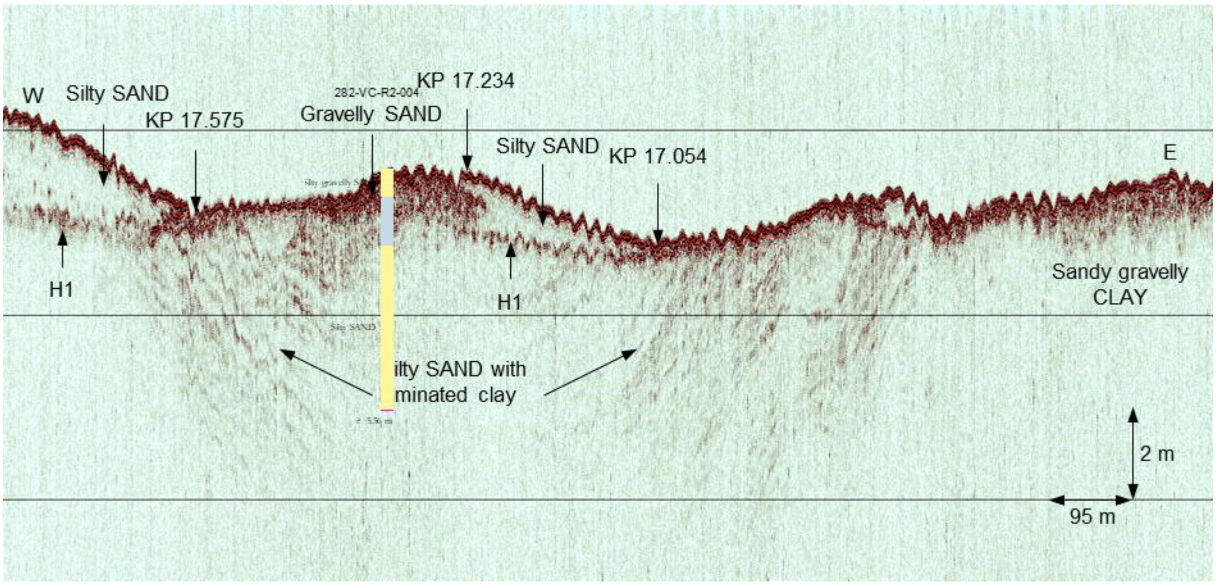


Figure 64 Innomar SBP data example from KP 16.408 (E) to KP 17.796 (W).
Showing silty SAND and gravelly SAND overlying sandy gravelly CLAY and channel infills, silty SAND with laminated CLAY.

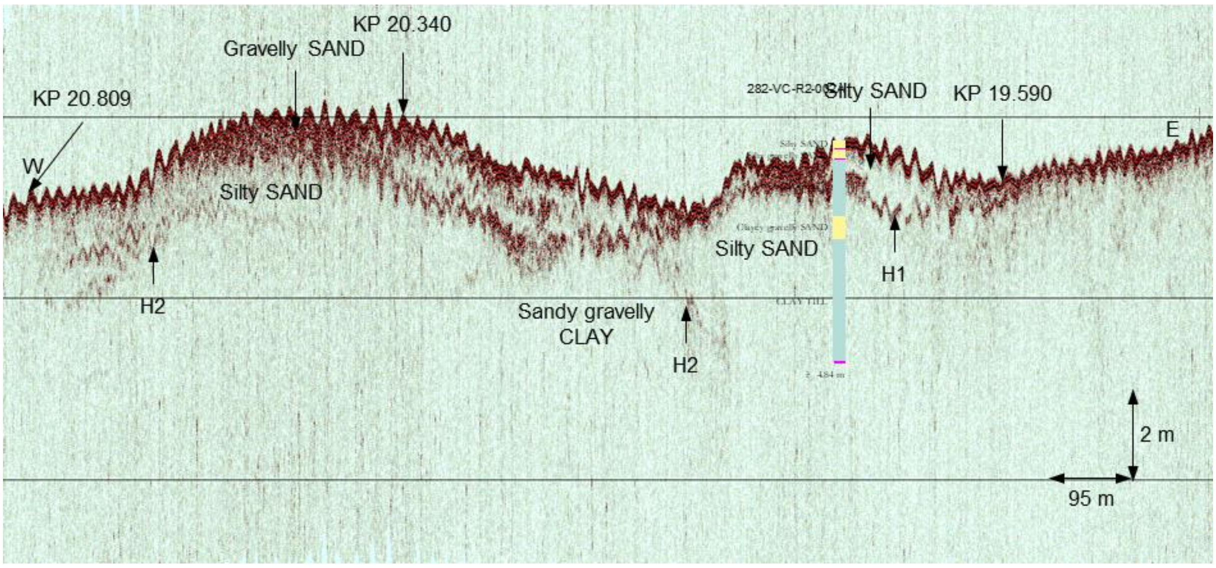


Figure 65 Innomar SBP data example from KP 19.419 (E) to KP 20.832 (W).
Showing silty SAND and gravelly SAND overlying either channel infills, silty SAND or sandy gravelly CLAY.

7.5.3 | CONTACTS AND ANOMALIES ROUTE 2

A total of 736 contacts were identified from the SSS and MBES data within the survey corridor on Route 2. The majority of the contacts have been classified as boulders. The SSS contacts are summarised in Table 26.

A total of 79 magnetic anomalies were detected on Route 2. Of these, 68 were unclassified, 9 formed part of a linear anomaly and 2 (S_R2_3012, S_R2_3015) were related to the military bunkers observed proximal to the landfall (Table 27 and Figure 66).

A total of 3 SSS contact positions correlated with detected magnetic anomalies, 2 of which were the military bunkers and 1 was an unknown item of debris.

Table 26 Summary of Route 2 SSS & MBES contacts.

CLASSIFICATION	**NUMBER**
Boulder	717
MMO (Manmade structure)	8
MMO (Debris)	11
Total	**736**

Table 27 Summary of Route 2 magnetic anomalies.

CLASSIFICATION	**NUMBER**
Unclassified, possible objects	69
Linear anomalies	9
Military bunkers	2
Total	**80**

Figure 66 Photograph, SSS and MBES image of a military bunker along Route 2 coastline.

7.6| ROUTE 3: KP 0.000 TO KP 24.401

7.6.1| OVERVIEW

Route 3 covers the Landfall 1 survey area and the 800 m wide route corridor out to OWF Entry 3.

BATHYMETRY

The topographical survey, conducted by aerial drone, covered a section of the landfall zone that measured 280 m long at the route and spanned the full width of the survey corridor. Where the route crosses the landfall and bathymetry data there is a 205 m gap which resulted from poor coverage of the beach by the aerial drone survey. Towards the north of the route the coverage is improved, with a minimum gap of 93 m. From KP 0.00 to KP 0.83 the route crosses a level but generally undulating field after which it crosses a large sand dune. This dune spans 135 m of the route and has a maximum elevation of +13.92 m and stands 12.5 m higher than the beach. The maximum slope value is 37.4° which is located on the landward (east) side of the dune. The western (seaward side) has a maximum slope angle of 30.4°. The dune gradually tapers off to the base at an elevation of +1.67 m at KP 0.229 where the beach gradually rises again to an elevation of +2.27 m at KP 0.264. From here the beach falls away more steeply to the edge of the drone coverage at KP 0.280 where the elevation is +0.76 m.

North of the route position the topography is largely similar with the exception of a complex two buildings (TUSKAER, Kulinarisk Kunst and Kulturcentre) centred on 446220 E and 6257559 N with access road. A vehicular access route to the beach crosses the dune at 446147 E, 6257148 N. South of the route the topography is also similar, however the dune narrows towards the route boundary and, on the landward side, there is a curving ridge, possibly associated with the road (181) located on its eastern side.

The bathymetry along Route 3 is highly variable. The variation is due to several shallow channels and sand banks along the proposed cable route. Nevertheless, slopes throughout the survey corridor tend to be gentle ranging between 1 to 2°, Figure 67 and Figure 68.

Between KP 0.488 (start of the MBES data along the route) and KP 4.000, the cable route starts from the sandy landfall and becomes deeper westward. The maximum depth is -18.72 m DTU15 MSL, at 442585.53 E and 6255353.16 N. The shallowest point is -1.86 m DTU15 MSL, at 442774.85 E and 6257282.93 N.

Between KP 4.000 and KP 6.000 the cable route crosses a wide sandbank orientated NE-SW. Across the cable route the sandbank extends 2,605 m which stands 5.5 m proud of the seabed. The maximum depth on the sandbank is -19.31 m DTU15 MSL, at 440252.38 E and 6253974.97 N, whilst the shallowest point is -14.69 m DTU15 MSL, at 441233.58 E and 6254632.50 N.

From KP 6.000 towards KP 10.000 the seabed gently deepens from the aforementioned sandbank. A number of shallow depressions aligned in a NE-SW orientation are also crossed. The minimum depth at the base of the sandbank is -16.55 m MSL at 440835.71 E and 6254377.04 N, whilst the maximum depth along the cable route is -24.76 m DTU15 MSL, at 437401.96 E and 6252325.70 N.

Between KP 12.000 and KP 14.100 the cable route crosses a number of shallow sandbanks and shallow depressions, approximately 250 m and 140 m wide respectively. The minimum depth of the sand banks is -23.74 m DTU15 MSL at 435119.29 E and 6250911.06 N. The maximum depth of the depressions is -28.12m DTU15 MSL, at 434113.90 E and 6250284.32 N.

Two more large sand banks are crossed by the cable route. The first, between KP 15.000 and KP 17.000 is 2.0 m and 3.0 m above the seabed with a maximum depth of -26.30 m DTU15 MSL, at 431690.78 E and 6248773.79 N and a minimum depth of -23.55 m DTU15 MSL, at 432288.92 E and 6249146.66 N. The second feature, is smaller and lies westwards from the first, between KP 20.300 and KP 20.600 and rises 1.7 m from the deepest part of the surrounding seabed, which is -24.59 m DTU15 MSL, at 428628.86 E and 6246865.04 N.

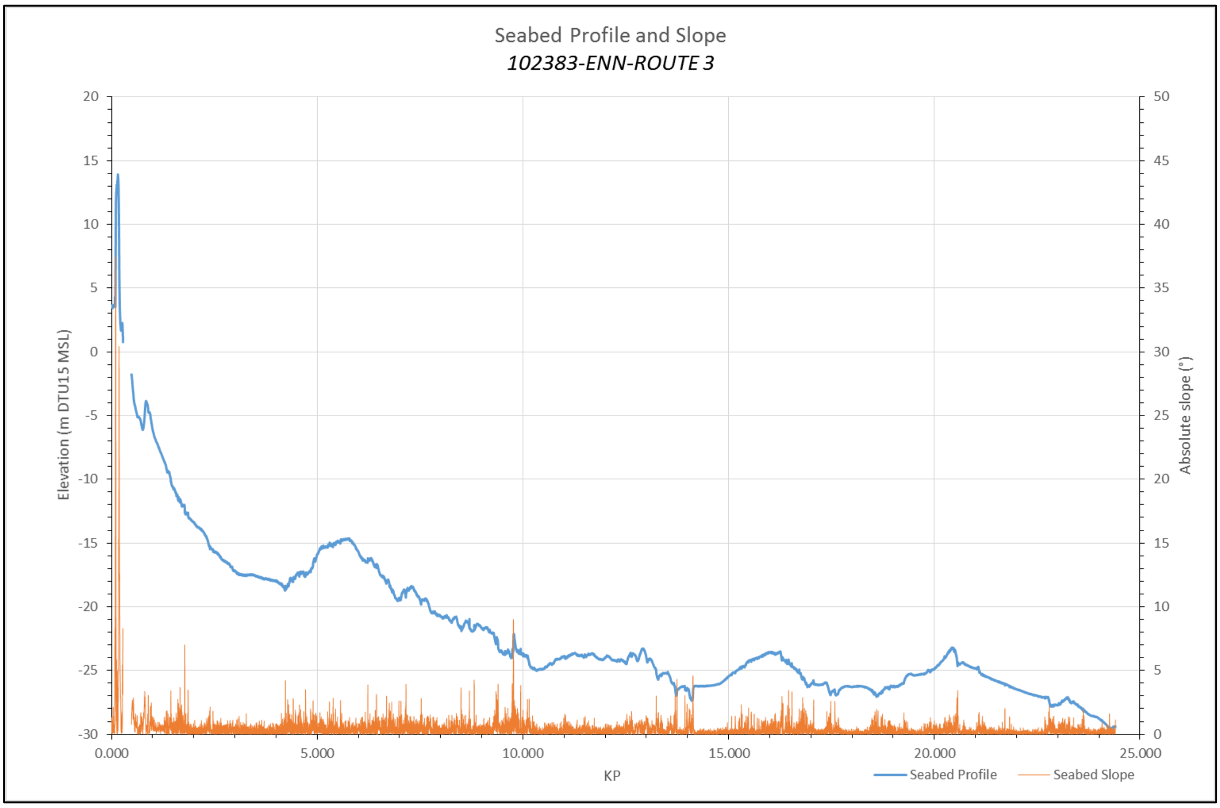


Figure 67 Route 3 bathymetry longitudinal profile.
Elevation is in metres (with bathymetric depths negative below MSL datum) and slope is in degrees (absolute value for visualisation). Vertical exaggeration x 300.

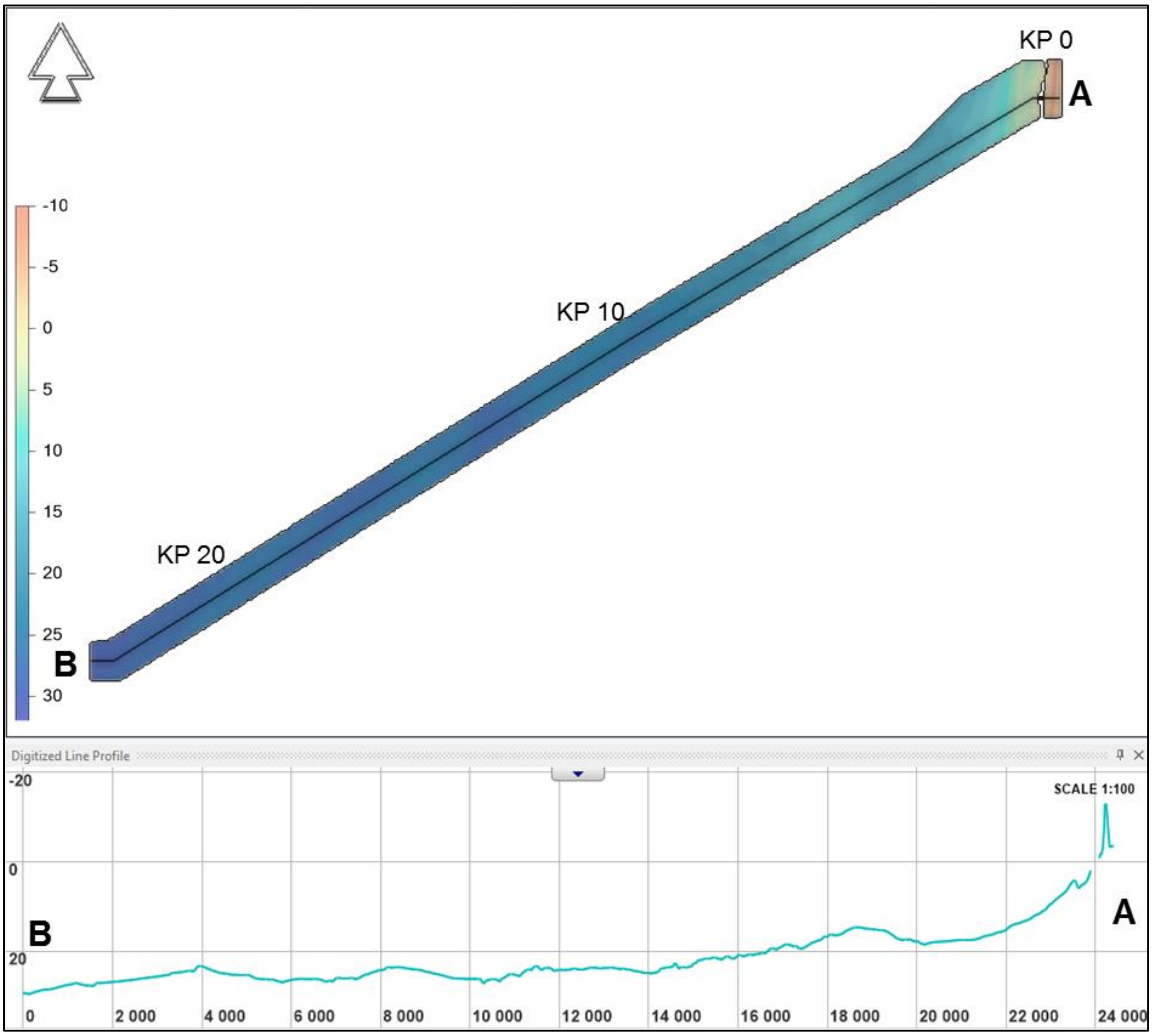


Figure 68 Overview image of Route 3.
The scale on the profile is in metres. X-axis shows distance along route from west to east. Depths in NaviModel presented positive down; vertical exaggeration of profile x100.

SURFICIAL GEOLOGY

The seabed sediments predominantly consist of SAND, especially from the start of the route until KP 8.000 and from KP 14.000 to the end of the route. The sandy sediments also merge with areas of GRAVEL and gravelly SAND to sandy GRAVEL in the central section of the route. Occasional, discrete areas of DIAMICTON are observed, mainly between KP 6.500 and KP 11.000.

Areas of ripples are observed throughout the corridor and generally form either thin bands or discrete areas that occasionally cross the survey corridor. The ripples are commonly associated with GRAVEL or gravelly SAND to sandy GRAVEL. The general direction of sediment transport in the area is N-S close to shore with a slight rotation toward NE-SW further out.

A large area of depressions, likely caused by changes in seabed current regime rather than shallow biogenic gas, are observed crossing the route from KP 14.976 to KP 16.533.

In total 1135 contacts were identified in the corridor the majority being boulders, however two potential wrecks or wreck debris were located at KP 5.370 (S_R3_0002, DCC 28 m) and KP 5.391 (S_R3_0108, DCC 6 m).

Detailed description of the surficial geology is presented in Table 28.

SHALLOW GEOLOGY

A detailed description of the shallow geologic changes observed along the proposed Route 3 can be found in the Route 3 seabed details table presented in Table 28.

A number of sedimentary units were identified in the sub-surface geology down to a maximum depth of 7.8 m below the seabed (-32.7 DTU15 MSL). The upper unit along the majority of the route has been confirmed to be SAND based on the geotechnical sampling results. These sediments are often laminated and acoustically transparent internally. Distinct and highly reflective layers are common within this section of the stratigraphy, varying in length, vertical placement, and amplitude (Figure 83). These were interpreted as internal layers within the Unit.

The upper SAND unit varies from silty SAND to SAND and GRAVEL. More localised areas of GRAVEL and CLAY, were also observed along the route. The SAND unit extends along the entire route at variable depths ranging from the seafloor to 3.1 m below seabed. The base horizon for this unit (H1) is often undulating in character.

From KP 2.052 to KP 24.401, the upper SAND unit, bounded by horizon H1, lies atop an erosional discontinuous surface named as H2 which represent the base of palaeo-channels of varying depths and extents. Based on the SBP penetration limit, the deepest channel structures reached was 7.8 m below the seabed.

The infill of these channels is variable, consisting of laminated and homogenous sediments which characterise the channel-fill along the route. In some channels the infill sediments form a uniform thick unit while others show a strong upper boundary reflector indicating a change in sediment characteristics. Based on the geotechnical results, sediments recovered ranged from Silty SAND and GRAVEL mixed to CLAY with PEAT and organic matter.

From KP 2.052 and heading nearshore, the SAND unit lies atop thick unit of gravelly SAND to SAND. The base of this unit is detectable from KP 1.713 to KP 2.052 and presented as nearshore internal.

A grid was created to map the base of the upper SAND unit (H1) detected from SBP data related to depth below seabed and related to the MSL datum.

7.6.2| DETAILED DESCRIPTION

A detailed presentation of the conditions and features on Route 3 are shown in Table 28.

Table 28 Route 3 seabed details.

KP	ASSOCIATED CHART	DESCRIPTION (INCLUDING MIN/MAX DEPTH BSB TO BASE OF UNIT)	REMARK
0.000 - 7.035	103282-ENN-MMT-SUR-DWG-ALR30001	**Bathymetry:** Initially flat field then crosses a dune between KP 0.083 to KP 0.229. The dune stands 12.5 m above the level of the beach at KP 0.229. The beach slopes gently down towards the surf zone. Maximum elevation +13.92 m at KP 0.156. Minimum elevation +0.76 m at KP 0.280 Moderately deepening seafloor from the beach outwards with shallow channels and sandbank/sandwave. Minimum depth -1.86 m at KP 0.488. Maximum depth -19.55 m at KP 6.951.	Very gentle to gentle slopes with a maximum value of 30.4°at landfall. Total elevation/depth range = 33.47 m. Maximum slope of 37.4° on the sand dune at landfall (KP 0.103). Shallow channels and sandbanks (Figure 69).
		Surficial geology: The surface geology is dominated by SAND interrupted by areas of GRAVEL and gravelly SAND to sandy GRAVEL. The gravelly areas are often associated with ripples as well as areas of numerous and occasional boulders (Figure 70, Figure 71). A nearshore sandbank/sandwave area is present between KP 0.465 and KP 0.955. In the latter part of the section, discrete areas of DIAMICTON is also present. An isolated patch of CLAY is observed from KP 1.627 to KP 1.864	Two SSS contacts are interpreted as being a possible wreck: • KP 5.370 (S_R3_0002, DCC 28 m) • KP 5.391 (S_R3_0108, DCC 6 m) These contacts are also present on MBES data and correlate with MAG anomalies. Field of occasional boulders crossing the route between: • KP 4.211 and KP 4.308

KP	ASSOCIATED CHART	DESCRIPTION (INCLUDING MIN/MAX DEPTH BSB TO BASE OF UNIT)	REMARK
		Shallow Geology: SBP coverage begins at KP 0.493. KP 0.493 to KP 2.052: SAND, fine to coarse (0.1 – 3.1 m BSB) overlaying a thick unit of gravelly SAND (0.6 – 2.6 m BSB). The base of the gravelly SAND unit is named on the charts as nearshore internal and it can be detected up to KP 1.713. KP 2.052 to KP 4.000: Silty SAND (0.3 – 1.4 m BSB) with internals of GRAVEL overlaying either channel infills, silty SAND and clay (0.6 – 3.6 m BSB) or sandy gravely CLAY. KP 4.000 to KP 4.319: Gravelly SAND (0.3 – 0.6 m BSB) overlaying channel infills, silty SAND (1.9 – 4.9 m BSB). KP 4.319 to KP 7.035: Gravelly SAND & Silty sandy GRAVEL (0.2 – 1.7 m BSB) overlaying silty SAND.	(Figure 76) and (Figure 77) (Figure 78) (Figure 79)
7.035- 14.129	103282-ENN-MMT-SUR-DWG-ALR30001 103282-ENN-MMT-SUR-DWG-ALR30002	**Bathymetry**: Relatively flat seabed with some areas of shallow channels and sandbanks Minimum depth -18.37 m at KP 7.290. Maximum depth -27.38 m at KP 14.107.	Very gentle to gentle slopes with a maximum value of 1.7°. Depths range = 9 m. Maximum slope = 9.0° at KP 9.767.
		Surficial Geology: This section is a complex region dominated by GRAVEL and gravelly SAND to sandy GRAVEL with less frequent areas of SAND (Figure 72, Figure 73) Patches of DIAMICTON are observed occasionally throughout this area but crosses the centre line only between KP 9.427 and KP 9.522. Ripples are frequently found, commonly associated with areas of GRAVEL.	Fields of occasional boulders cross the route between: • KP 8.807 and KP 8.877 • KP 8.939 and KP 8.943 • KP 8.959 and KP 9.362 • KP 9.522 and KP 9.721 • KP 9.810 and KP 9.878 • KP 9.889 and KP 9.897 • KP 10.006 and KP 10.128 • KP 10.602 and KP 10.718

KP	ASSOCIATED CHART	DESCRIPTION (INCLUDING MIN/MAX DEPTH BSB TO BASE OF UNIT)	REMARK
		Areas of occasional boulders are common throughout this section. Areas of numerous boulders are sparse, mainly located adjacent to the survey boundary as isolated discrete patches.	• KP 10.899 and KP 11.034 • KP 11.049 and KP 11.119 • KP 13.943 and KP 13.976 • KP 14.036 and KP 14.130 Fields of numerous boulders cross the route between: • KP 8.330 and KP 8.348 • KP 8.353 and KP 8.400 • KP 8.454 and KP 8.519 • KP 9.721 and KP 9.810
		Shallow Geology: KP 7.035 to KP 7.775: Silty SAND (0.3 – 2.6 m BSB) with internals of GRAVEL overlaying sandy gravely CLAY. KP 7.775 to KP 8.890: Gravelly SAND (0.3 – 0.8 m BSB) overlaying either channel infills, silty SAND (0.8 – 3.9 m BSB) or sandy gravelly CLAY. KP 8.890 to KP 10.252: Sandy gravelly CLAY outcrops at seabed. Faint channels with silty SAND and clay are also observed. KP 10.252 to KP 12.073: A thin layer of Gravelly SAND (0.3 – 0.8 m BSB) overlaying silty SAND. KP 12.073 to KP 12.782: Gravelly SAND (0.3 – 1.3 m BSB) overlaying channel infills, silty SAND (0.6 – 3.0 m BSB). KP 12.782 to KP 13.190: Silty SAND (0.3 – 2.0 m BSB) overlaying channel infills, silty SAND (1.2 – 2.4 m BSB). KP 13.190 to KP 13.743: Gravelly SAND (0.3 – 1.0 m BSB) overlaying channel infills, silty SAND (1.3 – 4.3 m BSB).	(Figure 79), (Figure 80), (Figure 81) and (Figure 82)

KP	**ASSOCIATED CHART**	**DESCRIPTION (INCLUDING MIN/MAX DEPTH BSB TO BASE OF UNIT)**	**REMARK**
		KP 13.743 to KP 13.942: Silty gravelly SAND (0.5 – 1.5 m BSB) overlaying channel infills, silty SAND (3.6 – 4.7 m BSB).	
14.129- 19.274	103282-ENN-MMT-SUR-DWG-ALR30002 103282-ENN-MMT-SUR-DWG-ALR30003	**Bathymetry**: The seabed undulates gently over this section. Minimum depth -23.50 m at KP 16.246. Maximum depth -27.09 m at KP 14.129.	Very gentle to gentle slopes with a maximum value of 0.9°. Depth range = 3.6 m. Maximum slope of 4.6° at KP 14.132.
		Surficial Geology: This section is dominated by SAND, often associated with areas of depressions (Figure 74). GRAVEL is observed to be frequently from KP 16.314 to the end of the section. Gravelly SAND to Sandy GRAVEL is less frequent generally forming elongate bands either parallel to the route or at an oblique angle crossing the survey corridor. Fields of numerous boulders are present within this section together with less frequent areas of occasional boulders. (Figure 74).	Occasional boulders crossing the route between: • KP 18.574 and KP 18.624 Numerous boulders crossing the route between: • KP 16.663 and KP 16.783 • KP 16.843 and KP 16.858 • KP 16.874 and KP 16.888 • KP 16.902 and KP 16.938 • KP 16.944 and KP 16.969 Areas of depressions crossing the route between: • KP 14.975 and KP 16.306 • KP 16.314 and KP 16.320 • KP 16.381 and KP 16.417 • KP 16.423 and KP 16.426 • KP 16.427 and KP 16.462 • KP 16.465 and KP 16.483 • KP 16.487 and KP 16.537 • KP 18.365 and KP 18.538

KP	ASSOCIATED CHART	DESCRIPTION (INCLUDING MIN/MAX DEPTH BSB TO BASE OF UNIT)	REMARK
		Shallow Geology: KP 14.129 to KP 16.678: Silty SAND (0.3 – 2.8 m BSB) with internals of gravel overlaying channel infills, silty SAND (2.1 – 4.7 m BSB). KP 16.678 to KP 16.793: Sandy gravelly CLAY outcrops at seabed. KP 16.793 to KP 17.232: Gravelly SAND (0.3 – 1.1 m BSB) overlaying channel infills, silty SAND (1.0 – 2.9 m BSB). KP 17.232 to KP 17.475: Sandy gravelly SAND outcrops at seabed. KP 17.467 to KP 18.564: Silty SAND (0.2 – 1.4 m BSB) with internals of gravel overlaying silty gravelly SAND. KP 18.564 to KP 19.274: Gravelly SAND (0.3 – 0.6 m BSB) overlaying channel infills, silty SAND (0.6 – 4.5 m BSB).	(Figure 83), (Figure 84) and (Figure 85) Vibrocore results (282-VC-R3-025) indicate discrete thin bed of fibrous firm peat within SAND at 1.60 m BSB.
19.274- 24.401	103282-ENN-MMT-SUR-DWG-ALR30003	**Bathymetry**: The seabed undulates gently mainly formed from shallow sandwaves. Minimum depth -23.19 m at KP 20.430. Maximum depth -29.67 m at KP 24.272.	Very gentle to gentle slopes with a maximum value of 0.9°. Depth range = 3.6 m. Maximum slope of 3.44° at KP 20.567.
		Surficial Geology: Surface sediments predominantly comprise SAND, associated with large areas of depressions. The SAND is interrupted by areas of GRAVEL and gravelly SAND to sandy GRAVEL. These areas are often associated with boulder fields and ripples, none of which are crossing the route. (Figure 75).	Areas of depressions cross the route between: • KP 19.620 and KP 19.820 • KP 21.582 and KP 21.887 • KP 21.952 and KP 22.012 • KP 22.069 and KP 22.207

KP	ASSOCIATED CHART	DESCRIPTION (INCLUDING MIN/MAX DEPTH BSB TO BASE OF UNIT)	REMARK
		An area of sandwaves (transport direction NE-SW) is present between KP 19.845 and KP 21.090.	
		Shallow Geology: KP 19.274 to KP 22.803: Gravelly SAND transitioning to Silty SAND (0.4 – 2.6 m BSB) with internals of gravel overlaying either channel infills, silty SAND (0.6 – 6.3 m BSB) or sandy gravelly CLAY. KP 22.803 to KP 23.063: A thin layer of Gravelly SAND (0.4 – 0.6 m BSB) overlaying sandy gravelly CLAY. KP 23.063 to KP 23.286: A thin layer of Silty SAND (0.3 – 0.6 m BSB) overlaying channel infills, silty SAND (0.6 – 1.7 m BSB). Overlies sandy gravelly CLAY. KP 23.286 to KP 23.624: A thin layer of Gravelly SAND (0.4 m BSB) overlaying channel infills, silty SAND (0.5 – 1.2 m BSB). Overlies sandy gravelly CLAY. KP 23.624 to KP 24.158: Silty SAND (0.3 – 0.8 m BSB) with internals of gravel overlaying channel infills, silty gravelly SAND (0.5 – 2.0 m BSB). Overlies sandy gravelly CLAY. KP 24.158 to KP 24.401: Gravelly SAND (0.3 – 0.6 m BSB) overlaying channel infills, silty SAND (0.6 – 1.4 m BSB). Overlies sandy gravelly CLAY.	(Figure 85), (Figure 86) and (Figure 87) Vibrocore results (282-VC-R3-018A) indicate clayey PEAT at 1.1 m BSB and some organic SAND at 1.55 m BSB.

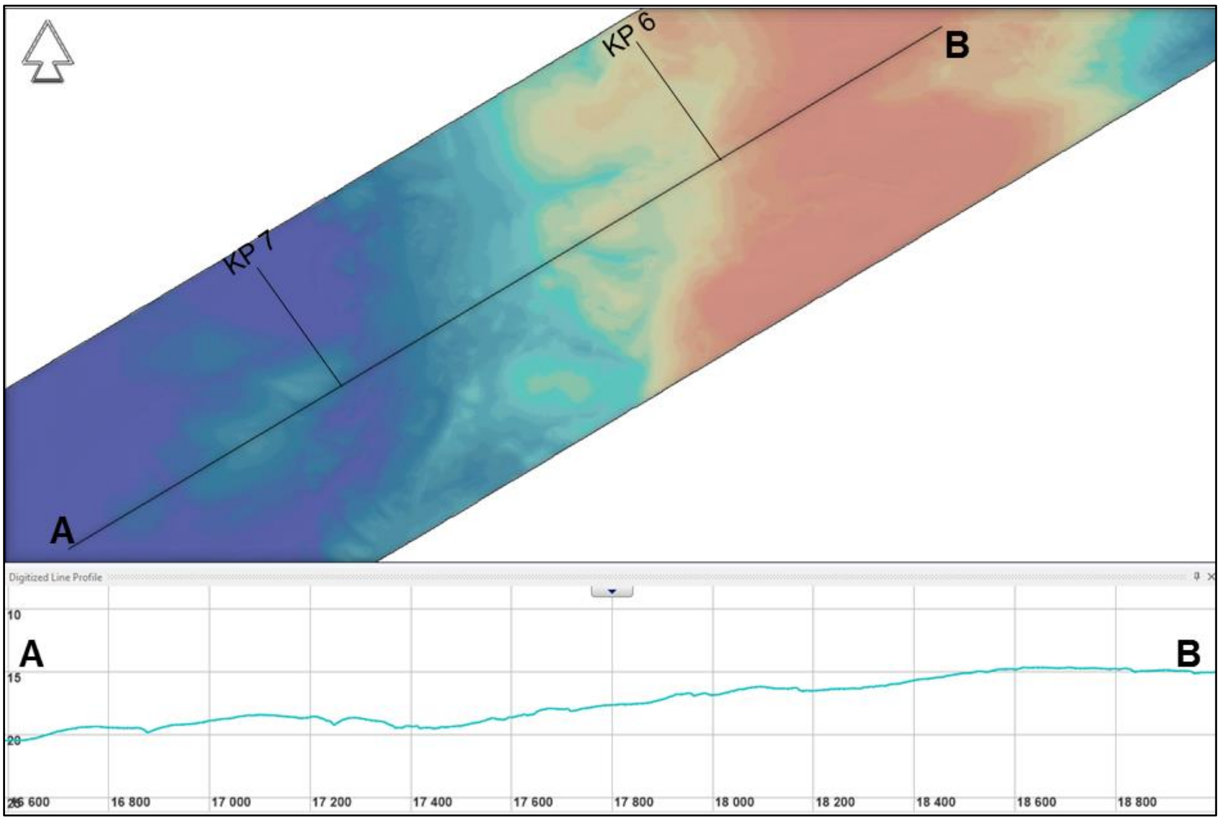


Figure 69 Relatively flat seabed with shallow sandbanks and channels.
Depths in NaviModel are presented positive down; vertical exaggeration of profile x25.

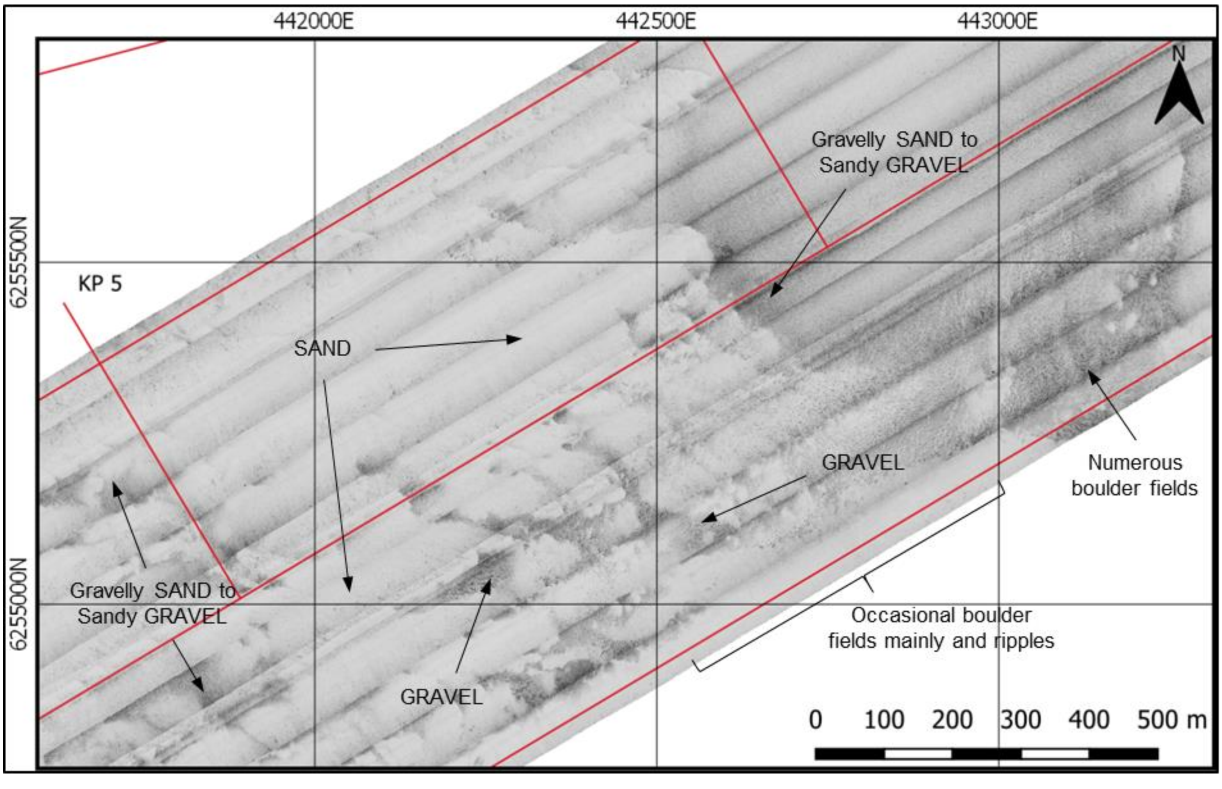


Figure 70 Overview of surficial geology from KP 3.4 to KP 5.4 as seen on SSS.

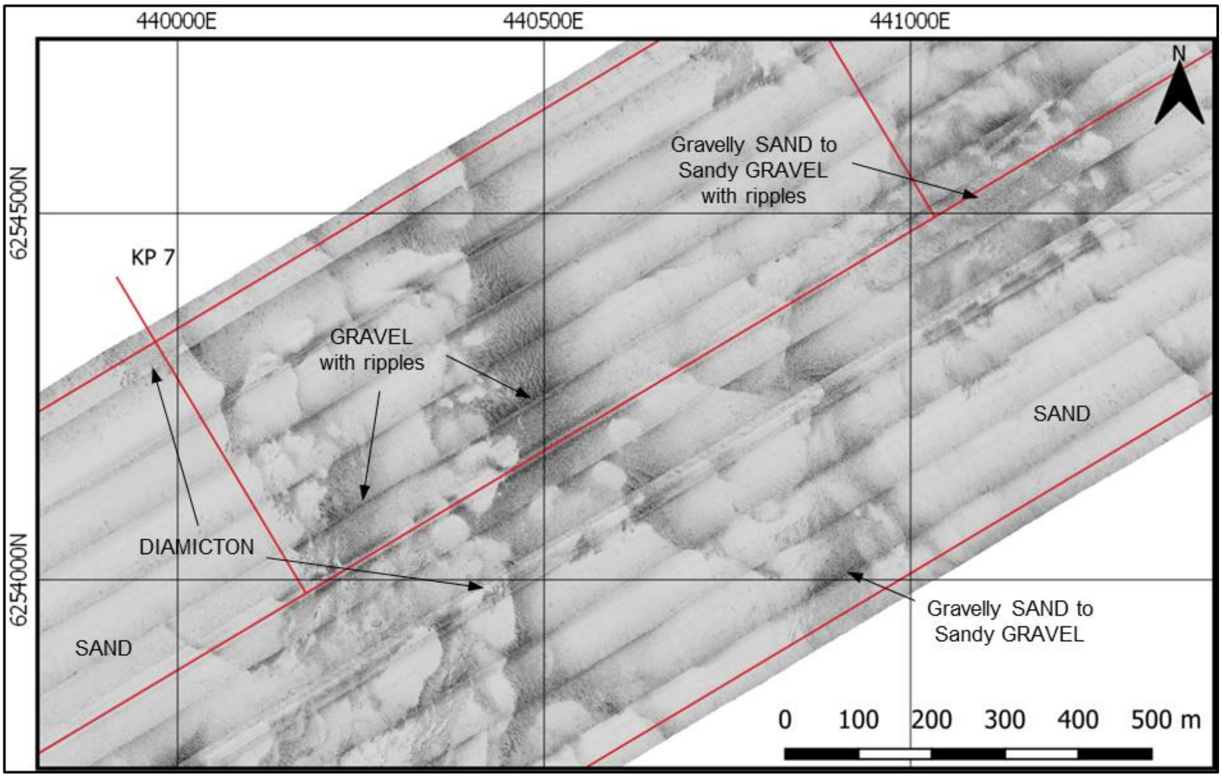


Figure 71 Overview of surficial geology from KP 5.6 to KP 7.4 as seen on SSS.

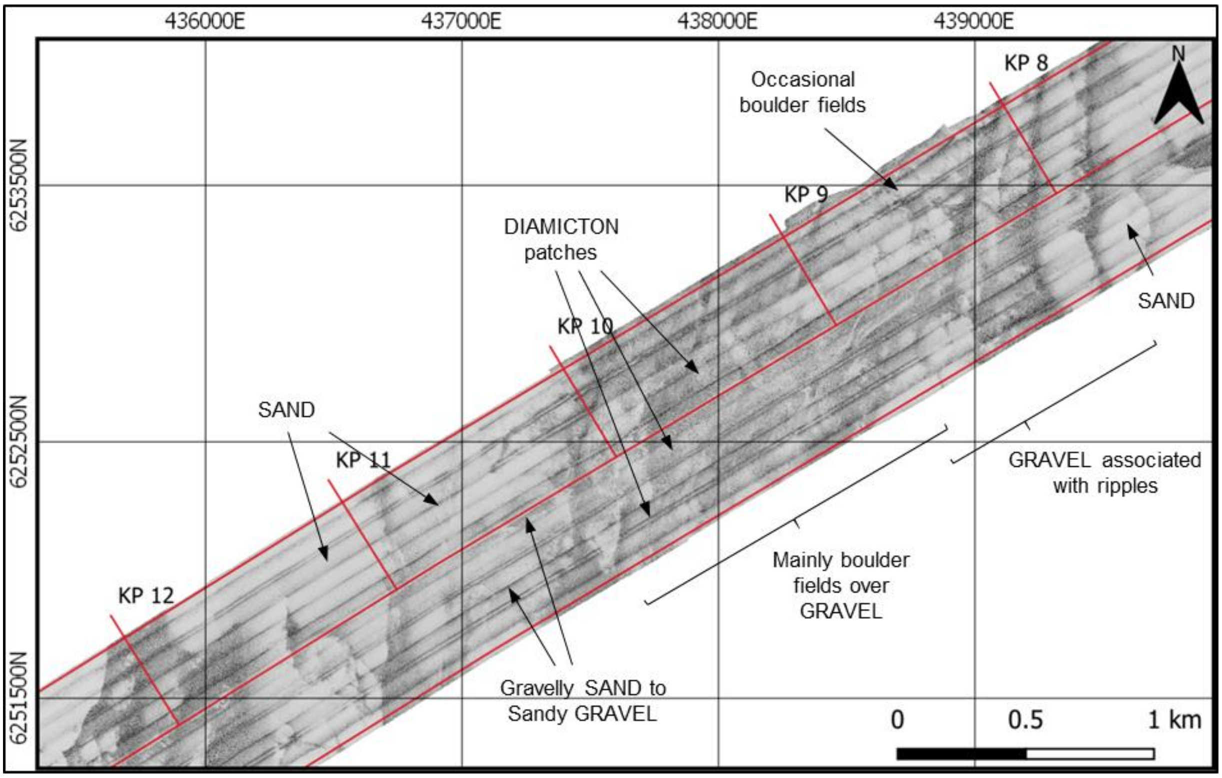


Figure 72 Overview of surficial geology from KP 7.2 to KP 12.4 as seen on SSS.

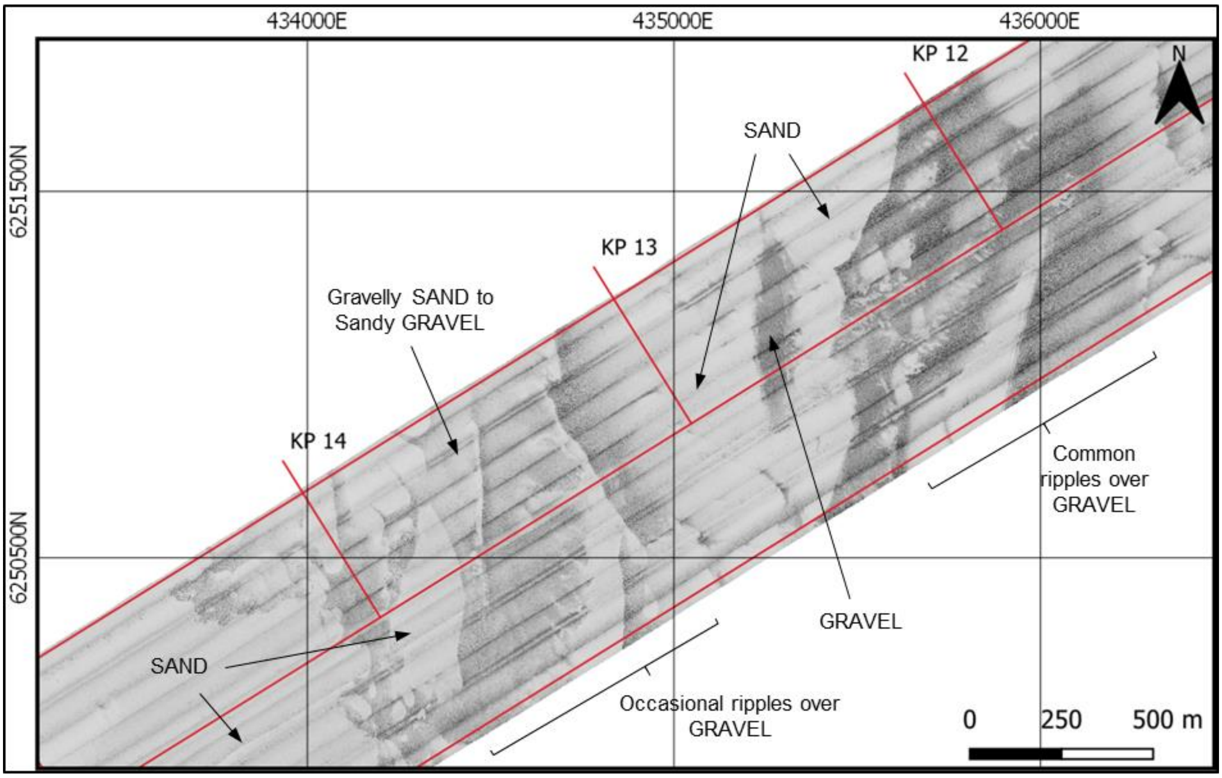


Figure 73 Overview of surficial geology from KP 11.4 to KP 14.6 as seen on SSS.

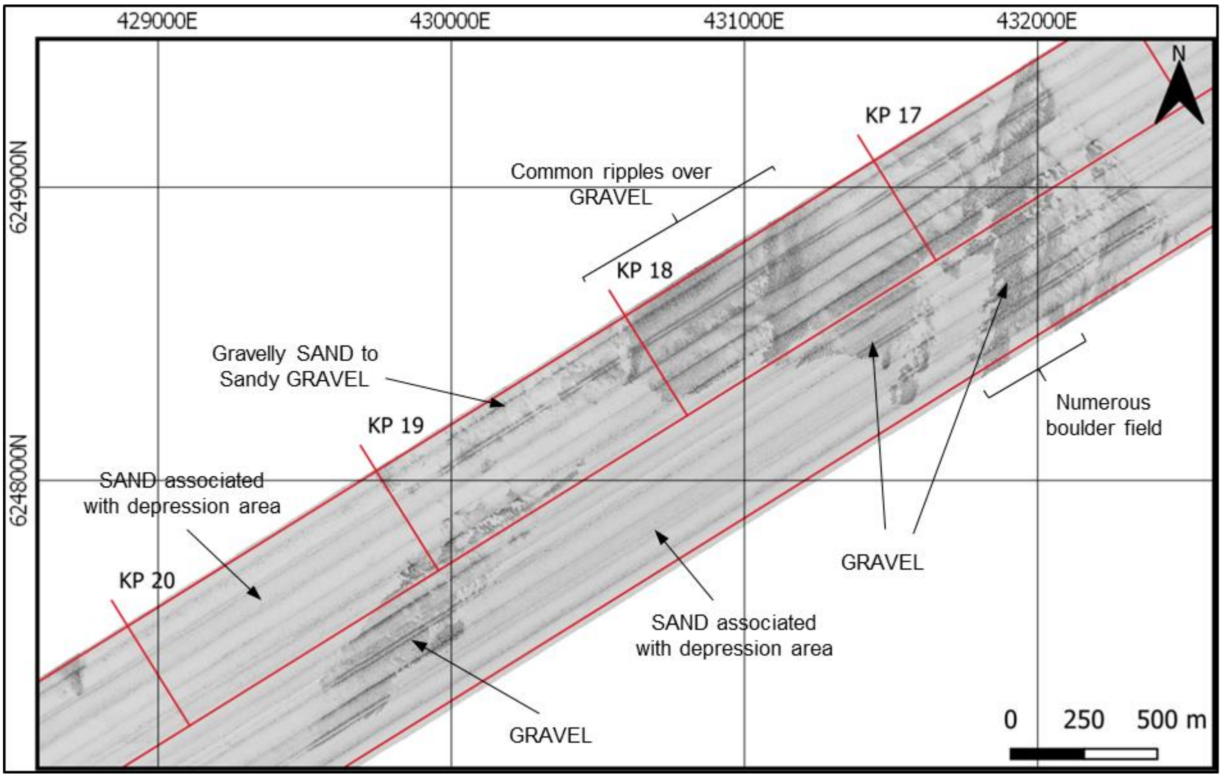


Figure 74 Overview of surficial geology from KP 15.8 to KP 20.3 as seen on SSS.

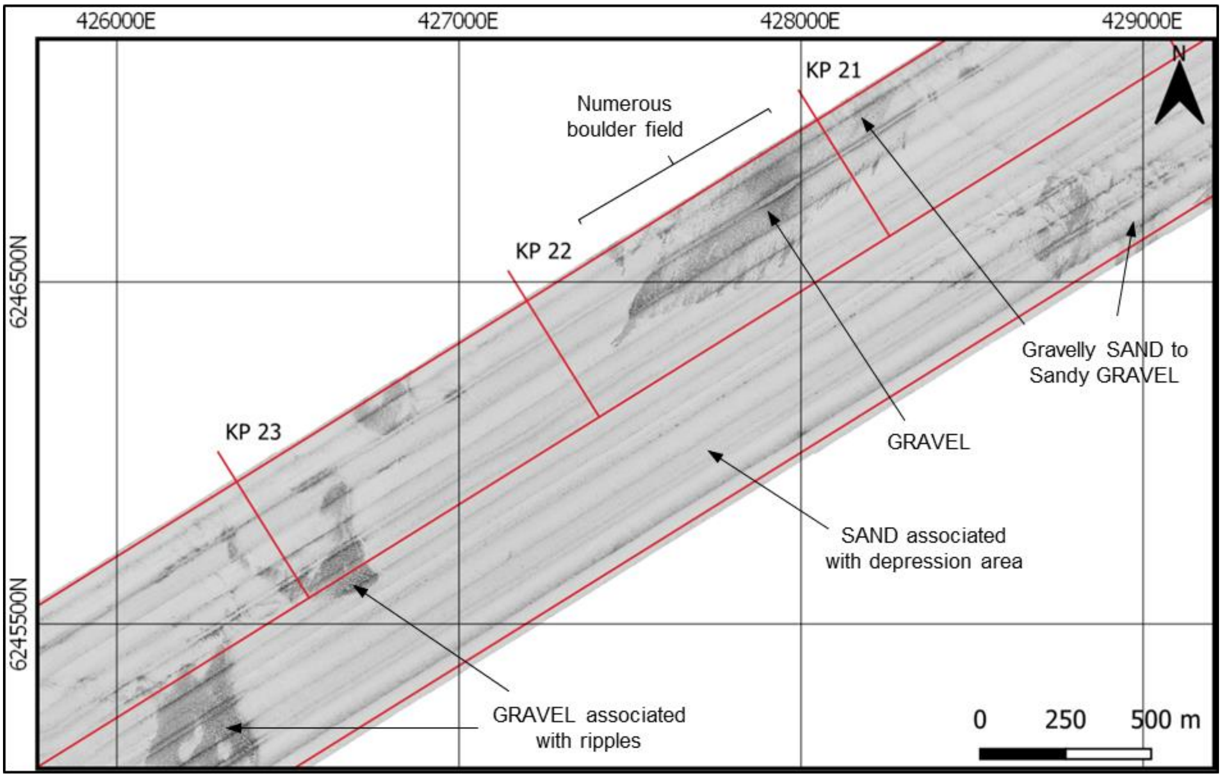


Figure 75 Overview of surficial geology from KP 19.9 to KP 23.9 as seen on SSS.

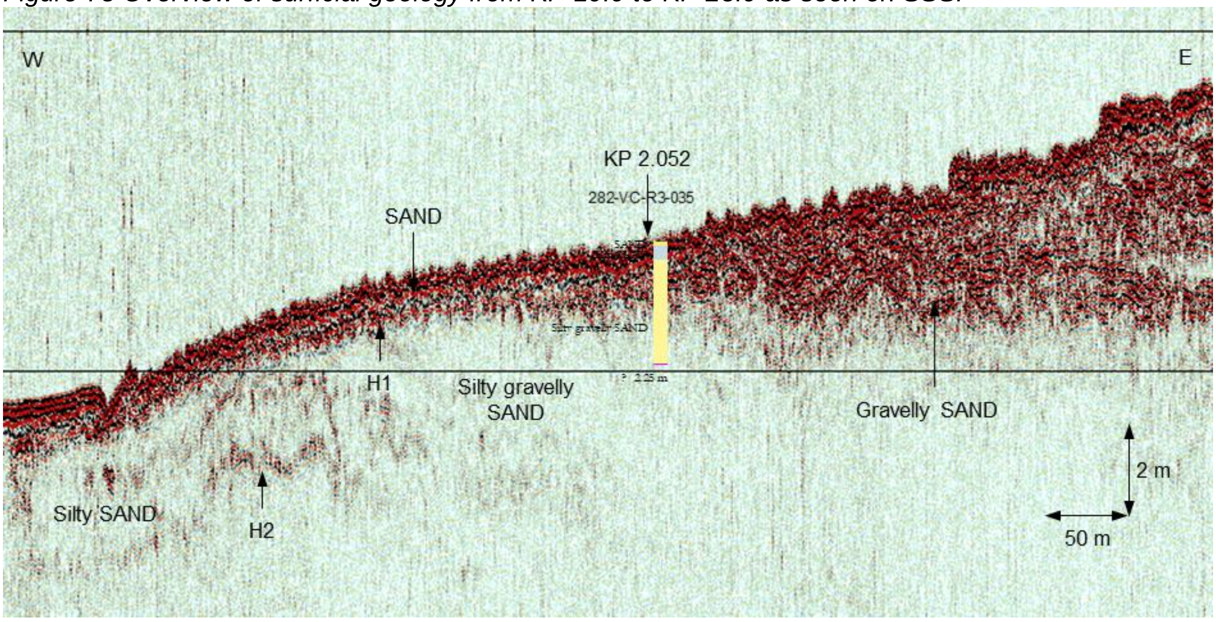


Figure 76 Innomar SBP data example from KP 1.706 (E) to KP 2.457 (W).
Showing SAND overlying either gravelly SAND or channel infills, silty gravelly SAND.

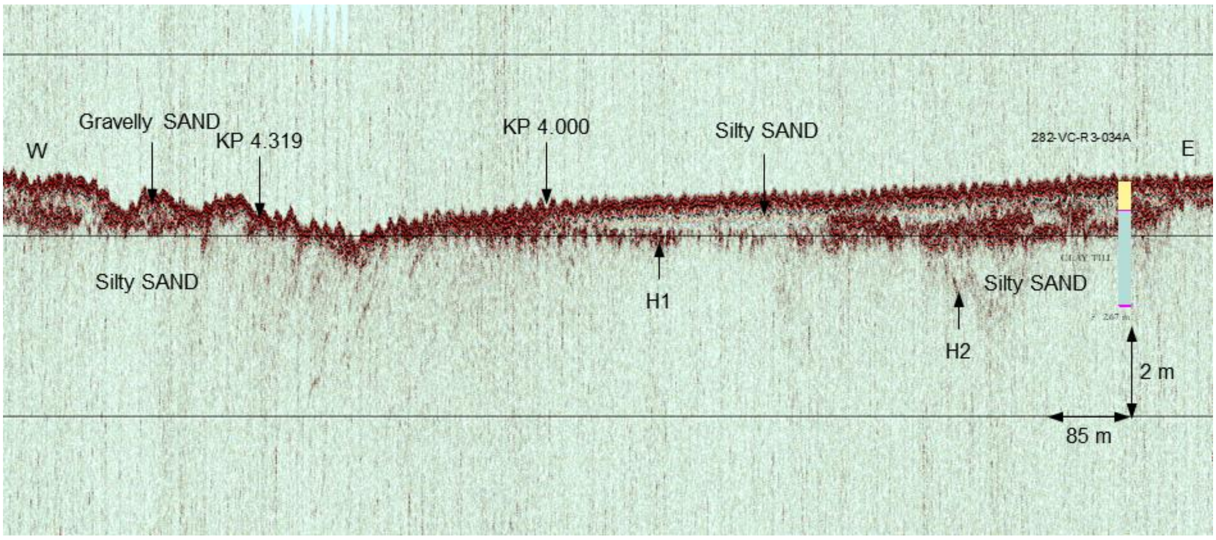


Figure 77 Innomar SBP data example from KP 3.326 (E) to KP 4.595 (W).
Showing silty SAND and gravelly SAND overlying channel infills, silty SAND.

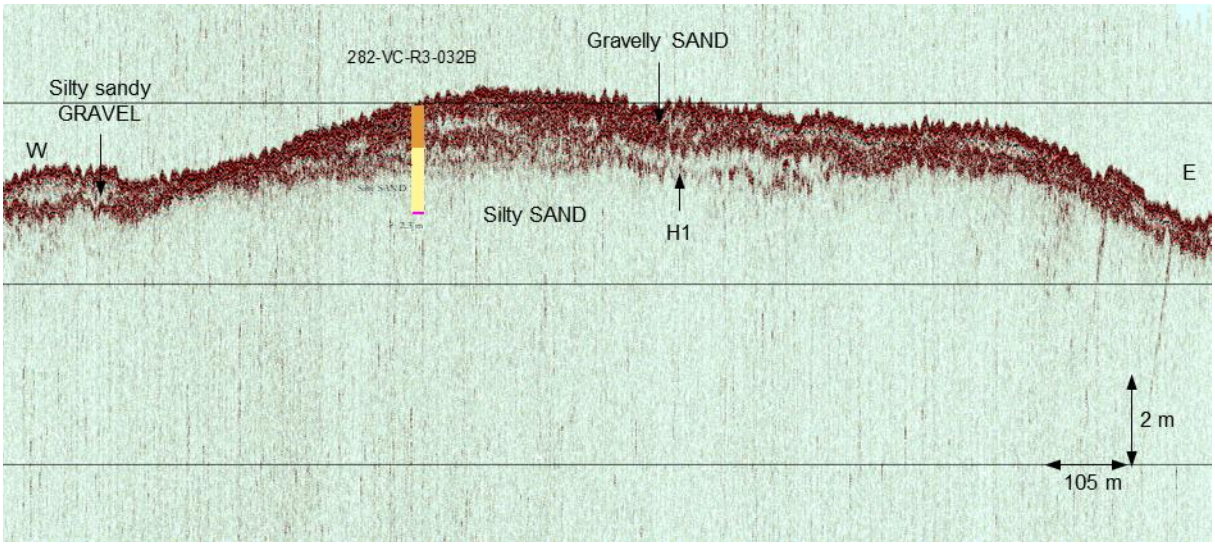


Figure 78 Innomar SBP data example from KP 4.795 (E) to KP 6.371 (W).
Showing gravelly SAND and silty sandy GRAVEL overlying silty SAND.

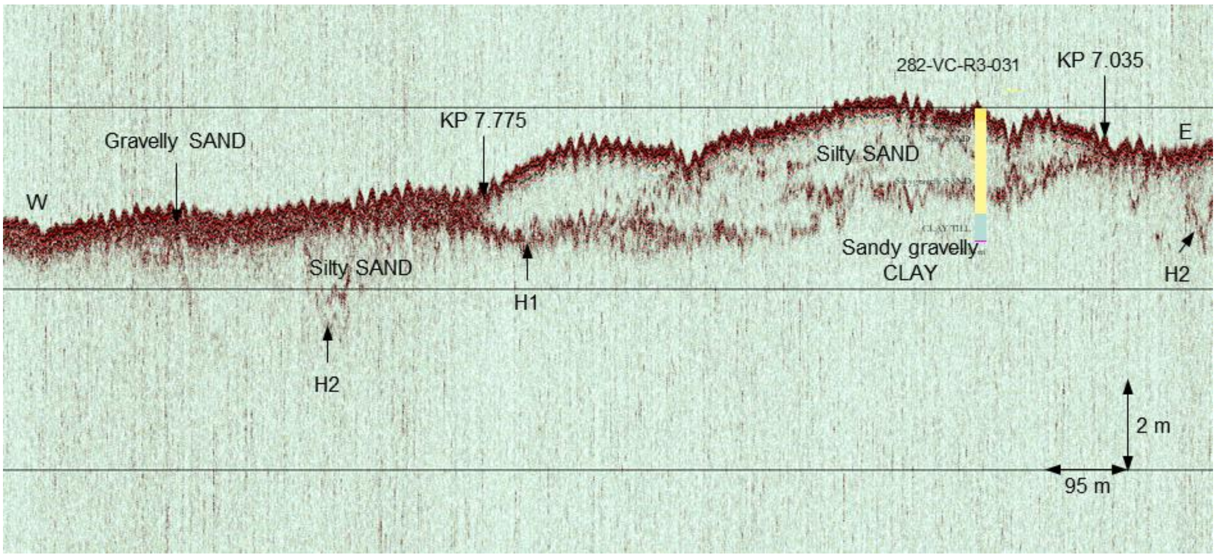


Figure 79 Innomar SBP data example from KP 6.913 (E) to KP 8.317 (W).
Showing silty SAND and gravelly SAND overlying either sandy gravelly CLAY or channel infills, silty SAND.

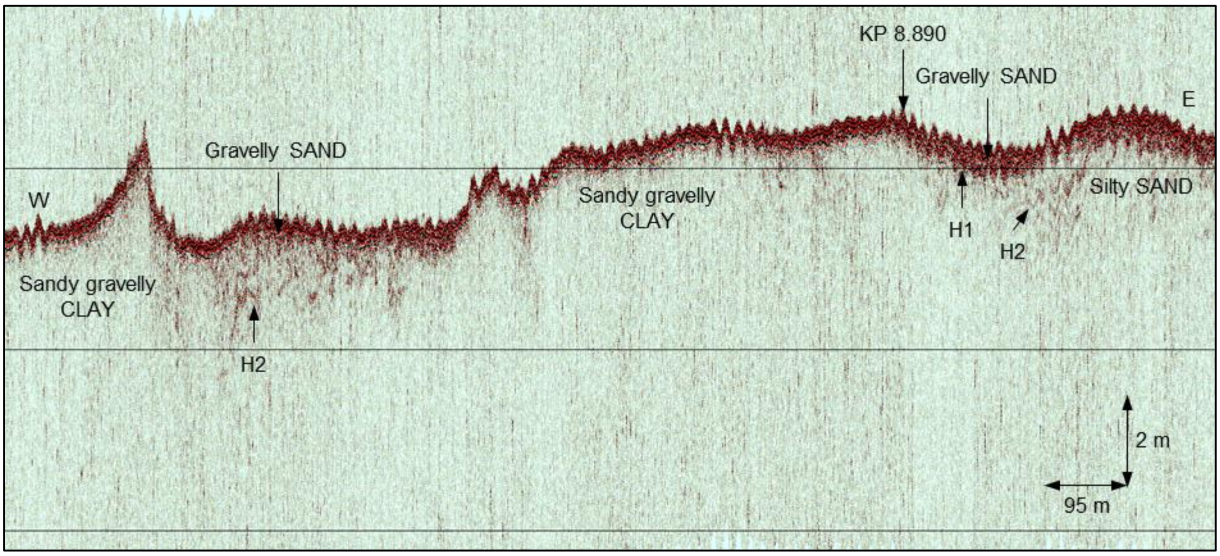


Figure 80 Innomar SBP data example from KP 8.529 (E) to KP 9.949 (W).
Showing gravelly SAND overlying channel infills, silty SAND. Sandy gravelly CLAY outcrops at seabed.

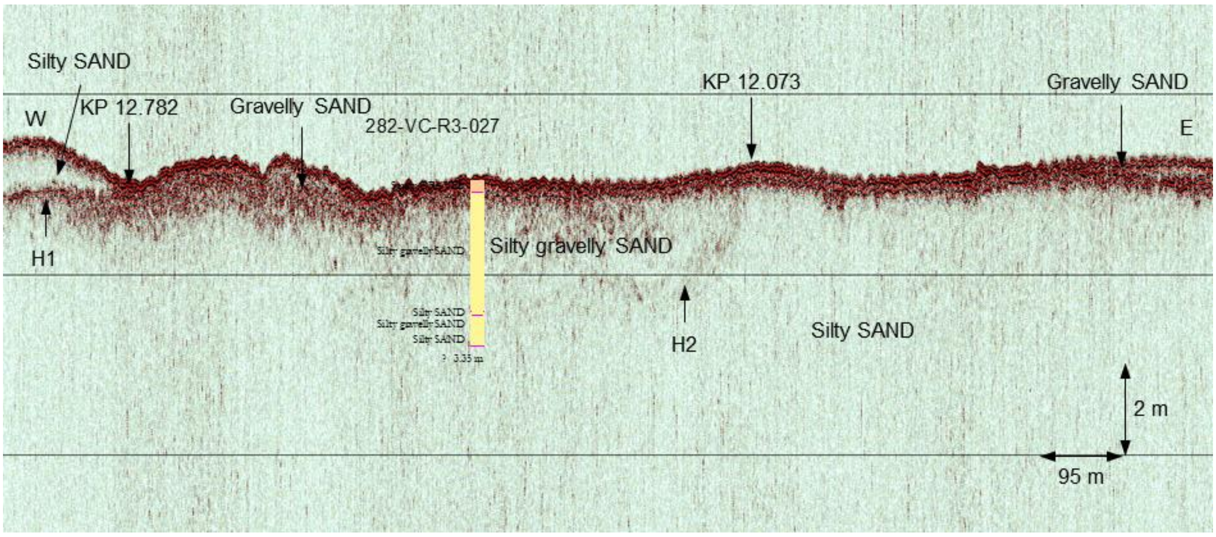


Figure 81 Innomar SBP data example from KP 11.540 (E) to KP 12.945 (W).
Showing gravelly SAND and silty SAND overlying channels infills, silty gravelly SAND, over silty SAND.

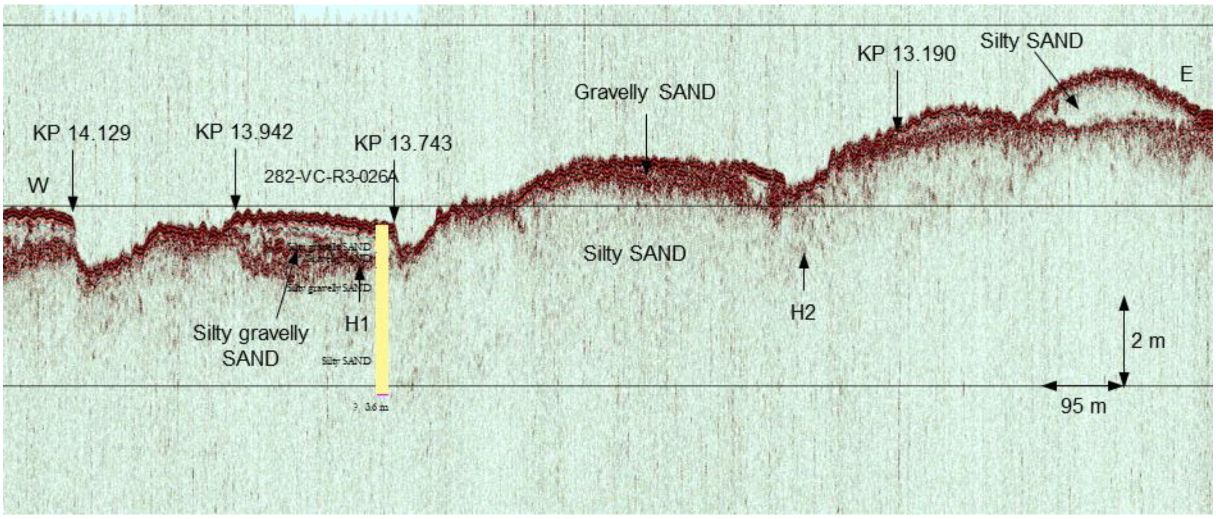


Figure 82 Innomar SBP data example from KP 12.785 (E) to KP 14.220 (W).
Showing gravelly SAND and silty gravelly SAND overlying channels infills, silty SAND.

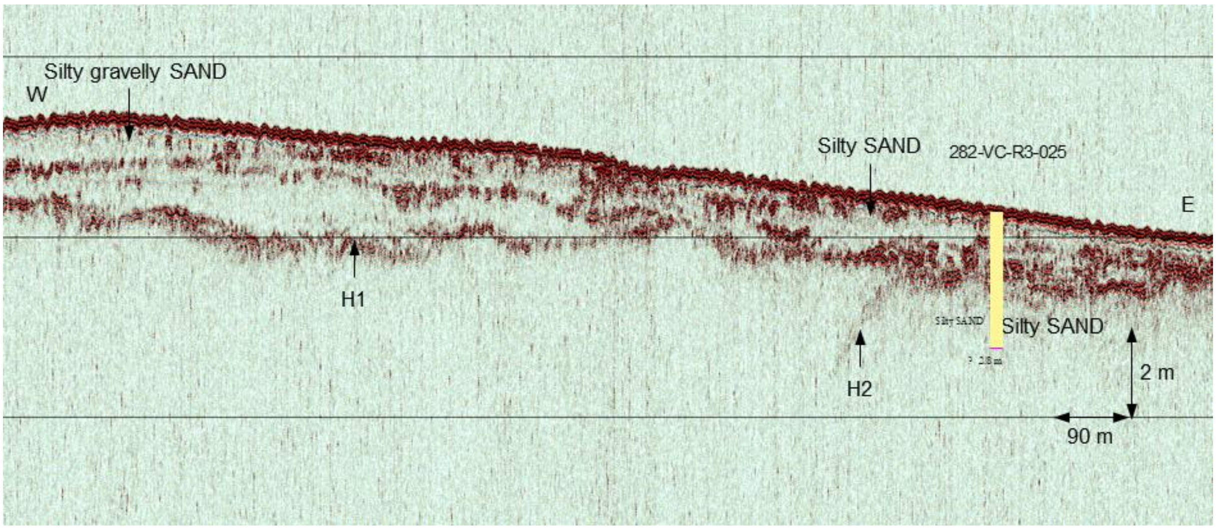


Figure 83 Innomar SBP data example from KP 14.729 (E) to KP 16.129 (W). Showing silty SAND overlying channels infills, silty SAND.

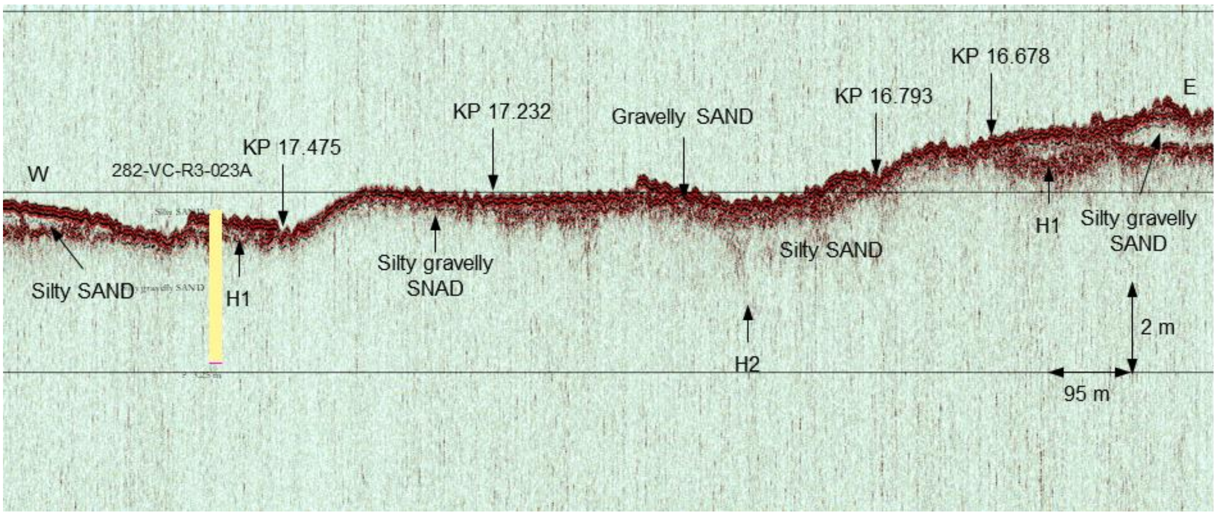


Figure 84 Innomar SBP data example from KP 16.386 (E) to KP 17.798 (W).
Showing silty SAND and gravelly SAND overlying channels infills, silty SAND. Sandy gravelly CLAY outcrops at seabed.

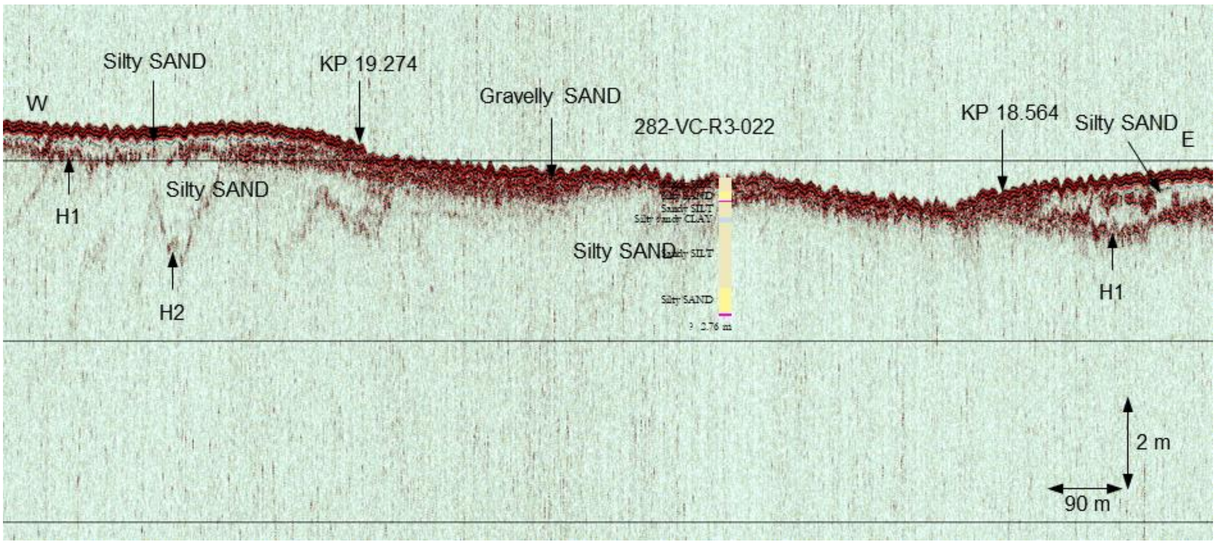


Figure 85 Innomar SBP data example from KP 18.284 (E) to KP 19.679 (W).
Showing silty SAND and gravelly SAND overlying channels infills, silty SAND.

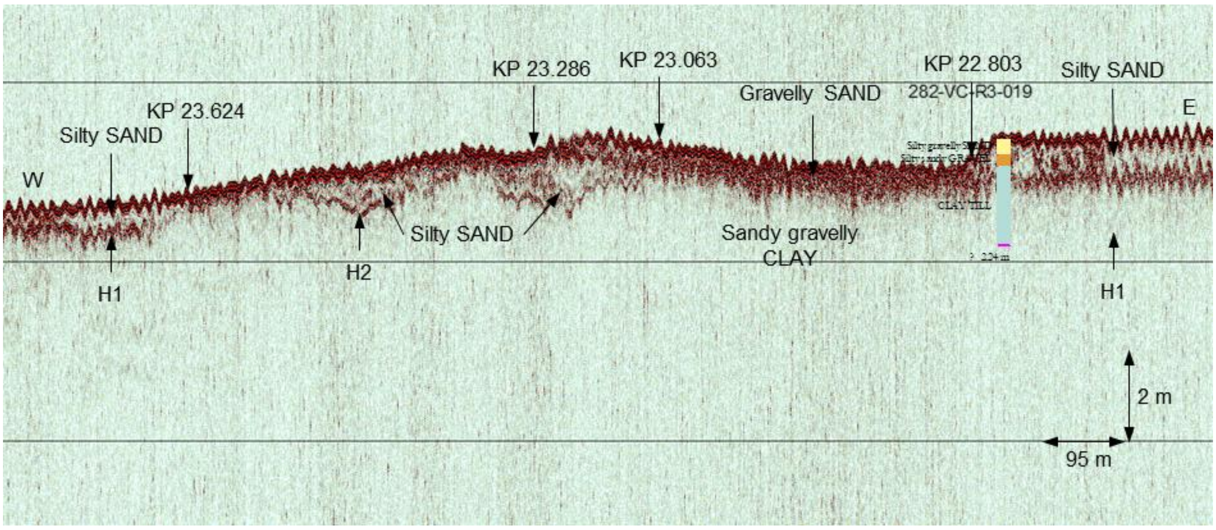


Figure 86 Innomar SBP data example from KP 22.508 (E) to KP 23.922 (W).
Showing silty SAND and gravelly SAND overlying channels infills, silty SAND. Overlies sandy gravelly CLAY.

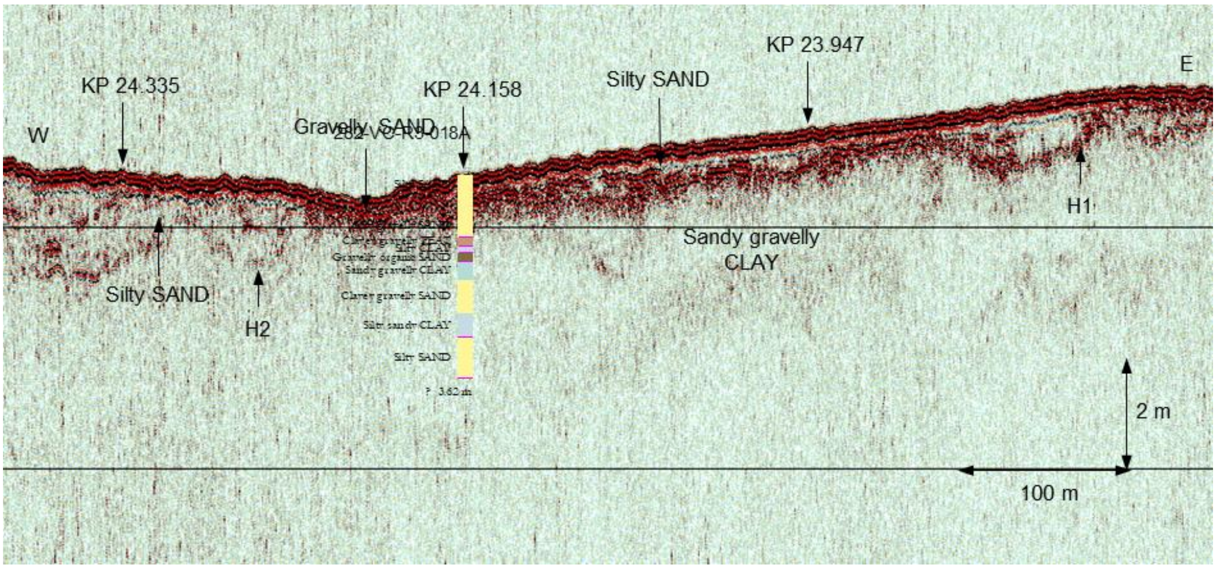


Figure 87 Innomar SBP data example from KP 23.947 (E) to KP 24.335 (W).
Showing silty SAND with internals of GRAVEL and gravelly SAND overlying channel infills, silty SAND. Overlies sandy gravelly CLAY.

7.6.3| CONTACTS AND ANOMALIES ROUTE 3

A total of 1135 contacts were identified from the SSS and MBES data within the survey corridor on Route 3. The majority of the contacts have been classified as boulders. The SSS contacts are summarised in Table 29.

A total of 34 magnetic anomalies were detected on Route 3. Of these, 32 were unclassified, and 2 were flagged as possible items of wreck debris, both of which were correlated to SSS contacts (Table 30).

Table 29 Summary of Route 3 SSS & MBES contacts.

CLASSIFICATION	**NUMBER**
Boulder	1127
MMO (Debris)	6
Wreck (Possible wreck debris)	2
Total	**1135**

Table 30 Summary of Route 3 magnetic anomalies.

CLASSIFICATION	**NUMBER**
Unclassified, possible objects	32
Possible wreck debris	2
Total	**34**

7.7| ROUTE 4: KP 0.000 TO KP 24.335

7.7.1| OVERVIEW

Route 4 covers the Landfall 2 survey area and the 800 m wide route corridor out to OWF Entry 3.

BATHYMETRY

The topographical survey, conducted by aerial drone, covered a section of the landfall zone that measured 246 m long at the route and spanned the full width of the survey corridor. Where the route crosses the landfall and bathymetry data there is a 214 m gap which resulted from poor coverage of the beach by the aerial drone survey. Towards the south of the route the coverage is improved, tapering to a minimum gap of 125 m at the boundary. To the north the gap is larger, up to 350 m.

From KP 0.00 to KP 0.134 the route crosses the undulating dune system and reaches a maximum elevation of +19.16 m at this point. From here the dune begins to slope down to a break in slope at KP 0.163 where the route crosses the seaward (western) face of the dune. The maximum slope angle is 43.0° at KP 0.167 on the dune. The western extent of the dune is reached at KP 0.205 where the route profile shows a local depression with an elevation of +2.11 m. From this point the crest of the dune stands 17.05 m above the level of the beach. From KP 0.205 there is a small increase in elevation before the beach slopes towards the sea at KP 0.222. The minimum elevation on the beach at the route is +1.26 m at KP 0.245.

North and south of the route the topography is broadly the same. To the east of the dune crest to the edge of the survey boundary the dune system creates a steeply undulating topography cut by numerous pedestrian and vehicular access routes to the beach. Near the northern boundary 4 buildings are covered by the survey area and in the south, 2 buildings are partially included.

The bathymetry along Route 4 is less variable than Routes 2 and 3. In spite of this, the bathymetry along Route 4 presents occasional shallow sandbanks as well as shallow channels. Very gentle to gentle slopes are observed along the route (Figure 88 and Figure 89).

From the landfall the bathymetry gently deepens westwards. Erosional features and localised sandbanks characterise the seabed from KP 17.000 to KP 20.000. The maximum depth along the route is -29.67 m DTU15 MSL, at KP 24.212, whilst the shallowest point along the route, within the surf zone (and the start of the MBES data) is -4.12 m at KP 0.488.

Between KP 1.291 and 2.000 the seabed is observed to be uneven, consisting of DIAMICTON outcrops and boulders. A further area of boulder fields is observed between KP 4.000 and KP 4.500. Whilst boulders are noticeable in the bathymetry the seabed itself is relatively flat with a bathymetry of approximately -20.00 m DTU15 MSL. However, some depressions, caused by scouring around the boulders, have a maximum depth of -20.41 m DTU15 MSL, at 441881.00 E and 6234347.82 N.

Between KP 8.600 and KP 9.000, the cable route crosses a sandwave (KP 8.585) that presents an E-W orientation. A scour, on its southern edge, is observed to be 1.85 m deeper than the highest part of the sandbank. At this point, the sandbank has a minimum depth of -20.06m DTU15 MSL, at 438276.21 E and 6236745.90 N.

Between KP 9.700 and KP 10.400 the cable route crosses the N-E edge of a sandbank, which has a width of 724 m parallel to the centre line. The sandbank rises 0.97 m from the seabed with a minimum depth of -19.87 m DTU15 MSL, at 437186.06 E and 6237471.12 N.

Between KP 17.000 and KP 20.000 the cable route crosses a system of shallow channels with. The maximum depth is -26.14 m MSL, at 431489.17 E and 6241260.97 N. Minimum depth is -22.47 m DTU15 MSL, at 430517.06 E and 6241907.67 N.

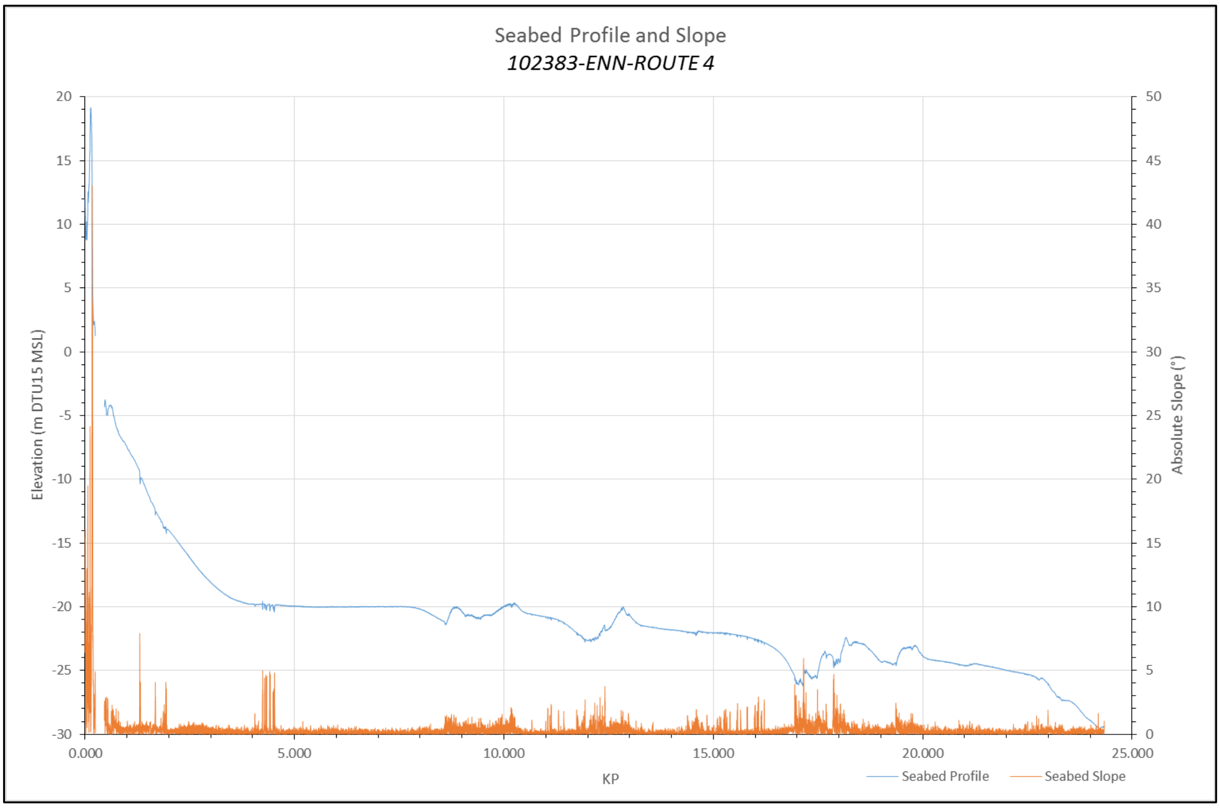


Figure 88 Route 4 bathymetry longitudinal profile.
Elevation is in metres (with bathymetric depths negative below MSL datum) and slope is in degrees (absolute value for visualisation). Vertical exaggeration x 300.

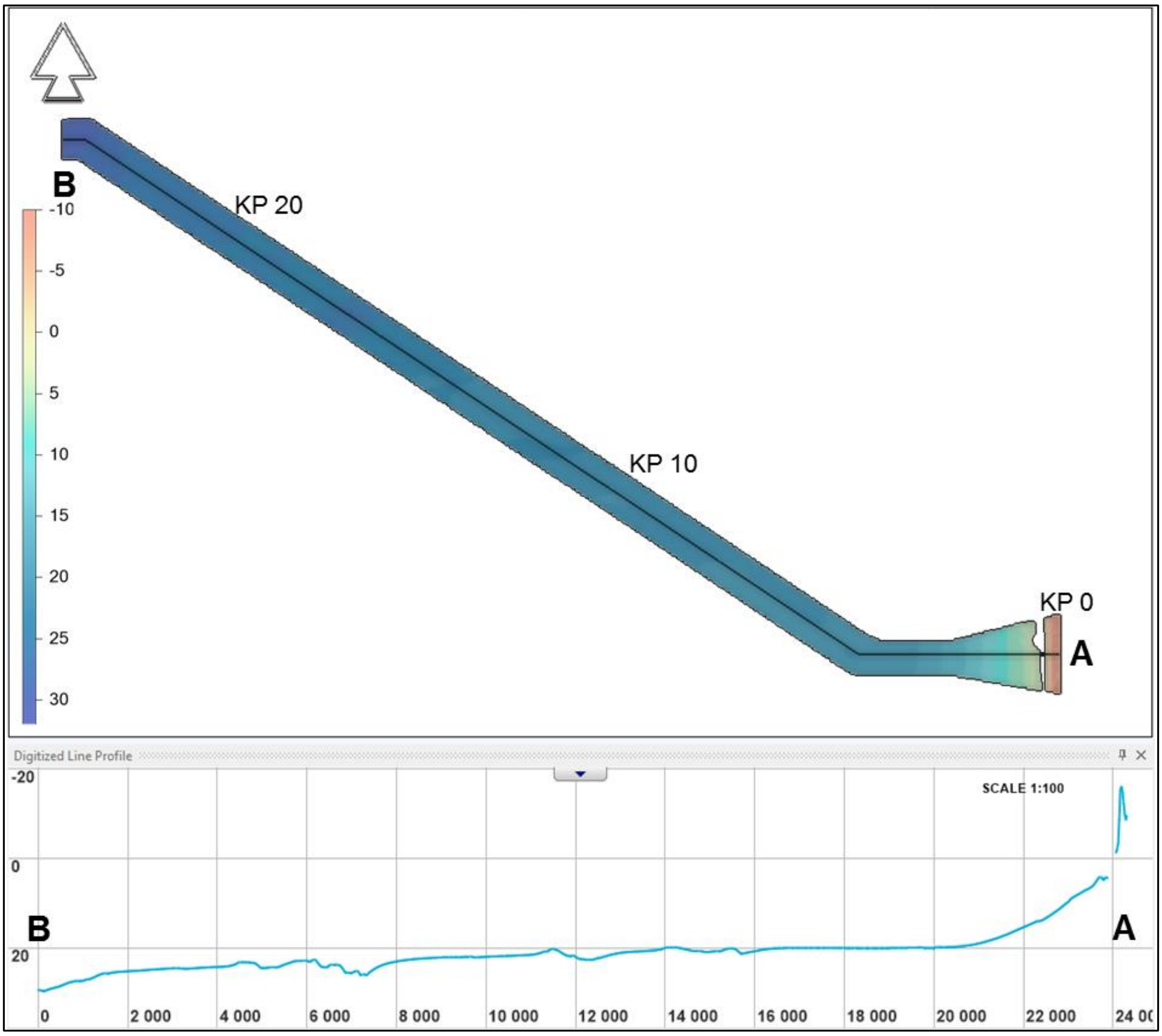


Figure 89 Overview image of Route 4.
The scale on the profile is in metres with distance from west to east given along the x-axis. Depths presented in NaviModel positive down; vertical exaggeration of profile x100.

SURFICIAL GEOLOGY

The surficial geology in Route 4 mainly comprise SAND with occasional areas of gravelly SAND to sandy GRAVEL and GRAVEL. DIAMICTON is almost exclusively present around KP 2.000 with a small patch adjacent to the route at approximately KP 17. 000. The general direction of sediment transport in the area is N-S close to shore with a slight rotation toward NE-SW further out.

Three main areas of depressions are present within the survey corridor. The largest crosses the survey corridor between KP 13.203 and KP 16.733. The areas of depressions are commonly associated with surface sediments comprising SAND. These features are visible as numerous depressions scattered across the seabed and are likely caused by changes in seabed current regime rather than shallow biogenic gas. The lack of gas blanking / turbidity in the upper layers of the SBP data suggests gas is unlikely to be the provenance for these features.

Occasional and numerous boulder fields are sparse, mainly observed in the areas around KP 2.00, KP 4.000 and KP 17.000. Ripples of any real extent are only observed in the first half of the route, notably around KP 9.500 and KP 12.500 and are commonly associated with gravelly sediments.

Two contacts (S_R4_0075, DCC 105 m and S_R4_0076, DCC 93 m) are observed as potential fishing debris, comprising a possible clump weight and rope. However, there were no MAG anomalies associated with these contacts.

Detailed description of the surficial geology is presented in Table 31.

SHALLOW GEOLOGY

A detailed description of the shallow geologic changes observed along the proposed Route 4 can be found in the Route 4 seabed details table presented in Table 31.

A number of sedimentary units were identified in the sub-surface geology down to a maximum depth of 7.7 m below the seabed (-27.9 DTU15 MSL). The upper unit along the majority of the route has been confirmed to be SAND based on the geotechnical sampling results. These sediments are often laminated and acoustically transparent internally. Distinct and highly reflective layers are common within this section of the stratigraphy, varying in length, vertical placement, and amplitude (Figure 104). These were interpreted as internal layers of GRAVEL within the Unit.

The SAND unit varies from silty SAND to SAND and GRAVEL. More localised areas of GRAVEL and CLAY, were also observed along the route. The SAND unit extends along the entire route at variable depths ranging from the seafloor to 3.0 m below seabed. The base horizon for this unit (H1) is often undulating in character.

The upper SAND unit, bounded by horizon H1, lies atop an erosional discontinues surface named as H2 which represent the base of palaeo-channels of varying depth and extents. Based on the SBP penetration limit, the deepest channel structures reached was 7.7 m below the seabed.

The infill of these channels is variable, consisting of laminated and homogenous sediments which characterise the channel-infill along the route. In some channels the infill sediments form a uniform thick unit while others show a strong upper boundary reflector indicating a change in sediment characteristics. Based on the geotechnical results, sediments recovered ranged from Silty SAND and GRAVEL mixed to CLAY and organic matter.

A grid was created to map the base of the upper SAND unit (H1) detected from SBP data related to depth below seabed and related to the MSL datum.

7.7.2| DETAILED DESCRIPTION

A detailed presentation of the conditions and features on Route 4 are shown in Table 31.

Table 31 Route 4 seabed details.

KP	ASSOCIATED CHART	DESCRIPTION (INCLUDING MIN/MAX DEPTH BSB TO BASE OF UNIT)	REMARK
0.000 – 11.734	103282-ENN-MMT-SUR-DWG-ALR40001 103282-ENN-MMT-SUR-DWG-ALR40002	**Bathymetry:** Undulating dune system between KP 0.000 and crest of dune at KP 0.134. Dune very steeply descends from 19.16 m to 2.11 m at KP 0.205. Beach gently slopes to surf zone at 1.26 m at KP 0.245. Maximum Elevation +19.16 at KP 0.134 Minimum Elevation +1.26 m at KP 0.245 Moderately deepening seafloor from landfall westward with sandwaves and channels. Minimum depth -3.75 m at KP 0.477. Maximum depth -22.02 m at KP 11.721.	Some evidence of boulder scattering at KP 1.900 and KP 4.000. Sandwaves and channels evident (Figure 90). Total elevation/depth range = 41.18 m Maximum slope on landfall of 43.0° at KP 0.167. Maximum slope sub-sea of 7.9° at KP 1.305.
		Surficial geology: SSS coverage starts at KP 0.427. This section is dominated by SAND. Adjacent to the landfall, patches of gravelly SAND to sandy GRAVEL and GRAVEL is occasionally observed. DIAMICTON is also present as scattered, discrete patches up until KP 4.523. The patches of DIAMICTON are often associated with surrounding occasional boulders fields. An area of sandwaves are present near the shore line at KP 0.427 to KP 0.685. A further, isolated sandwave crest crosses the survey corridor at KP 8.590.	Fields of occasional boulders crossing the route between: • KP 1.765 and KP 1.863 • KP 1.910 and KP 1.929 • KP 1.943 and KP 2.003 Fields of numerous boulders crossing the route between: • KP 3.794 and KP 3.799 • KP 4.006 and KP 4.156 • KP 4.185 and KP 4.317 • KP 4.424 and KP 4.429 • KP 4.468 and KP 4.486 • KP 4.509 and KP 4.515 • KP 4.522 and KP 4.532

KP	ASSOCIATED CHART	DESCRIPTION (INCLUDING MIN/MAX DEPTH BSB TO BASE OF UNIT)	REMARK
		A large area of depressions are present in the latter parts of the section, crossing the survey route between KP 10.635 and KP 11.367.	Area of depression crossing the route between: • KP 10.541 and KP 11.368
		Shallow Geology: SBP coverage begins at KP 0.477. KP 0.477 to KP 0.828: SAND, fine to coarse (0.8 – 3.0 m BSB) with internals of gravels overlaying either channel infills, silty SAND (1.2 – 5.1 m BSB) or silty sandy CLAY. KP 0.828 to KP 1.302: SAND, fine to coarse (0.2 – 1.4 m BSB) with internals of gravels overlaying silty sandy CLAY. KP 1.302 to KP 1.319: Sandy gravelly CLAY outcrops at seabed. KP 1.319 to KP 1.843: SAND, fine to coarse (0.3 – 1.0 m BSB) with internals of gravels overlaying sandy gravelly CLAY. KP 1.843 to KP 1.889: Sandy gravelly CLAY outcrops at seabed. KP 1.889 to KP 4.330: Silty SAND (0.3 – 1.9 m BSB) with internals of GRAVEL overlaying silty sandy CLAY. Channel infills (1.2 – 3.1 m BSB) with silty SAND were observed between KP 3.835 to KP 4.022. KP 4.330 to KP 4.338: Sandy gravelly CLAY outcrops at seabed. KP 4.338 to KP 4.410: A thin layer of gravelly SAND (0.2 – 0.7 m BSB) overlaying silty sandy CLAY.	(Figure 97), (Figure 98), (Figure 99), (Figure 100), (Figure 101) and (Figure 102)

KP	ASSOCIATED CHART	DESCRIPTION (INCLUDING MIN/MAX DEPTH BSB TO BASE OF UNIT)	REMARK
		KP 4.410 to KP 4.424: Sandy gravelly CLAY outcrops at seabed. KP 4.424 to KP 4.494: A thin layer of gravelly SAND (0.2 – 0.7 m BSB) overlaying silty sandy CLAY. KP 4.494 to KP 4.528: Sandy gravelly CLAY outcrops at seabed. KP 4.528 to KP 7.568: Silty SAND (0.3 – 2.3 m BSB) with internals of GRAVEL overlaying silty sandy CLAY. KP 7.568 to KP 11.734: Silty SAND (0.7 – 2.7 m BSB) with internals of GRAVEL overlaying either channel infills, Sandy CLAY (2.6 – 7.7 m BSB) or silty sandy CLAY.	
11.734 – 16.958	103282-ENN-MMT-SUR-DWG-ALR40002 103282-ENN-MMT-SUR-DWG-ALR40003	**Bathymetry**: The seabed undulates within this section as the route crosses erosion channels and occasional sandwaves. Minimum depth -20.00 m at KP 12.851. Maximum depth -25.79 m at KP 16.945.	Very gentle to moderate slopes. Depths range = 5.8 m. Maximum slope of 3.9° at KP 16.943.
		Surficial Geology: The surface geology is dominated by SAND associated with a large area of depressions (Figure 91).	Areas of depressions crossing the route between: • KP 13.204 and KP 14.461 • KP 14.655 and KP 16.732
		Shallow Geology: KP 11.734 to KP 11.873: Silty SAND (0.4 – 0.9 m BSB) with internals of GRAVEL overlaying silty SAND. KP 11.873 to KP 11.917: Fine silty SAND outcrops at seabed. KP 11.917 to KP 12.066: Silty gravelly SAND (0.4 – 0.8 m BSB) overlaying silty SAND.	(Figure 103), (Figure 104)

KP	ASSOCIATED CHART	DESCRIPTION (INCLUDING MIN/MAX DEPTH BSB TO BASE OF UNIT)	REMARK
		KP 12.066 to KP 12.251: Silty sandy CLAY outcrops at seabed. KP 12.251 to KP 16.958: Silty gravelly SAND (0.3 – 2.7 m BSB) overlaying channel infills, silty clayey SAND (0.8 – 4.9 m BSB).	
16.958 – 17.485	103282-ENN-MMT-SUR-DWG-ALR40003	**Bathymetry**: The seabed is broadly flat and smooth with occasional erosional channels. Minimum depth -24.90 m at KP 17.215. Maximum depth -26.24 m at KP 17.149.	Very gentle to gentle slopes. Depths range = 1.3 m. Maximum slope of 6.0° at KP 17.155
		Surficial Geology: Complex area with surface geology mainly composed of GRAVEL and gravelly SAND to sandy GRAVEL associated with occasional and numerous boulders and ripples (Figure 92). DIAMICTON is also present in the southern part of the corridor. (Figure 92).	Fields of occasional boulders cross the route between: • KP 16.958 and KP 16.976 • KP 16.976 and KP 17.010 • KP 17.010 and KP 17.044 • KP 17.044 and KP 17.099 • KP 17.111 and KP 17.149 Fields of numerous boulders cross the route between • KP 17.149 and KP 17.227 • KP 17.227 and KP 17.485
		Shallow Geology: KP 16.958 to KP 17.485: Silty gravelly CLAY outcrops at seabed.	(Figure 105)
17.485 – 24.335	103282-ENN-MMT-SUR-DWG-ALR40003	**Bathymetry**: The seabed deepens gently becoming more increasingly textured with ripples, occasional and numerous boulder fields. Minimum depth -22.40 m at KP 18.163. Maximum depth -29.67 m at KP 24.207.	Very gentle to gentle. Depth range =7.3 m. Maximum slope of 4.7° at KP 17.875
		Surficial Geology:	Area of depression crossing the route between:

KP	ASSOCIATED CHART	DESCRIPTION (INCLUDING MIN/MAX DEPTH BSB TO BASE OF UNIT)	REMARK
		The section is dominated by SAND Gravelly SAND to Sandy GRAVEL are frequently observed at the start of the section but become sparse towards the end of the route at KP 24.335. These coarse sediment areas are sometimes associated with ripples and numerous or occasional boulder fields. A discreet area of sandwaves are observed adjacent to the southern boundary of the survey corridor between KP 18.148 to KP 18.939 (sediment transport direction South). A large area of depressions is present in the latter part of the section (Figure 93).	• KP 22.240 and KP 23.002
		Shallow Geology: KP 17.485 to KP 18.000: Silty SAND (0.4 – 1.6 m BSB) with internals of GRAVEL overlaying channel infills, silty gravelly CLAY (1.1 – 2.2 m BSB). KP 18.000 to KP 18.025: Silty gravelly CLAY outcrops at seabed. The base of the channel infills is at 2.6 m BSB. KP 18.025 to KP 23.206: Silty SAND (0.3 – 1.8 m BSB) with internals of GRAVEL overlaying either channel infills, silty SAND (1.4 – 3.9 m BSB) through Sandy gravelly CLAY. KP 23.206 to KP 23.311: A thin layer of gravelly SAND (0.2 – 0.5 m BSB) overlaying channel infills, silty sandy CLAY (1.1 – 1.5 m BSB). Overlies silty SAND. KP 23.311 to KP 24.235: Silty SAND (0.3 – 0.8 m BSB) with internals of GRAVEL overlaying channel infills, silty SAND (0.6 – 2.3 m BSB).	(Figure 105), (Figure 106), (Figure 107) and (Figure 108)

KP	ASSOCIATED CHART	DESCRIPTION (INCLUDING MIN/MAX DEPTH BSB TO BASE OF UNIT)	REMARK
		KP 24.235 to KP 24.401: A thin layer of gravelly SAND (0.5 m BSB) overlaying channel infills, silty SAND (0.6 – 1.4 m BSB). Overlies silty Clayey gravelly SAND.	

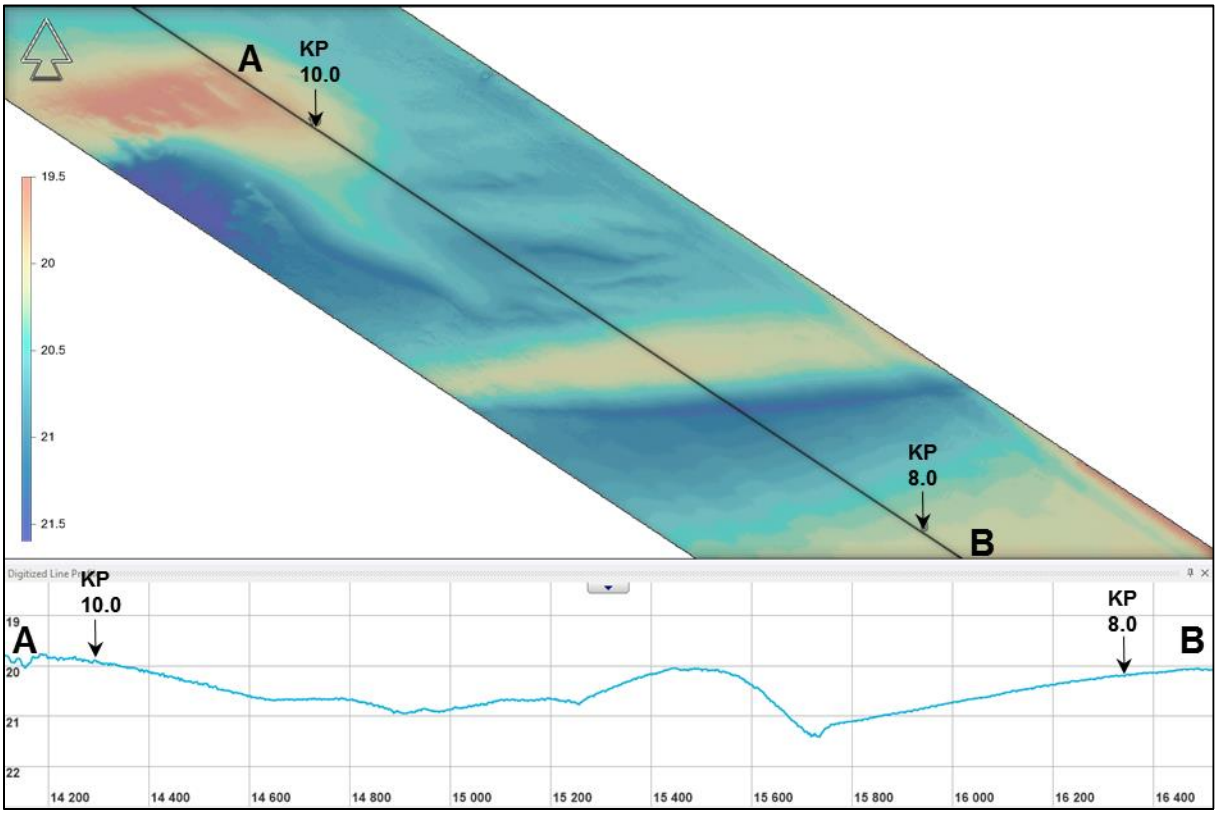


Figure 90 Sandwave and shallow channel at KP 8.225 to KP 11.148.
Depth convention in NaviModel is positive down; vertical exaggeration of profile x100.

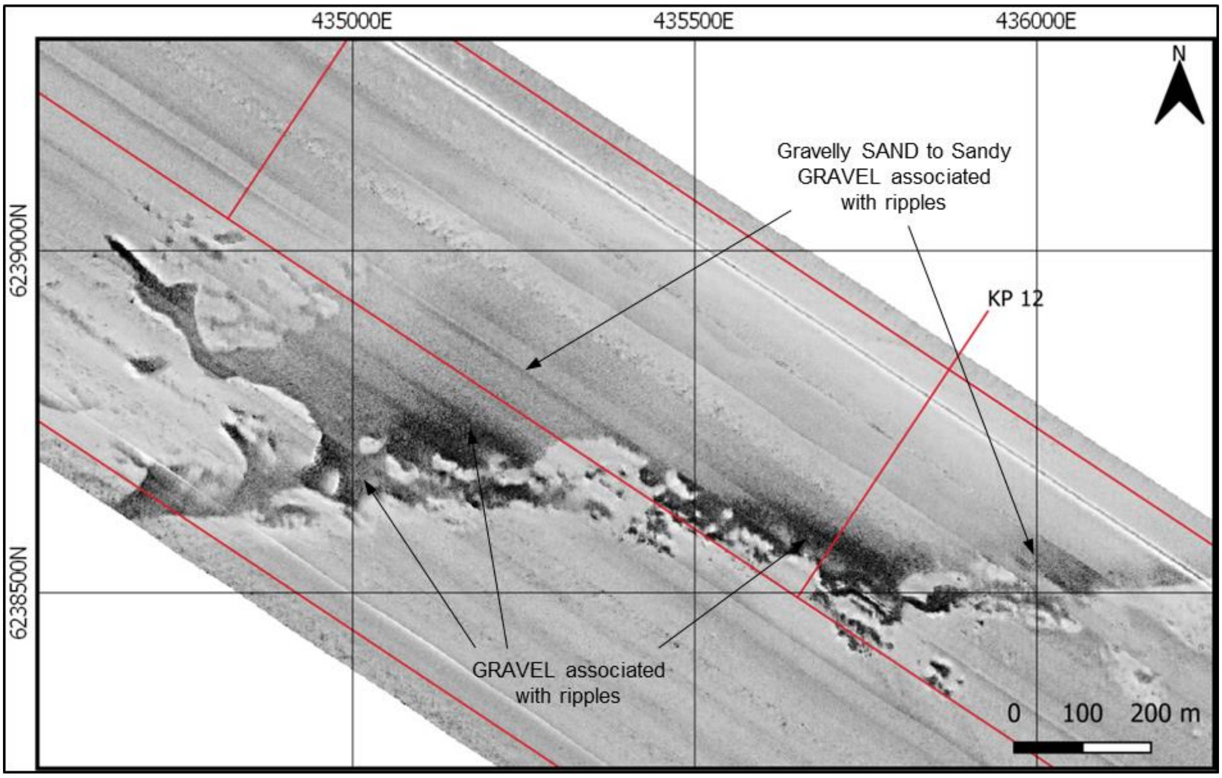


Figure 91 Overview of surficial geology from KP 11.5 to KP 13.3 as seen on SSS.

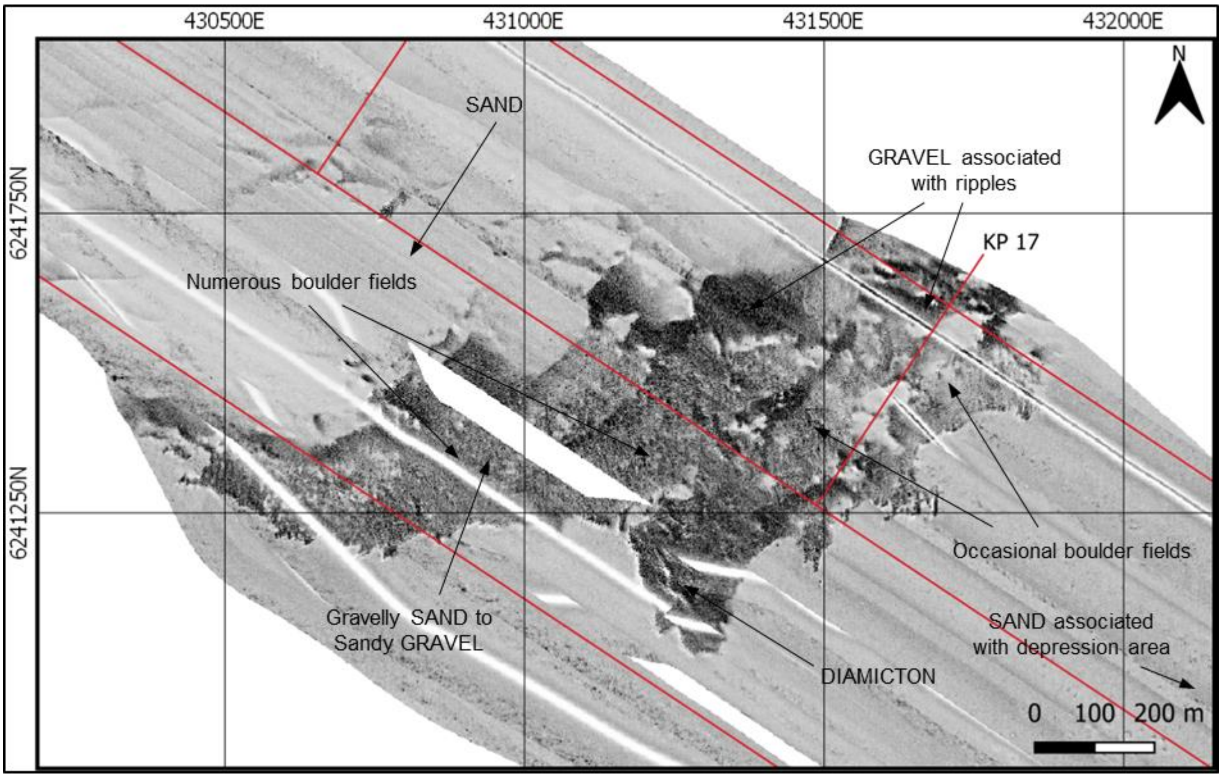


Figure 92 Overview of surficial geology from KP 16.5 to KP 18.3 as seen on SSS.
The gap is due to fishing equipment that required a deviation by the survey vessel to avoid entanglement.

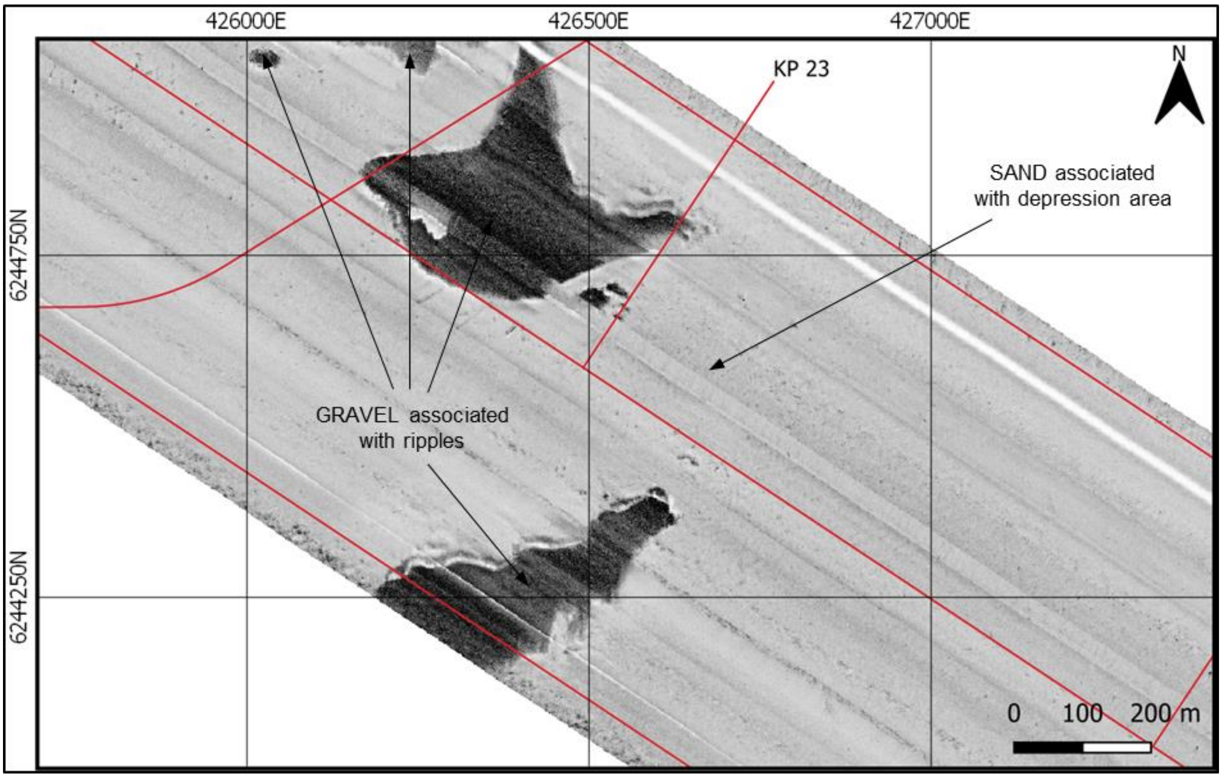


Figure 93 Overview of surficial geology from KP 21.9 to KP 23.6 as seen on SSS..

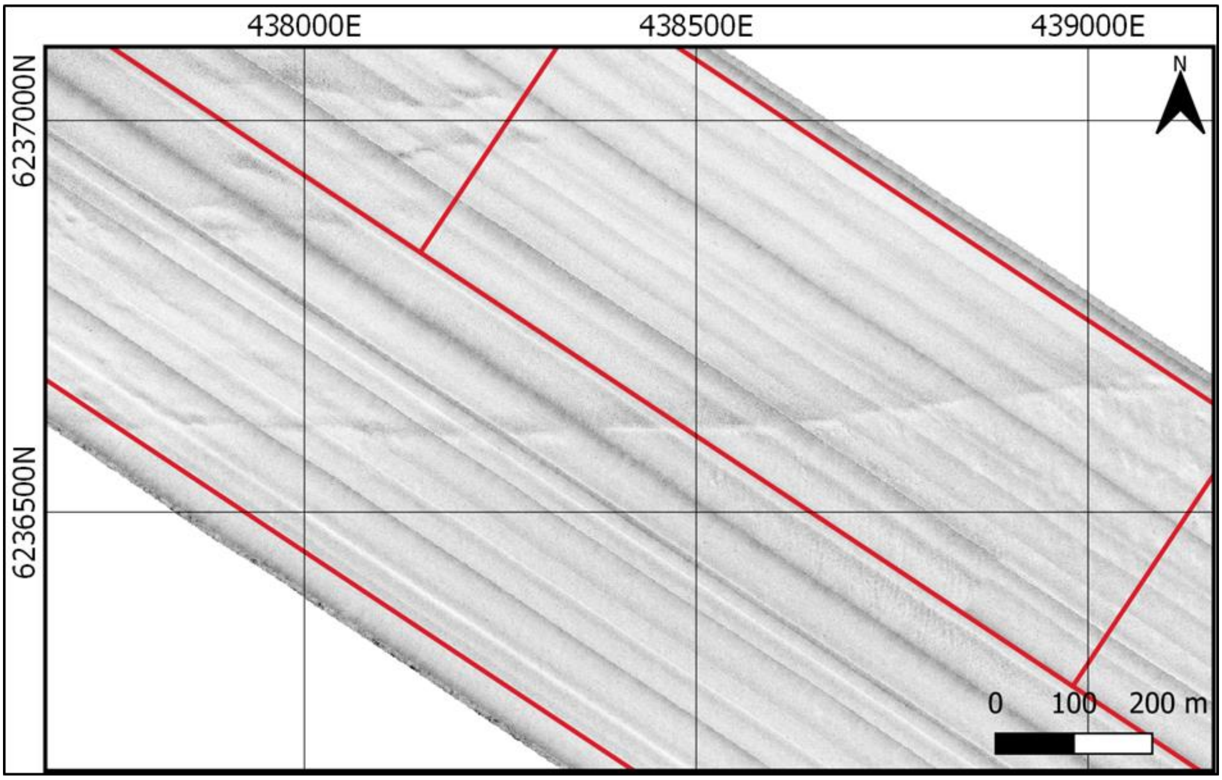


Figure 94 Side scan sonar image illustrating a sandwave crossing survey corridor at KP 8.588.

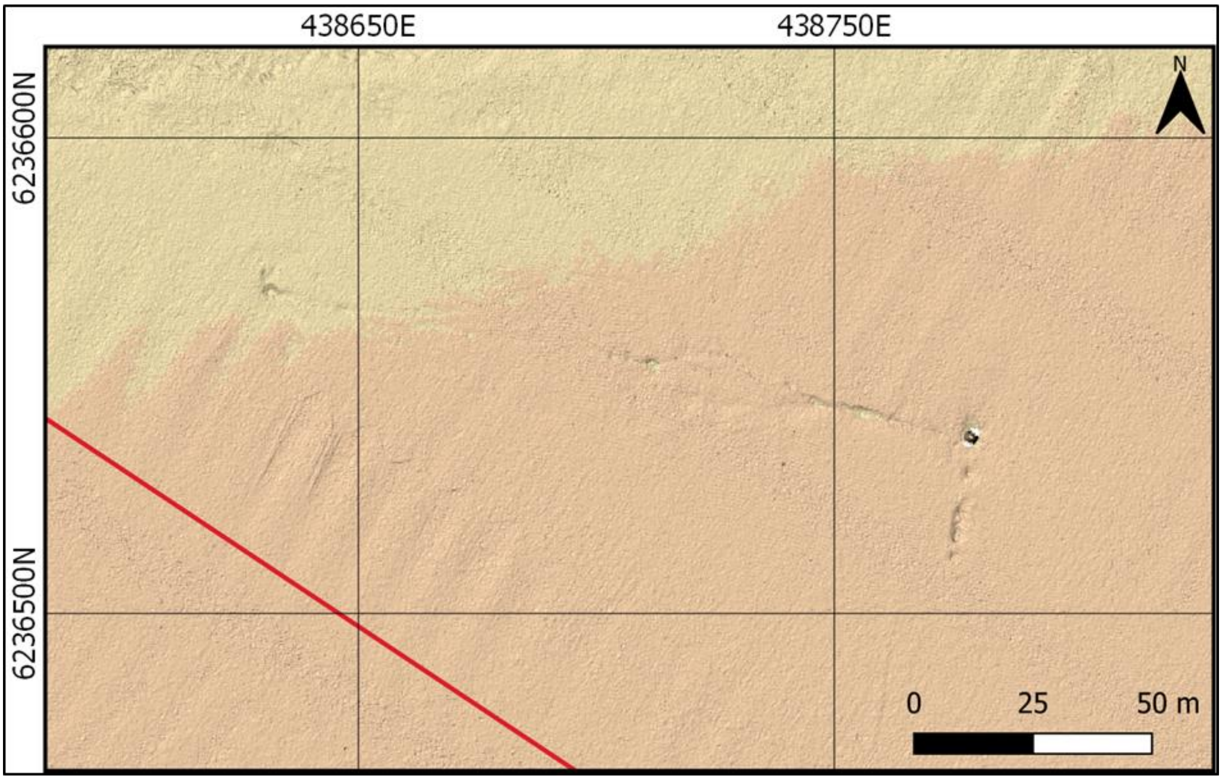


Figure 95 MBES image KP 8.311 (DCC 104.55)
Possible fishing gear with the rope still attached

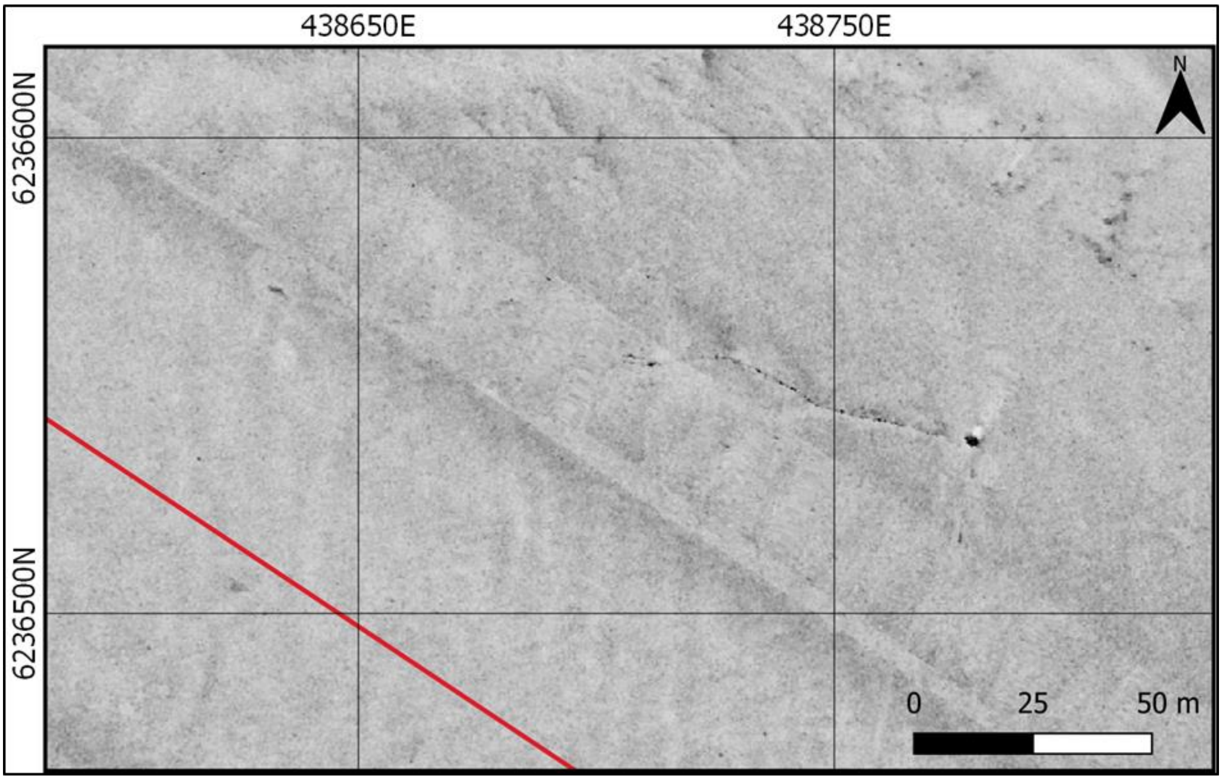


Figure 96 Side scan sonar image KP 8.311, (DCC 104.55)
Possible fishing gear with the rope still attached on SAND.

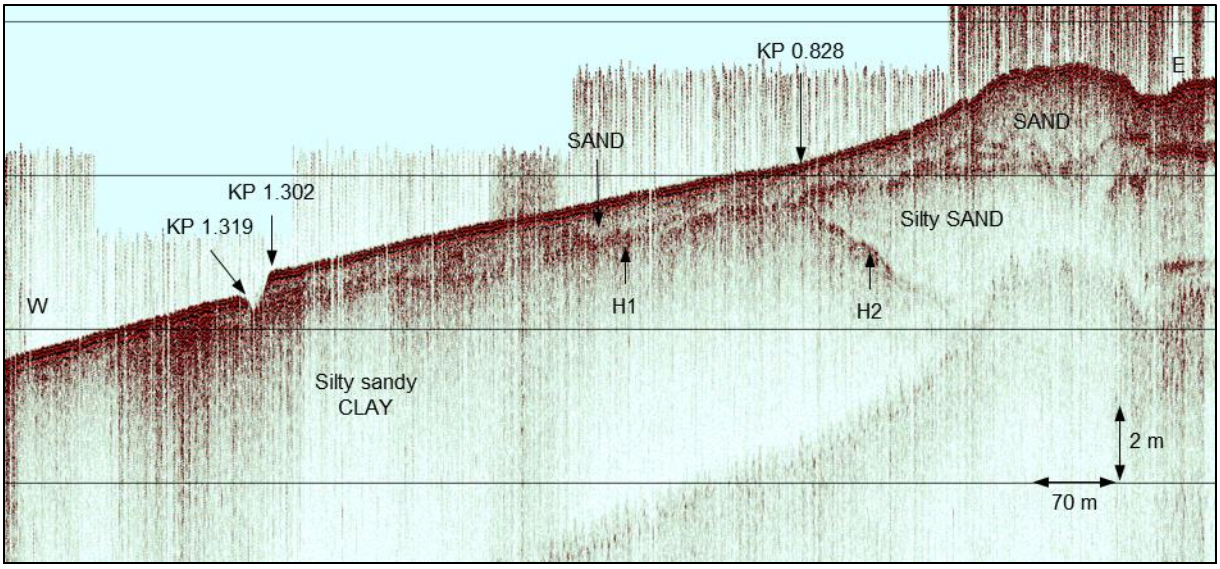


Figure 97 Innomar SBP data example from KP 0.497 (E) to KP 1.544 (W).
Showing SAND overlying channel infills, silty SAND. Silty sandy CLAY outcrops at seabed.

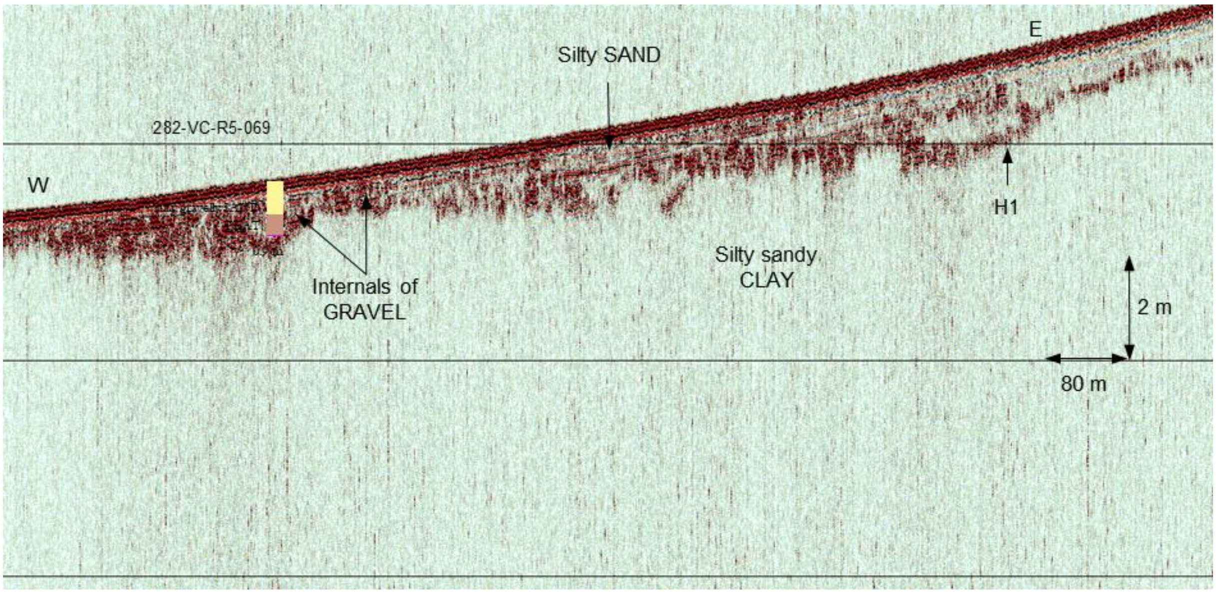


Figure 98 Innomar SBP data example from KP 2.461 (E) to KP 3.674 (W).
Showing silty SAND with internals of GRAVEL overlying silty sandy CLAY.

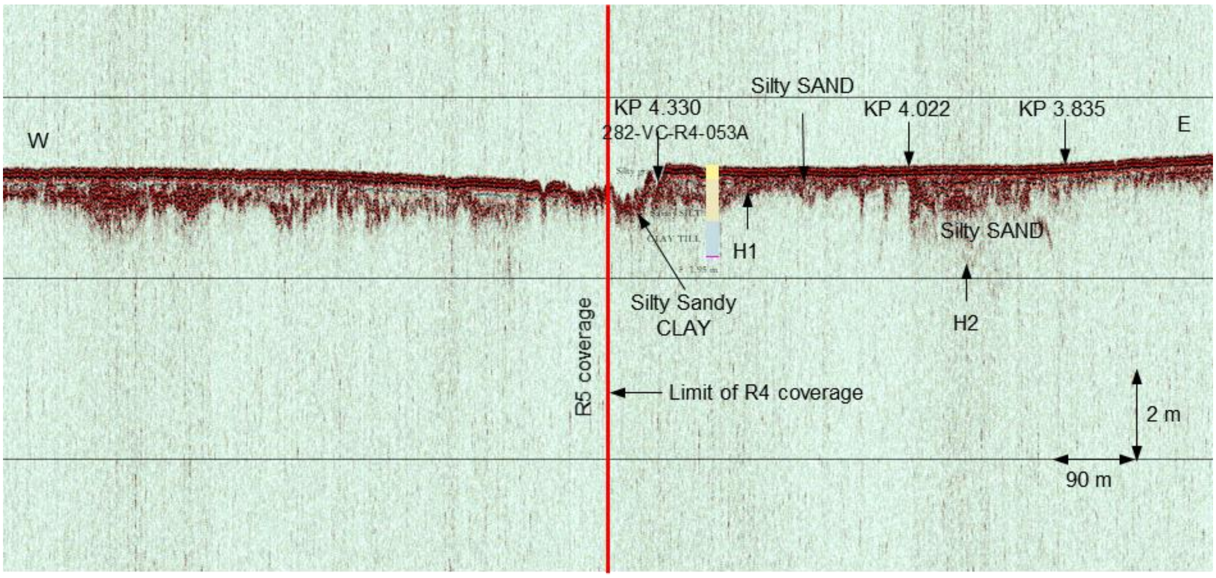


Figure 99 Innomar SBP data example from KP 3.670 (E) to KP 4.338 (W).
Showing silty SAND overlying channel infills, silty SAND. Silty sandy CLAY outcrops at seabed.

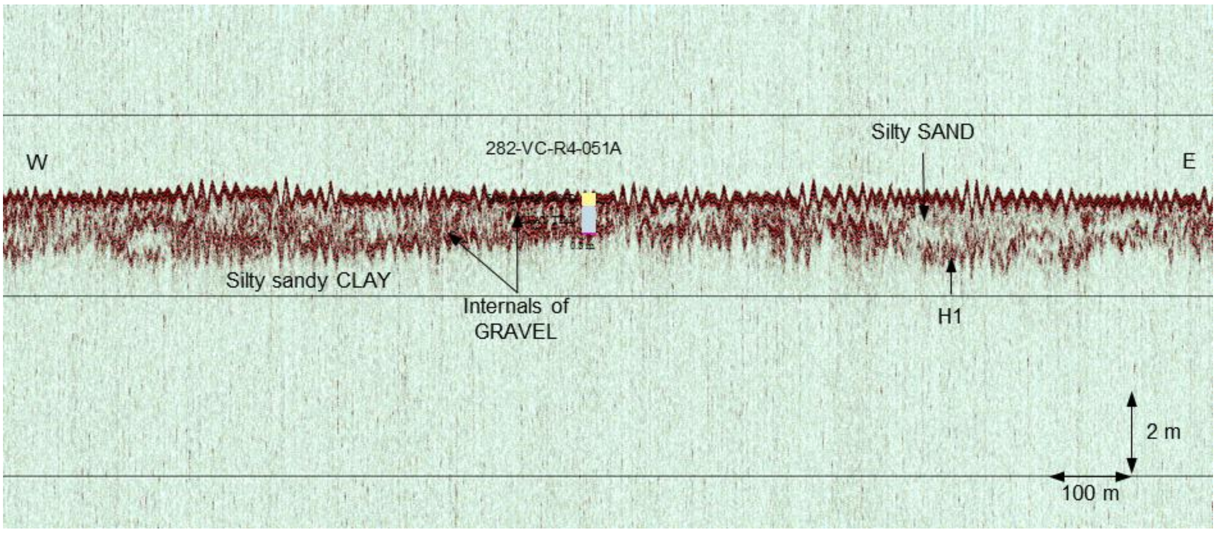


*Figure 100 Innomar SBP data example from KP 5.922 (E) to KP 7.299 (W).
Showing silty SAND with internals of GRAVEL overlying silty sandy CLAY.*

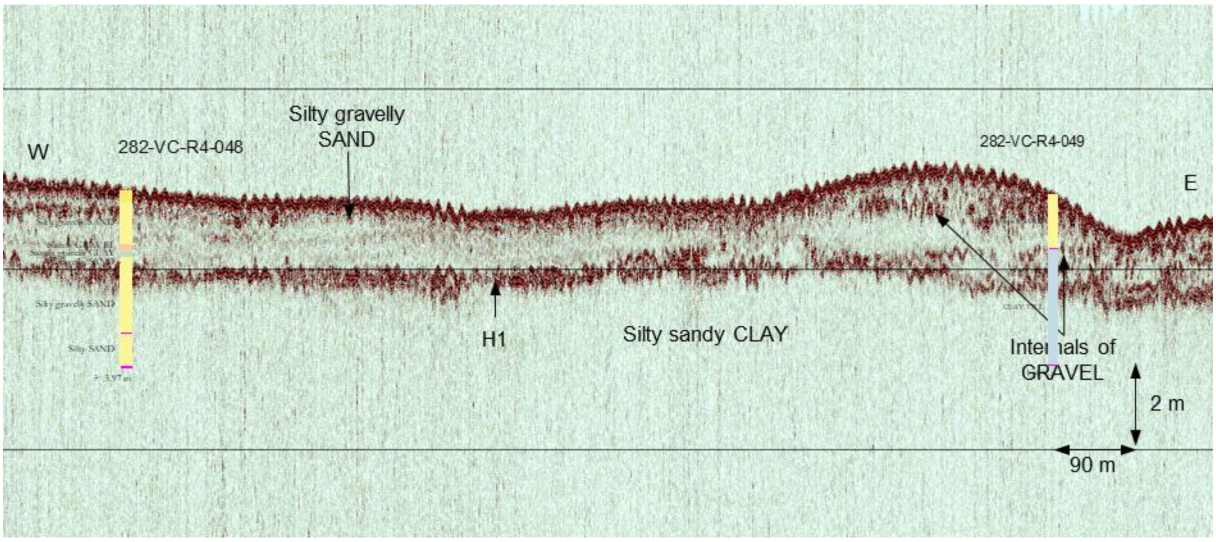


*Figure 101 Innomar SBP data example from KP 8.525 (E) to KP 9.911 (W).
Showing silty gravelly SAND overlying silty sandy CLAY.*

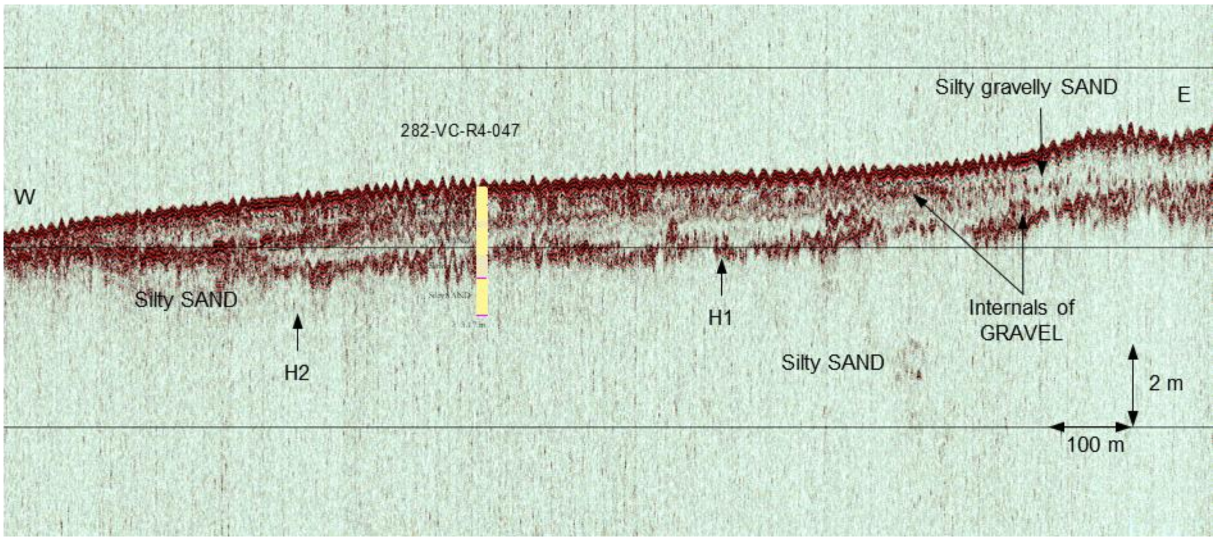


Figure 102 Innomar SBP data example from KP 10.173 (E) to KP 11.695 (W).
Showing silty gravelly SAND with internals of GRAVEL overlying channel infills, silty SAND.

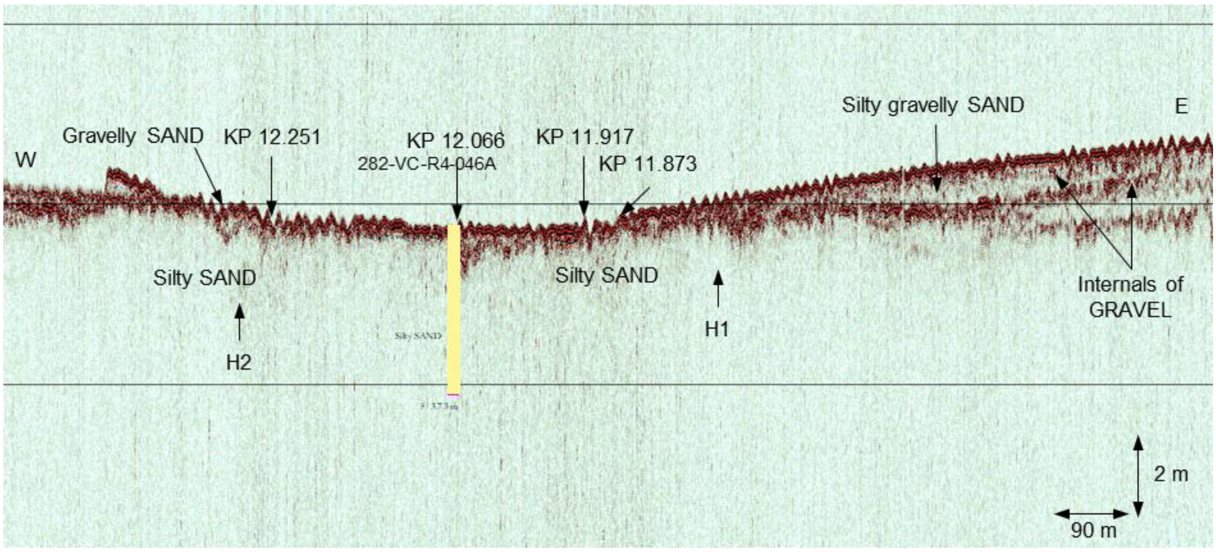


Figure 103 Innomar SBP data example from KP 11.152 (E) to KP 12.544 (W).
Showing silty gravelly SAND with internals of GRAVEL overlying channel infills, silty SAND. Silty SAND outcrops at seabed.

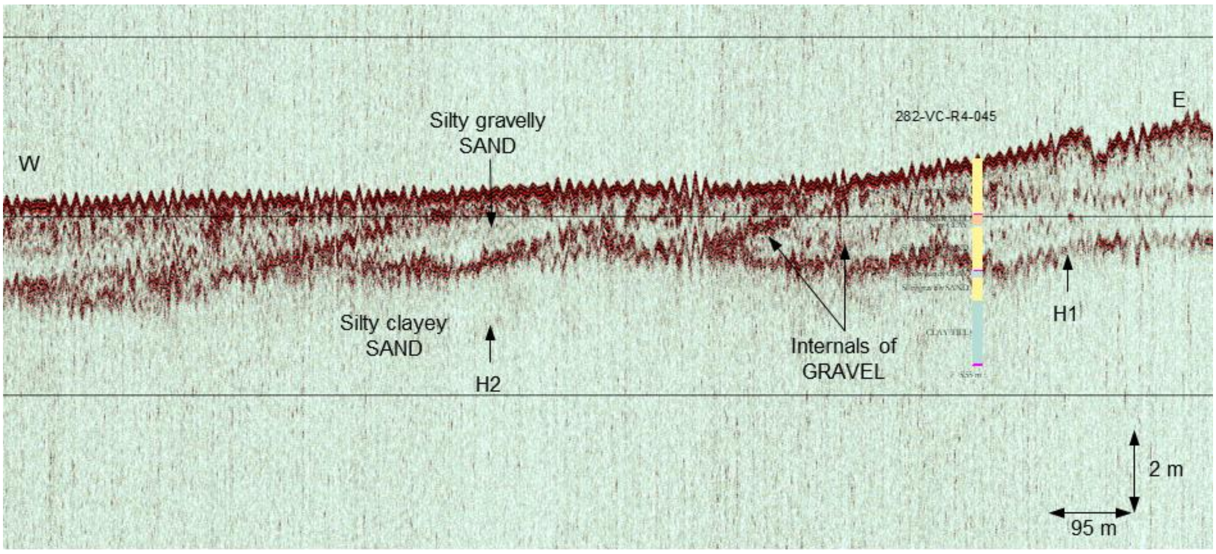


Figure 104 Innomar SBP data example from KP 12.826 (E) to KP 14.244 (W).
Showing silty SAND with internals of GRAVEL overlying either channel infills, silty SAND or silty sandy CLAY.

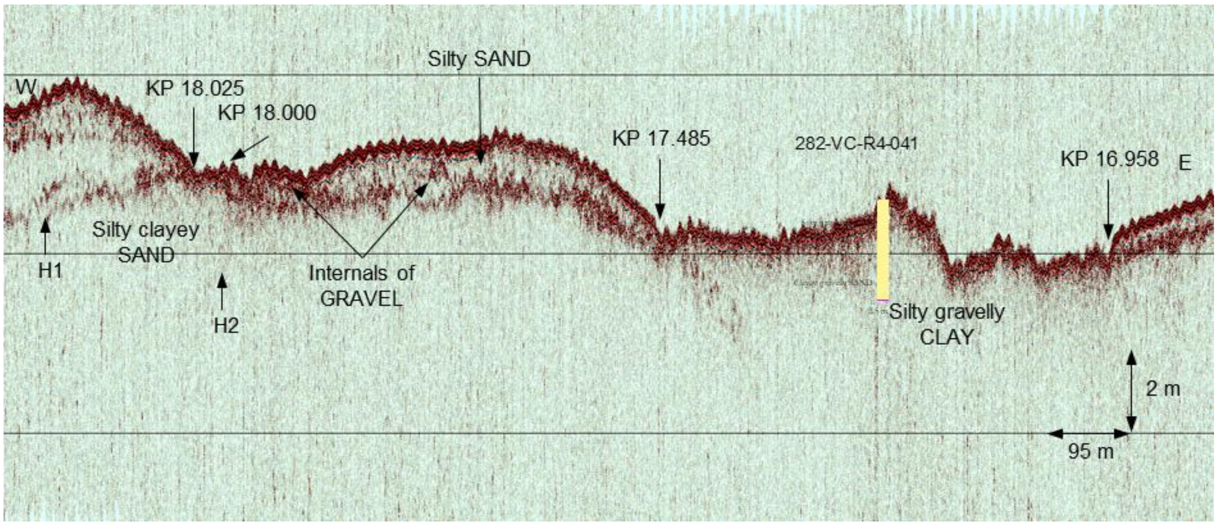


Figure 105 Innomar SBP data example from KP 16.841 (E) to KP 18.262 (W).
Showing silty SAND with internals of GRAVEL overlying channel infills, silty gravelly CLAY. Silty gravelly CLAY outcrops at seabed.

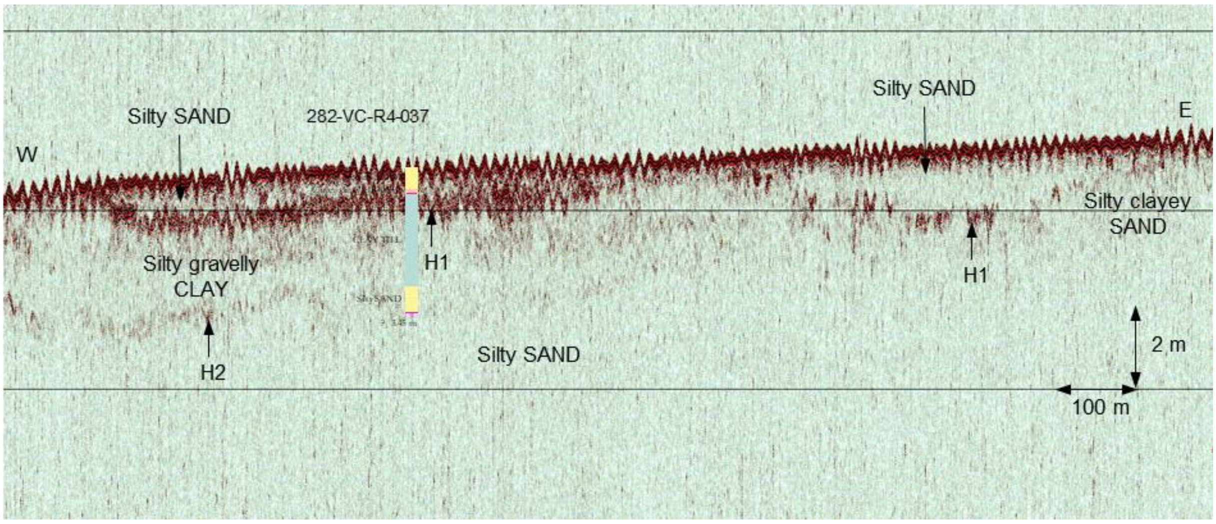


Figure 106 Innomar SBP data example from KP 21.331 (E) to KP 22.791 (W).
Showing silty SAND with internals of GRAVEL overlying either channel infills, silty SAND or silty gravelly CLAY.

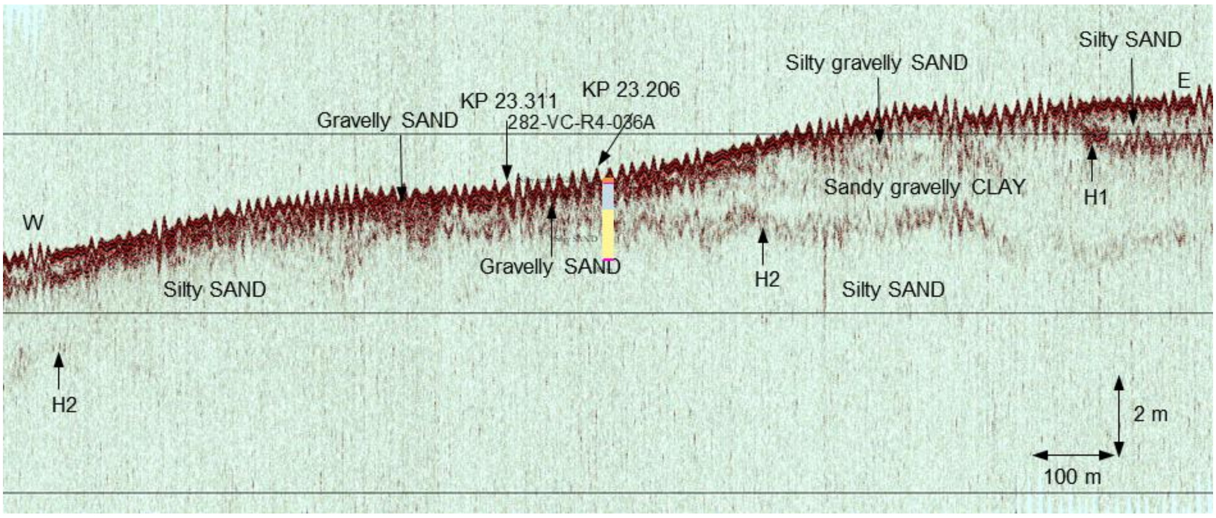


Figure 107 Innomar SBP data example from KP 22.498 (E) to KP 24.000 (W).
Showing silty SAND with internals of GRAVEL overlying channel infills, sandy gravelly CLAY. Overlies silty SAND.

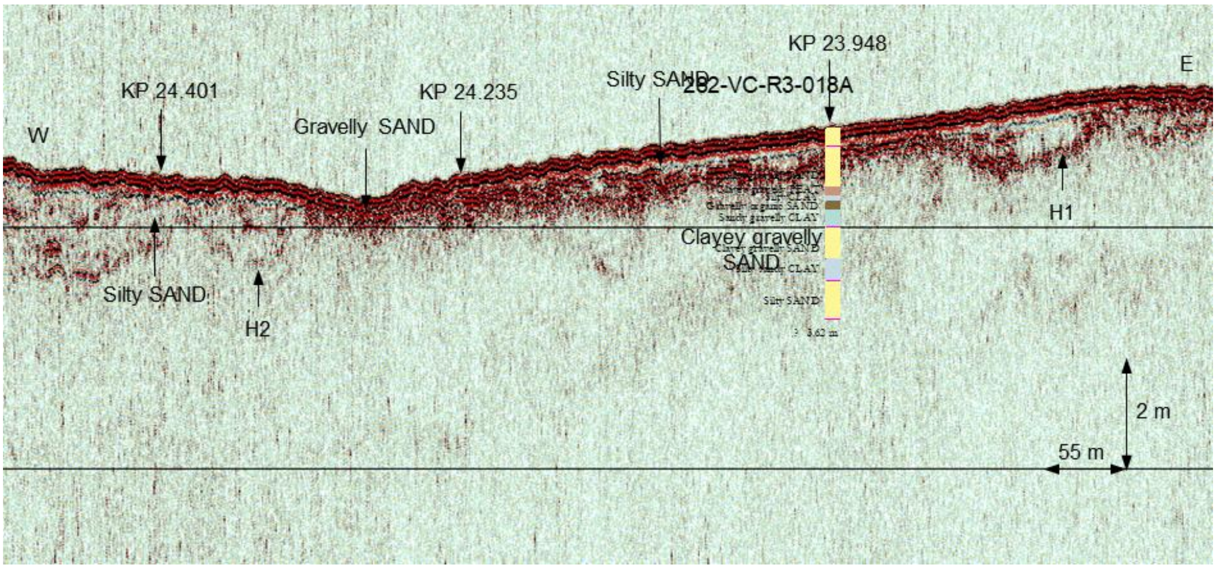


*Figure 108 Innomar SBP data example from KP 23.948 (E) to KP 24.401 (W).
Showing silty SAND with internals of GRAVEL and gravelly SAND overlying channel infills, silty SAND. Overlies clayey gravelly SAND.*

7.7.3 | CONTACTS AND ANOMALIES ROUTE 4

A total of 198 contacts were identified from the SSS and MBES data within the survey corridor on Route 4. The majority of the contacts have been classified as boulders. The SSS contacts are summarised in Table 32.

A total of 65 magnetic anomalies were detected on Route 4. Of these, 57 were unclassified and 8 were flagged as geology related.

No SSS contact positions correlated with detected magnetic anomalies.

Table 32 Summary of Route 4 SSS & MBES contacts.

CLASSIFICATION	NUMBER
Boulder	193
MMO (Debris)	3
MMO (Fishing gear)	2
Total	**198**

Table 33 Summary of Route 4 magnetic anomalies.

CLASSIFICATION	NUMBER
Unclassified, possible objects	57
Possible geology	8
Total	**65**

7.8| ROUTE 5: KP 0.000 TO KP 21.237

7.8.1| OVERVIEW

Route 5 covers the Landfall 2 survey area and the 800 m wide route corridor out to OWF Entry 4.

BATHYMETRY

The topographical survey, conducted by aerial drone, covered a section of the landfall zone that measured 246 m long at the route and spanned the full width of the survey corridor. Where the route crosses the landfall and bathymetry data there is a 214 m gap which resulted from poor coverage of the beach by the aerial drone survey. Towards the south of the route the coverage is improved, tapering to a minimum gap of 125 m at the boundary. To the north the gap is larger, up to 350 m.

From KP 0.00 to KP 0.134 the route crosses the undulating dune system and reaches a maximum elevation of +19.16 m at this point. From here the dune begins to slope down to a break in slope at KP 0.163 where the route crosses the seaward (western) face of the dune. The maximum slope angle is 43.0° at KP 0.167 on the dune. The western extent of the dune is reached at KP 0.205 where the route profile shows a local depression with an elevation of +2.11 m. From this point the crest of the dune stands 17.05 m above the level of the beach. From KP 0.205 there is a small increase in elevation before the beach slopes towards the sea at KP 0.222. The minimum elevation on the beach at the route is +1.26 m at KP 0.245.

North and south of the route the topography is broadly the same. To the east of the dune crest to the edge of the survey boundary the dune system creates a steeply undulating topography cut by numerous pedestrian and vehicular access routes to the beach. Near the northern boundary 4 buildings are covered by the survey area and in the south, 2 buildings are partially included.

The bathymetry along Route 5 gently deepens from -4.12 m DTU15 MSL, the start of the MBES data at KP 0.488 to -19.88 m DTU15 MSL, at KP 5.000; at this location the seabed gradient begins to level at approximately -20.0 m DTU15 MSL until KP 11.833. Here the seabed surface exhibits a number of erosional features. From this location the seabed gently deepens (< 1° slope) until the end of the route at KP 21.237 (Figure 109 and Figure 110).

The maximum depth along the route is -27.20 m DTU15 MSL at KP 19.048.

Between KP 1.291 and KP 2.000 the seabed is observed to be uneven, consisting of DIAMICTON outcrops and boulders. A further area of boulder fields is observed between KP 4.000 and KP 4.500. Whilst boulders are noticeable in the bathymetry the seabed itself is relatively flat with a bathymetry of approximately -20.00 m DTU15 MSL. However, some depressions, caused by scouring around the boulders, have a maximum depth of -20.06 m DTU15 MSL, at 441892.91 E and 6234247.80 N.

From KP 10.772 until KP 14.705 the seabed exhibits extensive depressions which also delineates the start of a varied and uneven surface with a number of erosional channels and localised highs, the latter often orientated in a ENE-WSW direction and in the order of 700 m wide (around KP 13.000). A further extensive area of depressions is observed between KP 15.630 and KP 18.150.

At the final approach to the OWF Entry 4 at KP 21.237, an area of sandwaves is observed that stretch across the survey corridor, crossing the proposed route at KP 20.670 which also defines the base of a channel that forms the eastern extent of the sandwave area.

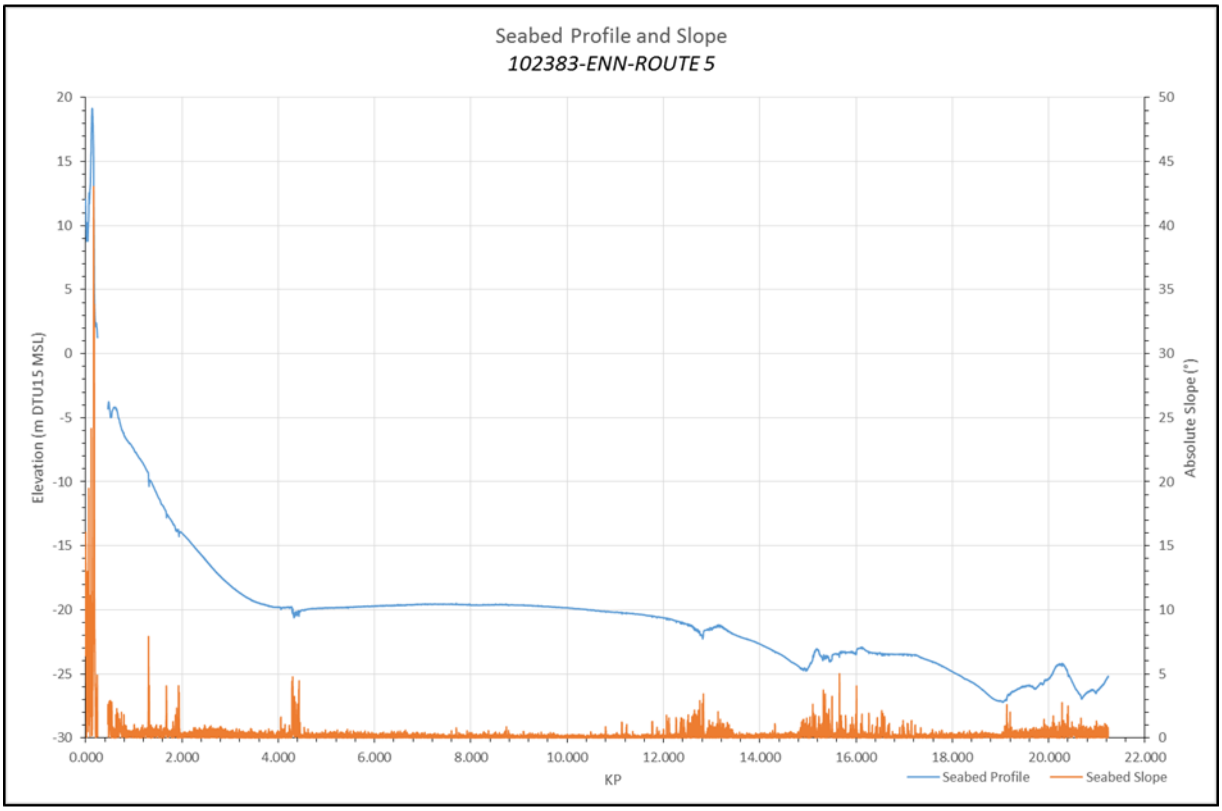


Figure 109 Route 5 bathymetry longitudinal profile.
Elevation is in metres (with bathymetric depths negative below MSL datum) and slope is in degrees (absolute value for visualisation). Vertical exaggeration x 250.

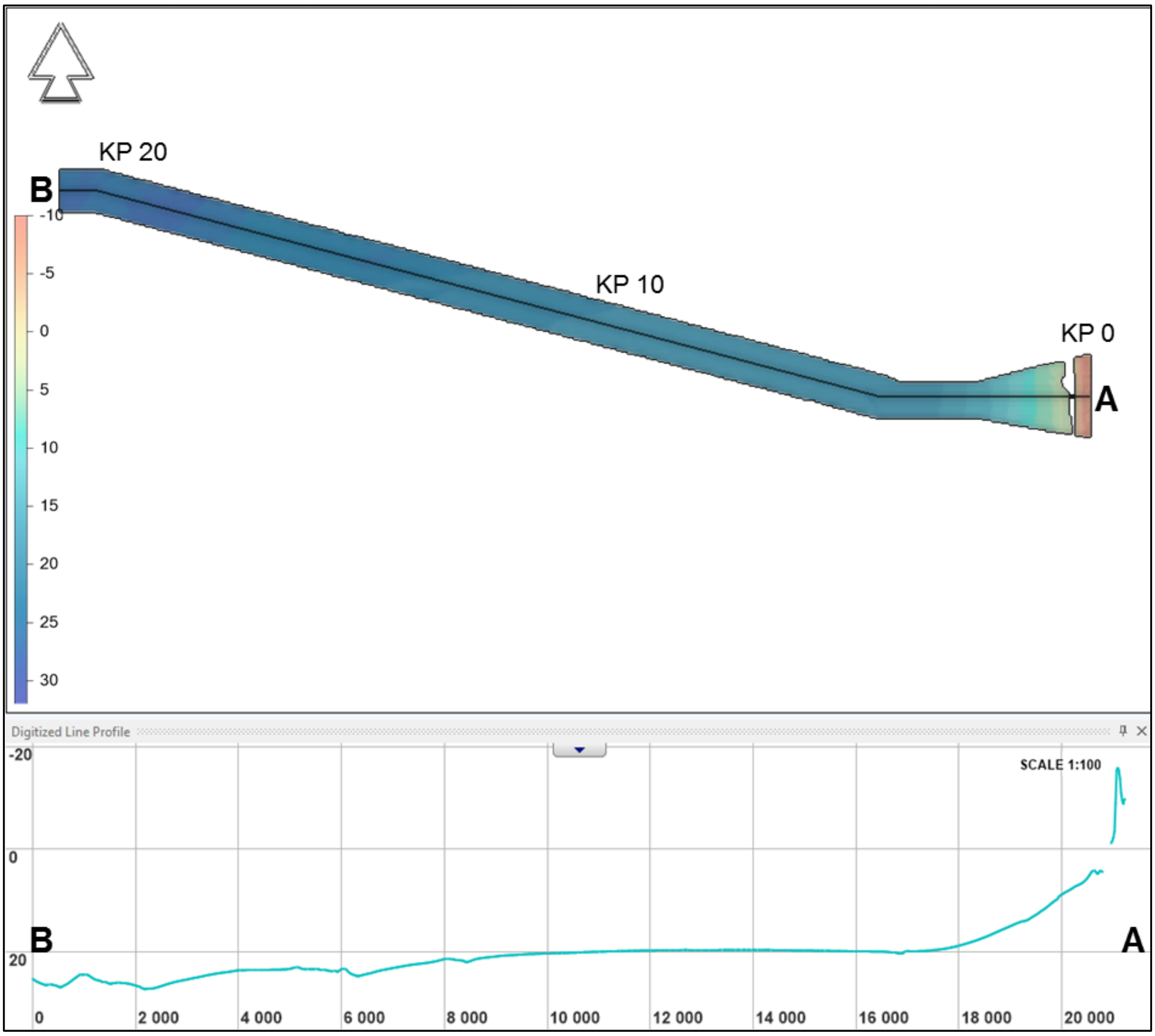


Figure 110 Overview image of Route 5.
The scale on the profile is in metres with distance given along the x-axis. Depth convention in NaviModel is positive down; Vertical exaggeration of profile x100.

SURFICIAL GEOLOGY

Route 5 is dominated by SAND, with large areas of depressions covering significant parts of the route. These features are visible as numerous depressions scattered across the seabed and are likely caused by changes in seabed current regime rather than shallow biogenic gas. The lack of gas blanking / turbidity in the upper layers of the SBP data suggests gas is unlikely to be the provenance for these features.

Occasional, discrete areas of gravelly SAND to Sandy GRAVEL and GRAVEL are mainly present in the nearshore zone and towards the end of the route.

DIAMICTON forms small discrete areas, mainly located between KP 1.000 and KP 2.000. These areas are commonly surrounded by fields of occasional boulders.

Minor areas of occasional boulders are also found, locally associated with the areas of gravelly SAND to sandy GRAVEL and GRAVEL (Appendix F|). Ripples too are associated with the coarser sediments along the route and are limited to a few areas. The general direction of sediment transport in the area is N-S close to shore with a slight rotation toward NE-SW further out.

A channel, dividing two sand banks is observed crossing the route at KP 20.670. The eastern sand bank also contains sand waves, indicative of active mobile sediments.

Contacts classified as man-made were detected in Route 5. In total, eight were observed, with one being classified as a possible wreck located at KP 4.226, (S_R5_0532, DCC -328 m). The rest of the contacts are unidentified debris.

A detailed description of the surficial geology is presented in Table 34.

SHALLOW GEOLOGY

A detailed description of the shallow geologic changes observed along the proposed Route 5 can be found in the Route 5 seabed details table presented in Table 34.

A number of sedimentary units were identified in the sub-surface geology down to a maximum depth of 9.8 m below the seabed (-30.0 m DTU15 MSL). The upper unit along the majority of the route has been confirmed to be SAND based on the geotechnical sampling results. These sediments are often laminated and acoustically transparent internally. Distinct and highly reflective layers are common within this section of the stratigraphy, varying in length, vertical placement, and amplitude (Figure 119). These were interpreted as internal layers of GRAVEL within the Unit.

The upper SAND unit varies from silty SAND to SAND and Gravel. More localised areas of GRAVEL and CLAY, were also observed along the route. The SAND unit extends along the entire route at variable depths ranging from the seafloor to 3.2 m below seabed. The base horizon for this unit (H1) is often undulating in character.

The upper SAND unit, bounded by horizon H1, lies atop an erosional discontinues surface named as H2 which represent the base of palaeo-channels of varying depth and extents. Based on the SBP penetration limit, the deepest channel structures reached was 9.8 m below the seabed.

The infill of these channels is variable, consisting of laminated and homogenous sediments which characterise the channel- infill along the route. In some channels the infill sediments form a uniform thick unit while others show a strong upper boundary reflector indicating a change in sediment characteristics. Based on the geotechnical results, sediments recovered ranged from Silty SAND and GRAVEL mixed to CLAY, PEAT and organic matter.

A grid was created to map the base of the upper SAND unit (H1) detected from SBP data related to depth below seabed and related to the MSL datum.

7.8.2 | DETAILED DESCRIPTION

A detailed presentation of the conditions and features on Route 5 are shown in Table 34.

Table 34 Route 5 seabed details.

KP	ASSOCIATED CHART	DESCRIPTION (INCLUDING MIN/MAX DEPTH BSB TO BASE OF UNIT)	REMARK
0.000 – 12.781	103282-ENN-MMT-SUR-DWG-ALR50001 103282-ENN-MMT-SUR-DWG-ALR50002	**Bathymetry:** Undulating dune system between KP 0.000 and crest of dune at KP 0.134. Dune very steeply descends from +19.16 m to +2.11 m at KP 0.205. Beach gently slopes to surf zone at +1.26 m at KP 0.245. Maximum elevation +19.16 m at KP 0.134. Minimum elevation +1.26 m at KP 0.245. Moderately deepening seafloor from the beach outwards with sandbanks and channels Minimum depth -3.75 m at KP 0.477. Maximum depth -22.00 m at KP 12.762.	There is a scattered field of small boulders at KP 4.000 Shallow Channel (Figure 111) Total elevation/depth range = 41.16 m. Maximum slope of landfall of 43.0° at KP 0.167. Maximum slope sub-sea of 7.9° at KP 1.305.
		Surficial geology: SSS coverage starts at KP 0.427. This section is dominated by SAND. Adjacent to the landfall, patches of gravelly SAND to sandy GRAVEL and GRAVEL are sparse. DIAMICTON is also present as scattered and discrete patches up until KP 4.523. The patches of DIAMICTON are often associated with surrounding fields of occasional boulders. An area of sandwaves are present near the shore line at KP 0.427 to KP 0.685. Large areas of depressions are present in the latter parts of the section .	Possible wreck at: KP 4.226 (DCC -328.81): possible wreck (7.2 m long, 2.7 m wide and 1.3 m high) identified on SSS and MBES data. No MAG correlation. Two possible linear feature identified with MAG data only crosses the route at • KP 3.830 • KP 7.204. The lack of corresponding SSS and MBES detection indicate possibly buried objects. Two contacts classified as debris have been identified within 50 m from the route on SSS and MBES data: • KP 2.000 (DCC 5.00) - S_R5_0083 • KP 4.136 (DCC 15.46) - S_R5_0028

KP	ASSOCIATED CHART	DESCRIPTION (INCLUDING MIN/MAX DEPTH BSB TO BASE OF UNIT)	REMARK
			Fields of occasional boulders crossing the route between: • KP 1.765 and KP 1.863 • KP 1.910 and KP 1.929 • KP 1.943 and KP 2.003 Fields of numerous boulders crossing the route between: • KP 3.794 and KP 3.799 • KP 4.006 and KP 4.156 • KP 4.185 and KP 4.286 • KP 4.346 and KP 4.372 • KP 4.393 and KP 4.470 Area of depressions crossing the route between KP 10.757 and KP 12.755
		Shallow Geology: SBP coverage begins at KP 0.477. KP 0.477 to KP 0.828: SAND, fine to coarse (0.8 – 3.0 m BSB) with internals of gravels overlaying either channel infills, silty SAND (1.2 – 5.1 m BSB) or silty sandy CLAY. KP 0.828 to KP 1.302: SAND, fine to coarse (0.2 – 1.4 m BSB) with internals of gravels overlaying silty sandy CLAY. KP 1.302 to KP 1.319: Silty sandy CLAY outcrops at seabed. KP 1.319 to KP 1.843: SAND, fine to coarse (0.3 – 1.0 m BSB) with internals of gravels overlaying silty sandy CLAY. KP 1.843 to KP 1.889: Silty sandy CLAY outcrops at seabed. KP 1.889 to KP 4.330: Silty SAND (0.3 – 1.9 m BSB) with internals of GRAVEL overlaying silty sandy CLAY. Channel infills are also present (1.2 – 3.1 m BSB).	(Figure 114), (Figure 115), (Figure 116), (Figure 117), (Figure 118) and (Figure 119) Vibrocore results (282-VC-R5-069) indicate PEAT layer between 0.56 m to 0.90 m BSB.

KP	ASSOCIATED CHART	DESCRIPTION (INCLUDING MIN/MAX DEPTH BSB TO BASE OF UNIT)	REMARK
		KP 4.330 to KP 4.440: Gravelly SAND outcrops at seabed. KP 4.440 to KP 6.694: Silty SAND (0.4 – 2.3 m BSB) with internals of GRAVEL overlaying sandy SILT. KP 6.694 to KP 12.781: Silty gravelly SAND (0.8 – 3.2 m BSB) with internals of GRAVEL overlaying either channel infills, silty CLAY (1.1 – 9.8 m BSB) or silty SAND.	
12.781 – 21.237	103282-ENN-MMT-SUR-DWG-ALR40002 103282-ENN-MMT-SUR-DWG-ALR40003	**Bathymetry:** Relatively flat seabed with areas of channels and sandbanks Minimum depth -21.17 m at KP 13.136. Maximum depth -27.22 m at KP 19.041.	Slope angles generally very gentle to gentle. Depth range = 6 m. Maximum slope of 5.0° at KP 15.655.
		Surficial Geology: The section is dominated by SAND (Figure 112, Figure 113). Different sediments are also present, often associated with ripples. Minor areas of Gravelly SAND to Sandy GRAVEL and isolated sections of GRAVEL (Figure 113) are also present and are also often associated with ripples. Boulder fields are conspicuous by their absence. Only two discrete areas, observed between KP 14.000 and KP 15.000 are present within this section, where they are approximately 138 m from the survey route. A sand bank is observed, crossing the route at KP 20.670.	One piece of debris is located close to the route at KP 15.655 (DCC 3.98 m) and is detected both on SSS and MBES data. No MAG anomaly correlates with this contact. Areas of depressions crossing the route between: • KP 12.876 and KP 12.932 • KP 13.240 and KP 13.732 • KP 13.830 and KP 14.697 • KP 15.634 and KP 15.938 • KP 15.953 and KP 18.145
		Shallow Geology: KP 12.781 to KP 12.825: Silty CLAY outcrops at seabed.	(Figure 119), (Figure 120), (Figure 121), (Figure 122) and (Figure 123)

KP	ASSOCIATED CHART	DESCRIPTION (INCLUDING MIN/MAX DEPTH BSB TO BASE OF UNIT)	REMARK
		KP 12.825 to KP 14.959: Silty gravelly SAND (0.4 – 2.3 m BSB) with internals of GRAVEL overlaying either channel infills, silty SAND and clay (0.7 – 6.4 m BSB) or sandy gravely CLAY. KP 14.959 to KP 15.136: Sandy gravelly CLAY outcrops at seabed. KP 15.136 to KP 15.252: Silty SAND (0.3 – 0.8 m BSB) with internals of GRAVEL overlaying either channel infills, silty SAND and clay (0.8 – 1.2 m BSB) or sandy gravelly CLAY. KP 15.252 to KP 15.372: Sandy gravelly CLAY outcrops at seabed. KP 15.372 to KP 15.495: Gravelly SAND (0.3 – 0.6 m BSB) overlaying either channel infills, silty SAND and clay (0.6 – 1.9 m BSB) or sandy gravely CLAY. KP 15.495 to KP 21.237: Silty SAND (0.3 – 1.8 m BSB) with internals of GRAVEL overlaying either channel infills, silty gravelly SAND and clay (0.9 – 7.3 m BSB) or sandy gravelly CLAY. Gravelly SAND outcrops at seabed between KP 19.124 to KP 19.220.	

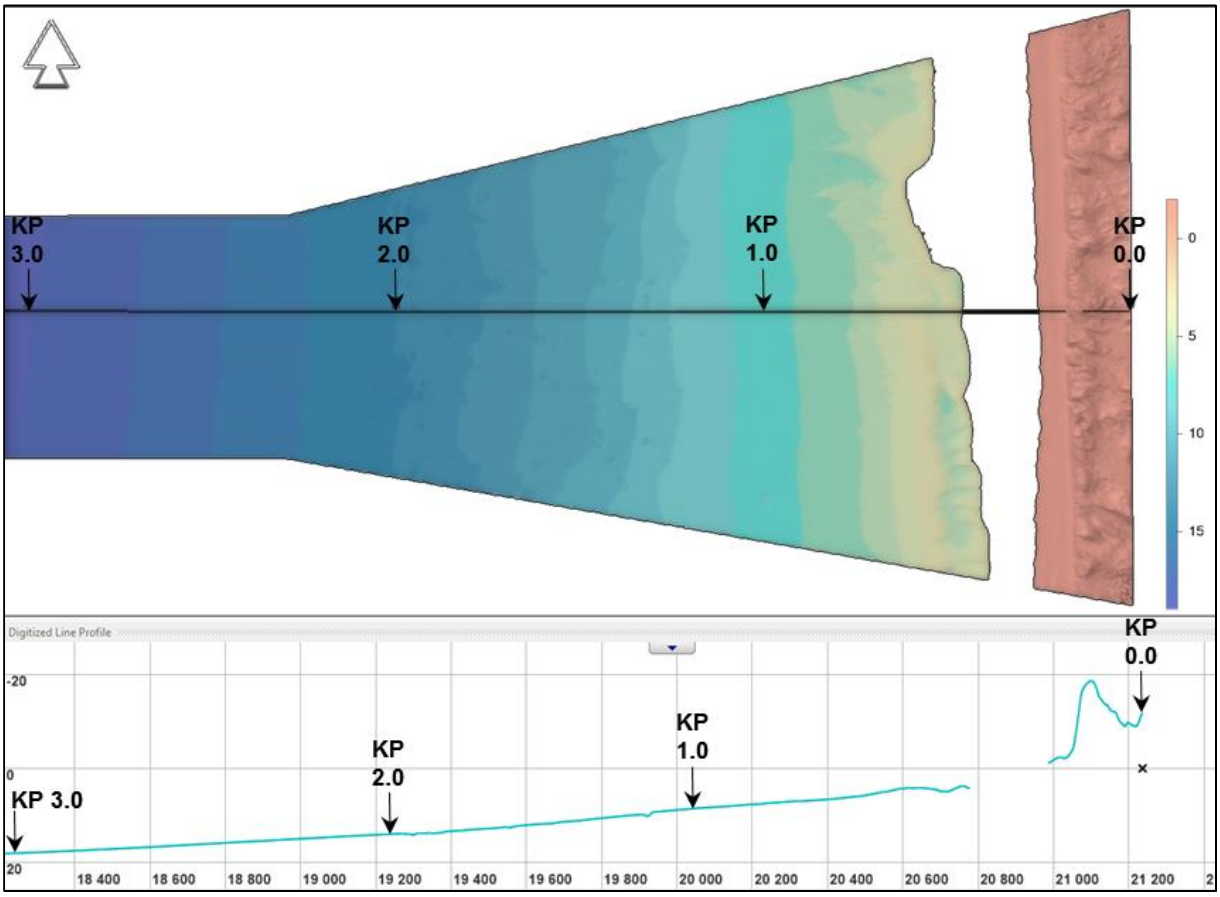


Figure 111 Shallow channel close to shore at Route 5 at KP 0.000 to KP 3.000.
Depth convention in NaviModel presented positive down; Vertical exaggeration of profile x12.5.

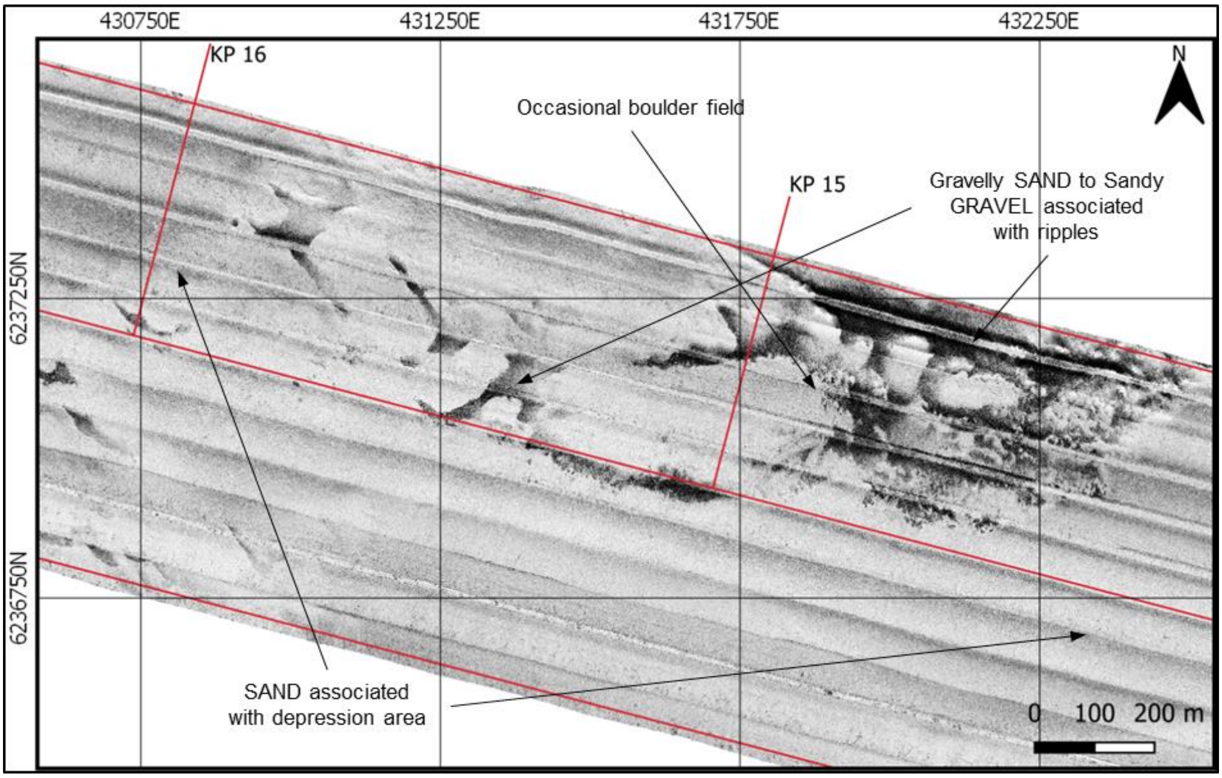


Figure 112 Overview of surficial geology from KP 14.1 to KP 16.2 as seen on SSS.

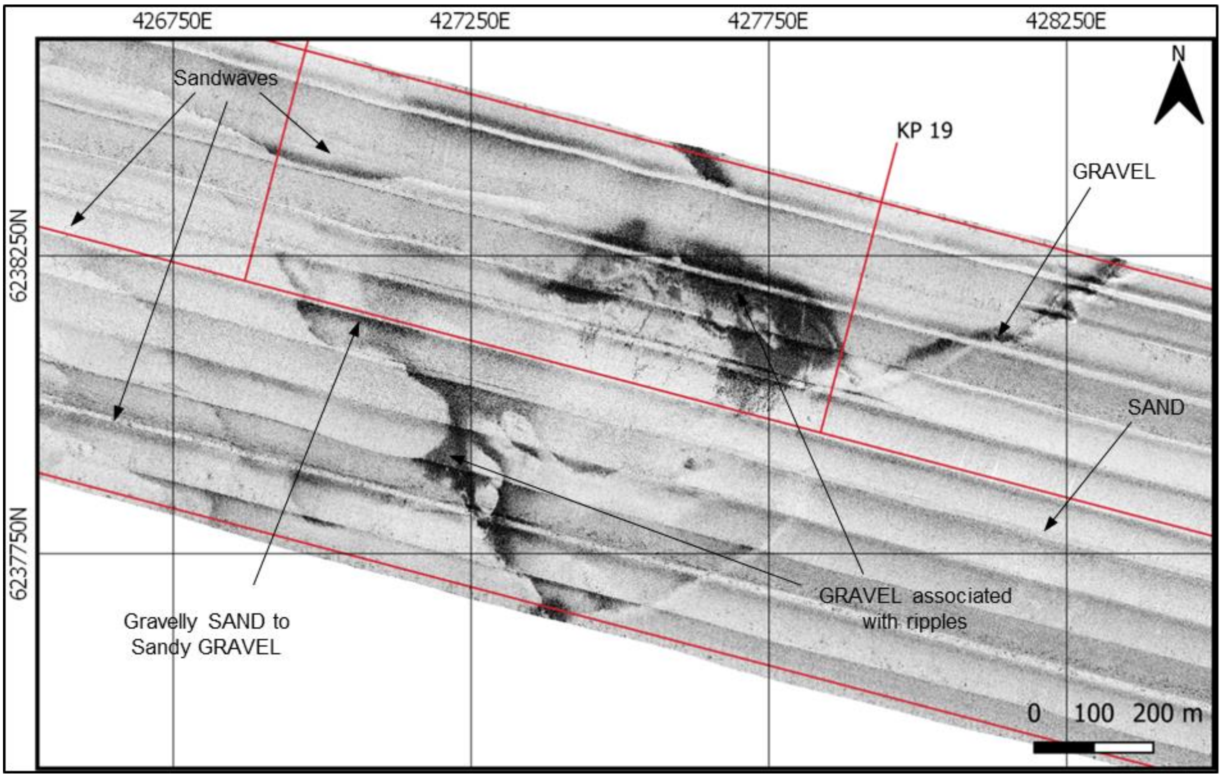


Figure 113 Overview of surficial geology from KP 18.3 to KP 20.4 as seen on SSS.

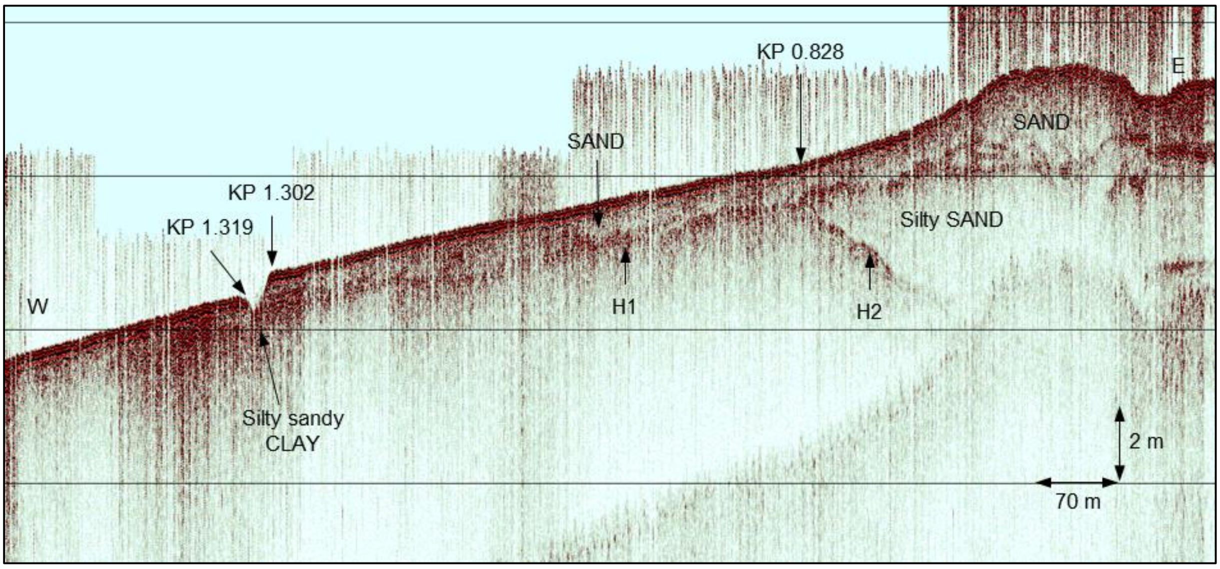


Figure 114 Innomar SBP data example from KP 0.497 (E) to KP 1.544 (W).
Showing SAND overlying channel infills, silty SAND. Silty sandy CLAY outcrops at seabed.

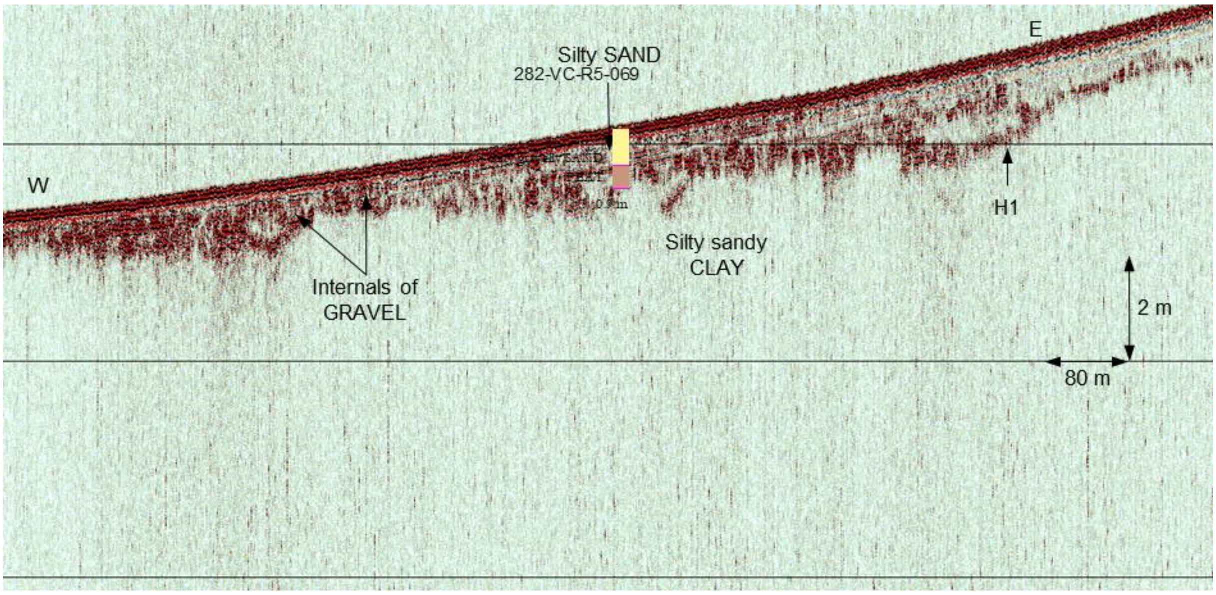


Figure 115 Innomar SBP data example from KP 2.461 (E) to KP 3.674 (W).
Showing silty SAND with internals of GRAVEL overlying silty sandy CLAY.

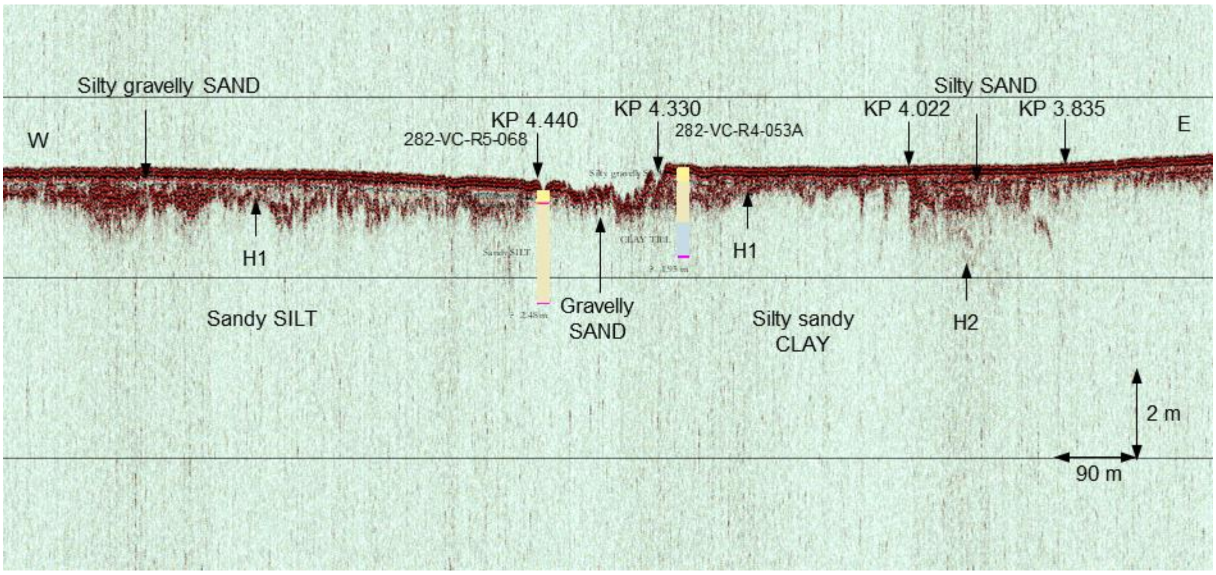


Figure 116 Innomar SBP data example from KP 3.670 (E) to KP 5.053 (W).
Showing silty SAND and silty gravelly SAND overlying channel infills, silty sandy CLAY through silty SAND.

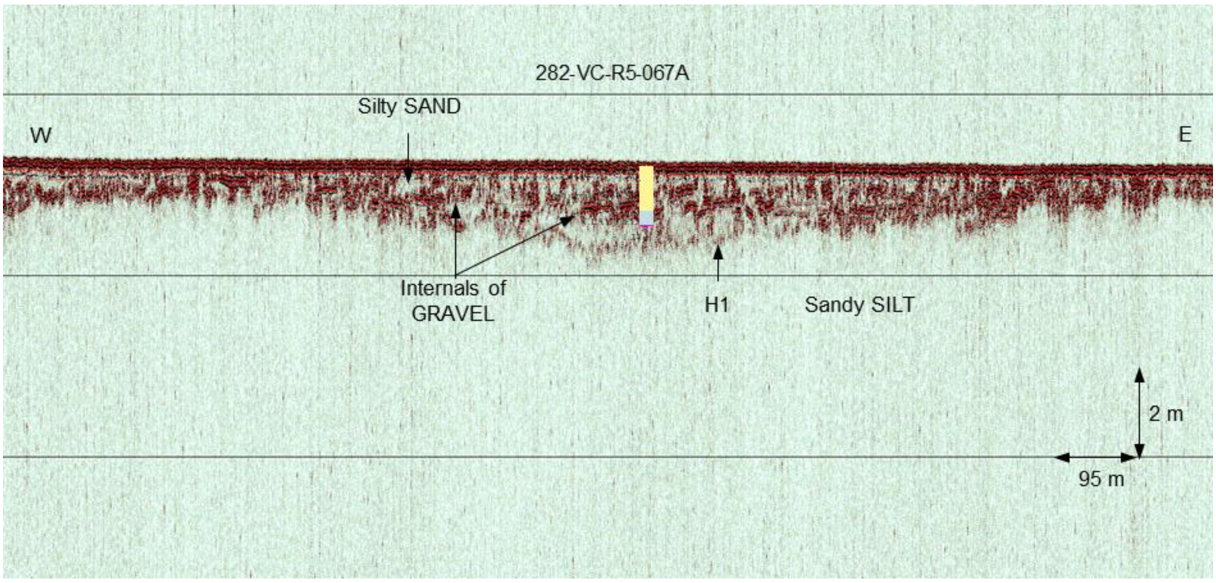


Figure 117 Innomar SBP data example from KP 5.133 (E) to KP 6.539 (W).
Showing silty SAND with internals of GRAVEL overlying sandy SILT.

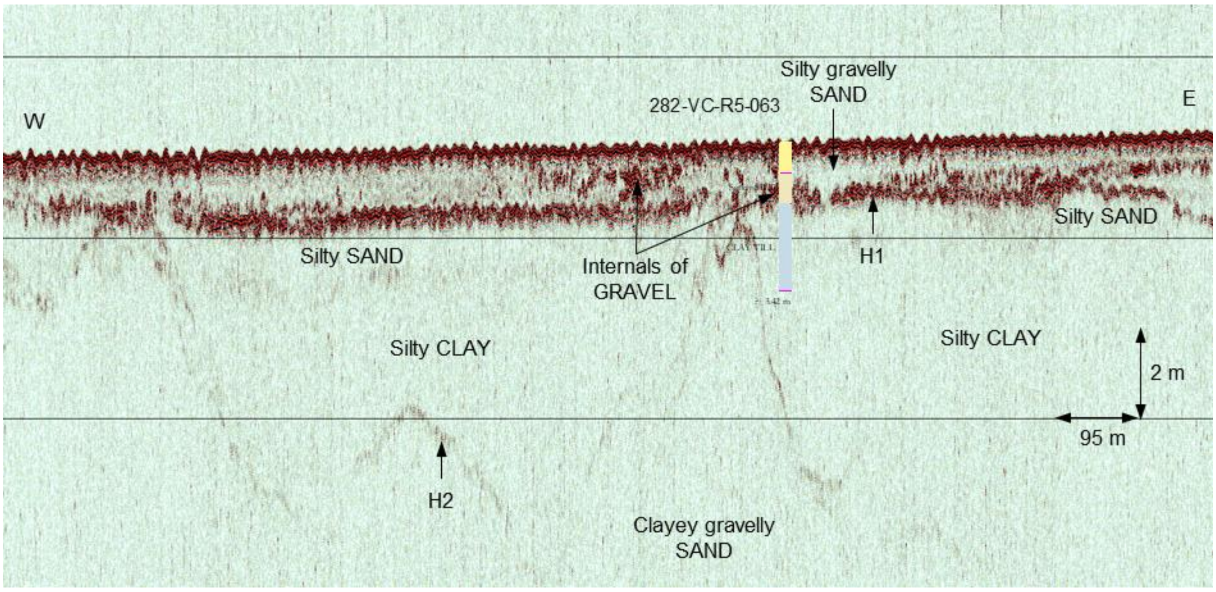


Figure 118 Innomar SBP data example from KP 9.969 (E) to KP 11.372 (W).
Showing silty gravelly SAND with internals of GRAVEL overlying either channel infills, silty SAND or silty CLAY over clayey gravelly SAND.

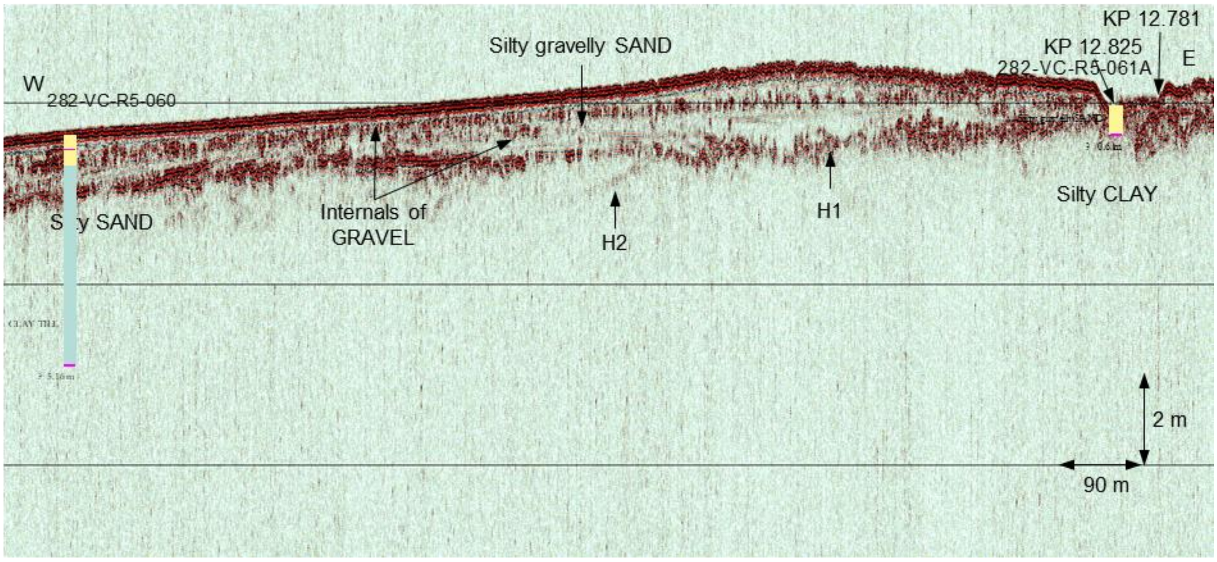


Figure 119 Innomar SBP data example from KP 12.695 (E) to KP 14.062 (W).
Showing silty gravelly SAND with internals of GRAVEL overlying channel infills, silty SAND and silty CLAY. Sandy gravelly CLAY outcrops at seabed.

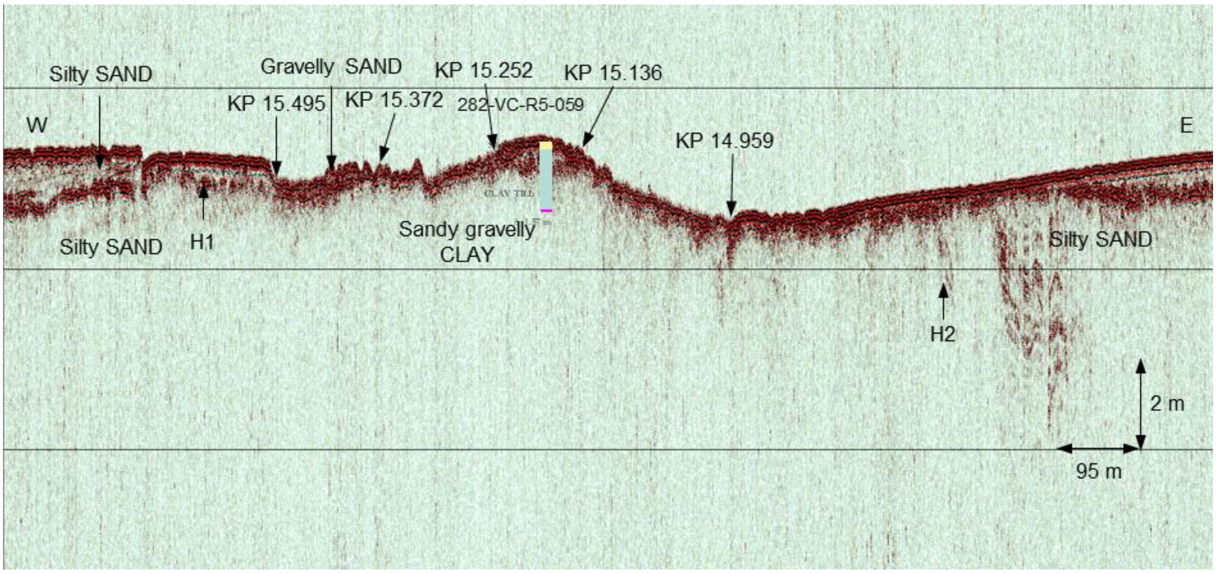


Figure 120 Innomar SBP data example from KP 14.372 (E) to KP 15.808 (W).
Showing silty SAND with internals of GRAVEL overlying channel infills, silty SAND. Sandy gravelly CLAY outcrops at seabed.

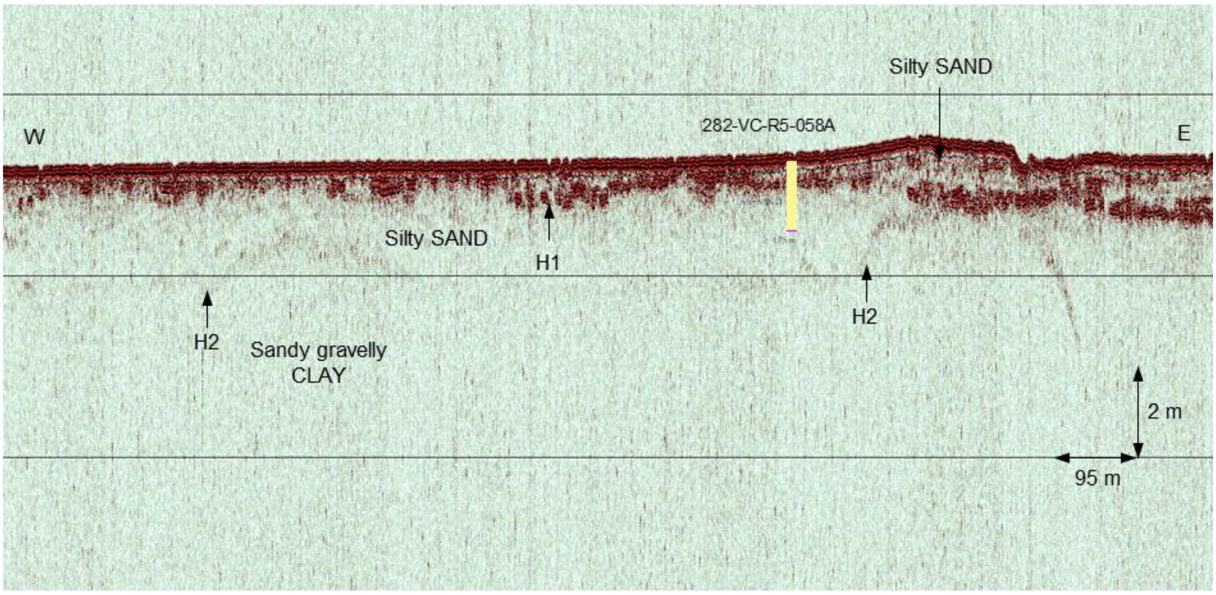


Figure 121 Innomar SBP data example from KP 15.775 (E) to KP 17.196 (W).
Showing silty SAND with internals of GRAVEL overlying either channel infills, silty SAND or sandy gravelly CLAY.

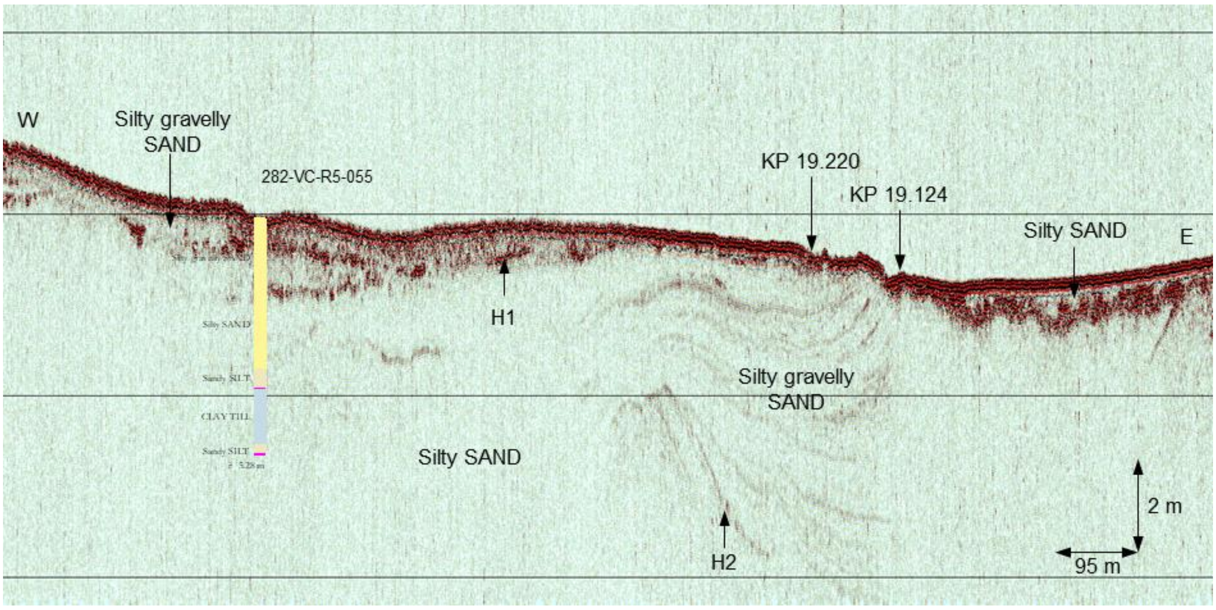


Figure 122 Innomar SBP data example from KP 18.737 (E) to KP 20.187 (W).
Showing silty SAND with internals of GRAVEL overlying either channel infills, silty SAND or silty gravelly SAND.

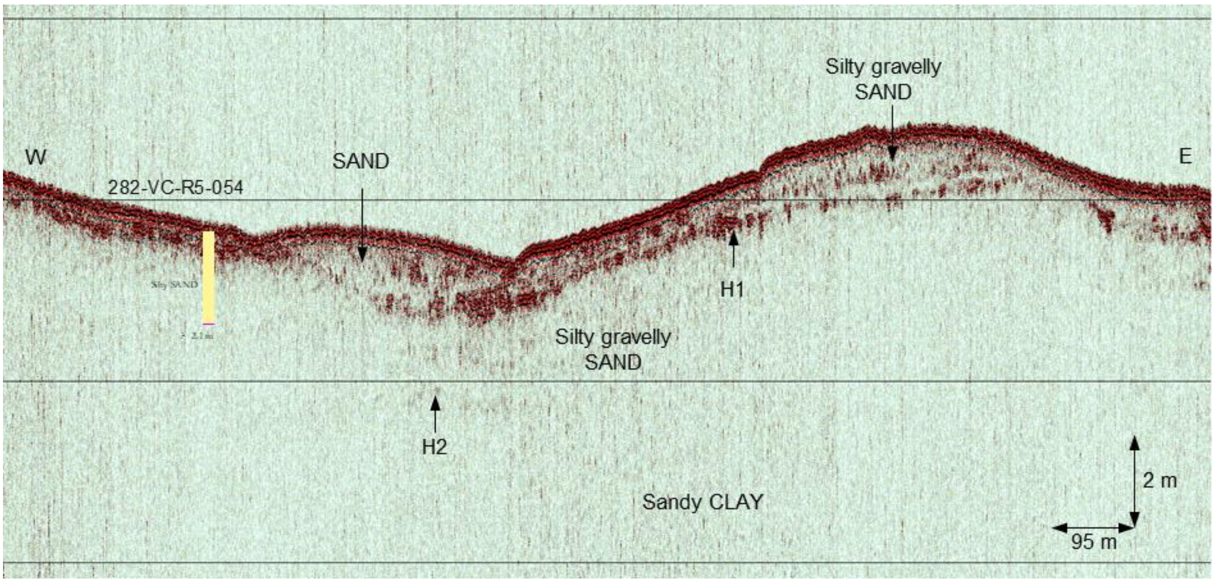


Figure 123 Innomar SBP data example from KP 19.902 (E) to KP 21.237 (W).
Showing silty gravelly SAND and SAND with internals of GRAVEL overlying either channel infills, silty gravelly SAND or sandy CLAY.

7.8.3 | CONTACTS AND ANOMALIES ROUTE 5

A total of 571 contacts were identified from the SSS and MBES data within the survey corridor on Route 5. The majority of the contacts have been classified as boulders. The SSS contacts are summarised in Table 35.

A total of 59 magnetic anomalies were detected on Route 5. Of these, 39 were unclassified, 9 were flagged as possibly geological and 11 as part of linear chain of anomalies (Table 36).

No SSS contact positions correlated with magnetic anomalies.

Table 35 Summary of Route 5 SSS & MBES contacts.

CLASSIFICATION	NUMBER
Boulder	567
MMO (Debris)	3
Wreck	1
Total	**571**

Table 36 Summary of Route 5 magnetic anomalies.

CLASSIFICATION	NUMBER
Unclassified, possible objects	39
Possible geology	9
Linear anomalies	11
Total	**59**

8| INSTALLATION CONSTRAINTS

The geological properties of the seafloor present a number of different challenges to the installation and protection of a subsea cable. This section details the features that may impose constraints on the cable laying operation. These cover bedrock and hard sediments, boulder fields, seabed gradients, mobile sediments, acoustic blanking, gas/fluid seepage features and unstable sediments. Man-made activities and features such as fishing, cables, pipelines, wrecks and UXO are also considered.

The information below is a generalized description of possible constraints. They are described in detail per route from section 8.2| onwards.

8.1| POSSIBLE CHALLENGES TO CABLE INSTALLATION AND PROTECTION

8.1.1| SEABED GRADIENTS

Steep ground is considered problematic when the seabed has a slope of a magnitude that affects the speed or effectiveness of the trenching operation. The critical slope angle depends on the trenching equipment. There may well be a difference in critical angle between along track slopes and across track slopes. Trenching and/or rock installation may also change slope stability and induce sediment slides.

Steep ground may affect cable installation. If the slope angle is great enough it can cause the cable to move out of position, which could also result in excess tension in the cable.

Steep slopes may cause problems for cable protection e.g., rock and gravel berms, if the slope angle causes the protective material to slide downhill and eventually expose the cable.

8.1.2| BEDROCK AND HARD SEDIMENT

Bedrock and hard sediment are considered an issue when the seabed proves to have properties that affect and effectively inhibit the use of the trenching methods.

Bedrock and hard sediment that subcrop or outcrop at seabed may cause problems with reaching the required burial depth. In addition, topographical irregularities in outcropping bedrock or hard sediment may cause freespan, point load, and abrasion. Methods to avoid problems with bedrock or hard sediment include appropriate micro-routeing, deployment of heavier trenching machines, or the installation of additional cable protection such as Pre lay rock installation/dredging to level the route to avoid free span.

8.1.3| BOULDER FIELDS

Fields of boulders may cause freespan and point load problems, and may also cause problems during the potential trenching of the cable. Methods of avoidance include, re-routing, boulder removal by using e.g. an ROV or a pulled plough pushing the boulders aside, and pre-lay rock placement.

Buried boulders can cause difficulties, especially if they are discovered during trenching of the cable. An effective method for pre-burial assessment of buried boulders is to perform a pre-lay trench.

8.1.4| MOBILE SEDIMENT

Mobile sediments may bury or expose the cable. Both scenarios are to be avoided, since excess burial depth may result in overheating, and exposure will leave cables vulnerable to damage.

Cable protection by trenching in sandwave areas is complicated, in particular where the trenching equipment will pass through a crest or trough, and the equipment is not properly supported on ground. In such situations, the burial depth is affected, complicating the procedure of reaching the designated depth and protection level.

In areas where there is evidence of mobile sediments, pre-dredging or pre-sweeping the cable route prior to laying and trenching is considered a good solution for mitigating future problems with cable exposure, or excessive burial depths.

Using rock placement on top of the laid cable is also a method to stabilise an area with mobile sediments. However, this solution may cause stones to sink and spread uncontrollably in sand if the erosional forces are strong, and may therefore require ongoing maintenance. Rock placements can also lead to scouring which may need post-lay control.

An often economically viable method of ensuring the safety of the cables is to perform frequent burial depth measurements and burial remediation, for example on a yearly basis in critical areas.

It is often necessary to perform a sandwave analysis, identifying any high risk areas in advance, and propose mitigation procedures based on pre-lay investigations. Post-lay activities may be very expensive, and are not always effective.

To be able to measure the mobility of the sediment, a reliable method is to compare at least two sets of data, which has been retrieved with some time elapsed in between the different surveys. Based on the result, the speed and volume of sediment movement can be calculated.

8.1.5| SLOPE STABILITY

Unstable sediment is a problem during cable installation, if sediment slumps, this may unbalance the equipment. Unstable sediments can cause problems for cable protection as a result of movement or collapse after installation. Unstable sediments can also cause problems for the operation integrity of the cable as slumping post installation can result in direct damage to the cable as well as freespan and exposure.

Trenching and/or rock installation may also change slope stability and induce sediment slides. Mitigation measures include cable re-routeing.

No areas of concern were identified during the survey.

8.1.6| ACOUSTIC BLANKING AND GAS SEEPAGE FEATURES

Shallow gas and gas seepage features, pockmarks and methane derived authigenic carbonate (MDAC) may cause problems to the cable installation. Sediment movements within pockmarks, uncontrollable movements of the cable may expose the cable to unnecessary strain. The thermal properties can be affected, causing problems with discharge of heat in the sediment around pockmarks. If a cable is laid in a pockmark or in a developing pockmark there is a risk for vortex induced vibrations in the cable, if it would go into freespan. Gas seeps may accelerate corrosion to the cable amour if seeps are corrosive.

The presence of MDAC and/or pockmarks can cause difficulties, especially if they are discovered during cable installation. During installation potential problems are reduced sediment stability, difficulties in choosing burial equipment, trencher instability, and potential problems to protect the cable in an acceptable way. It should also be considered that the presence of shallow gas may indicate larger amounts of gas at deeper levels.

Shallow gas may also be caused by organic matters, especially in the channel filled areas on the North Sea Plateau. Organic matters normally have a reduced thermal conductivity compared to minerogenic sediments and may cause overheating.

Mitigation includes cable re-routeing and additional protection measures.

8.1.7| CABLES AND PIPELINES

Cable crossings and pipeline crossings should ideally be made as perpendicular as possible. Thus simplifying the design of the crossing arrangement, and minimising the risk of future maintenance and repair operations on neighbouring installations affecting the cable.

Within the survey area, no cables or pipelines are known to cross the proposed survey routes.

8.1.8| WRECKS AND ANTHROPOGENIC DEBRIS

Wrecks and other anthropogenic debris present an abrasive threat to a cable, and may hold the cable in suspension from the seabed. Wreck sites can often be extended, with debris scattered around the main object. Subsequent secondary entanglement with fishing gear is another risk to a cable laid over wreck sites. It is also possible that shipwrecks may be considered of archaeological importance.

Mitigation includes cable re-routeing and additional protection measures and consultation with the relevant maritime authorities with regards to wrecks of archaeological significance.

8.1.9| UNEXPLODED ORDNANCE

If unexploded ordnance (UXO) or UXO related objects are present, they may be possible to avoid by appropriate micro-routeing. If re-routeing is impractical, UXO clearance operations will be necessary. Magnetometer records collected during the survey were used to identify cables/pipelines and ferrous objects on the seafloor within the survey corridor. Note that due to line spacing the magnetometer survey does not constitute as a UXO survey. A dedicated UXO survey is strongly recommended prior to the cable installation along any proposed cable route.

8.1.10| SEDIMENTS OF VARIABLE THERMAL RESISTIVITY

The thermal resistivity of soil varies with changes in water content, composition, compaction and temperature. Organic matter is known to have a high thermal resistivity and therefore where present in the vicinity of buried cables can cause the cable temperature to rise resulting in poor efficiency or failure. Fibrous material may also pose difficulties for trenching due to low material strength and compressibility under load.

Thermal resistivity tests were undertaken as part of the geotechnical workscope and are detailed in the Thor OWF Export Cable Routes Geotechnical Survey report (Table 6). Where organic rich or PEAT strata were encountered in VC logs, additional thermal readings were taken.

Mitigation includes cable re-routeing and appropriate burial assessment to select suitable burial depths.

8.1.11| FISHING ACTIVITY

Fishing activities have the potential to damage cable installations. In particular, demersal fishing, i.e. seafloor fishing, is associated with high risks. Trawling and scalloping are often mentioned as the most immediate threats, since they operate on the seafloor using heavy equipment with potential to penetrate relatively deep into the sediments. Pots and creels placed on the seafloor are attached to buoys with anchors, with the potential to penetrate into the sediments. Fish farms in the nearshore areas pose an installation constraint as well as the risk of damage to an installed cable should anchors and chains move.

The risk of fishing gear damaging the cable is very high if the cable is lying unprotected on top of the seafloor. However, sufficient burial of the cable with backfill or the installation of cable protection dramatically reduces this risk.

8.1.12| VERY LOW STRENGTH SOILS

Very low strength soils can pose a hazard for cable installation. Burial tool stability is an issue in low strength soils unless appropriate methods and mitigation are undertaken. Similar problems may occur when moving between soils of differential strengths whereby trenching tools or ploughs may dig in when moving to low strength soils or ride out when moving from low to higher strength soils. Pre lay trenches may encounter slope failure at the sides in very low strength soils. There may also be issues with rock placement for cable protection due to rock sinking into soft sediment and providing insufficient cover or potentially exposing the cable.

8.2| ROUTE 2: KP 0.000 TO KP 21.444

The following installation constraints should be considered when planning the cable in Route 2.

8.2.1| SEABED GRADIENTS

The average seabed gradients on Route 2 are very gentle at 0.1 degrees. Locally very steep gradients with a maximum of 37.4 degrees are encountered at the landfall area KP 0.103.

8.2.2| BEDROCK AND HARD SEDIMENT

Generally, DIAMICTON is observed as occasional, discrete areas within the survey corridor. However, a large band is also observed towards the end of the route at the OWF entry 2 location. Here the DIAMICTON crosses the full width of the corridor from KP 20.859 to KP 21.444.

8.2.3| BOULDER FIELDS

Boulder fields are frequently observed within the survey corridor (Table 25), most notably where the underlying sediment consists of Gravelly SAND to Sandy GRAVEL. The majority of boulder fields crossing the survey route occur between KP 6.011 to KP 10.238 and KP 12.051 to KP 14.784. Outside of these ranges isolated and discrete boulder field areas are observed within the corridor but offset from the survey centre line.

8.2.4| MOBILE SEDIMENT

Areas of ripples are occasionally present throughout the survey corridor, especially between KP 5.609 to KP 8.390 and KP 11.402 to KP 13.701. A nearshore sandbank/sandwave area is present between KP 0.465 and KP 0.900 (further details in Table 25).

8.2.5| SLOPE STABILITY

No areas of unstable sediment were encountered on Route 2.

8.2.6| ACOUSTIC BLANKING AND GAS SEEPAGE FEATURES

No areas of acoustic blanking were observed within the SBP data. Active gas release was also not observed in the water column. There are areas of depressions evident in the surficial geology, however they are more likely associated with changes in seabed current regime rather than shallow biogenic gas.

8.2.7| CABLES AND PIPELINES

No cable or pipeline crossings are listed or were detected on Route 2.

8.2.8| WRECKS AND ANTHROPOGENIC DEBRIS

No wrecks were identified.

However anthropogenic debris were observed on the nearshore region. These concern two military bunkers and patches of coastal defence blocks (103282-ENN-MMT-Data-Examples presentation). Isolated debris of less importance are also present within the corridor (Table 25).

8.2.9| UXO

Magnetometer records collected during the survey were used to identify cables/pipelines and large ferrous objects on the seafloor within the survey corridor. Note that due to line spacing and the use of a single MAG, this does not constitute as a UXO survey.

8.2.10| SEDIMENTS OF VARIABLE THERMAL RESISTIVITY

Thermal resistivity tests were undertaken as part of the geotechnical work scope and are detailed in the Thor OWF Export Cable Routes Geotechnical Survey report (Table 6). No sediments of high thermal resistivity are expected on Route 2.

Organic content traces were identified in two vibrocore samples: 282-VC-R2-013 indicate minor peat laminae within SAND at 0.70 m, 1.50 m and 1.71 m BSB at KP 6.786; 282-VC-R2-010 indicate CLAY has some organic content at 0.85 m and 282-VC-R2-009 shows organic CLAY from 1.34 m at KP 11.136.

8.2.11| FISHING ACTIVITY

No evidence of trawling was evident within Route 2. However, the lack of trawl marks does not constitute lack of fishing activity from other techniques. There is a high likely hood that pot and line fishing is active within the entire Thor project area.

During the survey campaign a number of fishing vessels were contacted in order to remove fishing gear and therefore it must be assumed that fishing activity is present within Route 2.

8.2.12| VERY LOW STRENGTH SOILS

On review of the draft VC logs, very soft clays (extremely low to low strength) are present in VC sample 282-VC-R2-004 at 1.0 m and 1.5 m.

This section is to be updated with geotechnical information on shear strength once final laboratory tests have been received.

8.3| ROUTE 3: KP 0.000 TO KP 24.401

The following installation constraints should be considered when planning the cable in Route 3.

8.3.1| SEABED GRADIENTS

The average seabed gradients on Route 3 are very gentle at 0.1 degrees. Locally very steep gradients with a maximum of 37.4 degrees are encountered at the landfall area KP 0.103.

8.3.2| BEDROCK AND HARD SEDIMENT

Generally, DIAMICTON is observed as occasional, discrete areas within the survey corridor. Small discrete areas are also observed close to or crossing the survey centre line between KP 8.327 to KP 11.049.

8.3.3| BOULDER FIELDS

Boulder fields are very common within the corridor of Route 3 (Table 28), mostly associated with GRAVEL sediments, they are particularly concentrated between KP 2.980 to KP 4.628, KP 7.923 to KP 11.148 and KP 20.682 to KP 21.861. Isolated individual boulders are also present.

8.3.4| MOBILE SEDIMENT

Areas of ripples are common throughout Route 3 (Table 28), either associated with GRAVEL or Gravelly SAND to Sandy GRAVEL sediments, they particularly follow the seabed morphology displaying N-S oriented stripes between KP 7.821 to KP 13.744. A nearshore sandbank/sandwave area is present between KP 0.465 and KP 0.955. A further area of sandwaves (transport direction NE-SW) is present between KP 19.845 and KP 21.090.

8.3.5| SLOPE STABILITY

No areas of unstable sediment were encountered on Route 3.

8.3.6| ACOUSTIC BLANKING AND GAS SEEPAGE FEATURES

No areas of acoustic blanking were observed within the SBP data. Active gas release was also not observed in the water column. There are areas of depressions evident in the surficial geology, however they are more likely associated with changes in seabed current regime rather than shallow biogenic gas.

A large area of depressions was observed crossing the survey corridor between KP 14.976 and KP 16.533.

8.3.7| CABLES AND PIPELINES

No cables or pipelines were identified within the survey corridor during the survey.

8.3.8| WRECKS AND ANTHROPOGENIC DEBRIS

Two contacts (S_R3_0002 and S_R3_0108) are possible wreck debris and have also been correlated to MAG anomalies (Table 28).

8.3.9| UXO

Magnetometer records collected during the survey were used to identify cables/pipelines and ferrous objects on the seafloor within the survey corridor. Note that due to line spacing this survey does not constitute as a UXO survey.

Several MAG anomalies were recorded, while some of them correlates with SSS and/or MBES data, it is hard to confirm or disprove the UXO nature of those anomalies without further investigations.

8.3.10| SEDIMENTS OF VARIABLE THERMAL RESISTIVITY

Thermal resistivity tests were undertaken as part of the geotechnical work scope and are detailed in the Thor OWF Export Cable Routes Geotechnical Survey report (Table 6). No sediments of high thermal resistivity are expected on Route 3.

8.3.11| FISHING ACTIVITY

No evidence of trawling was evident within Route 3. However, the lack of trawl marks does not constitute lack of fishing activity from other techniques. There is a high likely hood that pot and line fishing is active within the entire Thor project area.

During the survey campaign a number of fishing vessels were contacted in order to remove fishing gear and therefore it must be assumed that fishing activity is present within Route 3.

8.3.12| VERY LOW STRENGTH SOILS

On review of the draft VC logs, soft to firm clays (low to medium strength) are present in VC sample 282-VC-R3-019 at 0.9 m. However, this value is on the boundary between low and medium and constitute a minor section within a CLAY unit that is generally of high strength.

This section is to be updated with geotechnical information on shear strength once final laboratory tests have been received.

8.4| ROUTE 4: KP 0.000 TO KP 24.335

The following installation constraints should be considered when planning the cable in Route 4.

8.4.1| SEABED GRADIENTS

The average seabed gradients on Route 4 are very gentle at 0.1 degrees. Locally very steep gradients with a maximum of 24.1 degrees are encountered at the landfall area KP 0.117.

8.4.2| BEDROCK AND HARD SEDIMENT

Occasional DIAMICTON patches were found on Route 4. Of small extent but numerous, they are mainly concentrated between KP 1.204 and KP 2.052 and between KP 3.829 and KP 4.511.

8.4.3| BOULDER FIELDS

Boulder fields are occasionally present on Route 4, mostly in the vicinity or close to DIAMICTON patches, they are especially found between KP 1.424 to KP 2.071, KP 3.691 to KP 4.528 and between KP 16.935 to KP 17.809.

8.4.4| MOBILE SEDIMENT

Extensive area of ripples were identified on Route 4 (Table 31).

An area of sandwaves are present near the shore line at KP 0.427 to KP 0.685. A further, isolated sandwave crest crosses the survey corridor at KP 8.590. A discreet area of sandwaves are observed adjacent to the southern boundary of the survey corridor between KP 18.148 to KP 18.939. Sediment transport for the sandwaves are in a Southerly direction

8.4.5 | SLOPE STABILITY

No areas of unstable sediment were encountered on Route 4.

8.4.6 | ACOUSTIC BLANKING AND GAS SEEPAGE FEATURES

No areas of acoustic blanking were observed within the SBP data. Active gas release was also not observed in the water column. There are areas of depressions evident in the surficial geology, however they are more likely associated with changes in seabed current regime rather than shallow biogenic gas.

A large area of depressions was observed crossing the survey corridor between KP 10.541 and KP 11.368, KP 13.204 and KP 14.461, KP 14.655 and KP 16.732 and KP 22.240 and KP 23.002.

8.4.7 | CABLES AND PIPELINES

No cable or pipeline crossings are listed or were detected on Route 4.

8.4.8 | WRECKS AND ANTHROPOGENIC DEBRIS

No wrecks were identified on Route 4.

Five debris items were observed within Route 4, two of which are identified as fishing gear (S_R4_0075, DCC 105 m and S_R4_0076, DCC 93 m), comprising a possible clump weight and rope. (Table 32 and Table 33).

8.4.9 | UXO

Magnetometer records collected during the survey were used to identify cables/pipelines and ferrous objects on the seafloor within the survey corridor. Note that due to line spacing this survey does not constitute as a UXO survey.

Several MAG anomalies were recorded, while some of them correlates with SSS and/or MBES data, it is hard to confirm or disprove the UXO nature of those anomalies without further investigations

8.4.10 | SEDIMENTS OF VARIABLE THERMAL RESISTIVITY

Thermal resistivity tests were undertaken as part of the geotechnical work scope and are detailed in the Thor OWF Export Cable Routes Geotechnical Survey report (Table 6). No sediments of high thermal resistivity are expected on Route 4.

8.4.11 | FISHING ACTIVITY

Two debris items that could correspond to fishing gear at KP 8.311 and KP 8.347 indicate fishing activity within Route 4.

During the survey campaign a number of fishing vessels were contacted in order to remove fishing gear and therefore it must be assumed that fishing activity is present within Route 4. There is a high possibility that pot and line fishing is active within the entire Thor project area.

8.4.12 | VERY LOW STRENGTH SOILS

On review of the draft VC logs very soft clays (low strength) are present in VC sample 282-VC-R4-037 at 1.0 m, 2.0 and 2.5 m.

This section is to be updated with geotechnical information on shear strength once final laboratory tests have been received.

8.5| ROUTE 5: KP 0.000 TO KP 21.237

The following installation constraints should be considered when planning the cable in Route 5.

8.5.1| SEABED GRADIENTS

The average seabed gradients on Route 5 are very gentle at 0.1 degrees. Locally very steep gradients with a maximum of 24.1° degrees are encountered at KP 0.117.

8.5.2| BEDROCK AND HARD SEDIMENT

Occasional DIAMICTON patches were found on Route 5 mainly located between KP 1.000 and KP 2.000. These areas are commonly surrounded by occasional boulder fields.

8.5.3| BOULDER FIELDS

Occasional boulder fields are present essentially in the nearshore secretin only, forming two bands that extend across the corridor at approximately KP 2.000 and KP 4.000.

8.5.4| MOBILE SEDIMENT

Ripples are locally present on Route 5 (Table 34) as occasional discrete areas that rarely cross the survey route. Within Route 5 these are considered insignificant as a cable installation constraint. An area of sandwaves are present near the shore line at KP 0.427 to KP 0.685. A sandwave area is observed at the end of the route at KP 20.670 where two broad sand banks are separated by an erosion channel. This sandwave feature appears fairly symmetrical suggesting the feature is fairly static.

8.5.5| SLOPE STABILITY

No areas of unstable sediment were encountered on Route 5.

8.5.6| ACOUSTIC BLANKING AND GAS SEEPAGE FEATURES

No areas of acoustic blanking were observed within the SBP data. Active gas release was also not observed in the water column. There are areas of depressions evident in the surficial geology, however they are more likely associated with changes in seabed current regime rather than shallow biogenic gas.

Several areas of depressions were observed crossing the survey corridor between:

- KP 10.757 and KP 12.755
- KP 12.876 and KP 12.932
- KP 13.240 and KP 13.732
- KP 13.830 and KP 14.697
- KP 15.634 and KP 15.938
- KP 15.953 and KP 18.145

8.5.7| CABLES AND PIPELINES

No cable or pipeline crossings are listed or were detected on Route 5.

8.5.8| WRECKS AND ANTHROPOGENIC DEBRIS

One possible wreck was identified on Route 5 at KP 4.226. In addition, two other items classified as potential debris were also observed within 50 m of the route centre line (S_R5_0083 at KP 2.000 and S_R5_0028, at KP 4.136). See Table 34 and Table 35.

8.5.9| UXO

Magnetometer records collected during the survey were used to identify cables/pipelines and ferrous objects on the seafloor within the survey corridor. Note that due to line spacing this survey does not constitute as a UXO survey.

Several MAG anomalies were recorded, while some of them correlates with SSS and/or MBES data, it is hard to confirm or disprove the UXO nature of those anomalies without further investigations

8.5.10| SEDIMENTS OF VARIABLE THERMAL RESISTIVITY

Thermal resistivity tests were undertaken as part of the geotechnical work scope and are detailed in the Thor OWF Export Cable Routes Geotechnical Survey report (Table 6). No sediments of high thermal resistivity are expected on Route 5.

8.5.11| FISHING ACTIVITY

No evidence of trawling was evident within Route 5. However, the lack of trawl marks does not constitute lack of fishing activity from other techniques. There is a high likely hood that pot and line fishing is active within the entire Thor project area.

During the survey campaign a number of fishing vessels were contacted in order to remove fishing gear and therefore it must be assumed that fishing activity is present within Route 5.

8.5.12| VERY LOW STRENGTH SOILS

On review of the draft VC logs very soft clay (extremely low strength) are present in VC sample 282-VC-R5-064 at 2.0 m; 282-VC-R5-060 at 1.0 m and low strength CLAY at 1.5 m.

This section is to be updated with geotechnical information on shear strength once final laboratory tests have been received.

8.6 ARCHAEOLOGY CONSIDERATIONS

During the survey there was no obvious archaeological findings observed. Remnant defensive structures from WWII and an historic ship wreck have been described in the relevant sections above (Wrecks and Anthropogenic Debris). However, it is suggested that a full archaeology investigation be conducted on the data collected here by professionally qualified archaeologists in order to assess the possibility of palaeo landscapes that could have been occupied by early man. This type of analysis is out with the scope for this report.

9| CONCLUSIONS

A topographic, geophysical and geotechnical survey was successfully carried out along the Thor OWF export cable route survey corridors. The following datasets were collected from hull mounted, towed and ROTV platforms: MBES, SSS SBP, and MAG. Geotechnical sampling was completed using vibrocorer (VC), CPT and a Van Veen grab.

The survey was conducted in a safe manner and good quality data was acquired throughout. The survey was conducted in four sections; the onshore topographic survey, the nearshore geophysical survey, the offshore geophysical survey and the geotechnical survey.

ROUTE 2

Route 2 is generally characterised by gentle to moderate seabed slopes. The maximum slope for Route 2 on the landfall section is 37.4° at KP 0.103 (beach dunes) and, sub-sea, 6.1° at KP 21.057. Maximum and minimum depths of -29.23 m and -1.83 m occur at KP 21.444 and KP 0.340 respectively. Maximum and minimum elevations of +13.92 m and +0.76 m occur at KP 0.156 and KP 0.280, respectively. Surficial sediments predominately consist of SAND with patches and bands of gravelly SAND to sandy GRAVEL. Discrete areas of DIAMICTON are also present, mainly crossing the corridor from KP 20.854 to the end of the route at KP 21.444.

Occasional boulder fields are common throughout, as are ripples which generally form bands that cross the corridor on a NE-SW orientation.

In the near shore area manmade structures include two WWII concrete bunkers and an area of coastal defence concrete blocks. The former is located in the northern section of the intertidal zone and the latter towards the southern end of the site.

Shallow soils are characterised by an upper SAND unit that varies from silty SAND to SAND and Gravel. It extends along the entire route and ranges from seafloor to 3.4 m depth BSB. Below this unit is a discontinuous unit formed from channel infill sediments (from homogenous SANDS to laminated silty SAND, GRAVEL and CLAY) which occasionally contain PEAT and or organic material.

There are a number of factors for cable protection within the survey corridor of Route 2 that should be considered during planning of the final cable route.

- Low strength soils were not extensively sampled along the route. From the geotechnical data only one VC (282-VC-R2-004) encountered very soft CLAY within the upper 1.5 m BSB. However, this should be kept in mind during the installation phase as soft CLAY can cause problems during trenching if encountered within the required burial depth.
- Fishing, needs to be considered as it is associated with high risks to the cable if not buried sufficiently. Although trawl scars were not observed, fishing activity is clearly evident as witnessed by the survey teams during the survey campaign.
- A number of manmade structures were observed in the nearshore and should be given as wide a clearance as possible.
- A dedicated UXO survey has not been performed and this should at least be considered prior to the cable installation.

ROUTE 3

Route 3 is characterised by a varied seabed. Several erosional channels and broad sand waves are evident. The maximum sub-sea slope for Route 3 is 9.0° at KP 9.767 where a small bank is encountered. The maximum slope at the landfall is 37.4° at KP 0.103 where the route crosses the dunes. Maximum and minimum depths of -29.67 m and -1.77 m occur at KP 24.272 and KP 0.486, respectively. Maximum and minimum elevations of +13.92 m and +0.76 m occur at KP 0.156 and KP 0.280, respectively.

Surficial sediments predominately consist of SAND for the majority of the route; only in the central portion of the route corridor are areas of layered GRAVEL and gravelly SAND to sandy GRAVEL encountered. DIAMICTON is only really encountered between KP 6.500 and KP 11.000.

Areas of ripples are observed throughout the corridor and generally form thin bands that occasionally cross the corridor in a NNE-SSW orientation. Zones of seabed depressions are only observed from KP 15.000 onwards; the lack of acoustic blanking in the SBP records suggest these are formed from bottom current regime rather than shallow biogenic gas.

Two potential wrecks or wreck debris were located at KP 5.370 (S_R3_0002, DCC 28 m) and KP 5.391 (S_R3_0108, DCC 6 m).

Boulder fields are very common within the corridor and are particularly concentrated between KP 2.980 to KP 4.628, KP 7.923 to KP 11.148 and KP 20.682 to KP 21.861.

Shallow soils are characterised by an upper SAND unit that is typically acoustically transparent. It extends along the entire route and ranges from seafloor to 3.1 m depth BSB. Below this unit is a discontinuous unit formed from channel infill sediments (from homogenous SAND to laminated silty SAND, gravel and CLAY) and reach the limit of SBP penetration at 7.8 m BSB.

There are a number of factors for cable protection within the survey corridor of Route 3 that should be considered during planning of the final cable route.

- Low strength soils were not extensively sampled along the route. From the geotechnical data only one VC (282-VC-R3-019) encountered soft to firm CLAY within the upper 1.0 m BSB. However, this should be kept in mind during the installation phase as soft CLAY can cause problems during trenching if encountered within the required burial depth.
- Fishing, needs to be considered as it is associated with high risks to the cable if not buried sufficiently. Although trawl scars were not observed, fishing activity is clearly evident as witnessed by the survey teams during the survey campaign.
- A dedicated UXO survey has not been performed and this should at least be considered prior to the cable installation.

ROUTE 4

Route 4 is characterised by an undulating seabed with gentle gradients. The maximum sub-sea slope for Route 4 is 6.0° at KP 17.155. At landfall the maximum slope is 43.0° at KP 0.167. Maximum and minimum depths of -29.67 m DTU15 MSL and -3.75 m DTU15 MSL occur at KP 24.207 and KP 0.477, respectively. Maximum and minimum elevations of +19.16 m and +1.26 m occur at KP 0.134 and KP 0.245, respectively. Initial surficial sediments from the extent of the nearshore data to KP 2.000 consists of SAND with frequent, discrete outcrops of DIAMICTON.

Boulder fields are sparse along the entire route, being located as discrete bands at approximately KP 2.000, KP 4.000 and KP 17.000.

SAND with occasional areas of gravelly SAND to sandy GRAVEL and GRAVEL make up the sediments within the route corridor. Ripples, present where GRAVEL sediments are observed are not considered to be a major concern for cable lay.

Three main areas of depressions are present within the survey corridor. They cross the survey corridor between approximately KP 10.500 to KP 11.400, KP 13.000 to KP 16.500 and KP 22.200 to KP23.000.

Two contacts (S_R4_0075, DCC 105 m and S_R4_0076, DCC 93 m) are observed as potential fishing debris, comprising a possible clump weight and rope.

Shallow soils are characterised by an upper SAND / silty SAND. It extends along the entire route and ranges from seafloor to 3.0 m depth BSB. Below this unit is a discontinuous unit formed from channel infill sediments (from homogenous SANDS to laminated silty SAND, GRAVEL and CLAY) and reach the limit of SBP penetration at 7.7 m BSB.

There are a number of factors for cable protection within the survey corridor of Route 4 that should be considered during planning of the final cable route.

- Low strength soils were not extensively sampled along the route. From the geotechnical data only one VC (282-VC-R4-037) encountered very soft CLAY within the upper 2.5 m BSB. However, this should be kept in mind during the installation phase as soft CLAYS can cause problems during trenching if encountered within the required burial depth.
- Fishing, needs to be considered as it is associated with high risks to the cable if not buried sufficiently. Although trawl scars were not observed, fishing activity is clearly evident as witnessed by the survey teams during the survey campaign.
- A dedicated UXO survey has not been performed and this should at least be considered prior to the cable installation.

ROUTE 5

Route 5 is characterised by an undulating seabed with gentle gradients. The maximum sub-sea slope for Route 5 is 5.0° at KP 15.655. Maximum and minimum depths of -27.22 m DTU15 MSL at KP 19.041 and -3.75 m DTU15 MSL at KP 0.477, respectively. Maximum and minimum elevations of +19.16 m and +1.26 m occur at KP 0.134 and KP 0.245, respectively.

Surficial sediments are dominated by SAND throughout the Route 5 survey corridor. Discrete outcrops of DIAMICTON are present from KP 1.000 to KP 2.000.

Occasional boulder fields are present essentially in the nearshore secretin only, forming two bands that extend across the corridor at approximately KP 2.000 and KP 4.000.

Two large area of depressions was observed crossing the survey corridor between KP 10.757 and KP 14.697 and KP 15.634 and KP 18.145. No areas of acoustic blanking were noted within the SBP data.

A channel, dividing two sand banks is observed crossing the route at KP 20.670. The eastern sand bank also contains sand waves, indicative of active mobile sediments.

One contact, a possible wreck, was located at KP 4.226, (S_R5_0532, DCC -328 m).

There are a number of factors for cable protection within the survey corridor of Route 5 that should be considered during planning of the final cable route.

- Low strength soils were not extensively sampled along the route. From the geotechnical data only VC, 282-VC-R5-064 and 282-VC-R5-060 encountered very soft CLAY within the upper 2.0 m BSB. However, this should be kept in mind during the installation phase as soft CLAYS can cause problems during trenching if encountered within the required burial depth.
- Fishing, needs to be considered as it is associated with high risks to the cable if not buried sufficiently. Although trawl scars were not observed, fishing activity is clearly evident as witnessed by the survey teams during the survey campaign.
- A dedicated UXO survey has not been performed and this should at least be considered prior to the cable installation.

The survey corridors present challenges in a number of areas and careful routing as well as engineering solutions will be required to ensure safe installation and operation of this cable. This report and accompanying data provide a basis for this planning.

10| RESERVATIONS AND RECOMMENDATIONS

The geological surface and shallow geological units presented in this report and related charts, are generally based on the interpretation of the acoustic data obtained, and may include inaccuracies in the interpretation. The interpretation is only substantiated by geotechnical sampling and testing in limited parts of the extent both lateral and vertical. The results from the geotechnical investigations have been used for verification of the geological interpretations and is considered as ground truthing at those locations where collected. Where considered applicable the sampling and testing results have been extrapolated to constitute a base for verifications also in the surroundings.

Not all existing contacts are detectable in the SSS data due to resolution, material, and orientation of the object.

MMT's recommendations for further planning within the survey corridor areas of the Thor OWF export cable routes are:

- A dedicated UXO survey has not been performed and is strongly recommended prior to the cable installation.
- A full Benthic survey, specifically covering areas of possible marine growth near the landfall sites and in areas of depressions.
- Based on the results presented in this report initial thoughts would point to Route 4 or Route 5 as the preferred export cable route corridor. Here both routes have limited boulder fields, with the majority of the surface sediments consisting of SAND. The SBP data along the four centre lines presents a similar profile for all routes.

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12 | DATA INDEX

The deliverables listed in Table 37 accompany this report as digital and/or hard copy as specified.

Table 37 Deliverables.

NO	DATA TYPE	DATA PRODUCT
0	Data	UAV Orthophoto (R2 & R5)
1	Data	Bathymetry - Un-gridded soundings, (X,Y,Z) values in ASCII format. (ZIP on delivery)
2	Data	Bathymetry - Gridded soundings, 0.25m resolution, (X,Y,Z) values in ASCII format. (ZIP on delivery)
3	Data_GIS	Bathymetry - Gridded soundings, 0.25m resolution, ESRI grid format. (ZIP on delivery)
3a	Data_GIS	Bathymetry - Gridded soundings, 0.25m resolution, geotiff (tiled)
4	Data	Bathymetry - Gridded soundings, 1.00m resolution, (X,Y,Z) values in ASCII format. (ZIP on delivery)
5	Data_GIS	Bathymetry - Gridded soundings, 1.00m resolution, ESRI grid format. (ZIP on delivery)
5a	Data_GIS	Bathymetry - Gridded soundings, 1.00m resolution, geotiff (tiled)
6	Data	Bathymetry - Gridded soundings, 5.00m resolution, (X,Y,Z) values in ASCII format. (ZIP on delivery)
7	Data_GIS	Bathymetry - Gridded soundings, 5.00m resolution, ESRI grid format. (ZIP on delivery)
7a	Data_GIS	Bathymetry - Gridded soundings, 5.00m resolution, geotiff
8	Data_GIS	Bathymetry - Bathymetric contour curves with 50cm interval, as TSG object CONTOURS_LIN
9a	Data	Bathymetry - TVU 1.00 m resolution, (X,Y, TVU) values in ASCII format
9b	Data_GIS	Bathymetry - TVU 1.00 m resolution, ESRI grid format
9c	Data	Bathymetry - THU 1.00 m resolution (X,Y,THU) values in ASCII format
9d	Data_GIS	Bathymetry - THU 1.00 m resolution, ESRI grid format
9f	Data	SVP - sound velocity profiles as SVP comparison spreadsheet
9g	Data	Bathymetry - backscatter 32bit Geotiff
10	Data	SSS - Raw side scan data as XTF-files with corrected navigation, High frequency.
10a	Data	SSS- Raw side scan data as JSF-files with corrected navigation, High frequency
11	Data	SSS - Raw side scan data as XTF-files with corrected navigation, Low frequency
11a	Data	SSS- Raw side scan data as JSF-files with corrected navigation, Low frequency
12	Data	SSS - Navigation files, CSV-format.
13	Data	SSS - Processed side scan data, geo-referenced GeoTiff mosaics, High frequency.
14	Data	SSS - Processed side scan data, geo-referenced GeoTiff mosaics, Low frequency.
15	Data_GIS	SSS - instrument tracks, as TSG object TRACKS_LIN, indicate equipment carrier and equipment type in attributes.
16	Data_GIS	SSS - Anomaly target list, as TSG object SSS_ANOMALY_PTS, anomaly characteristics provided in attributes.
17	Data	MAG - measurements, CSV-format
18	Data_GIS	MAG - instrument tracks, as TSG object TRACKS_LIN, indicate equipment carrier and equipment type in attributes.

NO	DATA TYPE	DATA PRODUCT
19	Data_GIS	MAG - Anomaly target list, as TSG object MAG_ANOMALY_PTS, anomaly characteristics provided in attributes.
20	Data	SBP - Processed SBP recordings, SEGY format.
20a	Data	SBP - Processed SBP recordings, Tiff format
21	Data_GIS	SBP - instrument tracks, as TSG object TRACKS_LIN, indicate equipment carrier and equipment type in attributes.
22	Data_GIS	SBP - Anomaly target list, as TSG object SBP_ANOMALY_PTS, anomaly characteristics provided in attributes
23	Data	SBP - Interpretation of the processed seismic data CSV
23a	Data	SBP - Kingdom Project
24a	Data_GIS	SBP - Generated elevation grids relative to vertical datum for each interpreted horizon - ESRI grid
24b	Data	SBP - Generated elevation grids relative to vertical datum for each interpreted horizon - (X,Y,Z) values in ASCII format
24c	Data	SBP - Generated elevation grids relative to vertical datum for each interpreted horizon - GeoTiff file
25a	Data_GIS	SBP - Generated depth below seabed (BSB) grids for each interpreted horizon - ESRI grid
25b	Data	SBP - Generated depth below seabed (BSB) grids for each interpreted horizon - (X,Y,Z) values in ASCII format
25c	Data	SBP - Generated depth below seabed (BSB) grids for each interpreted horizon - Geotiff file
27	Data_GIS	Grab - Grab sample positions, as TSG object GEOTECHNIC_PTS, indicate sampling characteristics in attributes.
28	Data	Grab - Grab sample classification, MS-Excel spread sheet
29	Data	Grab - Grab sample laboratory analysis, overview table and result tables, MS-Excel spread sheet.
30	Data_GIS	Vibrocore and CPT sample positions, as TSG object GEOTECHNIC_PTS, indicate sampling characteristics in attributes.
31	Data	Geotechnical laboratory test, overview table and result tables, MS-Excel spread sheet.
32	Data	All CPT tests, Vibrocore, Piston core and laboratory test results provided as an AGS 4 data file (see e.g. www.agsdataformat.com).
33	Data_GIS	Seabed Surface Geology, as TSG object SEABED_GEOLOGY_POL, indicate surface geological unit in attributes.
34	Data_GIS	Seabed Surface Features, as TSG object SEABED_SURFACE_PTS, indicate surface forms in attributes.
35	Data_GIS	Seabed Surface Features, as TSG object SEABED_SURFACE_LIN, indicate surface forms in attributes.
36	Data_GIS	Seabed Surface Features, as TSG object SEABED_SURFACE_POL, indicate surface forms in attributes.
37	Data_GIS	Man-Made-Objects, as TSG object MMO_PTS, indicate MMO type in attributes
38	Data_GIS	Man-Made-Objects, as TSG object MMO_POL, indicate MMO type in attributes
39	Data_GIS	Man-Made-Objects, as TSG object MMO_LIN, indicate MMO type in attributes.
40	Data_GIS	Benthic - Program point features class in ESRI File Geodatabase
41	Data_GIS	Benthic - Program line features class in ESRI File Geodatabase
42	Report	Operational Report
43	Report	Geophysical Report & charts, drawings and enclosures

NO	DATA TYPE	DATA PRODUCT
44	Report	Benthic Scope Report
46	Report	Project Execution Plan
47	Report	Field Report

APPENDIX A | ROUTE POSITION LISTS

APPENDIX B | LIST OF PRODUCED CHARTS

APPENDIX C | CONTACT AND ANOMALY LIST

APPENDIX D | GEOTECHNICAL REPORT

APPENDIX E | GEODETIC BENCHMARKS

APPENDIX F | BOULDER FIELD IMAGES