Energy Island

Cable Route Survey

Baltic Sea

Danish Baltic Sea

April - August 2022

CLIENT
Energinet

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ENERGINET

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EXECUTIVE SUMMARY

Baltic Sea OWF and Energy Islands LOT1 Cable Route Survey Overview

Energinet have contracted Ocean Infinity (OI) to perform a Cable Route Survey (CRS) in the Baltic (LOT1), connecting two offshore wind farms (OWFs) with Bornholm and connecting Bornholm with the island of Sjælland. The survey work consists of a geophysical, geotechnical and pipe/cable tracking surveys. The project is divided into three parts. Part 1 is located near Bornholm and Part 3 is located near Koge. Part 1 and Part 3 will be performed during 2022; Part 2, which was proposed for 2023, has been removed from the scope.

This report has been re-worked to only cover the route and cable survey alternatives within a defined boundary (Kabelrute OWF-BHM) at Bornholm landfall. The integrated results of the geophysical and geotechnical surveys provide information on the seabed and sub-seabed conditions, obstructions and geotechnical installation constraints.

An overview image of the defined section of Part 1 is presented in Figure 1.

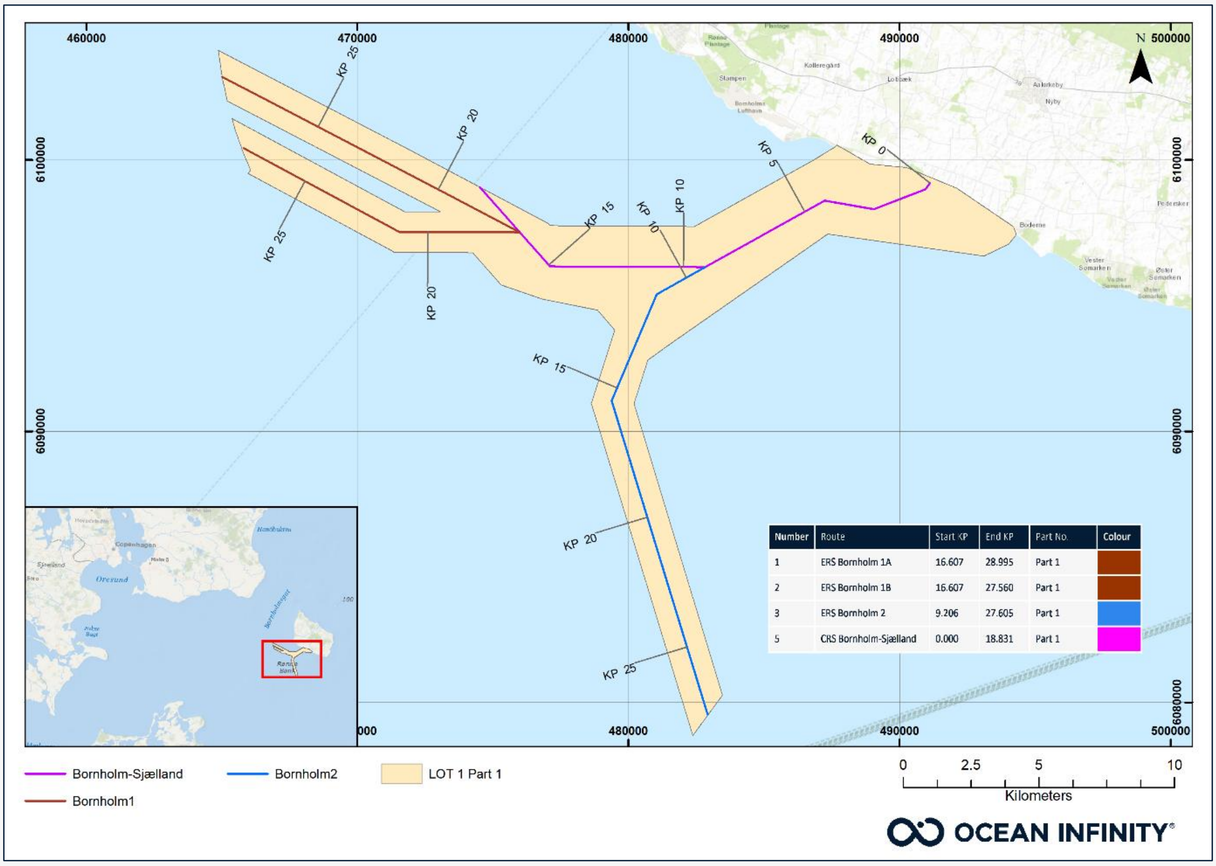

Figure 1 Overview of defined section of Part 1, Bornholm.

Principal Route Information - CRS Bornholm-Sjælland (BH-DK2) (Part 1)

Bathymetry and Seabed Morphology

The route starts at landfall where the elevation varies between approximately 13 m and 34 m. The irregular rocky foreshore drops falls onto the rocky beach between KP 0.008 and KP 0.050. This fall delineates the start of a varied and uneven surface with seabed formation orientated NW-SE. From here the seabed is uneven due to outcrops and ridges which result in slopes up to a maximum value of 28.55° however overall, the seabed is deepening on a gentle gradient westward.

The area of uneven variable seabed continues until the end of the route, at KP 18.831.

Seabed Sediments and Features

The start of the route is highly variable characterised by outcrops of SEDIMENTARY ROCK with areas of SAND, GRAVEL and coarse SAND and DIAMICTON. DIAMICTON is composed of sand, gravel and clay with cobbles and boulders. The outcropping SEDIMENTARY ROCK forms ridges at seabed and sediments infill the erosional surface of the bedrock. Glacial debris is prevalent between KP 0 and KP 17.748, with high density boulder fields. The middle of the route between KP 17.786 to KP 18.831 is characterised by a large area of GRAVEL and coarse SAND which transitions to SAND. Areas of ripples often occur within the areas of GRAVEL and coarse SAND, ripple crests are orientated north to south in line with the prevailing storm wave base.

In total 60 SSS contacts and 913 magnetic anomalies were detected in the corridor. In addition to SSS contacts a total of 1 406 526 MBES boulders were identified within the defined boundary (Kabelrute OWF-BHM) at Bornholm. Multiple utilities cross the proposed route detected from the MAG, SSS and MBES datasets.

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 15.0 m below seabed (BSB) in CRS Bornholm-Sjælland.

From the start of the route to KP 15.143, Upper Cretaceous SEDIMENTARY ROCK was interpreted to be present outcropping at the surface or below thin veneers of recent Holocene silty to gravelly SAND (P1_H10). Through this section, the top of the SEDIMENTARY ROCK was difficult to detect. This was due to the coarseness of the overlying seabed sediments, weathered interface of the rock and very irregular rock bedding. Occasional channels of silty SAND and firm to stiff CLAY have also been interpreted (P3_H45i). A firm to soft silty sandy gravelly Glacial CLAY was also encountered in the uppermost 4.0 m from KP 12.291 to KP 14.228 (P1_H50).

Across the central section of the route from KP 15.143 to KP 18.831, the ground conditions are more variable. Recent Holocene and Late / Post Glacial Silty SAND to silty gravelly SANDs (P1_H10, P1_H20, P1_H35i) are predominantly encountered up to the seabed, with the SAND thickness variable from occasional thin veneers of 0.2 m thickness from KP 15.143 to KP 18.831, increasing up to a maximum thickness of 6.0 m. The SAND units typically overlay high strength cohesive material, being firm to stiff silty sandy gravelly Glacial CLAY (P1_H50), however occasionally this unit can be traced up to the seabed. The thickness of the CLAY unit gradually increases from 2.0 m at KP 15.143 to a maximum thickness of 6.0 m at KP 18.831.

Principal Route Information – ERS Bornholm 1A: KP 16.607 to KP 28.995
Bathymetry and Seabed Morphology
This section begins in an area of undulating seabed which extends from the section start at KP 16.607 to KP 19.218. In this area, the maximum gradient of 10.2° is located at KP 17.268 and the routes most shallow depth of 21.88 m is located at KP 17.266. Thereafter, the seabed gently deepens from approximately 24.56 m at KP 19.706 to 38.97 m at KP 25.044. Here the seabed alternates between broad flat-topped banks and deeper areas of rippled seabed that cut between these banks. The changes in elevation across these banks is very slight with a maximum change of 0.88 m. From this point till the end of the section at KP 28.995 the seabed has a very gentle gradient, reaching a maximum depth of 44.20 m at KP 28.561.
Seabed Sediments and Features
The start of the route is predominantly composed of Gravel and coarse SAND and a small area of DIAMICTON. DIAMICTON is composed of sand, gravel and clay with cobbles and boulders. The middle of the route transitions from GRAVEL and coarse SAND to SAND. Towards the end of the route the sediments are composed of muddy SAND. Glacial debris is prevalent between KP 16.607 and KP 19.417, with high density boulder fields. Boulders were detected in other areas in reduced numbers. Areas of ripples occur within the areas of GRAVEL and coarse SAND, ripple crests are orientated north to south in line with the prevailing storm wave base. An area of trawl scars covers the route from KP26.030 to KP 28.945. In total 63 SSS contacts and 54 magnetic anomalies were detected in the corridor. In addition to SSS contacts a total of 1 406 526 MBES boulders were identified within the defined boundary (Kabelrute OWF-BHM) at Bornholm. Three wrecks were identified within the corridor and have associated debris fields surrounding them. Two utilities cross the proposed route detected from the MAG, SSS and MBES datasets.
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 14.0 m below seabed in ERS Bornholm 1A. At the start of the route, firm to stiff CLAY is present at the surface (P1_H50), often lying beneath a veneer of GRAVEL and coarse SAND, with Holocene silty SAND (P1_H10) and Late/Post Glacial silty gravelly SAND (P1_H20) appearing at the surface between KP 19.464 KP 28.666. The SAND units vary in thickness along the route between approximately 0 to 2.0 m and display localised variations in composition, reflected by two internal units (P1_H05i and P1_H06i). Between KP 22.634 to KP 28.666 a silty SAND unit appears (P1_H30) which contains multiple internal high amplitude parallel reflectors and a highly undulating basal reflector, resulting in a variable thickness along the profile, approximately between 0.7 to 3.0 m. Moving west along the profile, the CLAY unit thickens significantly as it moves deeper, with the top of the underlying Upper Cretaceous, featureless SEDIMENTARY ROCK moving beyond the depth of Innomar penetration at KP 25.187. At KP 22.760 an internal reflector has been identified with the CLAY, occupying the majority of the uppermost 2.5 to 5.0 m of the unit and indicating a change in stiffness with very soft to soft CLAY (P1_H40i), overlying the firmer, stiffer CLAY (P1_H50) below.

Principal Route Information – ERS Bornholm 2

Bathymetry and Seabed Morphology

The route starts at KP 9.206 moving over high-density boulder fields and outcrops. From KP 9.206 to approximately KP 17.0 the seafloor slope varies between very gentle and very steep. Within this section the maximum gradient of 26.2° is located at KP 12.868 and the shoal depth of 10.16 m is located at KP 13.145. Between approximately KP 17.0 and KP 19.0 the seafloor is very gentle and shoaling until KP 19.206 where the seafloor undulates until KP 22.206.

From KP 22.206 until KP 26.30 the seafloor is flat. At KP 26.30 there is very steep break in seafloor off the Ronne Bank from 15 m to 27 m depth over approximately 25 m distance: a slope of approximately 25°. For the remainder of the route the seafloor is gently deepening from KP 26.50 to 27.60; where maximum depth of 33.44 m is located.

Seabed Sediments and Features

The start of the route between KP 9.206 and KP 13.957 is highly variable characterised by outcrops of SEDIMENTARY ROCK with areas of SAND, GRAVEL and coarse SAND and DIAMICTON. The DIAMICTON is composed of sand, gravel, clay with cobbles and boulders. The SEDIMENTARY ROCK forms ridges at seabed and sediments infill the erosional surface of the bedrock. Glacial debris is prevalent between KP 9.206 and KP 14.372, with high density boulder fields. A large area of GRAVEL and coarse SAND occurs between KP 13.957 to KP 26.367 extending across the entire width of the corridor, north-south trending ribbons of SAND break up this area. There is a seabed ridge at KP 26.367, following the ridge the seabed sediment is composed primarily of SAND. Areas of ripples occur within the areas of GRAVEL and coarse SAND, ripple crests are orientated north to south in line with the prevailing storm wave base.

In total 47 SSS contacts and 54 magnetic anomalies were detected in the corridor. In addition to SSS contacts a total of 1 406 526 MBES boulders were identified within the defined boundary (Kabelrute OWF-BHM) at Bornholm. Two utilities cross the proposed route detected from the MAG, SSS and MBES datasets.

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 15.0 m below seabed in ERS Bornholm 2. From the start of the route to KP 14.093, Upper Cretaceous SEDIMENTARY ROCK was interpreted to be present outcropping at the surface or below thin veneers of recent Holocene silty to gravelly SAND (P1_H10). Through this section, the top of the SEDIMENTARY ROCK was difficult to detect. This was due to the coarseness of the overlying seabed sediments, weathered interface of the rock and very irregular rock bedding. Occasional channels interpreted to contain silty SAND and firm to stiff CLAY have also been interpreted (P3_H45i). The rest of the ERS Bornholm 2 route is largely dominated by recent Holocene to Late / Post Glacial silty SAND, with local variations to clayey SAND and gravelly SAND (P1_H10, P1_H20, P1_H35i). Between KP 14.093 to KP 17.742, these SANDs gradual increase in thickness from < 1.0 m to over 6.0 m at KP 17.742. After this, the base of SAND is unable to be distinguished on the SBP data and SAND is interpreted dominate the shallow geology, extending beyond the depth of SBP penetration, for the rest of the route until KP 26.411.

A silty sandy gravelly Glacial CLAY unit (P1_H50) is also present between KP 14.093 to KP 17.742, found below the SANDs but above the SEDIMENTARY ROCK. The CLAY similarly gradually increases in thickness from < 1.0 m to over 6.5 m at KP 17.742, where it is also interpreted to extend beyond the depth of SBP penetration for the rest of the route until KP 26.411. Beyond KP 26.411, after a sharp decrease in water depth, thinner layers of silty SAND (P1_H10 and P1_H20), are interpreted to be present to 1.5 m BSB, with Glacial CLAY (P1_H50) below.

Principal Route Information – ERS Bornholm 1B

Bathymetry and Seabed Morphology

This section begins with undulating seabed between KP 16.607 and KP 17.374, where the maximum gradient of 9.1° at KP 17.140 is located. From KP 17.374 the seabed is gently shallowing. This shallowing continues until KP 17.902 where the depth on the route reaches its minimum of 19.81 m.

From KP 17.902 to KP 18.102 the seabed deepens on a very gentle gradient along the route before levelling out with slight undulations up to KP 20.607. After this point, until the end of the section at KP 27.560, there is a general deepening on a very gentle gradient with some undulations in the seabed as the route crosses over the Ronne Banke. Maximum depth of 39.43 m is located within this section at KP 26.705.

Seabed Sediments and Features

The start of the route between KP 16.607 and KP 18.783 is predominantly composed of DIAMICTON and SAND. DIAMICTON is composed of sand, gravel and clay with cobbles and boulders. Following this between KP 18.783 and KP 24.217 the route is composed of GRAVEL and coarse SAND. The end of the route between 24.217 and KP 27.560 is a mix of Gravel and coarse SAND and SAND. Glacial debris is prevalent between KP 16.607 and KP 17.337, with high density boulder fields. Boulders were detected in other areas in reduced numbers. Areas of ripples occur within the areas of GRAVEL and coarse SAND, ripple crests are orientated north to south in line with the prevailing storm wave base.

In total 50 SSS contacts and 95 magnetic anomalies were detected in the corridor. In addition to SSS contacts a total of 1 406 526 MBES boulders were identified within the defined boundary (Kabelrute OWF-BHM) at Bornholm. Two utilities cross the proposed route detected from the MAG, SSS and MBES datasets.

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 12.0 m below seabed in ERS Bornholm 1B.

At the start of the route, firm to stiff CLAY is present at the surface (P1_H50), often lying beneath a veneer of GRAVEL and coarse SAND, with Holocene silty SAND (P1_H10) and Late/Post Glacial silty gravelly SAND (P1_H20) appearing at the surface from KP 17.345 and occupying the uppermost units for the majority of route until KP 27.560. The SAND units generally occupy the uppermost 0 to 3.0 m, thickening along the slope to approximately 4.0 m before thinning to < 1.0 m at the base of the slope between KP 23.944 to KP 25.141 as the firm to stiff CLAY (P1_H50) approaches the seabed and thickening again to >1 m towards the end of the profile as the CLAY deepens. Local variations in composition can be seen throughout the SANDs, reflected by two internal units identified as P1_H05i and P1_H06i. Towards the end of the route, between KP 25.679 to KP 27.560, another silty SAND unit appears (P1_H30) which contains multiple internal high amplitude parallel reflectors identified as Late/Post Glacial clayey silt by the geotechnical data. It displays a highly undulating basal reflector, resulting in a variable thickness along the profile, approximately between 0.2 to 1.8 m.

Moving west along the profile, the CLAY unit thickens significantly as it moves deeper, with the top of the underlying Upper Cretaceous, featureless SEDIMENTARY ROCK moving beyond the depth of Innomar penetration at KP 19.711 until the end of the route, as the amplitude of the base of CLAY decreases, making it undistinguishable from the surrounding sediments. Whilst the CLAY appears to be predominantly stiff to very stiff, beyond the base of the slope, between KP 24.751 to KP 27.560, the CLAY is very soft to soft for the majority of the uppermost 0 to 7.0 m of the unit, thickening towards the end of the profile, with the internal boundary identified by P1_H40i.

Revision History

REVISION	DATE	STATUS	CHECK	APPROVAL	CLIENT APPROVAL
03	2023-08-31	Issue for Use	DO/DP	KG	
02	2023-06-28	Issue for Client Review	DO/DP	KG	
01	2023-06-27	Issue for Internal Review			

Revision Log

DATE	SECTION	CHANGE
2023-08-31	Various	As per client Comment Sheet: Deliverable_Register_VO9_ERS_OWF-BH_rev00
2023-06-28	Various	Report re-worked to include defined section of Part1 (Kabelrute OWF-BHM)

Document Control

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Abbreviations and Definitions

ASCII ....American Standard Code for Information Interchange (used as a term for data stored in a text file format)

BEK ....Bekendtgørelsen

BH..Bornholm

BP ....Before Present

BSB ....Below Seabed

BSL..Below Sea Level

CAD..Computer Aided Design

CL..Centre Line

CPT ....Cone Penetration Test

CRS ....Cable Route Survey

CSV ....Comma Separated Variable

CTD ....Conductivity, Temperature and Depth

CUBE..Combined Uncertainty and Bathymetry Estimatior

DCC..Distance Cross Course (m)

DK..Denmark

DPR..Daily Progress Report

DTM..Digital Terrain Model

DTU ....Technical University of Denmark

DV..Deep Volans (Inshore Survey Vessel)

DW ....Deep Wind (Inshore Survey Vessel)

DWG..Drawing file extension

ECR ....Export Cable Route

EEZ..Exclusive Economic Zone

ENE ....Energient

ENF ....Emergency Notification Flowchart

ENN ....Energinet

ERS ....Export Route Surveys

ETRS..European Terrestrial Reference System

FME ....File Manipulation Engine (by Safe Software)

FMGT..Fledermaus Geocoder Toolbox

GEUS..Geological Survey Of Denmark And Greenland

GIS ....Geographic information system

GNSS..Global Navigation Satellite Systems

GR..Geo Ranger (Offshore Survey Vessel)

GRS ....Geodetic Reference System

GS ....Grab Sample

HAZOP ....Hazard and Operability Study

HSE ....Health, Safety and Environment

IMU ....Inertial Measurement Unit

INS...Inertial Navigation System

IODP ....Integrated Ocean Drilling Program

ISO...International Organisation for Standardisation

K m/W ....Kelvin metres per Watt - Units of Thermal Resistivity

km ....kilometre

KP ....Kilometre Post, used to describe distance along a route (design)

kPa...KiloPascal

KS ....Karlstrup Strand

LiDAR...Light Detection and Ranging

m ....metre

M/V ....Motor Vessel

MAC...Mobilisation and Calibration

MAG ....Magnetometer

MBBS...Multibeam Backscatter

MBES ....Multibeam Echo Sounder

MDR ....Master Document Register

Mg/m3 ....Megagrams per cubic metre - units of Bulk Density

MINCS ....Improvement and Non Conformity System

MMO..Manmade Objects

MPa ....MegaPascal

MSL ....Mean Sea level (vertical datum)

NA..Not Applicable

nT ....nanotesla

OI ....Ocean Infinity

OM ....Offshore Manager

OWF ....Offshore Wind Farm

PPS ....Pulse Per Second

PSD ....Particle Size Distribution Analysis

QC..Quality Control

QINSy...Quality Integrated Navigation System

ROV ....Remotely Operated Vehicle

RPL ....Route Position List

SBP ....Sub-Bottom Profiler

SE...Sjælland

SGY ....Sonarwiz file format

SOW ....Scope Of Work

SSI..Seabed Sediment Index

SSS...Side Scan Sonar

SVP ....Sound Velocity Profile

THU ....Total Horizonal Uncertainty

TQ ....Technical Query

TSG ....Template Survey Geodatabase

TVU...Total Vertical Uncertainty

UAS...Unmanned Aircraft System

USBL ....Ultra Short Baseline System

UTC...Universal Time

UTM ....Universal Transverse Mercator

UXO ....Unexploded Ordnance

VC...Vibrocore

WGS84 ....World Geodetic System

WP..Work Package

NB: Abbreviations for cardinal Directions have not been included in the list but appear in the report. These may be presented as 1 to 3 characters. For example, N = North, NE = Northeast and ENE = East-Northeast.

1. Introduction

1.1 Project Information

Following a decision in the Danish Parliament June 2020, Denmark is on the path to establish offshore energy infrastructure in the Danish North Sea and in the Danish Baltic Sea to connect respectively 10 GW and 3 GW offshore wind energy to the Danish mainland and to neighboring countries via offshore energy hubs, called Energy islands. In the Baltic the Energy Island is situated on the Island Bornholm (*Figure 2*).

Figure 2 Energy Island positions in the North Sea and the Baltic Sea.

For the subsea cables connecting the energy islands to the Danish power grid it is required to survey cable routes. Energinet have awarded Ocean Infinity to perform the Cable Route Survey in the Baltic (LOT1), connecting two offshore wind farms with Bornholm and connecting Bornholm with the island of Sjælland. The survey work consists of a geophysical, geotechnical and pipe/cable tracking surveys.

The project is divided into three parts. Part 1 is located on the Bornholm side (east side) and Part 3 is located on the Koge side (west side). Part 1 and Part 3 will be performed during 2022; Part 2 which was expected to be performed in 2023, has now been removed from the scope.

This report has been re-worked to only cover the route and cable survey alternatives within a defined boundary (Kabelrute OWF-BHM) at Bornholm landfall. An overview image of the defined section of Part 1 is presented in Figure 3. The project details are summarized in Table 1.

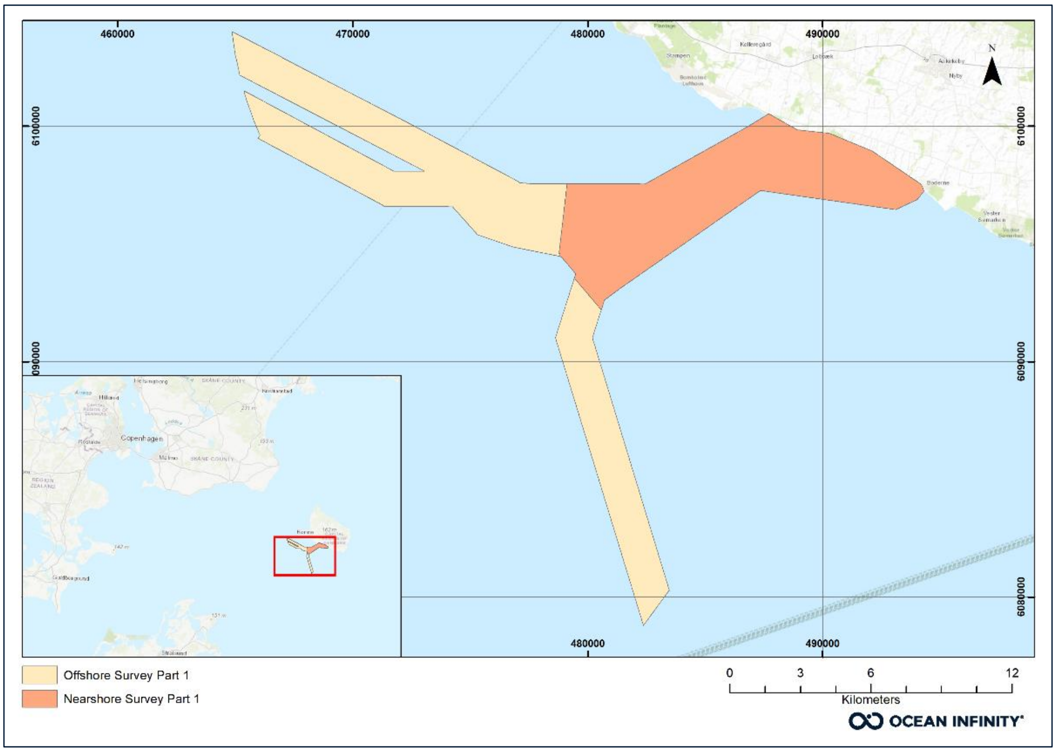


Figure 3 Project overview.

Table 1 Project details.

Client:	Energinet
Project:	Baltic Sea OWF and Energy Islands LOT1 Cable Route Survey
OI Project Number:	103971
Survey Type:	Geophysical and Geotechnical and Pipe/Cable Tracking Cable Route Survey
Area:	South Baltic Sea
Survey period:	April – August 2022
Survey Vessel:	Geo Ranger, Northern Cecilia, Deep Volans, Deep Seapal, Deep Wind
OI Project Manager:	Karin Gunnesson
CLIENT Project Manager:	Nicky Hein Witt

2. Scope of Work

Ocean Infinity (OI) shall carry out a Geophysical survey, together with a Pipe/Cable tracking survey on crossings and a Geotechnical investigation for the cable routes. The project is divided into three parts, Part 1 to Part 3. Part 1 and Part 3 will be performed during 2022; Part 2 which was expected to be performed in 2023, has been removed from the scope. An overview of the different parts within the defined boundary (Kabelrute OWF-BHM) of Part 1 can be seen in Table 2.

Table 2 Overview of Part 1.

Part	Site	Region	Route Length	Corridor Width	Contract Lot
1	Bornholm to OWF I + II	Baltic Sea	88.51 km	1 000 - 4 438 m	1
2	Bornholm to Sjælland (SE)	Baltic Sea	84.91 km	1 998 m	1
3	Bornholm to Sjælland (DK)	Baltic Sea	57.17 km	1 000 – 2 305 m	1

Water depths in Part 1 expects to range between 0m and 40m depth Mean Sea Level (MSL).

The purpose of the survey is to get:

- Initial marine archaeological site assessment.
- Planning of environmental investigations.
- Assessment of subsea cable burial design.
- Assessment of installation conditions for subsea cables.
- Site information enclosed the tender for the offshore wind farm concession.

OI shall carry out a detailed mapping of the seabed surface within the surveyed area in order to provide:

- Accurate bathymetric data and charts in the surveyed area
- The morphology and natural features of the seabed surface such e.g. as mega-ripples, sand-waves, boulders, outcropping geology, seaweed and reefs
- Possible man-made features such as wrecks, debris, fishing gear, trawl scars, anchor, scars, objects of potential archaeological interests
- Outline habitat and biotope mapping including ground truthing
- Identification of features of potential conservation interest including but not limited to; sandbanks, gravel reef, cobble reef, rocky reef and biogenic reef structures

The sub-surface of the seabed must be investigated to provide:

- The soil stratification and seismic units to 10 m below seabed
- The soil types, geotechnical properties and thermal properties of the soil units down to 6 m below seabed

At the landfall location the beach area behind the shoreline must be mapped:

- To provide a Digital Terrain Model (DTM) that connects the marine bathymetry to the onshore topography
- To chart any obstacles or infrastructure in the beach area

WORK PACKAGE A – OFFSHORE CABLE ROUTE SURVEY > 15M MSL

A geophysical survey shall be performed with commencement in 2022 (Part 1) and completion as soon as possible. The survey shall have full coverage in the cable corridor. The survey shall map the bathymetry, the static and dynamic elements of the seabed surface and upper soil stratification to ca. 10 m below seabed.

WORK PACKAGE B – NEARSHORE AND LANDFALL SURVEY < 15M MSL

Same scope as Work Package (WP) A performed for shallow water and intertidal parts of the cable route. Work Package B also contains a few limited onshore activities for mapping of landfall.

WORK PACKAGE C – GEOTECHNICAL INVESTIGATIONS.

Upon completion and interpretation of the Work Packages A and B, a geotechnical campaign shall be performed to provide the soil parameters of the interpreted soil strata. Samples to be taken every 1 km, half of them 3 m and half of them 6m. Using both Cone Penetration Test (CPT) and Vibrocore (VC).

WORK PACKAGE D – CROSSINGS SURVEY

A dedicated Remotely Operated Vehicle (ROV) based survey with cable- and pipeline-tracking sensors shall be performed to map existing third party utilities, that cross or intersect the area of investigation. The survey determines the horizontal location as well as the depth of burial of the third party utility.

Table 3 Export cable route extents.

Number	Route	Start KP	End KP	Part No.	Colour
1	ERS Bornholm 1A	16.607	28.995	Part 1	
2	ERS Bornholm 1B	16.607	27.560	Part 1	
3	ERS Bornholm 2	9.206	27.605	Part 1	
5	CRS Bornholm-Sjælland	0.000	18.831	Part 1	

Overview image of the routes within defined section of Part 1 (Bornholm) is shown below in Figure 4.

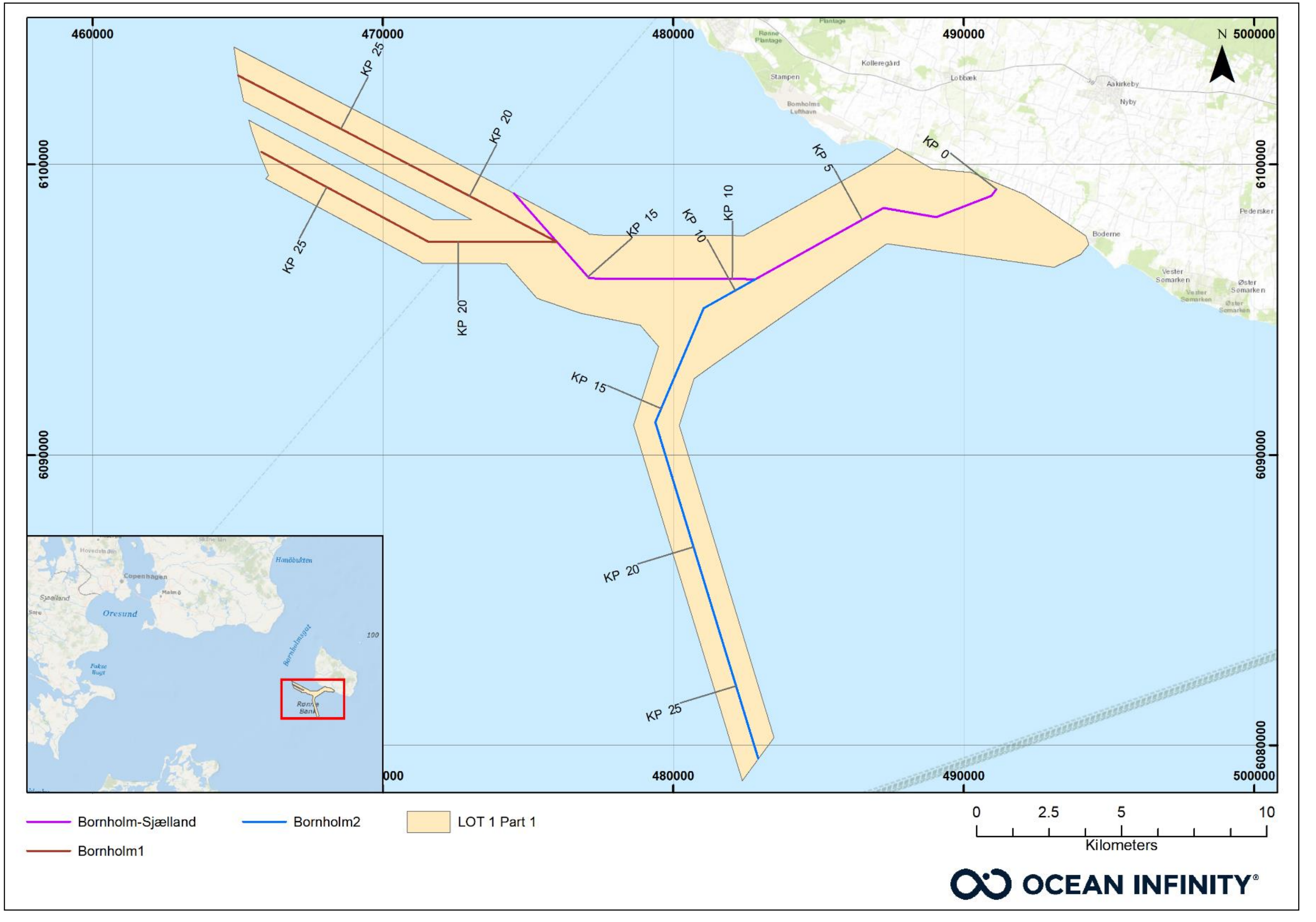


Figure 4 Overview of the defined section of Part 1 export cable routes and Denmark nearshore, Bornholm.

2.1 Survey Objectives

The survey objectives for this project were to acquire bathymetric soundings, magnetometer, seabed imagery and sub-seabed geological information along the six surveyed route corridors (of variable widths) between the island of Bornholm and Koge on the Danish coast. Acquisition of these data sets was conducted to provide comprehensive bathymetric soundings, seabed features maps including contact listings and shallow geological information in order to create a geological ground model and assist the mapping of magnetic anomalies. The interpretation of the datasets was charted and reported to assist 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 geotechnical sampling (VC) and testing (CPT) 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.

Overview image showing the survey blocks and the vessels that operated in each, is given in Figure 5.

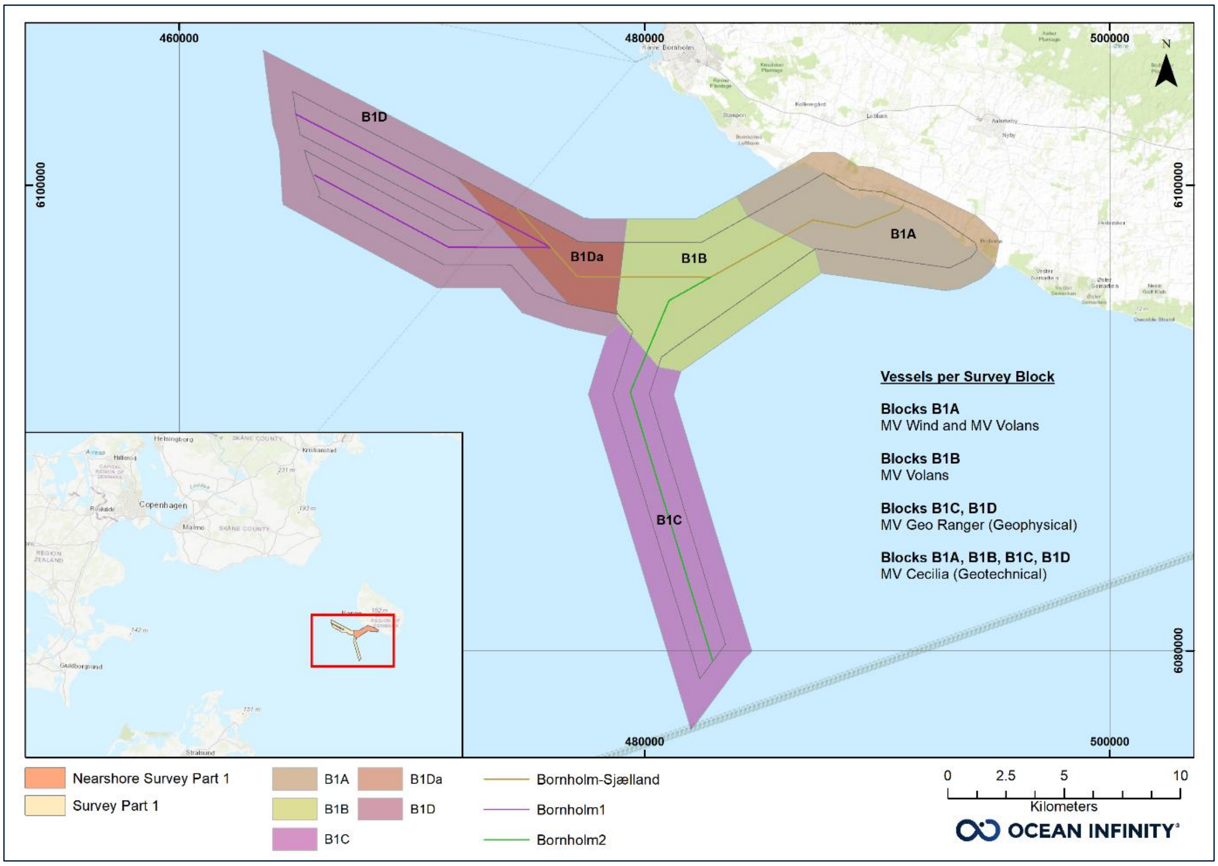


Figure 5 Overview image showing the vessels that worked in each block within Part 1.

2.2 Deviations to Scope of Work

WP-A: Offshore Cable Route Survey (M/V Geo Ranger)

During the geophysical survey there were six deviations from the original Scope of Work (SOW) (Table 4). For a full explanation of deviations and issues encountered while surveying, please refer to the Operations Report, 103971-ENN-OI-SUR-REP-OPREPWPA-A.

Table 4 Deviations from the SOW, WP-A (M/V Geo Ranger).

Date	Description	Decision/Result/Conclusion
2022-04-22	Update on line plan	The Client made changes to the northern part of B1D lines - rerouted
2022-04-26	Two additional lines	Two additional lines parallel to the steep slope at B1C due to MAG altitude above the limit while crossed the slope
2022-04-28	MBES holes >= 3.5m	MBES holes over the boulder area less than 3.5m are acceptable by the Client due to shadowing effect
2022-05-03	40m spacing line plan	Due to the influence of the pycnocline on the SSS data, it was decided to reduce the spacing between the lines to 40m
2022-05-06	100% coverage for SSS due to Pycnocline infill	Due to pycnocline effect on SSS data and to meet 100% coverage for SSS for the blocks where pycnocline was present. Decision was made to infill the B3A with the lines between the original lines
2022-05-11	Lower MAG signal quality for west bound lines	OI requested/ clarified to lower the signal quality threshold for infill survey to 200-250

WP-B: Nearshore and Landfall Survey (M/V Deep Volans and M/V Deep Wind)

During the geophysical survey there were seven deviations from the original SOW (Table 5). For complete explanations on all scope deviations and issues encountered while surveying, please refer to Operations Report, 103971-ENN-OI-SUR-REP-OPREPWPB-A.

Table 5 Deviations from SOW WP-B (M/V Volans & M/V Wind).

Date	Description	Decision/Result/Conclusion
2022-04-22	Update on line plan	Changes to the northern part of B1D lines - rerouted
2022-04-28	MBES gaps >= 3.5m	MBES gaps over the boulder area less than 3.5m are acceptable by the Client due to shadowing effect
2022-05-11	TQ2 Shallow Water Backscatter-SSS	SSS to be used instead of Backscatter on 0-3m depth
2022-06-27	TQ14 SSS Pycnocline relaxation	100% coverage accepted in areas of pycnocline
2022-06-01	TQ16 – SSS/MAG flying height	Flying height >6m accepted in areas of challenging topography
2022-06-03	TQ20 - Nearshore towed sensors scope relaxation	Towed equipment can be excluded from the shallow sections as well as the areas with steep topography.
2022-07-06	TQ21 – Bornholm Lidar Survey	Bathymetric Lidar to be acquired in areas shallower than 2m depth

WP-C: Geotechnical Investigations (M/V Northern Cecilia)

During the geotechnical investigations there were no deviations from the original SOW. For a complete breakdown of operations, please refer to Operations Report, 103971-ENN-OI-SUR-REP-OPREPWPC-A.

2.3 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 1 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, to ground truth, the survey results.

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

2.4 Report Structure

The results from the Lot 1 survey campaign are presented in five separate reports.

- Operations Reports (WP-A, WP-B & WP-C)
- Crossing 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.

2.4.1 Geophysical Survey Report

This report presents the Lot 1 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

2.4.2 Charts

The OI Charts describe and illustrate the results from the survey. The charts include an overview chart with a scale of 1:75 000 and alignment charts with a horizontal scale of 1:10 000, vertical scale of 1:200 and vertical exaggeration of 1:50. 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 RPL. The chart also includes the bathymetry presented as a shaded relief colour image.

Alignment charts

The alignment charts show the following:

- **Bathymetry** presented as a shaded relief colour image with 3 m colour interval, overlaid with contour lines (0.5 m (minor) and 5 m (major)) with depth labels;

- **Surface geology and seabed features** presented as solid hatches (geologic classifications include: mud and sandy mud, muddy sand, sand, gravel and coarse sand, till/diamicton, and sedimentary rock); surface morphology presented as solid hatches (morphologic classifications). Geotechnical and grab sampling locations with IDs are also provided;
- **SSS and magnetic contacts and linear features**; seabed features divided into seven different classes (ripples, low density boulder fields, medium density boulder fields, high density boulder fields, trawl mark areas, extraction area and sea grass) and are presented as hatches with patterns;
- **SSS Mosaic**: Image overlain by the multibeam track lines from the survey.
- **Longitudinal Profile with shallow geology**: sub-seabed geology profiles with interpreted horizons related to seabed level and geotechnical sample results.

2.5 Reference Documents

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

Table 6 Reference documents.

DOCUMENT NUMBER	TITLE	AUTHOR
DANMARKS OG GRØNLANDS GEOLOGISKE UNDERSØGELSE RAPPORT 2021/63	Geological Desktop Study – Geological seabed screening in relation to possible location of cable transects	From Client
103971-ECR-MMT-QAC-PRO-PROJMANU-05	Project Manual and Quality Assurance Plan	OI
103971-ECR-MMT-MDR-PRO-MDR002	Master Document Register	OI
103971-ENN-OI-SUR-REP-CROSSWPD	Crossing Report	OI
103971-ENN-MMT-QAC-PRO-CADGIS	CAD and GIS Specification	OI
103971-ECR-MMT-MAC-REP-GEORANGER_REVA	Mobilisation and Calibration Report – Geo Ranger	MMT
P3956_DW_MOBCAL_R03	Mobilisation and Calibration Report – Wind	DEEP
P3956_DV_MOBCAL_R03	Mobilisation and Calibration Report – Volans	DEEP
103971-ECR-OI-MAC-REP-CECILIA-REVA	Mobilisation and Calibration Report – Northern Cecilia	OI
103971-ENN-OI-SUR-REP-OPREPWPA-A	Operations Report WP-A – Geo Ranger	OI
103971-ENN-OI-SUR-REP-OPREPWPB-A	Operations Report WP-B – Volans & Wind	DEEP
103971-ENN-OI-SUR-REP-OPREPWPA-A	Operations Report WP-C – Northern Cecilia	OI
103971-ENN-OI-SUR-REP-OPREPWPD-A	Operations Report WP-D – Geo Ranger	OI
103971-ECR-MMT-HSE-PRO-ENFGEORA	Emergency Notification Flow Chart – Geo Ranger	OI
103971-ECR-MMT-HSE-PRO-HAZOP-A	Hazard Identification & Risk Assessment: Geophysical	OI
103971-ECR-MMT-HSE-PRO-HSEPLAN	Project HSE Plan	OI

2.6 Corridor Line Plan

The Lot 1 survey line spacing and minimum parameters are detailed in Table 7 together with the planned and accumulated distance surveyed.

Table 7 Survey line parameters.

GEOPHYSICAL SURVEY SETTINGS	SCOPE	ACCUMULATED[1]
Part 1 (Offshore)	1,775 km	3,478 km (Includes infills)
Part 1 (Nearshore)	3,053 km	2,753 km (Includes infills)
Line spacing offshore geophysical Main Lines	70 m	NA
Line spacing offshore geophysical Cross Lines	5 km	NA
Line spacing nearshore geophysical Main Lines	20 m	NA
Line spacing nearshore geophysical Cross Lines	5 km	NA

[1]Accumulated distance calculated from SSS tracks.

3. Survey Parameters

3.1 Geodetic Datum and Grid Coordinate System

3.1.1 Acquisition

The geodetic parameters used for SSS, SBP, raw MBES during acquisition are presented in Table 8. The geodetic parameters used for magnetometer during acquisition are presented in Table 9.

Table 8 Geodetic parameters.

Horizontal datum: WGS84	
Datum	World Geodetic System 1984 (6326)
Ellipsoid	World Geodetic System 1984 (7030)
Prime Meridian	Greenwich (8901)
Semi-major axis	6 378 137.000 m
Semi-minor axis	6 356 752.3142 m
Inverse Flattening (1/f)	298.257223563
Unit	International metre

Table 9 Geodetic parameters used during acquisition for magnetometer, SSS, SBP and MBES.

Horizontal datum: ETRS89	
Datum	ETRS89
Ellipsoid	GRS80
Prime Meridian	Greenwich
Semi-major axis	6 378 137.000 m
Semi-minor axis	6 356 752.3142 m
Inverse Flattening (1/f)	298.257222101
Unit	International metre

3.1.2 Processing

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

Table 10 Geodetic parameters used during processing.

Horizontal datum: ETRS89	
Datum	ETRS89
Ellipsoid	GRS80
Prime Meridian	Greenwich
Semi-major axis	6 378 137.000 m
Semi-minor axis	6 356 752.3142 m
Inverse Flattening (1/f)	298.257222101
Unit	International metre

3.2 Transformation Parameters

The transformation parameters used during the project are presented in Table 11. Test transformations are presented in Table 12.

Table 11 Transformation parameters.

https://planner.mmt.se/wiki/index.php/Geodetic_Parameters

Datum Shift From WGS84 to ETRS89 (right-handed convention for rotation - coordinate frame rotation)	
Parameters	**Epoch 2022.5**
Shift dX (m)	+1.016730
Shift dY (m)	+1.228060
Shift dZ (m)	-0.856010
Rotation rX (“)	-0.041514
Rotation rY (“)	+0.022120
Rotation rZ (“)	+0.037257
Scale Factor (ppm)	-0.014520

Table 12 Test coordinate for datum shift.

UTM Zone	Datum	Easting (m)	Northing (m)	Latitude	Longitude
33	WGS84	-	-	55° 06' 00.000" N	14° 00' 00.000" E
	ETRS 89	436191.173	6106375.557	55° 05' 59.981" N	13° 59' 59.966" E

3.3 Projection Parameters

The projection parameters used for processing and reporting are presented in Table 12.

Table 13 Projection parameters.

Projection Parameters	
Projection	UTM
Zone	33 North
Central Meridian	15° 00’ 00’’ E
Latitude origin	0°
False Northing	0 m
False Easting	500 000 m
Central Scale Factor	0.9996
Units	metres

3.4 Vertical Reference Parameters (Vessel Based Survey)

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

Table 14 Vertical reference parameters.

Vertical Reference Parameters	
Vertical reference	MSL
Height model	DTU21

Vessel height data is reduced to the project vertical datum in QPS QINSy through the application of a geoid/height model in real-time. Through this method the bathymetry data are corrected to MSL, the defined vertical reference level (Figure 6).

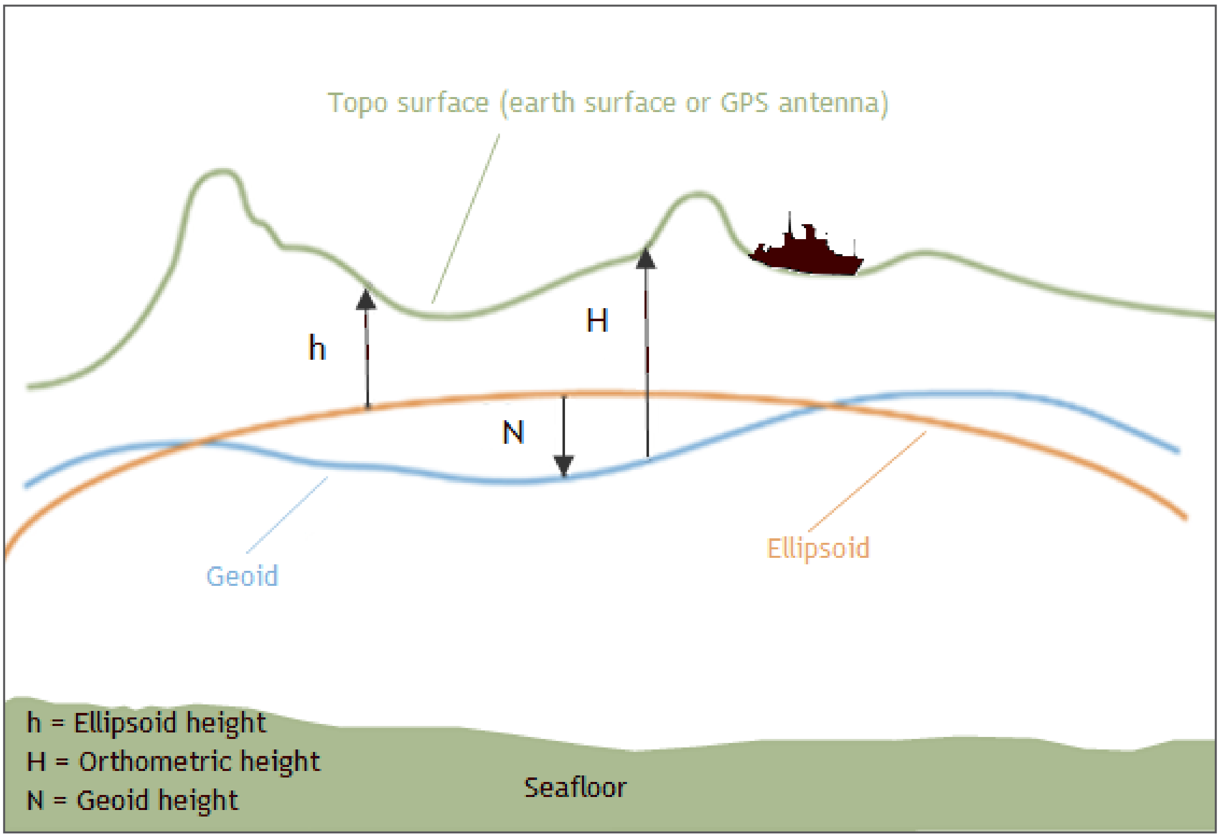


Figure 6 Overview of the relation between different vertical references.

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.

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.

3.5 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.

3.6 KP Protocol

For the export cable routes, the RPL are based off the client supplied shape file, 2022_04_14_ROUTE_LIN.

KP 0.000 is located at the Bornholm landfall (Part 1), with KP values increasing towards the proposed Offshore Wind Farm (OWF) survey areas. KPs were calculated based upon the relevant UTM mapping projection zone and were at all times related to the client provided shape files.

4. Survey Platforms

4.1 M/V Geo Ranger

GEOPHYSICAL SURVEY OFFSHORE

The offshore geophysical survey operation was conducted by the survey vessel M/V Geo Ranger.

Figure 7 M/V Geo Ranger.

Table 15 M/V Geo Ranger equipment.

Instrument	Name
Primary Positioning System	C-Nav 3050 using C2 corrections
Secondary Positioning System	Trimble SPS852 using Fugro G2 corrections
Primary Gyro and INS System	IXBLUE HYDRINS
Secondary Gyro and INS System	Kongsberg HiPAP 502
Underwater Positioning System	QPS QINSy
Survey Navigation System	C-Nav 3050 using C2 corrections
Surface Pressure Sensor	Vaisala Pressure Sensor
Multibeam Echo Sounder	Kongsberg EM2040D (200-400 kHz)
Side Scan Sonar	EdgeTech 2200-CSS (300/600 kHz) and Focus II ROTV
Sub-Bottom Profiler	Innomar Medium
Magnetometer	Geometrics G882
Sound Velocity Sensor	Valeport SWiFT SVP, over the side Valeport miniSVS, hull-mounted at the MBES transducers
Grab Sampler	Day Grab
PAM	PAM

Table 16 ROTV-mounted positioning/geophysical equipment.

Instrument	Name
Primary Positioning and INS System	IXBLUE ROVINS
Pressure Gauge	Valeport miniSVS&P
Altimeter	Kongsberg 1007
USBL Transponder	Kongsberg cNODE
Side Scan Sonar	EdgeTech 2200 (300/600 kHz)
Magnetometer	Geometrics G882

4.2 M/V Volans

GEOPHYSICAL SURVEY NEARSHORE

The nearshore geophysical survey operation was conducted mainly by the survey vessel Deep Volans.

Figure 8 M/V Deep Volans.

Table 17 M/V Deep Volans equipment.

Instrument	Name
Primary Positioning System	Septentrio AsteRx-U GNSS receiver with 4G RTK corrections
Secondary Positioning System	Septentrio AsteRx-U GNSS receiver with 4G RTK corrections
Heading / motion	IXSEA Octans MRU
Underwater Positioning System	Sonardyne Ranger 2
Survey Navigation System	QPS QINSY

Instrument	Name
Multibeam Echosounder	NORBIT iWBMS dual head system Addition: R2Sonic 2024 mounted on satellite survey platform Deep Lorean (operated from the Deep Volans)
Side Scan Sonar	Edgetech 4200
Sub Bottom Profiler	Innomar Standard (pole mounted)
Sound Velocity Sensor	SVP14 / SVP15 and Valeport mini
Magnetometer	Geometrics G882 (towed behind SSS)
Grab sampler	Grab sampler

4.3 M/V Deep Wind

GEOPHYSICAL SURVEY NEARSHORE

The shallowest nearshore geophysical survey operations were conducted by the survey vessel Deep Wind.

Figure 9 M/V Deep Wind.

Table 18 M/V Deep Wind equipment.

Instrument	Name
Primary Positioning System	Trimble SP885 using RTK corrections
Secondary Positioning System	Applanix surfmaster
Heading / motion	IXSEA Octans MRU
Multibeam Echosounder (Medium to Shallow Water)	PING DSP system
Sound Velocity Sensor	SVP14 / SVP15 and Valeport mini

5. Data Processing and Interpretation Methods

5.1 Bathymetry Data

The workflow diagram for MBES processing is shown in figure below.

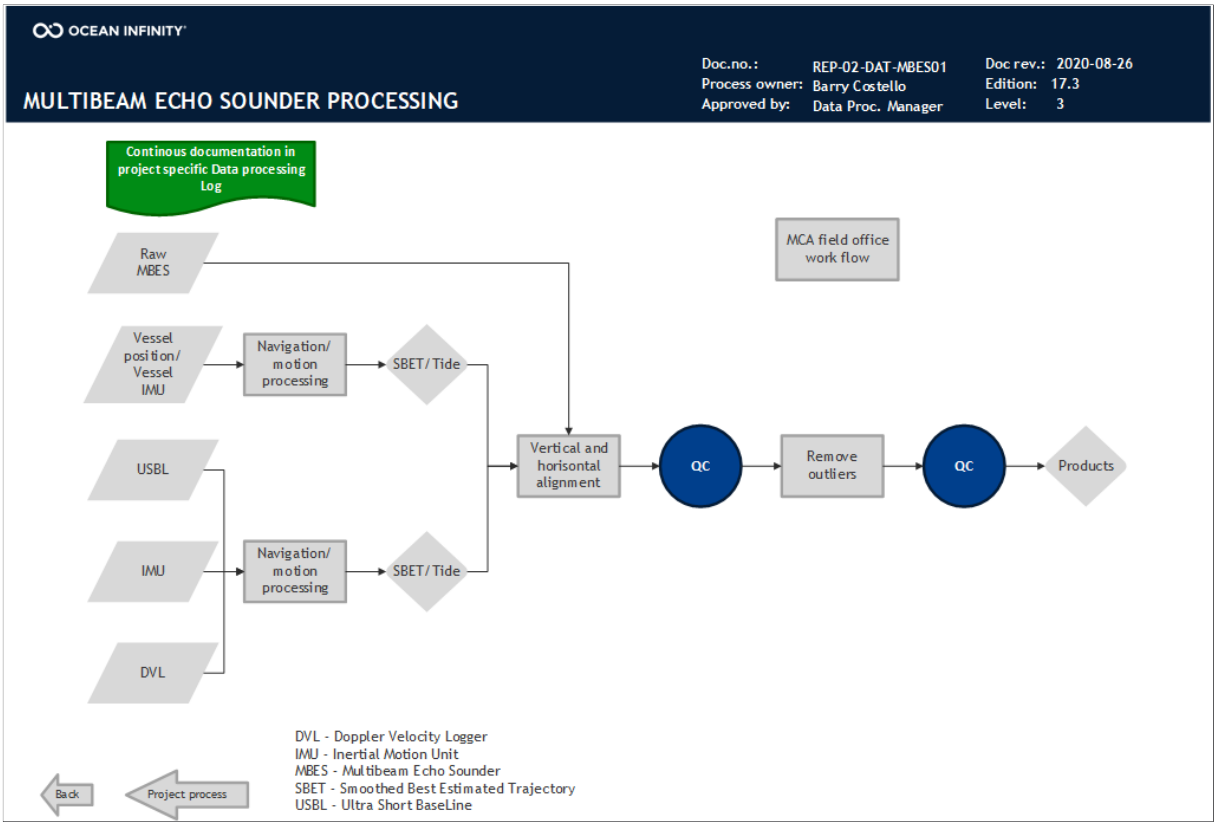


Figure 10 Workflow MBES processing. The workflow outlines the processing that occurred on M/V Geo Ranger.

The objective of the processing workflow was 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 to homogenise the dataset and data cleaning in order to remove outliers.

WPA and WPB was collected and processed with different software and equipment (WPA collected by OI and WPB by Deep BV).

For WPA the data from the Multibeam (QINSy .db) merged with real-time navigation and attitude from both inertial measurement unit (IMU) data records and corrected GNSS recorded positions and referenced to the survey vertical datum via a Geoid model was imported directly into the Qimera program and converted to .qpd format. Since the data amount was very large each survey block had to be processed individually and in some cases those blocks were also divided into sub-blocks.

The multibeam data was corrected for variations in sound velocity, ray bending and other environmental/atmospheric effects. When corrections had been applied a DTM was created to undergo cleaning of outliers. This was done either manually or using filtering algorithms such as the Combined Uncertainty Best Estimation (CUBE) filtering functionality in Qimera. Filtering was always followed up by manual verification of the affected area.

The Standard Deviation at 95% confidence interval was also checked 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. 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.

For WPB the data was acquired in Beamworx NavaQ and then processed in the BeamworX Autoclean workflow, the data is turned into a 3D model which undergoes further checks and data cleaning processes. Multiple filters are applied to the data to remove any outliers although some manual cleaning may also take place. After this data is cleaned sufficiently it is ready for the additional quality check within Autoclean software. If the dataset passes Quality Control (QC) checks, then products (DTMs, contours and shaded images) can be exported for delivery or for further internal use.

Once the data was considered to meet survey specifications, exports were generated from Qimera and Autoclean for further use in other software such as NaviModel, Feature Manipulation Engine (FME) or ArcGIS.

Files exported after processing:

- Un-gridded Soundings of all blocks and sub blocks (all accepted x,y,z values in ASCII format).
- Gridded average depth soundings of all blocks and sub blocks (x,y,z values) in 25 cm, 1 m and 5 m sizes.
- Gridded CUBE soundings of all blocks (x,y,z values) as 25 cm for use during boulder detection.
- Vessel Tracks of all utilised survey lines in the data. (For use in ArcGIS).
- Gridded Total Horizonal Uncertainty (THU) soundings (x,y,THU values) at 1 m resolution from all survey blocks.
- Gridded Total Vertical Uncertainty (TVU) soundings (x,y,TVU values) at 1 m resolution from all survey blocks.

When the files had been exported, NaviModel was used for assembly of surfaces and to export products for AutoCAD and ArcGIS. All gridded type soundings (depth, THU, TVU) was imported block-by-block into DTMs in 25 cm, 1 m and 5 m resolution. Each DTM was then cut down to block size, removing overlapping data between each block.

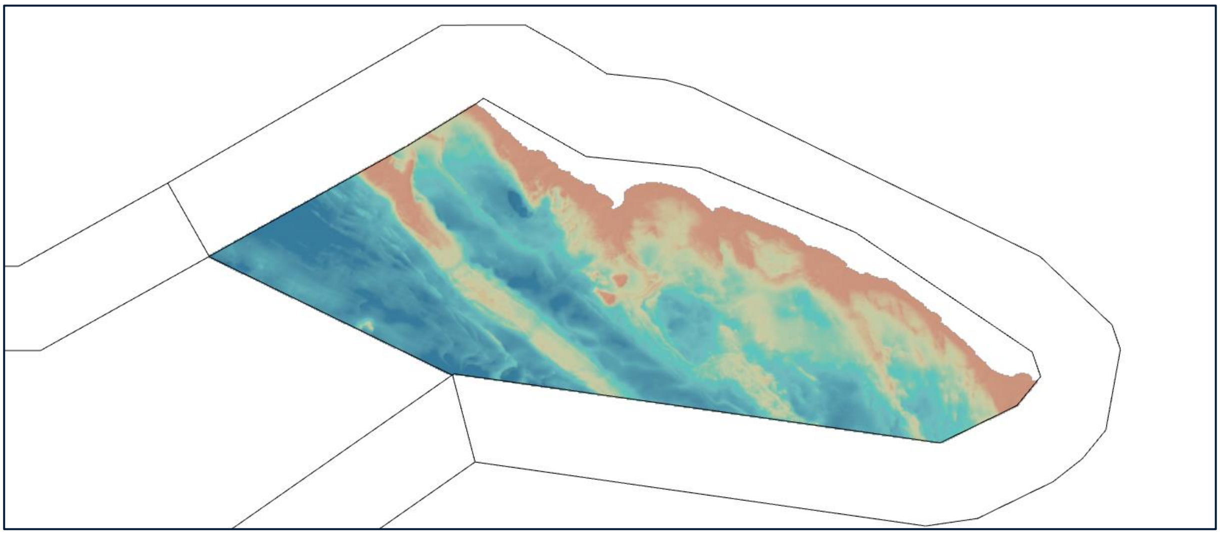


Figure 11 showing DTM in WPA, Block B1A cut according to the survey block area.

Files exported from NaviModel:

- All gridded ASCII soundings (xyz, THU, TVU) exported block by block for tiling and creation of GeoTIFF data.
- Depth Contours in 50 cm interval.

In the final steps Feature Manipulation Engine (FME) was used to finalize products for delivery. All gridded ASCII data were tiled and renamed following a 2 km squared UTM grid. The lower left corner of each grid cell was used to name the gridded tiles with the first three numbers of the east coordinate and the first four numbers of the north coordinate*. Ex. 480_6094_B1B_MBES_1m (EEE_NNNN_B1B_MBES_1m).*

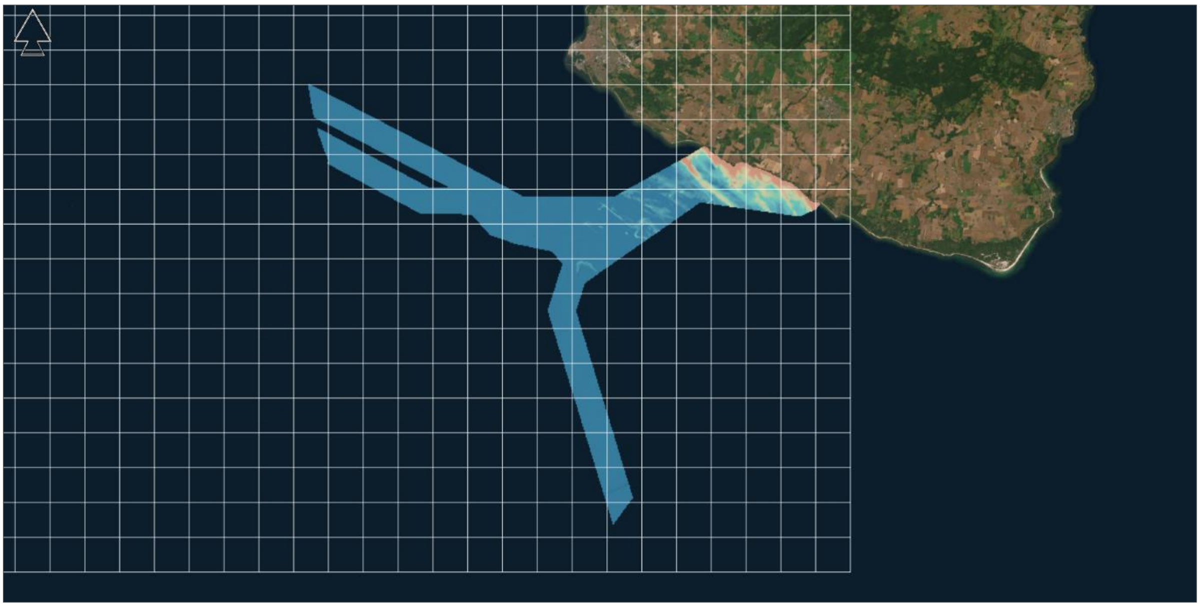


Figure 12 showing the UTM grid overlaid on the multibeam data (Bornholm).

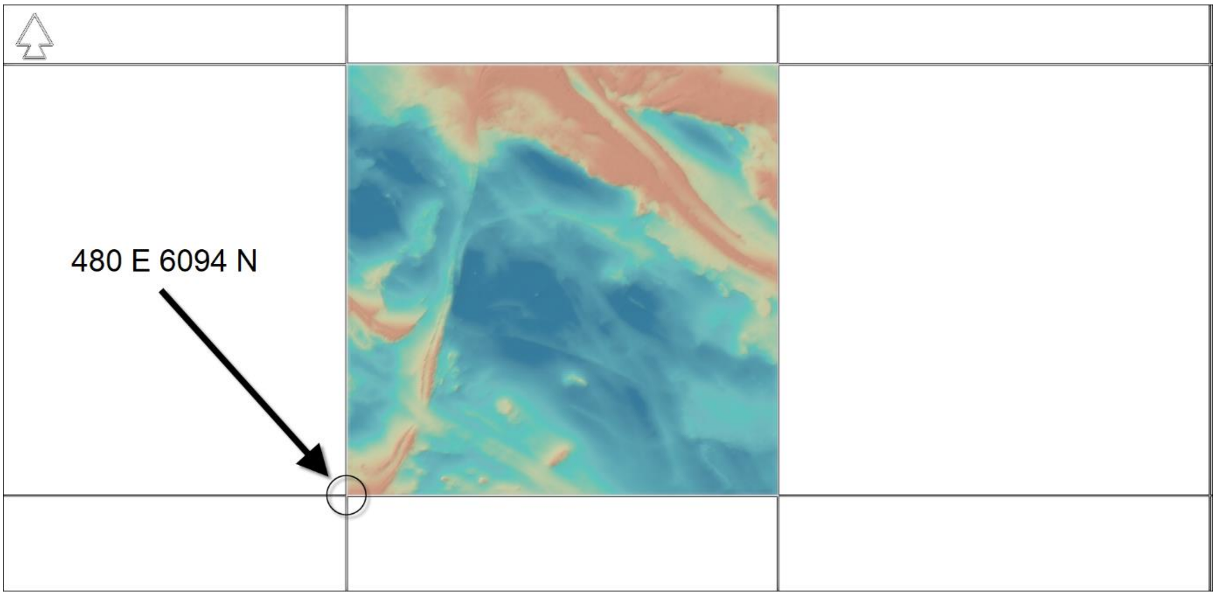


Figure 13 showing a closeup of tiled 1 m grid (E 480 000 m N 6 094 000 m). The filename for this tile is 480_6094_B1B_MBES_1m.

Once all gridded files have been tiled in FME all gridded ASCII tiles are also converted to into 32 -bit floating GeoTIFFs for import use in ArcGIS.

Multibeam files converted and exported through FME:

- All gridded ASCII files as named according to UTM grid.
- All exported ASCII UTM tiles as 32 -bit floating point tiffs.

5.1.1 Boulder Detection

OI Boulder detection (WPA) is done through a workflow using ArcGIS and FME. The extraction of data needed to pick the boulders is done by using a 32 -bit floating raster produced in FME by using XYZ CUBE surfaces exported from Qimera. Contacts are inferred as deviations between a high-resolution bathy dataset and a smoothed surface that closely follows the topography and has the same resolution as the bathymetry data.

Workflow of boulder picking:

- A surface difference calculation is performed with contacts corresponding to parts of the difference raster that lie above the smoothed surface (in ArcGIS).
- The user adjusts the threshold until false positives are masked by the background and you are left with the contacts highlighted (in ArcGIS).
- The difference raster is exported as image rasters (from ArcGIS)
- The image rasters are used alongside the bathymetry and surface difference data rasters to calculate dimensions and position. (This process happens in FME)
- Contact data is exported as shapefile polygons, shapefile points and Comma Separated Variable (CSV) points (for use in ArcGIS).
- QC in GIS is efficient through expressions in the attribute table and through checking the alignment of the shapefile polygon and the contact in plan view.
- Contacts with Lengths >1.0 m were used to create data driven Boulder Field Density maps and exported as a boulder target shape file for use in the ArcGIS database.

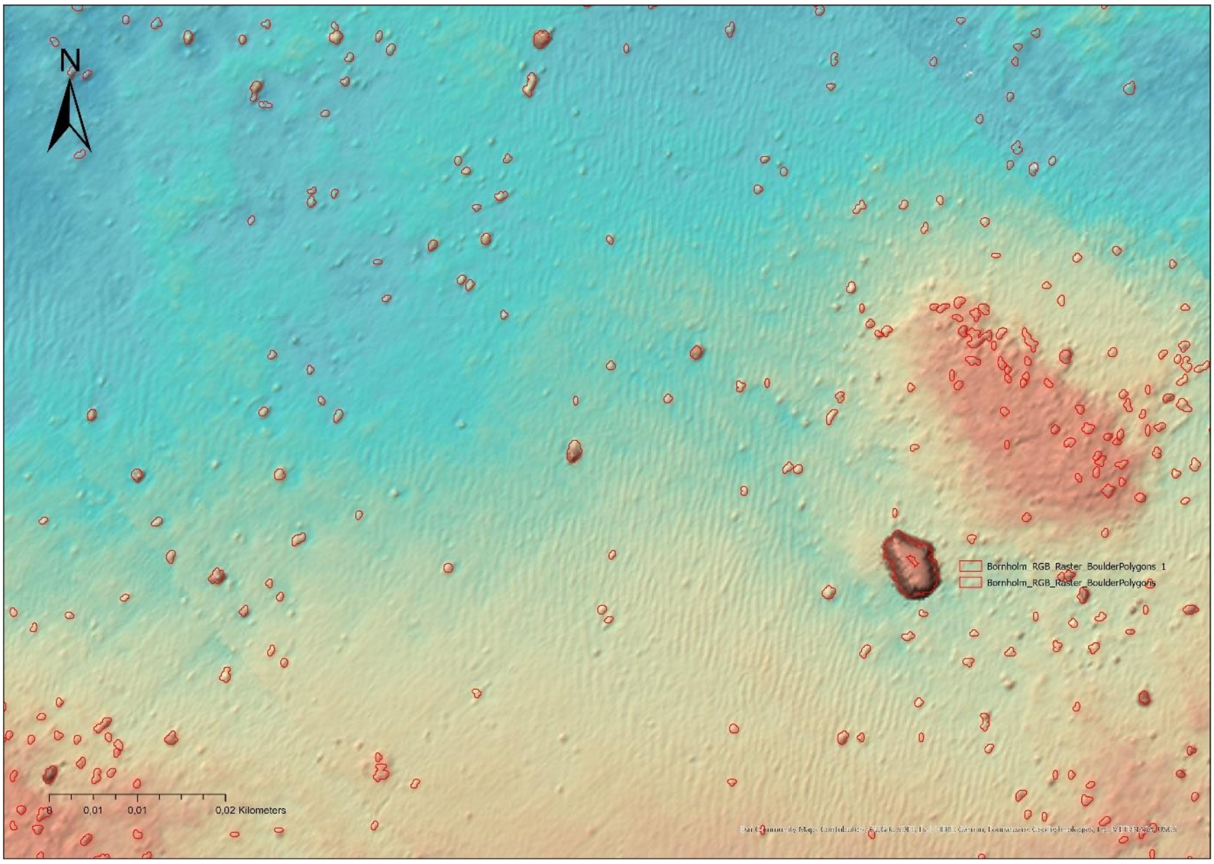


Figure 14 Results of the Auto-Boulder picking using the OI process.
Only >1.0 m boulders are being marked in this image.

For WPB, boulders were picked in Autoclean with an automated process in the software. Checks have been made where data sets between WPA and WPB are adjacent and the results line up very well (Figure 15).

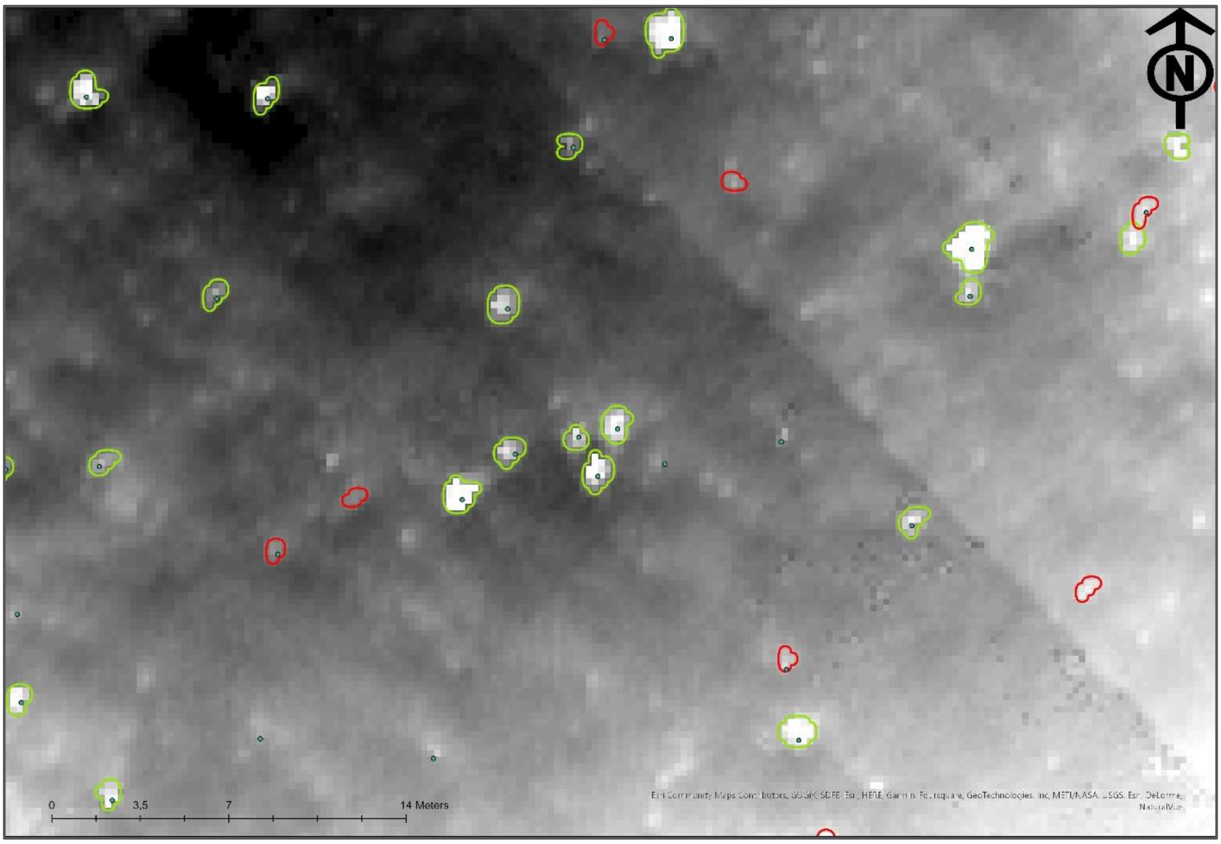


Figure 15 Comparison of Contact Auto-Picking by DEEP and OI.

The polygons surrounding contacts are created by the OI process. Green polygons are ≥ 1 m, Red < 1 m. The green points are created by the Auto-clean process.

QC of MBES Contacts

Whilst the automated procedures used within the project enabled swift and efficient capture and measuring of boulders their abundance and the complexity of the seabed in some areas created a challenge for quality control.

False positives (areas of the seabed that have been falsely flagged as boulders) come in a variety of forms, which include:

- Bedforms such as ripple/sandwave crests
- Ridges and bedrock features
- Man-made objects
- Depressions
- MBES artefacts (edges of overlapping lines or noise)
- Multiple picks on larger features

The QC steps for both sources of auto picked contacts are as follows:

- Contacts with Length < 1m are filtered from the datasets
- Linear features (ridges, bedform crests) are removed by filtering in ArcGIS using the Length:Width ratio.
- Each feature in the SSS contact list is visited and any features that have been captured are deleted so that Man-Made Objects (MMOs) are not also classed as boulders.
- The boulder polygons (or points) are viewed over a hillshade in ArcGIS and the surface is systematically checked at a scale of 1:250 to check for false positives over the items listed above.
- At the same time features that have escaped detection or have been improperly captured can be added manually.

5.1.2 Boulder Field Heat Map Generation

Once the finalised contact lists for each block have been QCd the entire dataset is combined into a single point shapefile. Since the listing contains (approximately) all of the contacts within the survey area (with length ≥ 1 m) the boulder field polygons can be created using a data driven approach. Careful tailoring of the workflow was required to reduce the complexity of the polygons whilst providing the detail of areas of seabed free of boulders.

The boulder field map creation was undertaken using ArcGIS Pro and FME with the process involving the following steps.

- A point density raster was created in ArcGIS Pro with a 1 m resolution and a 100 m neighbourhood – The generalised boulder field source data.
    - This raster was contoured to extract the 20, 40 and 80 boulders per hectare polygons.
- A second point density raster was created with a 10 m resolution and a 10m neighbourhood – this was used to expose areas of seabed free of boulders.
    - This raster was contoured to extract the 20 boulder per hectare polygon which serves as the ultimate extent of the boulder field areas.
- All contours were generalised in FME with polygons lying as close neighbours amalgamated to simplify the output maps. Small gaps within the polygons were dissolved.
- The generalised polygon areas were clipped with the detailed boulder field extent polygon to open up as much of the seabed for routing options.
- The area, number of contacts contained and boulder density per hectare for each polygon was calculated. At the request of the client, LOW and INT class polygons with areas less than 5000 m^2 were removed from the final polygon file.

A section of the boulder field map from the Bornholm side of the survey area is shown in Figure 16 with the contacts overlaid as grey dots. This shows a transitional zone from low density areas which do not meet the boulder field criteria to a region with a high density of boulders.

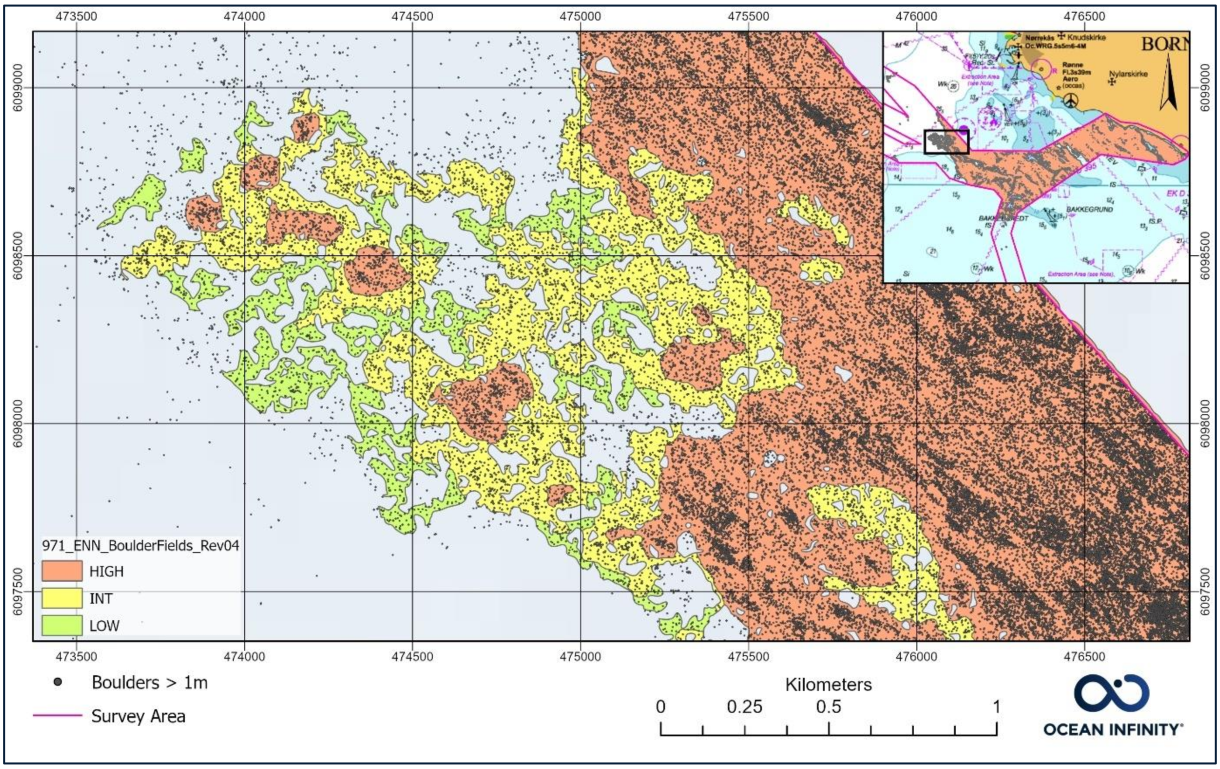


Figure 16 Example of data-driven boulder field mapping.

5.1.3 LiDAR Data

Collection of Light Detection and Range (LiDAR) data was not in the original scope of work but was used as an alternative to collect topological data instead of with a GPS backpack. With the help of green LiDAR the gap between nearshore data below sea level and land could be filled in as well. The LiDAR data was collected on two occasions. One time with standard LiDAR for topological use on land and one second time with green LiDAR to fill in the gaps between topo and the MBES.

- The LiDAR data was processed outside of Oi and then delivered to us as .las files.
- The LiDAR files was imported into NaviModel and checked vertically against MBES data.
- The LiDAR data was then exported as .xyz -files in 50 cm grids and floating point GeoTiff for delivery.

5.2 Backscatter Data

For WPA MBES backscatter data was processed on both M/V Geo Ranger and at the OI Gothenburg office using QPS Fledermaus GeoCoder Toolbox (FMGT) as processing software to calculate Backscatter with the Kongsberg .all raw files collected online. Processing backscatter is a very data intensive task, so each survey block was processed individually.

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. Survey lines that run obliquely to the main survey

line directions were excluded to reduce the presence of artefacts in areas that already have 100% coverage.

All backscatter data was built as a 25 cm mosaic and exported as 32 -bit floating GeoTiffs. Normally the mosaics will be exported with an intensity setting with starting value of -40dB and the ending value at -10dB. This is a value that can vary depending on what multibeam system was used to collect the data. The tiffs were reprojected and clipped to boundary of the survey areas using Feature Manipulation Engine (FME). Final tiffs will be imported and stored in an ESRI file geodatabase as a deliverable.

For WPB the processing was at first performed in the QPS software package Fledermaus Geocoder Toolbox (FMGT), replaced in the later stage of the project by BeamworX Autoclean Raw Processing due to easier workflows and data handling. Raw data which came from the Multibeam (NavAQ for AC Backscatter) was imported directly into the FMGT program (in the later stage of the project to the Autoclean Raw Processing). Mosaics was generated accordingly with the client specification. ASCII files containing backscatter intensity (XY+i) were exported from FMGT/Autoclean at 25 cm resolution.

Figure 17 showing the result of processed backscatter data. WPA, Block B1D.

5.3 Side Scan Sonar Data

SSS processing and interpretation was conducted within SonarWiz (V7.08.01.). Prior to importing raw SSS JSF files the water sound velocity at towing depth was written to the raw JSF files online and checked noted when importing to SonarWiz. The raw SSS data was then imported into SonarWiz without the application of any gains, and the following QC/processes were conducted:

1. Navigation data QC'd and any occasional 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 to meet client coverage requirements

The SSS processing workflow is outlined in Figure 18 and Figure 19.

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 and exported as DXF files. For digitisation in AutoCAD, SSS mosaics were exported from SonarWiz loaded into AutoCAD and line and polygon features mapped. Before the mosaic were exported as a GeoTiffs, the files were arranged so the best available data is uppermost. The nadir was made transparent for data in overlapping files that cover the nadir gap, to be seen.

The geo-boundaries (interpreted changes in surface geology) were reviewed against backscatter, MBES and magnetometer (MAG) grid data so an integrated interpretation was obtained based upon all available data. Seabed sediment classifications were also reconciled against the geotechnical grab sample (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 man-made objects were digitised checking the MBES, MAG and backscatter datasets to confirm contact confidence (See Table 19). Wrecks/cables were correlated to existing databases. The contact list was then correlated to MAG.

Boulders >1m were picked using the MBES dataset using an auto-picking algorithm in ArcMap. SSS contacts were checked against the boulder picking to ensure correct classification. Based on these results, boulder fields were delineated in ArcMap using a density classification and heat maps created.

Table 19 SSS Contact interpretation confidence level

Confidence Level	Contact identified on:
1 / Low	One SSS file
2/ Medium	Two SSS files
3/ High	Two SSS files and MBES dataset
4/ High	Two SSS files, MBES and MAG datasets

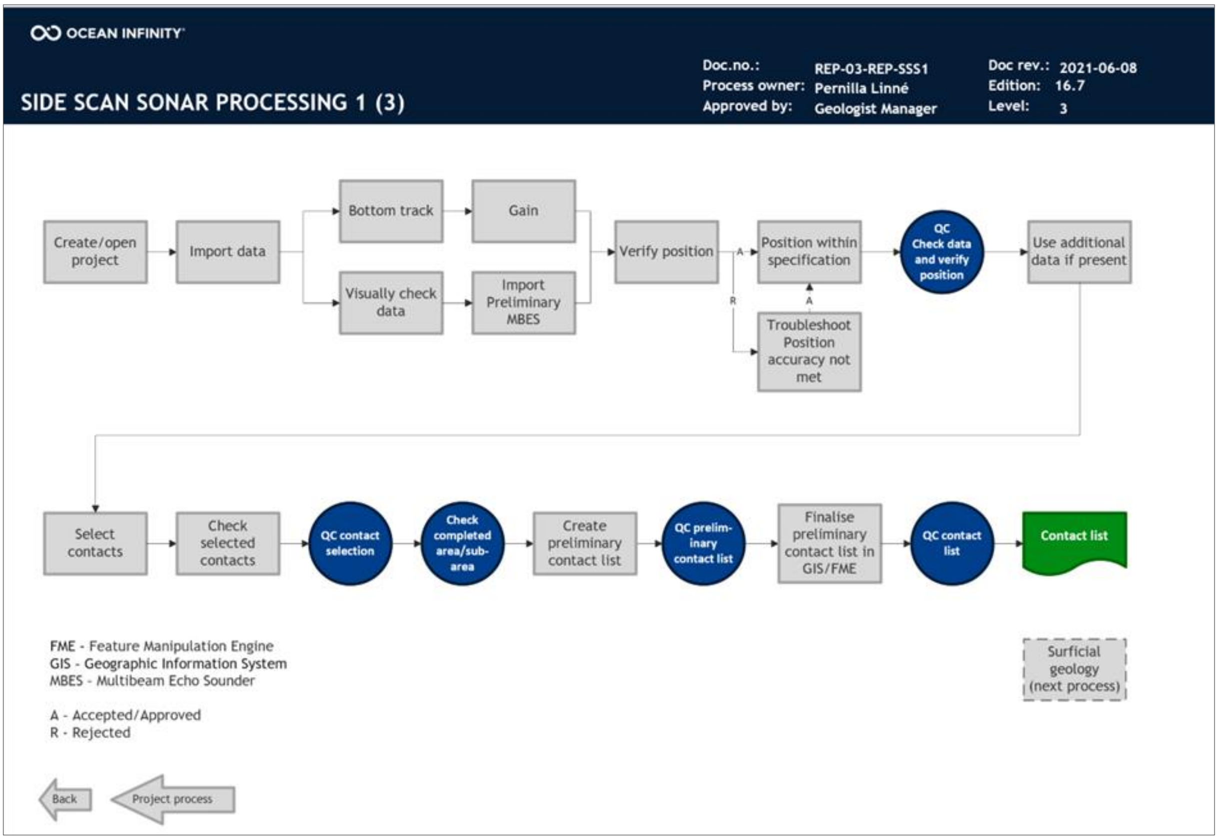


Figure 18 Workflow side scan sonar processing (1 of 2).

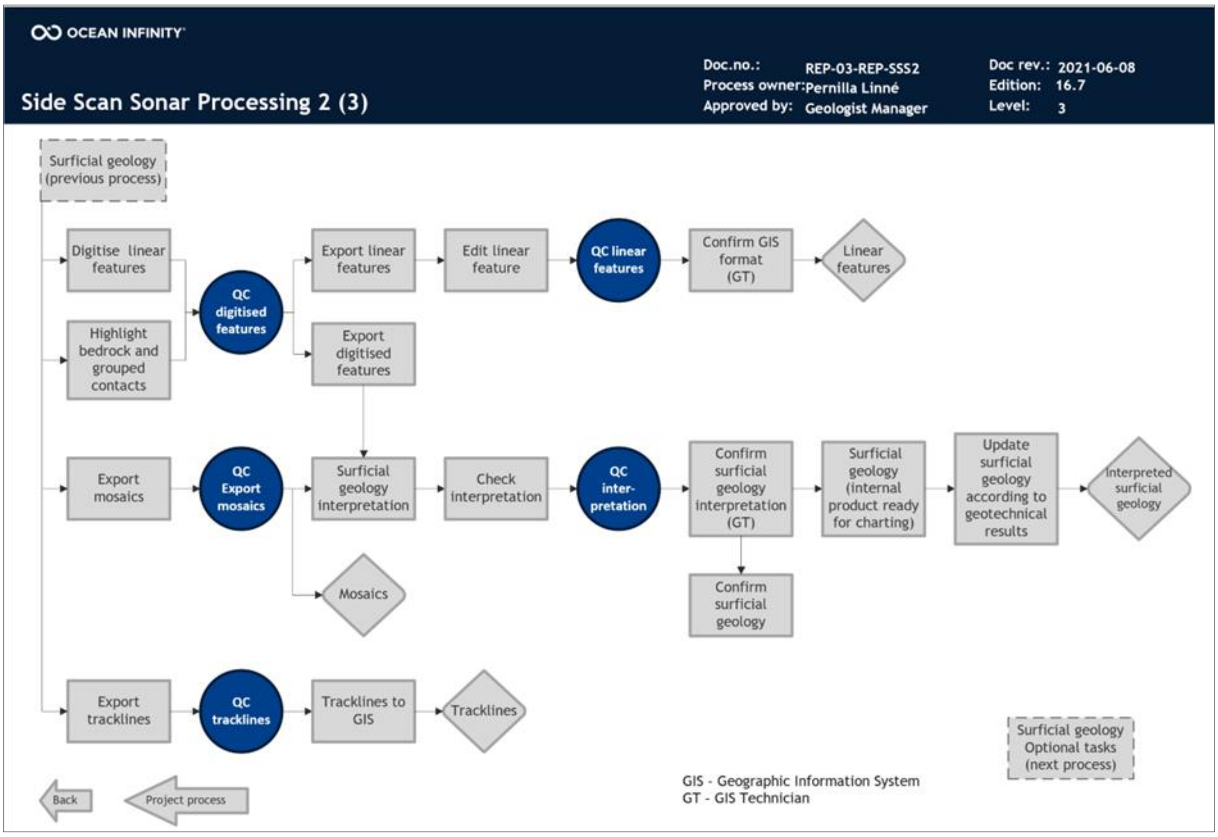


Figure 19 Workflow side scan sonar processing (2 of 2).

5.4 Magnetometer Data

MAG data was processed and interpreted within Oasis Montaj software (V2021.2).

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 are interpolated and bigger navigational gaps are flagged for infill. 100 samples are interpolated: at 4 knots survey speed with a sample rate of 10 Hz, approximately 20m is the maximum interpolation distance. 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 performed and additional spikes removed as needed. Once despiked a small rolling statistic smoothing filter is applied for each sensor.

The raw MAG data was de-spiked using a pre-set cut off value of 45000 nT and 56000 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:

- Non-linear filter 1; Width = 60, Tolerance = 1.2
- Non-linear filter 2; Width = 30, Tolerance = 0.5
- Non-linear filter 3; Width = 15, Tolerance = 0.25
- Non-linear filter 4; Width = 7, Tolerance = 0.125

Example of the filter result can be seen in Figure 20.

The same set of filters were used over the whole dataset to remove the regional background field.

No altitude correction has been performed on the magnetic data set.

Each file was individually studied for anomalies. The criteria for magnetic anomalies are 10 nT (peak to peak). However, clear anomalies below the threshold have also been picked.

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 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 was manually measured. Once completed, each picked anomaly was individually Quality Checked to confirm stored values.

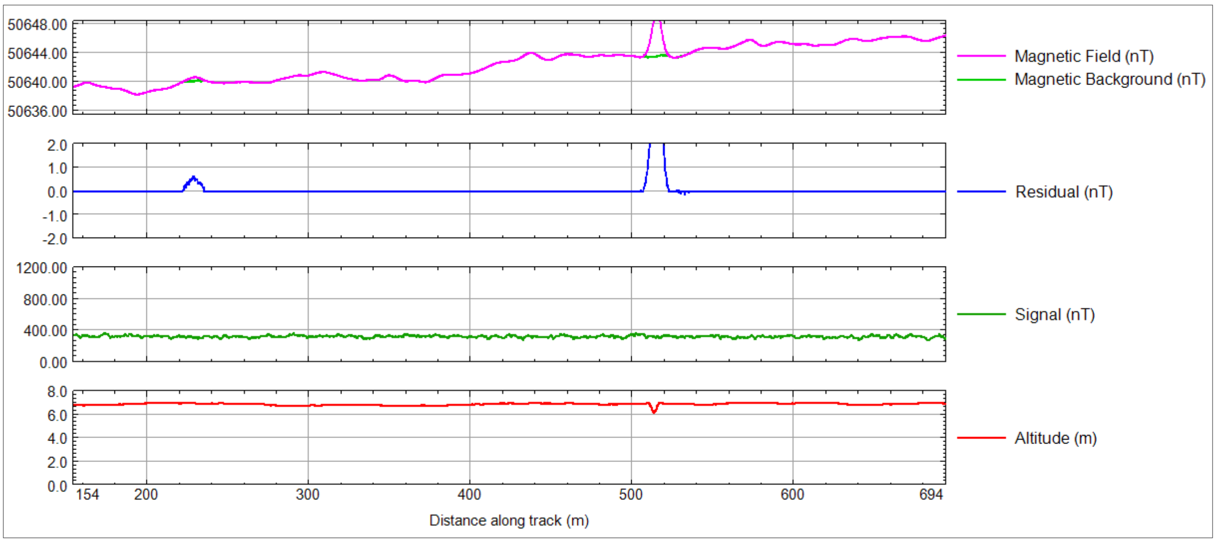


Figure 20 Data example of processed background trend and the resulting residual signal of the magnetometer data.

The general workflow of the MAG processing is outlined in Figure 21 and Figure 22.

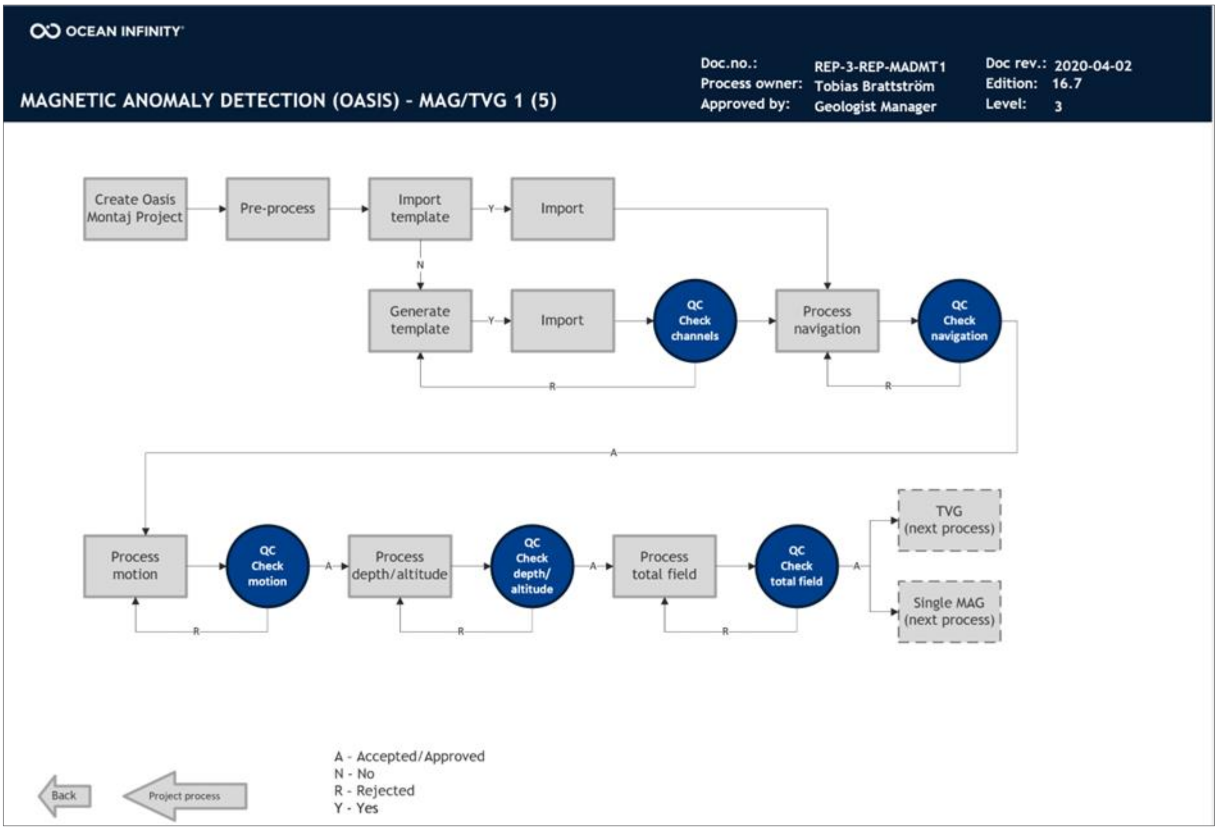


Figure 21 Workflow MAG processing (1 of 2).

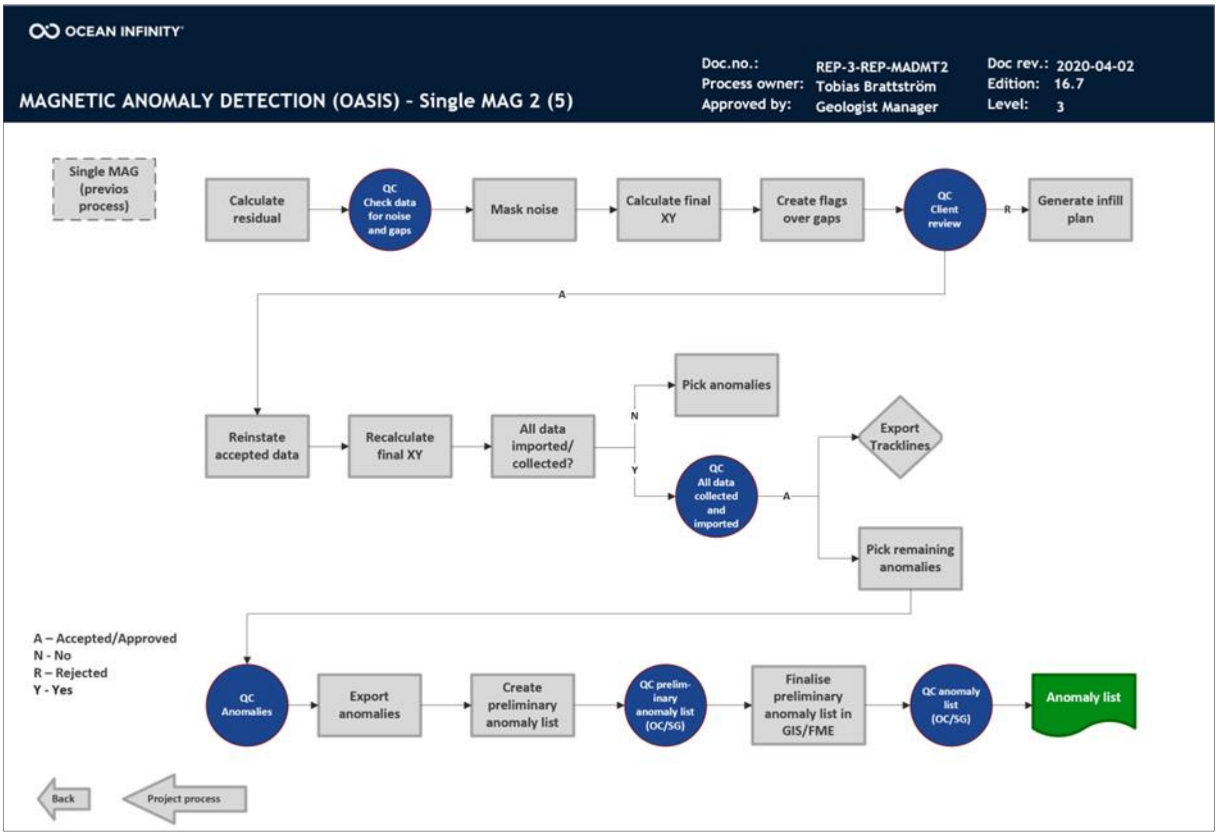


Figure 22 Workflow MAG processing (2 of 2).

5.5 Sub-Bottom Profiler Data

The SBP data files were converted from SES3 format to SGY format using an in-house software; MMT GeoTools. The conversion software corrects the navigation and applies vertical corrections to the data by extracting the height value stored within the SES3 file. The SGY files were then imported into RadExPro for signal processing. The seabed was auto tracked and then quality checked and manually adjusted, if required. Positional accuracy was verified during the Mobilisation and Calibration (MAC) by using MBES data to locate features clearly distinguishable in both data sets and comparing the positions. Within RadExPro the processing flows were designed to improve the quality and resolution of the data by removing noise and enhancing the primary signal. In general, the signal processing flow applied to the data was:

- Burst noise removal
- TFD noise attenuation
- Source signature deconvolution
- Butterworth filtering
- Amplitude correction
- Amplitude recovery
- 2D spatial filter (nearshore only)
- Export in standard SGY

Visual QC was performed before and after each processing step to check:

- The natural continuity of geological units was preserved
- Creations of artefacts which could mislead the interpretation process
- Suppression and/or removal of all kinds of noise without compromising the true signal

Another in-house software, MMT PostProc GeoTools, was then used to write the final processed ASCII textual header to all SGYs. This program was also used to export corrected instrument tracklines and high-resolution images of each SGY. The final SGY exported from MMT PostProc GeoTools is in the time domain with a corrected ASCII header. The general workflow of the SBP processing is outlined in Figure 23 and Figure 24.

After data processing, the final SGY data was loaded into Kingdom Suite using Seismic Direct where geological interpretation was performed on the data in the time domain. Subsequently the interpretation was converted to the depth domain using a standard value of 1600 m/s for the near surface sediments.

Three types of grids were produced as part of the final deliverable dataset. These included depth below seabed (BSB) grids, elevation grids relative to the vertical datum and isochore (layer thickness) grids. Each of these grids were generated for each interpreted horizon in 5 m resolution as both geoTIFF and ASCII formats. All grids were generated with a 5 x 5 m cell size in IHS Kingdom using the Flex Gridding algorithm with minimum curvature and midway smoothness parameters. The interpolation limit used was 50 m from the acquired SBP survey data.

The below seabed grids were generated by subtracting subsurface reflectors from the seabed reflector (picked from the SBP data) and converted to depth using a sediment velocity of 1600 m/s. These grids were then added to the seabed return (obtained from the MBES data) to generate elevation grids relative to the vertical datum, MSL.

The isochore (layer thickness) grids were calculated by subtracting the sum of the thicknesses of all units present above the horizon of interest, minus the seabed reflector, from the SBP data. Internal horizons were not considered for these calculations.

The vertical depth scale within SBP figures throughout this report has been generated by converting from two-way travel time using a sediment velocity of 1600 m/s.

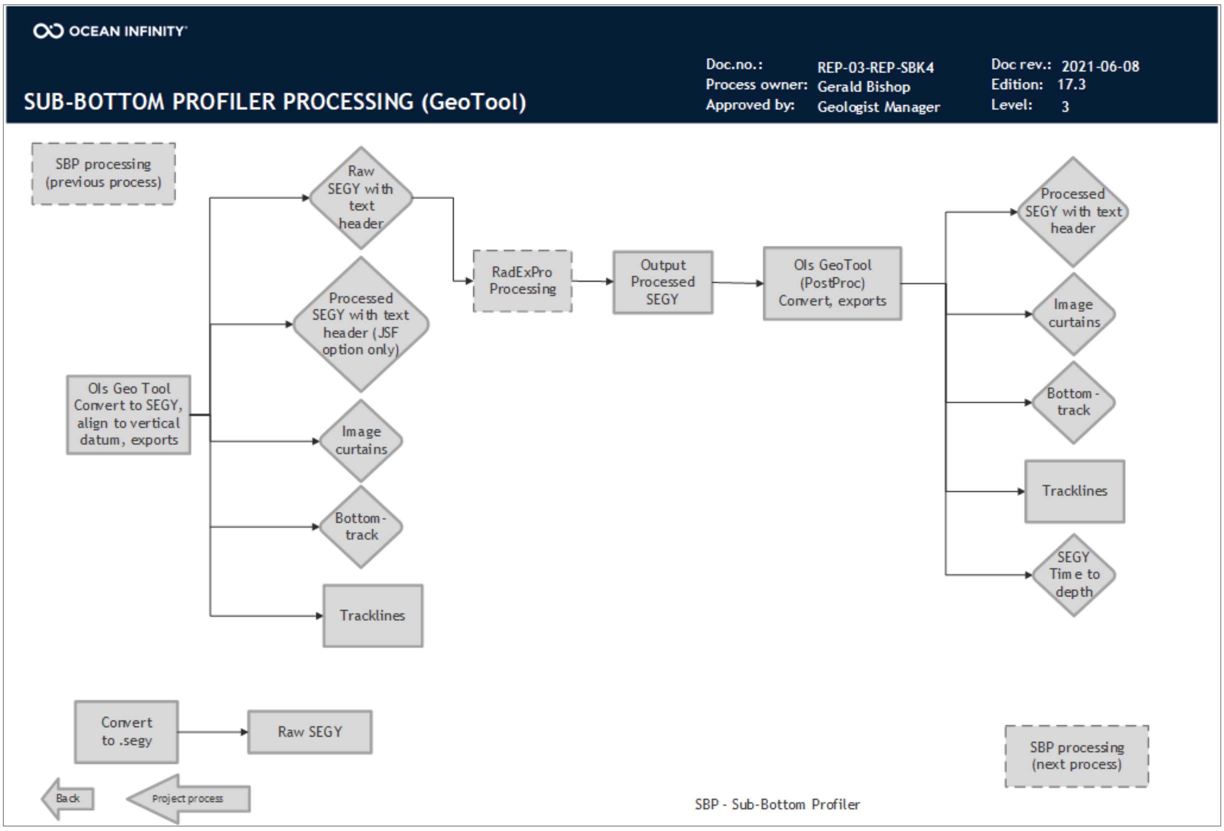


Figure 23 Workflow SBP processing (1 of 2).

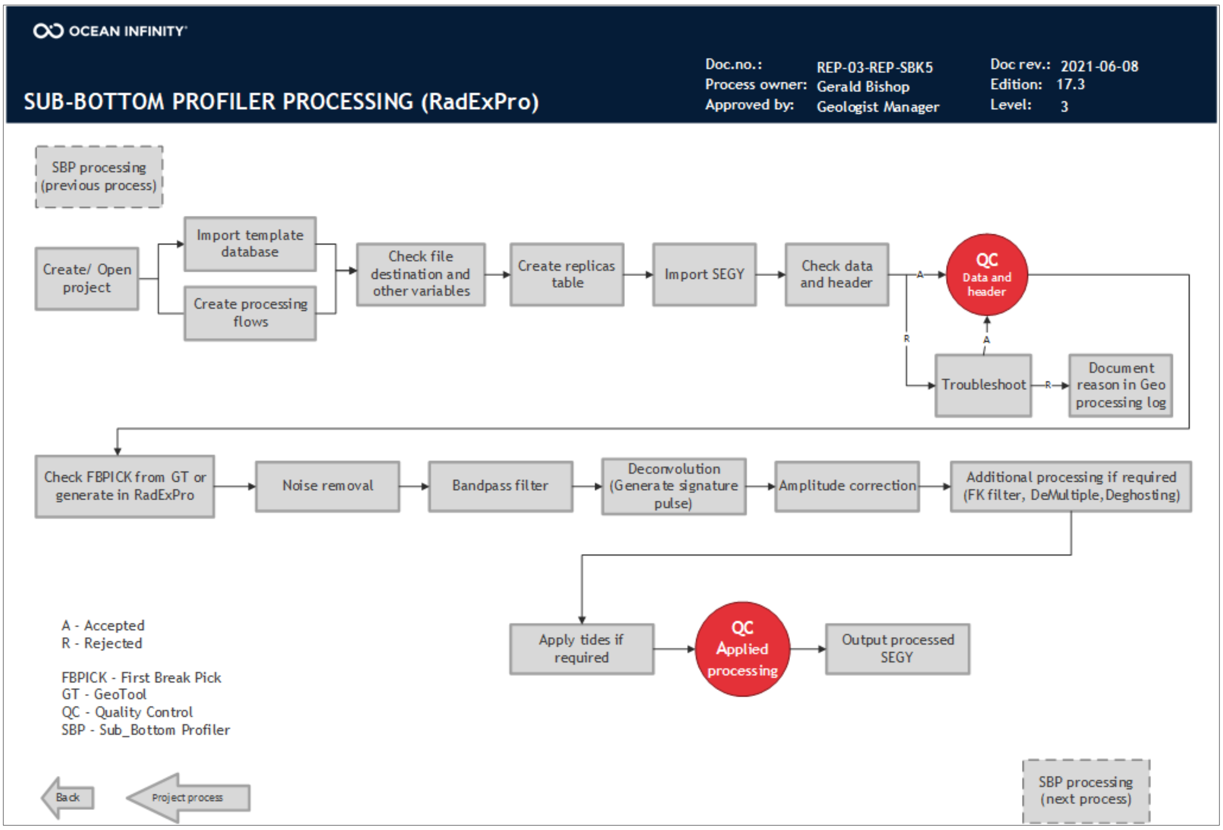


Figure 24 Workflow SBP processing (2 of 2).

6. Data Quality

6.1 Bathymetry Data

Overall, the processed MBES data meets the required specifications. Horizontal and vertical uncertainty is within acceptable tolerance. During this project, one major influencer on data quality has been the sound velocity related errors due to the pycnocline effect. Whenever vertical misalignment occurs, the sound velocity is what's causing it.

The initial project specification for MBES coverage was of full coverage on 25 cm grid; where 4 adjacent empty cells were considered a gap (please refer to TQ-012). The shadows cast by boulders and extreme topography, however, did create gaps bigger than that. Given the nature of the area, it is not practical to try and fill all those gaps. In some cases, low density cells can occur due to shadowing or cells that was flagged as rejected during office data cleaning.

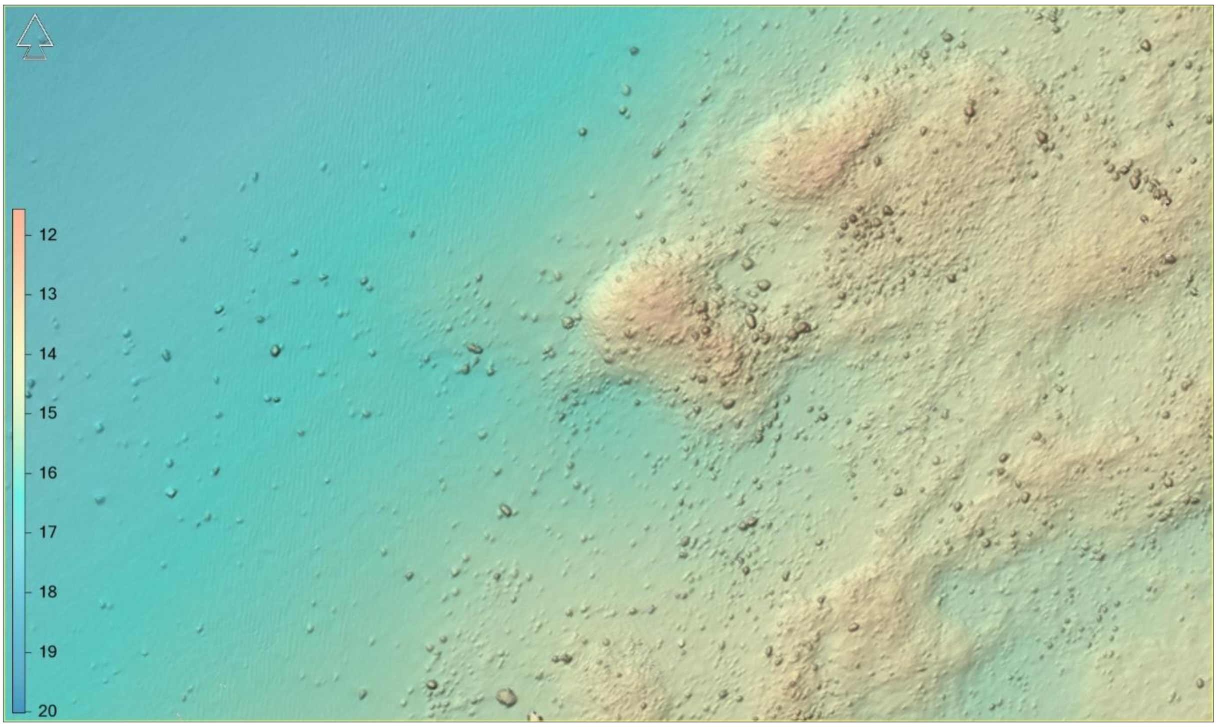


Figure 25 showing good example of quality data in WPA, B1D. Bedrock and sand ripples can be made out, boulders are seen clearly (largest is 2 - 2.5m long). Data resolution is 25 cm.

The MBES data from the two vessels M/V Geo Ranger and M/V Deep was combined in the OI Gothenburg office during and after survey operations were completed. QC checks was made to ensure that data from all vessels were aligned vertically, and data was checked between surfaces B1D and B1B. A 2 m grid difference model has been created between the two datasets. From that model an average value for the whole model was created in excel. The two datasets have also been inspected by looking at them in detail as profiles overlapping each other and checking the data with the Standard Deviation at 95 % confidence. The average difference between the adjacent areas B1B and B1D was 7 cm. No steps have been taken to adjust the alignment since the offset is sometimes fluctuating and is within the range of uncertainty.

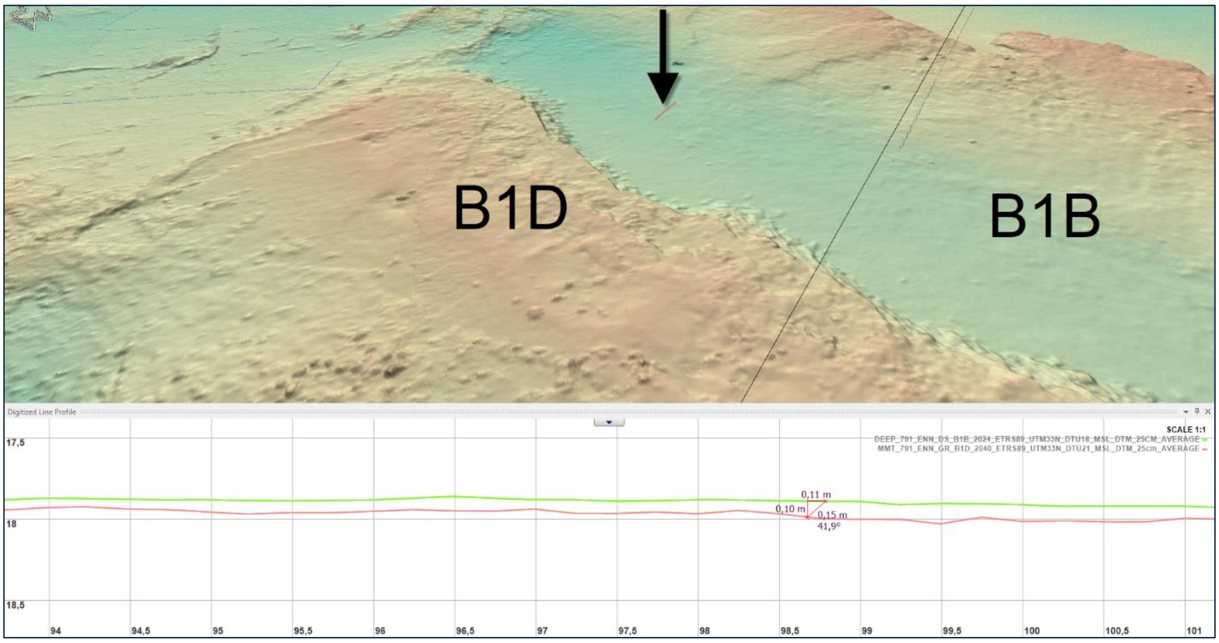


Figure 26 showing flat, soft area where data is overlapping between B1B and B1D. Approx. 10 cm difference.

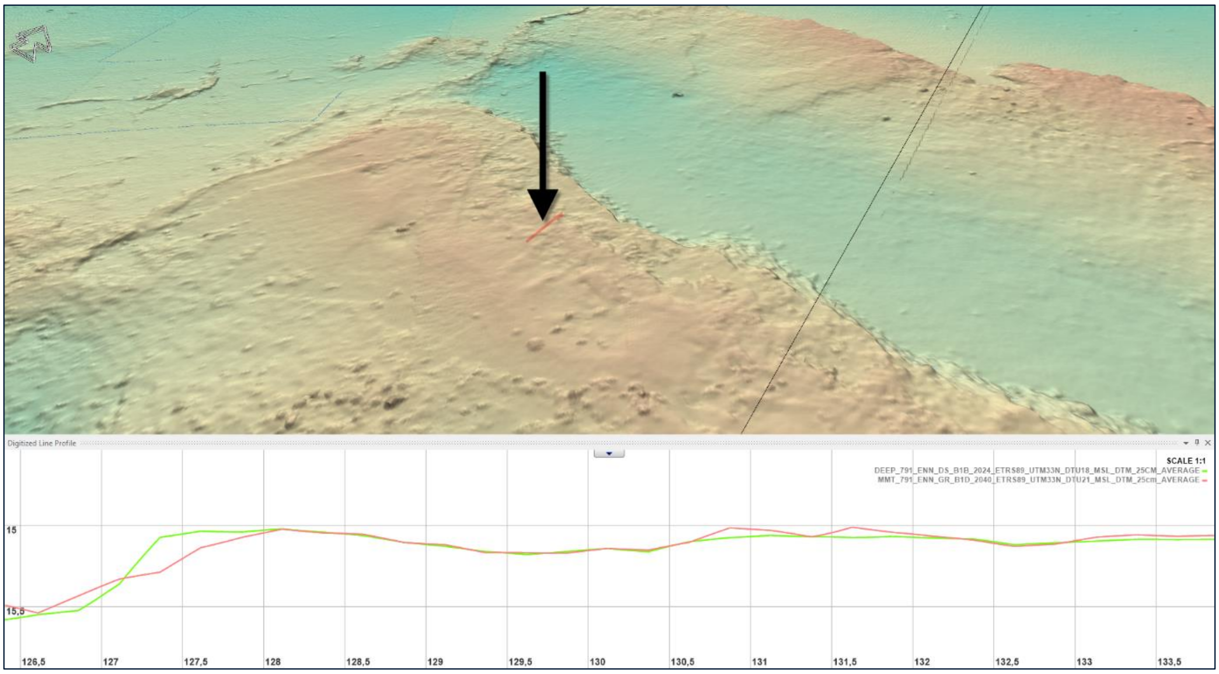


Figure 27 showing fluctuating data between B1B and B1D.

The major source of misalignment in depth between run lines in the survey has been issues with sound velocity related errors due to the pycnocline effect and rapidly changing sound velocity. Even though the data remains within specifications, sound velocity errors create unwanted fluctuation in the outer beams and slight "bending" of the seafloor which causes visual errors and, in worst cases, can affect the data and make it harder to interpret. Even though efforts were made during processing of the data, rapid and great changes in sound velocity creates errors that are basically impossible to remedy completely. So, in spite the fact that extensive amount of SVPs taken there will still be slight misalignments in some problem areas. Results of sound velocity profiles can be seen in Figure 28, Figure 29 and Figure 30.

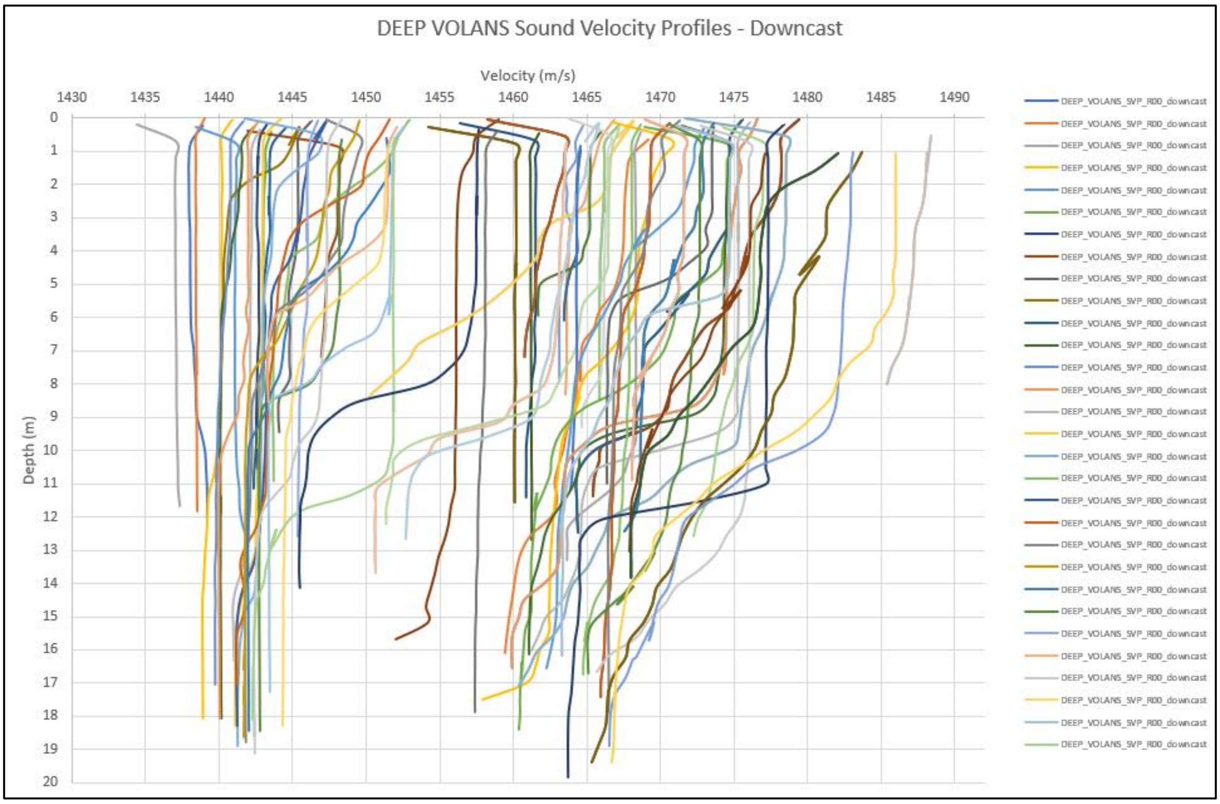


Figure 28 Sound velocity comparisons from Deep Volans. Charts are showing rapid changes and fluctuation through the water column.

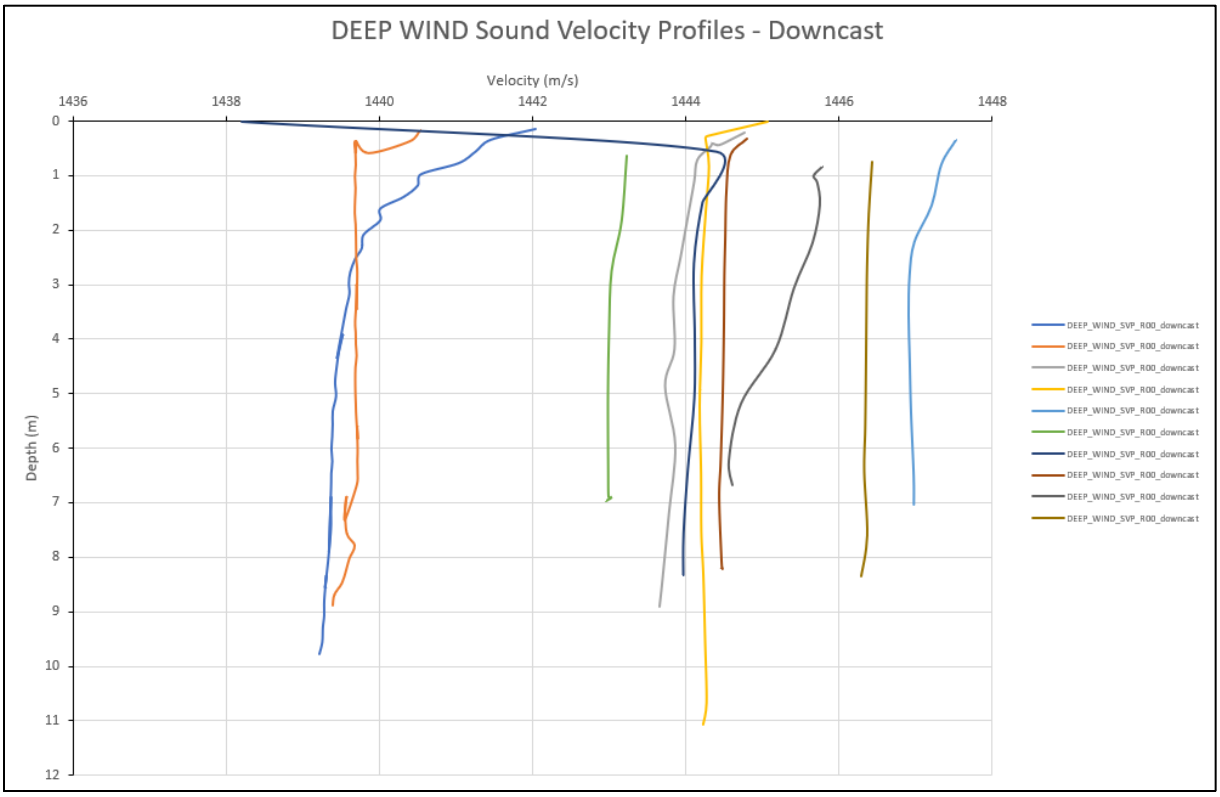


Figure 29 Sound velocity comparisons from Deep Wind

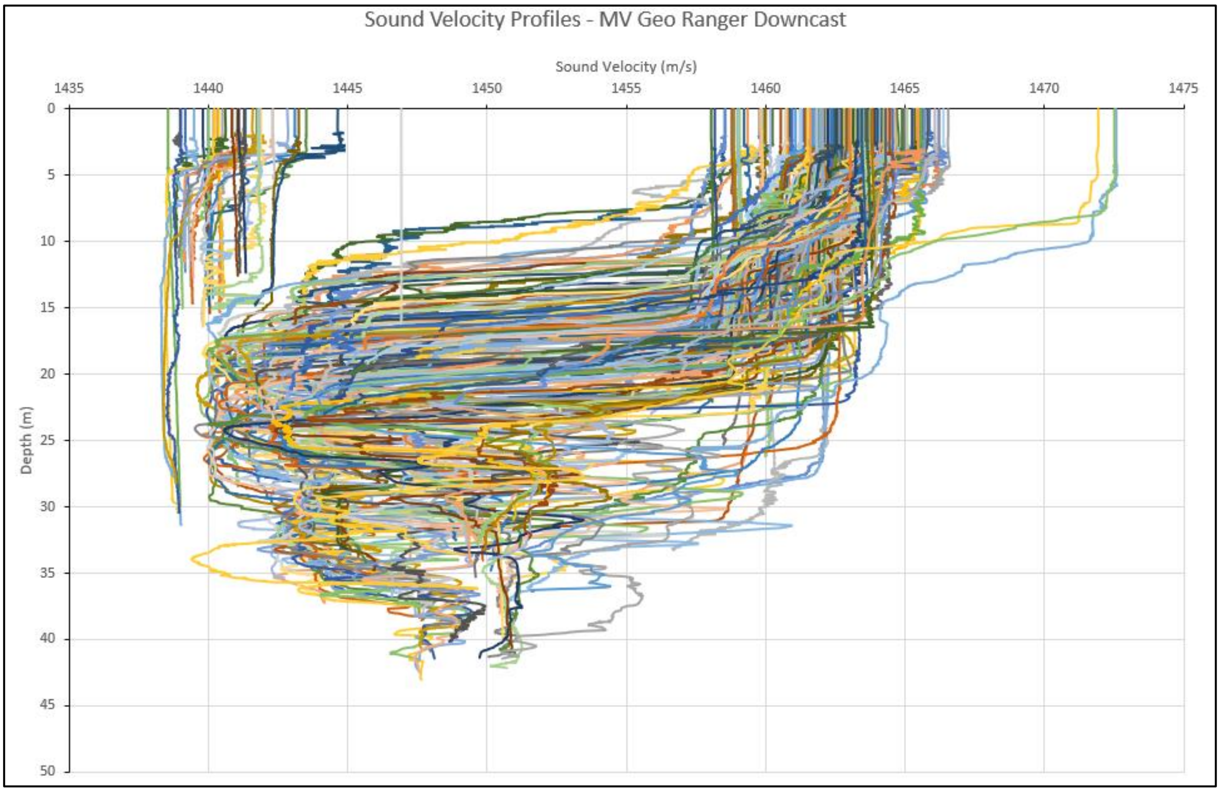
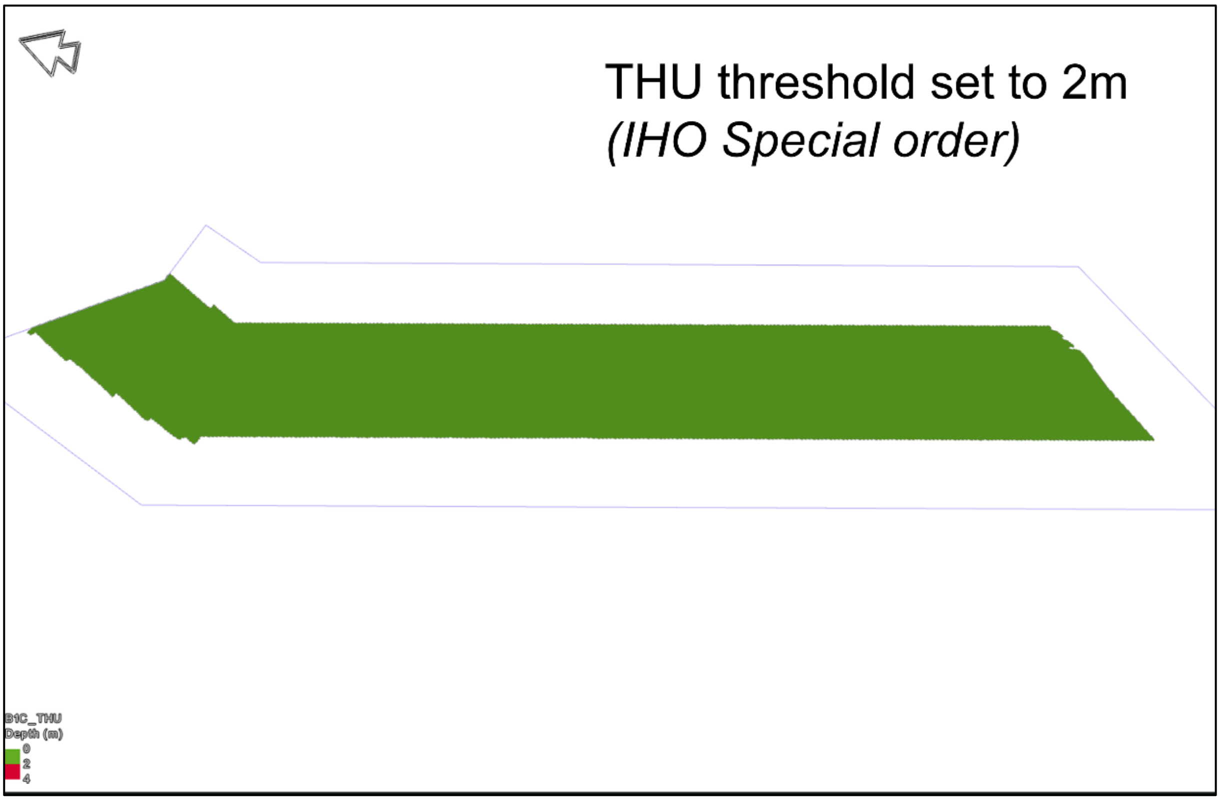


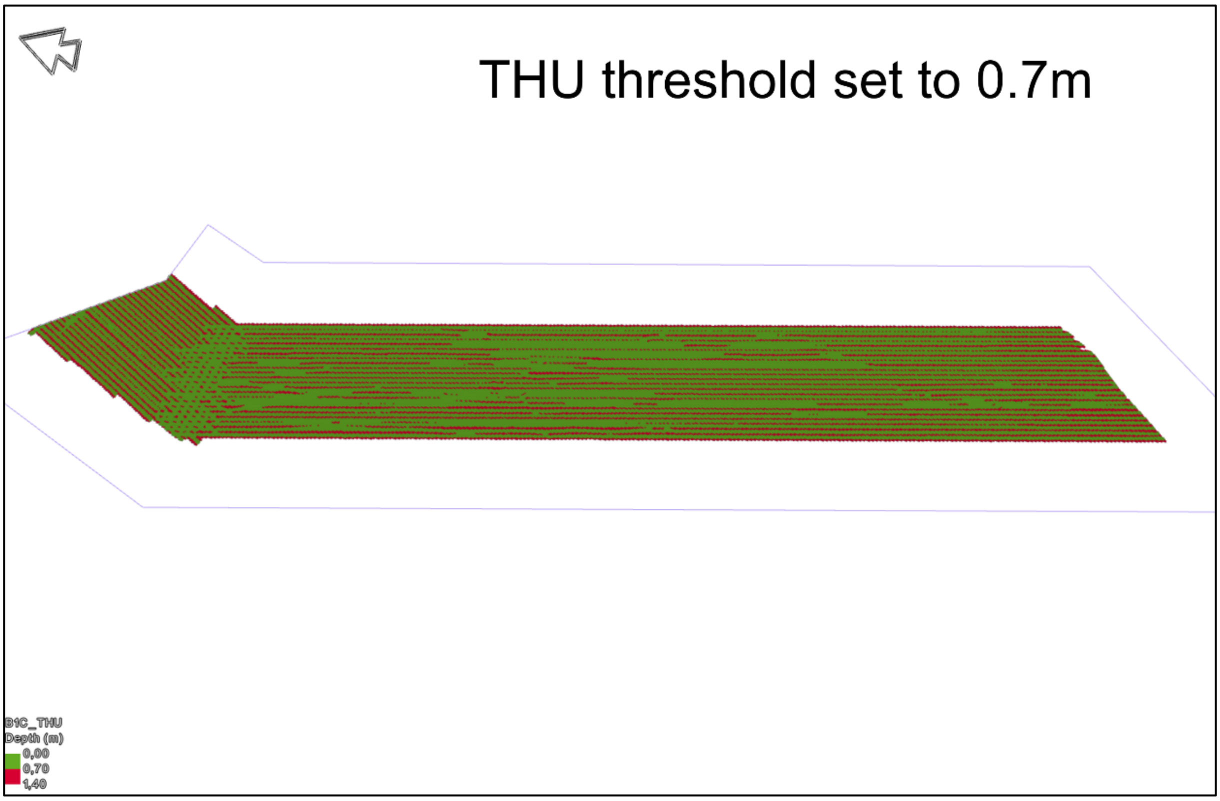
Figure 30 Sound velocity comparisons from Geo Ranger. Charts are showing rapid changes and fluctuation through the water column

Data in the same area (as in all other areas) was checked also looking at THU and TVU values. TVU and THU gives you an indication on how reliable your gathered raw data is. It is a measure of the Uncertainties that exist due to various contributing factors such as the precision of individual sensors and the technical limitations of the hardware, localized environmental conditions, tidal information and measurement errors.

In this case the cause of high TVU/THU values is most likely that the GPS solution has changed to a different mode. For example, from RTK to RTK Float, causing the MBES data to be acquired with larger Uncertainty values. It should be noted that this does not mean that the acquired data is incorrect, but more that there is a higher degree of Uncertainty associated with the data.

We usually conclude after full post processing whether the data is within specifications or not, even if raw data and/or the propagated errors may sometimes show otherwise.


THU threshold set to 2m
(IHO Special order)
B1C_THU
Depth (m)
0
2
4


THU threshold set to 0.7m
B1C_THU
Depth (m)
0,00
0,70
1,40

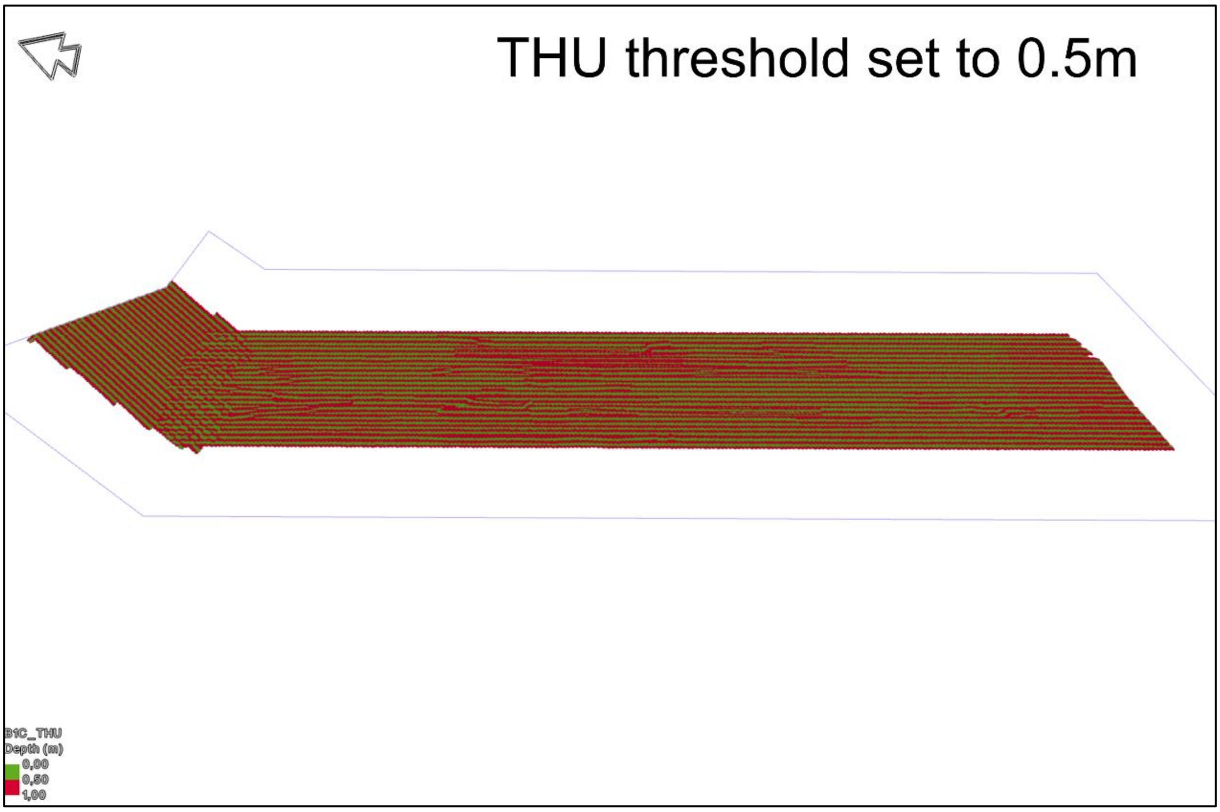


Figure 31 showing THU values in B3A with different thresholds in the colour palette. The data holds up below one meter. At 70 centimetres errors can be seen and at 50 centimetres it is clearly visible.

6.2 LiDAR Data

The LiDAR data was collected on two different occasions. The first one on May 9th, 2022, was performed on all cable landings. The second, using green LiDAR to penetrate the water column and cover areas in very shallow areas, was executed on June 23rd, 2022.

The Green LiDAR flight was executed on June 23rd 2022 on all cable landings. On B1A, penetration was sufficient, and the gap has been fully covered.

The final DTM resolution achieved by the green LiDAR survey was of 50 cm. This does not comply with the bathymetric data requirements (25 cm grid full coverage). However, it does comply with the topographic survey requirements (resolution to allow for 50 cm contour lines). The collected LiDAR data was checked vertically against collected multibeam and the profiles line up very well.

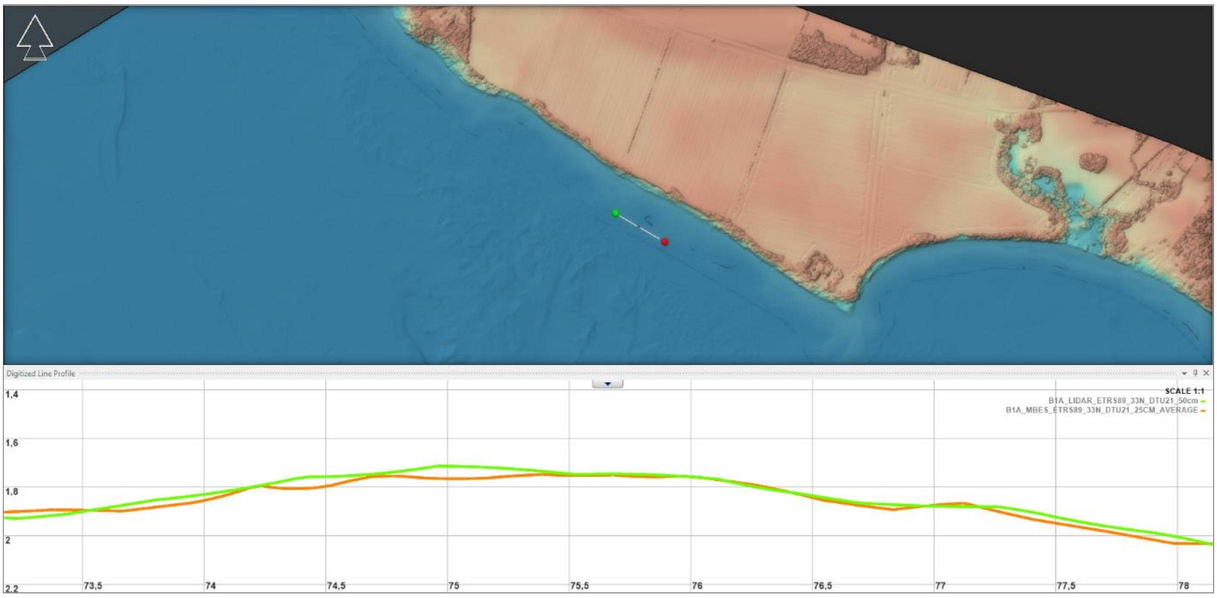


Figure 32 is showing overlap between MBES and LiDAR in B1A. The green profile represents the multibeam.

6.3 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 Kongsberg .all raw bathymetry files in FMGT. Each block was imported to ArcGIS where they could be viewed as a single dataset.

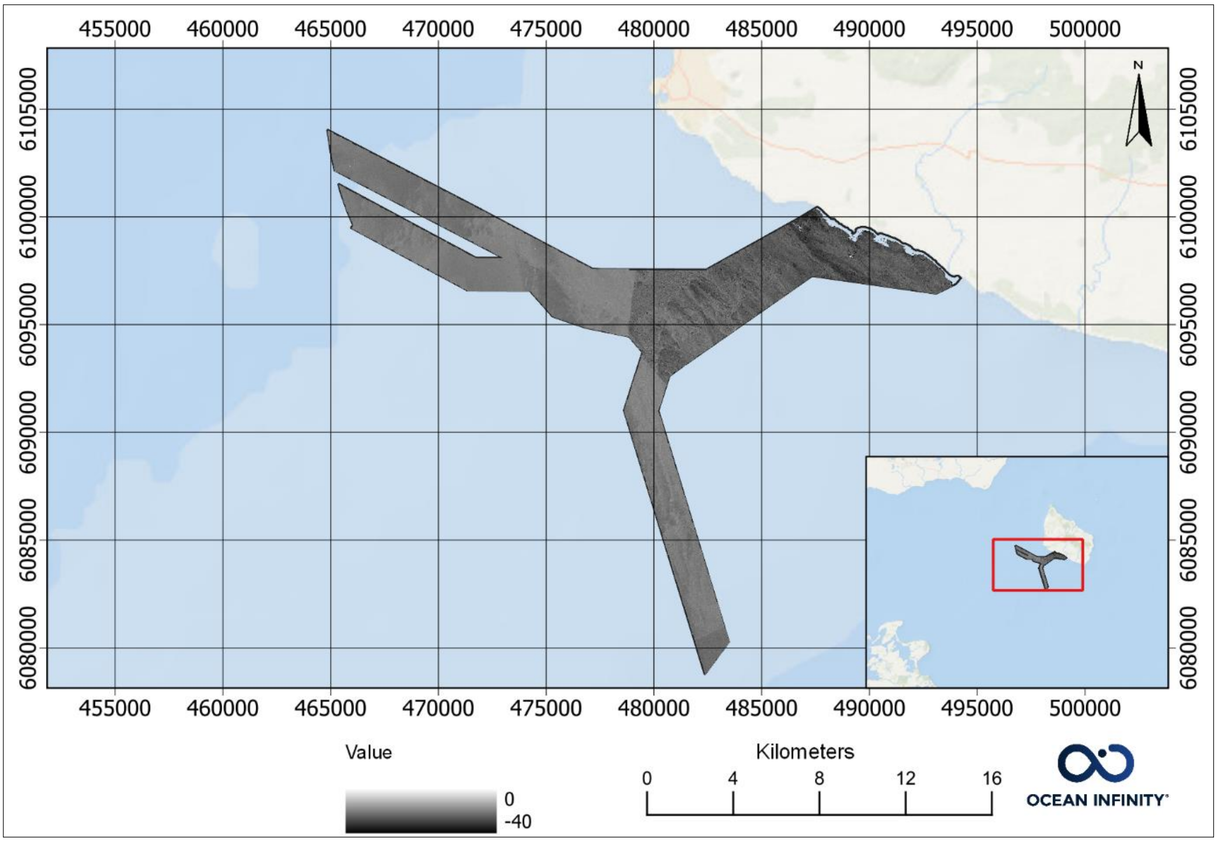


Figure 33 shows an overview of backscatter data on the Bornholm side.

The backscatter rasters are of high quality for most parts and enable an accurate interpretation of the seafloor sediment boundaries. 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. The data was processed from raw files directly, no cleaning of data outliers or adjustment for other possible sources of error, so the Backscatter data might have some visual errors due to excessive motion, sound velocity errors or bubble wash and so on.

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).

In the early stages of the survey of the project it was noted that Kongsberg SIS, which is the software that is used for collecting .all files, was suffering from short computer freezes. These have caused small rectangular gaps in the data. This is occurring in very few areas and the problem was resolved. The problem did not affect regular multibeam data since that is collected through QINSy Software. Example shown in Figure 34.

Other artefacts can arise from the survey line 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 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.

The presence of artefacts can be visually distracting but does not affect the results of the seabed interpretation. Experienced marine geologists can see beyond the artefacts and use the multiple layers data of to determine whether these variations arise from real features of the seabed.

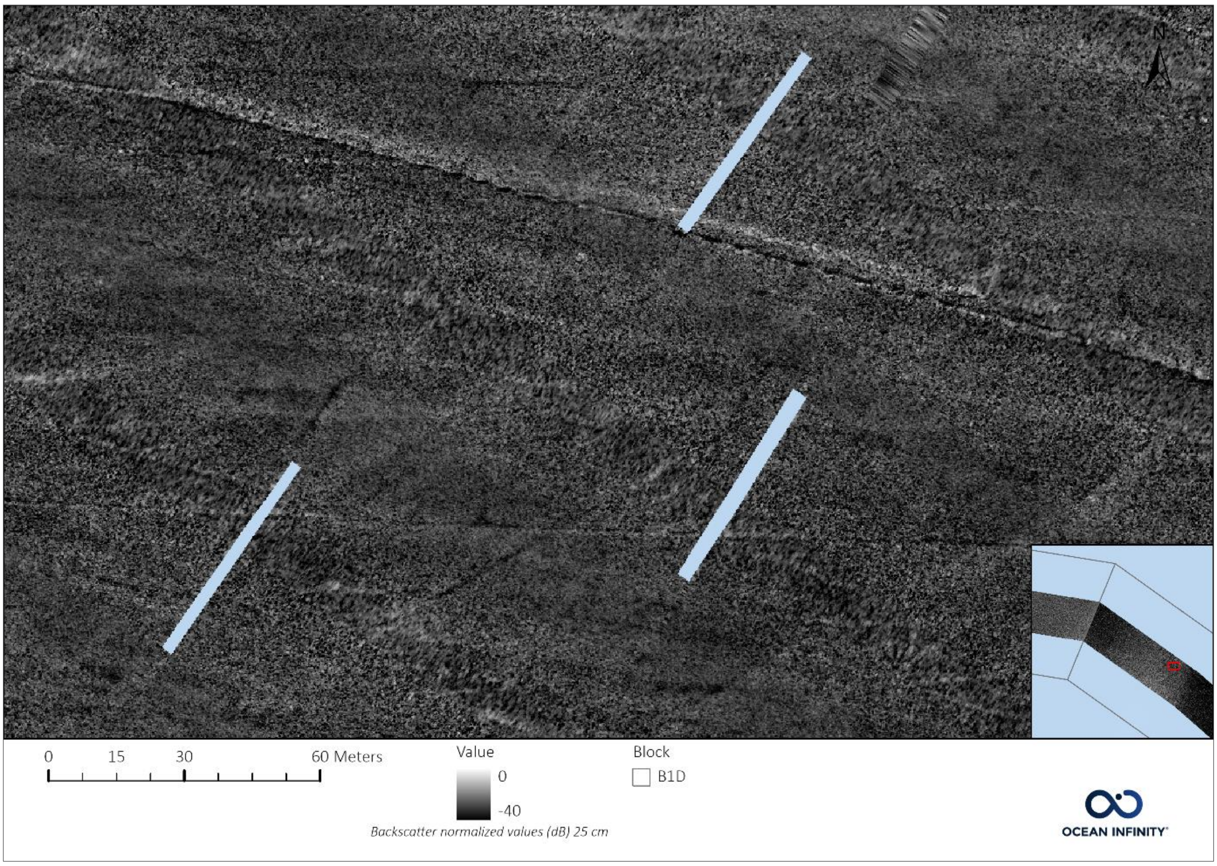


Figure 34 showing occurrence of the software freeze problem in B1D.

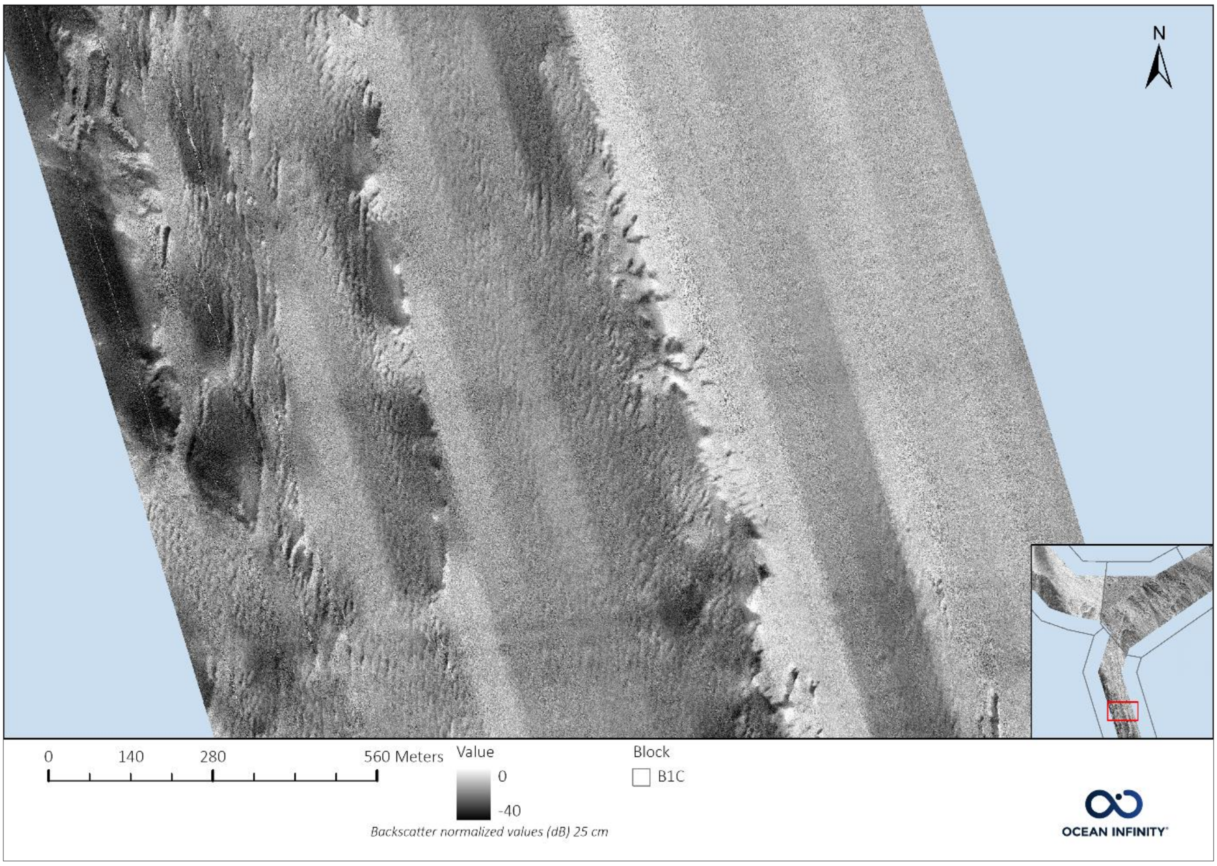


Figure 35 Smearing effect seen in B1C.

6.4 Side Scan Sonar Data

As detailed by the clients SOW, the SSS data were to provide 80 m range 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 to ensure overlap with the nadir of adjacent lines. Object detection was specified as >0.5 m for individual targets.

The SSS data quality was very much dependant on a strong pycnocline, affecting the data in the outer ranges; in some sections up to 70% of the data was affected (Figure 36). Pycnocline affected areas were trimmed out of the data and multiple infill lines were appropriately acquired. To reduce the pycnocline affect the altitude was decreased when acquiring some of the infills, thus reducing the range of this data to 40 m.

Following multiple infill lines and trimming of the pycnocline, some areas had 100% coverage in the nadir gap and between adjacent lines. This data was accepted by the client with 100% coverage *(reference to TQ-014-Side scan sonar – Pycnocline relaxation)*.

Several fish shoals were observed in the data as medium to high reflectivity ‘smudge’. The fish shoals could be readily identified and disregarded as noise when checking against adjacent lines. SSS data quality is described per block in Table 20.

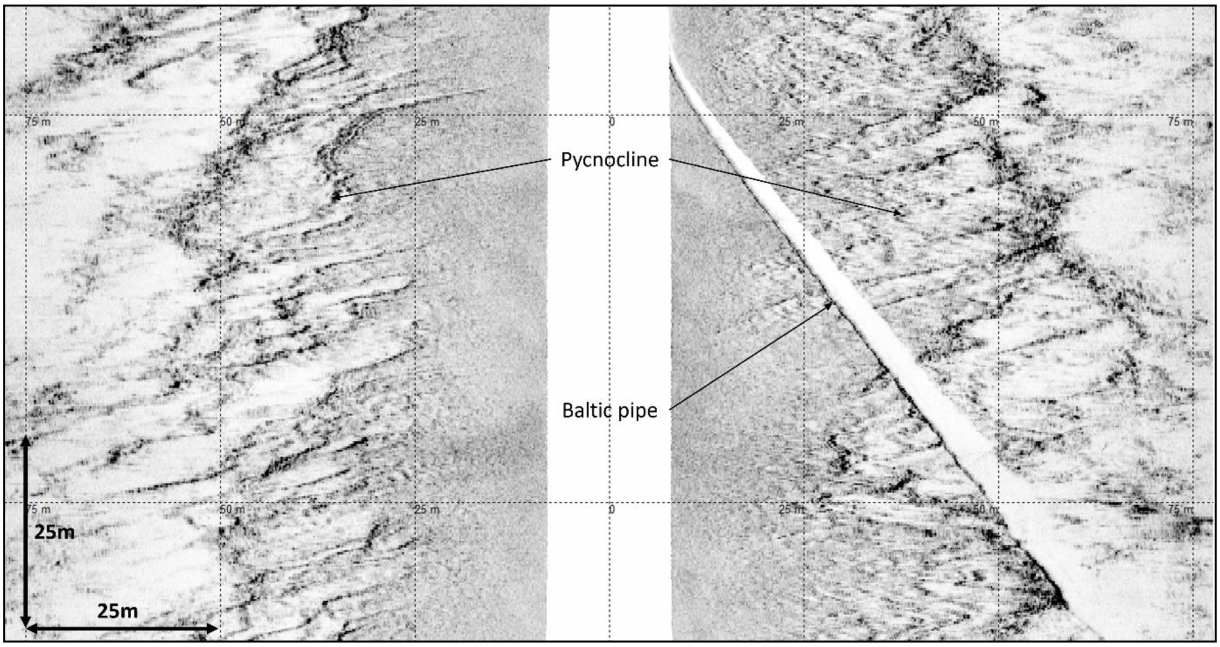


Figure 36 Pycnocline as observed on B1D; route ID Bornholm 1.

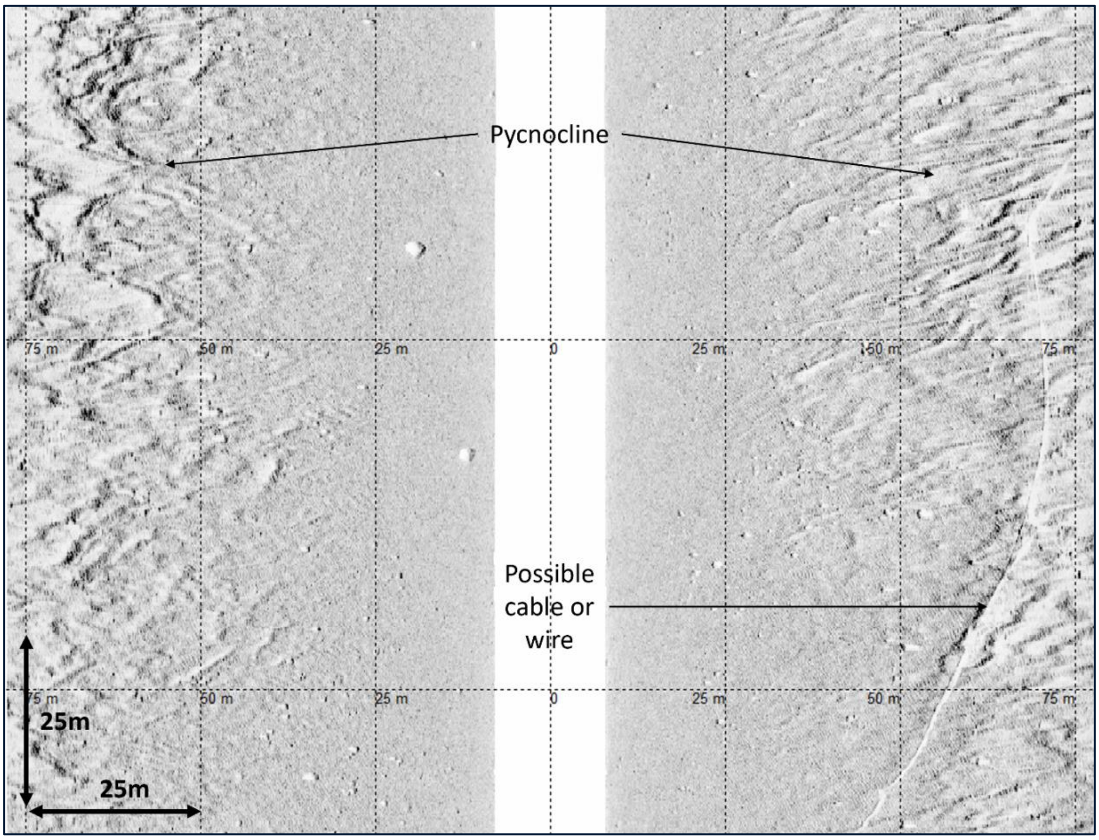


Figure 37: Pycnocline as observed on B1D; Route ID Bornholm-Sjælland.

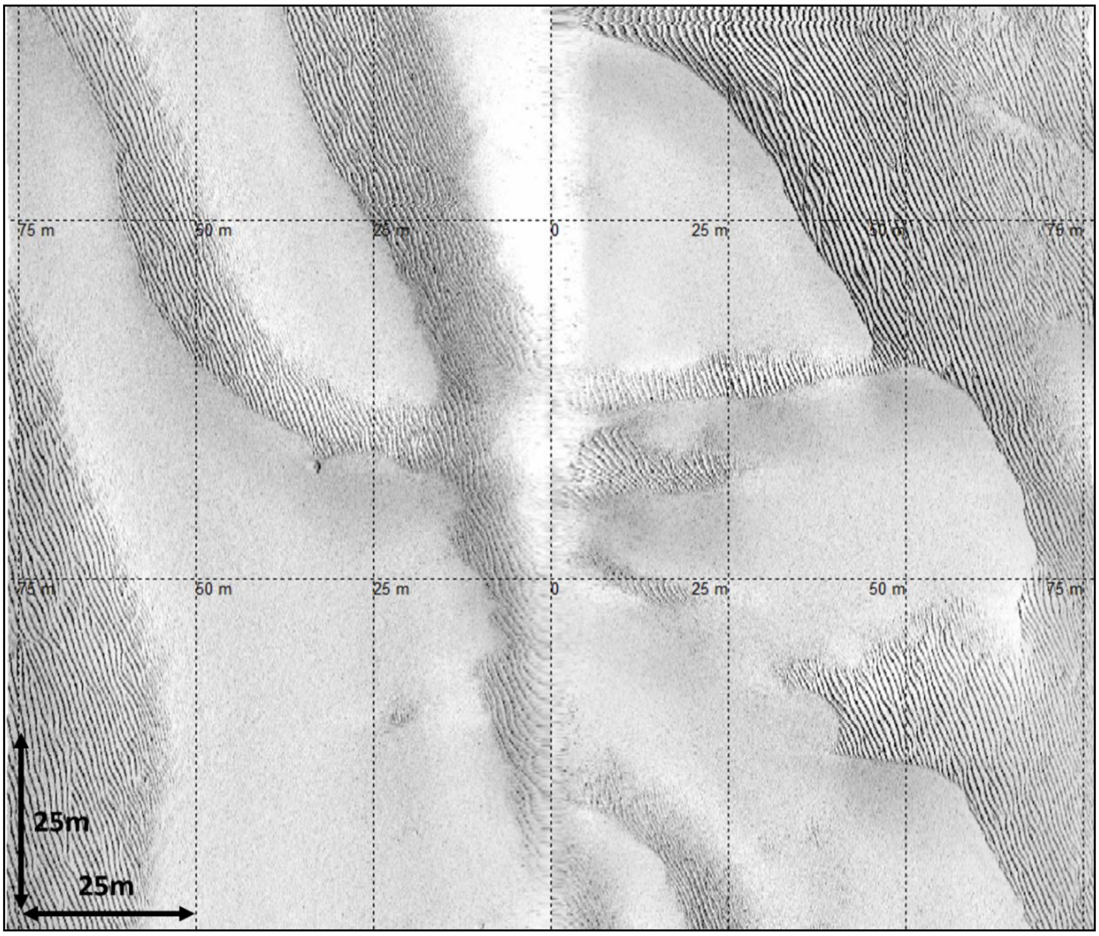


Figure 38 Example of good HF data from B1C.

Table 20 SSS data quality description by block

Block	SSS High Frequency Data Quality
B1A	Deep Volans and Deep Wind acquired data, towed side scan fish. No Pycnocline observed. Some weak weather/motion related noise affecting some outer ranges, marginal data trimmed post survey. SSS range was 50 m except in the shallow water environment where range and altitude vary accordingly. Line spacing is generally 20 m throughout the block except in the shallow areas.
B1B	Deep Volans acquired data, towed side scan fish. Few weak to moderate pycnocline effect on lines, starting weak at the beginning of May in the south of the block and becoming moderate throughout the block into June. SSS range 50 m throughout with marginal data being trimmed out post survey. Line spacing was generally 20 m throughout the block.
B1C	Geo Ranger acquired data, ROTV mounted. Few weak weather-related noise bursts. Poor altitude over the ridge in the south of the block, parallel infill lines acquired here. SSS range was 80 m throughout survey area and line spacing 70 m, except for a few infill lines.
B1D-BH1A	Geo Ranger acquired data, ROTV mounted. Weak to strong pycnoclines throughout the block, pycnocline affect is worse in the east of the area. SSS range 80 m throughout with mainline line spacing at 70 m. Where required infill lines were acquired in-between the mainlines resulting in a line spacing of 35m.
B1D-BH1B	Geo Ranger acquired data, ROTV mounted. Weak to strong pycnoclines throughout the block, pycnocline affect is worse in the southern part of the area. SSS range was 80 m throughout with mainline line spacing at 70 m. Where required infill lines were acquired in-between the mainlines resulting in a line spacing of 35m.
B1D-BH-SL	Geo Ranger acquired data, ROTV mounted. Weak to strong pycnoclines throughout the block, pycnocline affect is worse in the southeast of the area. SSS range was 80 m throughout with mainline line spacing at 70 m. Where required infill lines were acquired in-between the mainlines resulting in a line spacing of 35m, a few infills were acquired at 20m line spacing from the mainlines.
B1Da-BH-SL	Geo Ranger acquired data, ROTV mounted. Moderate to strong pycnoclines throughout the block, pycnocline affect is worse in the southeast of the area. SSS range was 80 m throughout with mainline line spacing at 70 m. Two rounds of infill were acquired, the first spaced 35 m from the mainlines and the second offset by 15 m.

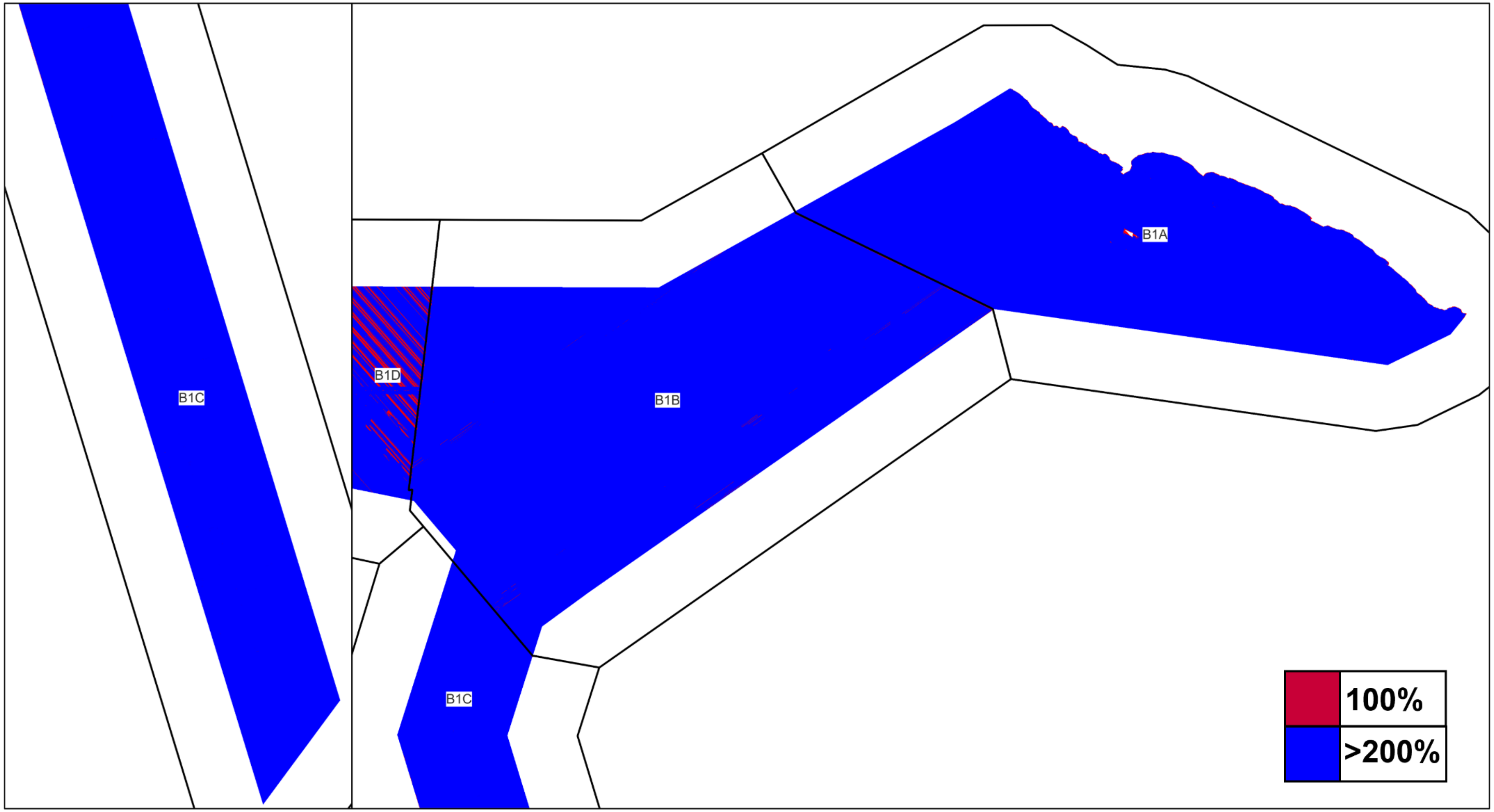


Figure 39 SSS coverage plots in Block 1A, 1B and 1C.

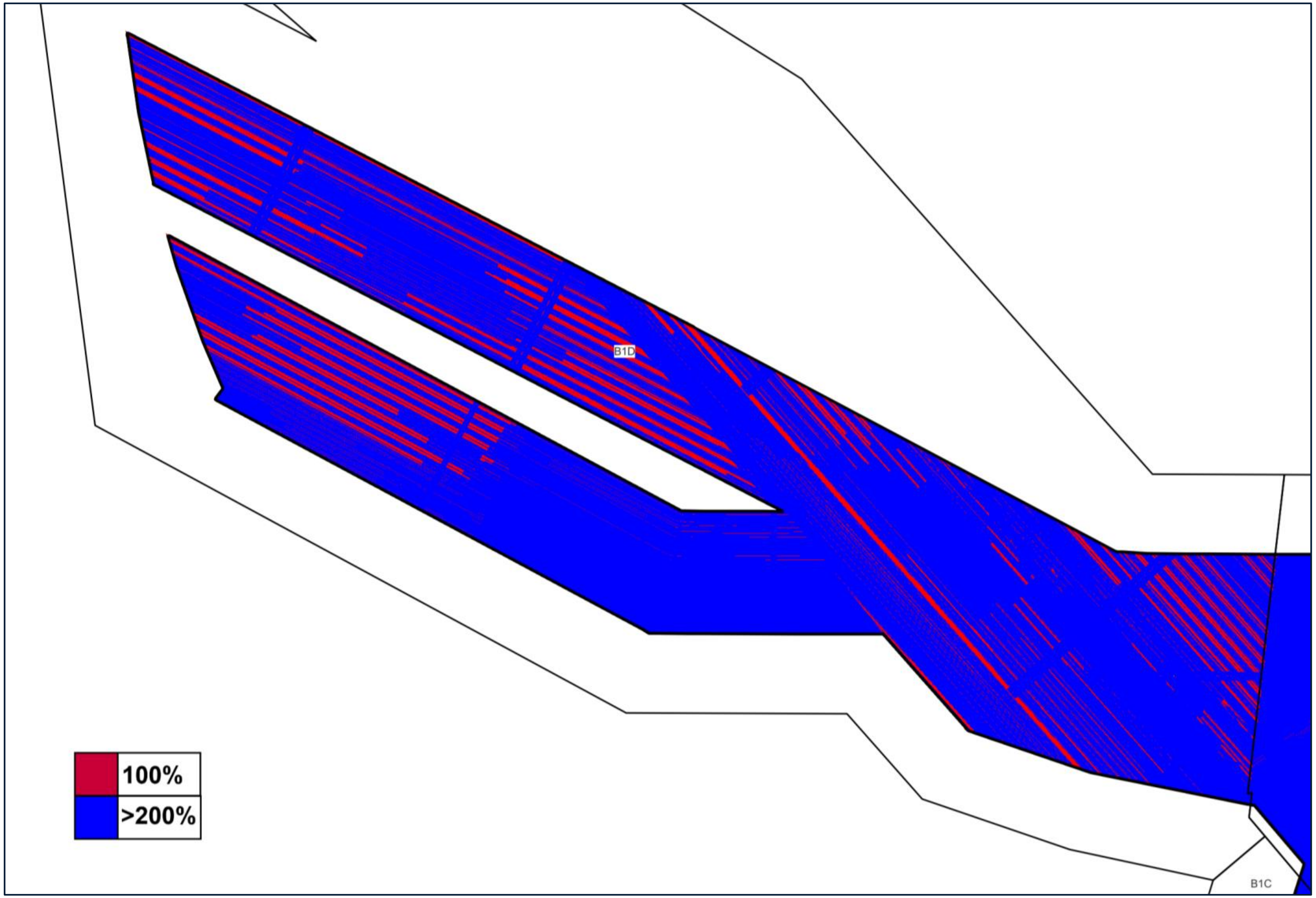


Figure 40 SSS coverage plots within defined boundary in Block 1D.

6.5 Magnetometer Data

Onboard the Geo Ranger the MAG was piggy backed on the ROTV with a tow length of 10 m. On the Deep Volans and Deep Wind the mag was towed directly from the vessels. Data was acquired with a 10 Hz sample rate.

The project specifications required the MAG to fly with an altitude of 5 m or less, however the MAG was piggy backed behind the SSS and so altitudes between 5 m and 6 m were expected. The flying altitude of the MAG was therefore dictated by the SSS, with the MAG generally flying 1 to 1.5 m below the SSS altitude. When the SSS altitude was lowered to reduce the pycnocline affect the MAG altitude was subsequentially at 2 m to 3 m. The change in altitude magnifies the magnetometer sensitivity, increasing the ability to detect ferrous targets on the seabed. However, in turn, the proximity to the seabed amplifies the background geology (Figure 41 & Figure 42). The MAG altitude was also out of specification in a few areas with challenging terrain. *(TQ – 019 – MAG Flying Height Bornholm – Geo Ranger, TQ – 016-SSS_MAG Flying Height Bornholm*).

Magnetic anomalies were identified with a 10 nT detection (peak to peak) threshold when surveying with an altitude of 5 m to 6 m. When at this altitude, isolated anomalies above 10 nT (peak to peak) have been picked, linear features below this picking threshold have also been picked. When surveying at lower altitudes of 2 m to 3 m a higher picking threshold of 20 nT (peak to peak) was used due to the increase in the magnetic field, this background increase was more pronounced in areas of outcropping bedrock, boulders and till.

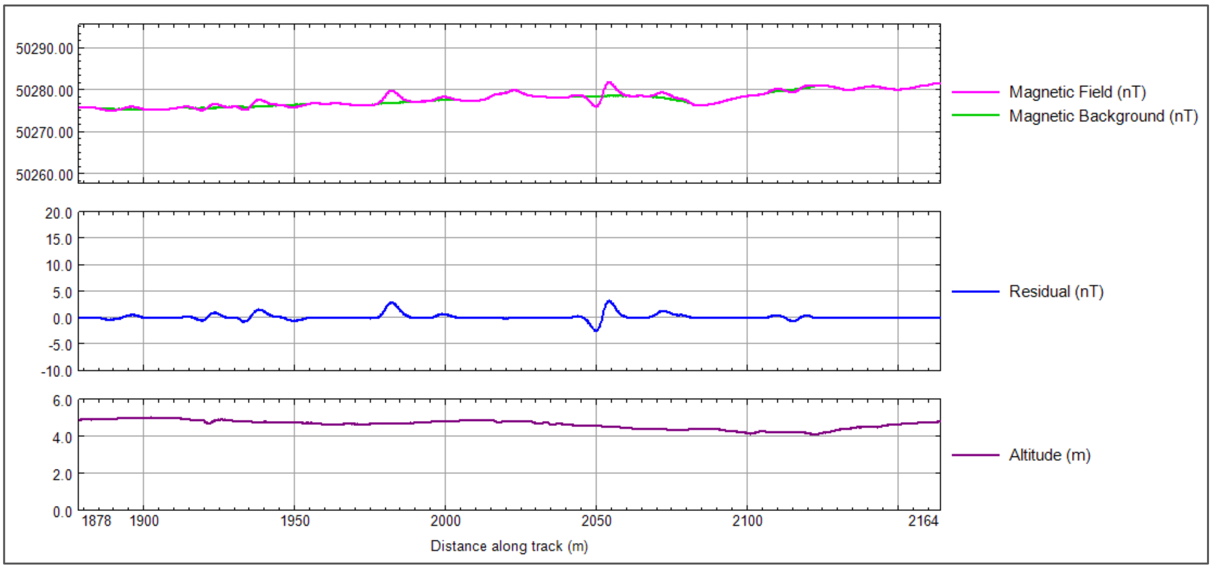


Figure 41 Magnetic field and residual profile at 5 m altitude.

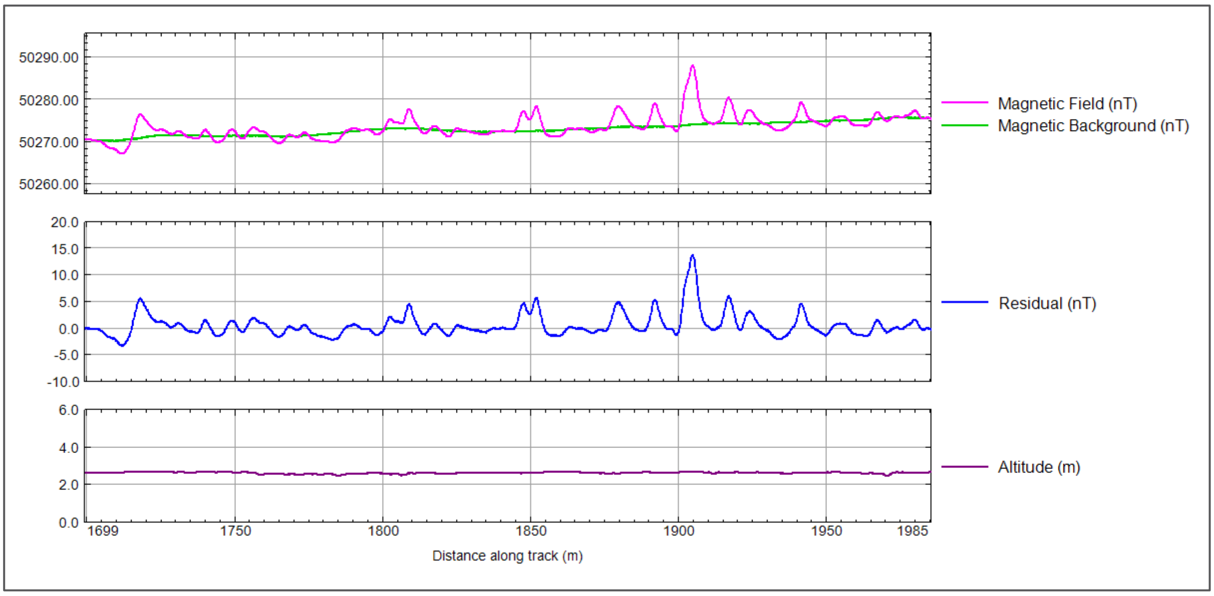


Figure 42 Magnetic field and residual profile at 2.5 m altitude.

Magnetometer data quality was predominantly above the 450 value, which OI nominally use as a QC indicator. The signal quality dropped below 450 when the altitude was lowered and on certain headings in Block 1C due to the sensor orientation contra to the earth's magnetic field. This drop in signal quality due to heading was not encountered in the opposite headings. The magnetic field values remained stable throughout the affected lines with magnetic features continuous across the survey area *(TQ – 017 –MAG data quality*) (Figure 44).

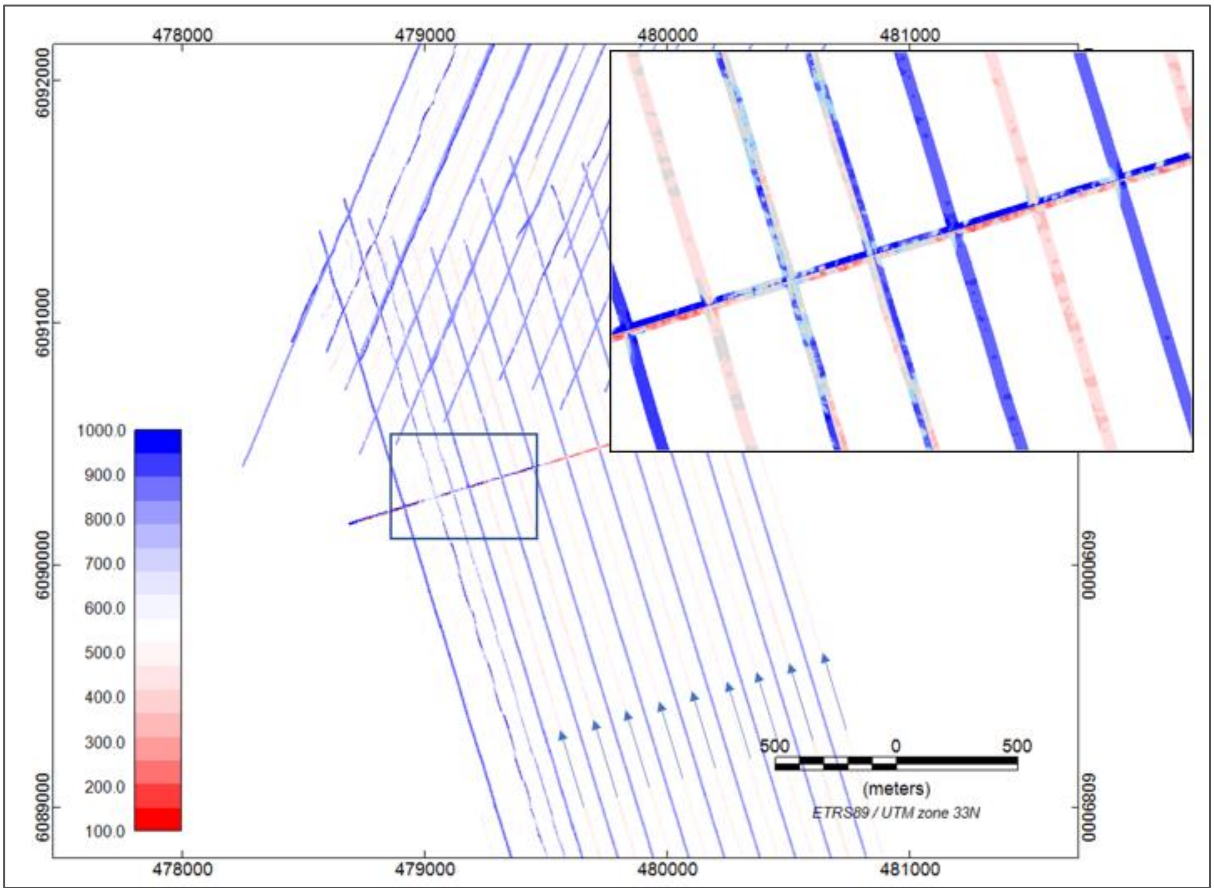


Figure 43 Magnetic signal quality grid, showing a crossline surveyed in opposite directions in B1C.

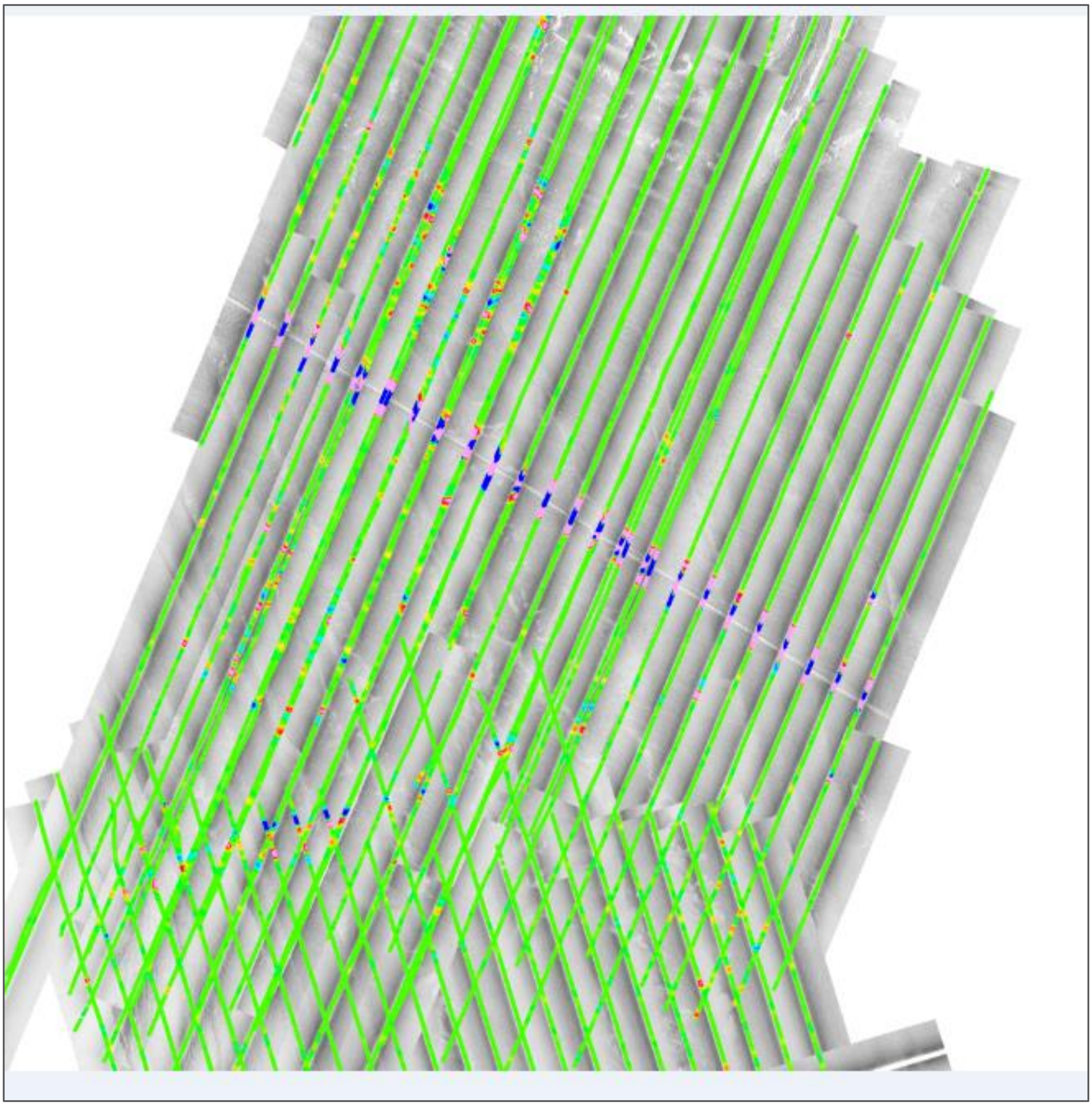


Figure 44 Magnetic residual grid over pipeline crossing showing feature continuity with opposite survey heading.

Table 21 Summary of magnetometer tow altitudes.

Block	Alt Mean	Alt Min	Alt Max	St dev	Distance [km]
B1A	3.28	2.4	3.84	0.34	1036.02
B1B	3.43	1.5	5.15	0.46	1624.63
B1C	5.45	1	6.0	0.29	7859.53
B1D BH-SL	4.82	1.22	6.0	0.4	263.63
B1D-BH1A	4.43	2.22	6.0	0.72	517.09
B1D-B1B	4.54	2.5	6.0	0.69	618.90
B1Da BH-SL	4.83	1.01	6.0	0.42	627.90

6.6 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 sub-seabed geology. During this project, the Innomar data was of good quality with penetration generally between 4 and 10 m (Figure 45). Occasionally the penetration surpasses 10 m, particularly in the softer sediment and more clay rich areas. Penetration beyond the base of the stiffer clays is limited due to the presence of underlying bedrock; below which it is rare to see additional reflectors. Occasionally, the presence of gravel on the seabed also reduces the signal penetration.

For the offshore part of the survey, a 10 kHz pulse was used for the first full day of acquisition, before changing to 8 kHz to improve penetration. 10 kHz was used for the entirety of the nearshore area.

The data was highly resolute allowing several parallel reflectors to be defined in units which contained multiple closely spaced laminations. Data was occasionally affected by the weather, causing cavitation along the profile to occur (Figure 46). However, drop outs were rare and always less than 10 m along track. Whilst data processing reduced the effects, during periods of poorer weather, the applied heave compensation did not successfully compensate for all heave encountered. Despite this, interpretation could still be conducted with confidence (Figure 47).

A few infills were necessary to acquire due to incorrect seabed tracking of the data, after the acquisition software tracked a multiple as the seabed or was unable to keep up in areas of rapid water depth changes, windowing out and occasionally cutting part of the data. Other infills were related to crashes in the main survey software.

Other examples of noise observed occurred in the nearshore data in the form of electrical noise which appeared sporadically but was dealt with during the data processing flow without any negative effects on the interpretability of the data.

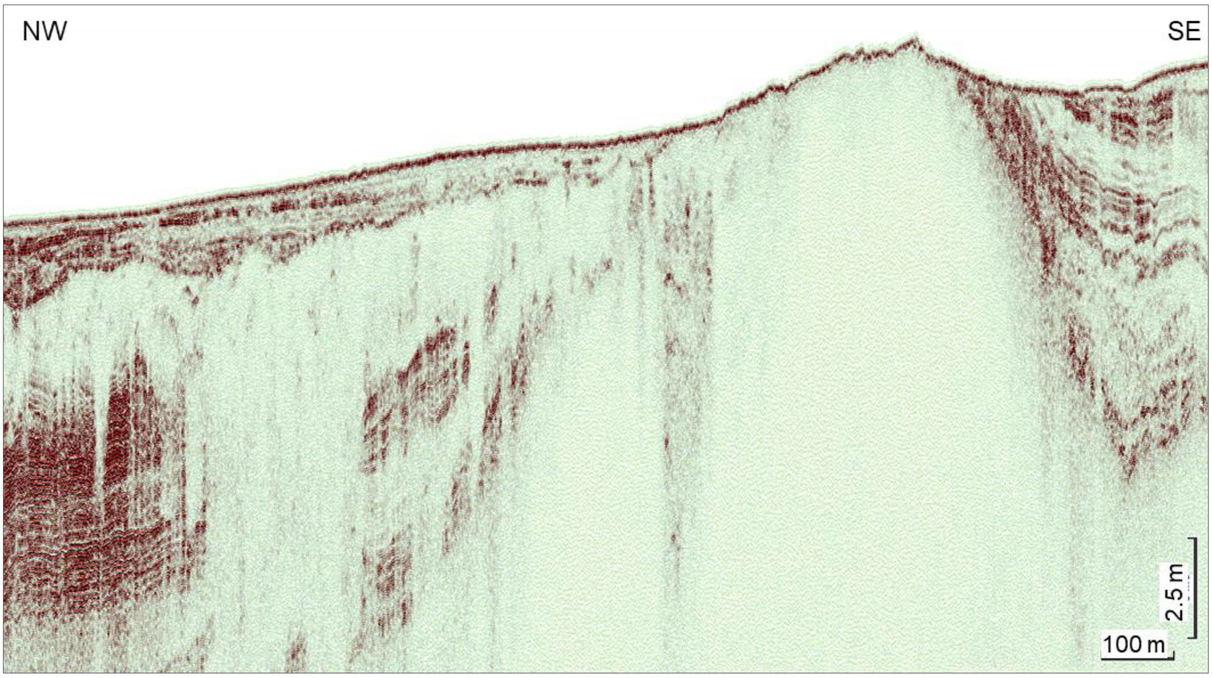


Figure 45 Example of good data, displaying penetration >10m and multiple laminations within geological units, from line P140, block B1D from KP 26.078 to KP 24.378 on CRS BH-DK2

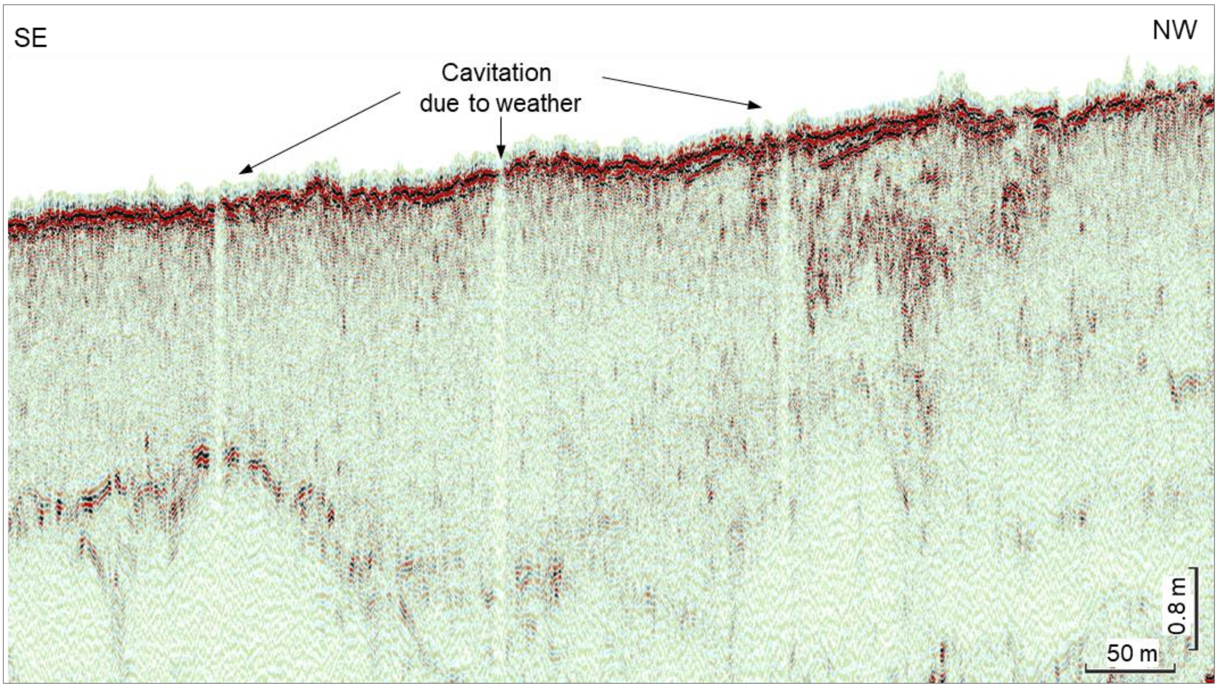


Figure 46 Cavitation caused by weather. Line 47, Block B3D from 204.126 to KP 204.803 on CRS KS

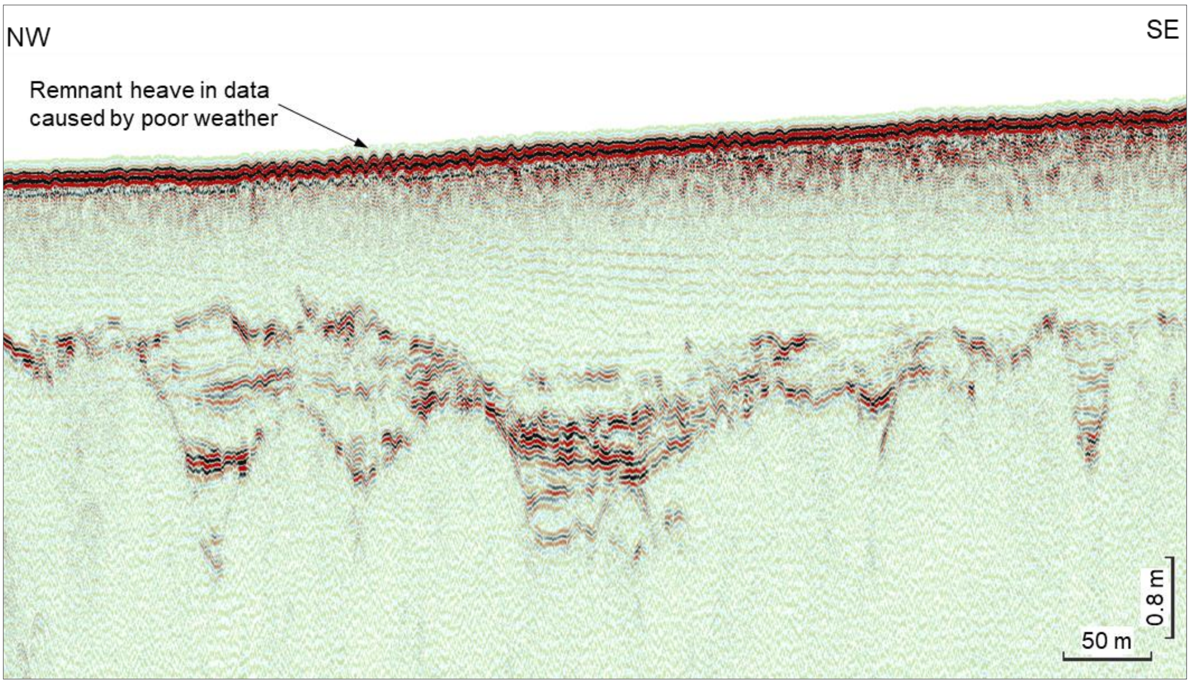


Figure 47 Remnant heave in data caused by poor weather. Line 560, Block B1D from KP 23.597 to KP 22.914 on CRS BH-DK2

7. Seabed Classification and Stratigraphy

7.1 Seabed Gradient Classification

The seabed gradient is classified according Table 22.

Table 22 Seabed gradient classification.

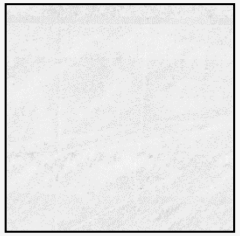
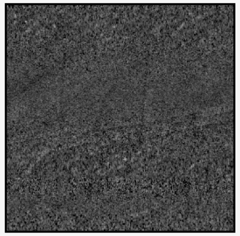
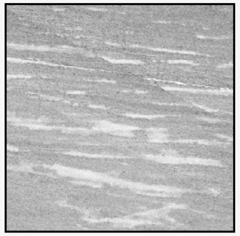
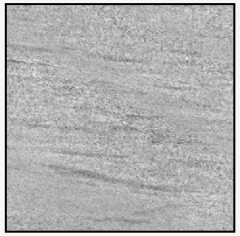
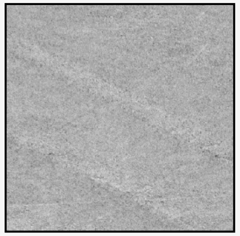
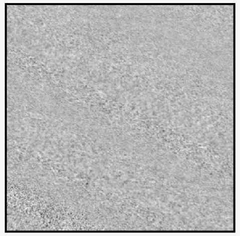
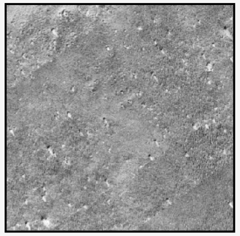
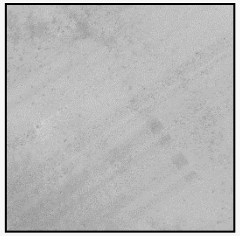
CLASSIFICATION	GRADIENT
Very Gentle	<1°
Gentle	1° - 4.9°
Moderate	5° - 9.9°
Steep	10° - 14.9°
Very Steep	>15°

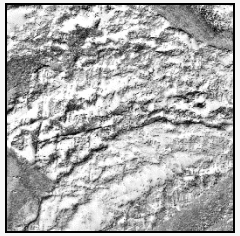
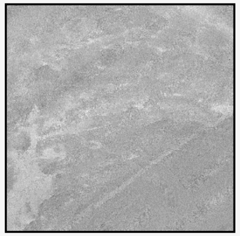
7.2 Seabed Sediment Classification

The interpretation of surficial sediment types was derived from the acoustic character of the high 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 for boulder field interpretation and to correct for the effects of seabed slope on sonar returns.

The ID column in Table 23 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). Primarily the seabed surface geology classes used for charts and Template Survey Geodatabase (TSG) have been made in accordance with that of the Geological Survey of Denmark and Greenland (GEUS) seabed sediment classes. An additional broadly analogous dataset "seabed substrate type" was made in accordance with Danish Råstof- bekendtgørelsen (BEK no. 1680 of 17/12/2018, Phase IB and is broadly aligned to that of the GEUS classes.

Table 23 Seabed sediment classification.

ID	SSS IMAGE	BS IMAGE	ACOUSTIC DESCRIPTION	SEABED SURFACE GEOLOGY	SEABED SUBSTRATE TYPE
			Low acoustic reflectivity. No texture. Seabed scars visible.	**MUD and SANDY mud** Predominantly mud (silt & clay), may contain sand.	**1C -** Clay bottom
			Low to medium acoustic reflectivity, slightly grainy texture.	**Muddy SAND** Predominantly sand with variable fractions of mud (silt & clay).	**1A -** Sand, silty, soft bottom
			Medium acoustic reflectivity. Slightly grainy to grainy texture, coarse texture in places.	**SAND** Predominantly sand, may have minor fractions of clay, silt and/or gravel.	**1B -** Sand, solid sandy bottom
			Medium to high acoustic reflectivity. Grainy, coarse texture with boulders.	**GRAVEL and coarse SAND** Predominantly gravelly sand, may contain silt. The ratio between sand and gravel can vary within this sediment type.	**2B -** Sand, gravel and pebbles – seabed cover of larger stones 1% to 10%

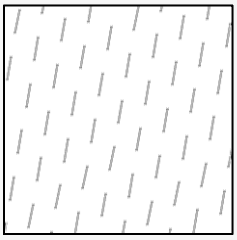
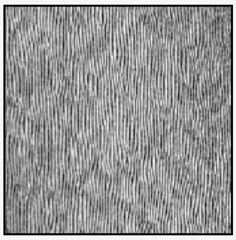
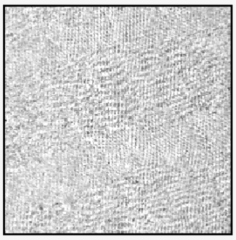
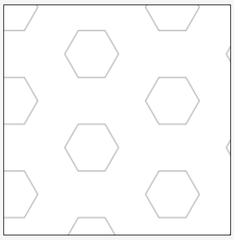
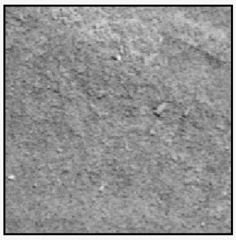
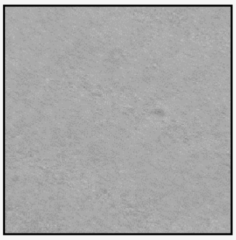
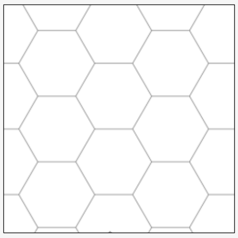
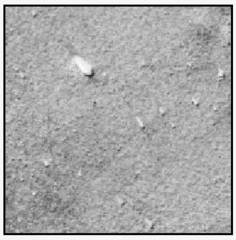
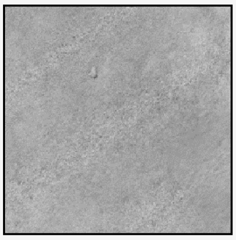
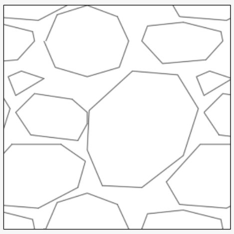
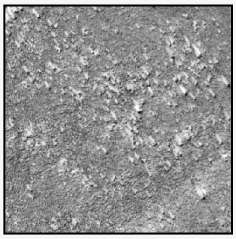
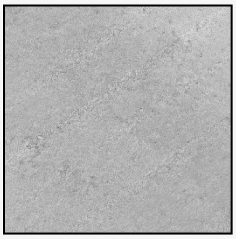
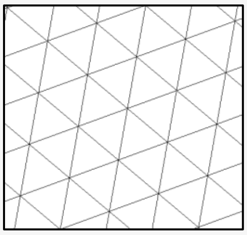
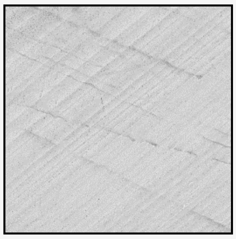
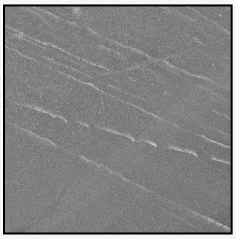
ID	SSS IMAGE	BS IMAGE	ACOUSTIC DESCRIPTION	SEABED SURFACE GEOLOGY	SEABED SUBSTRATE TYPE
			Medium to high acoustic reflectivity. Bands of high reflectivity interspersed with pockets of low reflectivity. Slightly grainy to coarse texture with boulders.	**TILL/DIAMICTON** Mixed sediment type of glacial origin. Often covered by a thin layer of sand, gravel, boulder and/or sandy mud washed out of the till.	**3 -** Sand, gravel and pebbles – seabed cover of larger stones 10% to 25%
			High acoustic reflectivity. Rugged texture with bedding planes and boulders visible	**SEDIMENTARY ROCK** Outcropping Mesozoic deposits	**4 -** Stony areas and stone reefs - seabed cover of larger stones 25% to 100%

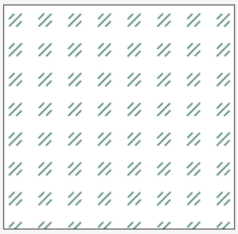
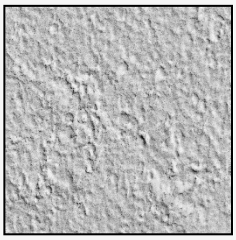
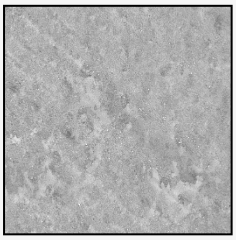
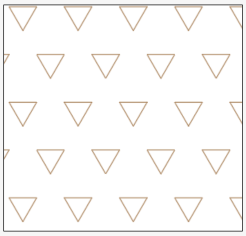
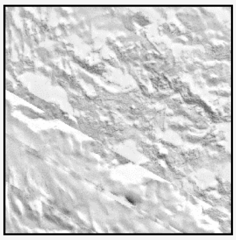
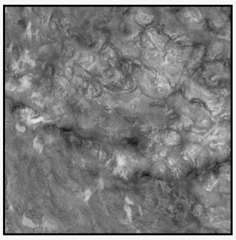
7.3 Seabed Feature/Bedform Classification

The ID column in Table 24 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, features are predominantly digitized manually based on acoustic response, texture, geotechnical and background information. The delineation of boulder fields is done automatically from heatmaps of the boulder detection results.

Table 24 Seabed features classification.

ID	SSS IMAGE	BS IMAGE	SEABED FEATURE	CRITERIA
			Ripples	Wave length <5 m Height <1.0 m
			Boulder zone type 1: Low boulder density All >1.0 m	20- 40 boulders per 100x100 m.
			Boulder zone type 2: Intermediate boulder density All >1.0 m	40 - 80 boulders per 100x100 m.
			Boulder zone type 3: High boulder density All >1.0 m	>80 boulders per 100x100 m.
			Trawl Mark Area	Area with multiple trawl scars/seabed scars.

ID	SSS IMAGE	BS IMAGE	SEABED FEATURE	CRITERIA
			Area of seagrass	Found within Block 3D and 3F in water depths <8.0 m
			Extraction area	One area found within Block 3E

7.4 Classification of Contacts and Anomalies

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

- Biogenic (possible biological features)
- Boulder
- Linear debris (cables, wires fishing gear)
- Debris (Man made objects)
- Wreck

Man made objects (debris/ wrecks etc.) were primarily identified/ catalogued in the SSS dataset and checked relative the MBES and Mag datasets. Objects are picked based on irregular shape and amplitude response of the features and/or in association with a strong magnetic anomaly. Boulders are typically identified based upon a rounded shape.

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

- Boulder zone type 1: Low boulder density field: 20-40 boulders per 100x100 m (this band was introduced for charting purposes)
- Boulder zone type 2: Intermediate boulder density field: 40 - 80 boulders per 100x100 m
- Boulder zone type 3: High boulder density field: > 80 boulders per 100x100 m

Magnetic anomalies, if identified, are classified according to the following criteria:

- Dipole, monopole or complex shape
- Discrete anomaly or anomalies creating a linear trend

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. Further to this a manual check was performed to add any obvious correlations above 5 m. A note was then made in the combined contact listing, as well as in the GIS database confidence.

SBP point contacts were identified when diffraction hyperbolas are present in the SBP data and can be clearly related to a single object. The SBP point contacts have only been assessed on the centre line only. Manual checks were performed on the SBP contacts to assess correlation with the MBES, SSS and MAG contacts and a note made in the combined contact listing, as well as in the GIS database, where such correlations exist. For large contacts, the correlation between those identified on the MAG and SBP datasets was occasional over 5 m due to the nature of the acquisition and line spacing.

SBP anomalies such as geohazards including peat and shallow gas (seen as acoustic blanking in the SBP data) have been assessed across all survey lines and identified as reflectors in the IHS Kingdom project, as well as presented in the grids, profiles and TSG deliverable datasets. No shallow gas was interpreted to be present in the SBP data in Part 1.

7.5 Geological Framework

The geological framework and background geological model for the survey area, as outlined in the following sections, has been summarised from review of the Desktop Study from GEUS 2021 (Geological desk study Bornholm Windfarm cable transects, GEUS Rapport 2021/63). All figures inserted in this survey report have also been extracted from this Desktop Study.

The desktop study shows that South-Western area of the Baltic Sea is known to be dominated by sediments derived from Pre-Quaternary and Quaternary stratigraphic events, including Glacial, Glaciolacustrine, Post-Glacial Transition and Recent Marine sedimentation.

The Pre-Quaternary geology near Bornholm comprises of bedrock consisting of Jurassic to Danien sediments, while the Arkona Basin (Transect B) consists of Danien limestone, and Fakse to Køge Bugt (Transects C and D) consists of Upper Cretaceous Chalk, with Danien limestone present primarily outside the survey area (Figure 48). Complex faulting is known to be present in the Pre-Quaternary sediments due to the presence of the 30-50 km wide WNW-ESE-trending Sorgenfrei–Tornquist Zone that transects this region of the Baltic Sea.

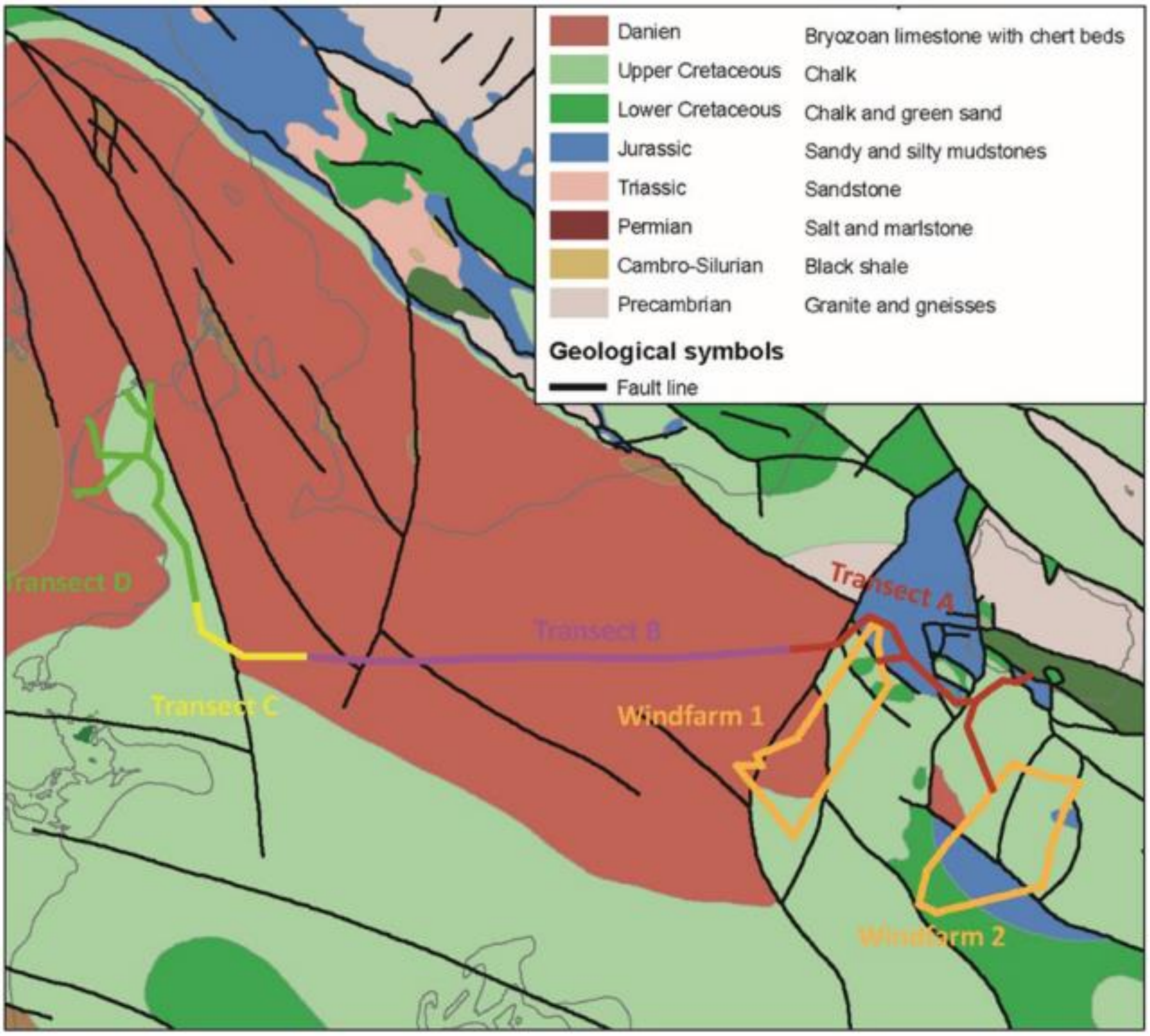


Figure 48 Bedrock geology in the survey area from Koge to Bornholm. From Varv (1992).

The Quaternary sediments in the Bornholm, Arkona Basin, Køge Bugt, Fakse Bugt regions are known to be only a few metres to about 30 m thickness, although in the basins around this South-Western Baltic Sea region, the thickness of the Quaternary sediments can exceed 100 m (Jensen et al. 2017).

The Quaternary sediments in this region are dominated by the history of Late Saalian to Late Weichselian glacial events, which were separated by periods of inter-glacial, interstadial marine or glaciolacustrine conditions.

The Scandinavian Ice Sheet reached its maximum extent in Denmark about 22000 years Before Present (BP), followed by stepwise retreat. The general deglaciation and postglacial history of the south-western Kattegat and the western Baltic is presented in the following palaeogeographical maps (Figure 49).

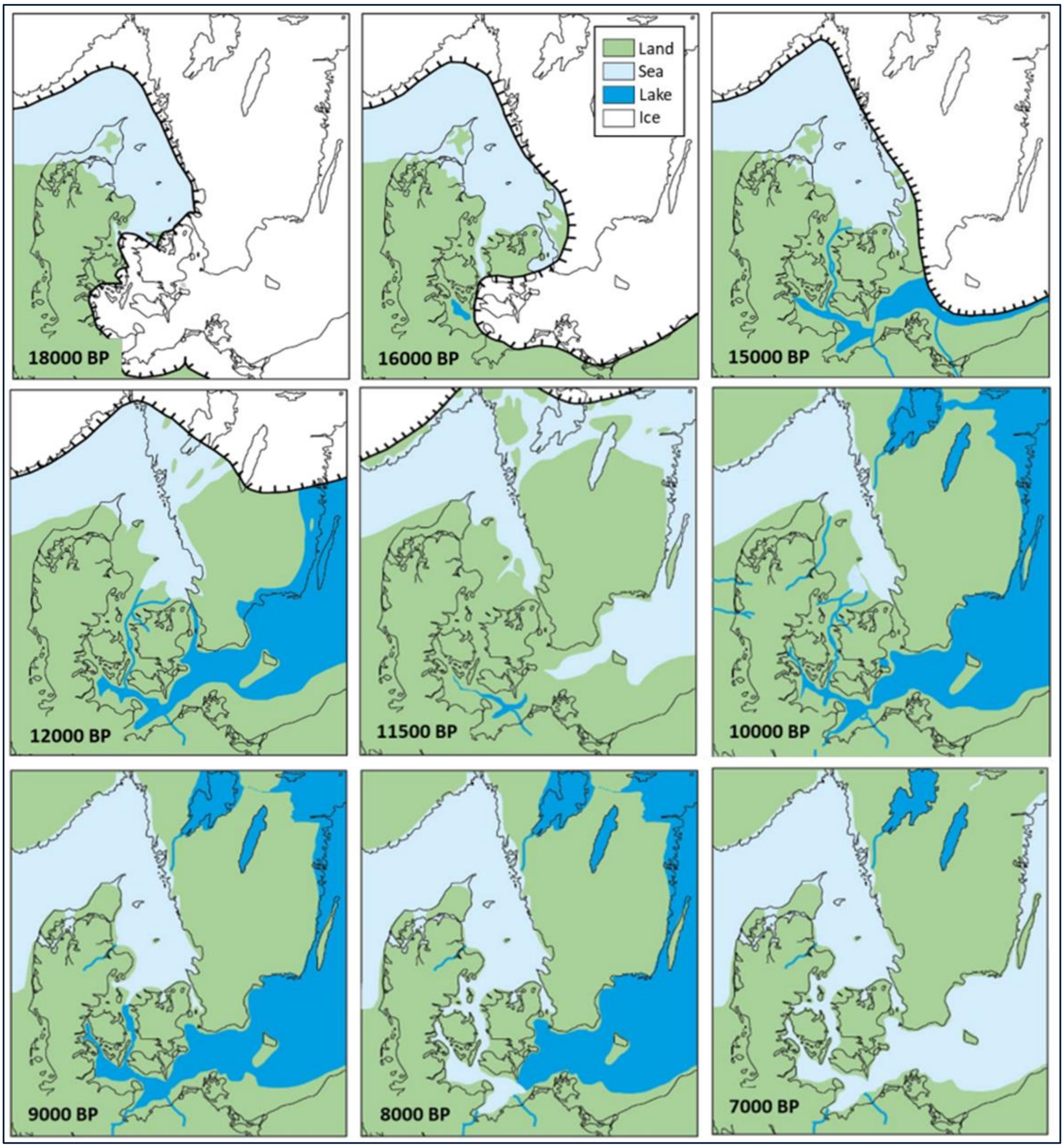


Figure 49 Paleogeographical maps showing the development of the Danish area from ca. 18000 to ca. 7000 years BP. Modified from Jensen et al. (2003)

Approximately 16000 years BP, the largest glacier extension had retreated as such that the ice lobe covered the southern part of Zealand and followed the present southern coastline of the Baltic Sea. As a result, the south-westernmost Baltic Sea, in the Køge Bugt region at the northern end of the Part 3 survey area, became dominated by broad meltwater channels and localised lakes that formed along the ice margin. Køge Bugt was a proximal freshwater dominated basin, with sedimentation of coarse-grained sands in the lower part of the Late Glacial part, fining up to silts and clays in the uppermost meters. The distribution of near surface glacial deposits and late glacial sediment basins as a result of this glacial retreating 16000 years ago can be seen in Figure 50.

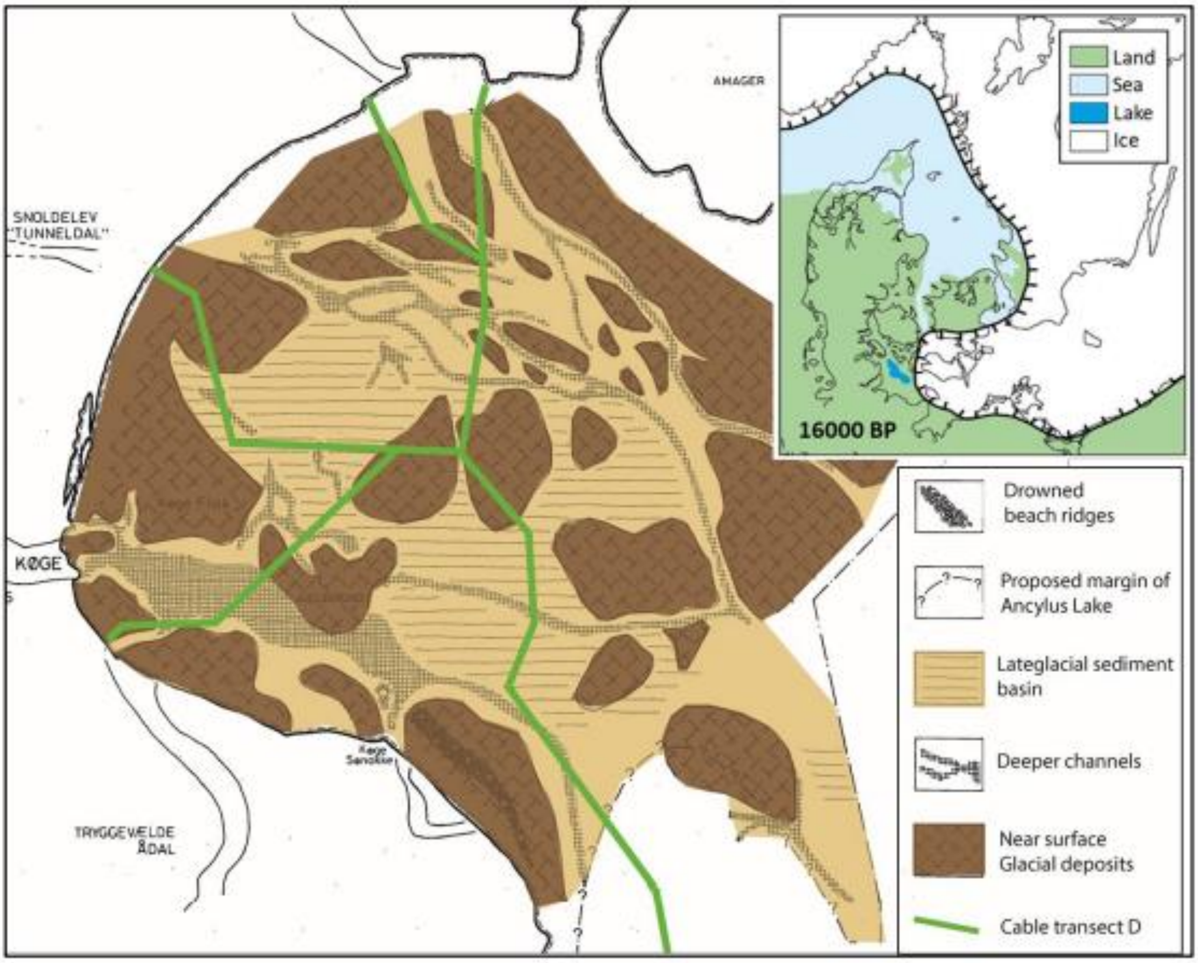


Figure 50 General distribution of near surface glacial deposits (till) and Late-Glacial sediment basins (from Skov og Naturstyrelesen 1987).

Approximately 15000 years BP, the Part 1 survey area region was deglaciated due to the glacier retreating further. The Baltic Ice Lake was thought to have started to form during this time, after being dammed in front of the ice sheet. This led to a glaciolacustrine depositional environment in the Bornholm Basin, as illustrated in Figure 51. Apart from meltwater flow from the glacier area west of Bornholm, major meltwater contributions were also provided by German and Polish rivers, as proved by the existence of major late glacial delta deposits.

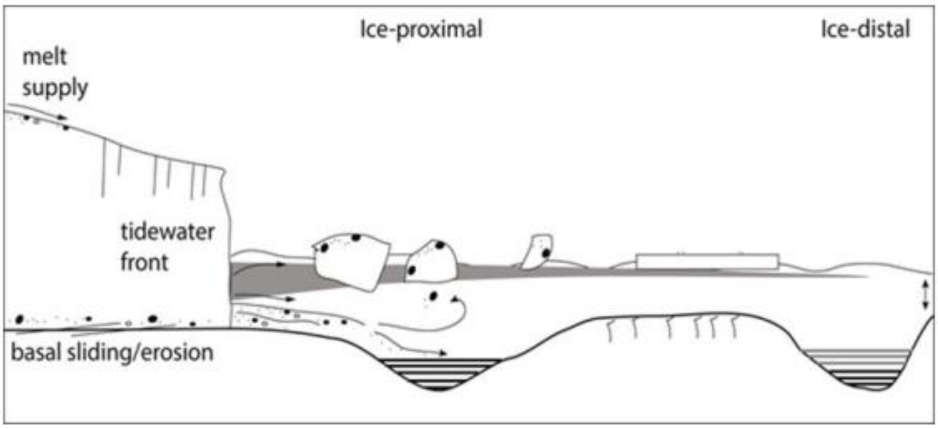


Figure 51 Illustration of a glaciolacustrine depositional environment.

After the initial damming of The Baltic Ice Lake, two phases of damming occurred followed by major discharge events. The last and most extensive damming was at its maximum about 12000 years ago.

Approximately 11500 years BP, a strait was established though south-central Sweden and the Baltic Basin was transformed into the Yoldia Sea. Continuous glacio-isostatic uplift of south-central Sweden then led to the closure of the sea and the last lake phase of the Postglacial Baltic was established, called the Ancylus Lake. Due to damming, the lake reached a maximum level about 10200 years ago with only a narrow drainage pathway through the Great Belt into the southern Kattegat, and calm lake sedimentation occurred.

This was followed by a change into brackish conditions about 9400 years BP, marking the beginning of the Littorina transgression. By 8000 years BP, the transgression had reached the Darss Sill- Gedser Reef area and by 7000 years BP, a fully marine environment was reached across all of the western part of the Baltic Proper. During the past 6000 years, the water level has increased a few metres only. The global eustatic sea level rise has surpassed the glacio-isostatic uplift of the region, and fossil shorelines and landscapes are submerged.

It should be noted that the difference between the Rønne Banke region and the Køge Bugt region is caused by higher glacio-isostatic uplift in the Køge Bugt region than in the Rønne Banke region after the Baltic Ice Lake stages. The deeper parts of the Arkona Basin have been continuously submerged after the last deglaciation, but shallow water areas in the region would have been dry land for long periods after the last deglaciation of the region.

7.5.1 Background Geological Model

A general background geological model for the south-western Baltic, as outlined in the Desktop Study (GEUS 2021), was established by Jensen et al. (2017), primarily based on seismic data and core data from Integrated Ocean Drilling Program (IODP) Expedition 347 in October 2013, located in the large basin to the East of Bornholm (Figure 52).

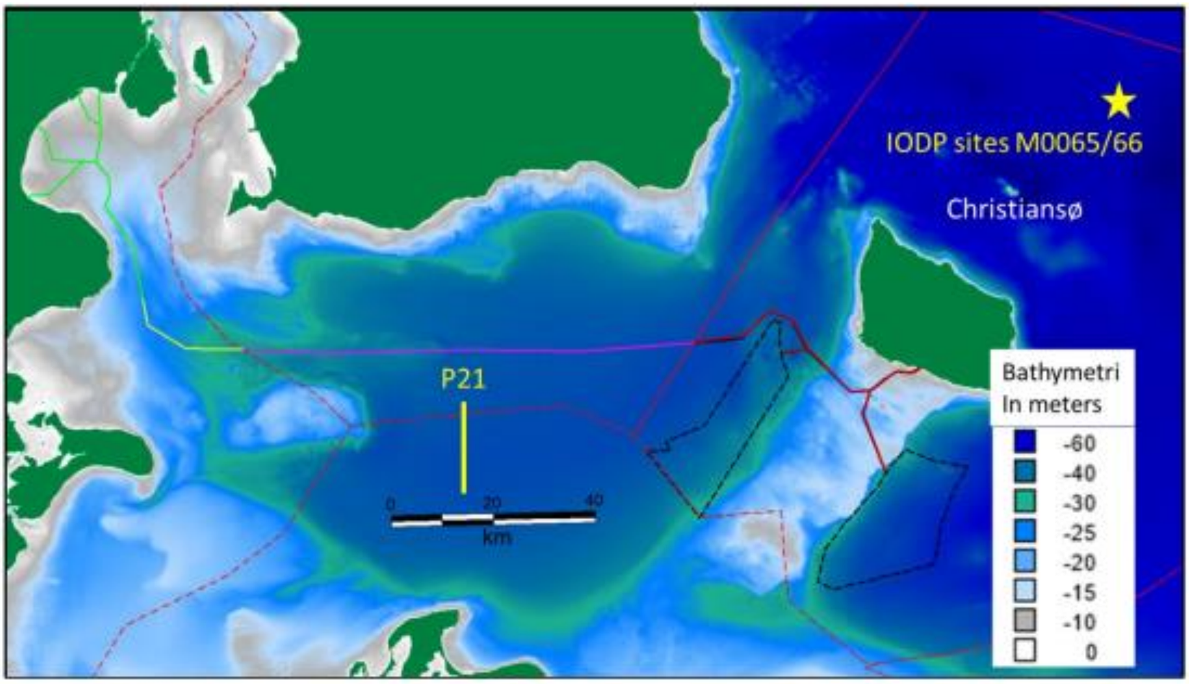


Figure 52 Map of the south-western Baltic Sea with the location of the IODP sites that formed the basis of the geological model related to the survey area

Six seismic units were described, all separated by unconformities (Figure 53). The Crystalline basement and Sedimentary bedrock Unit V, as well as the Glacial Unit IV, were mainly identified on deeper seismic airgun data, whereas details of the late- and post-glacial softer deposits are best imaged with higher resolution sub-bottom profilers. The bedrock distribution follows the deeper structures, and the glacial deposits follow the regional glaciations. The late and postglacial Units III–I were deposited in basins with a changing shore level, well known in the southwestern Baltic Sea (Andrén 2000 and Uscinowicz 2006).

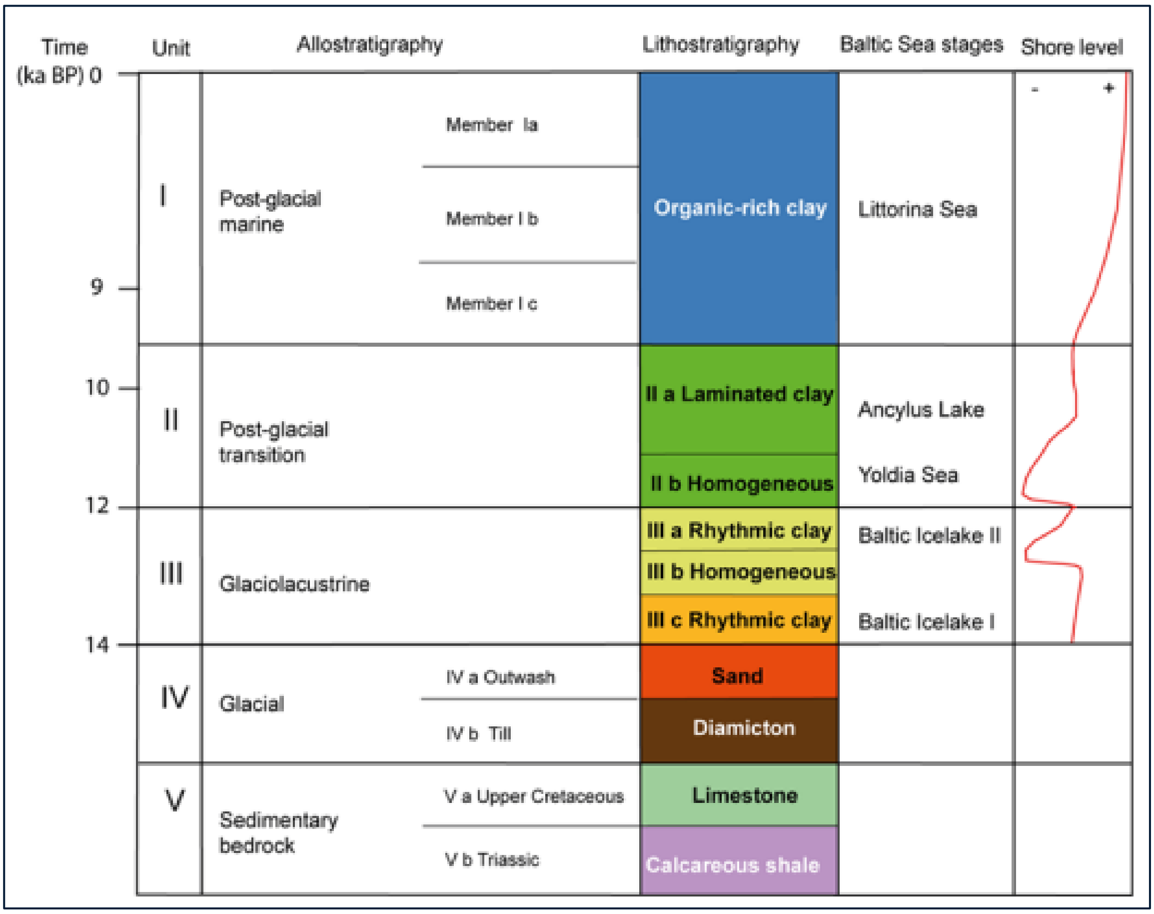


Figure 53 General stratigraphic model of Parts 1 and 3, within the Bornholm Basin (Jensen et al. 2017).

The glacial deposits (Unit IV) drape the pre-Quaternary irregular surface and are usually 10–20 m thick, but in places crystalline basement rocks can be found at the seabed, and in nearby strike slip fault basins, the unit is more than 50 m thick. The upper reflector is an irregular unconformity, and the internal configuration is mostly chaotic, consisting of diamicton and glacial outwash sediments, Andrén (2014).

The glaciolacustrine sediments (Unit III) cover the irregular unconformity of the glacial deposits in the Bornholm Basin. In the basin areas, a strong upper reflector marks the top of the glaciolacustrine deposits, which in general drape the underlying topography with a thickness of 10–20 m. The internal reflection configuration varies throughout the basin, from rhythmically layered clays deposited during the Baltic Ice Lake, homogenous clays related to the first Baltic Ice Lake drainage event, and more complex clays and sands, potentially deposited due to slumping in unstable sloping environments.

The Early Post-glacial transition clays (Unit II) conformably drape the glaciolacustrine sediments generally with a more constant thickness of about 4 m and a strong reflector is seen at the upper boundary. The seismic characteristics of Unit II also vary, with more homogenous parts interpreted to represent deposition in the Yoldia Sea, with more laminated parts representing Ancylus Lake clay.

The Mid and Late Post-glacial marine muds and clays in the Bornholm Basin show complex internal reflection patterns and vary spatially throughout the basin. The complex reflection pattern indicates that late Postglacial down-faulting resulted in episodic, synsedimentary deposition in the strike-slip basins and that sub-recent to recent sedimentation is asymmetrical with sedimentation in the southern central basin and erosion at the north-eastern margin of the basin. Transport of sediments from the Arkona Basin west of Bornholm into the Bornholm Basin and along the southern basin margin is a likely process to have provided sediment deposited as a wedge-shaped contourite.

7.5.2 Geological Framework – Part 1

An overview of the expected nearshore geology in Part 1 (Bornholm) can be seen in Figure 54, as extracted from the desktop study (GEUS 2021). Transect A shows near coastal seabed sediments are dominated by Jurassic and Cretaceous bedrock deposits at the seabed, with patchy remnants of glacial and postglacial boulders and sandy sediments.

An overview of the expected offshore geology in Part 1 (Bornholm) can be seen in Figure 55, as extracted from the desktop study (GEUS 2021). The distribution of shallow sediments reflects to some degree the bathymetry of the region. Fine-grained mud has accumulated in the central parts of the basins, with thickening of glaciolacustrine clayey/silty sediments and deepening of the Quaternary glacial till towards the Arkona Basin. Till and bedrock are often located at or near the surface in the shallow parts, indicative of non-deposition or erosion. In the absence of confirmative ground truthing the bedrock units were detected along the route proximal to Bornholm Island is group termed as “SEDIMENTARY ROCK”. From approximately KP 0.000 to KP 15.000 (i.e., B1A, B1B and north end of B1C) the top of the SEDIMENTARY ROCK was difficult to detect. This was due to the coarseness of the overlying seabed sediments, weathered interface of the rock and very irregular rock bedding.

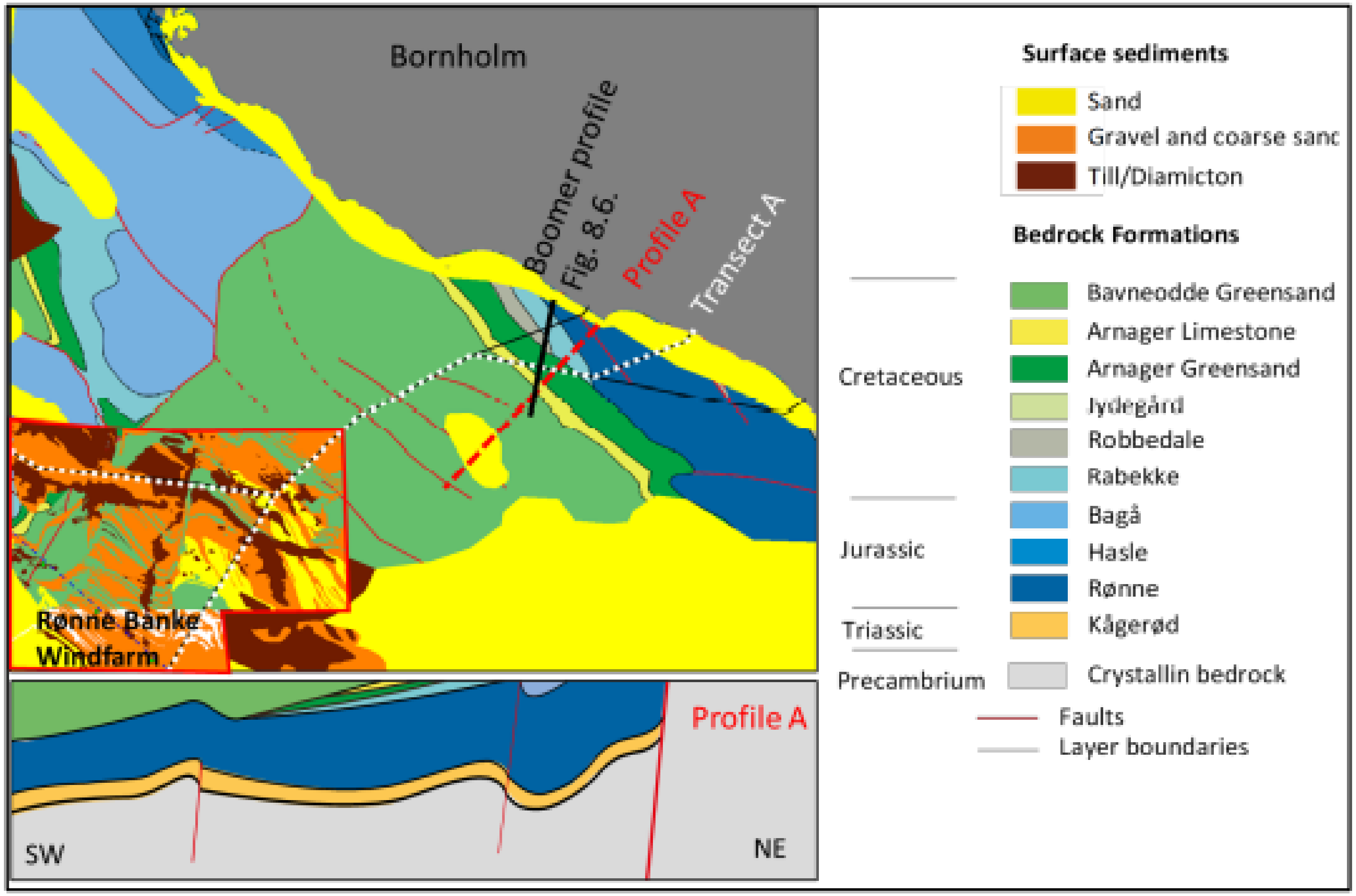


Figure 54 Shallow sediments in nearshore area of Part 1(Bornholm) from south-west Rønne Banke Windfarm, to north-east Sose Bugt landfall.

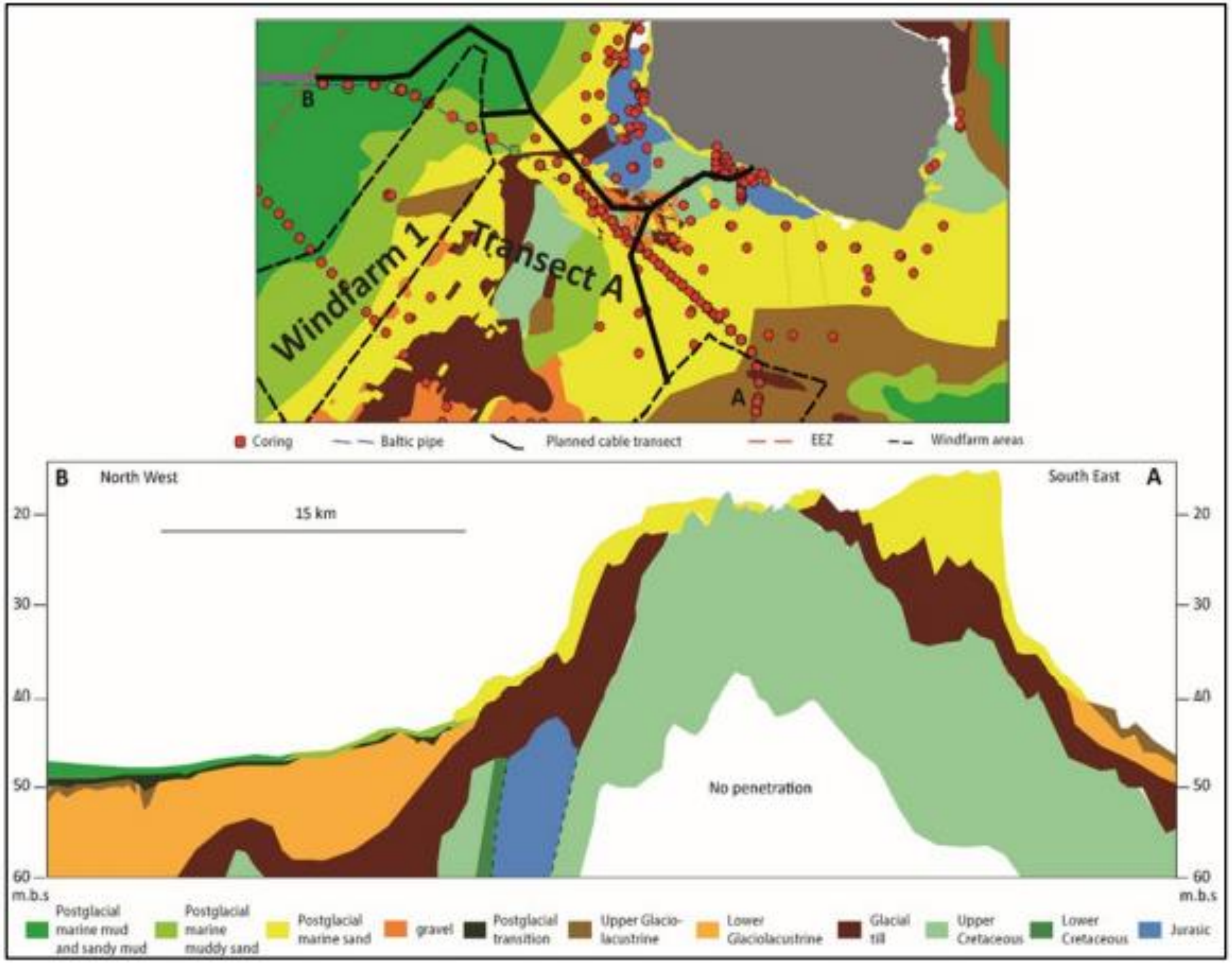


Figure 55 Shallow sediments in offshore area of Part 1 (Bornholm) between Windfarm areas 1 and 2.

7.6 Seabed Sediment Classification Based on Grain Size

The seabed sample soil classifications are based on ISO 14688-1 (Table 25).

Table 25 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

7.7 Sub-Seabed Geology Classification

The classifications of the sub-seabed geology have been derived through a combination of analysis and interpretation of the acoustic character of the SBP data, geotechnical results and knowledge of background information, as outlined in Section 7.5.

The descriptions of the sub-seabed geological units are provided according to the seismic facies, stratigraphic boundaries, and internal reflector terminations. Descriptions of the units identified in Part 1 are presented in Table 26. The distribution of all units within each Part are outlined in Table 27

The reflectors identified in the survey area have been interpreted to define the base of recent Holocene marine sediments, Late and Post Glacial deposits and Glacial deposits. Shallow bedrock from the Upper Cretaceous period, has also been identified in the survey area but the basal reflector is beyond the depth of the SBP penetration. The bedrock dominating in Part 1 is interpreted to be SEDIMENTARY ROCK.

The reflector P1_H10 is interpreted to define the base of the Holocene marine sediments, predominantly consisting of SAND with localised variations in composition between finer deposits, such as CLAY and SILT, and coarser deposits such as GRAVEL. This unit was mapped across all survey lines, where present, in order to create a gridded surface to the base of the unit.

The reflectors P1_H50 is interpreted to identify the base of a Glacial Deposit unit, predominantly a firm to very stiff sandy gravelly Glacial CLAY. The base of the unit was not continuous or well defined in Part 1 but was mapped on all lines where possible and a gridded surface was able to be produced. In some places this unit is visible up to the seabed, where a GRAVEL and coarse SAND and/or TILL/DIAMICTION are observed. Caution should therefore be taken where this Glacial CLAY unit is encountered as geohazards such as boulders may be present in the shallow geology but not able to be identified in the SBP data.

There were three further sedimentary units identified in Part 1. Each of these units were classified based on their distinct characteristics, with all of these interpreted to be older than the Holocene H10 unit, but younger than the Glacial H50 unit, therefore indicative of Late to Post Glacial Freshwater, Washdown and Meltwater deposition. All these units were mapped across all survey lines where they were determined to be present and gridded surfaces to the base of these units were also produced. Caution should be taken in the presence of some of the units as they can represent localised geohazards such as soft seabed, often with some organic matter (commonly associated with occurrence of P1_H15 and P1_H30).

Within each unit, if reflectors were present indicating minor variations in sediment type, these were digitised as internal reflectors (denoted with ‘i’ at the end of the horizon name e.g. P3_H05i). These were identified on the centreline for the purpose of the alignment charts.

Table 26 Summary of interpreted sub-seabed geological units in Part 1.

Geological Units	Location	Acoustic Facies and Internal Configuration	Lower Bounding Surface		Expected Composition	Kingdom Reflector Colour	Stratigraphy	
			Morphology	Nature			Depositional Environment	Depositional Age
P1_H05i (Internal)	B1D	Slight change in facies with P1_H10 unit, with low reflectivity above P1_H05 and little to no internals structures visible.	Irregular, discontinuous, low to high amplitude.	Depositional	SAND with local variations in grain size from silty to gravelly	**Medium Gray**	Marine sand deposits	**Holocene**
P1_H06i (Internal)	B1D	Thin lamination within P1_H10, generally a sharp, high amplitude reflector.	Mostly flat, discontinuous, high amplitude.	Depositional	Thin laminations of silty SAND and/or CLAY	**Dark Gray**	Marine deposits	**Holocene**
P1_H10	B1A, B, C, D	Generally low amplitude unit with occasional sub-horizontal high amplitude internal reflectors. This is the youngest and uppermost unit within the shallower water central and southern areas of Part 1.	Mostly flat, continuous, high amplitude.	Depositional	SAND with local variations in grain size from silty to gravelly	**Yellow**	Marine sand deposits	**Holocene**
P1_H15	B1D, E	Acoustically homogenous, very low amplitude unit with no visible internal structures. Seabed morphology along top of unit is very flat and low amplitude. This is the youngest and uppermost unit within the deeper water northern areas of Part 1.	Flat, continuous, very low amplitude.	Depositional	Soft to very soft silty sandy CLAY, with some SILT in places.	**Violet Red**	Low energy marine clay deposits	**Holocene**
P1_H20	B1C, D	Generally low amplitude unit abundant in sub-horizontal high amplitude internal reflectors. This unit is located either directly below P1_H10 or is observed up to the seabed.	Mostly flat, continuous, high amplitude.	Depositional	SAND with local variations in grain size from silty to gravelly	**Blue**	Washdown and/or meltwater deposits	**Late/Post Glacial**
P1_H30	B1D, E	Unit contains distinctive high amplitude parallel horizontal internal reflectors, indicative of thick to thin laminae and/or thin beds of alternating sediments. This unit is	Undulating, continuous. Base can be difficult to define in deeper	Erosional	Clayey silty SAND to very soft to soft silty sandy CLAY with closely spaced thick	**Dark Green**	Meltwater deposits	**Late/Post Glacial**

Geological Units	Location	Acoustic Facies and Internal Configuration	Lower Bounding Surface		Expected Composition	Kingdom Reflector Colour	Stratigraphy	
			Morphology	Nature			Depositional Environment	Depositional Age
		finer grained in the deeper water northern areas of Part 1, either directly below P1_H15, or is observed up to the seabed. In the central section of B1D the unit is more granular and present below P1_H10.	water areas, occasionally picked based on a facies change from higher to lower amplitude.		to thin laminae of clayey SILT.			
P1_H35i (Internal)	B1B, C, D	Generally low amplitude facies abundant in sinuous high amplitude internal reflectors. Base of facies is gradational, fading from a lower amplitude above into a higher amplitude facies below reflector. Often found directly above Glacial Deposit unit (P1_H50).	Low amplitude, discontinuous, gradational.	Erosional	Silty clayey SAND with some CLAY laminae.	**Turquoise**	Meltwater deposits	**Late Glacial**
P1_H40i (Internal)	B1D	Acoustically homogenous, very low amplitude facies with little to no visible internal structures. Interpreted on centre line (CL) only, in correlation with geotechnical results to indicative change in strength and stiffness properties of sediment.	Undulating, interpreted along base of facies change from low amplitude above to higher amplitude laminated below.	Erosional	Soft CLAY	**Dark Yellow**	Meltwater deposits	**Late Glacial**
P1_H45i (Internal)	B1A, B	Channel features within Part 1 nearshore area only. Channels contain high amplitude chaotic infill and occasional high amplitude sinuous reflectors.	Gradational, low amplitude base, often poorly defined but depicting U or V shaped channels.	Erosional	SAND and CLAY of various grain sizes and stiffness properties with occasional CLAY and SILT laminae.	**Dark Cyan**	Washdown and/or meltwater deposits	**Post/Late Glacial**
P1_H50	B1B, C, D	Low to high amplitude unit, often with chaotic internal structure and occasional higher amplitude broader non-continuous reflectors. Unit thickens to north of Part 1 (in B1D) and	Gradational base, often depicting change from higher amplitude chaotic	Erosional	Silty, sandy, gravelly Glacial CLAY (often firm to very stiff). Geohazards such as	**Orange**	Glacial - likely outwash and/or till/diamicton	**Glacial**

Geological Units	Location	Acoustic Facies and Internal Configuration	Lower Bounding Surface		Expected Composition	Kingdom Reflector Colour	Stratigraphy	
			Morphology	Nature			Depositional Environment	Depositional Age
		deepens to south of Part 1 (in B1C), eventually extending beyond depth of Innomar penetration in both areas.	to lower amplitude structure-less facies below.		boulders may be present within unit.			

Table 27 Distribution of interpreted sub-seabed geological units in Part 1.

	P1BH			P1BH1A	P1BH1B	P1BH2
	B1A	B1B	B1D	B1D	B1D	B1C
Seabed						
P1_H05i						
P1_H06i						
P1_H10						
P1_H15						
P1_H20						
P1_H30						
P1_H35i						
P1_H40i						
P1_H45i						
P1_H50						

7.8 Seabed Sediment Index

A scale has been derived for the purpose of the discussion and simplification of the geotechnical data called the Seabed Sediment Index (SSI). The SSI can be viewed as a semi-quantitative scale in respect of the encountered ground conditions, and to some respect, the likely difficulties for engineering activities in the investigated depth below seabed level. For this report, the assigned SSI values provided are based on the geological and geotechnical characteristics of the encountered material at depths from 0.5 m, then every 0.5 m to 3 m depth, and finally every 1 m depth to a maximum of 6 m. A depth from the seabed up to 3 m may be considered the typical trenching depth range for submarine cables. However, it is prudent to consider the ground conditions up to the maximum depths achieved during the survey, approaching 6 m, to account for any 'difficult' geological or geotechnical eventualities.

For a detailed assessment of the sediment below this depth, the reader should consult the relevant complete VC records, together with the laboratory testing results provided in the Appendices. Note is made that where a VC has terminated at shallow depths, the SSI is provided to the nearest depth. In the case of a CPT with dense granular material below low strength cohesive strata, the granular density is extrapolated to the next 0.5 or 1 m depth increment, to indicate the potential nature of the basal refusal material.

A summary of the SSI scale used to quantify each survey location is presented in below (Table 28). Granular density descriptors are based on the calculated Density Index, from the CPT data. The undrained shear strength descriptor for cohesive sediment is derived from the calculated shear strength from the CPT data, combined with an assessment of any laboratory test data from the VC material

Table 28 Summary of the Seabed Sediment Index scale.

SSI	Typical Seabed Sediment
1	Sedimentary Rock
2	Dense to very dense Glacial deposits
3	Very dense granular
4	Medium to high strength cohesive (Glacial Till)
5	Dense granular
6	Medium dense granular
7	Loose granular
8	Low to medium strength cohesive
9	Very low to low strength cohesive
10	Extremely low strength cohesive
O	Organic material *sensu stricto*, containing PEAT

8. Results – Part 1 - Cable Route Bornholm-Sjælland (BH-DK2)

The results from the geophysical and geotechnical surveys within the defined boundary of Part 1 are presented in this report together with associated alignment charts. The charts are presented in Appendix B. The results are presented by route (Table 29), 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 29 Export cable routes results

Number	Start KP	End KP	Results
CRS Bornholm-Sjælland	0.000	18.831	Section 8.2
ERS Bornholm 1A	16.607	28.945	Section 8.3

The results focus on bathymetry, surficial geology, and shallow geology. A summary of all contacts, anomalies and features is also presented. All reports, appendices, and charts refer to the client supplied “2022_04_14_KP_REF_TAB.shp” RPL (Appendix A).

The terms elevation and depth have been used throughout the report. 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 as per TQ-009. In this case elevations have negative values and depths positive values. Although referring to the same parameter, the vertical position relative to the DTU21 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.

Additionally, report imagery obtained from the EIVA NaviModel software inherently stores DTMs with depth conventions of positive down. Examples of such images include Figure 88 and Figure 98.

8.1 Description of Data Interpretation

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

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.

Contacts were detected on the SSS data. Boulders were automatically picked on MBES data. SSS contacts were QCd against the automatic boulder picking to remove duplication and to ensure contacts classified as boulders were not in fact, manmade objects (MMO).

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 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. Further to this a manual check was performed to add any obvious correlations above 5 m.

With the Green LiDAR technology, penetration was achieved up to approximately 2.5 m water depth, allowing the gap between bathymetric and topographic data acquired by the initial (conventional) LiDAR campaign.

It was also noted that the vegetation had grown during the duration of the project. A lot of crops, plants and trees were visible in the green LiDAR data set. To achieve the best possible dataset conventional LiDAR for the terrestrial sections were used and the green LiDAR for the very shallow water/surf zone sections.

In the variation order and TQ-021 it was specified that a density of at least 6-8 points per m^2 was to be expected. This was unfortunately not achieved. In general LiDAR coverage was sufficient to fill in a 50 cm resolution grid. Large boulders are visible on the LiDAR data, even at 50 cm resolution.

From the combined LiDAR survey 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 into GIS for hatching and merging with the marine data set.

8.2 CRS Bornholm-Sjælland: KP 0.000 to KP 18.831

8.2.1 Overview

The route covers the Landfall at Bornholm, where the survey corridor extends to approximately 7.5 km along the coastline and approximately 300 m landward of the low water mark. The offshore corridor within the defined boundary varies in width between 2 and 3 km (Figure 56).

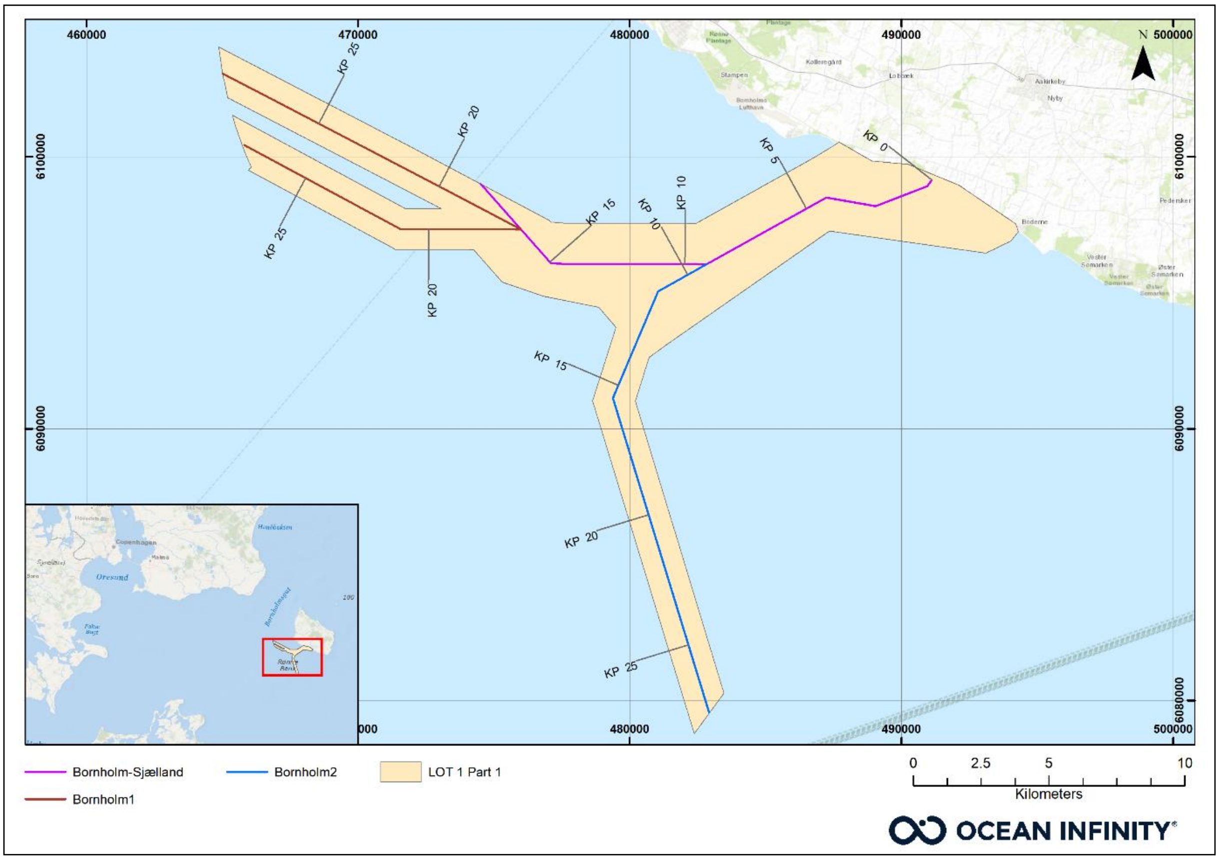


Figure 56 Overview image showing the cable routes and ECR within defined boundary of Part 1.

8.2.2 Bathymetry

The topographical survey, conducted by aerial aircraft, covered a section of the landfall zone that measured 440 m long at the route and spanned the full width of the survey corridor. Full coverage of the landfall has been reached thanks to the use of an additional Green LiDAR to cover the gap that was remaining between the LiDAR survey data and the bathymetry data.

Beyond the start of the route in the Northwest direction, the shoreline and 300 m landward, is covered by the LiDAR data and also includes buildings (farm, houses, etc), trees, fields as well as man-made objects like cars (Figure 76). Vehicular access to the buildings is seen as curving ridges as well as the agricultural lines in the fields. The elevation seen at the landfall varies between approximately 13 m and 34 m.

The rocky foreshore is seen from KP 0.000 followed by a steep drop wall of 23 m height orientated NW-SE with a maximum slope along the route of 48.1° at KP 0.035.

This fall delineates the start of the rocky beach and a varied and uneven bathymetric surface. Nevertheless, slopes and seabed features tend to become gentler going westwards.

From KP 0.050 to KP 3.350 the seabed slopes gently down from an elevation of 1.63 m to a depth of 12.79 m. The maximum depth is 17.91 m at 488087.4 E, 6099270.6 N in a seabed large depression. Between KP 3.350 and

KP 4.250 the route crosses a raised rocky outcrop with ridges and the seabed shoals from 2.56 m at 486772.88 E, 6099474.63 N.

Such ridges are seen across the corridor crossing the route mostly orientated NW-SE but also undulating in multiple directions from KP 0.150 up to the end of the block at KP 18.830 (Figure 57). They are associated with very steep slopes on their ridges reaching a maximum value along the route of 28.6° at KP 8.989.

Amongst those seabed ridges, raises identified as boulders and glacial debris are observed in the bathymetry (Figure 58). Scour depressions are also seen around some of those features.

From KP 3.350 to KP 17.400 the seabed continues slowly deepening westward with a very irregular bathymetry and moderate to very steep slopes due to seabed formations. The minimum depth along the route is 6.64 m at KP 3.724 and the maximum depth along the route is 24.58 m at the end at KP 18.823.

From KP 17.400 to the end at KP 18.830 the slopes are gentle, generally below 1.5° with a moderately deepening seafloor. Between KP 17.400 and KP 18.830 the minimum depth along the route is 23.09 m at KP 17.477 and the maximum depth is 28.45 m at KP 8.988.

From KP 15.000 to end KP 18.830, the Baltic Pipe pipeline is seen as a linear raised seabed feature to the South of the route at the edge of the MBES corridor.

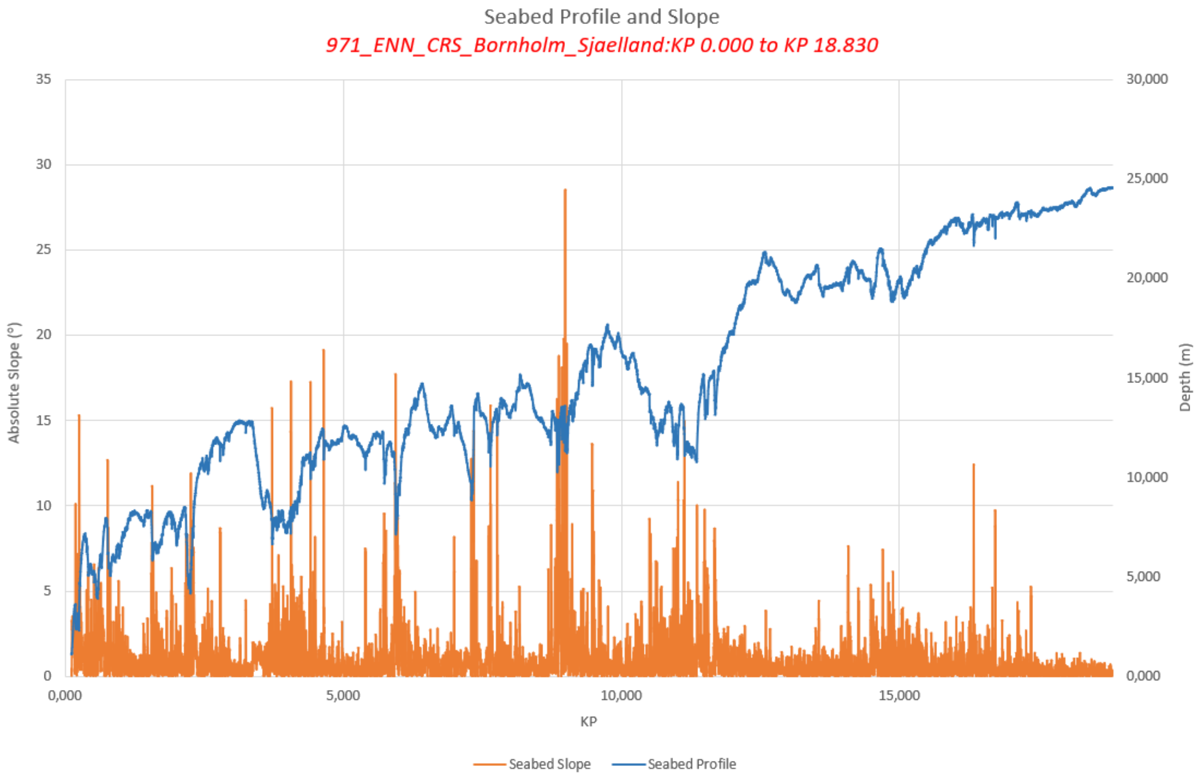


Figure 57 Route Bornholm-Sjælland_P1 bathymetry longitudinal profile and slope

Depths is in metres (with bathymetric depths positive below MSL datum and topographic elevations negative above MSL datum) and slope is in degrees (absolute value for visualisation).

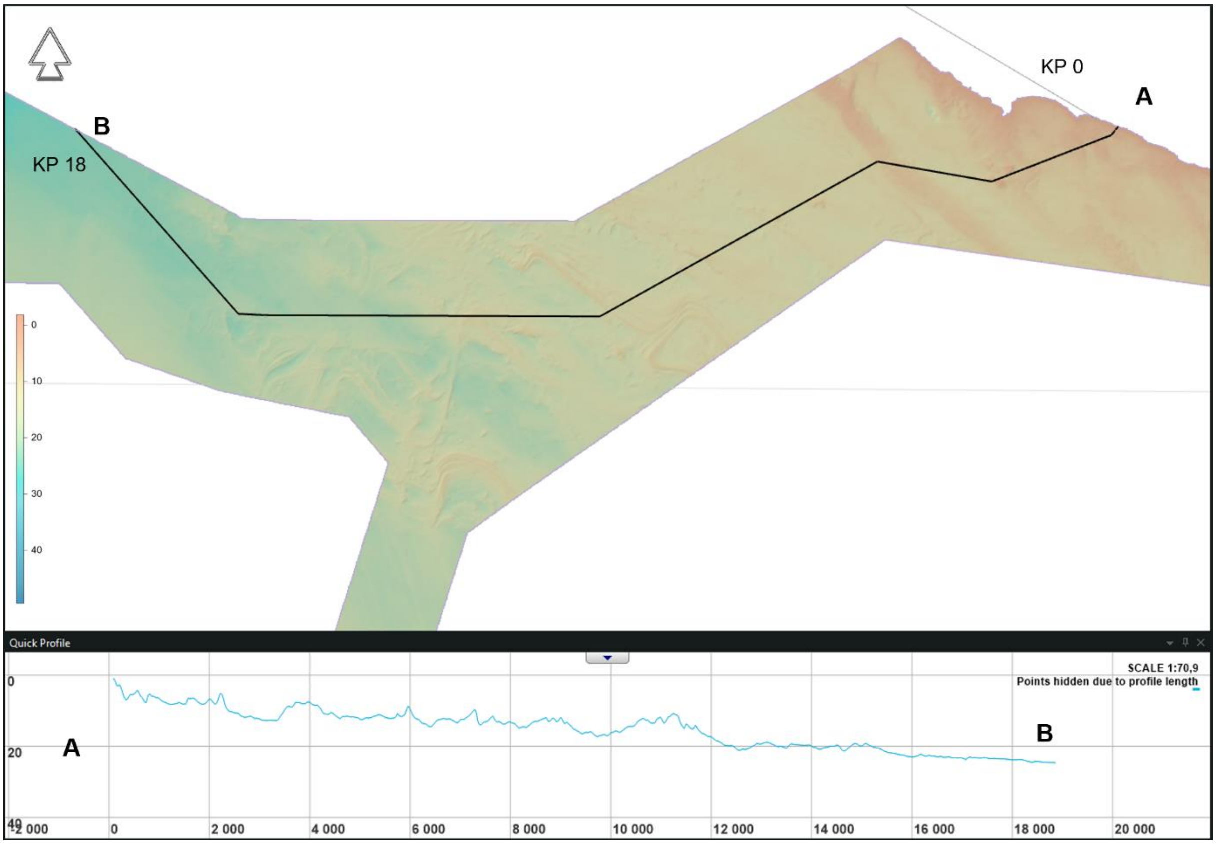


Figure 58 Overview image of CRS Bornholm-Sjælland: KP 0.000 to KP 18.830 along Route Bornholm-Sjælland_P1.

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 x69.

8.2.3 Grab Sampling

The following grab samples were acquired, Figure 59 and Table 30. Full description of the grab sample results is contained in Table 30.

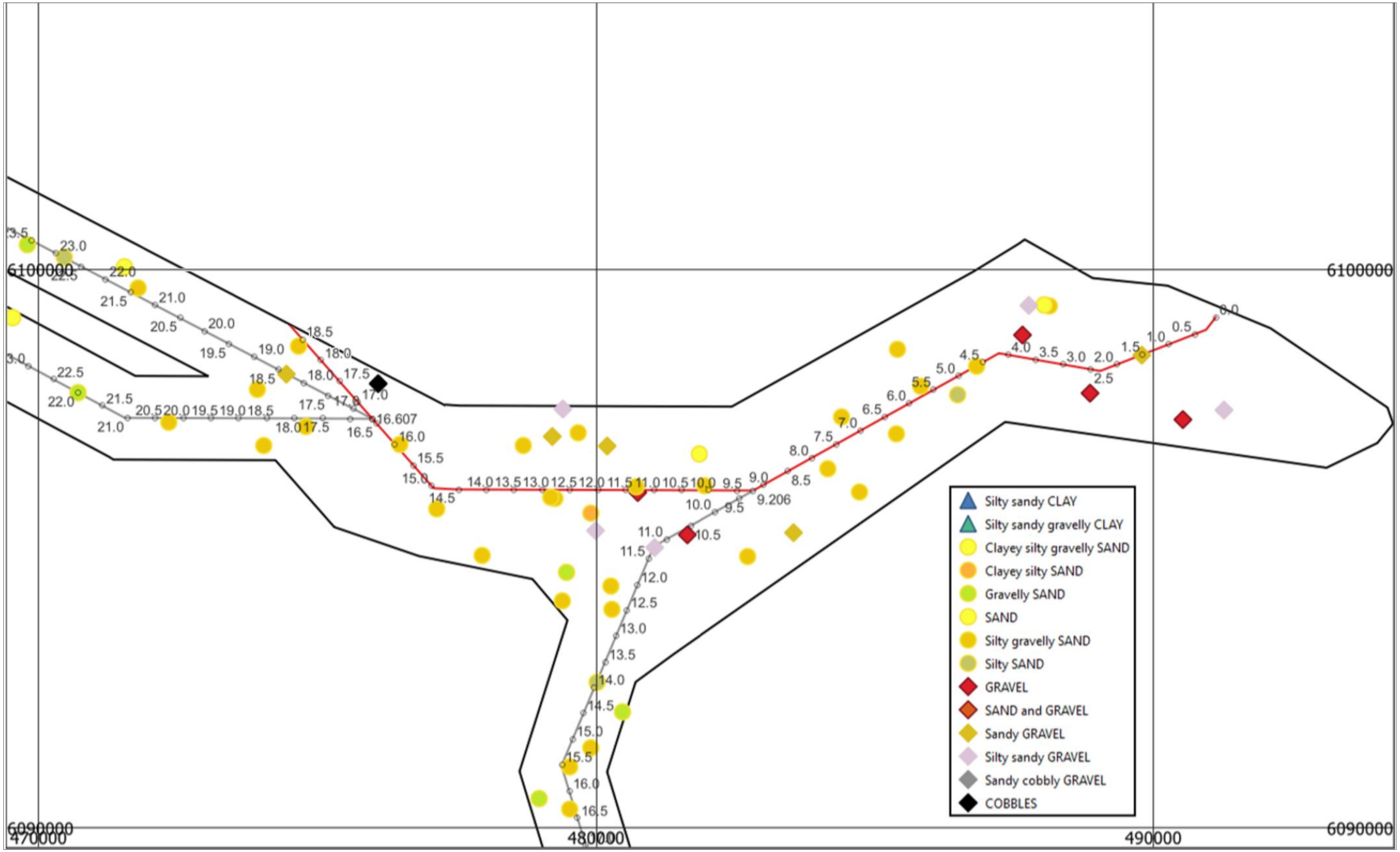


Figure 59 CRS Bornholm-Sjælland grab Sampling overview KP 0.000 to KP 18.831.

Table 30 CRS Bornholm-Sjælland grab Sampling overview within defined boundary.

ID	KP	DCC (m)	Depth	Description
971-ENE-DV-GS-125	0.498	-1466	9.03	GRAVEL, gravel is 95% subangular to subrounded fine to medium of various lithologies and 5% subangular fine shell fragments, poorly sorted, slightly silty, very sandy, sand is medium to coarse, greyish brown, non-calcareous.
971-ENE-DV-GS-124	1.255	-1354	8.42	GRAVEL, 2 no. subrounded medium of SANDSTONE, brown, non-calcareous.
971-ENE-DV-GS-121	1.529	3	8.39	GRAVEL, 100% subangular to subrounded medium to coarse of various lithologies, sorted, slightly sandy, sand is medium to coarse, dark orangish brown and dark grey, non-calcareous.
971-ENE-DV-GS-116	2.422	-430	10.34	GRAVEL, 100 % subangular to subrounded fine to coarse of various lithologies, some very thin black marine plant debris, greyish black and brownish red, non-calcareous.
971-ENE-DV-GS-120	3.425	985	12.91	SAND, fine to coarse, unsorted, slightly silty, slightly gravelly, gravel is 100% subrounded fine to medium of various lithologies, brownish grey, non-calcareous.
971-ENE-DV-GS-119	3.512	991	16.42	SAND, fine, sorted, slightly clayey, very silty, slightly gravelly, gravel is 100% subrounded fine of disarticulated mussel shells, frequent subrounded fine gravel size pockets of black fine sandy silt, organic odour, blackish grey, non-calcareous.
971-ENE-DV-GS-122	3.777	931	11.42	GRAVEL, 100% subangular to subrounded fine to coarse of various lithologies, unsorted, slightly silty, very sandy, sand is fine to coarse, brownish grey, non-calcareous.
971-ENE-DV-GS-118	3.811	390	11.03	GRAVEL, 100% subangular to subrounded fine to coarse of granite and fine grained limestone, pinkish brown and light grey, calcareous (limestone).
971-ENE-DV-GS-117	4.628	-13	12.52	SAND, fine to coarse, poorly sorted, slightly silty, slightly gravelly, gravel is 100% subrounded fine to medium of various lithologies, brownish grey, non-calcareous.
971-ENE-DV-GS-114	5.168	-287	11.00	SAND, fine to medium, poorly sorted, slightly silty, brownish grey, non-calcareous.
971-ENE-DV-GS-113	5.677	175	11.50	SAND, fine to coarse, poorly sorted, slightly silty, gravelly, gravel is 100% subrounded fine to coarse of various lithologies, occasional subrounded fine gravel size pockets of dark grey silty sand and very thin plant debris, slight organic odour, brownish grey, non-calcareous.
971-ENE-DV-GS-115	5.716	948	12.00	SAND, fine to coarse, poorly sorted, slightly silty, slightly gravelly, gravel is 100% subrounded fine of various lithologies, brownish grey, non-calcareous.

ID	KP	DCC (m)	Depth	Description
971-ENE-DV-GS-112	6.466	-373	13.54	SAND, fine to coarse, poorly sorted, slightly silty, very gravelly, gravel is 100% subangular to subrounded fine to medium of various lithologies, occasional subrounded fine gravel size pockets of dark grey silty sand, slight organic odour, brownish grey, non-calcareous.
971-ENE-DV-GS-111	7.182	380	11.86	SAND, fine to coarse, sorted, slightly silty, slightly gravelly, gravel is 100% subrounded fine disarticulated and articulated mussel shells, light brownish grey, non-calcareous.
971-ENE-DV-GS-136	7.548	-947	13.12	SAND, fine to coarse, poorly sorted, slightly silty, slightly gravelly, gravel is 100% subrounded fine of various lithologies, greyish brown, non-calcareous.
971-ENE-DV-GS-110	7.851	-319	12.82	SAND, fine to coarse, poorly sorted, slightly silty, slightly gravelly, gravel is 100% subrounded fine to medium of various lithologies, greyish brown, non-calcareous.
971-ENE-DV-GS-135	8.954	-1012	13.43	GRAVEL, 100% subangular to subrounded fine to medium of various lithologies, sorted, very sandy, sand is medium to coarse, grey and orangish brown, non-calcareous.
971-ENE-DV-GS-134	9.304	-1178	15.07	SAND, fine to coarse, poorly sorted, slightly silty, slightly gravelly, gravel is 100% subangular fine shell fragments, light brownish grey, non-calcareous.
971-ENE-DV-GS-109	10.078	89	16.43	SAND, fine to coarse, unsorted, slightly silty, very gravelly, gravel is 100% subrounded fine to coarse of various lithologies, greyish brown, non-calcareous.
971-ENE-DV-GS-108	10.186	651	16.43	SAND, fine to coarse, sorted, light brownish grey, non-calcareous.
971-ENE-DV-GS-105	11.290	-36	11.27	MUSSELS, sample is entirely black and brown, fine to medium gravel size articulated and disarticulated bivalves, some marine plant debris, slight organic odour.
971-ENE-DV-GS-126	11.311	59	13.72	SAND, fine to coarse, unsorted, slightly silty, very gravelly, gravel is 95% subangular to subrounded fine to medium of various lithologies and 5% subangular fine shell fragments, orangish and greyish brown, non-calcareous.
971-ENE-DV-GS-133	11.841	783	16.77	GRAVEL, gravel is 95% subangular to subrounded fine to coarse of various lithologies and 5% subangular fine shell fragments and rare disarticulated mussels, unsorted, very sandy, sand is medium to coarse, dark greyish brown, non-calcareous.
971-ENE-DV-GS-102	12.048	-720	21.31	GRAVEL, 100% subangular to subrounded fine to coarse of various lithologies, unsorted, slightly silty, very sandy, sand is fine to coarse, light greyish brown and reddish brown, non-calcareous.
971-ENE-DV-GS-127	12.135	-416	20.44	SAND, fine to coarse, poorly sorted, slightly clayey, very silty, occasional subrounded fine gravel size pockets of dark greyish black silty sand, greyish brown, non-calcareous.

ID	KP	DCC (m)	Depth	Description
971-ENE-DV-GS-132	12.359	1014	17.30	SAND, fine to coarse, unsorted, slightly silty, very gravelly, gravel is 95% subangular to subrounded fine to coarse of various lithologies and 5% subangular fine shell fragments and disarticulated mussels, dark brownish grey, non-calcareous.
971-ENE-DV-GS-131	12.635	1450	15.33	GRAVEL, 100% subangular fine of various lithologies, sorted, slightly silty, very sandy, sand is medium to coarse, disarticulated mussel shells and some thin marine plant debris, dark brownish grey, non-calcareous.
971-ENE-DV-GS-128	12.762	-155	19.39	SAND, fine to coarse, poorly sorted, slightly silty, very gravelly, gravel is 100% subangular to rounded fine to coarse of various lithologies, greyish brown, non-calcareous.
971-ENE-DV-GS-130	12.825	949	18.65	GRAVEL, 100% subangular to subrounded medium to coarse of various lithologies, unsorted, very sandy, sand is medium to coarse, occasional disarticulated mussel shells, 1 no. subangular cobble of SANDSTONE, 70 x 50 x 60mm), dark grey and orangish brown, non-calcareous.
971-ENE-DV-GS-129	12.839	-133	18.71	SAND, fine to coarse, poorly sorted, slightly silty, very gravelly, gravel is 90% subangular to rounded fine to medium shell fragments and disarticulated mussels and 10% subangular to subrounded fine to medium of various lithologies, organic odour, dark grey, non-calcareous.
971-ENE-GR-GS-073	13.342	798	18.29	SAND, fine to coarse, poorly sorted, slightly silty, gravelly, gravel is 90% subangular to subrounded fine to medium of various lithologies and 10% subrounded fine shell fragments, light greyish brown, non-calcareous.
971-ENE-GR-GS-071	14.070	-1182	18.38	SAND, fine to coarse, slightly silty, very gravelly, gravel is 100% subangular to subrounded fine to medium of various lithologies, dark greyish brown, non-calcareous.
971-ENE-GR-GS-072	14.874	-373	20.81	SAND, fine to coarse, poorly sorted, slightly silty, very gravelly, gravel is 100% subangular to subrounded fine coarse of various lithologies, 1 no. subangular cobble of granite (110 x 70 x 40 mm), light brownish grey, non-calcareous.
971-ENE-GR-GS-074	15.934	69	22.72	SAND, fine to coarse, poorly sorted, slightly silty, gravelly, gravel is 80% subrounded fine to medium shell fragments and disarticulated mussels and 20% subangular fine to medium of various lithologies, 1 no. subrounded cobble of SANDSTONE with encrusting articulated mussels (120 x 111 x 60 mm), strong organic odour, dark brownish grey, non-calcareous.
971-ENE-GR-GS-075	17.017	492	21.92	COBBLE, subrounded, grey granite, partial encrusting marine organisms and mussels, cobble is 140 x 130 x 120 mm in size, non-calcareous.
971-ENE-GR-GS-076	18.456	-139	24.36	SAND, fine to coarse, sorted, slightly gravelly, gravel is 100% subrounded fine to medium of various lithologies, light greyish brown, non-calcareous.

8.2.4 Surficial Geology

The surficial geology between KP 0 and KP 17.786 is highly variable characterised by outcrops of SEDIMENTARY ROCK with areas of SAND, GRAVEL and coarse SAND and DIAMICTON. DIAMICTON is composed of sand, gravel and clay with cobbles and boulders. The outcropping SEDIMENTARY ROCK forms ridges at seabed and sediments infill the erosional surface of the bedrock. Glacial debris is prevalent between KP 0 and KP 17.748, with high density boulder fields.

Areas of ripples often occur within the areas of GRAVEL and coarse SAND, ripple crests are orientated north to south in line with the prevailing storm wave base. The last occurrence of SEDIMENTARY ROCK outcropping along the route is at KP 16.352. A large band of GRAVEL and coarse SAND occurs between KP 17.786 to KP 18.831 extending across the entire width of the corridor.

Detailed descriptions of the surficial geology are presented in Table 32 to Table 34.

8.2.5 Geotechnical Results

Ground Conditions

The geotechnical VC locations on the Bornholm - Sjælland (B-S) route are shown below (Figure 60). Fifteen VC were carried out with co-located CPT at every location, with the exception of location B-S-04. The investigated locations cover approximately 15.2 km, from KP 2.911 through to KP 18.088.

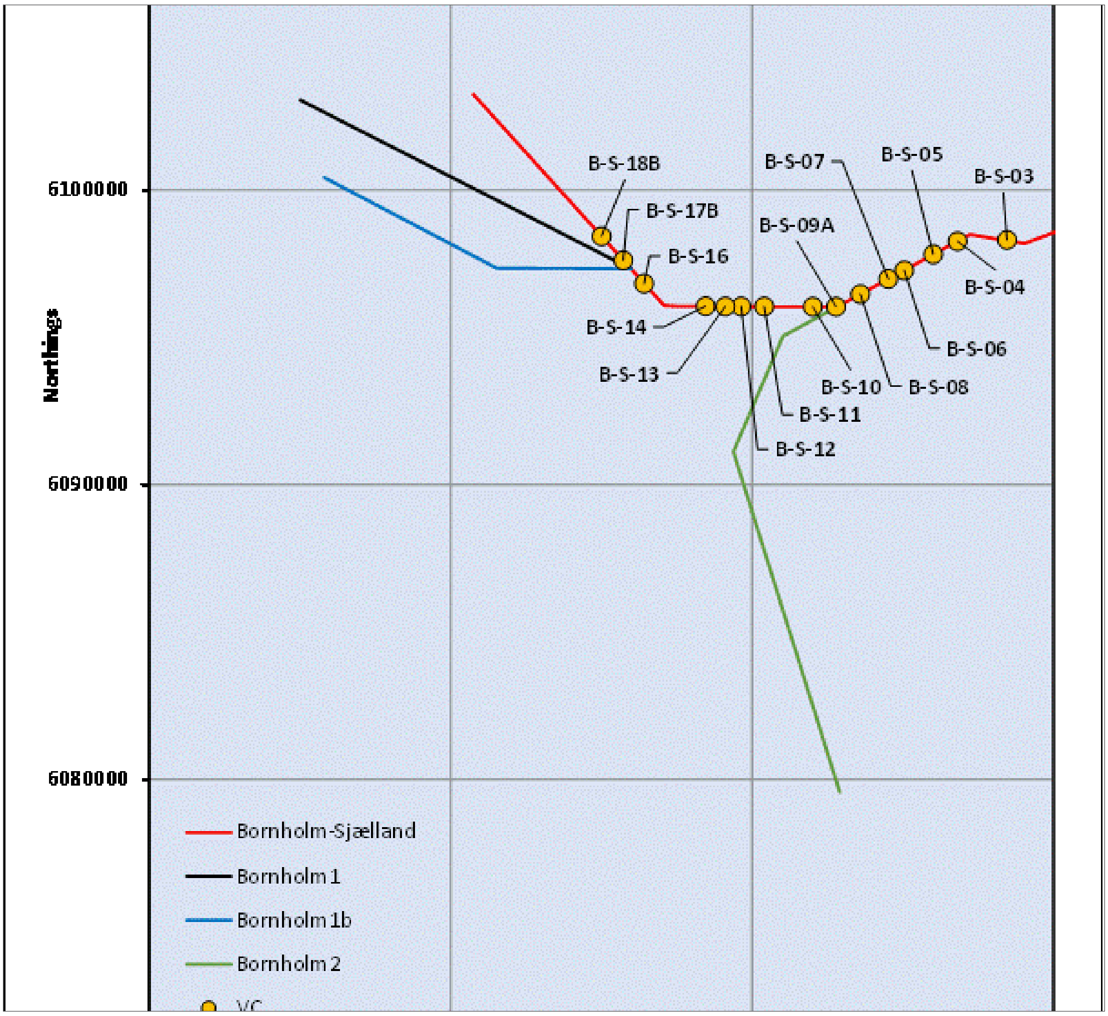
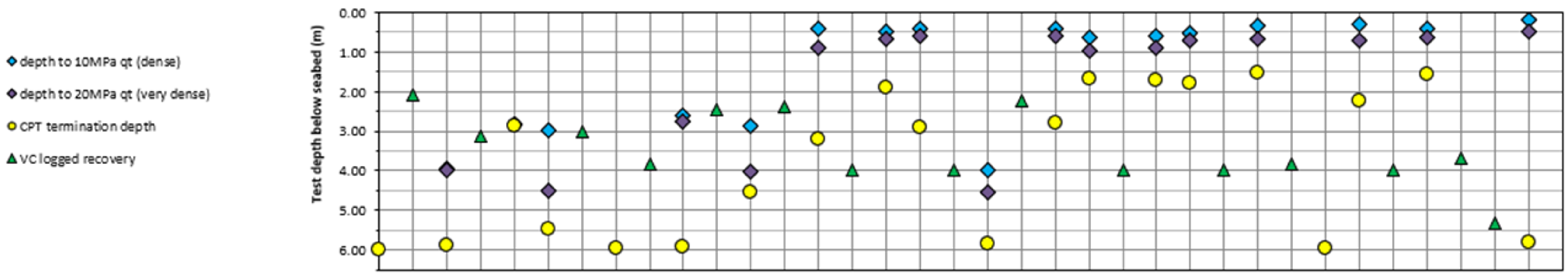


Figure 60 Geotechnical locations on the B-S route.

The assigned Seabed Sediment Index for the B-S route is shown below (Figure 61).



Location ID	B-S-18	B-S-18B	B-S-17	B-S-17B	B-S-16	B-S-16A	B-S-16	B-S-14	B-S-14	B-S-13	B-S-13	B-S-12	B-S-12	B-S-11	B-S-11	B-S-10	B-S-10A	B-S-10	B-S-09	B-S-09A	B-S-08A	B-S-08	B-S-08	B-S-07	B-S-07A	B-S-07	B-S-07B	B-S-06	B-S-06	B-S-05A	B-S-05	B-S-05	B-S-04	B-S-03	B-S-03
Route KP	18.088	18.083	16.997	16.993	15.958	15.954	15.952	13.583	13.576	12.924	12.917	12.397	12.389	11.634	11.628	10.025	10.024	10.018	9.252	9.245	8.331	8.330	8.325	7.275	7.271	7.270	7.263	6.661	6.656	5.557	5.557	5.553	4.636	2.916	2.911
Location type	CPT	VC	CPT	VC	CPT	CPT	VC	CPT	VC	CPT	VC	CPT	VC	CPT	VC	CPT	CPT	VC	CPT	VC	CPT	CPT	VC	CPT	CPT	VC	CPT	VC	CPT	CPT	VC	CPT	VC	VC	CPT
VC penetration		2.10		3.25			3.20		4.40		2.50		2.40		4.00			4.00		2.30			4.00			4.00		3.90			4.00		3.70	5.40	
VC recovery		2.08		3.12			3.00		3.82		2.45		2.38		3.98			4.00		2.23			4.00			4.00		3.85			3.98		3.67	5.34	
CPT termination depth	6.00		5.90		2.88	5.48		5.94		5.92		4.54		3.20		1.90	2.90		5.84		2.80	1.68		1.70	1.78		1.52		5.96	2.24		1.58			5.82
Depth to 10 MPa (dense)			3.94		2.82	2.98				2.62		2.86		0.42		0.48	0.42		4.00		0.42	0.62		0.60	0.54		0.34			0.30		0.42			0.18
Depth to 20 MPa (very dense)			4.00		2.84	4.50				2.76		4.04		0.88		0.68	0.60		4.54		0.60	0.96		0.88	0.70		0.66			0.70		0.62			0.50

Depth below seabed (m)																																			
0.5	4	4	4	4	8	8	8	8	8	8	8	8	8	5	5	5	5	5	8	8	5	5	5	6	5	5	5	8	8	3	3	3	3	3	3
1.0	4	4	4	4	8	8	8	8	8	8	8	8	8	3	3	3	3	3	8	8	3	3	3	3	3	3	3	8	8	3	3	3	6	6	6
1.5	4	4	4	4	8	8	8	8	8	8	8	8	8	3	3	3	3	3	8	8	3	3	3	3	3	3	3	8	8	3	3	3	6	6	6
2.0	4	4	4	4	7	7	8	8	8	8	8	6	8	3	3	3	3	3	8	8	3		3		3	3		8	8	3	3		6	6	6
2.5	4		4	4	4	4	4	8	8	8	8	6	8	3	3		3	3	8		3		3			3		8	8		3		6	6	6
3.0	4		4	4	3	6	4	8	8	5		5		3	3		3	3	8		3		3			3		4	4		3		6	6	6
4.0	4		5			6		8	8	6		5			3			3	5				3			3		4	4		3		6	6	6
5.0	4		6			5		4		6									5										4					5	5
6.0	4		6					4		4									5										4						6

SSI	Typical Seabed Sediment
1	Bedrock (CHALK)
2	Dense to very dense Glacial Deposits
3	Very dense granular
4	Medium to high strength cohesive (Glacial Till)
5	Dense granular
6	Medium dense granular
7	Loose granular
8	Low to medium strength cohesive
9	Very low to low strength cohesive
10	Extremely low strength cohesive
0	Organic material *sensu stricto* , containing PEAT

Figure 61 Seabed Sediment Index for B-S route (KP 18.088 to KP 2.911), Part 1.

In the first part of this route, from KP 2.911 (location B-S-03) through to KP 11.634 (location B-S-11) the ground conditions are dominated by SAND, being fine to coarse, slightly silty slightly gravelly. Locally the material is silty to very silty, occasionally slightly clayey. The gravel component is generally various lithologies. Cohesive material is present at two locations. At KP 6.661 (location B-S-06), a thin seabed veneer of SAND overlies a 2.58 m thick layer of intermediate plasticity low to medium strength very silty sandy CLAY. The CLAY is slightly gravelly and contains thin to thick laminae of clayey silt. At 2.73 m depth Glacial Till is seen, being a medium strength firm very silty sandy slightly gravelly CLAY. CLAY is also seen at KP 9.245 (location B-S-09) where 2.17 m of low to intermediate plasticity very silty sandy slightly gravelly CLAY overlies a basal clayey silty gravelly fine to coarse SAND.

From KP 12.389 (location B-S-12) through to KP 18.088 (location B-S-18) CLAY becomes more prevalent (Figure 62). Glacial Till is present in this section, from 5.22 m depth at KP 12.924, becoming present at seabed level towards the end of this section at KP 18.083 (location B-S-18). The Glacial Till is typically low to intermediate plasticity, medium to high strength firm very silty very sandy slightly gravelly CLAY. The CLAY is calcareous. At most locations, the Glacial Till is overlain by a low to medium strength, intermediate to high plasticity, vey silty sandy CLAY, locally slightly gravelly. Thin to thick silt laminae are often present. This CLAY can be up to 6.00 m thick (location CPT-B-S-18).

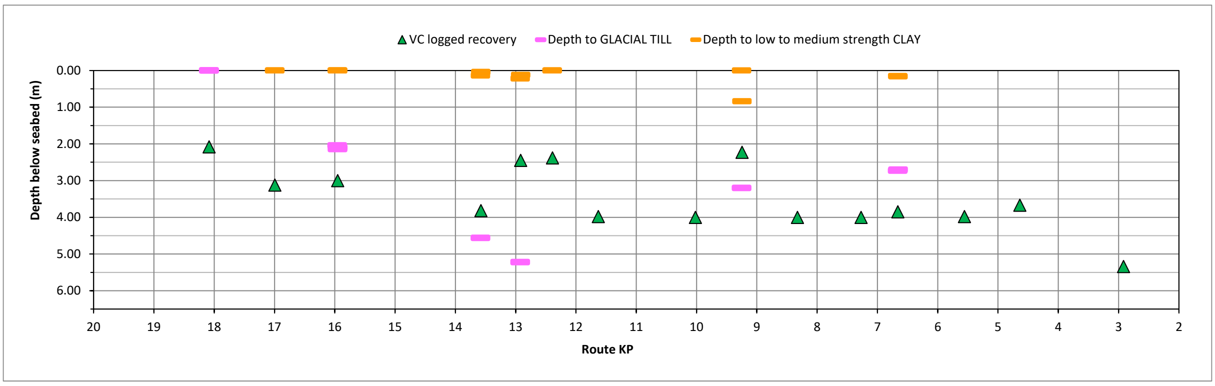


Figure 62 Plot of VC recovery and interpreted strata depths for route B-S, Part 1.

Granular material is variably present from seabed level. At some locations SAND is absent, but at other locations the SAND can be up to 4.34 m thick (location CPT-B-S-03). The SAND is typically fine to medium, silty, locally clayey and slightly gravelly.

Laboratory Test Data

A summary table below (Table 31) details the quantities of laboratory testing carried out on material from the route B-S.

Table 31 Summary table of laboratory testing for the route B-S, Part 1.

<table>
<tr><th colspan="2">Type</th><th>Quantity</th></tr>
<tr><td colspan="2">Moisture Content (MC)</td><td>52</td></tr>
<tr><td colspan="2">Bulk Density (BD)</td><td>40</td></tr>
<tr><td colspan="2">Dry Density (DD)</td><td>40</td></tr>
<tr><td colspan="2">Particle Density (PD)</td><td>2</td></tr>
<tr><td colspan="2">Min/Max Dry Density (MM)</td><td>2</td></tr>
<tr><td colspan="2">Atterberg Limits (AT)</td><td>13</td></tr>
<tr><td colspan="2">Particle Size Distribution Analysis (PSD)</td><td>24</td></tr>
<tr><td colspan="2">PSD sedimentation (SED)</td><td>16</td></tr>
<tr><td colspan="2">Shear strength (Lab Vane, LV)</td><td>19</td></tr>
<tr><td colspan="2">Shear strength (Torvane, TV)</td><td>31</td></tr>
<tr><td colspan="2">Shear strength (Torvane, offshore TVO)</td><td>8</td></tr>
<tr><td colspan="2">Shear strength (Pocket Pen., offshore PPO)</td><td>9</td></tr>
<tr><td colspan="2">Shear strength (Unconsolidated undrained triaxial, UU)</td><td>3</td></tr>
<tr><td colspan="2">Thermal (TR)</td><td></td></tr>
<tr><td>Chemical tests (CHEM)</td><td>Organic matter content:</td><td></td></tr>
</table>

A plot below shows the PSD data plotted schematically, in KP order, from the B-S route (Figure 63). This shows the mix of granular and cohesive material in the first part of this route, with the dominance of CLAY after location B-S-16. Glacial Till where tested has total fines contents of 51 to 66 %, with a sand component of 25 to 33 %. Gravel contents are low, at < 12 %. Low to medium strength CLAY in the first part of the route, is more variable with totals fines contents ranging from 53 to 89 %. Sand contents vary from 8 to 42 %, whilst gravel contents are 0 to 12 %.

Tested SAND strata have sand contents of 93 to 96 %, with a single tested stratum being a very gravelly SAND with a gravel content of 46 %. Total fines are < 7 %.

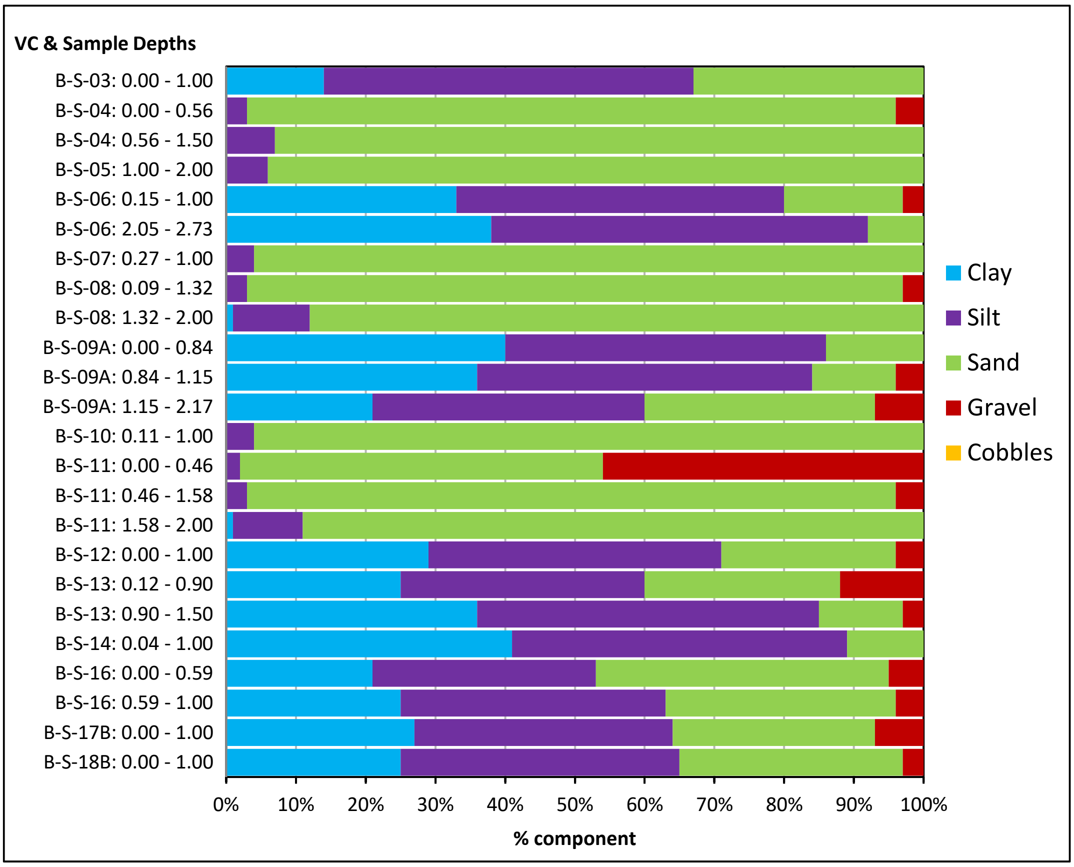


Figure 63 Schematic summary plot of PSD data for route B-S, Part 1.

PSD data for the tested material are also shown below (Figure 64).

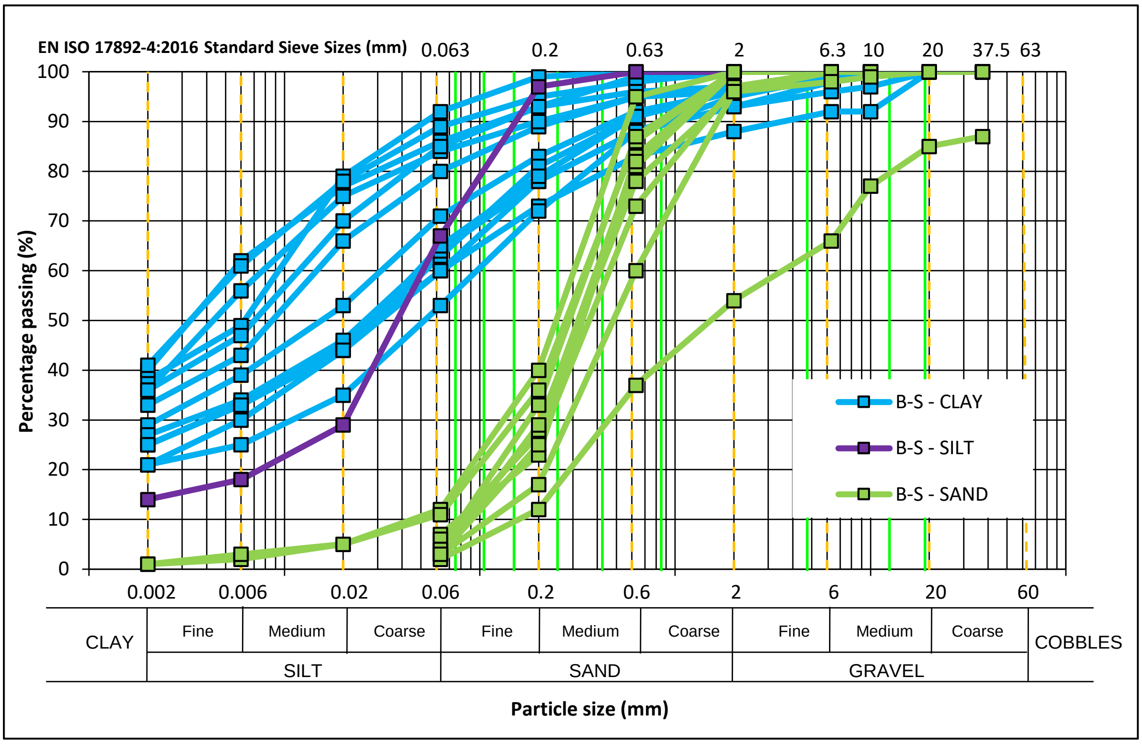


Figure 64 PSD plots for the tested material from route B-S, Part 1.

Laboratory test data are summarised below for granular material (Figure 65). The tested material has bulk and dry densities in the ranges from 1.54 to 2.13 Mg/m^3, and 1.36 to 1.89 Mg/m^3, respectively. There is a general increase in density with depth. Min and max dry density results are in the ranges 1.36 to 1.47 Mg/m^3, and 1.69 to 1.75 Mg/m^3, respectively. Particle densities are 2.56 to 2.60 Mg/m^3. Moisture contents in granular material are in the range 11 to 23 %.

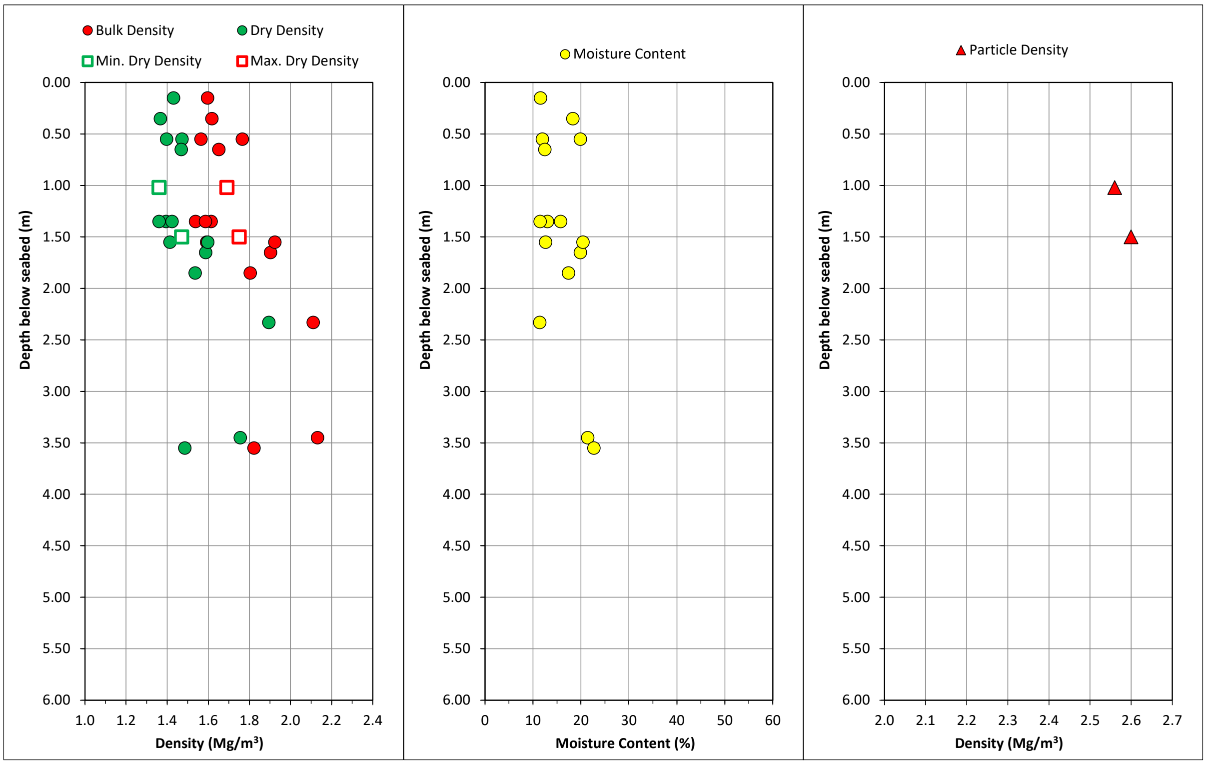


Figure 65 Laboratory test data for granular material, route B-S, Part 1.

Laboratory density test data are summarised below for cohesive material (Figure 66). Bulk and dry densities for Glacial Till are in the ranges from 1.97 to 2.22 Mg/m^3, and 1.57 to 1.90 Mg/m^3, respectively. In lower strength CLAY bulk and dry densities are in the large ranges 1.54 to 1.95 Mg/m^3, and 0.98 to 1.53 Mg/m^3, respectively. Determined moisture contents are also shown below for cohesive material. Glacial Till typically has moisture contents in the range 16 to 27 %, whilst lower strength CLAYs are much more variable, from 15 to 57 %.

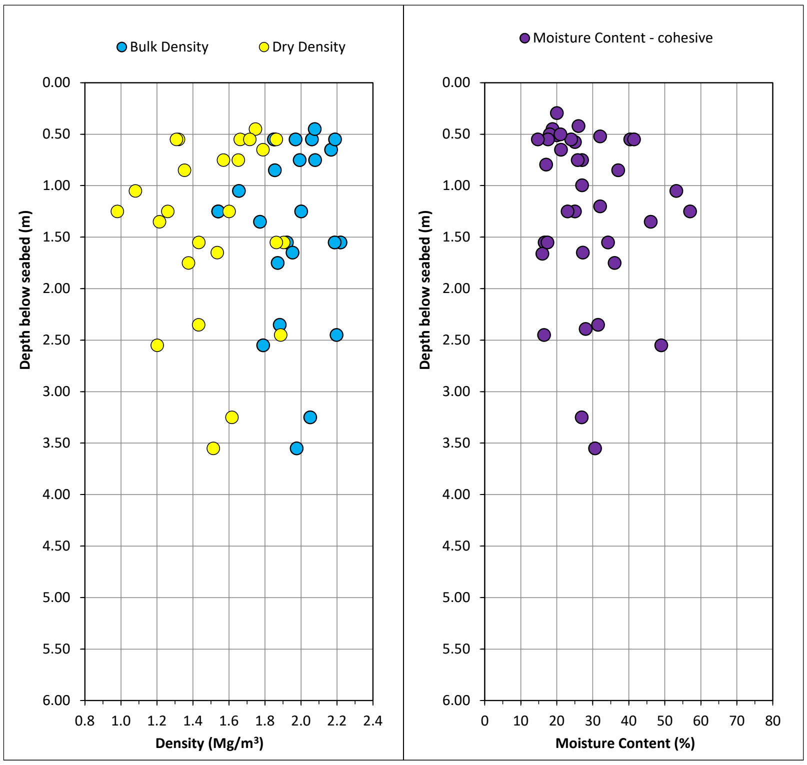


Figure 66 Laboratory test data for cohesive material, route B-S, Part 1.

Thirteen Atterberg Limit tests were carried out on material from this route (Figure 67). Results from Glacial Till returned as CLAY of low to intermediate plasticity. Lower strength CLAY returned as intermediate plasticity.

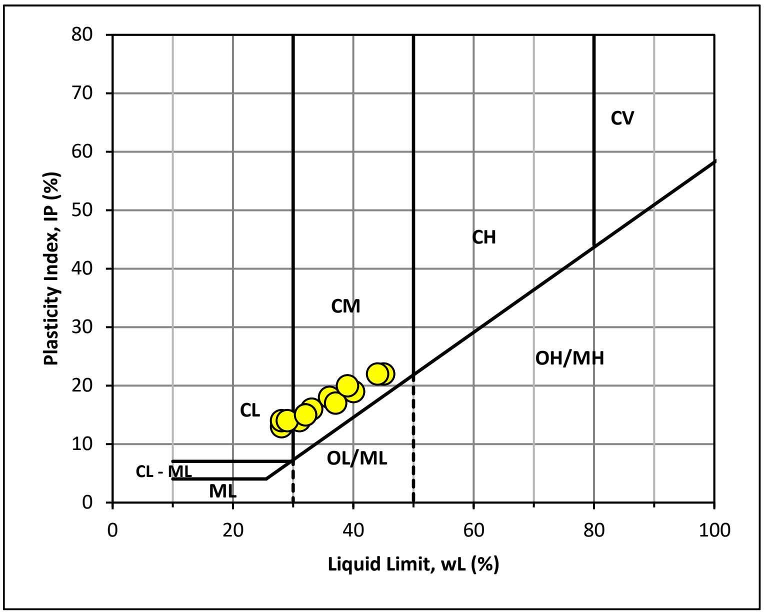


Figure 67 Plasticity Chart for route B-S, Part 1.

Laboratory shear strength data for cohesive material are shown below Figure 68). The data indicates two groups. Stiff to very stiff CLAY, considered to be Glacial Till are typically in the medium to high strength ranges, whilst non-glacial CLAY is generally very low to low strength. In most cores, there is a general increase in undrained shear strength with increasing depth.

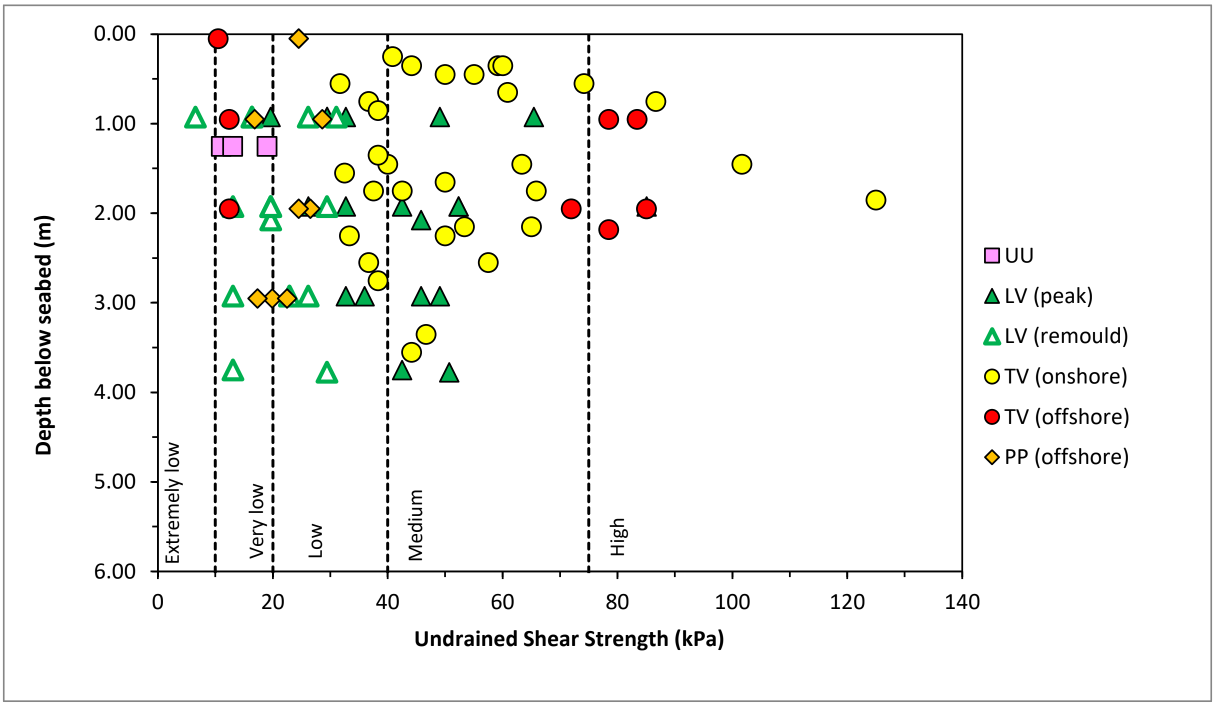


Figure 68 Laboratory shear strength data for route B-S, Part 1.

A summary of the acquired thermal resistivity data is shown below (Figure 69). The data for cohesive material shows the expected trend of increasing resistivity with increasing moisture content. Data from a single granular material is low, at 0.38 K m/W. Two higher results from granular material from locations B-S-05 and B-S-07, at low moisture contents of 11 and 13 % should be treated with caution.

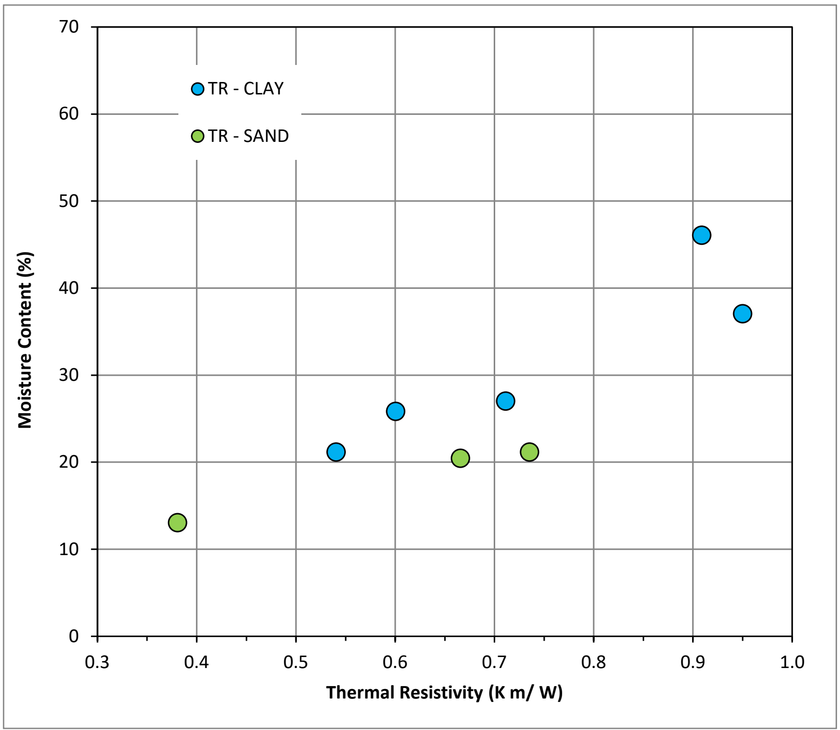


Figure 69 Summary of thermal data for route B-S, Part 1.

Cone Penetration Testing

Twenty CPT were carried out at the fourteen locations on this route. Re-attempts were carried out at five locations due to the presence of shallow dense to very dense granular material (Figure 70). Where Glacial Till was encountered along the route CPT penetration was generally good, with some dense to very dense granular layers visible within the glacial deposits. The measured cone responses were good with the resulting sediment interpretation being considered accurate and often close to the ground conditions in the co-located VC locations.

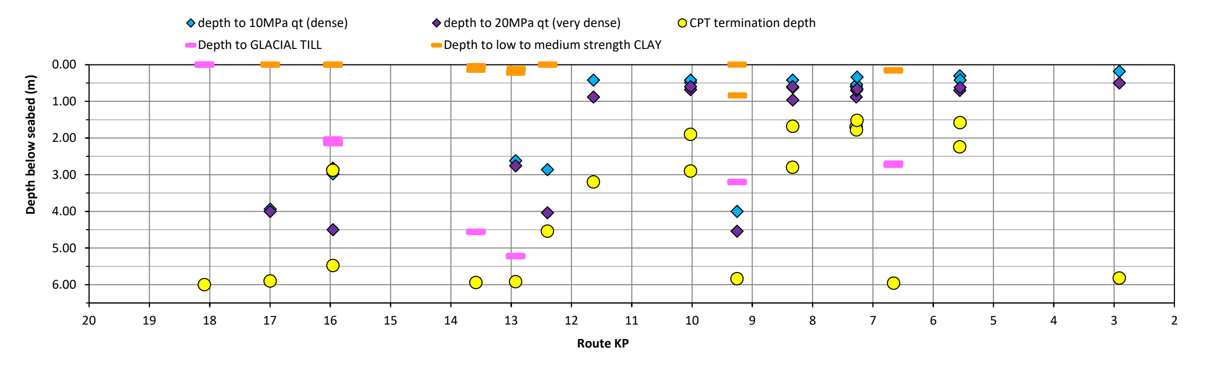


Figure 70 Plot of CPT test depths and interpreted stratum depths for route B-S.

Measured cone resistances from the CPT are shown below (Figure 71). In those tests in the first part of the route, up to location B-S-11, cone resistances are typically high, reflecting the presence of dense to very dense granular material. At other locations, up to KP 18.088, the cone resistances are more variable reflecting the presence of SAND, together with Glacial Till and lower strength CLAY.

Figure 72 below shows the calculated relative density profiles from the CPT data. The granular material seen in the first part of the route, up to location B-S-11 is typically medium dense to very dense at shallow depths, < 1.00 m. At other locations the granular material, where present, is in the range loose to dense.

Figure 72 also shows the calculated shear strength profiles for the encountered CLAY, at an Nkt factor of 17.5. For the Glacial Till and low to medium strength CLAY the shear strengths are high, typically > 20 kPa, with some variability towards very high strengths, approaching 160 kPa.

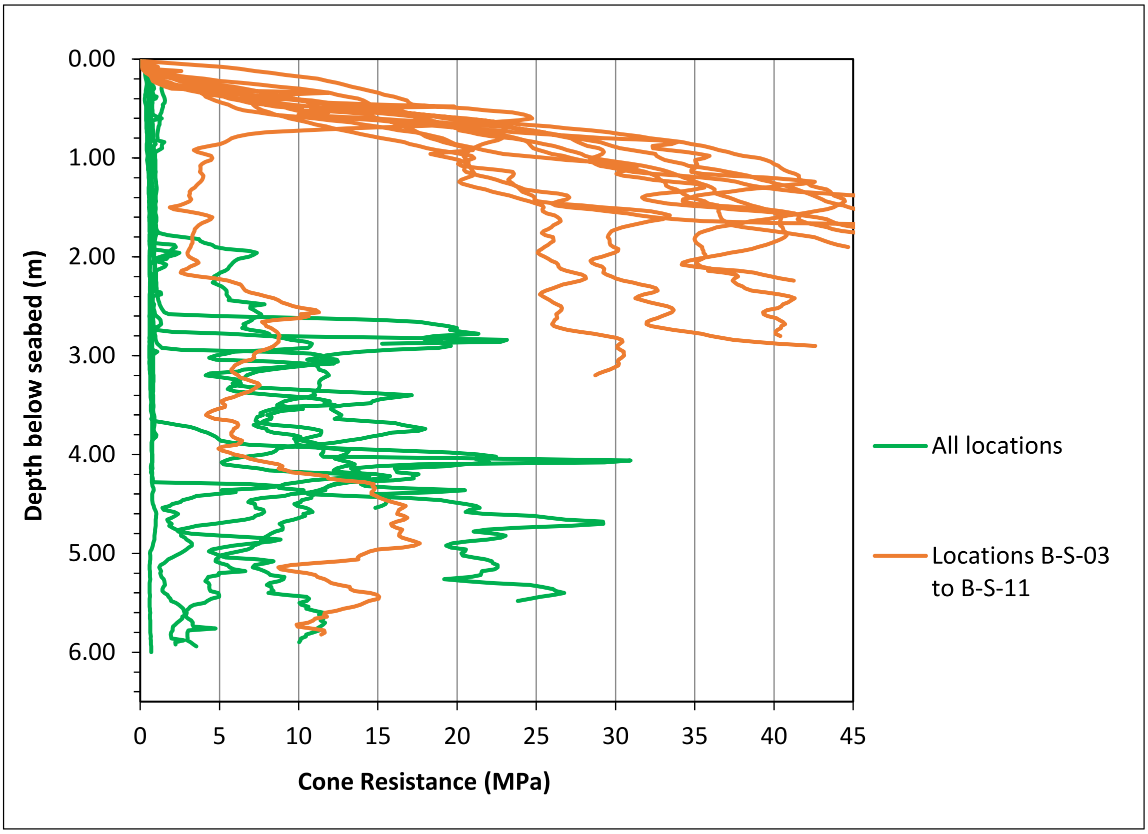


Figure 71 Plot of cone tip resistances for route B-S, Part 1.

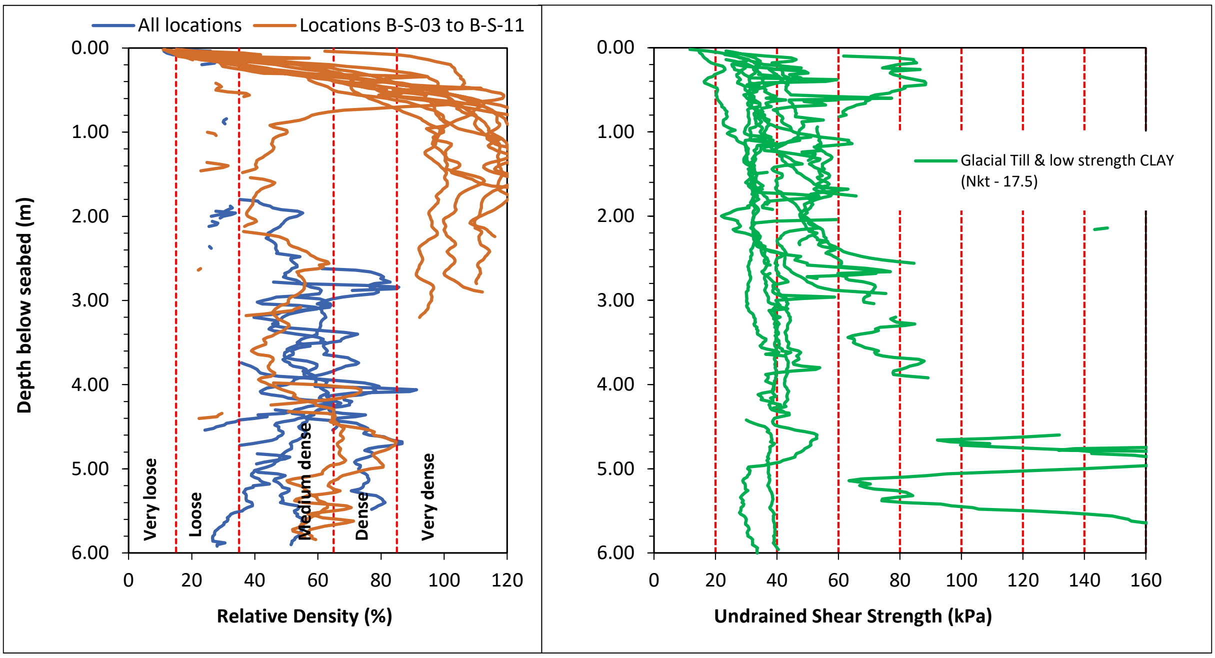


Figure 72 Plot of CPT derived parameters for route B-S, Part 1.

8.2.6 Shallow Geology

A number of sedimentary units were identified in the sub-surface geology along the proposed route CRS Bornholm-Sjælland, down to a maximum depth of 15.0 m below the seabed. A detailed description of the changes in shallow geology observed along this route can be found in the shallow geology section presented in Table 32 to Table 34.

The start of the route, in the shallow nearshore area close to Bornholm Island, from KP 0.000 to KP 12.291, is largely dominated by SEDIMENTARY ROCK, either outcropping, present below thin veneers (< 1.0 m) of more recent marine SAND, GRAVEL or TILL, or below channels of late/post glacial SAND and CLAY. Where present, these veneers and channels have been identified as the units P1_H10 and P1_H45i respectively. The channels have only been identified on the centre line. Variations in the internal structure of the SEDIMENTARY ROCK are visible on the SBP data but these have not been mapped or interpreted. Between KP 0.000 and KP 15.200 there is significant uncertainty determining the top of Bedrock. This is due to the coarseness of the seabed sediments, weathered interface of the rock and very irregular rock bedding. Geotechnical points have been sited where there is sufficient sediment to sample. Caution should be taken extrapolating the depth of sediment cover between geotechnical sites. An overview of the interpreted shallow geology in this nearshore section at the start of the route can be seen in Figure 73.

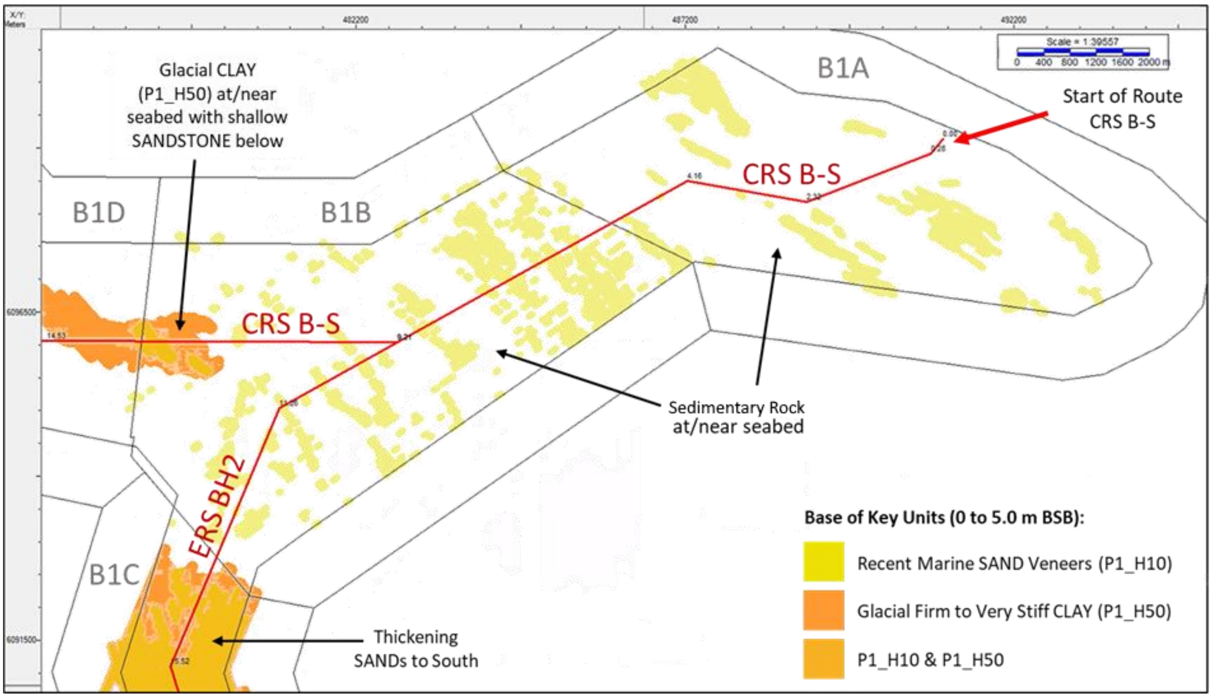


Figure 73 Overview map of the distribution of interpreted geological units along CRS Bornholm-Sjælland KP 0 to KP 15.

The centre of the route from KP 12.291 to KP 18.831 is largely dominated by units of silty SAND and firm to stiff glacial CLAY, typically undulating from the seabed to between 2.0 to 8.0 m thick, with SEDIMENTARY ROCK interpreted to be present below. The exception to this is from KP 14.228 to KP 15.143, whereby Glacial CLAY and shallow SEDIMENTARY ROCK are interpreted to be at, or just below the seabed. Detailed description is presented in Section 8.2.7.

An overview of the distribution of interpreted SAND units in this central section can be seen in Figure 74.

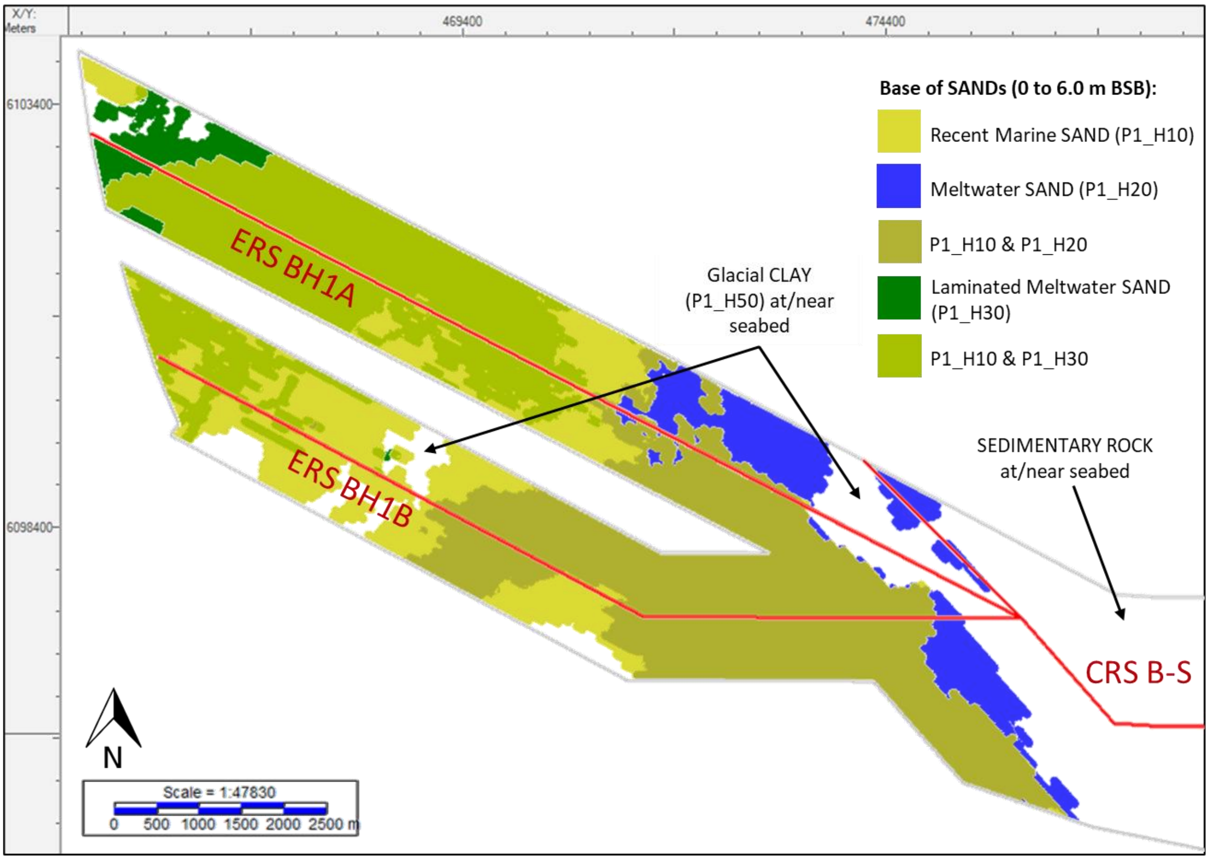


Figure 74 Overview map of the distribution of interpreted SAND units along CRS Bornholm-Sjælland KP 14 to KP 18.

Below these SAND units, a Glacial CLAY unit (P1_H50) is present in this central KP range, as shown in Figure 75. The Glacial CLAY unit has a slightly silty, sandy and gravelly composition which is variable across this section of the route, though this is not identified in the profiles for the purposes of simplification. Details of compositional variation have been described in Section 8.2.7. The unit predominantly displays a low to high amplitude chaotic internal structure in the SBP data, but in places high amplitude internal reflectors can be observed. The geotechnical results confirm that the Glacial CLAY unit is predominantly firm to stiff.

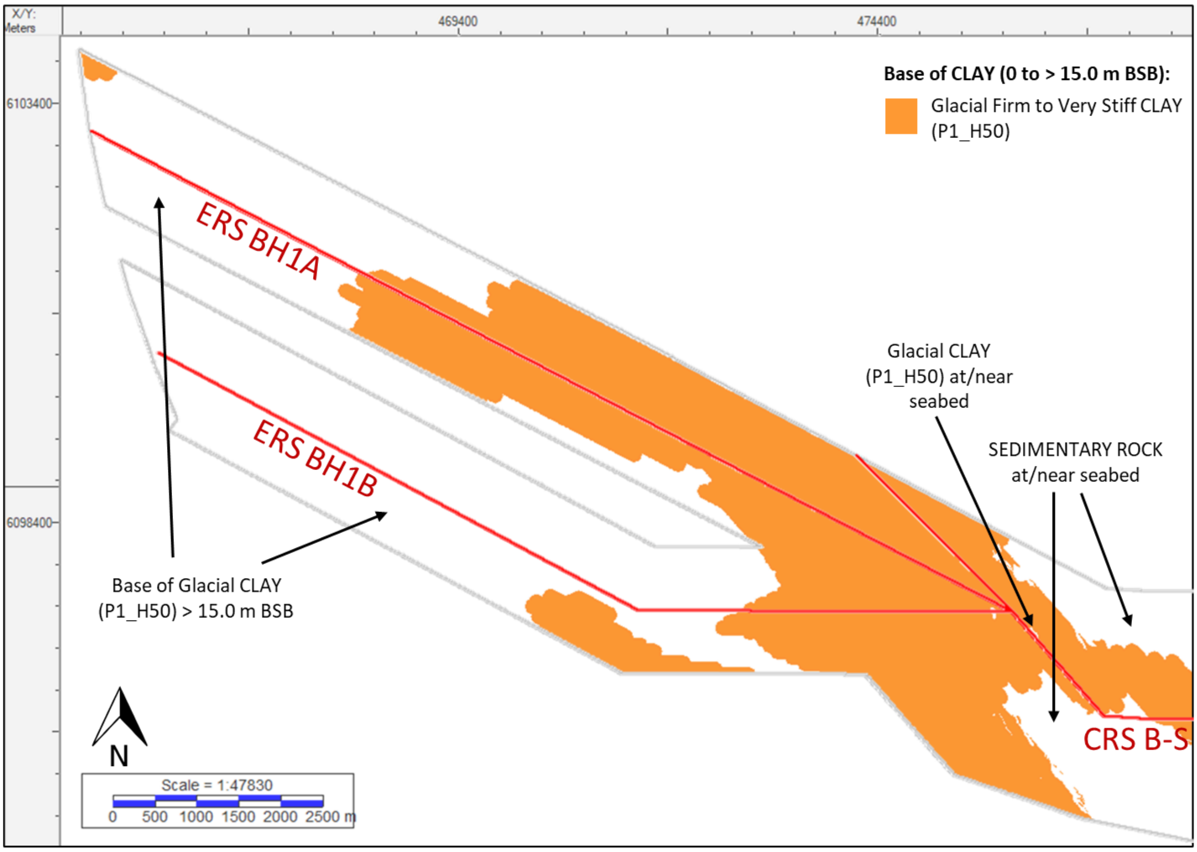


Figure 75 Overview map of the distribution of interpreted Glacial CLAY along CRS Bornholm-Sjælland KP 15 to KP 19.

8.2.7 Detailed Description

A detailed presentation of the conditions and features of CRS Bornholm - Sjælland are shown in Table 32 to Table 34 and associated figures.

Table 32 CRS Bornholm-Sjælland detailed description for alignment chart 103971-ENN-OI-SUR-DWG-P1BH001 (KP 0.000 – 7.425).

Alignment Chart 103971-ENN-OI-SUR-DWG-P1BH001 (KP 0.000 – 7.425)	
Description (including min/max depth BSB to base of unit)	**Remark**
Bathymetry: The irregular rocky foreshore drops onto the rocky beach between KP 0.008 and KP 0.050. This fall delineates the start of a varied and uneven surface with seabed formation orientated NW-SE. Moderately deepening seafloor from the beach outwards.	Total elevation/depth range along route = 38.6 m. Subaerial: Very steep slopes in NE-SW direction due to the rocky foreshore drop. Maximum elevation along route 23.88 m at KP 0.019. Minimum elevation along route 0.00 m at KP 0.063. Subsea: Moderate to very steep slopes with a maximum value of 19.1° at the ridge of a rock outcrop. Minimum depth along route 0.00 m at KP 0.063. Maximum depth along route 14.72 m at KP 6.421. Maximum slope of 48.1° along route at KP 0.035 due the rocky beach drop (Figure 76).
Surficial Geology: SSS coverage starts at KP 0.098 The seabed in this section is characterised by SEDIMENTARY ROCK, ridges are formed where the rock outcrops. Bedding planes of the sedimentary rock are observed at seabed (Figure 80). GRAVEL and coarse SAND and DIAMICTON infill the erosional surface of the bedrock (Figure 78 to Figure 84). A narrow band of SAND is present along the nearshore and intersects the route between KP 0.010 to KP 0.179 Between KP 0.098 and KP 4.249 the predominant seabed surface is SEDIMENTARY ROCK which is interspersed with deposits of GRAVEL and coarse SAND and DIAMICTON	**Infrastructure:** Utility ID 04 (cable, DK-PL 1) detected in on MAG and SSS datasets and WPD, crossing at KP 5.007 (Figure 82) **Grab sample locations:** 971-ENE-DV-GS-111 971-ENE-DV-GS-112 971-ENE-DV-GS-113 971-ENE-DV-GS-114

Alignment Chart 103971-ENN-OI-SUR-DWG-P1BH001 (KP 0.000 – 7.425)	
Description (including min/max depth BSB to base of unit)	**Remark**
Between KP 4.249 and KP 6.141 the dominant seabed sediment is DIAMICTON. This area is broken by ridges of SEDIMENTARY ROCK generally trending north to south. Between KP 6.141 and KP 7.425 The DAMICTON is further broken by bands of GRAVEL and coarse SAND. Ripples occur in some areas of GRAVEL and coarse SAND, crests are orientated north to south in line with the prevailing storm wave base (Figure 83). The entire section is covered by glacial debris mostly falling under the high-density boulder field category. Patches where boulder density is low include ridges of rock outcrops and some areas within GRAVEL and coarse SAND (Figure 83).	971-ENE-DV-GS-115 971-ENE-DV-GS-116 971-ENE-DV-GS-117 971-ENE-DV-GS-118 971-ENE-DV-GS-119 971-ENE-DV-GS-120 971-ENE-DV-GS-121 971-ENE-DV-GS-123 971-ENE-DV-GS-124 971-ENE-DV-GS-125
Shallow Geology: SBP coverage starts at KP 0.258. KP 0.258 – KP 7.425 (Figure 85, Figure 86, Figure 87): SEDIMENTARY ROCK is observed either outcropping at the seabed or beneath thin veneers of recent marine surficial sediments. The base of SEDIMENTARY ROCK is beyond the seabed multiple return between approximately 6.0 m to 7.0 m BSB until KP 2.323, and then, beyond the SBP record length (> 12.0 m BSB) from KP 2.323 to KP 7.425. High amplitude internal reflectors with variable orientation and morphology are visible within the SEDIMENTARY ROCK (Figure 85, Figure 86). Within this KP range, five isolated U to V shaped Late to Post Glacial channels (P1_H45i) have been identified on the CL (Figure 87). These are predominantly filled with silty SAND or sandy SILT. Locations: KP 1.134 to KP 1.323 – Maximum depth 4.7 m BSB KP 2.870 to KP 2.932 – Maximum depth 3.5 m BSB KP 4.978 to KP 5.021 – Maximum depth 2.3 m BSB KP 6.128 and KP 6.784 – Maximum depth > 13.0 m BSB – Channel contains CLAY infill, varying from soft silty slightly sandy CLAY in the upper 2.7 m to firm silty slightly sandy slightly gravelly in the deeper parts of the channel (Figure 87, VC B-S 06). KP 6.931 to KP 6.986 – Maximum depth 4.1 m BSB	**Vibrocores and CPTs:** B-S-03 and B-S-03-CPT B-S-04 B-S-05 and B-S-05-CPT B-S-06 and B-S-06-CPT B-S-07 and B-S-07A-CPT

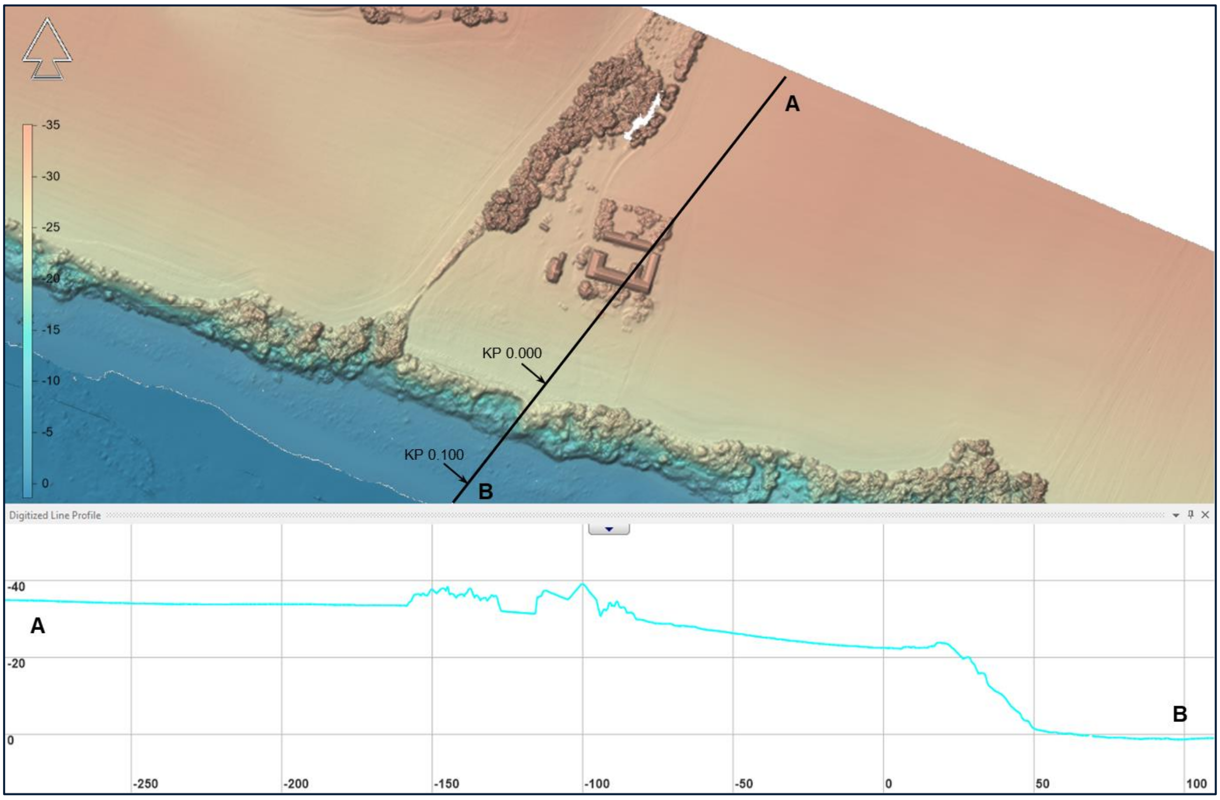


Figure 76 Inshore section of Route Bornholm-Sjælland_P1 showing LIDAR data and nearshore bathymetry KP 0.0.

Horizontal scale is distance in metres from eastern end of the route. Depths in NaviModel presented positive down; vertical exaggeration of profile x1.3.

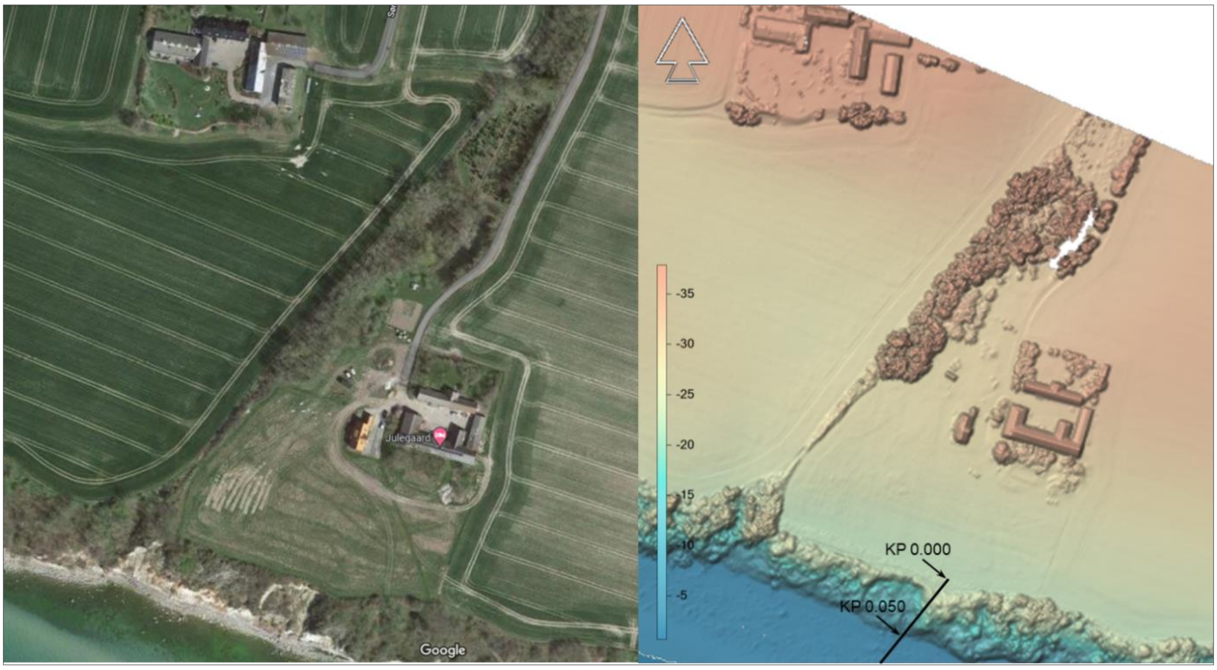


Figure 77 Aerial Image (Left - source: Google Maps) against LIDAR data (Right) of shoreline coast at Bornholm KP 0.0.

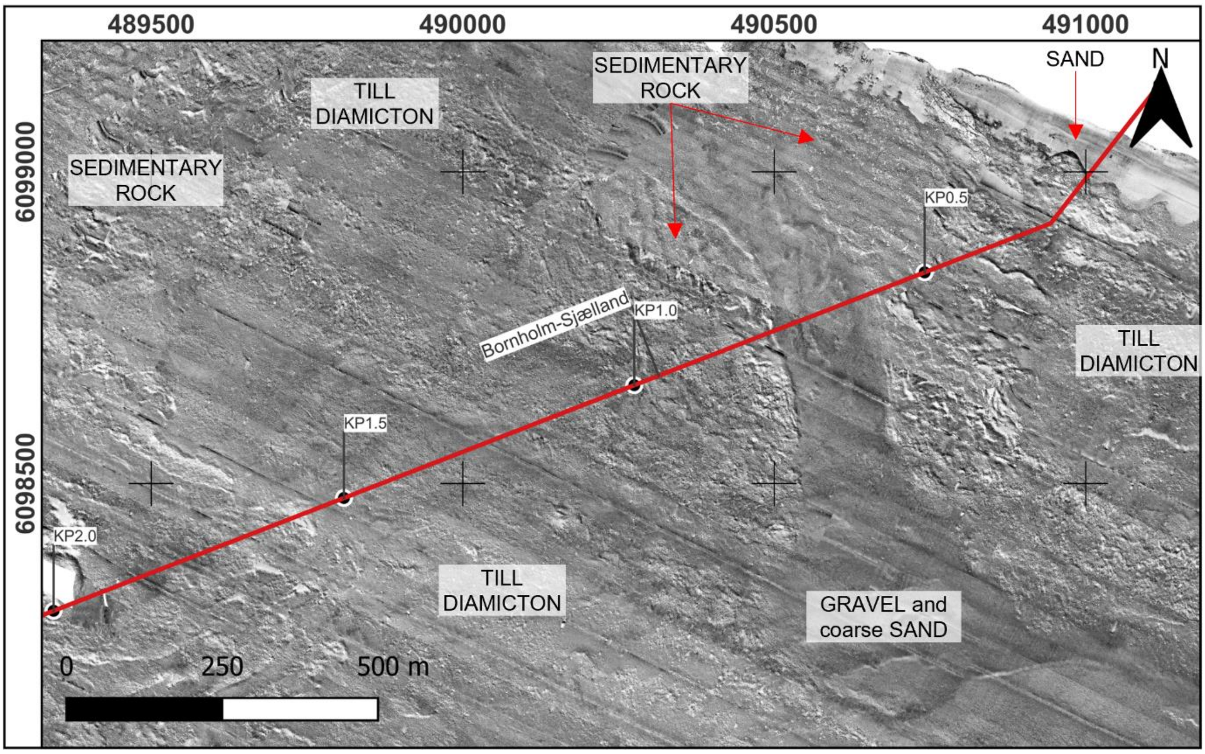


Figure 78 Overview of surficial geology from KP 1.5 to KP 3.5 as seen on SSS.

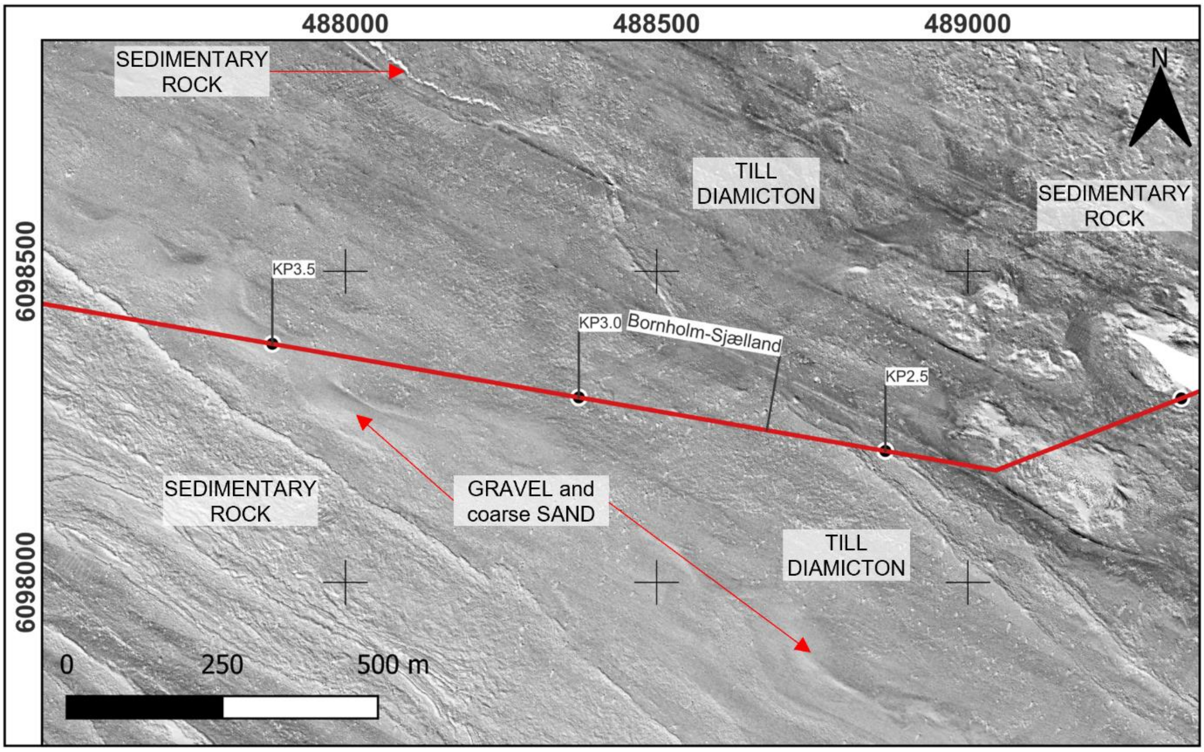


Figure 79 Overview of surficial geology from KP 2.0 to KP 4.0 as seen on SSS.

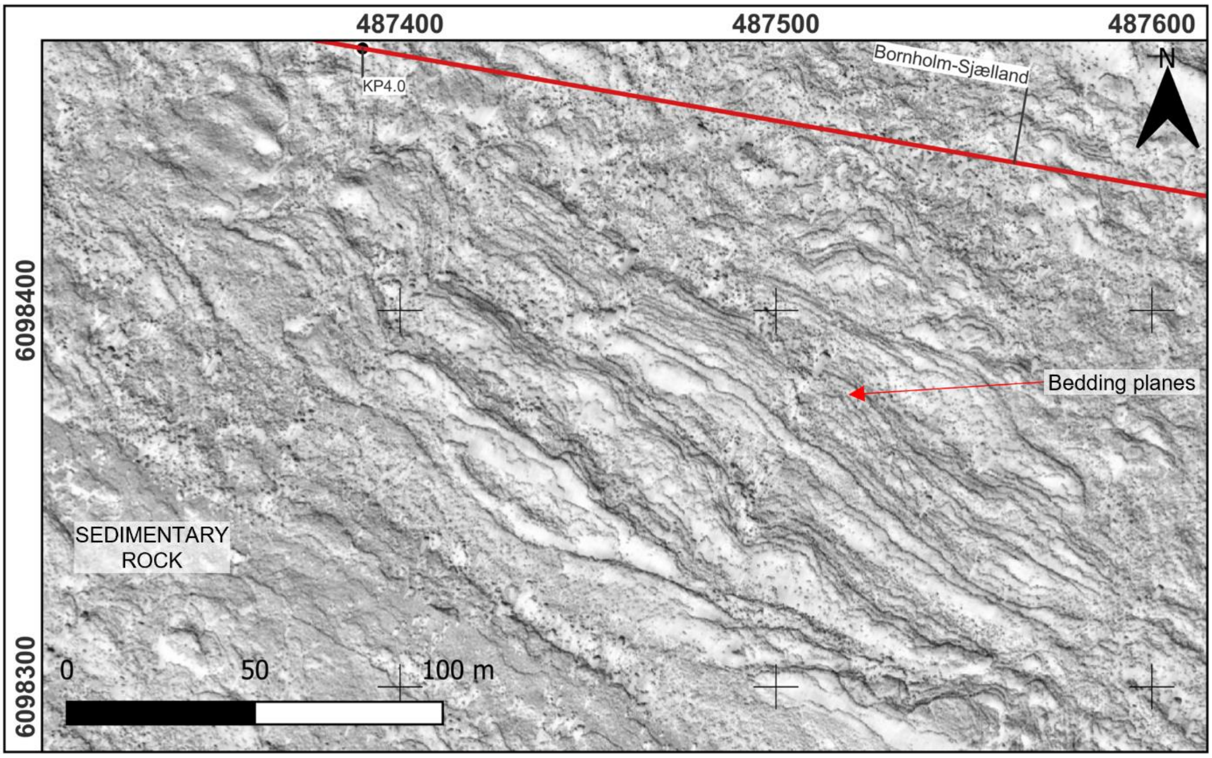


Figure 80 Overview of surficial geology from KP 4.0 as seen on SSS.

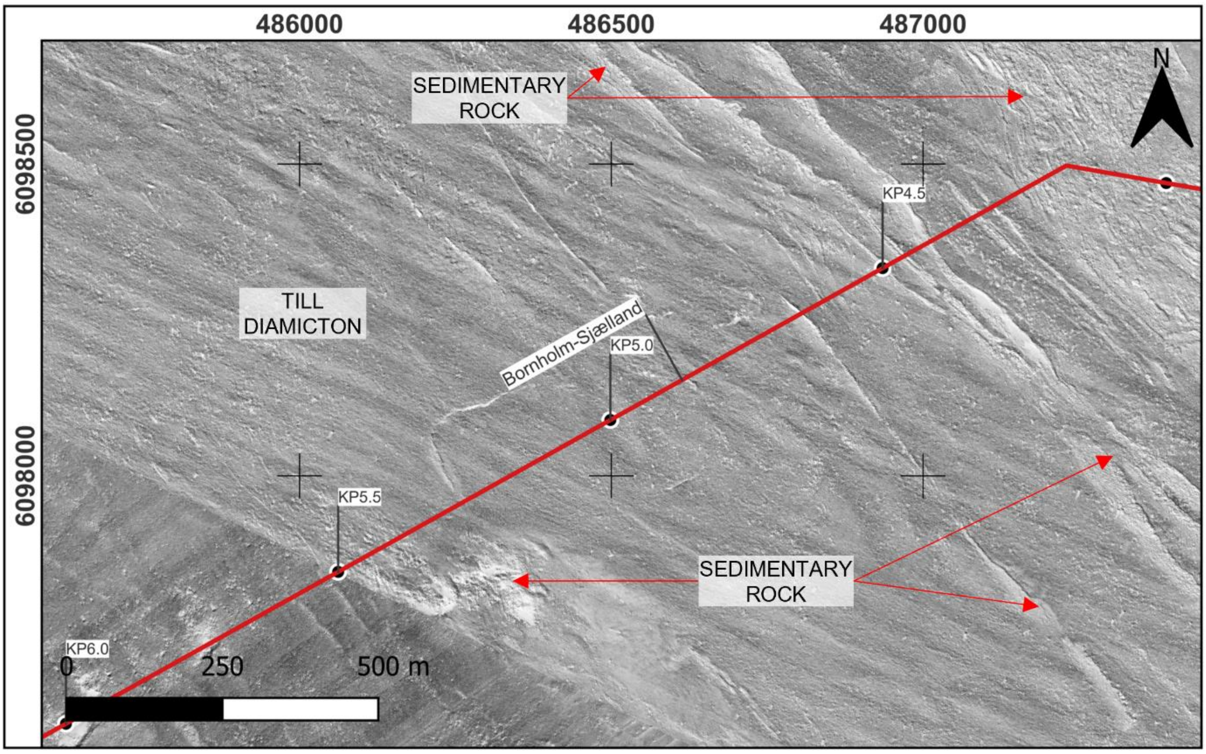


Figure 81 Overview of surficial geology from KP 4.0 to KP 6.0 as seen on the SSS data.

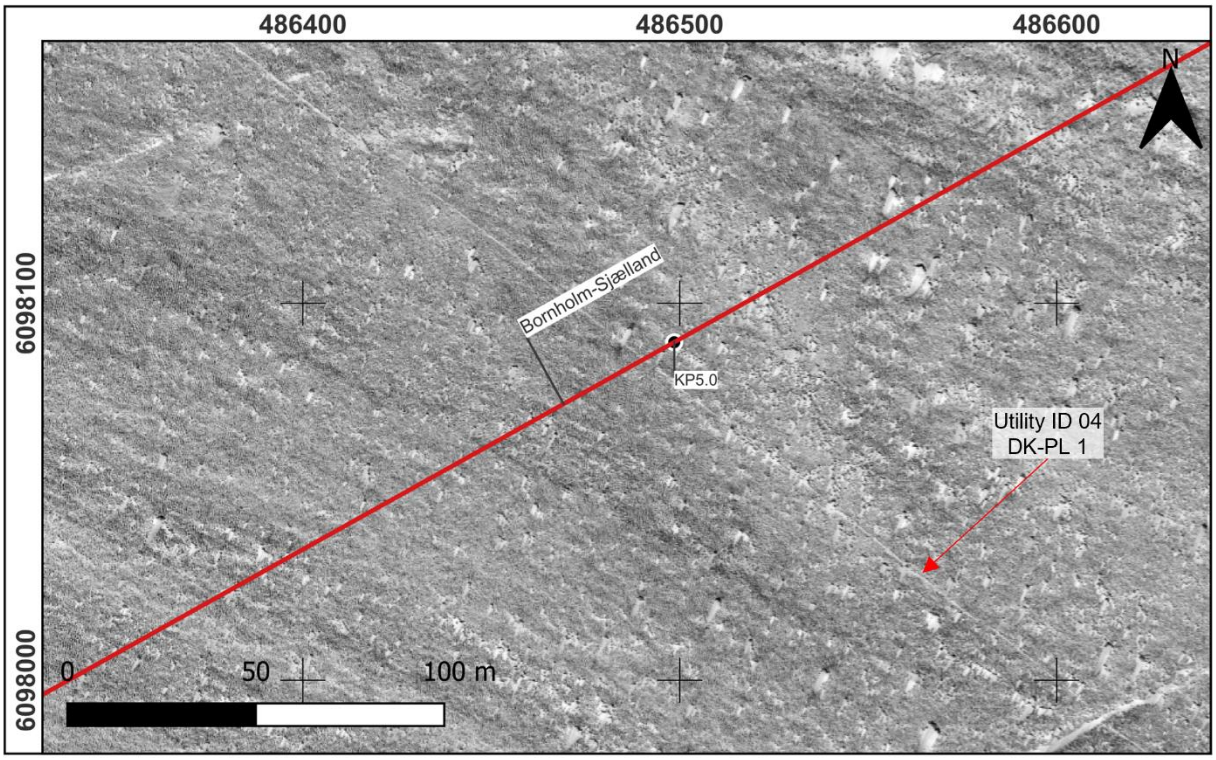


Figure 82 Cable crossing at KP5.009, Utility 04 telecommunication cable DK-PL 1.

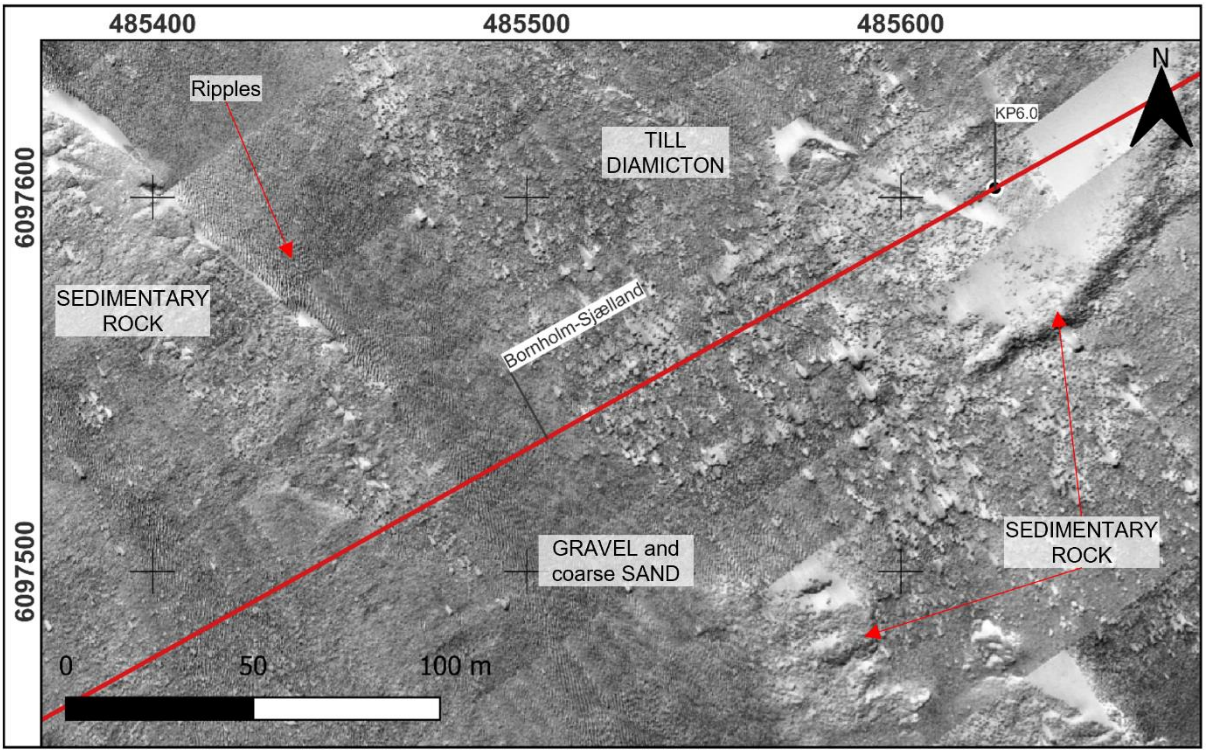


Figure 83 Overview of surficial geology from KP 6.0 as seen on SSS.

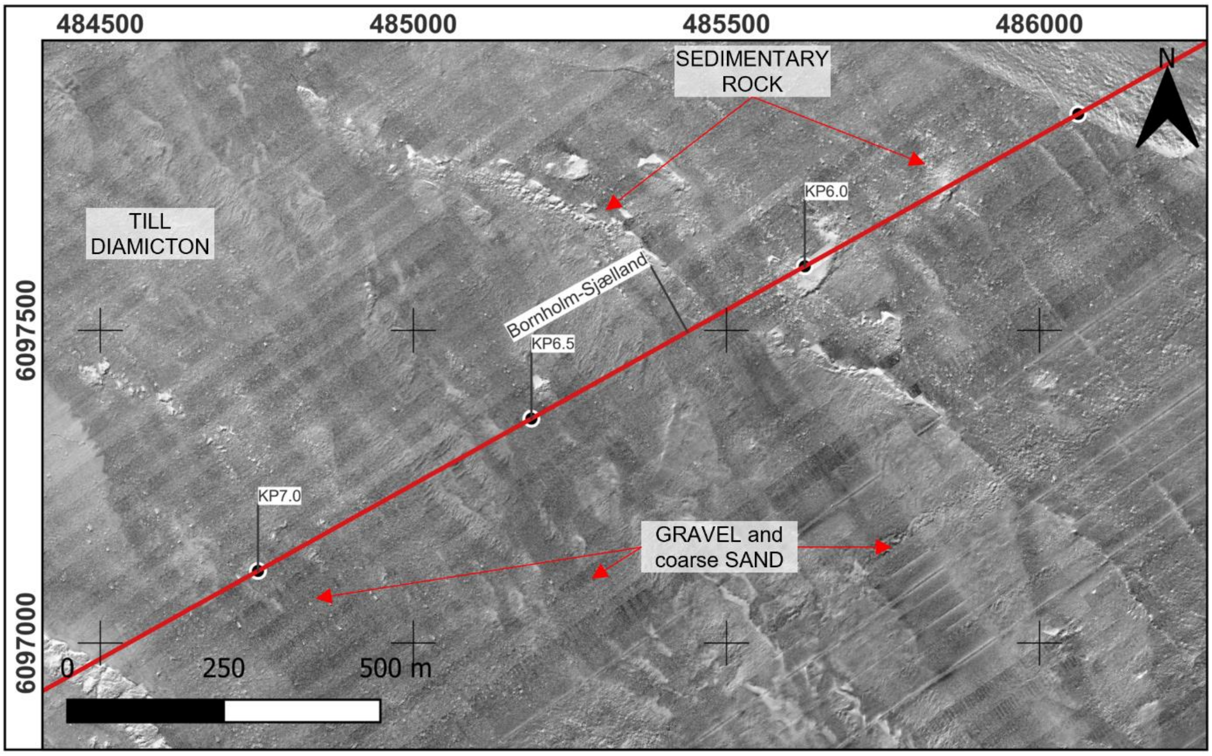


Figure 84 Overview of surficial geology from KP 5.5 to KP 7.5 as seen on SSS.

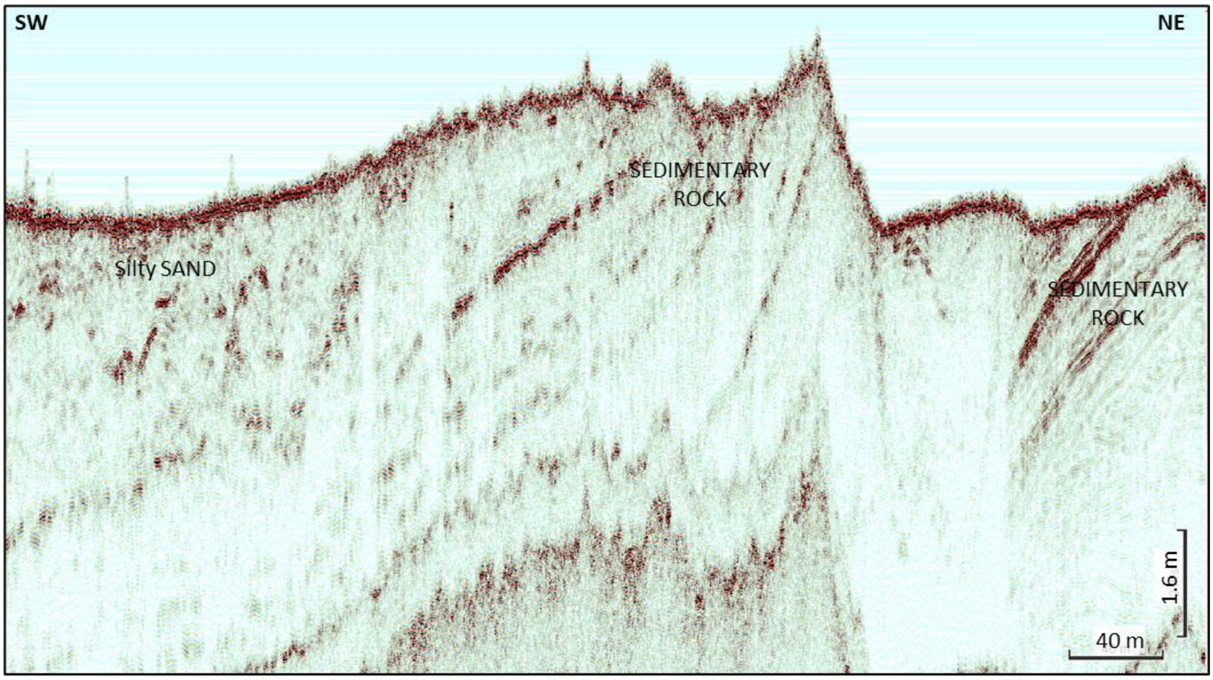


Figure 85 Innomar SBP data example from KP 1.922 (SW) to KP 1.402 (NE).

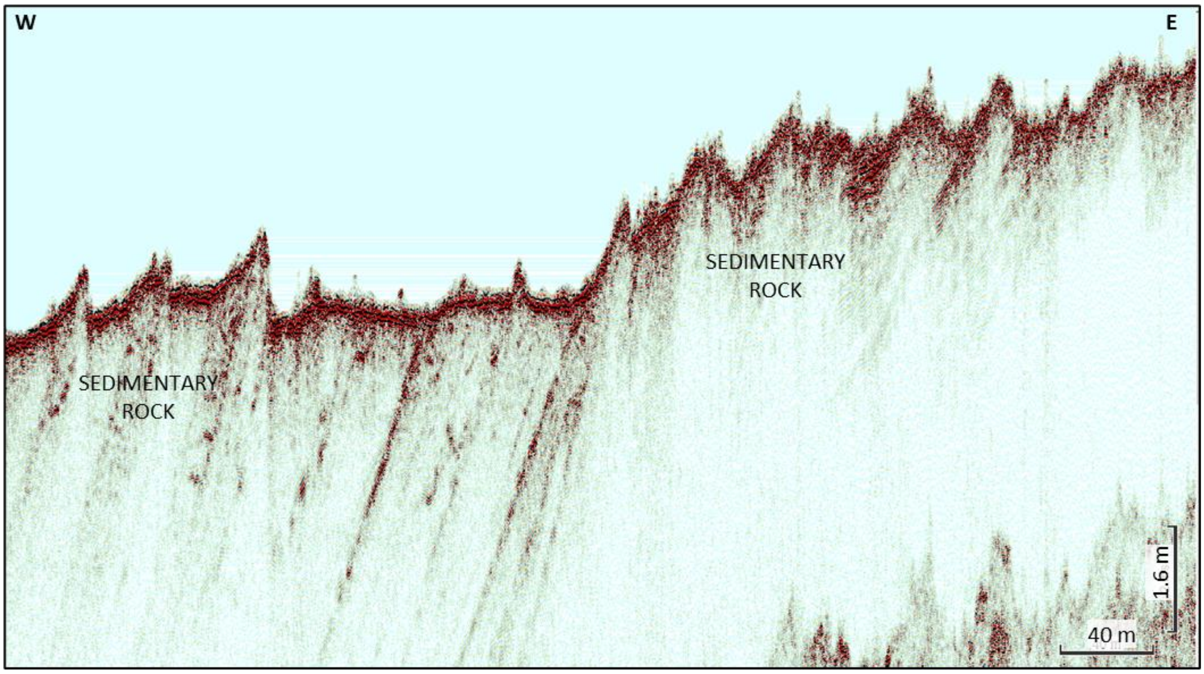


Figure 86 Innomar SBP data example from KP 4.531 (W) to KP 3.996 (E).

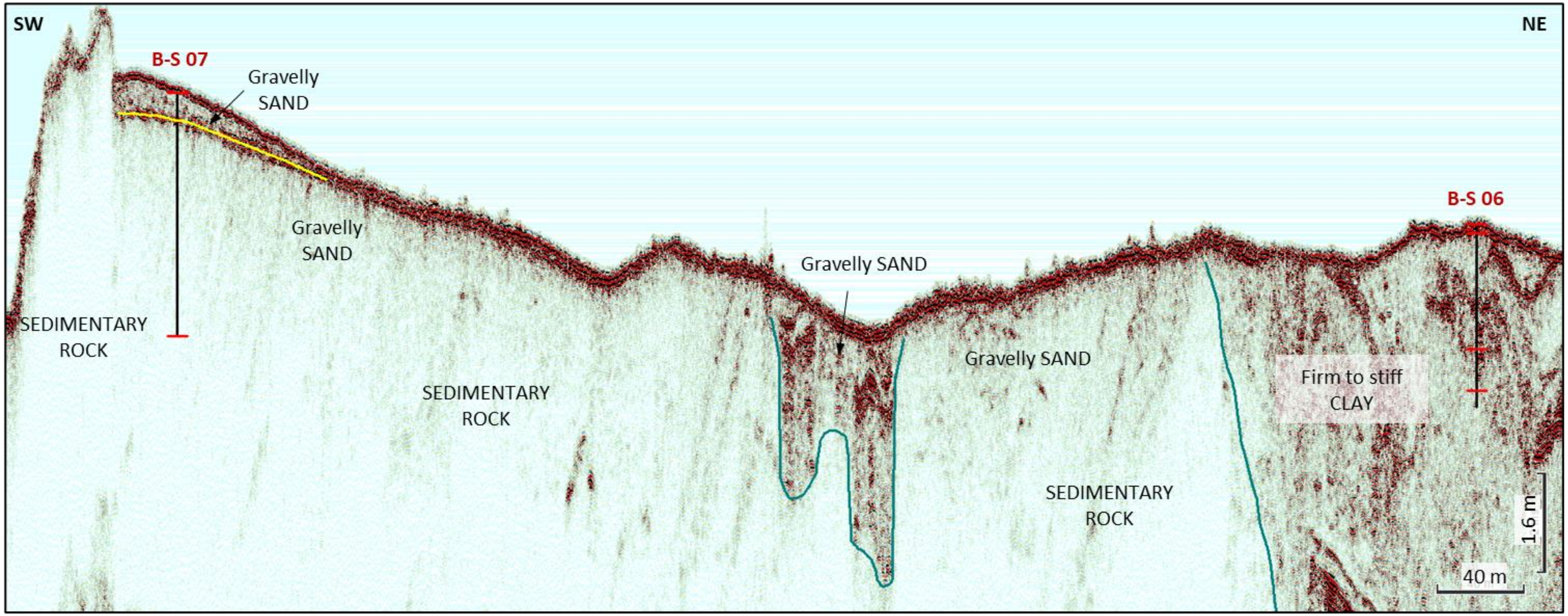


Figure 87 Innomar SBP data example from KP 7.352 (SW) to KP 6.620 (NE).

Table 33 CRS Bornholm-Sjælland detailed description for alignment chart 103971-ENN-OI-SUR-DWG-P1BH002 (KP 6.925 – 15.865).

Alignment Chart 103971-ENN-OI-SUR-DWG-P1BH002 (KP 6.925 – 15.865)	
Description (including min/max depth BSB to base of unit)	Remark
Bathymetry: Uneven surface with outcrops and ridges orientated in multiple directions crossing the corridor (Figure 88). Seabed gently sloping down westwards.	Depth range along route = 13.77 m. Moderate to very steep slopes with a maximum value of 28.55° along the route at the ridge of a rock outcrop. Minimum depth along route 8.85 m at KP 7.304. Maximum depth along route 22.62 m at KP 15.817. Maximum slope along route of 28.55° at KP 8.989.
Surficial Geology: The seabed in this section is characterised by SEDIMENTARY ROCK, ridges are formed where the rock outcrops. GRAVEL and coarse SAND and DIAMICTON infill the erosional surface of the bedrock (Figure 89 and Figure 90). Between KP 6.925 and KP 8.594 the predominant seabed sediment is DIAMICTON. This is broken by outcrops of SEDIMENTARY ROCK. In the south side of this KP range a folded section of SEDIMENTARY ROCK outcrops forming ridges at seabed (Figure 89). Between KP 8.594 to KP 9.234 SEDIMENTARY ROCK outcrops forming a series of ridges orientated north to south crossing the corridor and joining with the folded outcrop in the south. Between the ridges there are deposits of GRAVEL and coarse SAND (Figure 90). Between KP 9.234 and KP 10.210 DIAMICTON is the predominate seabed sediment, this is interspersed with outcrops of SEDIMENATRY ROCK and deposits of GRAVEL and coarse SAND (Figure 91). Between KP 10.210 and KP 12.173 there is a large area of SEDIMENATRY ROCK, this surface is undulating and forms some ridges. GRAVEL and coarse SAND infill depressions within this area. To the north and south of the route there are large areas of DIAMICTON (Figure 92).	**Infrastructure:** Utility ID 06 (cable, unknown) detected on the MAG dataset trending south-west to north-east. Not seen on the SSS and MBES datasets or WPD. The linear magnetic anomalies were not detected crossing the route, magnetic signal may be masked by SEDIMENTARY ROCK. Detected between KP 10.6 and KP 12.2 **Grab Samples:** 971-ENE-DV-GS-102 971-ENE-DV-GS-103 971-ENE-DV-GS-105 971-ENE-DV-GS-106 971-ENE-DV-GS-107 971-ENE-DV-GS-108 971-ENE-DV-GS-109 971-ENE-DV-GS-110 971-ENE-DV-GS-111 971-ENE-DV-GS-126

Alignment Chart 103971-ENN-OI-SUR-DWG-P1BH002 (KP 6.925 – 15.865)	
Description (including min/max depth BSB to base of unit)	Remark
Between KP12.173 and KP 14.479 there is a large area of GRAVEL and coarse SAND. To the south and north of the route there are large areas of SEIMENTARY ROCK and patches of DIAMICTON (Figure 93). Between KP14.479 to KP15.865 there is a large area of DIAMICTON broken by one outcrop aligned along the route between KP 15.300 and KP 15.523. To the north of this area there is GRAVEL and coarse SAND and to the south SEDIMENTARY ROCK (Figure 99). Some areas of ripples occur areas of Gravel and coarse SAND, crests are orientated north to south in line with the prevailing storm wave base. The entire area is covered by glacial debris mostly falling under the high-density boulder field category. Patches where boulder density is low include ridges of rock outcrops and neighbouring deep pockets of sediment and some areas within Gravel and coarse SAND.	971-ENE-DV-GS-127 971-ENE-DV-GS-128 971-ENE-DV-GS-129 971-ENE-DV-GS-130 971-ENE-DV-GS-131 971-ENE-DV-GS-132 971-ENE-DV-GS-133 971-ENE-DV-GS-134 971-ENE-DV-GS-135 971-ENE-DV-GS-136 971-ENE-GR-GS-071 971-ENE-GR-GS-072 971-ENE-GR-GS-073
Shallow Geology: KP 6.925 – KP 12.291 (Figure 94): SEDIMENTARY ROCK is observed either outcropping at the seabed or beneath a thin veneer of recent marine surficial sediments and is visible to beyond the SBP data extent (> 12.0 m BSB). High amplitude internal reflectors with variable orientation and morphology are visible within the SEDIMENTARY ROCK. Within this KP range, five isolated U and V shaped silty SAND and sandy CLAY filled Late to Post Glacial channels (P1_H45i) have been interpreted on the CL: KP 6.931 to KP 7.951 – Maximum depth 4.1 m BSB KP 7.845 to KP 1.323 – Maximum depth 4.5 m BSB KP 8.744 to KP 8.810 – Maximum depth 6.7 m BSB KP 9.210 to KP 9.267 – Maximum depth 8.9 m BSB KP 10.101 to KP 10.297 – Maximum depth 11.1 m BSB (Figure 94)	**Vibrocores and CPTs:** B-S-07 and B-S-07A-CPT B-S-08 and B-S-08A-CPT B-S-09A and B-S-09-CPT B-S-10 and B-S-10A-CPT B-S-11 and B-S-11-CPT B-S-12A and B-S-12-CPT B-S-13 and B-S-13-CPT B-S-14 and B-S-14-CPT

Alignment Chart 103971-ENN-OI-SUR-DWG-P1BH002 (KP 6.925 – 15.865)	
Description (including min/max depth BSB to base of unit)	Remark
KP 12.291 to KP 14.228 (Figure 95): A Glacial CLAY unit (P1_H50) with an undulating erosional base is present from the seabed to between 2.5 and 7.8 m BSB. The CLAY is firm to stiff, silty, slightly sandy, slightly gravelly between KP 12.291 to KP 12.916 before gradationally transitioning to a soft silty, slightly sandy Glacial CLAY from KP 13.576 to KP 14.228. SEDIMENTARY ROCK is present below the Glacial CLAY to beyond the SBP data extent (>13.0 m BSB). No internal reflectors are visible within the unit in this KP range. KP 14.228 to KP 15.143 (Figure 96 and Figure 97): SEDIMENTARY ROCK is present either outcropping at the seabed or beneath a thin veneer of recent marine surficial sediments to beyond the extent of the SBP data (> 12.0 m BSB). High amplitude internal reflectors with variable orientation and morphology are visible within the SEDIMENTARY ROCK. KP 15.143 to KP 15.865 (Figure 102): A Glacial CLAY unit (P1_H50) with an undulating erosional base is present from the seabed to between 1.7 and 6.0 m BSB. The CLAY is firm to stiff, silty, slightly sandy, slightly gravelly. SEDIMENTARY ROCK is present from below the Glacial CLAY to beyond the SBP data extent (>13.0 m BSB). No internal reflectors are visible within the unit in this KP range.	

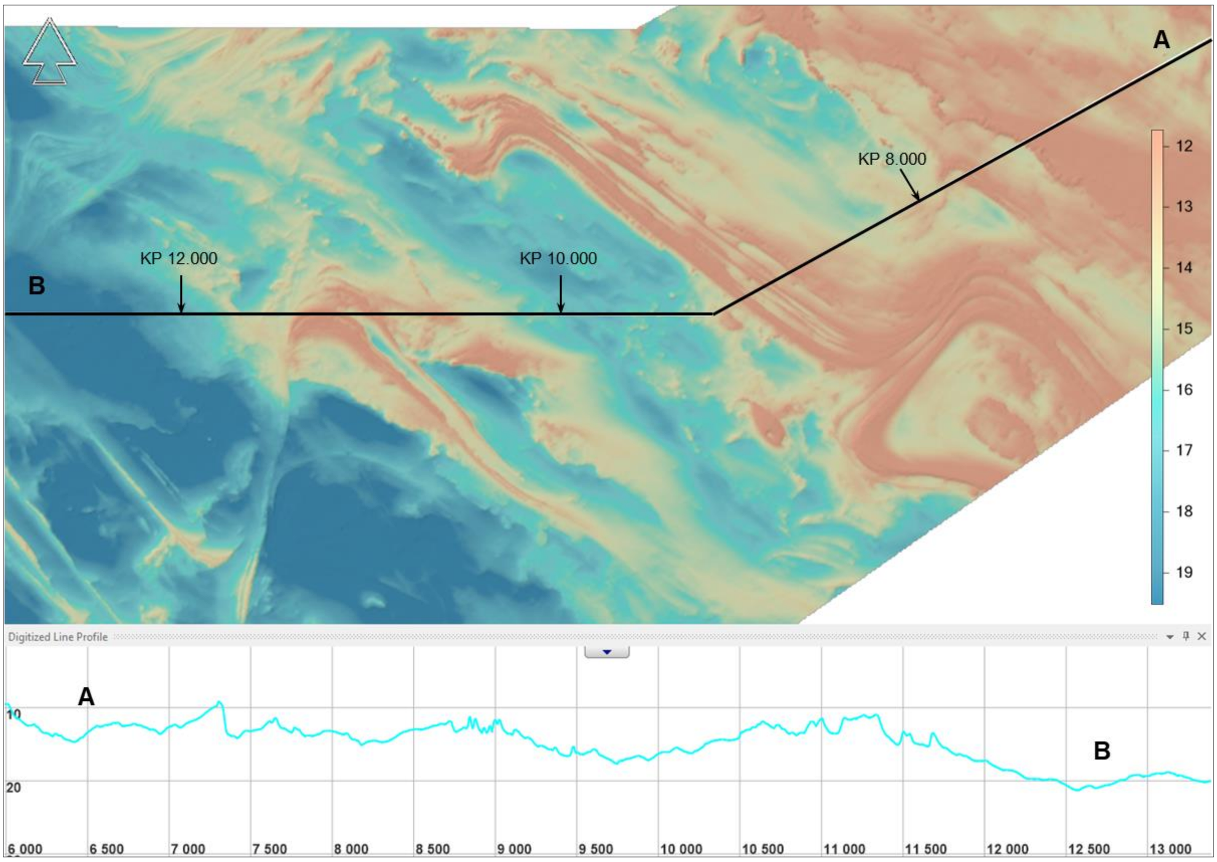


Figure 88 Ridges and undulations of sedimentary rock seen in bathymetry KP 6.5 to KP 13.0.

Horizontal scale is distance in metres from eastern end of the route. Depths in NaviModel presented positive down; vertical exaggeration of profile x40.

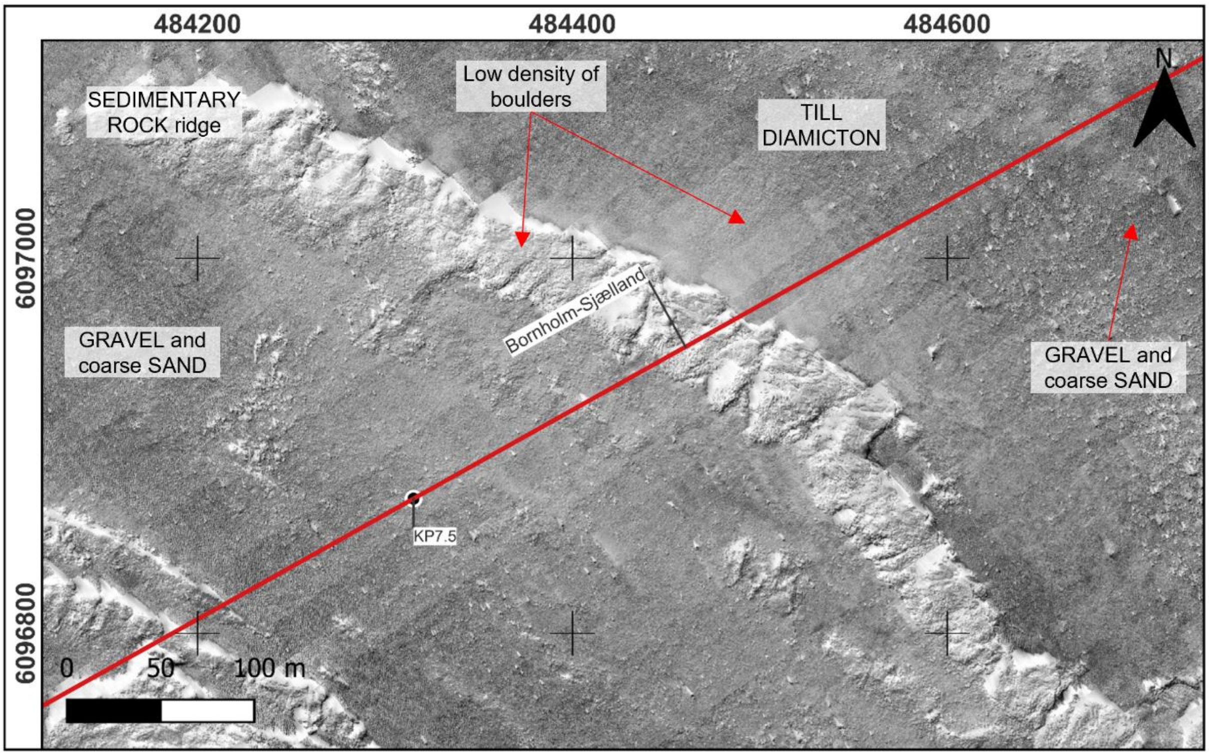


Figure 89 SSS image of SEDIMENTARY ROCK ridge at KP 7.3

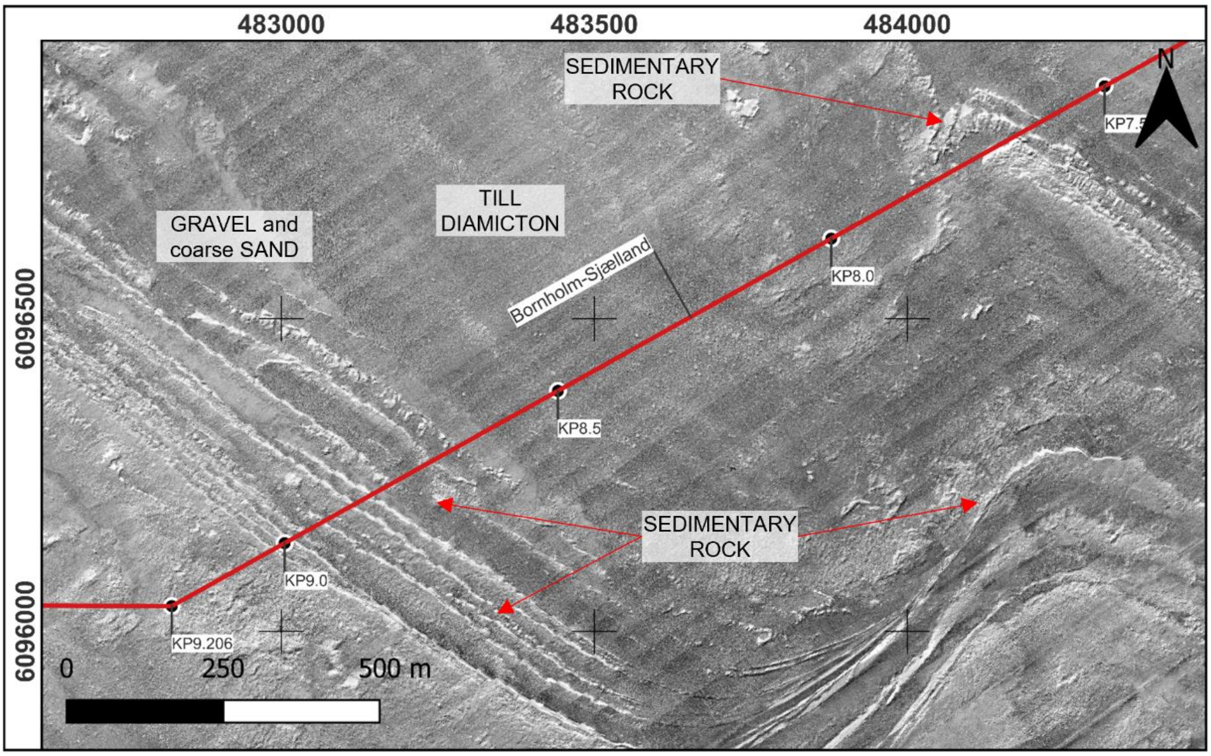


Figure 90 Overview of surficial geology from KP 7.5 to KP 9.5 as seen on SSS

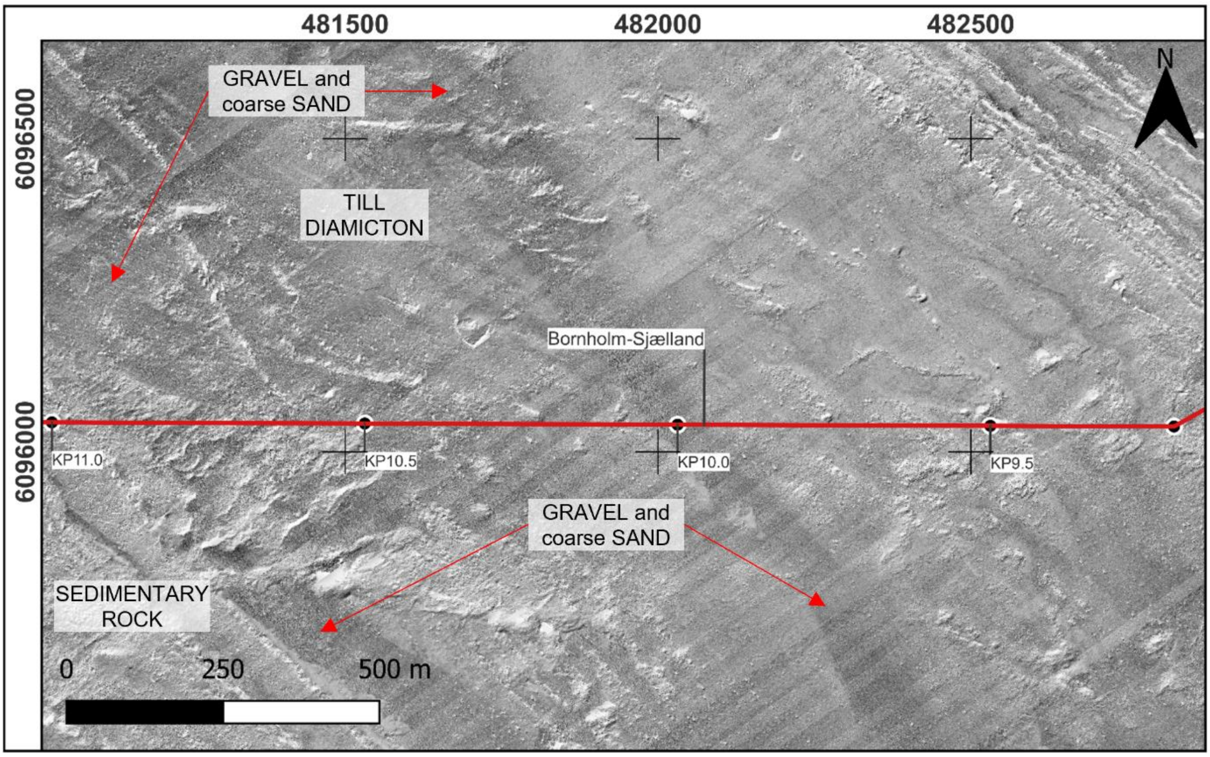


Figure 91 Overview of surficial geology from KP 9.2 to KP 11.0 as seen on SSS

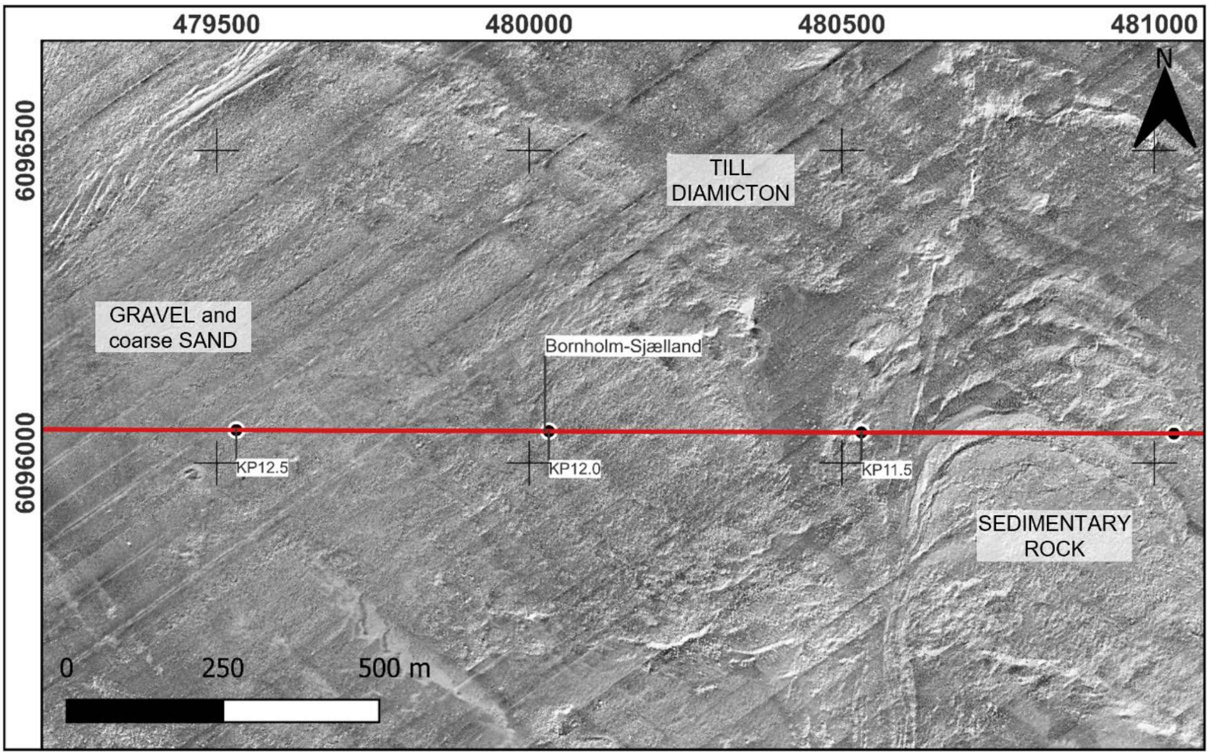


Figure 92 Overview of surficial geology from KP 11.0 to KP 13.0 as seen on SSS

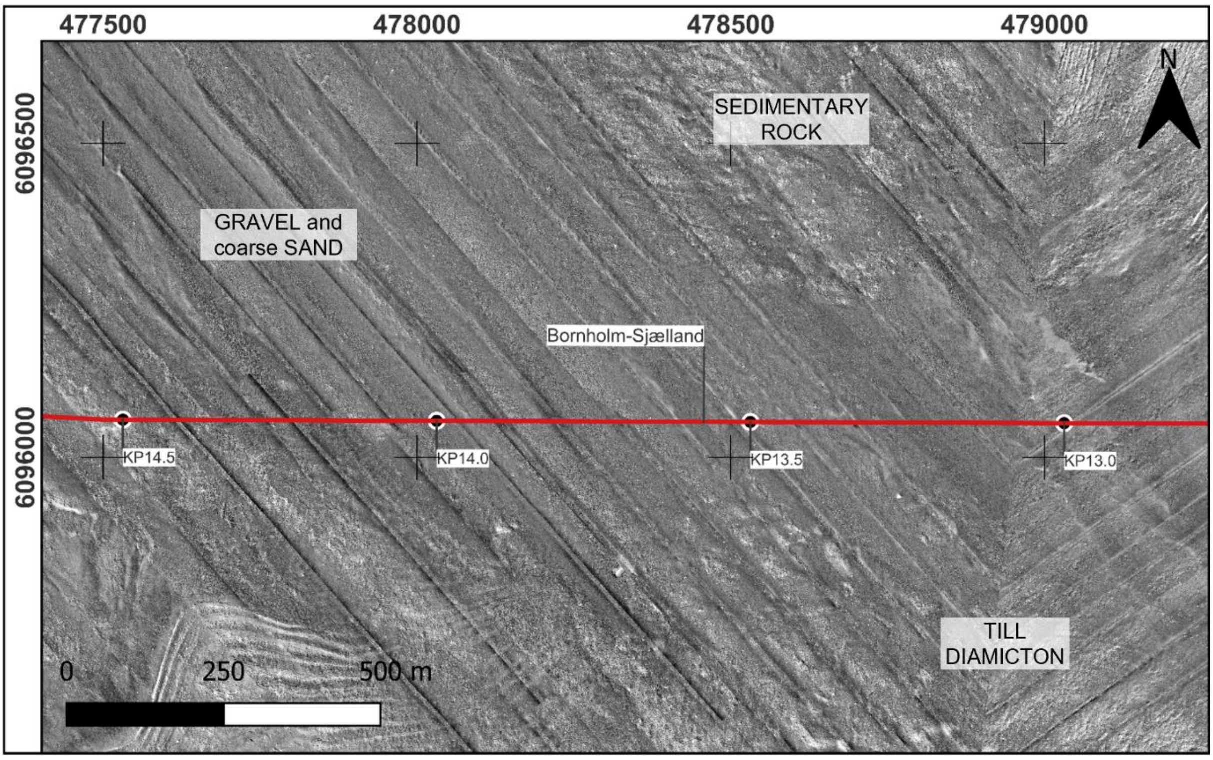


Figure 93 Overview of surficial geology from KP 12.5 to KP 14.5 as seen on SSS

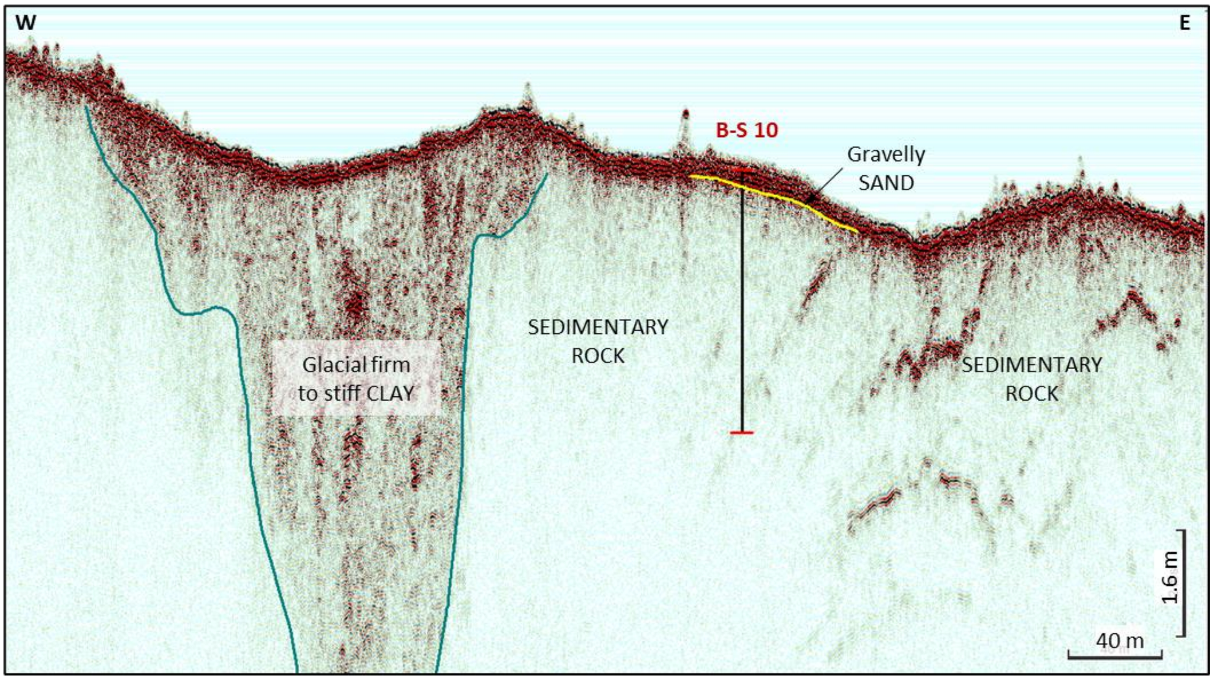


Figure 94 Innomar SBP data example from KP 10.333 (W) to KP 9.820 (E).

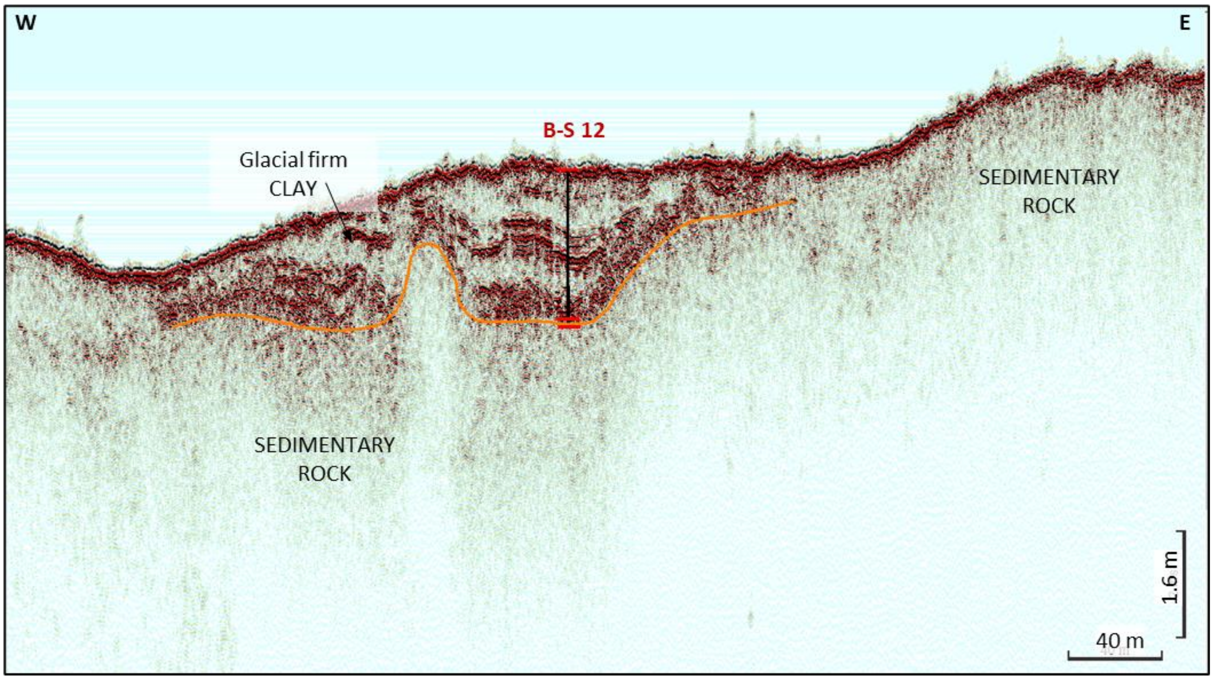


Figure 95 Innomar SBP data example from KP 12.633 (W) to KP 12.110 (E).

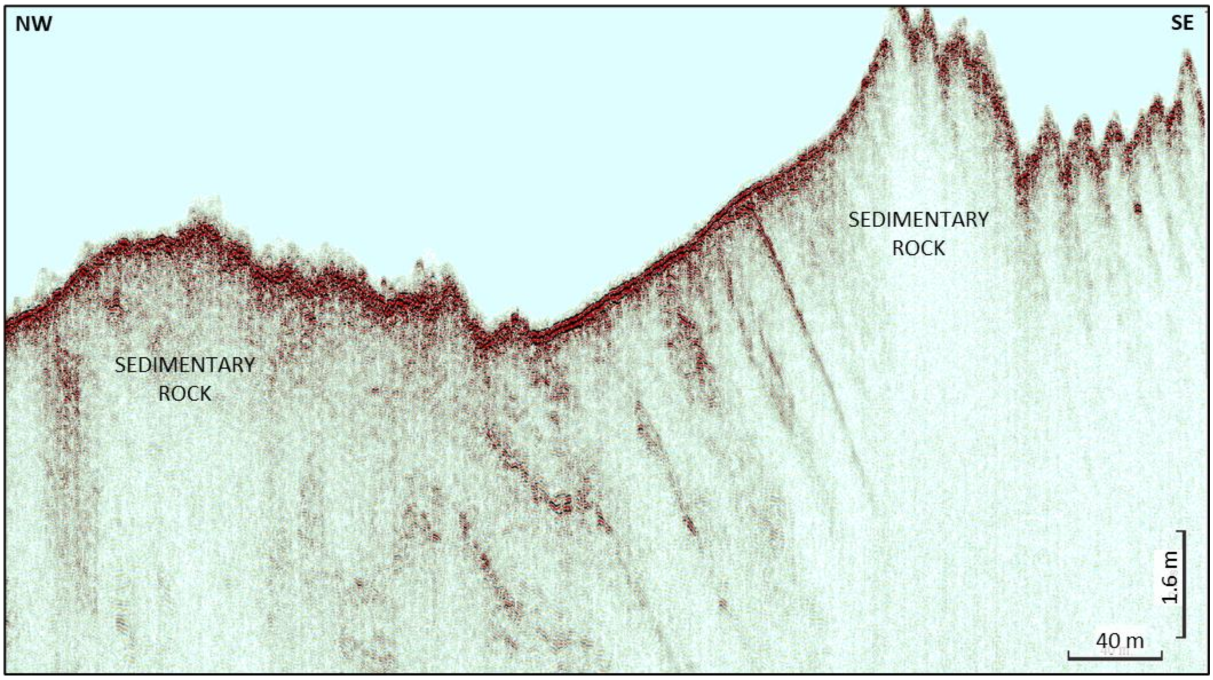


Figure 96 Innomar SBP data example from KP 14.724 (NW) to KP 14.387 (SE).

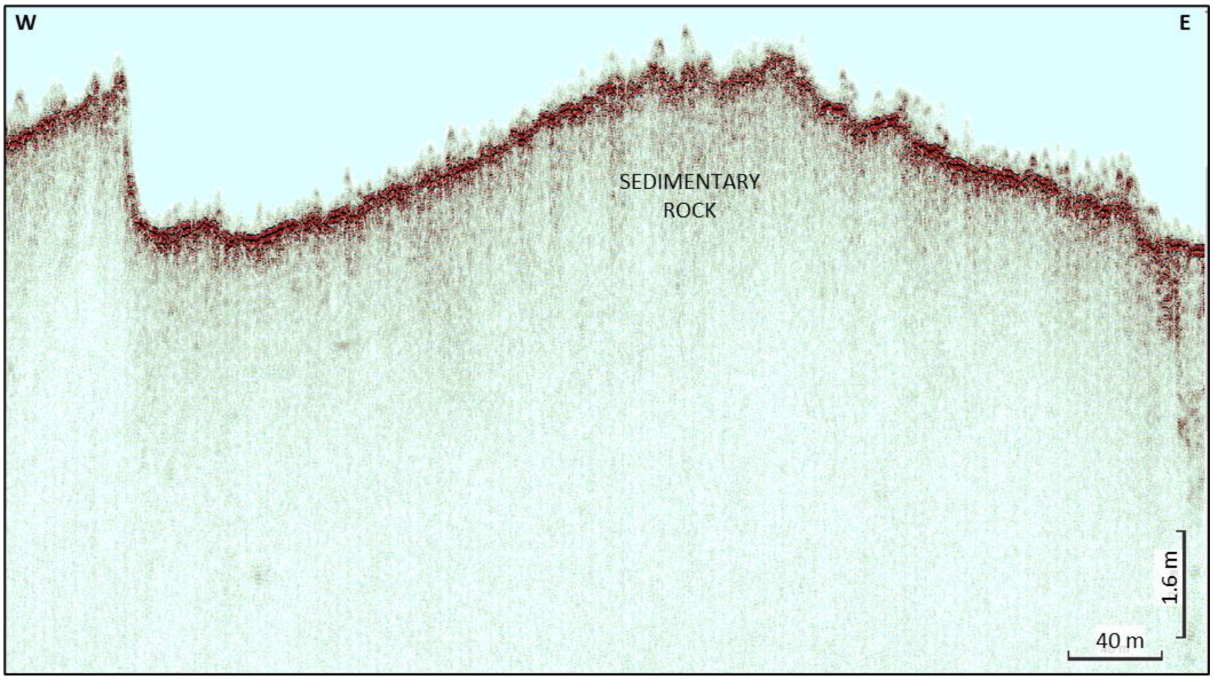


Figure 97 Innomar SBP data example from KP 15.119 (W) to KP 14.669 (E).

Table 34 CRS Bornholm-Sjælland detailed description for alignment chart 103971-ENN-OI-SUR-DWG-P1BH003 (KP 14.941 – 18.831).

Alignment Chart 103971-ENN-OI-SUR-DWG-P1BH003 (KP 14.941 – 18.831)	
Description (including min/max depth BSB to base of unit)	Remark
Bathymetry: Uneven seabed surface alternating between rock outcrops, ridges and boulder areas across the corridor (Figure 98). Shallow scours and depression seen around boulders. Seabed moderately deepening up to the end of the route at KP 18.831.	Depth range along route = 5.67 m. Moderate to steep slopes up to KP 17.400 with a maximum value of 12.4° along the route due to a localized rocky raise. Minimum depth along route 19.00 m at KP 15.084. Maximum depth along route 24.58 m at KP 28.802. Maximum slope along route of 12.4° at KP 16.333.
Surficial Geology: The seabed in this section is characterised by SEDIMENTARY ROCK, ridges are formed where the rock outcrops. GRAVEL and coarse SAND and DIAMICTON infill the erosional surface of the bedrock (Figure 99 to Figure 100). Between KP 14.941 and KP 17.786 the predominant seabed sediment is DIAMICTON. This is broken by outcrops of SEDIMENTARY ROCK between KP15.300 - KP 15.523, KP 16.122 - KP 16.222 and KP 16.323 - KP 16.352. On the south-west side of the DIAMICTON area there is a large area of SAND. On the north-east of the corridor is a mix of DIAMICTON, SEDIMENTARY ROCK and GRAVEL and coarse SAND (Figure 99 to Figure 100). Between KP 17.786 and KP 18.831 the seabed is composed of GRAVEL and coarse SAND covering the corridor (Figure 101). From KP 14.941 to KP 17.748 is covered by glacial debris mostly falling under the high-density boulder field category. Patches where boulder density is low include ridges of rock outcrops and neighbouring deep pockets of sediment and some areas within Gravel and coarse SAND. Boulders are present on seabed between KP 17.748 to KP 18.831. The density in this area is generally less than 20 boulders per 100x100 m, however small areas of higher density do occur.	**Infrastructure:** Utility ID 10 (cable, unknown) detected on the MAG dataset and WPD, not seen on the SSS or MBES. Crossing the route at KP 16.152. **Debris:** S_GR_WPA_B1D_0033 (Linear debris) crossing route at KP18.466. **Grab Samples:** 971-ENE-GR-GS-074 971-ENE-GR-GS-075 971-ENE-GR-GS-076 971-ENE-GR-GS-119

Alignment Chart 103971-ENN-OI-SUR-DWG-P1BH003 (KP 14.941 – 18.831)	
Description (including min/max depth BSB to base of unit)	Remark
Shallow Geology: KP 15.865 to KP 18.188 (Figure 102): Firm to stiff, silty, slightly sandy, slightly gravelly Glacial CLAY (P1_H50) with an undulating basal reflector is present from the seabed to between 1.3 and 6.7 m BSB. SEDIMENTARY ROCK is present from below the Glacial CLAY to beyond the SBP data extent (>15.0 m BSB). No internal reflectors are visible within the unit in this KP range. KP 18.188 to KP 18.831 (Figure 103): Thin veneers (< 0.2 m BSB) of Late/Post Glacial meltwater silty SAND to silty gravelly SAND (P1_H20) are present in this KP range. Below this a Glacial CLAY unit (P1_H50) with an undulating basal reflector is present to a maximum depth of between 6.4 to 8.4 m BSB. Between KP 18.258 to KP 18.434, the Glacial CLAY unit deepens beyond 8.4m, with its base unidentifiable in the SBP data. The Glacial CLAY is firm to stiff, silty, slightly sandy, slightly gravelly. SEDIMENTARY ROCK is present from below the Glacial CLAY to beyond the SBP data extent (>15.0 m BSB).	**Vibrocores and CPTs:** B-S-16 and B-S-16A-CPT B-S-17B and B-S-17-CPT B-S-18 and B-S-18-CPT

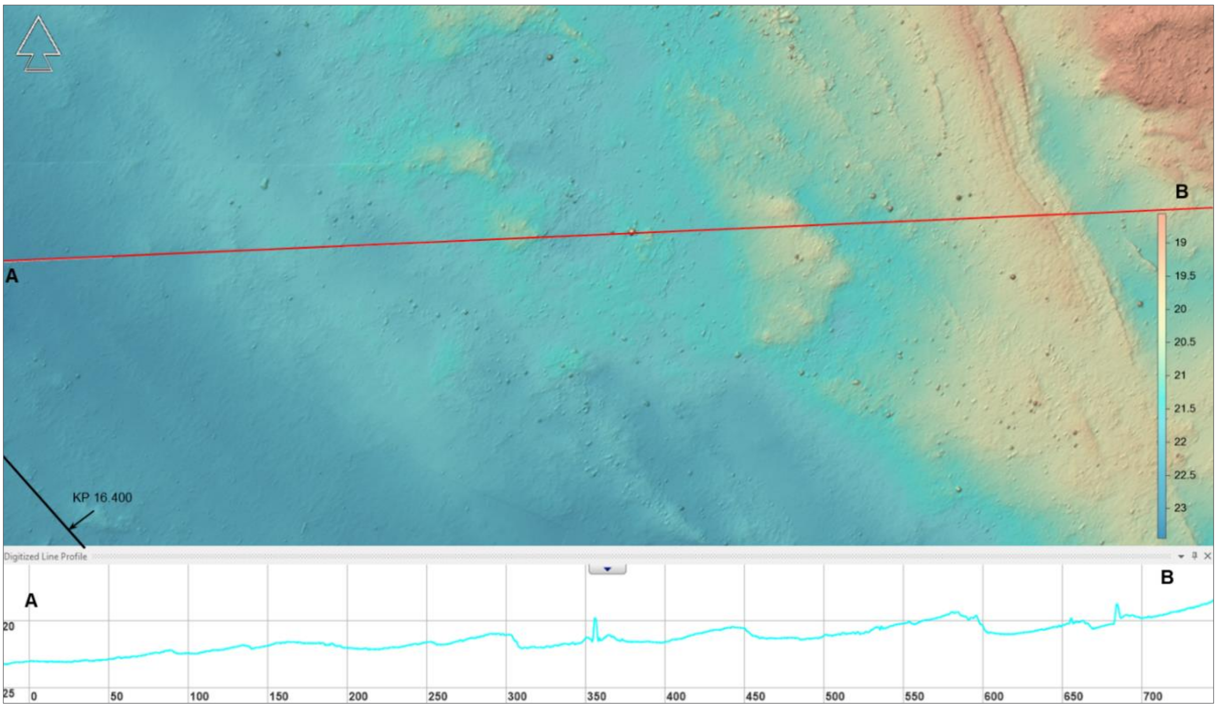


Figure 98 Irregular seabed identified as rock outcrops and glacier debris seen in bathymetry NE of the route at KP 16.4.

Horizontal scale is distance in metres along the red line from its western end. Depths in NaviModel presented positive down; vertical exaggeration of profile x8.4.

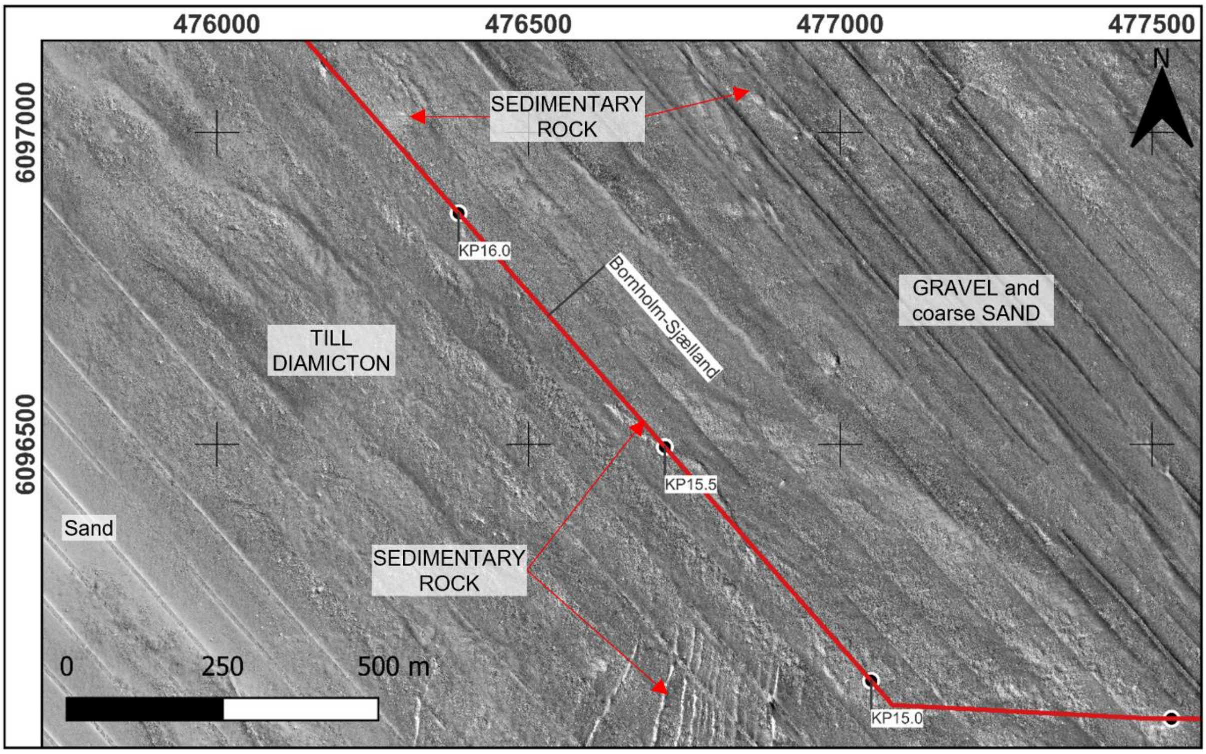


Figure 99 Overview of surficial geology from KP 14.5 to KP 16.5 as seen on SSS.

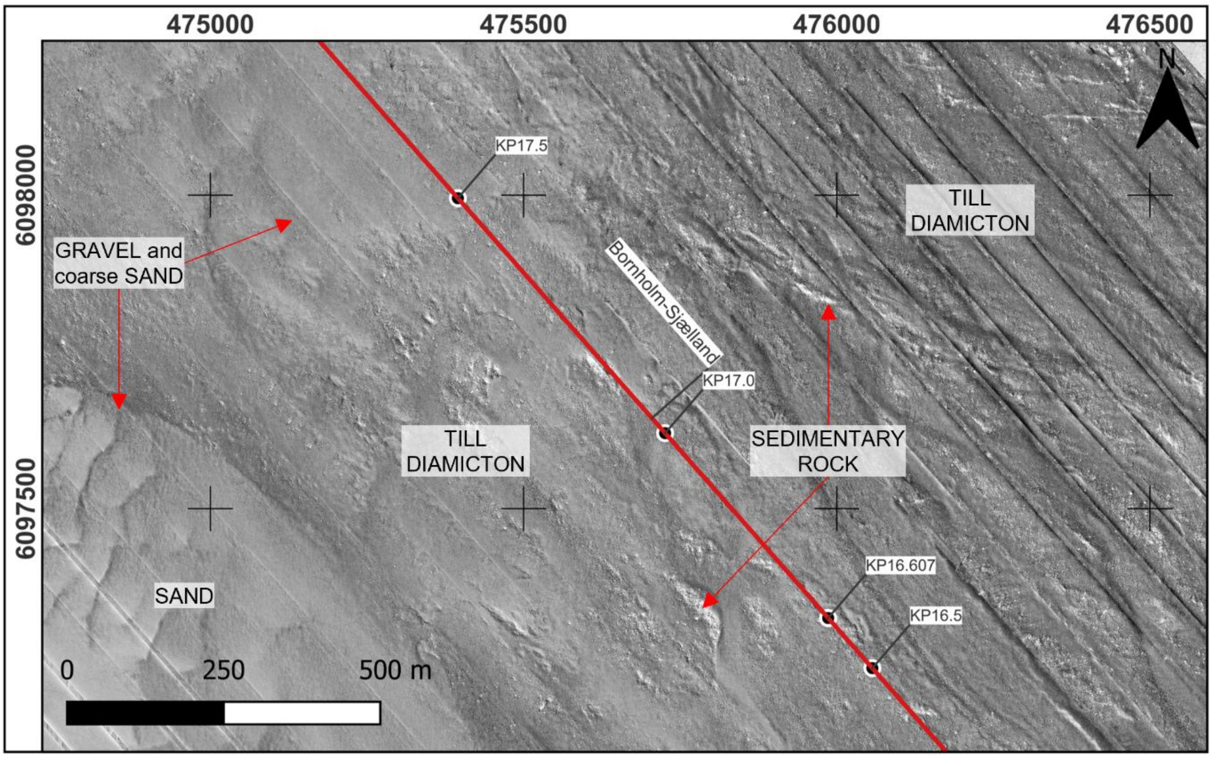


Figure 100 Overview of surficial geology from KP 16.0 to KP 18.0 as seen on SSS.

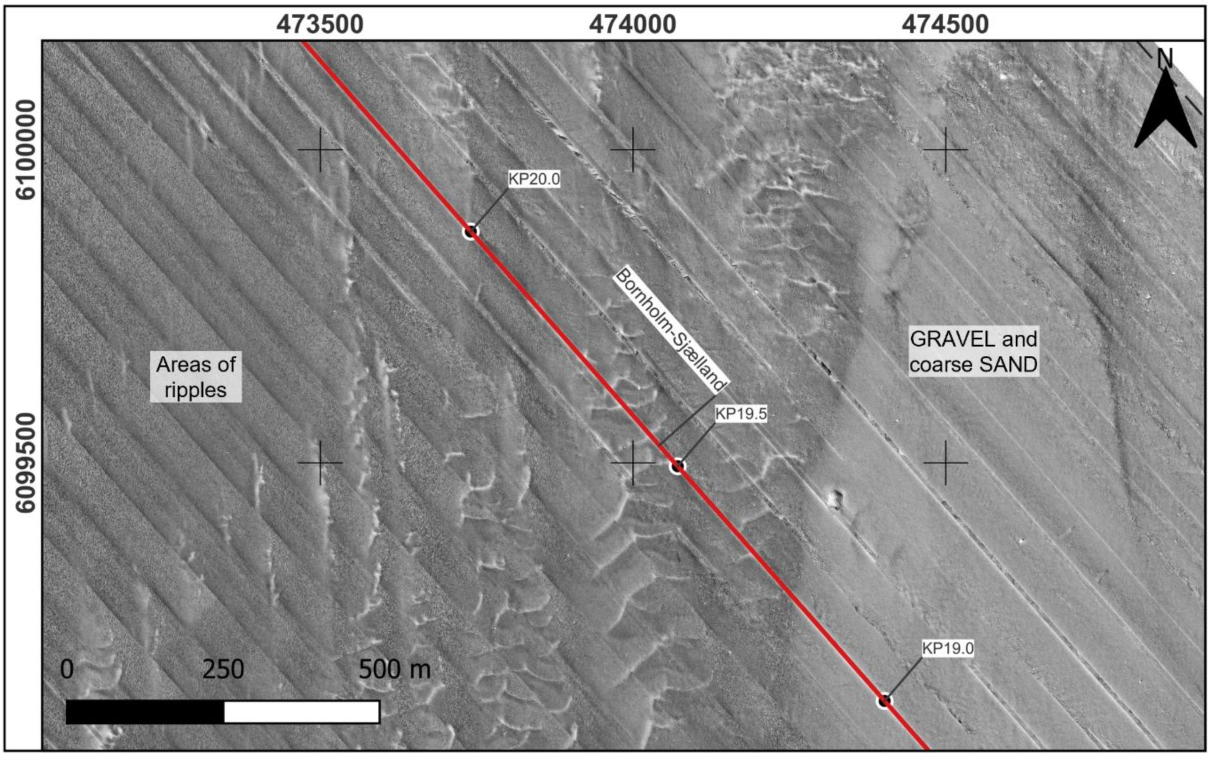


Figure 101 Overview of surficial geology from KP 18.75 to KP 21.0 as seen on SSS.

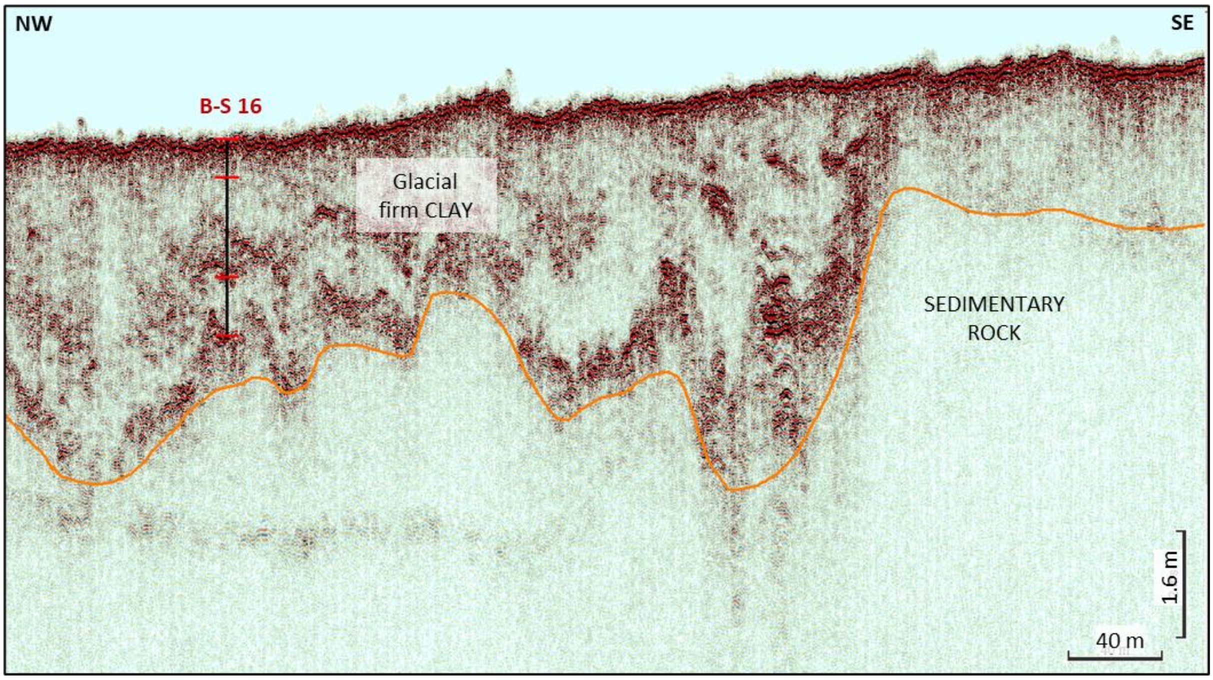


Figure 102 Innomar SBP data example from KP 16.049 (NW) to KP 15.504 (SE).

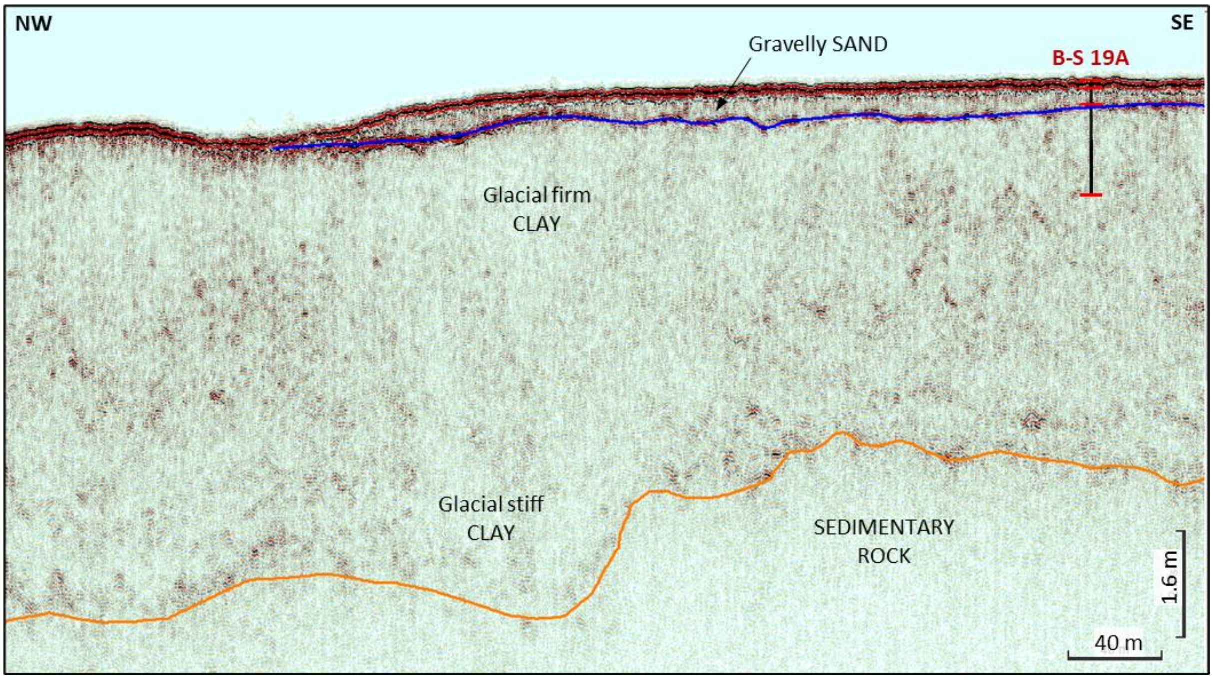


Figure 103 Innomar SBP data example from KP 19.356 (NW) to KP 18.837 (SE).

8.2.8 Integrated Seabed Index

Table 35 Integrated Seabed index for CRS Bornholm-Sjælland KP 0.000 to KP 18.831.

Location ID							B-S-03	B-S-03			B-S-04			B-S-05	B-S-05A		B-S-06	B-S-06	
Route KP	0.000	0.500	1.000	1.500	2.000	2.500	2.911	2.916	3.500	4.000	4.636	5.000	5.500	5.557	5.557	6.000	6.656	6.661	7.000
Data type	SBP	SBP	SBP	SBP	SBP	SBP	CPT	VC	SBP	SBP	VC	SBP	SBP	VC	CPT	SBP	CPT	VC	SBP
Depth below seabed (m) 0.5	1	1	1	1	1	1	3	3	1	1	3	3	1	3	3	1	8	8	3
1.0	1	1	1	1	1	1	6	6	1	1	6	6	1	3	3	1	8	8	3
1.5	1	1	1	1	1	1	6	6	1	1	6	6	1	3	3	1	8	8	3
2.0	1	1	1	1	1	1	6	6	1	1	6	1	1	3	3	1	8	8	3
2.5	1	1	1	1	1	1	6	6	1	1	6	1	1	3		1	8	8	3
3.0	1	1	1	1	1	1	6	6	1	1	6	1	1	3		1	4	4	3
4.0	1	1	1	1	1	1	6	6	1	1	6	1	1	3		1	4	4	1
5.0	1	1	1	1	1	1	5	5	1	1		1	1			1	4		1
6.0	1	1	1	1	1	1	6		1	1		1	1			1	4		1

Location ID	B-S-07	B-S-07A			B-S-08	B-S-08A			B-S-09A	B-S-09		B-S-10	B-S-10A				B-S-11	B-S-11	
Route KP	7.270	7.271	7.500	8.000	8.325	8.331	8.500	9.000	9.245	9.252	9.500	10.018	10.024	10.500	11.000	11.500	11.628	11.634	12.000
Data type	VC	CPT	SBP	SBP	VC	CPT	SBP	SBP	VC	CPT	SBP	VC	CPT	SBP	SBP	SBP	VC	CPT	SBP
Depth below seabed (m) 0.5	5	5	5	5	5	5	5	1	8	8	1	5	5	1	1	1	5	5	1
1.0	3	3	3	3	3	3	3	1	8	8	1	3	3	1	1	1	3	3	1
1.5	3	3	3	3	3	3	3	1	8	8	1	3	3	1	1	1	3	3	1
2.0	3	3	3	1	3	3	1	1	8	8	1	3	3	1	1	1	3	3	1
2.5	3		1	1	3	3	1	1		8	1	3	3	1	1	1	3	3	1
3.0	3		1	1	3	3	1	1		8	1	3	3	1	1	1	3	3	1
4.0	3		1	1	3		1	1		5	1	3		1	1	1	3		1
5.0			1	1			1	1		5	1			1	1	1			1
6.0			1	1			1	1		5	1			1	1	1			1

Location ID	B-S-12	B-S-12			B-S-13	B-S-14					B-S-16A	B-S-16		B-S-17B	B-S-17		B-S-18B	B-S-18	
Route KP	12.389	12.397	12.400	12.700	12.924	13.583	14.000	14.500	15.000	15.500	15.954	15.958	16.500	16.993	16.997	17.500	18.083	18.088	18.500
Data type	VC	CPT	SBP	SBP	CPT	CPT	SBP	SBP	SBP	SBP	CPT	CPT	SBP	VC	CPT	SBP	VC	CPT	SBP
Depth below seabed (m) 0.5	8	8	8	8	8	8	8	1	1	8	8	8	4	4	4	4	4	4	4
1.0	8	8	8	8	8	8	8	1	1	8	8	8	4	4	4	4	4	4	4
1.5	8	8	8	8	8	8	8	1	1	8	8	8	4	4	4	4	4	4	4
2.0	8	6	8	1	8	8	8	1	1	8	7	7	4	4	4	4	4	4	4
2.5	8	6	1	1	8	8	8	1	1	8	4	4	1	4	4	4		4	4
3.0		5	1	1	5	8	8	1	1	1	6	3	1	4	4	1		4	4
4.0		5	1	1	6	8	1	1	1	1	6		1		5	1		4	4
5.0			1	1	6	4	1	1	1	1	5		1		6	1		4	4
6.0			1	1	4	4	1	1	1	1			1		6	1		4	4

8.2.9 Seabed features, Contacts and Anomalies

A total of 60 contacts were identified from the SSS data within the defined boundary of the survey corridor on CRS Bornholm Sjælland. The SSS contacts are summarised in Table 36. In addition to SSS contacts a total of 1 406 526 MBES boulders were identified within the defined boundary (Kabelrute OWF-BHM) at Bornholm.

A total of 913 magnetic anomalies were detected within the defined boundary along the on CRS Bornholm Sjælland. Of these, 160 are related to linear features or cables/Pipelines. The MAG targets are summarised in Table 37.

A total of 17 SSS contact positions correlated with detected magnetic anomalies.

Infrastructure detected:

- Utility ID 04 (cable, DK-PL 1) detected in on MAG and SSS datasets and WPD, crossing at KP 5.007 (Figure 82).
- Utility ID 06 (cable, unknown) detected on the MAG dataset trending south-west to north-east. Not seen on the SSS and MBES datasets or WPD. The linear magnetic anomalies were not detected crossing the route, magnetic signal may be masked by SEDIMENTARY ROCK. Detected between KP 10.6 and KP 12.2
- Utility ID 10 (cable, unknown) detected on the MAG dataset and WPD, not seen on the SSS or MBES. Crossing the route at KP 16.152.

Table 36 Summary of Route CRS Bornholm Sjælland SSS & MBES contacts.

CLASSIFICATION	NUMBER
Debris	39
Linear Debris	17
Wire/Rope	4
Total	**60**

Table 37 Summary of Route CRS Bornholm Sjælland magnetic anomalies.

CLASSIFICATION	NUMBER
Unclassified, possible objects	753
Linear anomalies	160
Total	**913**

8.3 ERS Bornholm 1A: KP 16.607 to KP 28.995

8.3.1 Overview

The Route deviates to the west northwest from the Bornholm – Sjælland route at KP 16.607, where the survey corridor is approximately 2.8 km wide. The survey corridor then remains at 1.5 km wide until the termination of the route at KP 28.995 (see Figure 104).

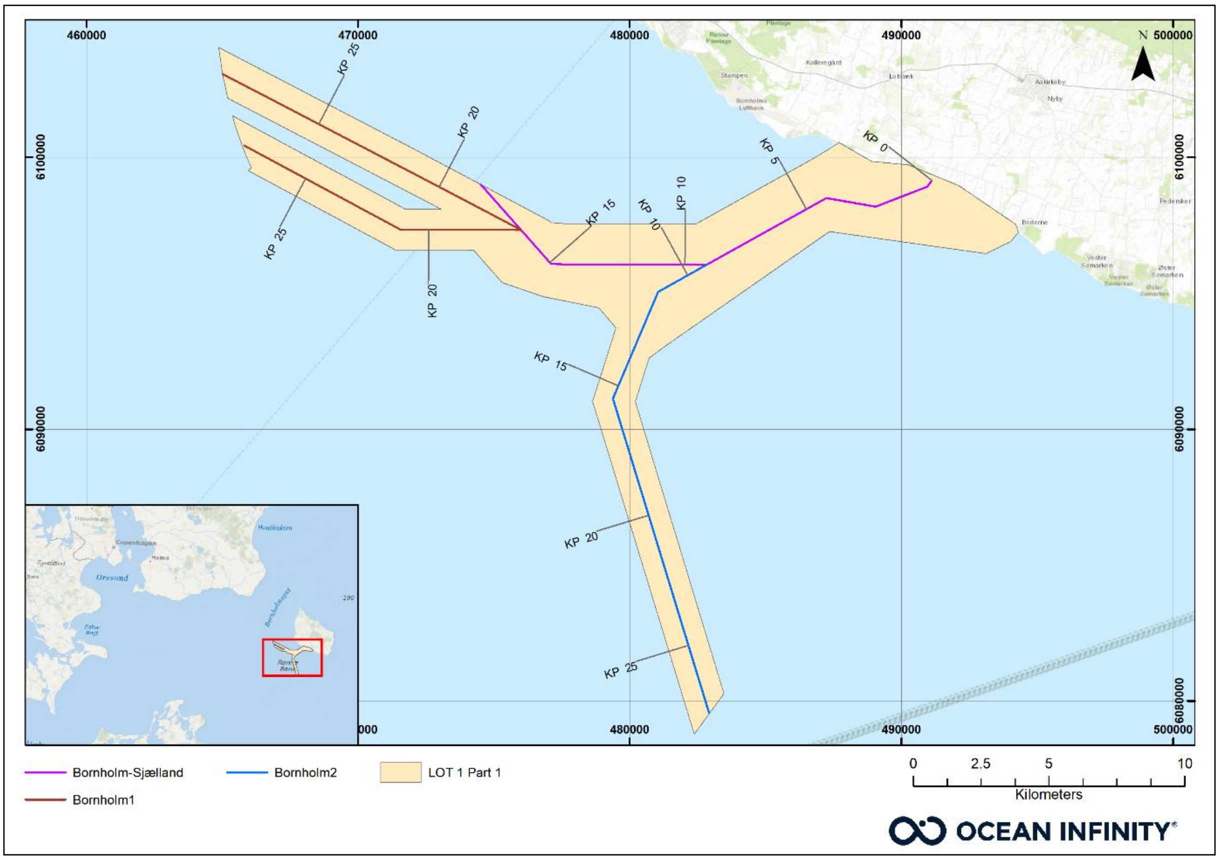


Figure 104 Overview image showing the cable routes and ECR within defined area of Part 1.

8.3.2 Bathymetry

This section begins in an area of undulating seabed which extends from the section start at KP 16.607 to KP 19.218. In this area, the seabed gently deepens from approximately 22.71 m to 24.19 m in the centre of the corridor. The bathymetry on the northern side of the corridor is mostly the same however on the southern side of the corridor the seabed is shallower due to the corridor intersecting the edge of a sandbank. This shallower section runs from KP 16.607 to KP 20.421, with the minimum depth being 19.51 m at 474721.88 E and 6097374.63 N.

Between KP 19.218 to KP 24.250 the seabed continues the general deepening trend. Here the seabed alternates between broad flat-topped banks and deeper areas of rippled seabed that cut between these banks (Figure 123). The changes in elevation across these banks is very slight with a maximum change of 0.88 m.

Between KP 24.250 and the end of the section at KP 28.995 the seabed has a very gentle gradient deepening from 38.73 m to 43.90 m in the centre of the corridor.

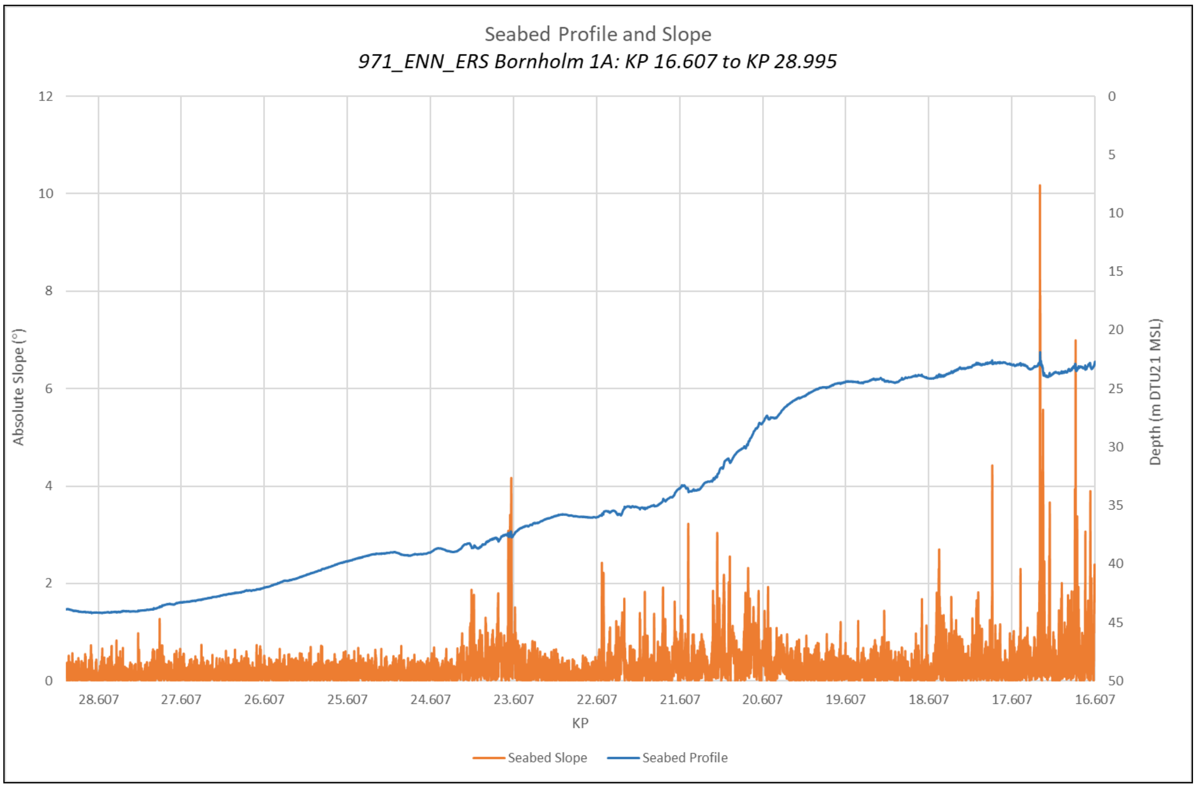


Figure 105 Route Bornholm 1A bathymetry longitudinal profile and slope.

Depth is in metres (with bathymetric depths positive below MSL datum) and slope is in degrees (absolute value for visualisation).

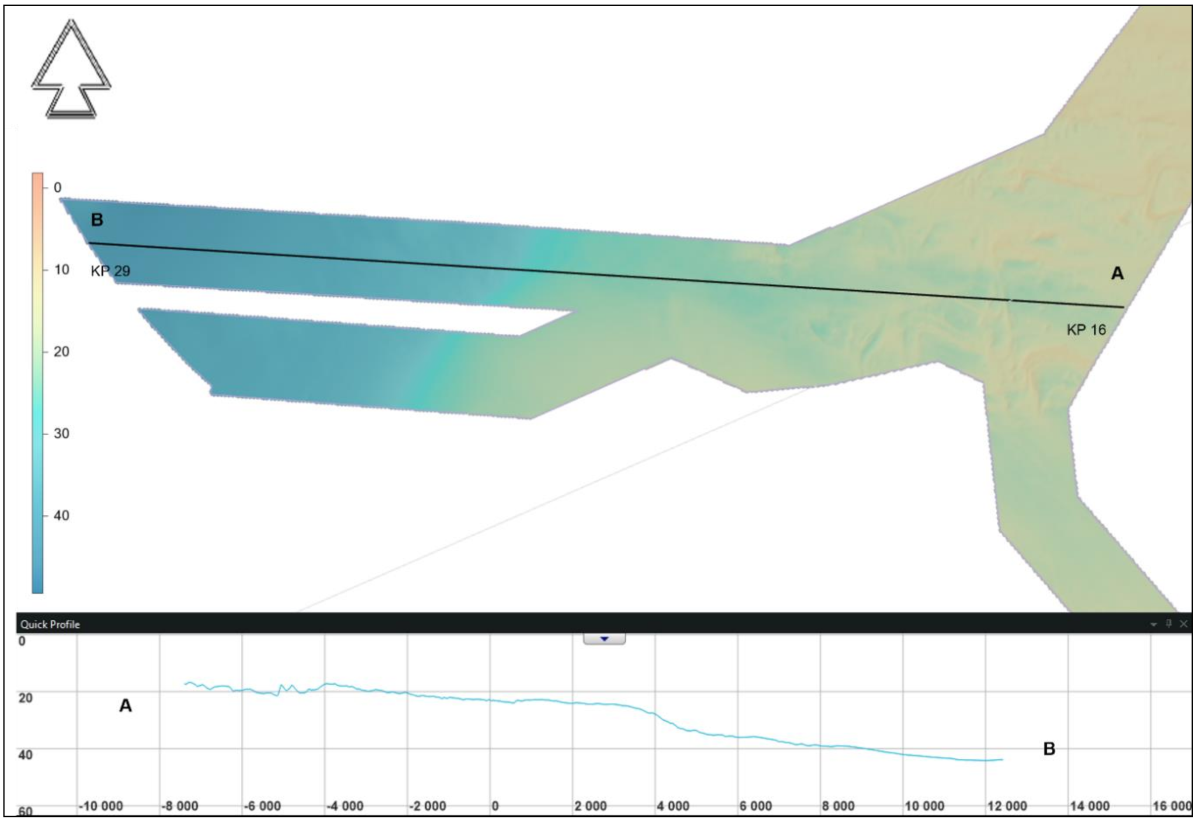


Figure 106 Overview image of ERS Bornholm 1A: KP 16.607 to KP 28.995 along route Bornholm 1A.

The scale on the profile is in metres with distance the x-axis. Depths presented in NaviModel depth convention is positive down; vertical exaggeration of profile x71.6.

8.3.3 Grab Sampling

The following grab samples were acquired, Figure 107 and Table 38. Full description of the grab sample results is contained in Appendix D.

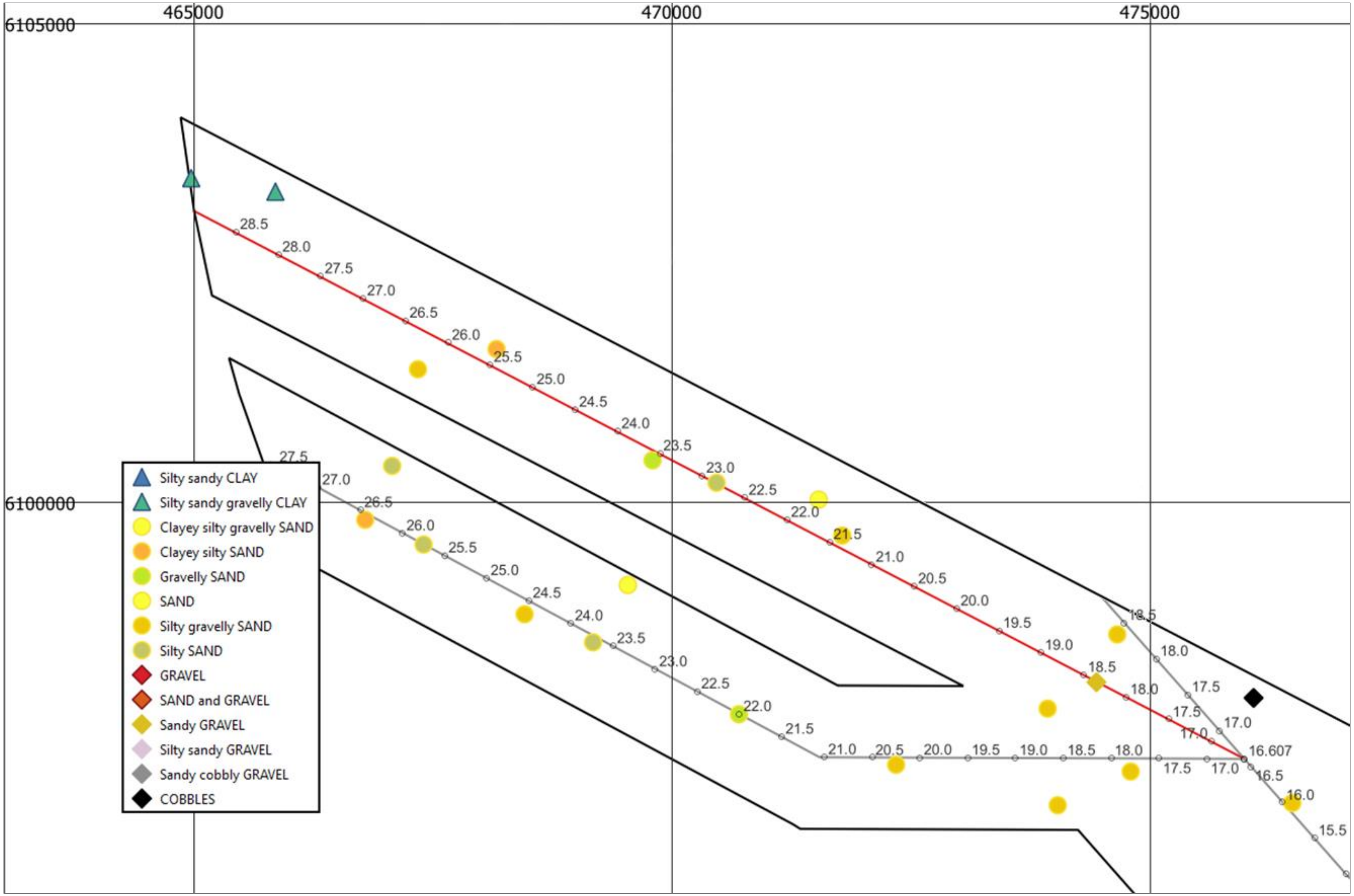


Figure 107 ERS Bornholm 1A grab sampling overview KP 16.607 to KP 28.995.

Table 38 ERS Bornholm 1A grab sampling overview KP 16.607 to KP 28.995

ID	KP	DCC	Depth	Detailed Description
971-ENE-GR-GS-118	18.348	-5	23.72	GRAVEL, 70% subangular to subrounded fine to coarse of various lithologies and 30% subangular fine to medium shell fragments, unsorted, very sandy, sand is medium to coarse, dark greyish brown and black, non-calcareous.
971-ENE-GR-GS-119	18.671	-485	22.18	SAND, fine to coarse, poorly sorted, slightly silty, slightly gravelly, gravel is 100% subangular fine of various lithologies, light greyish brown, non-calcareous.
971-ENE-GR-GS-120	21.415	122	33.71	SAND, fine to coarse, poorly sorted, slightly silty, gravelly, gravel is 80% subangular fine of various lithologies and 20% subangular fine shell fragments, occasional subrounded fine to medium gravel size pockets of dark grey fine sand, greyish brown, non-calcareous.
971-ENE-GR-GS-121	21.808	346	34.87	SAND, fine to medium, sorted, occasional subrounded fine to medium gravel size pockets of black fine sand, brownish grey, non-calcareous.
971-ENE-GR-GS-122	22.834	-1	35.97	SAND, fine to medium, poorly sorted, slightly silty, frequent subrounded fine to medium gravel size pockets of black fine sandy silt, greyish brown, non-calcareous.
971-ENE-GR-GS-123	23.539	-103	37.29	SAND, fine to coarse, poorly sorted, slightly gravelly, gravel is 100% subangular fine shell fragments, occasional subrounded fine to medium gravel size pockets of dark grey fine sand, greyish brown, non-calcareous.
971-ENE-GR-GS-124	25.513	175	39.87	SAND, fine to medium, sorted, slightly clayey, very silty, occasional subrounded fine gravel size pockets of black silt, dark brownish grey, non-calcareous.
971-ENE-GR-GS-125	26.148	-385	39.93	SAND, fine to coarse, poorly sorted, slightly silty, slightly gravelly, gravel is 100% subangular to subrounded fine to medium shell fragments, frequent subrounded fine to medium gravel size pockets of black fine sand, slight organic odour, dark greyish brown, non-calcareous.
971-ENE-GR-GS-126	28.332	561	44.53	CLAY, silty, very sandy, slightly gravelly, sand is fine to medium, gravel is 80% subangular to subrounded fine to coarse of various lithologies and 20% subrounded fine to medium shell fragments, brownish grey, slightly calcareous.
971-ENE-GR-GS-127	28.995	332	43.34	CLAY, very silty, sandy, slightly gravelly, sand is fine to coarse, gravel is 100% subangular fine shell fragments, frequent irregular pockets and lenses of black silt, slight organic odour, greyish brown, non-calcareous.

8.3.4 Surficial Geology

The surficial geology in this area varies from DIMICTON, GRAVEL and COARSE SAND, SAND and Muddy SAND. Glacial debris is prevalent between KP 16.607 and KP 19.417, with high density boulder fields. Areas of ripples occur within the areas of GRAVEL and coarse SAND, ripple crests are orientated north to south in line with the prevailing storm wave base. An area of trawl scars begins at KP 26.030 and continues to the end of the route, covering the width of the corridor. Detailed descriptions of the surficial geology are presented in Table 40 & Table 41.

8.3.5 Geotechnical Results

Ground Conditions

The geotechnical VC locations on the Bornholm1 (BH1A) route are shown below (Figure 108). Eleven VC were carried out with co-located CPT at every location. The investigated locations cover approximately 10.7 km, from KP 17.712 to KP 28.410.

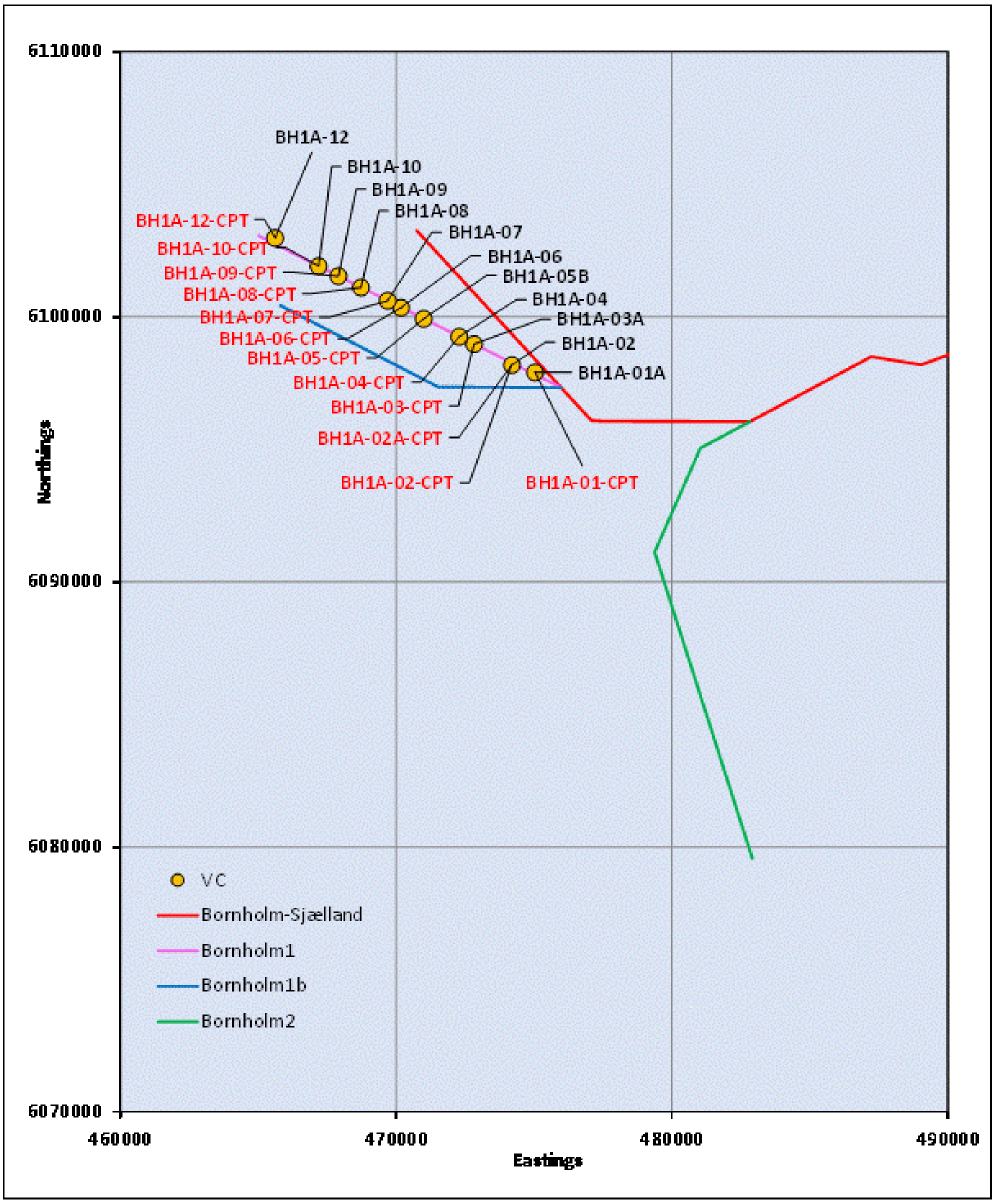
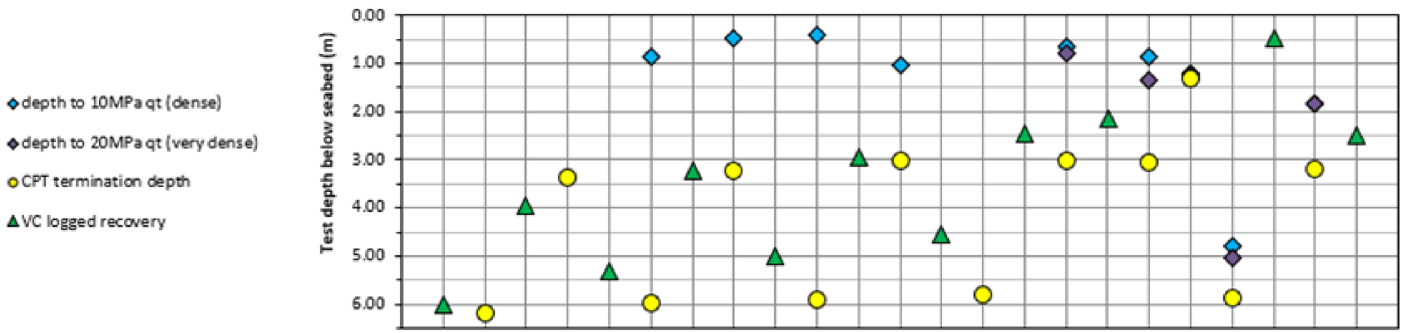


Figure 108 Geotechnical locations on the BH1A route, Part 1.

The assigned Seabed Sediment Index for the BH1A route is shown below (Figure 109).



Location ID	BH1A-12	BH1A-12	BH1A-10	BH1A-10	BH1A-09	BH1A-09	BH1A-08	BH1A-08	BH1A-07	BH1A-07	BH1A-06	BH1A-06	BH1A-05B	BH1A-05	BH1A-04	BH1A-04	BH1A-03A	BH1A-03	BH1A-02	BH1A-02A	BH1A-02	BH1A-01	BH1A-01A
Route KP	28.410	28.403	26.526	26.521	25.710	25.705	24.784	24.779	23.703	23.698	23.148	23.140	22.227	22.221	20.775	20.769	20.168	20.162	18.593	18.588	18.585	17.714	17.712
Location type	VC	CPT	VC	CPT	VC	CPT	VC	CPT	VC	CPT	VC	CPT	VC	CPT	VC	CPT	VC	CPT	CPT	CPT	VC	CPT	VC
VC penetration	6.00		4.00		6.00		3.80		5.00		3.80		4.55		2.75		2.40				0.75		2.50
VC recovery	6.00		3.97		5.30		3.23		5.00		2.94		4.55		2.47		2.15				0.47		2.50
CPT termination depth		6.18		3.36		5.98		3.22		5.92		3.00		5.80		3.02		3.06	1.32	5.86		3.20	
Depth to 10 MPa (dense)						0.86		0.48		0.42		1.02				0.64		0.86	1.22	4.78		1.82	
Depth to 20 MPa (very dense)																0.78		1.34	1.24	5.04		1.84	

Depth below seabed (m)																							
0.5	10	10	6	6	5	5	5	5	5	5	6	6	6	6	5	5	6	6	4	4	4	4	4
1.0	9	10	6	6	5	5	6	6	5	5	5	5	5	5	3	3	5	5	4	4		4	4
1.5	9	10	6	6	5	5	8	6	6	6	5	5	4	4	3	3	5	4	3	4		4	4
2.0	9	9	7	7	5	5	9	9	6	6	6	6	4	4	3	3	4	5		6		3	4
2.5	9	9	7	7	6	6	9	9	6	9	9	9	4	4	4	4		4		4		4	4
3.0	9	9	9	9	9	9	9	9	8	9	9	9	4	4		4				4		5	
4.0	9	9	9		9	9			8	8			4	8						4			
5.0	9	9			9	9			8	8				8						5			
6.0	9	9				9				8				8						4			

SSI	Typical Seabed Sediment
1	Bedrock (CHALK)
2	Dense to very dense Glacial Deposits
3	Very dense granular
4	Medium to high strength cohesive (Glacial Till)
5	Dense granular
6	Medium dense granular
7	Loose granular
8	Low to medium strength cohesive
9	Very low to low strength cohesive
10	Extremely low strength cohesive
0	Organic material *sensu stricto* , containing PEAT

Figure 109 Seabed Sediment Index for BH1A route, Part 1.

The ground conditions from the recovered VC across this route are variable. From KP 17.712 (location BH1A-01A) through to KP 22.227 (location BH1A-05B) the ground conditions are characterised by a varying thickness of SAND overlying Glacial Till (Figure 110). The SAND is typically fine to medium, slightly silty, varying to fine to coarse, slightly silty slightly to very gravelly at the seabed, with the gravel component being of various lithologies. The SAND is non-calcareous. Thin slightly silty sandy GRAVEL strata are rarely present, up to 0.15 m thick (location BH1A-04). The thickness of SAND overlying Glacial Till varies, from only 0.04 m at location BH1A-02, to 2.26 m depth at location BH1A-04. At location BH1A-01, the Glacial Till is present from the seabed level. The VC recovery across this part of the route was generally reduced.

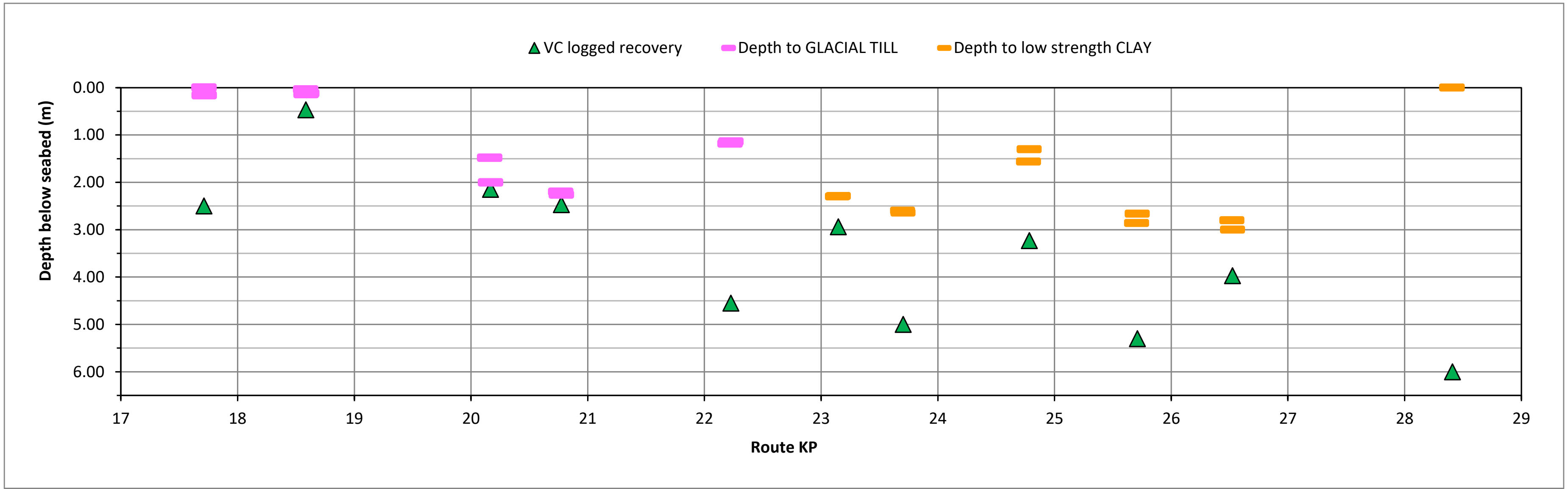


Figure 110 Plot of VC recovery and interpreted strata depths for route BH1A, Part 1.

The Glacial Till is a low plasticity, medium to high strength stiff to very stiff, very silty very sandy slightly gravelly CLAY. The gravel is entirely various lithologies. The CLAY is calcareous.

From KP 23.140 (location BH1A-06) through to the end of the route at KP 28.410 (location BH1A-12) Glacial Till is absent in the recovered material. At almost all locations granular material is present from seabed level, to a depth of 3.00 m, with the exception of location BH1A-12 (KP 28.410). The SAND is typically fine to medium, silty, locally slightly gravelly. In places the SAND is clayey, with thin laminae of silt and clay. The gravel is generally shell fragments close to the seabed, becoming various lithologies with increasing depth.

At all locations CLAY is present below the SAND, at depths from 1.30 to 3.00m. At location BH1A-12, CLAY is present from seabed level. The CLAY is extremely low to low strength very soft to soft, of intermediate to high plasticity and non- to slightly calcareous. The CLAY is slightly sandy silty to very silty, locally slightly gravelly, with the gravel component being various lithologies.

Laboratory Test Data

A summary table below (Table 39) details the quantities of laboratory testing carried out on material from the route BH1A.

Table 39 Summary table of laboratory testing for the route BH1A, Part 1.

Type		Quantity
Moisture Content (MC)		45
Bulk Density (BD)		37
Dry Density (DD)		37
Particle Density (PD)		5
Min/Max Dry Density (MM)		4
Atterberg Limits (AT)		8
Particle Size Distribution Analysis (PSD)		21
PSD sedimentation (SED)		16
Shear strength (Lab Vane, LV)		20
Shear strength (Torvane, TV)		28
Shear strength (Torvane, offshore TVO)		10
Shear strength (Pocket Pen., offshore PPO)		3
Shear strength (Unconsolidated undrained triaxial, UU)		2
Thermal (TR)		6
Chemical tests (CHEM)	Organic matter content:	-

A plot below shows the PSD data plotted schematically, in KP order, from the BH1A route (Figure 111). This shows the presence of CLAY in the tested material, with Glacial Till at locations BH1A-01A to BH1A-05B having total fines contents from 51 to 66 %. Gravel contents in the Glacial Till are generally low, in the range 1 to 19 %, with sand contents of 30 to 37 %. In the low strength, intermediate to high plasticity CLAY from location BH1A-06 onwards, total fines contents are 79 to 98 %. Gravel is almost absent in the tested samples, whilst sand contents are 2 to 18 %. In the tested granular material, SAND contents range from 56 to 98 %, with gravel contents from 0 to 42 %. Total fines contents are generally <30 %, with a single tested very clayey very silty SAND having a high total fines content of 42 %.

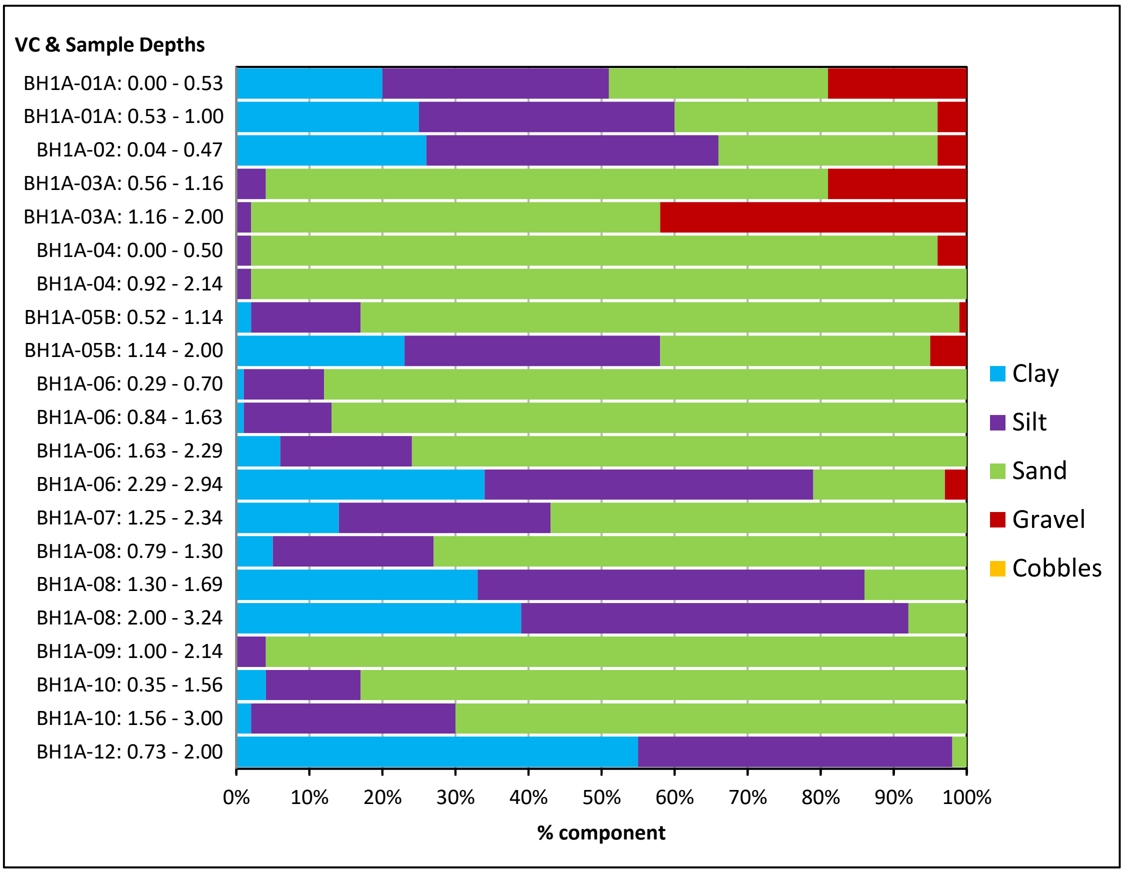


Figure 111 Schematic summary plot of PSD data for route BH1A, Part 1.

PSD data for the tested material are also shown below (Figure 112).

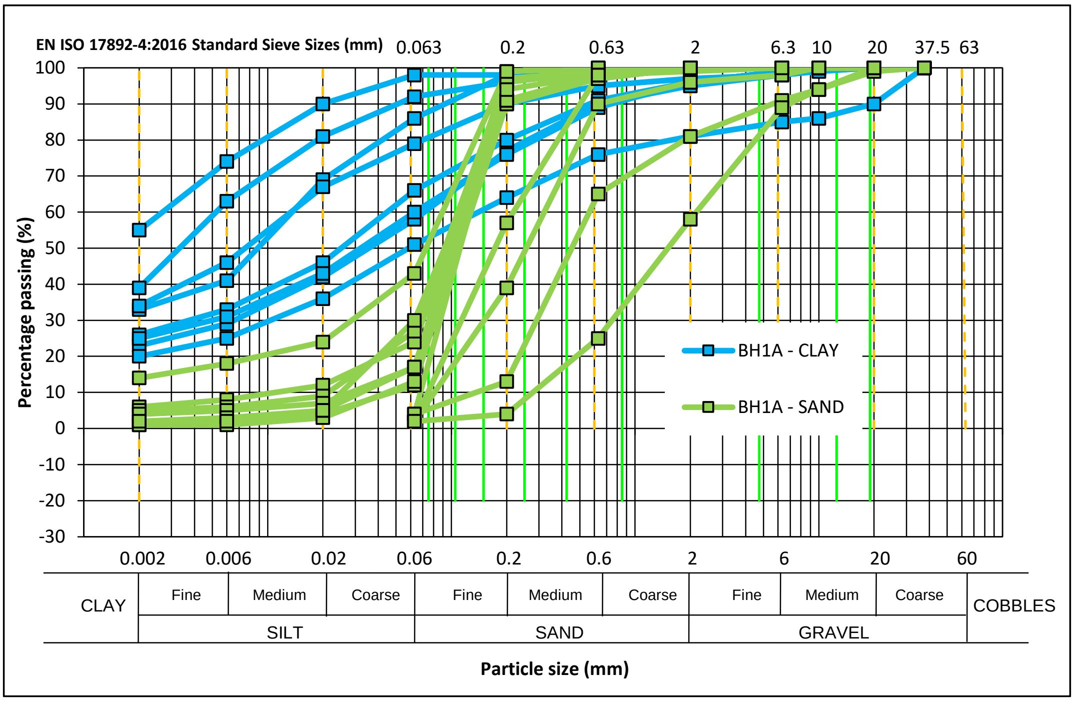


Figure 112 PSD plots for the tested material from route BH1A, Part 1.

Laboratory test data are summarised below for granular material (Figure 113). The tested material has bulk and dry densities in the ranges from 1.57 to 2.02 Mg/m^3, and 1.39 to 1.65 Mg/m^3, respectively. There is a general increase in density with depth.

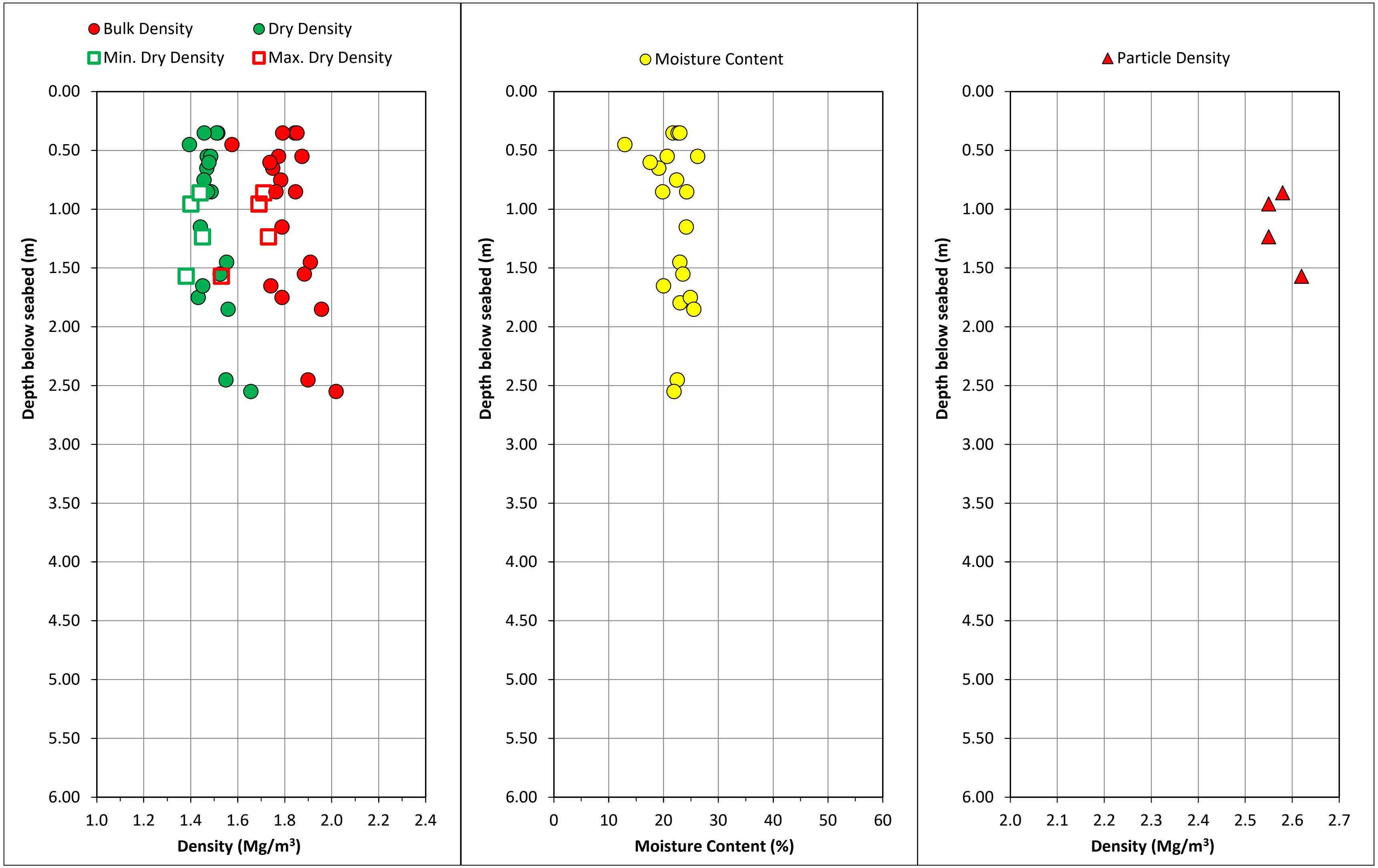


Figure 113 Laboratory test data for granular material, route BH1A, Part 1.

Min and max dry densities are in the close ranges 1.38 to 1.45 Mg/m^3, and 1.53 to 1.73 Mg/m^3, respectively. Particle densities are in the range 2.55 to 2.62 Mg/m^3. Moisture contents in granular material are in the range 13 to 26 %.

Laboratory density test data are summarised below for cohesive material (Figure 114). Bulk and dry densities for Glacial Till are in the ranges from 2.01 to 2.23 Mg/m^3, and 1.66 to 1.94 Mg/m^3, respectively. In lower strength CLAY bulk and dry densities are lower, in the ranges 1.39 to 1.95 Mg/m^3, and 0.88 to 1.54 Mg/m^3, respectively.

Determined moisture contents are also shown below for cohesive material. Glacial Till typically has moisture contents in the range 14 to 21 %, whilst lower strength CLAYs are more variable, from 24 to 83 %.

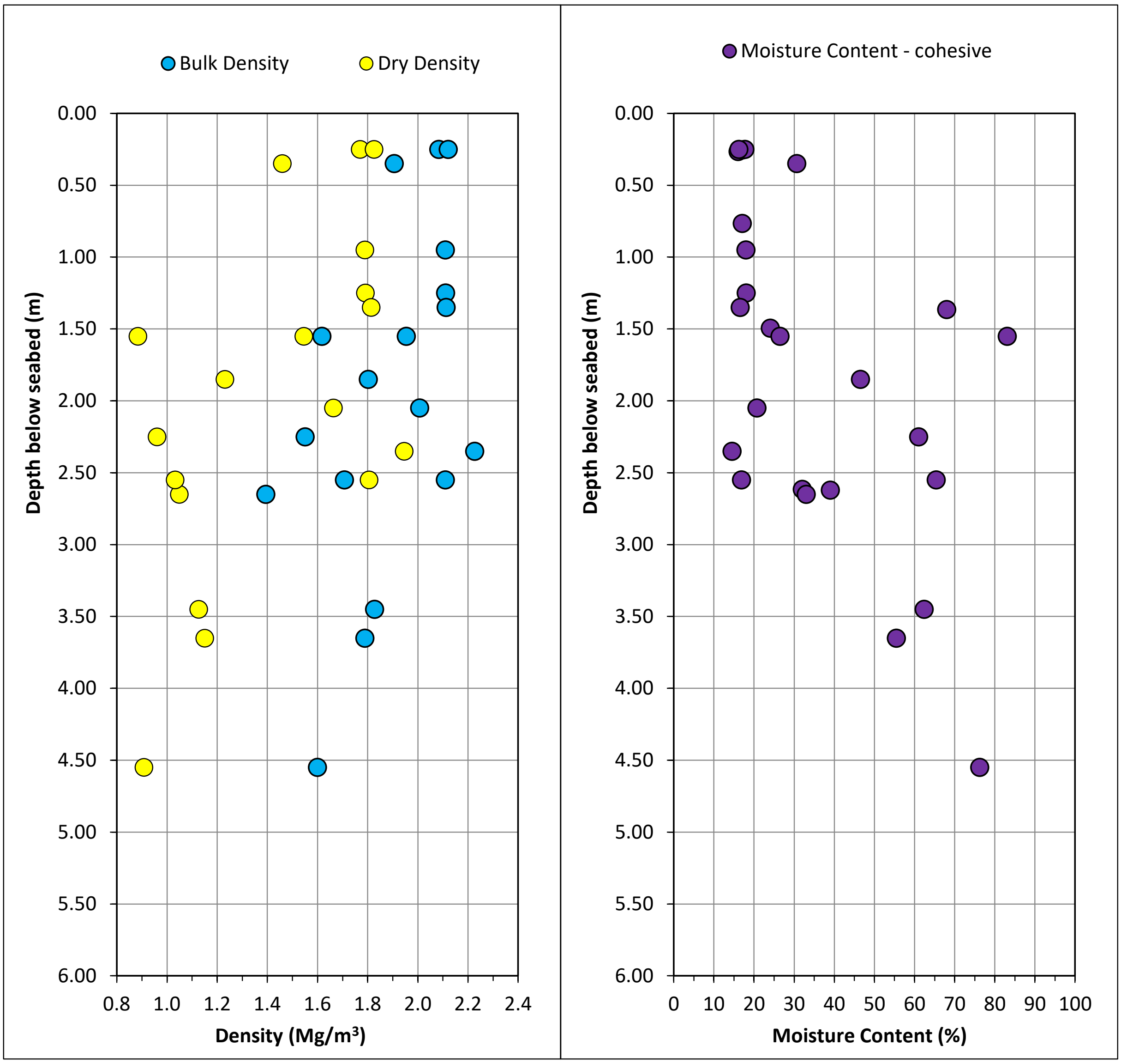


Figure 114 Laboratory test data for cohesive material, route BH1A, Part 1.

Eight Atterberg Limit tests were carried out on material from this route. The data are plotted below (Figure 115). Three of the tests returned as CLAY of low plasticity which represents the Glacial Till. Lower strength CLAY returned as intermediate to high plasticity.

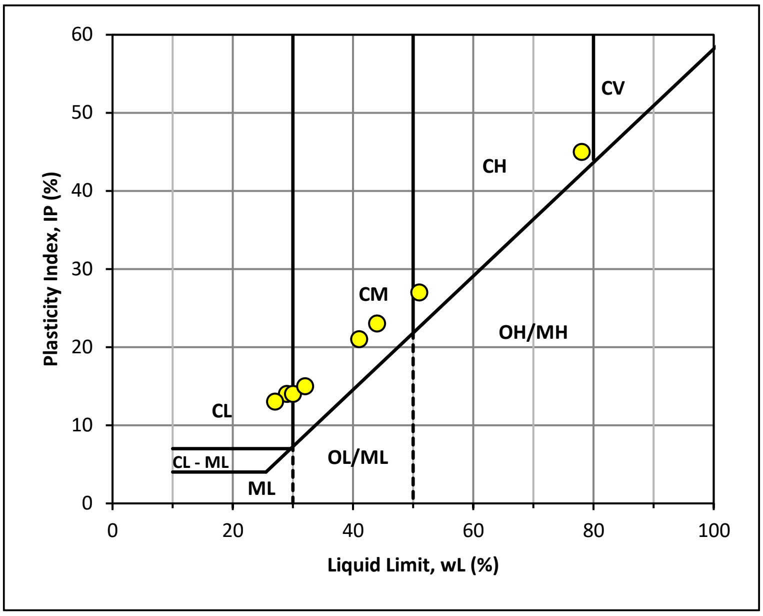


Figure 115 Plasticity Chart for route BH1A, Part 1.

Laboratory shear strength data for cohesive material are shown below (Figure 116). The data indicates two groups. Stiff to very stiff CLAY, considered to be Glacial Till are typically in the medium to high strength ranges, whilst non-glacial CLAY is generally extremely low to low strength. In most cores, there is a general increase in undrained shear strength with increasing depth.

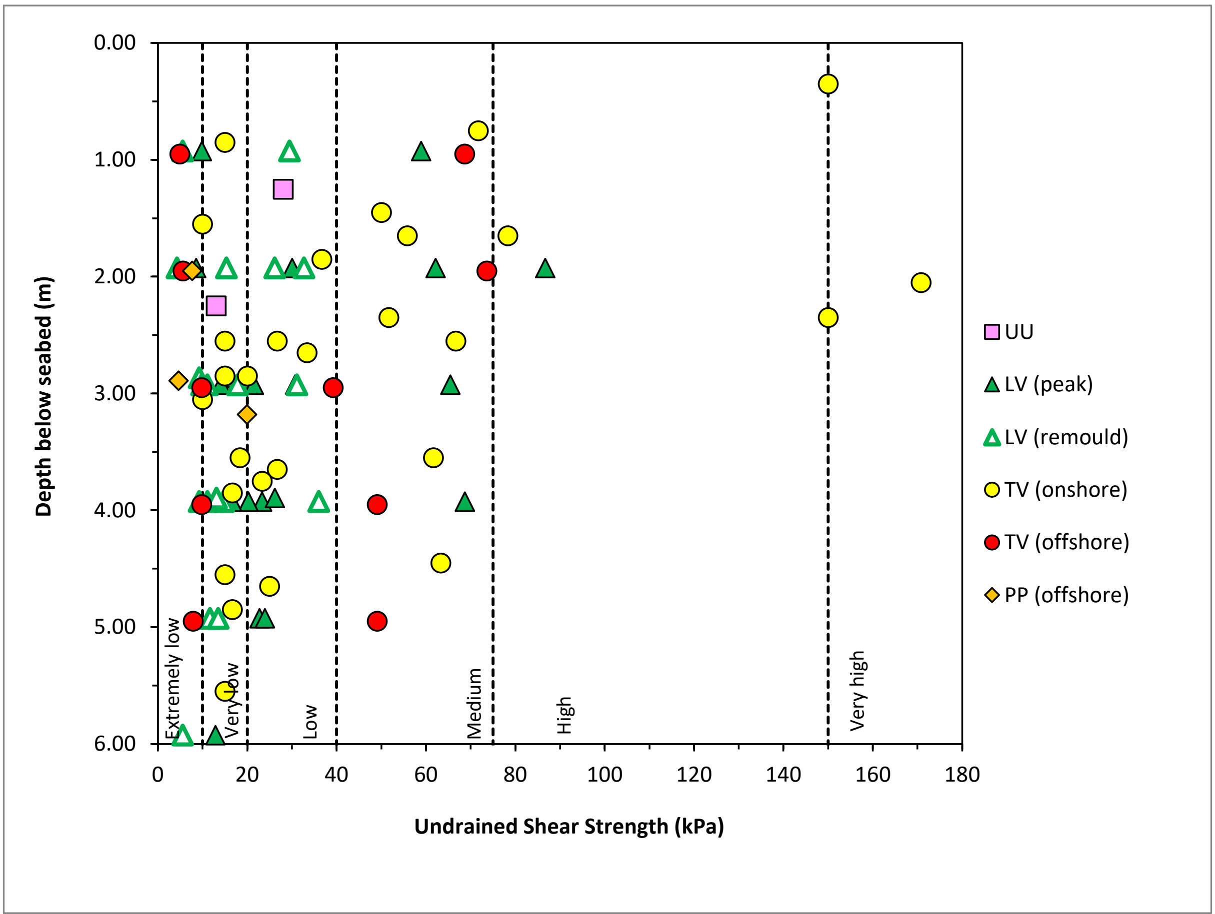


Figure 116 Laboratory shear strength data for route BH1A, Part 1.

A summary of the acquired thermal resistivity data is shown below (Figure 117). The data for both cohesive and granular material are mostly in the range 0.44 to 0.49 K m/W, with the low values in Glacial Till reflecting the low moisture contents. A single CLAY from location BH1A-01A does however, have a higher resistivity value of 0.74 K m/W.

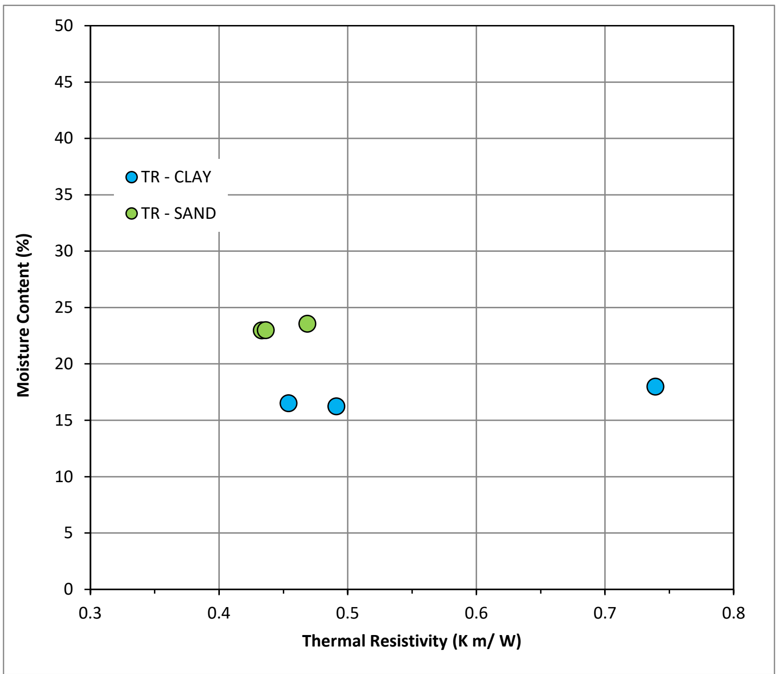


Figure 117 Summary of thermal data for route BH1A, Part 1.

Cone Penetration Testing

Twelve CPT were carried out at the eleven locations on this route. A single re-attempt was carried out at location BH1A-02, due to initial shallow refusal of 1.32 m depth. Glacial Till was encountered in the first part of this route (KP 17.714 to KP 22.221), at varying depths from seabed level to 0.80 m to 2.26 m (see Figure 118). Penetration in the Glacial CLAY was generally good, with some dense to very dense granular layers visible within TILL strata (KP 17.714 to KP 18.588). Some dense to very dense granular material overlying the Glacial Till was seen at KP 20.162 to KP 20.775.

In the second part of the route where granular material overlies low strength CLAY, the CPT penetration was good with all tests reaching the required depths. Some dense granular material was seen at depths from 0.42 to 1.02 m at KP 23.140 to KP 23.705. The measured cone responses were good with the resulting sediment interpretation being considered accurate and often close to the ground conditions in the co-located VC locations.

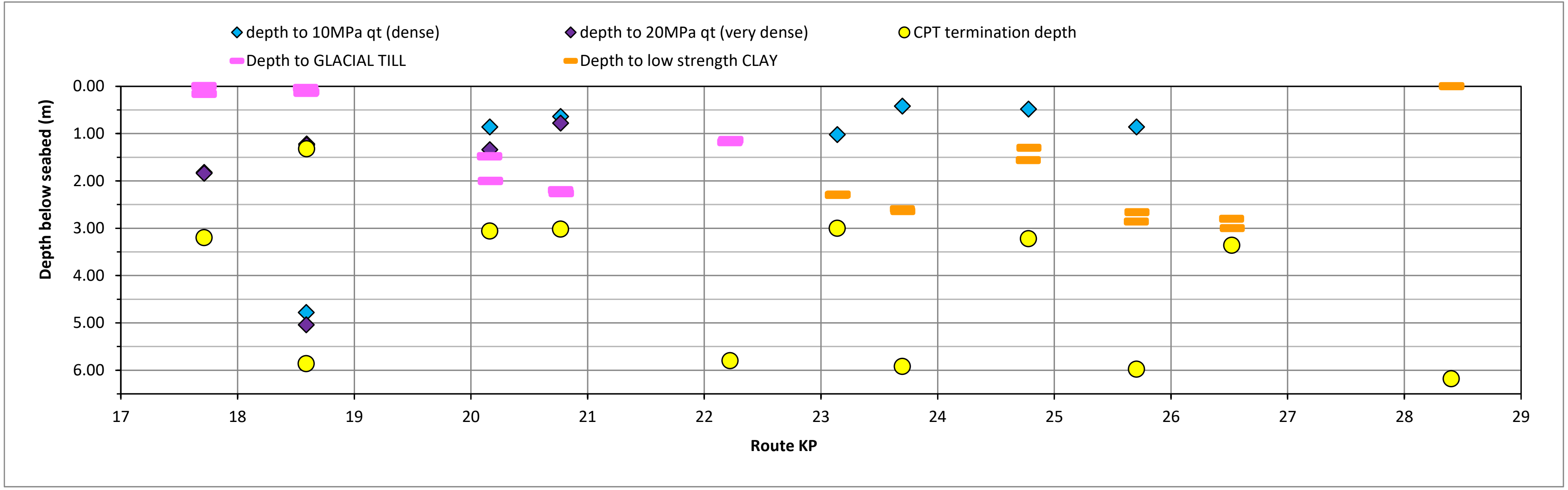


Figure 118 Plot of CPT test depths and interpreted stratum depths for route BH1A, Part 1.

Measured cone resistances from the CPT are shown below (Figure 119). Granular material overlying CLAY along the entire route shows high tip resistances in the upper 3.00 m depth range. Those tests where Glacial Till was encountered beneath the granular material show tip resistances in the range 2 to 4 MPa, whilst in the low strength CLAY the tip resistances are reduced, typically < 1 MPa.

Figure 120 below shows the calculated relative density profiles from the CPT data. The granular material is typically medium dense to dense at shallow depths, < 2.00 m, occasionally very dense. Figure 120 also shows the calculated shear strength profiles for the encountered CLAY, at an Nkt factor of 17.5. For the Glacial Till shear strengths are high, typically > 50 kPa. In the low strength CLAY calculated shear strengths are lower, generally in the range 10 to 30 kPa. The laboratory derived shear strength data are broadly consistent with the spread of CPT derived data from the two different types of CLAY encountered.

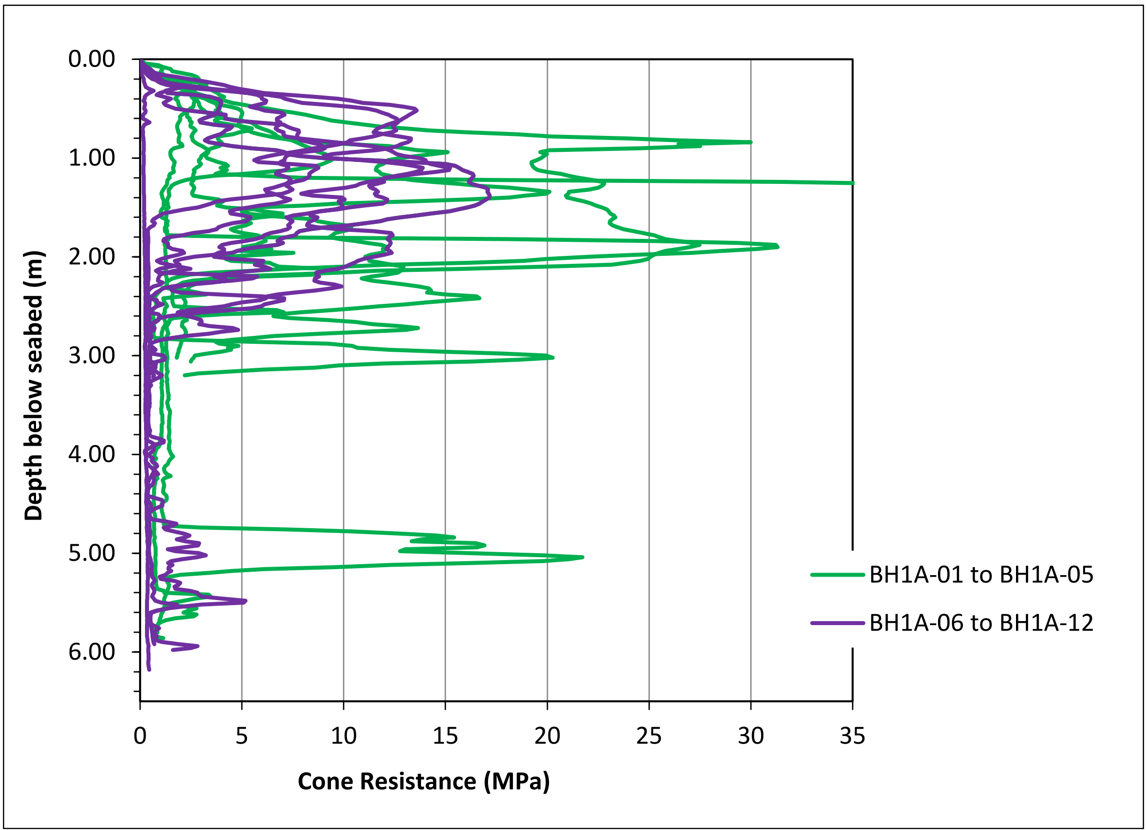


Figure 119 Plot of cone tip resistances for route BH1A, Part 1.

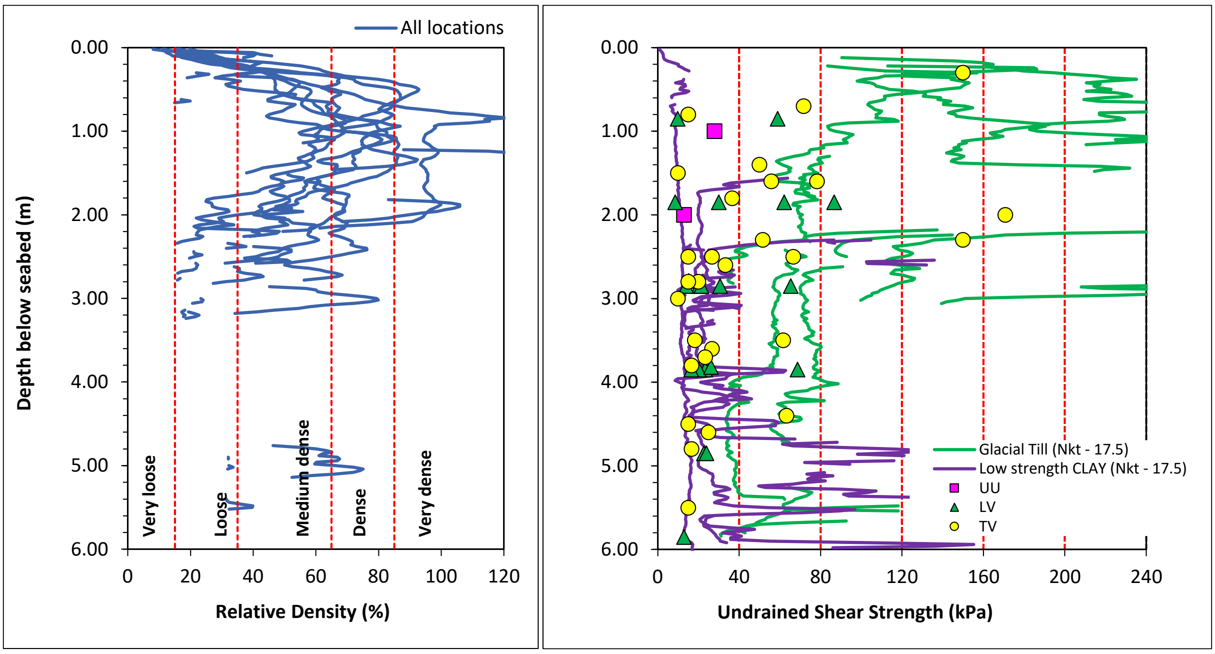


Figure 120 Plot of CPT derived parameters for route BH1A, Part 1.

8.3.6 Shallow Geology

A detailed description of the changes in shallow geology observed along the proposed route ERS Bornholm 1A can be found in the shallow geology section presented in Table 40 and Table 41.

A number of sedimentary units were identified in the sub-surface geology along this route, down to a maximum depth of 12.6 m below the seabed. The uppermost units along the majority of the route (KP 19.464 to KP 28.666) have been confirmed to be SANDs based on the geotechnical sampling results, with Glacial CLAYs below this. However, at the start and end of the route (KP 16.607 to KP 19.464, and KP 28.666 to KP 28.945) no upper SAND units are present and CLAYs of varying stiffness are observed up to the seabed.

The uppermost, and youngest, unit along the majority of the route (KP 19.464 to KP 28.008) has been confirmed to be recent marine silty SAND based on the geotechnical sampling results, with some gradational lateral variation from silty gravelly SAND to gravelly SAND. The unit is predominantly classified as silty SAND or gravelly SAND on the profiles for simplification, with details of localised variations documented in Section 8.3.7. The base horizon for this unit (P1_H10) is mostly flat and present from depths ranging from 0 - 2.0 m below seabed. These sediments are often acoustically transparent internally with occasional low-high amplitude internal reflectors interpreted to represent local changes in grain size from silty to gravelly, or vice versa. Where possible on the CL, these have been identified by the internal reflectors P1_H05i and P1_H06i.

Below this horizon are two further SAND units, each with distinctively different internal characteristics, as well as having different spatial distributions along the route. The first SAND unit (P1_H20) predominantly represents a Late/Post Glacial washdown/meltwater silty gravelly SAND and is spatially distributed along the steeper sloping section in the centre of the route from KP 19.522 to KP 22.302. The unit is predominantly classified as silty SAND on the profiles for simplification, with details of localised variations documented in Section 8.3.7. This unit varies in thickness along the route, with maximum thickness approximately 2.3 m, and is abundant in internal reflectors with varying in length, orientation, and amplitude. It also has a mostly flat, high amplitude basal reflector which separates it from the sediments below.

The other SAND unit has been identified as P1_H30. This is present in the deeper water section from the centre of the route at KP 22.634 to westerly end of the route at KP 28.666. The unit is uniquely identifiable due to the abundance of internal high amplitude parallel reflectors visible in the SBP data, as well as its undulating basal reflector. The geotechnical sampling results confirm that these internal parallel reflectors are very closely to closely spaced thin to thick laminae of Late/Post Glacial clayey SILT. The unit is predominantly classified as silty SAND on the profiles for simplification, with details of localised variations documented in Section 8.3.7. This unit varies in thickness, but is predominantly between 0.7 m to 3.0 m thick along this route.

An overview of the interpreted SAND units along this route can be seen in Figure 121.

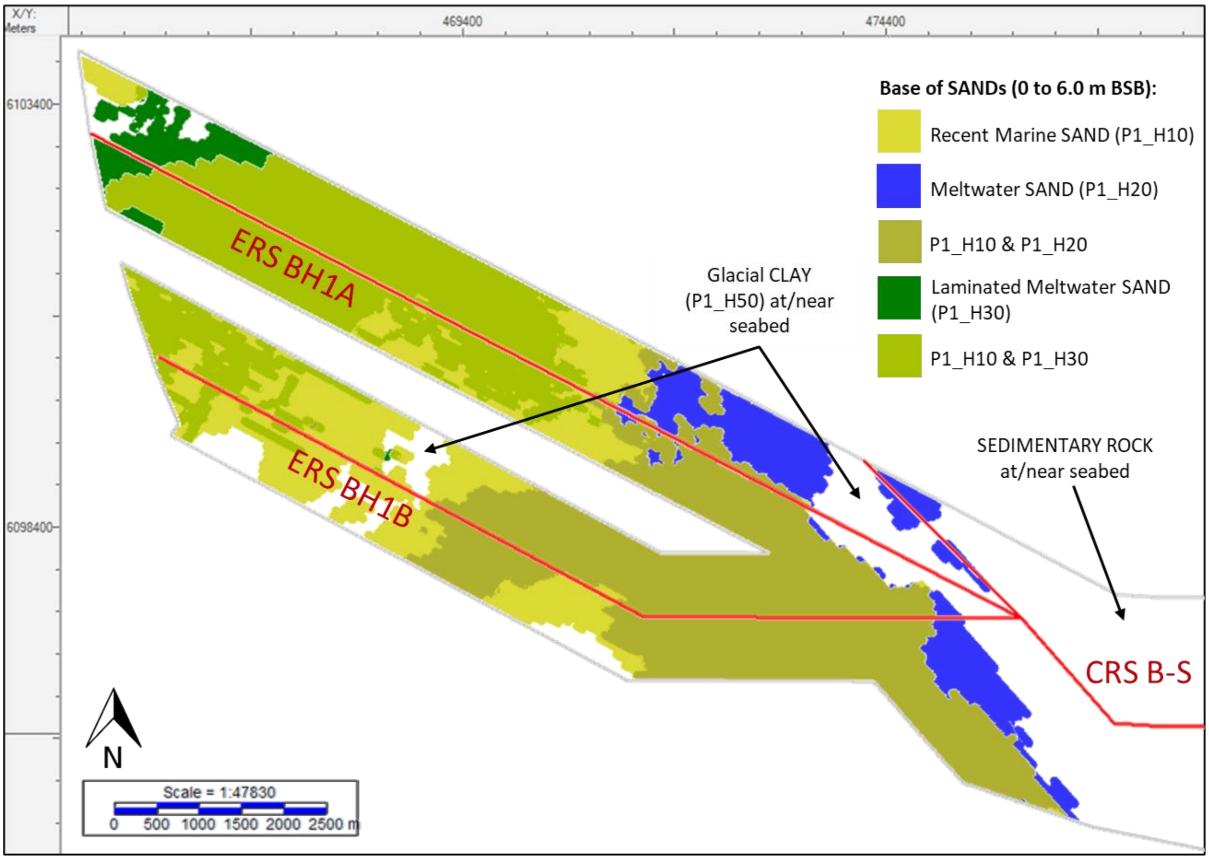


Figure 121 Overview map of the distribution of interpreted SAND units along ERS Bornholm 1A KP 16 to KP 19.

Below these SAND units, a Glacial CLAY unit (P1_H50) is present. The Glacial CLAY unit has a slightly silty, sandy and gravelly composition which is variable across the route, as documented in Section 8.3.7, but not populated on the profiles for the purpose of simplification. The geotechnical results confirm that the Glacial CLAY unit is predominantly stiff to very stiff, but between KP 22.992 to KP 28.995 the CLAY is interpreted to be of Late Glacial meltwater origin and very soft to soft for the majority of the uppermost 2.5 to 5.0 m of the unit. Where possible, these change in stiffness properties have been delineated by an internal reflector (P1_H40i) on the CL only.

The P1_H50 Glacial CLAY unit predominantly displays a low to high amplitude chaotic internal structure in the SBP data, but in places high amplitude internal reflectors and laminations can be observed. From KP 16.607 to KP 25.187, the base of the Glacial CLAY can be observed as a non-distinct low amplitude erosional surface interpreted to lie on top of Upper Cretaceous SEDIMENTARY ROCK. From KP 25.187 to the end of the route at KP 28.995, the base of the Glacial CLAY unit is not able to be defined as the thickness of the unit appears to increase beyond the depth of SBP penetration. In some places this Glacial CLAY unit is visible up to the seabed, where a GRAVEL and coarse SAND and/or TILL/DIAMICTION are observed. Caution should therefore be taken where this Glacial CLAY unit is encountered as geohazards such as boulders may be present in the shallow geology but not able to be identified in the SBP data.

An overview of the distribution of the interpreted Glacial CLAY along this route can be seen in Figure 122.

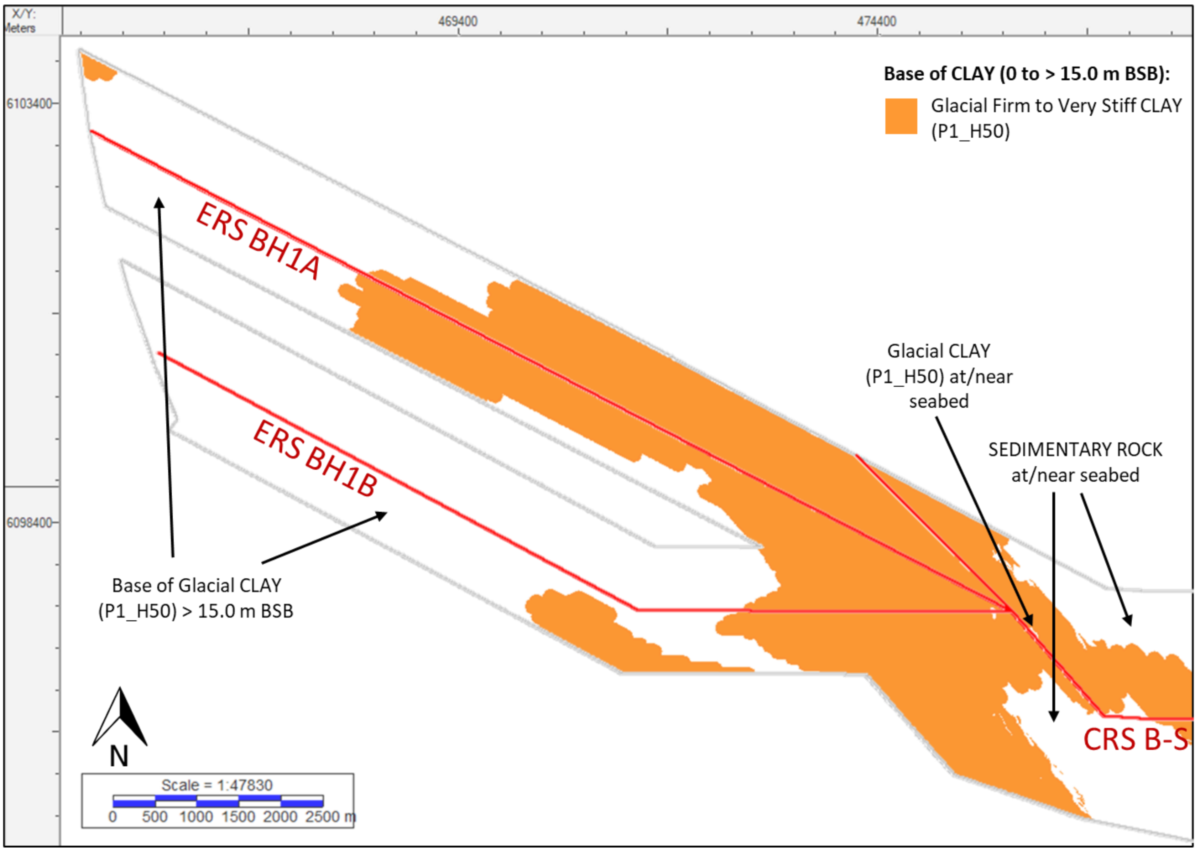


Figure 122 Overview map of the distribution of interpreted Glacial CLAY along ERS Bornholm 1A KP 16 to KP 29.

8.3.7 Detailed Description

A detailed presentation of the conditions and features of ERS Bornholm 1A Route are shown in Table 40 & Table 41 and associated figures.

Table 40 ERS Bornholm 1A detailed description for alignment chart 103971-ENN-OI-SUR-DWG-P1BH1A001 (KP 16.607 – 25.097).

Alignment Chart 103971-ENN-OI-SUR-DWG-P1BH1A001 (KP 16.607 – 25.097)	
Description (including min/max depth BSB to base of unit)	**Remark**
Bathymetry: Undulating seabed from KP 16.607 to KP 19.218. Flat topped sandbanks with areas of deeper rippled seabed from KP 19.218 to KP 24.250 (Figure 123). Shallower section along southern edge of corridor between KP 16.607 and KP 20.421, due to a sandbank. From KP 24.250 to KP 25.097 the seabed exhibits a very gentle gradient. Overall, very gently deepening seafloor westward.	Total depth range = 17.41 m Maximum slope of 10.16° at KP 17.268. This is on a boulder situated on the route. Minimum depth along route 21.88 m at KP 17.266. Maximum depth along route 39.29 m at KP 24.849.
Surficial geology: The seabed between KP 16.607 and KP 18.527 is dominated by DIAMICTON in the centre of the corridor. On the north of the corridor, GRAVEL and COARSE SAND is present. On the south of the corridor there is a mix of GRAVEL and COARSE SAND and SAND (Figure 124). Between KP 18.527 to KP 20.493 the seabed is composed of GRAVEL and COARSE SAND. Between KP 20.493 to KP 22.027 the seabed is predominantly composed GRAVEL and COARSE SAND with patches of SAND (Figure 125). Between KP 22.027 to KP 25.097 the seabed sediment transitions to predominantly SAND, patches of Gravel and coarse SAND still occur within this area. Glacial debris is prevalent between KP 16.607 and KP 19.417, with high density boulder fields. Boulders occur within the rest of the area, generally these are isolated but some small areas of low, intermediate and high-density boulder fields occur. Areas of ripples occur within the areas of GRAVEL and coarse SAND, ripple crests are orientated north to south in line with the prevailing storm wave base. An area of trawl scars covering the entire corridor begins at KP 26.030.	**Infrastructure:** Utility ID 11 (cable, Bornholm-Rugen) detected MAG datasets, not detected on SSS or MBES dataset. Crossing route at KP 19.216. Utility ID 08 (Pipeline, Baltic Pipe) detected on SSS and MAG datasets, runs parallel to the southern boundary of the corridor from KP 19.564 (Figure 125). **Debris:** Unknown linear feature (Unknown 03) detected on MAG data set, not detected on SSS and MBES datasets or WPD. Crossing route at KP 28.783. S_GR_WPA_B1C_0025 (Correlated with MAG anomaly) KP 18.347 DCC 1.19 m. **Wrecks:** S_GR_WPA_B1D_2037, KP 26.894 DCC 548.79 m (Figure 136 Wreck S_GR_WPA_B1D_2037. MBES hillshade and SSS mosaic) S_GR_WPA_B1D_2045, KP 26.561 DCC -249.11 m (Figure 137) S_GR_WPA_B1D_2064, KP 27.919 DCC 305.61 m (Figure 138) **Grab Samples:** 971-ENE-GR-GS-075 971-ENE-GR-GS-076

Alignment Chart 103971-ENN-OI-SUR-DWG-P1BH1A001 (KP 16.607 – 25.097)	
Description (including min/max depth BSB to base of unit)	**Remark**
	971-ENE-GR-GS-077 971-ENE-GR-GS-078 971-ENE-GR-GS-108 971-ENE-GR-GS-118 971-ENE-GR-GS-119 971-ENE-GR-GS-120 971-ENE-GR-GS-121 971-ENE-GR-GS-122 971-ENE-GR-GS-123
Shallow Geology: KP 16.607 to KP 19.464 (Figure 126 and Figure 127): At the start of the route, firm to stiff to very stiff, silty, slightly sandy, slightly gravelly Glacial CLAY (P1_H50) is present between 0.0 to 7.5 m BSB. The base of Glacial CLAY (P1_H50) is an undulating reflector, with SEDIMENTARY ROCK interpreted to be present below, with its base beyond extent of the SBP data. Geotechnical results show thin (< 0.1 m) veneers of GRAVEL and coarse SAND are present in places at seabed (VC BH1A-02A), though this is unable to be resolved the on SBP data. KP 19.464 to KP 22.634 (Figure 128 and Figure 129): This section of the route predominantly contains SAND from 0 – 2.3 m BSB. The SANDs have been separated into a recent marine silty slightly gravelly SAND unit (P1_H10) from the seabed to a maximum of 1.1 m BSB, and a late/post glacial meltwater slightly silty, slightly gravelly SAND (P1_H20) that is present either below P1_H10 or up to the seabed to a maximum depth of 2.3 m BSB. The lower SAND unit is abundant in high amplitude internals reflectors with varying length, orientation and amplitude. Below the SANDs, stiff to very stiff, silty, slightly sandy, slightly gravelly Glacial CLAY (P1_H50) is present to maximum extents of between 0.5 m to 8.5 m BSB. Below the undulating basal reflector of the Glacial CLAY, SEDIMENTARY ROCK is present.	**Vibrocores and CPTs:** BH1A-01A and BH1A-01-CPT BH1A-02 and BH1A-02A-CPT BH1A-03A and BH1A-03-CPT BH1A-04 and BH1A-04-CPT BH1A-05B and BH1A-05-CPT BH1A-06 and BH1A-06-CPT BH1A-07 and BH1A-07-CPT BH1A-08 and BH1A-08-CPT

Alignment Chart 103971-ENN-OI-SUR-DWG-P1BH1A001 (KP 16.607 – 25.097)	
Description (including min/max depth BSB to base of unit)	**Remark**
KP 22.634 to KP 25.097 (Figure 130 and Figure 131): Recent marine slightly silty, slightly gravelly SAND (P1_H10) is present from 0 – 1.8 m BSB. The unit contains occasional internal reflectors, often of comprising of GRAVEL (P1_H05i and P1_H06i). Below the recent marine SAND is a late/post glacial silty SAND unit (P1_H30) with closely spaced thin to thick laminae of clayey SILT. This has a highly undulating basal reflector which extends to a maximum depth of 3.5 m BSB. Below these predominantly SAND units, Late Glacial to Glacial CLAYs are present, which increase in strength with depth. The shallowest CLAYs are Late Glacial very soft to soft, silty, slightly sandy meltwater CLAY (P1_H40i), which has been interpreted along the CL in correlation with the geotechnical data, undulating to a maximum of 5.4 m BSB. Stiff Glacial CLAY (P1_H50) is present below this, with the base of CLAY is present at approximately 10.5 m BSB, with SEDIMENTARY ROCK below.	

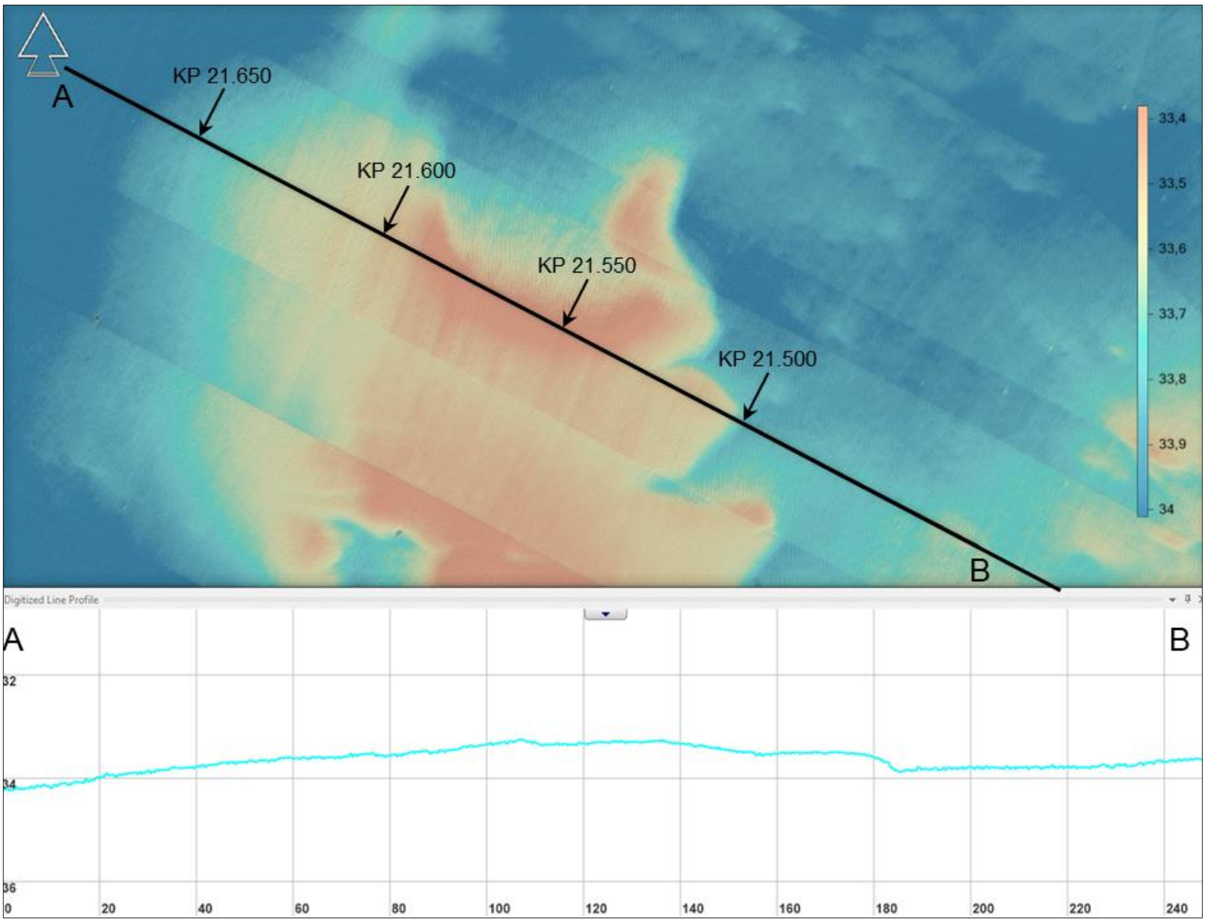


Figure 123 Flat topped banks surrounded by rippled seabed. Depth convention in NaviModel is positive down; vertical exaggeration of profile x7.

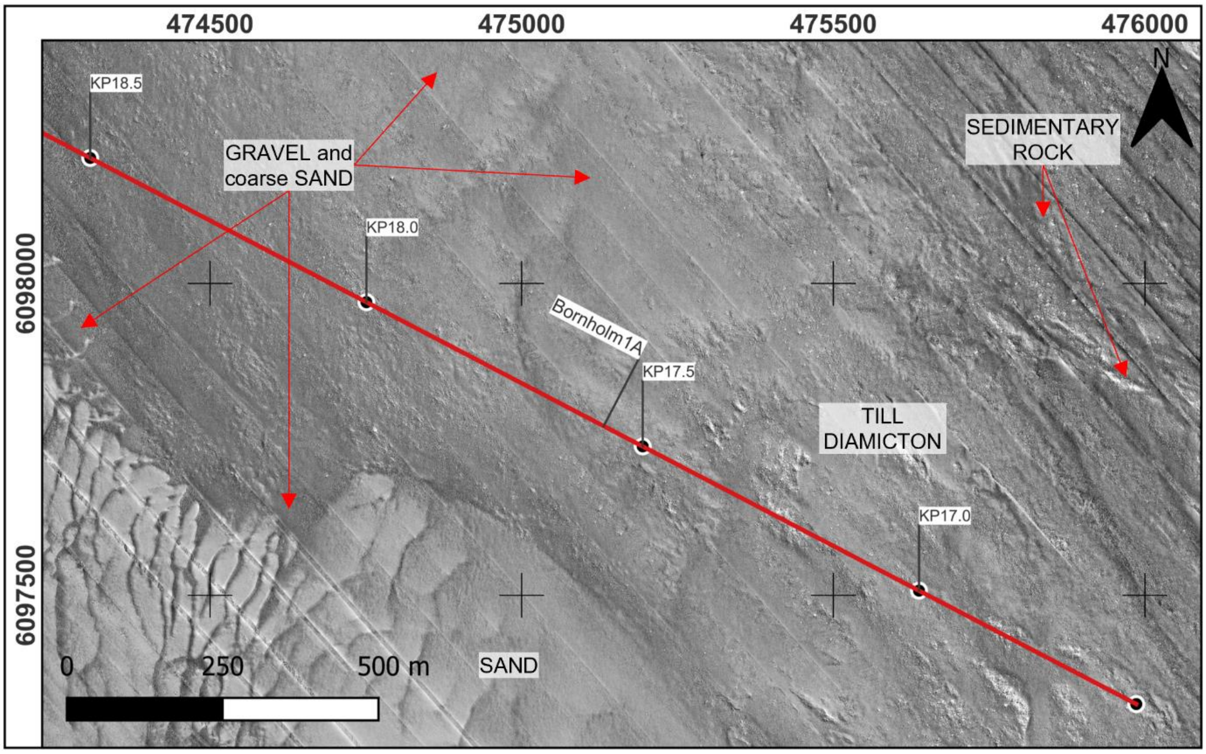


Figure 124 Overview of surficial geology from KP 16.6 to KP 18.6 as seen on SSS.

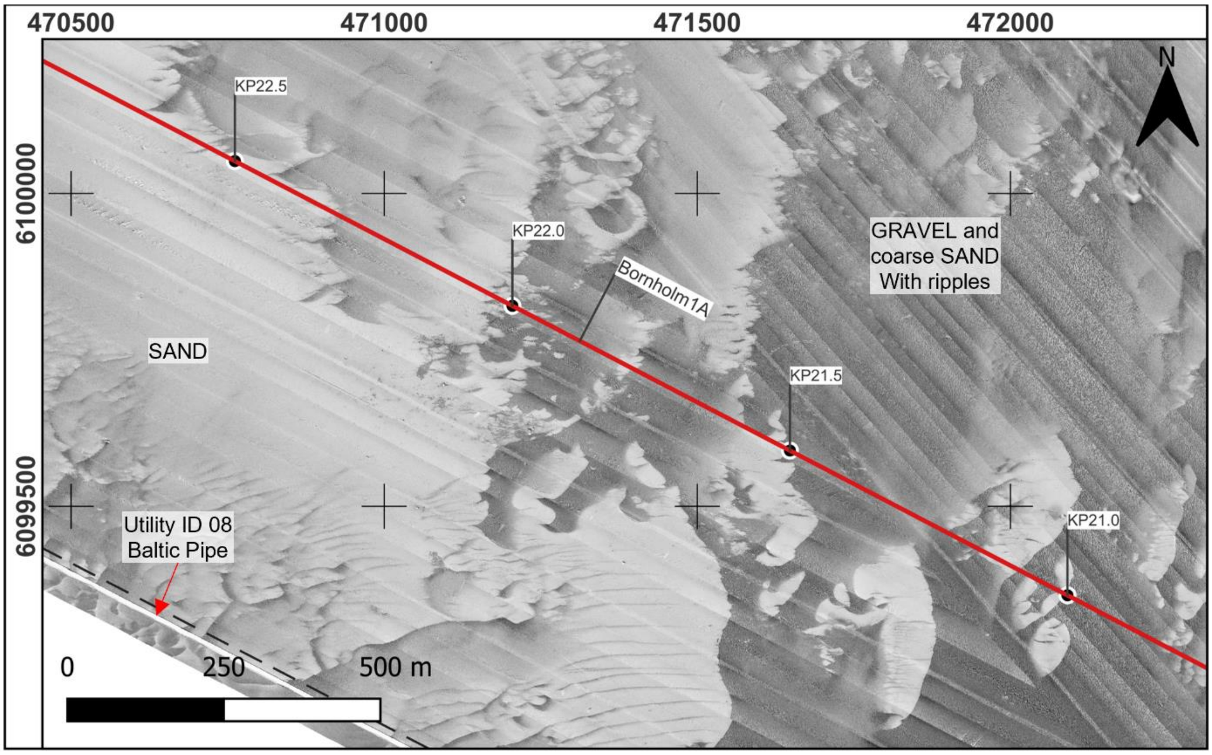


Figure 125 Overview of surficial geology from KP 20.7 to KP 22.7 as seen on SSS.

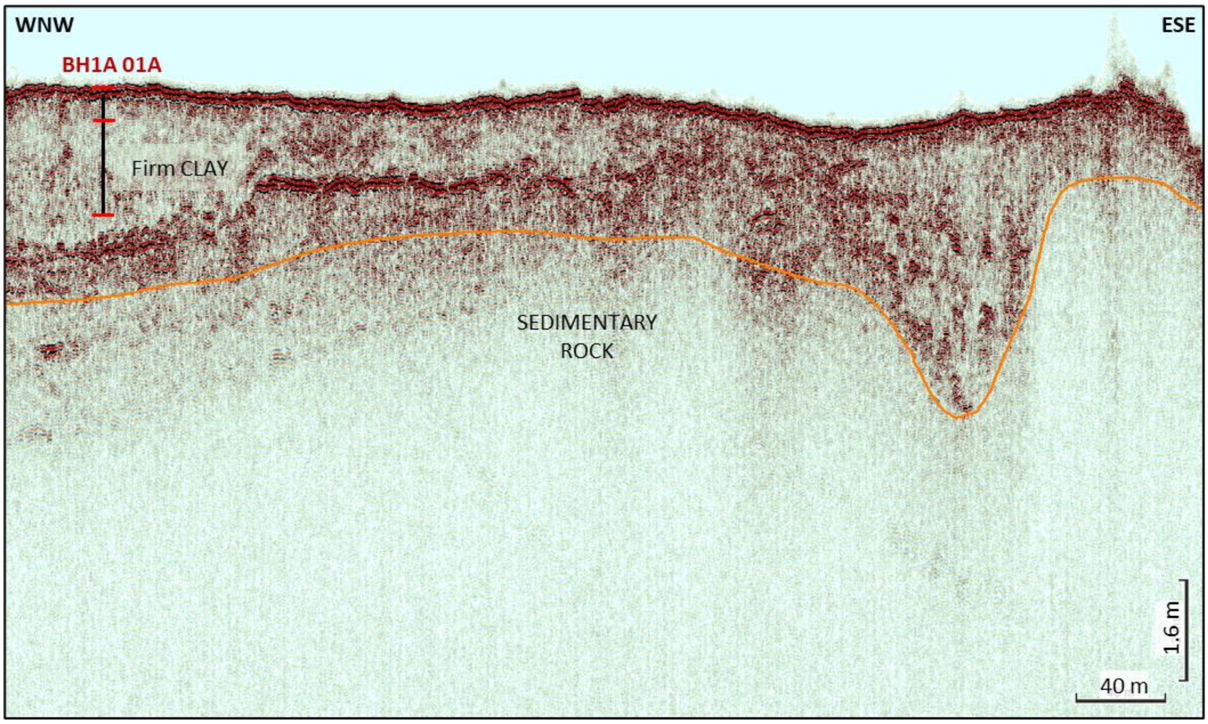


Figure 126 Innomar SBP data example from KP 17.756 (WNW) to KP 17.223 (ESE).

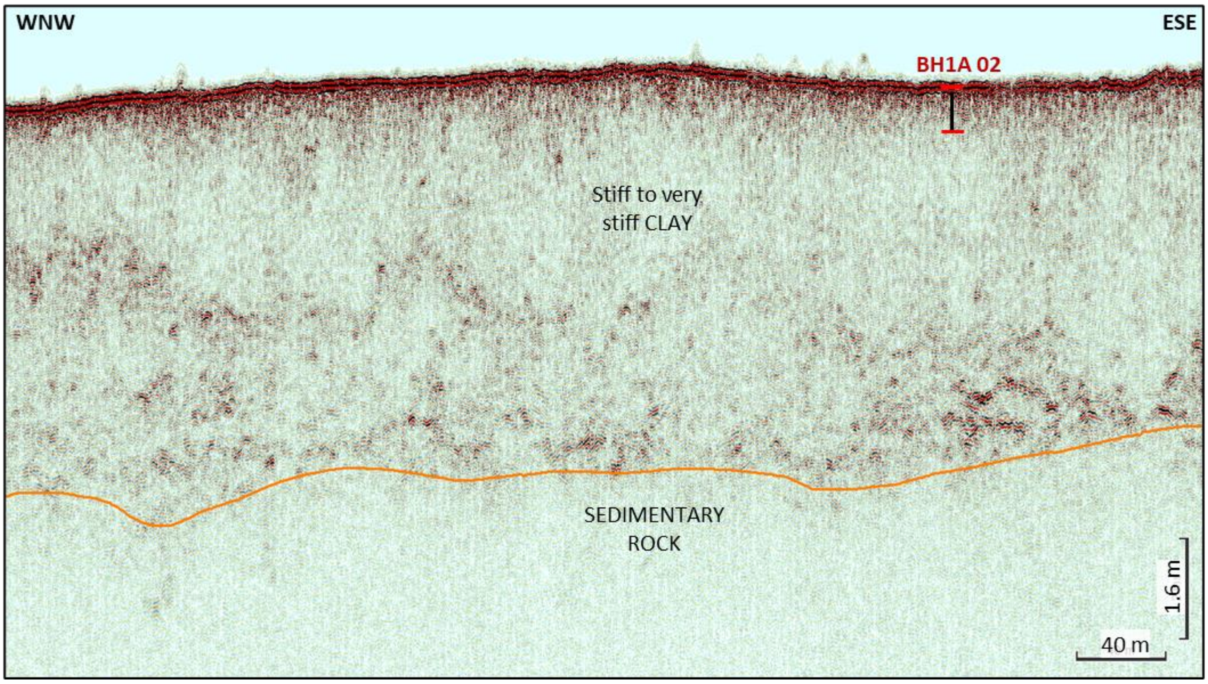


Figure 127 Innomar SBP data example from KP 18.999 (WNW) to KP 18.469 (ESE).

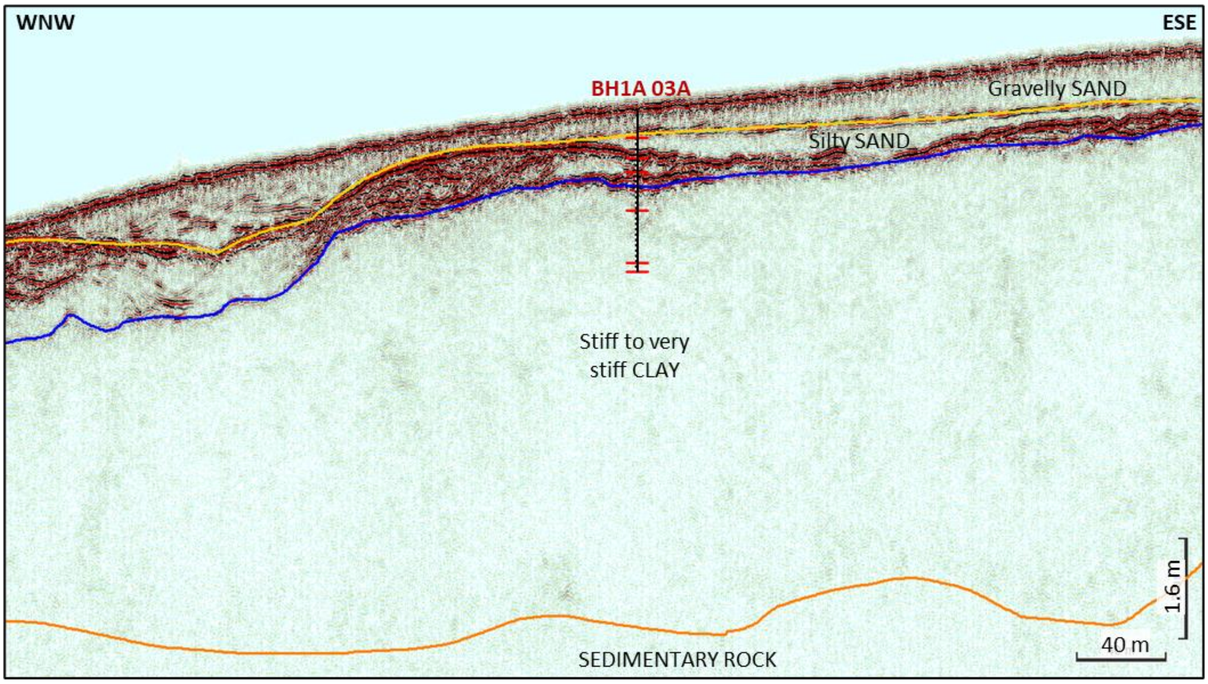


Figure 128 Innomar SBP data example from KP 20.454 (WNW) to KP 19.911 (ESE).

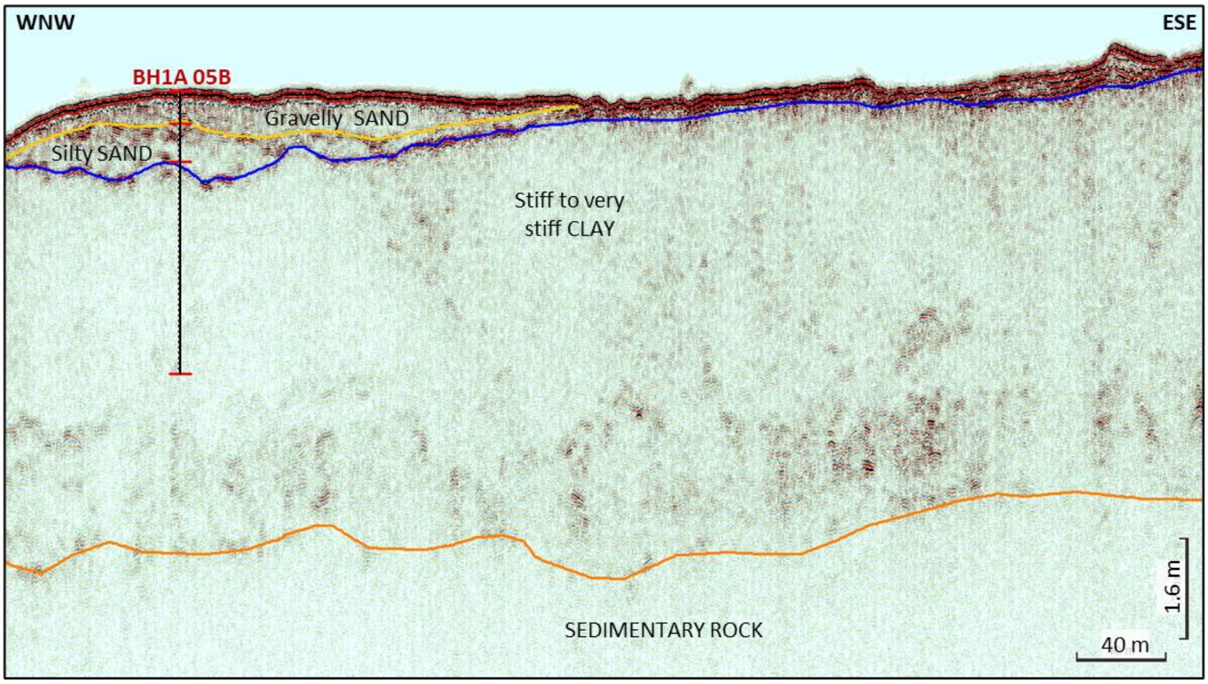


Figure 129 Innomar SBP data example from KP 22.306 (WNW) to KP 21.762 (ESE).

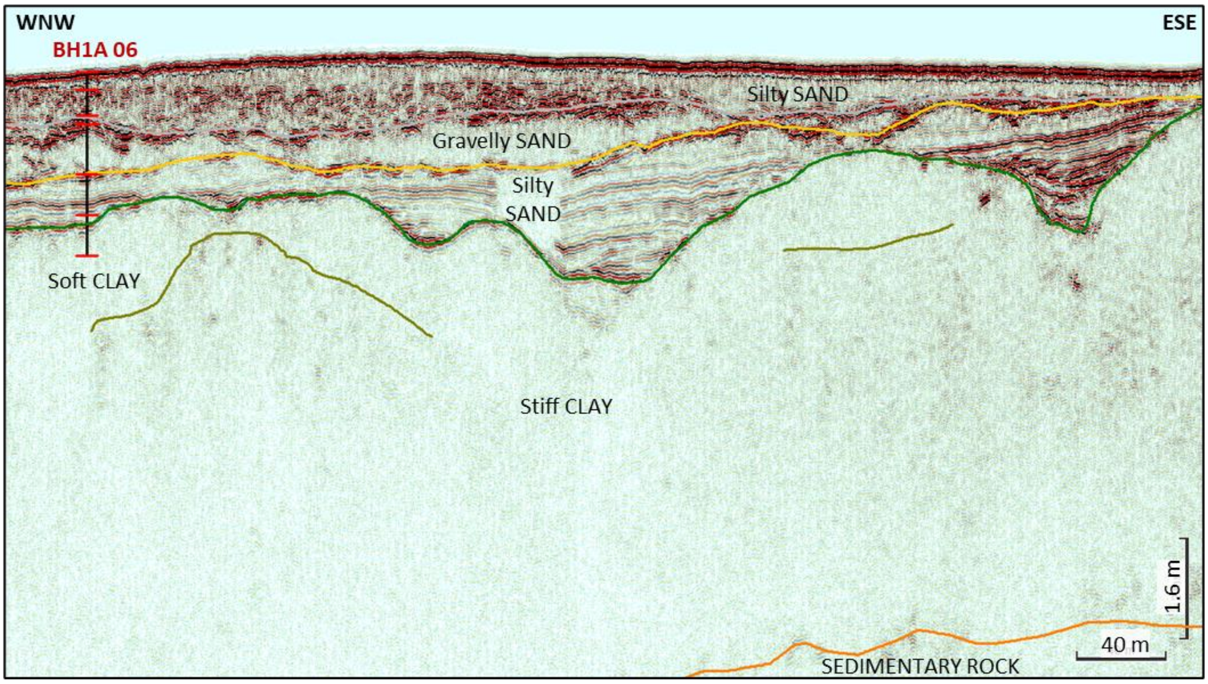


Figure 130 Innomar SBP data example from KP 23.187 (WNW) to KP 22.645 (ESE).

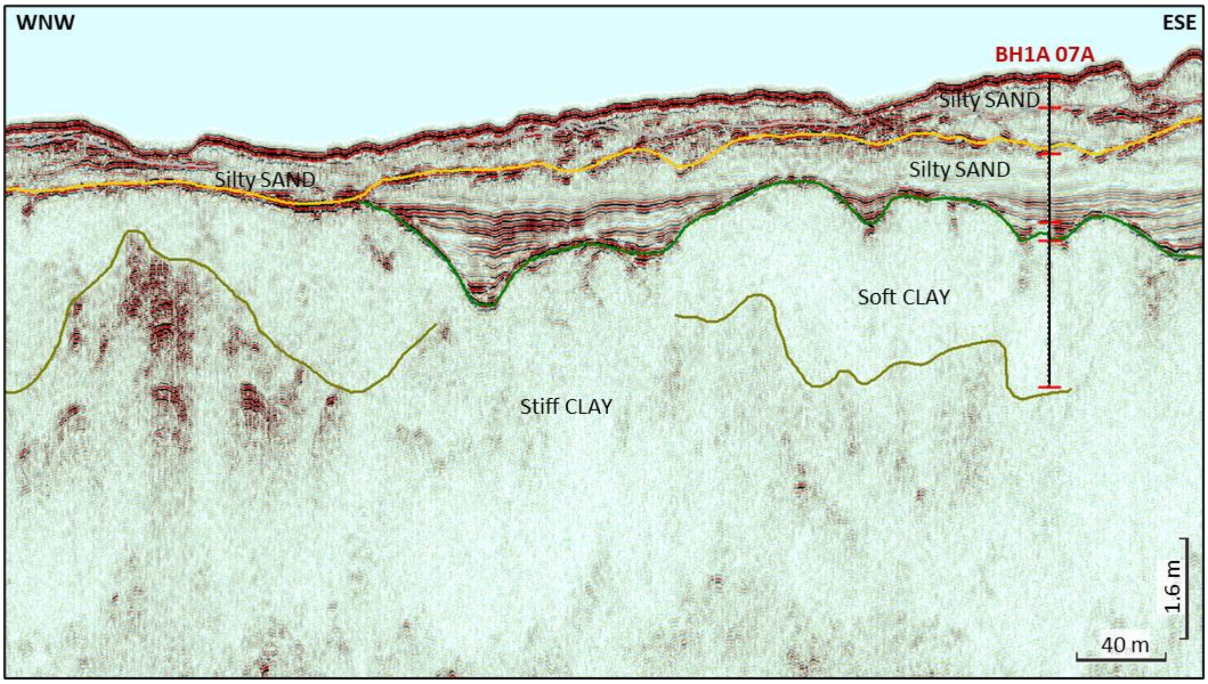


Figure 131 Innomar SBP data example from KP 24.170 (WNW) to KP 23.634 (ESE).

Table 41 ERS Bornholm 1A detailed description for alignment chart 103971-ENN-OI-SUR-DWG-P1BH1A002 (KP 24.597 – 28.995).

Alignment Chart 103971-ENN-OI-SUR-DWG-P1BH1A002 (KP 24.597 – 28.995)	
Description (including min/max depth BSB to base of unit)	**Remark**
Bathymetry: Seabed exhibits a very gentle to gentle gradient deepening westwards towards the end of the section.	Depths range = 5.25 m. Maximum slope of 1.27° at KP 27.868. Minimum depth 38.95 m at KP 24.597. Maximum depth 44.20 m at KP 28.561.
Surficial geology: The seabed between KP 24.597 and KP 27.915 is dominated by SAND. At KP 26.530 an area of GRAVEL and COARSE SAND extends to the south of the corridor (Figure 132). Between KP 26.530 to KP 28.995 the seabed is composed of Muddy SAND. Boulders occur within the area, generally these are isolated but some small areas of low and intermediate density boulder fields occur. An area of trawl scars begins at KP 26.030 and continues to the end of the route, covering the width of the corridor. The Baltic Pipe (Utility ID 08) runs parallel to the southern boundary of the corridor (Figure 132).	**Grab Samples:** 971-ENE-GR-GS-124 971-ENE-GR-GS-125 971-ENE-GR-GS-126 971-ENE-GR-GS-127
Shallow Geology: KP 24.597 to KP 28.008 (Figure 133, Figure 134): Recent marine slightly silty, slightly gravelly SAND (P1_H10) is present from 0.0 – 1.5 m BSB. This unit contains occasional internal reflectors, predominantly comprising of GRAVEL (P1_H05i and P1_H06i). Below the recent marine SAND is a late/post glacial silty SAND unit (P1_H30) with closely spaced thin to thick laminae of clayey SILT. This has a highly undulating basal reflector which extends to a maximum depth of 4.8 m BSB. Below these predominantly SAND units, Late Glacial to Glacial CLAYs are present, which increase in strength with depth. The shallowest CLAY is a Late Glacial very soft to soft, silty, slightly sandy meltwater CLAY (P1_H40i), which has been interpreted along the CL in correlation with the geotechnical data, undulating to a maximum of 8.0 m BSB. Stiff Glacial CLAY (P1_H50) is present below this, with the base of CLAY present to 12.5 m BSB until KP 25.187, at which point the unit	**Vibrocores and CPTs:** BH1A-08 and BH1A-08-CPT BH1A-09 and BH1A-09-CPT BH1A-10 and BH1A-10-CPT BH1A-12 and BH1A-12-CPT

Alignment Chart 103971-ENN-OI-SUR-DWG-P1BH1A002 (KP 24.597 – 28.995)	
Description (including min/max depth BSB to base of unit)	**Remark**
thickens beyond extent of the SBP data until the end of this route at KP 28.995. SEDIMENTARY ROCK is present below the Glacial CLAY. KP 28.008 to KP 28.666 (Figure 135): Late/post glacial silty SAND with closely spaced thin to thick laminae of clayey SILT (P1_H30) is present from the seabed to 1.3 m BSB. Below this, Late Glacial to Glacial CLAYs are present, which increase in strength with depth. The shallowest CLAY is a Late Glacial very soft, silty, slightly sandy meltwater CLAY (P1_H40i), which has been interpreted along the CL in correlation with the geotechnical data, undulating to a maximum depth of between 2.8 to 6.2 m BSB. Stiff Glacial CLAY is present below this, with its base beyond extent of the SBP data. KP 28.666 to KP 28.995: The end section of the route contains CLAYs from the seabed to beyond the extent of the SBP data, increasing in strength with increased depth. The shallowest CLAY is a Late Glacial very soft, silty slightly sandy slightly gravelly CLAY (P1_H40i), which has been interpreted along the CL in correlation with the geotechnical data, undulating to a maximum depth of 4.9 m BSB. Stiff Glacial CLAY is present below this, with its base beyond extent of the SBP data.	

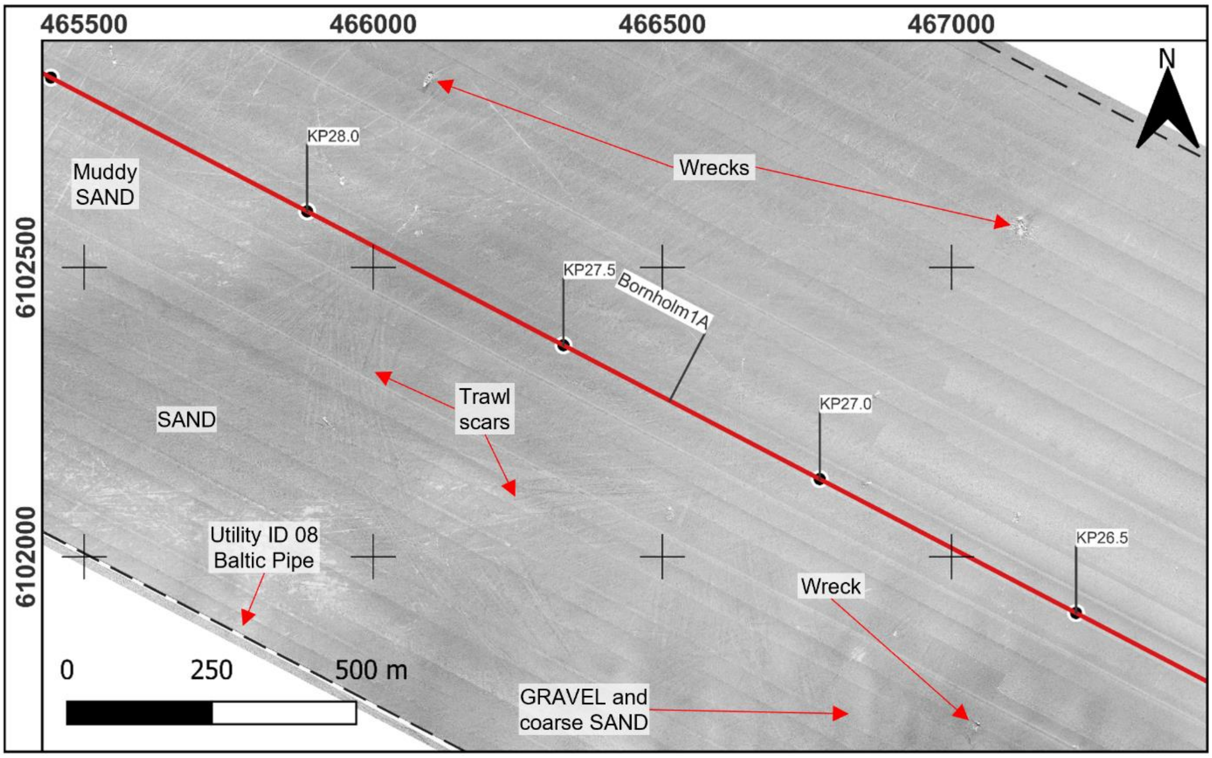


Figure 132 Overview of surficial geology from KP 26.2 to KP 28.5 as seen on SSS.

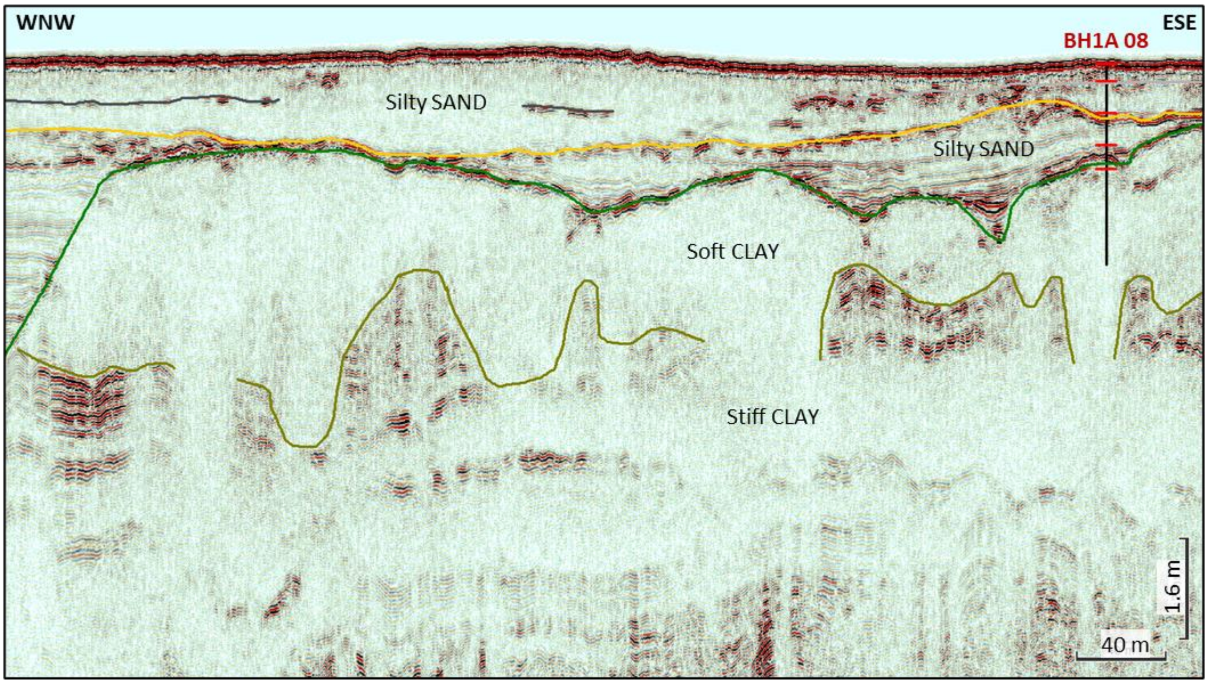


Figure 133 Innomar SBP data example from KP 25.277 (WNW) to KP 24.740 (ESE).

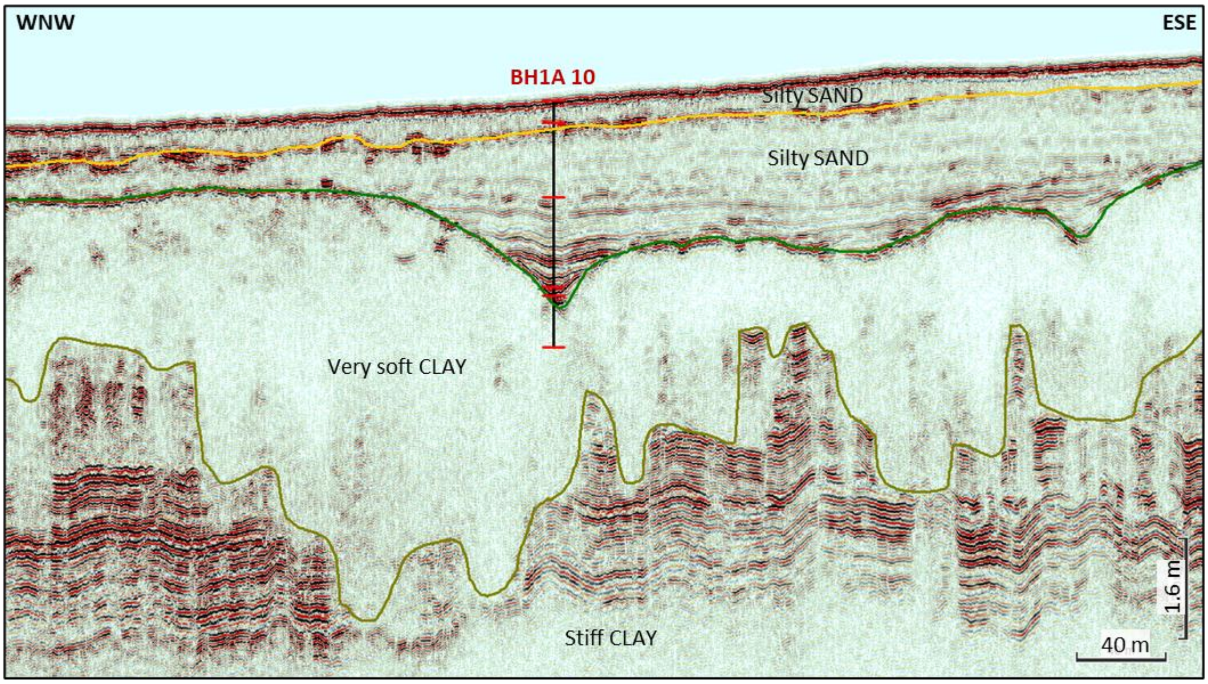


Figure 134 Innomar SBP data example from KP 26.779 (WNW) to KP 26.227 (ESE).

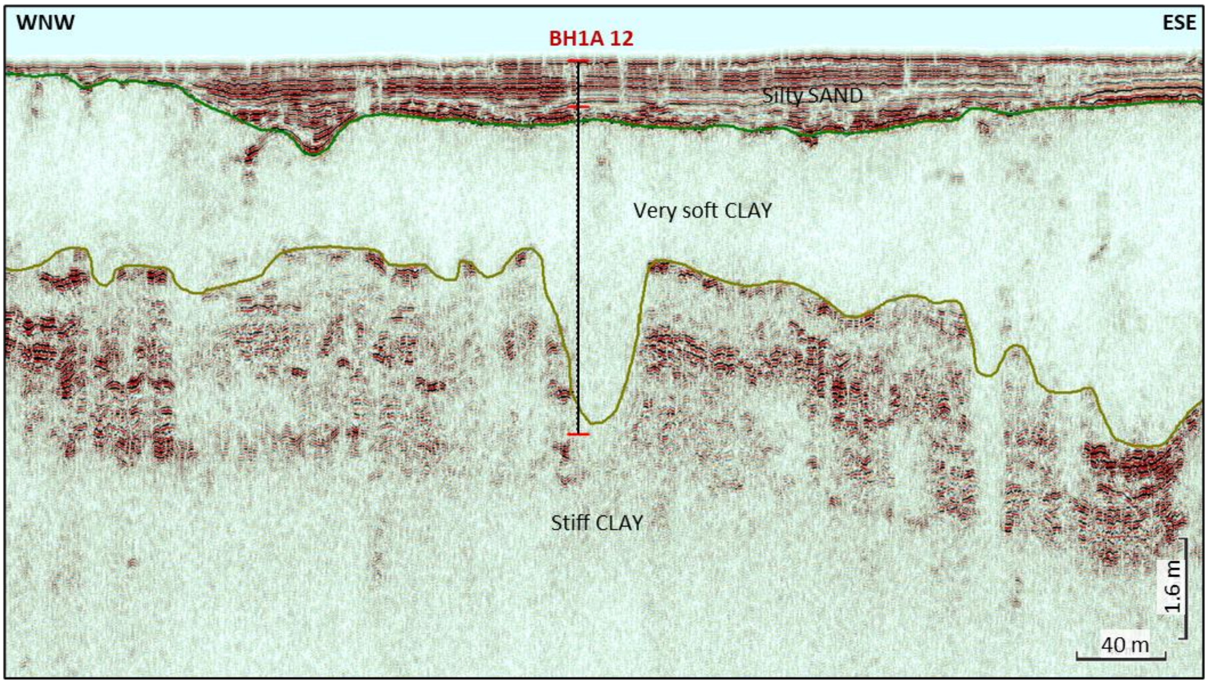


Figure 135 Innomar SBP data example from KP 28.672 (WNW) to KP 28.127 (ESE).

8.3.8 Integrated Seabed Index

Table 42 Integrated Seabed index for ERS Bornholm 1A KP 16.607 to KP 28.995

	Location ID			BH1A-01A	BH1A-01		BH1A-02	BH1A-02				BH1A-03	BH1A-03A		BH1A-04	BH1A-04			BH1A-05	BH1A-05B	
	Route KP	16.606	17.200	17.712	17.714	18.000	18.585	18.593	18.600	19.100	19.600	20.162	20.168	20.200	20.769	20.775	21.200	21.700	22.221	22.227	22.700
	Data type	SBP	SBP	VC	CPT	SBP	VC	CPT	SBP	SBP	SBP	CPT	VC	SBP	CPT	VC	SBP	SBP	CPT	VC	SBP
Depth below seabed (m)	0.5	4	4	4	4	4	4	4	4	4	5	6	6	6	5	5	6	6	6	6	6
	1.0	4	4	4	4	4		4	4	4	3	5	5	5	3	3	4	4	5	5	5
	1.5	4	4	4	4	4		3	4	4	4	4	5	5	3	3	4	4	4	4	5
	2.0	4	1	4	3	4			4	4	4	5	4	4	3	3	4	4	4	4	6
	2.5	1	1	4	4	4			4	4	4	4		4	4	4	4	4	4	4	4
	3.0	1	1		5	1			4	4	4			4	4		4	4	4	4	4
	4.0	1	1			1			4	4	4			4			4	4	4	4	4
	5.0	1	1			1			4	4	4			4			4	4	4		4
	6.0	1	1			1			4	4	4			4			4	4	4		4

	Location ID	BH1A-06	BH1A-06	BH1A-07	BH1A-07		BH1A-08	BH1A-08		BH1A-09	BH1A-09		BH1A-10	BH1A-10				BH1A-12	BH1A-12	
	Route KP	23.140	23.148	23.698	23.703	24.200	24.779	24.784	25.200	25.705	25.710	26.000	26.521	26.526	27.000	27.500	28.000	28.403	28.410	28.992
	Data type	CPT	VC	CPT	VC	SBP	CPT	VC	SBP	CPT	VC	SBP	CPT	VC	SBP	SBP	SBP	CPT	VC	SBP
Depth below seabed (m)	0.5	6	6	5	5	5	5	5	5	5	5	5	6	6	6	6	6	10	10	9
	1.0	5	5	5	5	5	6	6	5	5	5	5	6	6	6	6	9	10	9	9
	1.5	5	5	6	6	9	6	8	5	5	5	6	6	6	6	9	9	10	9	9
	2.0	6	6	6	6	9	9	9	5	5	5	6	7	7	9	9	9	9	9	9
	2.5	9	9	9	6	9	9	9	9	6	6	9	7	7	9	9	9	9	9	9
	3.0	9	9	9	8	9	9	9	9	9	9	9	9	9	9	9	9	9	9	9
	4.0			8	8	9			9	9	9	9		9	9	9	9	9	9	9
	5.0			8	8	9			9	9	9	9			9	9	9	9	9	9
	6.0			8		9			9	9		9			9	9	9	9	9	9

8.3.9 Seabed features, Contacts and Anomalies

A total of 63 contacts were identified from the SSS data within the survey corridor on ERS Bornholm 1A. The SSS contacts are summarised in Table 43. In addition to SSS contacts a total of 1 406 526 MBES boulders were identified within the defined boundary (Kabelrute OWF-BHM) at Bornholm.

A total of 54 magnetic anomalies were detected on ERS Bornholm 1A. Of these, 51 are related to linear features or cables/Pipelines. The MAG targets are summarised in Table 44. A total of 11 SSS contact positions correlated with detected magnetic anomalies.

Three wrecks were identified within the corridor as detailed in Table 45 and have associated debris fields surrounding them (Figure 136 to Figure 138). An area of trawl scars begins at KP 26.030 and continues to the end of the route, covering the width of the corridor.

Infrastructure detected:

- Utility ID 11 (cable, Bornholm-Rugen) detected MAG datasets, not detected on SSS or MBES dataset. Crossing route at KP 19.216.
- Utility ID 08 (Pipeline, Baltic Pipe) detected on SSS and MAG datasets, runs parallel to the southern boundary of the corridor from KP 19.564 (Figure 126).

Table 43 Summary of ERS Bornholm 1A SSS & MBES contacts.

CLASSIFICATION	NUMBER
Debris	43
Linear debris	13
Biogenic	3
Disturbed seabed	1
Wrecks	3
Total	**63**

Table 44 Summary of ERS Bornholm 1A magnetic anomalies.

CLASSIFICATION	NUMBER
Unclassified, possible objects	3
Linear anomalies	51
Total	**54**

Table 45 Wrecks identified in ERS Bornholm 1A

MMT SSS ID	Easting (m)	Northing (m)	KP	DCC	Comment
S_GR_WPA_B1D_2037	467120.55	6102571.62	26.893	548.79	Unknown
S_GR_WPA_B1D_2045	467046.18	6101710.38	26.561	-249.11	Unknown
S_GR_WPA_B1D_2064	466099.32	6102830.11	27.918	305.61	Unknown

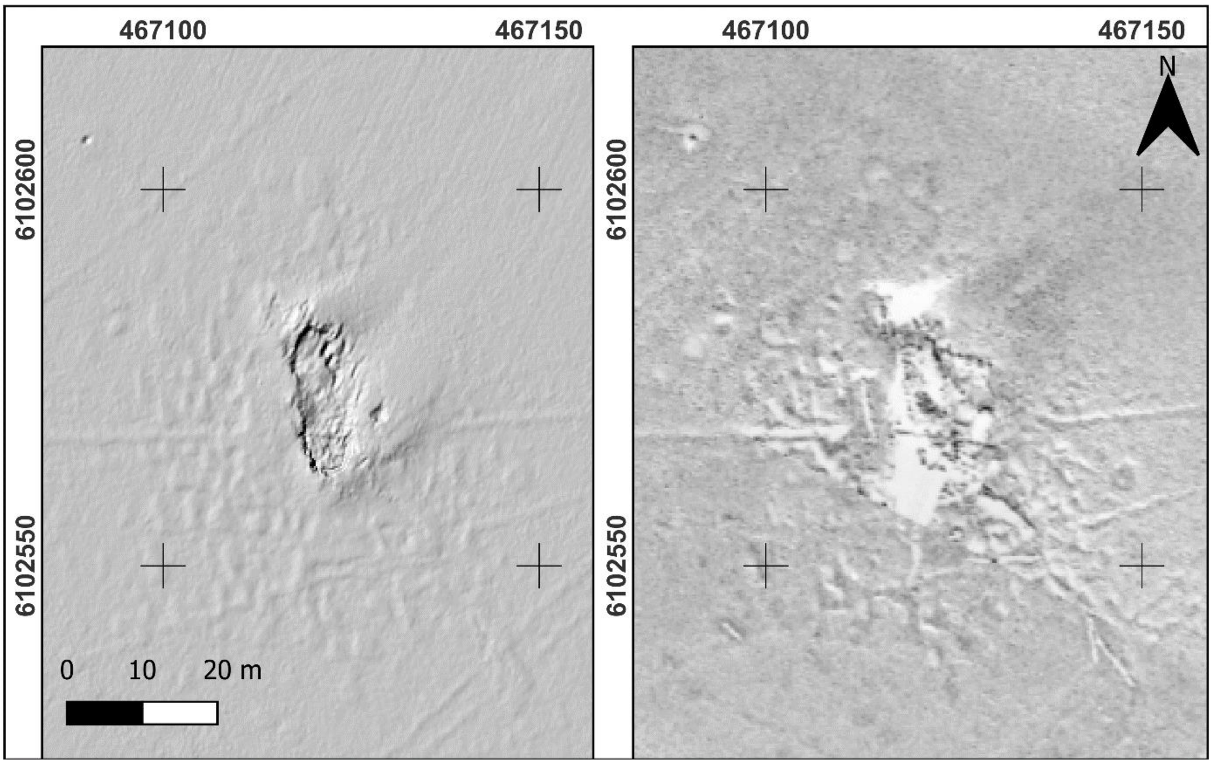


Figure 136 Wreck S_GR_WPA_B1D_2037. MBES hillshade and SSS mosaic

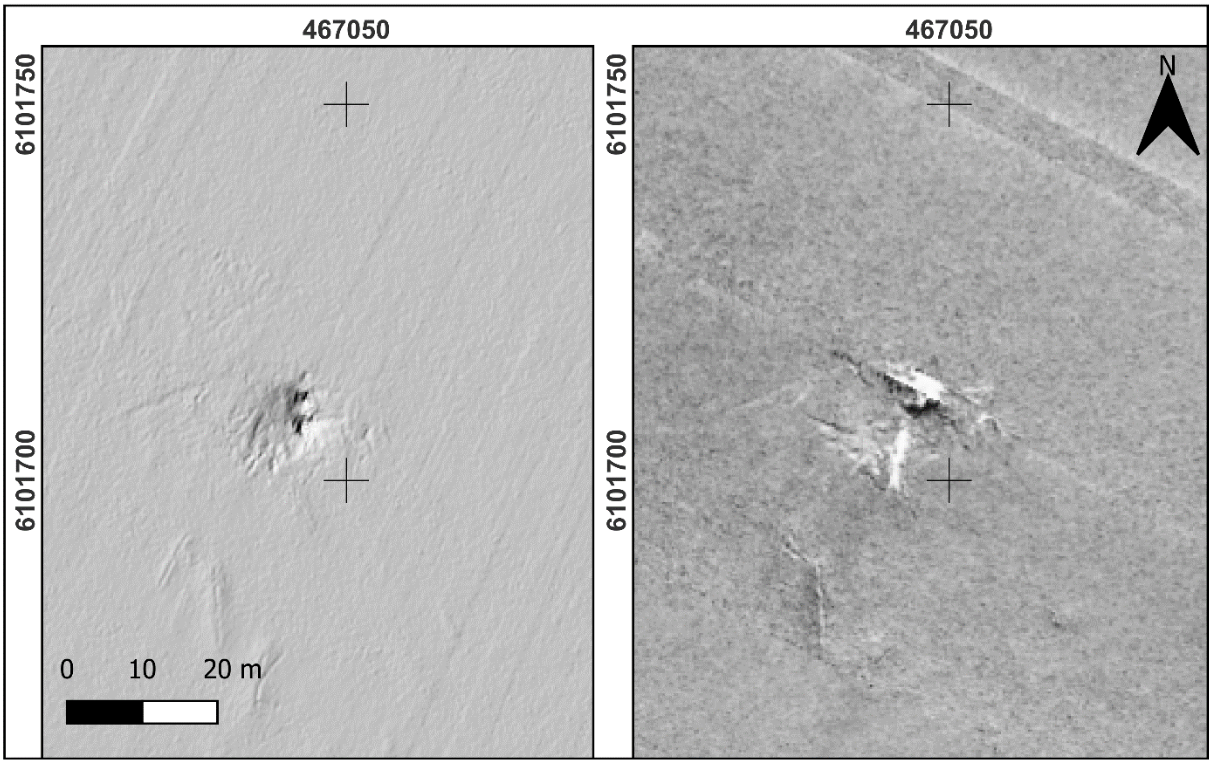


Figure 137 Wreck S_GR_WPA_B1D_2045. MBES hillshade and SSS mosaic

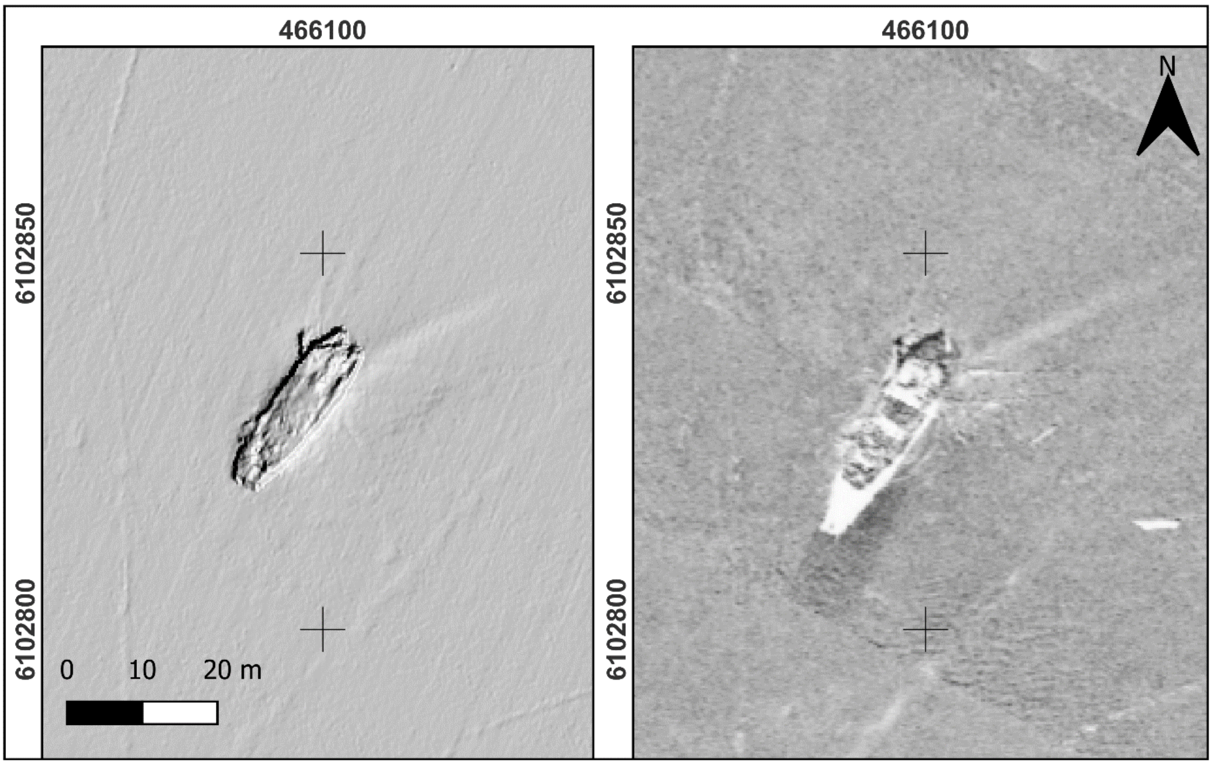


Figure 138 Wreck S_GR_WPA_B1D_2064. MBES hillshade and SSS mosaic

8.4 Cable and Pipeline Crossings

A detailed description of the utilities and unknown linear features is made in the 103971-ENN-OI-SUR-REP-CROSSWPD-02 crossing report.

8.5 LIDAR Survey

A LiDAR survey was conducted at one location on the Bornholm landfall where the Bornholm-Sjælland route starts at KP 0.000. From the landfall the route descends a steep, 20 m cliff which is heavily vegetated. The slope of the cliff is approximately 26°. The cliff and rough vegetation are typical of this rocky coastline (Figure 139 and Figure 140). Behind the cliff, landward, is a mixture of well managed agricultural land, isolated dwellings and woodlands.

Along the circa. 7.5 km of coastline that makes up the survey corridor at Bornholm, are numerous rocky points and curved bays. The intertidal zone is observed to consist of large boulders, cobbles and sand. During the survey the small inshore vessel, M/V Deep Wind struggled to survey the intertidal zone due to the frequency of boulders.

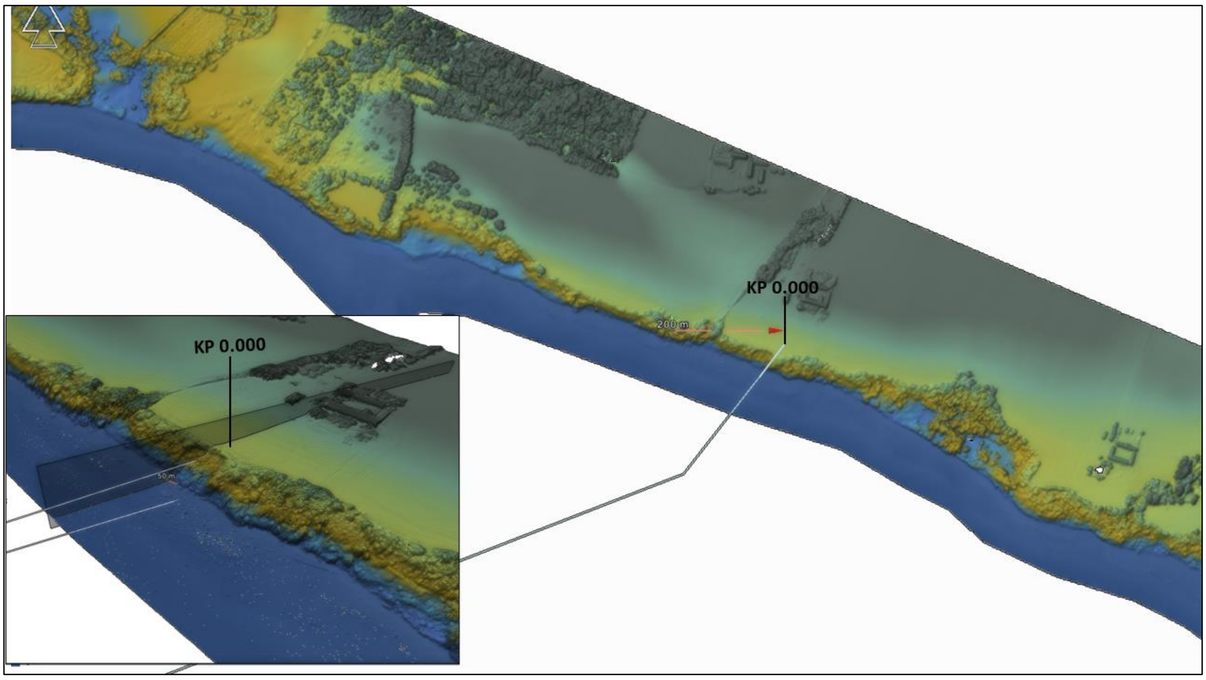


Figure 139 LiDAR image of KP 0.0 at Bornholm. The inset image shows the profile along the route line and the 20 m high cliff.

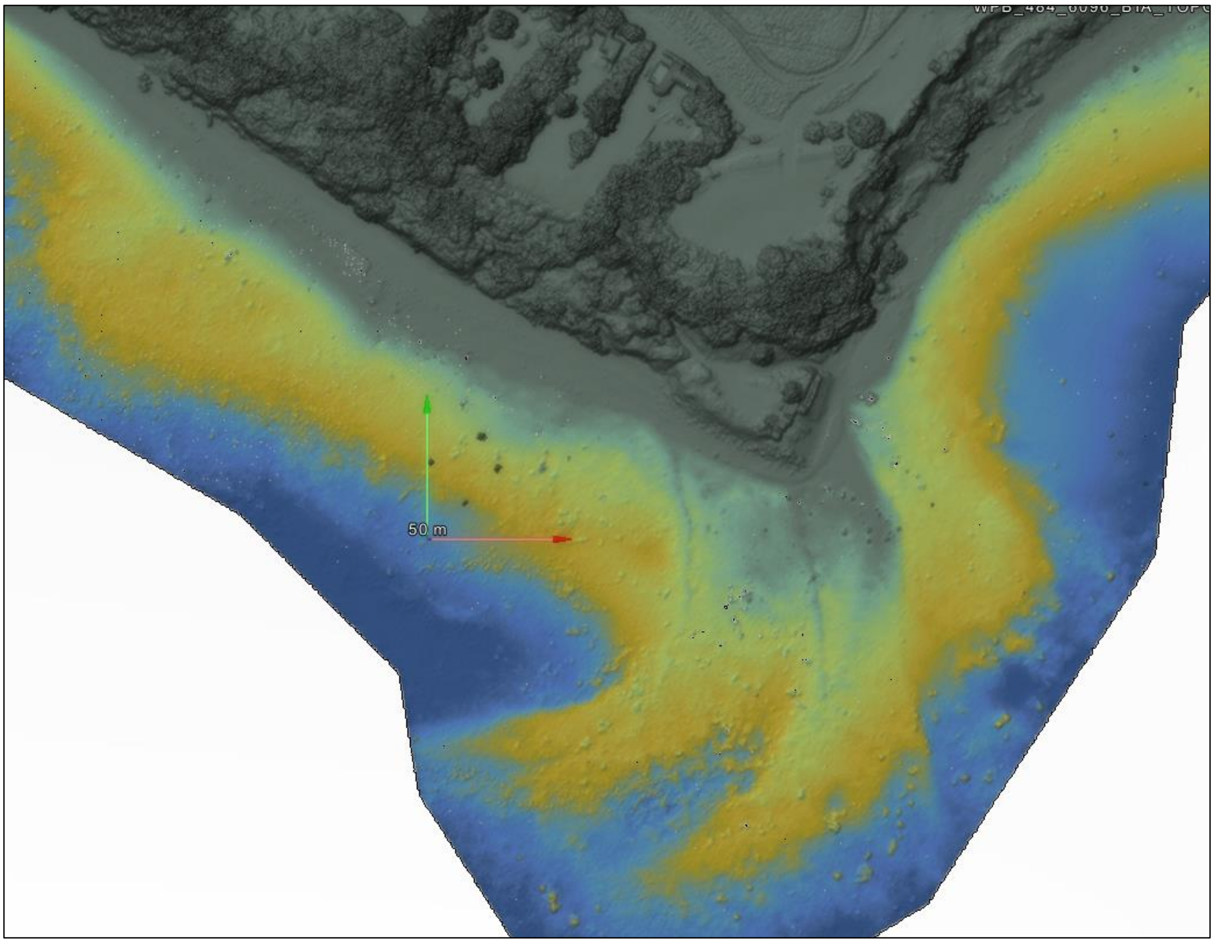


Figure 140 LiDAR image showing the rocky intertidal zone at Sose Odde.

8.6 Archaeology Considerations

During the survey there was no obvious archaeological findings observed. Three historic shipwrecks have been described in the relevant sections above. It is suggested that a fully qualified archaeologist examine the data collected here to assess the likelihood of palaeo landscapes within the data sets.

8.7 Benchmark Installation

The benchmark installation requirement was for three stations at each land fall location for the use of future construction purposes. The stations must be of a suitable quality that they can exist for at least 5 years.

For the Bornholm landfall, three stations, VP2, VP3 and VP6 were established. A brief description is given below, for the full information and coordinates see Appendix E.

Benchmark VP2 & VP3

The location benchmark 2 and 3 is adjacent to Søndre Landevej street, which is located in the South part of Bornholm island in Denmark. It is one of the main roads in the direction of Bornholm Airport (Rønne). Benchmark 2 is marked as a ground control point on, the west side of the road crossing. It is placed on the bicycle path, close to the advertisement board "Lilli's glass design" and the beach entrance.

Figure 141 Benchmark VP2 at the cycle path with the crossing of a local road and Søndre Landevej street.

Benchmark 3 is marked as a ground control point, on the west side of the road crossing. It is placed on the bicycle path, close to the traffic sign.

Figure 142 Benchmark 3 is located at the cycle path with the crossing of Hovedgårdsvejen and Søndre Landevej streets.

Benchmark VP6

Søndre Landevej street is located in the South part of Bornholm island in Denmark. It is one of the main roads in the direction of Bornholm Airport (Rønne). Benchmark 6 is marked as a ground control point, at the parking on the side of the road. It is placed close to the information sign.

Figure 143 Benchmark 6 is located at the parking at the side of the Søndre Landevej street. VP6 is close to the tourist information sign.

9. Results – Part 1 - Export Cable Route - Bornholm (ERS OWF-BH)

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 29), 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 46 Export cable routes results.

Number	Start KP	End KP	Results
ERS Bornholm 2	0.000	27.605	Section 9.2
ERS Bornholm 1B	16.607	27.560	Section 0

The results focus on bathymetry, surficial geology, and shallow geology. A summary of all contacts, anomalies and features is also presented. All reports, appendices, and charts refer to the client supplied “2022_04_14_KP_REF_TAB.shp” RPL (Appendix A).

The terms *elevation* and *depth* have been used throughout the report. Although referring to the same parameter, the vertical position relative to the DTU21 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 as per TQ-09. In this case elevations have negative values and depths positive values.

Additionally, report imagery obtained from the EIVA NaviModel software inherently stores DTMs with depth conventions of positive down.

9.1 Description of Data Interpretation

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

From the LiDAR survey a 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.

Contacts were detected on the SSS data. Boulders were automatically picked on MBES data. SSS contacts were QC'd against the automatic boulder picking to remove duplication.

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 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. Further to this a manual check was performed to add any obvious correlations above 5 m.

9.2 ERS Bornholm 2: KP 9.206 to KP 27.605

9.2.1 Overview

The route separates from the Bornholm – Sjælland route at KP 9.206 at which point the survey corridor is approximately 3 km wide. The Bornholm2 route initially heads in a south westerly direction before turning south and then southeast at approximately KP 15.5. The corridor from this point to the end of the route at KP 27.605 is 1.5 km wide. This route is defined by a steep scarp that crosses the survey corridor at approximately KP 26.30 and is the junction between the relatively shallow waters of the Ronne Banke and the deeper offshore waters beyond (see Figure 144).

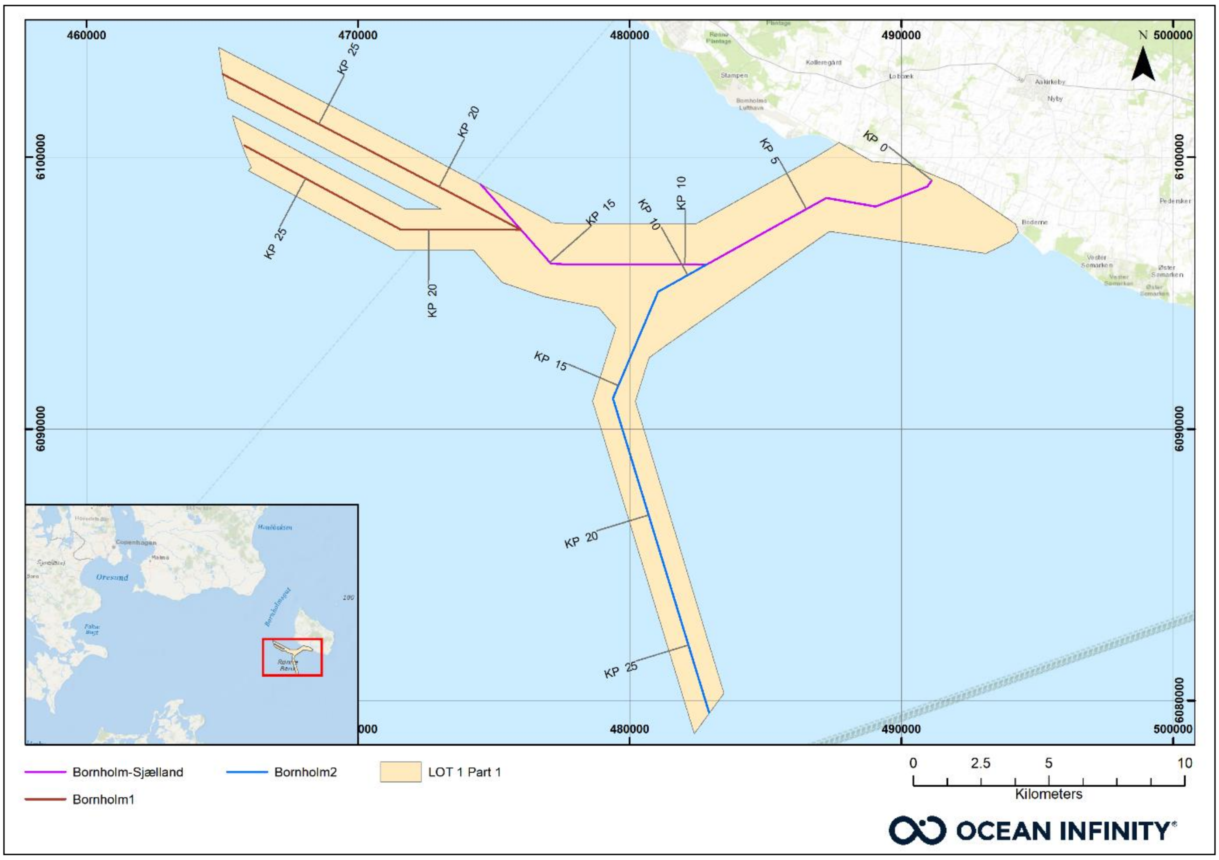


Figure 144 Overview image showing the cable routes and ECR within Part 1 survey area.

9.2.2 Bathymetry

The route starts at KP 9.206 moving towards the southwest over high-density boulder fields and outcrops. From KP 9.206 to approximately KP 17.0 the seafloor slope varies. Between approximately KP 17.0 and KP 19.0 the seafloor is very gentle and shoaling until KP 19.206 where the seafloor undulates until KP 22.206.

From 22.206 until KP 26.30 the seafloor is flat. At KP 26.30 there is very steep break in seafloor off the Ronne Bank from 15 m to 27 m depth over approximately 25 m distance: a slope of approximately 25°. For the remainder of the route the seafloor is gently deepening from KP 26.50 to 27.60 which is the end of the route.

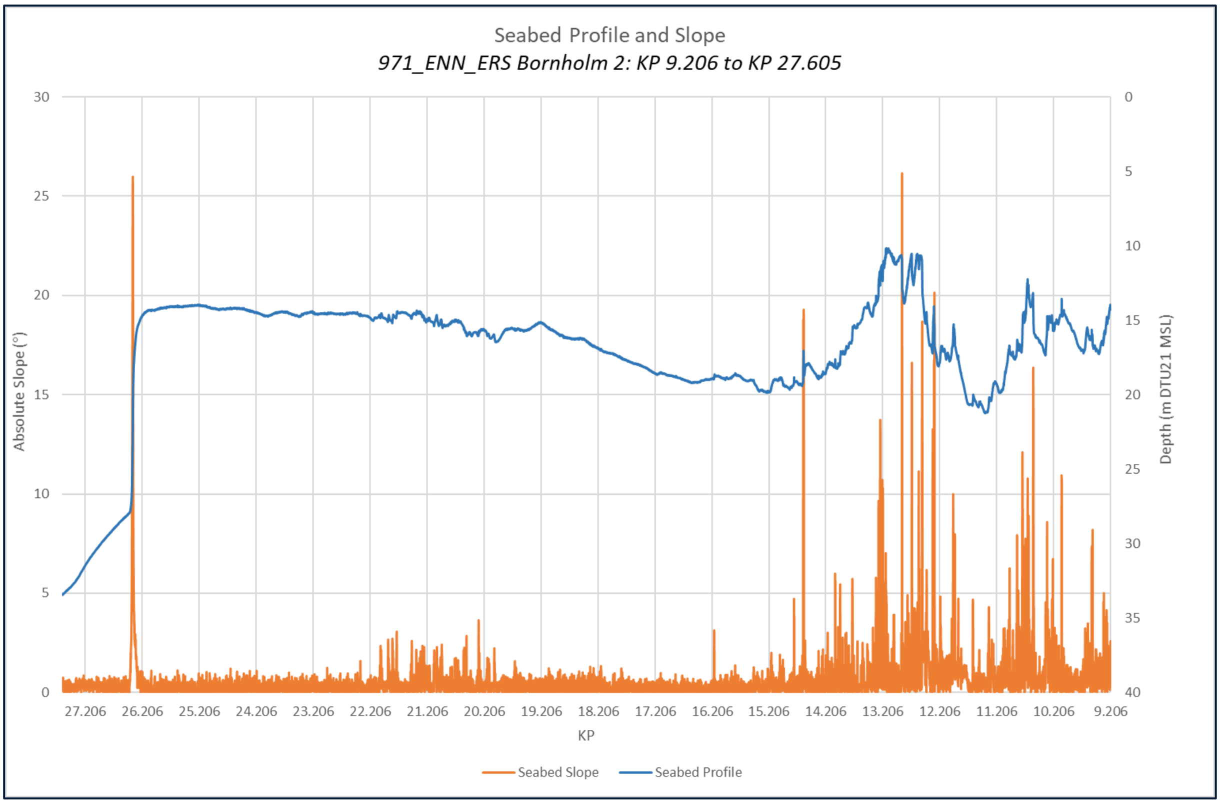


Figure 145 Route Bornholm 2 bathymetry longitudinal profile and slope.

Depth is in metres (with bathymetric depths positive below MSL datum) and slope is in degrees (absolute value for visualisation).

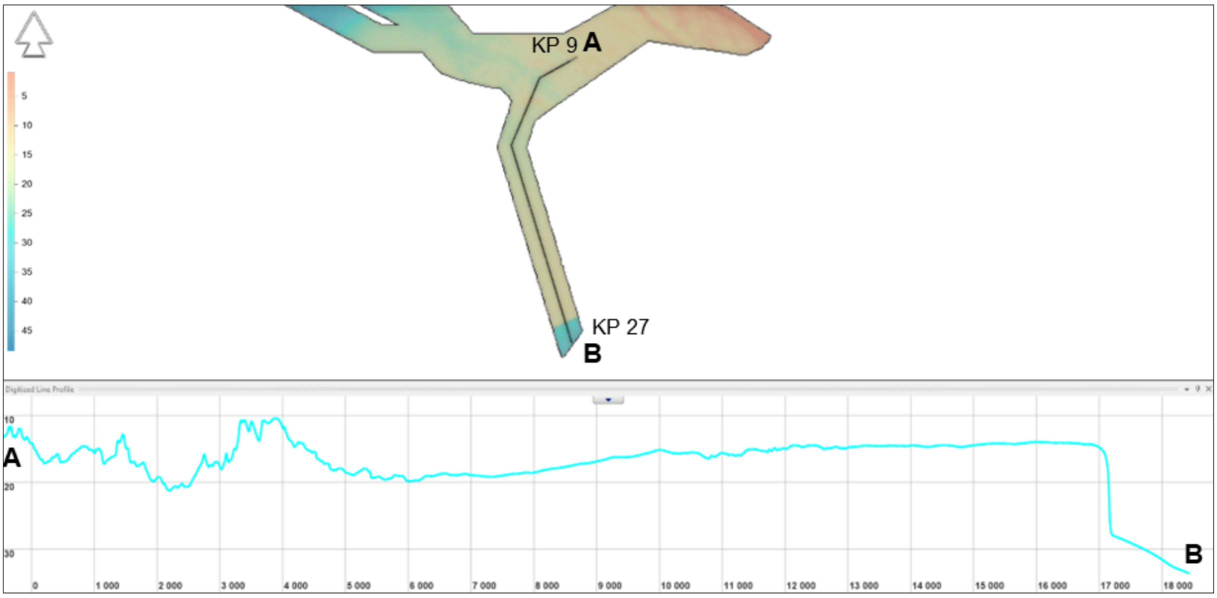


Figure 146 Overview image of route Bornholm 2.

The scale on the profile is in metres. X-axis shows distance along route from west to east; vertical exaggeration of profile x96.

9.2.3 Grab Sampling

The following grab samples were acquired, Figure 147 and Table 47. Full description of the grab sample results is contained in Appendix D.

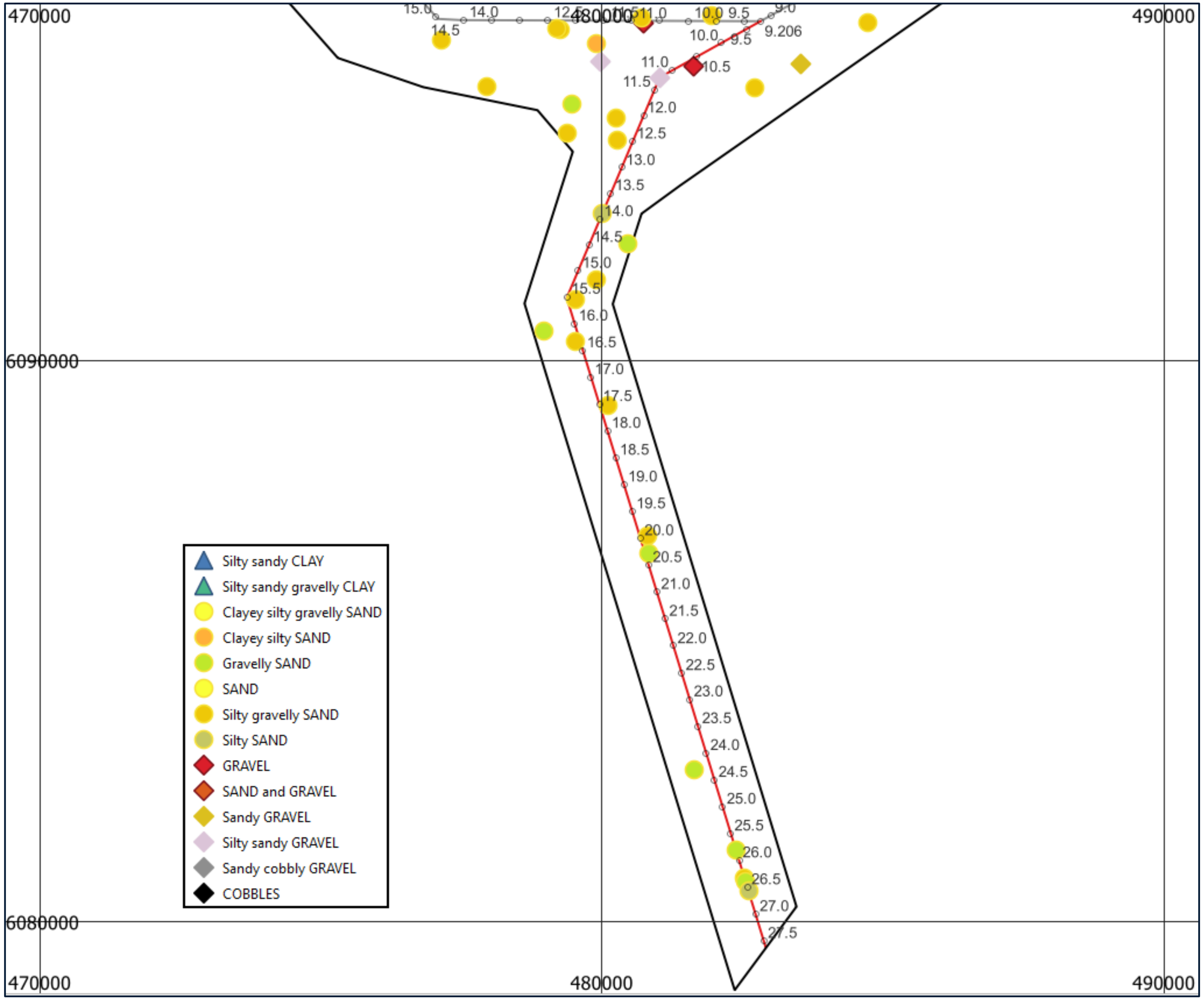


Figure 147 ERS Bornholm 2 grab sampling overview KP 9.206 to KP 27.605

Table 47 ERS Bornholm 2 grab sampling overview KP 9.206 to KP 27.605

ID	KP	DCC	Depth	Detailed Description
971-ENE-DV-GS-107	10.635	-117	12.95	MUSSELS, sample is entirely black and brown, fine to medium gravel size articulated and disarticulated bivalves, frequent marine plant debris, slight organic odour.
971-ENE-DV-GS-106	11.270	-17	19.68	GRAVEL, gravel is 95% subangular to subrounded fine to coarse of various lithologies and 5% subrounded medium articulated mussel shells, unsorted, slightly silty, very sandy, sand is medium to coarse, dark greyish black, non-calcareous.
971-ENE-DV-GS-101	12.221	431	16.10	SAND, fine to coarse, poorly sorted, slightly silty, slightly gravelly, gravel is 100% subrounded fine to medium of various lithologies, greyish brown, non-calcareous.
971-ENE-DV-GS-103	12.305	1266	17.24	SAND, fine to medium, sorted, gravelly, gravel is 100% subrounded fine to coarse of various lithologies, greyish brown, non-calcareous.
971-ENE-DV-GS-100	12.580	254	16.01	SAND, fine to coarse, poorly sorted, slightly silty, gravelly, gravel is 100% subrounded fine to medium of various lithologies, greyish brown, non-calcareous.
971-ENE-DV-GS-104	12.802	1125	18.69	SAND, fine to coarse, poorly sorted, slightly silty, slightly gravelly, gravel is 100% subrounded fine to coarse of various lithologies, light brownish grey, non-calcareous.
971-ENE-GR-GS-060	13.892	2	17.23	SAND, fine to medium, silty, frequent articulated mussels and marine organisms, 2 no. subangular cobbles of orangish brown gneiss (140 x 100 x 70, 120 x 80 x 60 mm), dark grey non-calcareous.
971-ENE-GR-GS-063	14.204	-631	18.27	SAND, medium to coarse, poorly sorted, gravelly, gravel is 100% subangular to subrounded fine to coarse of various lithologies, occasional subrounded medium gravel size pockets of dark grey silt, greyish brown, non-calcareous.
971-ENE-GR-GS-062	15.012	-356	19.30	SAND, medium to coarse, sorted, slightly silty, slightly gravelly, gravel is 100% subrounded fine of various lithologies, occasional subrounded medium gravel size pockets of soft grey clay, greyish brown, non-calcareous.
971-ENE-GR-GS-058	15.589	-138	19.95	SAND, medium to coarse, sorted, slightly silty, slightly gravelly, gravel is 80% subrounded fine of various lithologies and 20% subangular fine shell fragments, occasional subrounded medium gravel size pockets of soft grey clay, greyish brown, non-calcareous.
971-ENE-GR-GS-057	15.966	565	17.91	SAND, medium, sorted, slightly gravelly, gravel is 100% subangular fine shell fragments, occasional subrounded fine to medium gravel size pockets of dark grey organic silt, light greyish brown, non-calcareous
971-ENE-GR-GS-059	16.303	76	18.68	SAND, medium to coarse, poorly sorted, slightly silty, very gravelly, gravel is 80% subrounded fine to medium of various lithologies and 20% subangular fine shell fragments, greyish brown, non-calcareous.
971-ENE-GR-GS-061	17.574	-135	17.46	SAND, medium to coarse, sorted, slightly silty, very gravelly, gravel is 90% subangular to subrounded fine to medium of various lithologies and 10% subangular fine shell fragments, light greyish brown, non-calcareous.

ID	KP	DCC	Depth	Detailed Description
971-ENE-GR-GS-064	19.998	-141	16.14	SAND, fine to coarse, poorly sorted, slightly silty, very gravelly, gravel is 95% subangular to subrounded, fine to medium of various lithologies and 5% subrounded shell fragments, light brown, non-calcareous.
971-ENE-GR-GS-065	20.297	-68	16.20	SAND, fine to medium, poorly sorted, slightly gravelly, gravel is 100% subangular to subrounded fine shell fragments, light brownish grey, non-calcareous.
971-ENE-GR-GS-066	24.228	283	14.68	SAND, fine to coarse, poorly sorted, slightly gravelly, gravel is 50% subrounded fine shell fragments and 50% subrounded fine of various lithologies, light brownish grey, non-calcareous.
971-ENE-GR-GS-067	25.803	0	14.16	SAND, fine to coarse, poorly sorted, slightly gravelly, gravel is 50% subrounded fine shell fragments and 50% subrounded fine of various lithologies, occasional subrounded medium gravel size pockets of dark grey fine sand, light brownish grey, non-calcareous.
971-ENE-GR-GS-068	26.331	1	16.72	SAND, fine to coarse, poorly sorted, slightly silty, slightly gravelly, gravel is 50% subrounded fine shell fragments and 50% subrounded fine of various lithologies, occasional subrounded medium gravel size pockets of dark grey fine sand, light brownish grey, non-calcareous.
971-ENE-GR-GS-069	26.389	2	26.73	SAND, fine to coarse, poorly sorted, very gravelly, gravel is 100% subangular to subrounded fine to coarse shell fragments and articulated mussels, strong organic odour, dark grey, non-calcareous.
971-ENE-GR-GS-070	26.569	-1	28.47	SAND, fine to medium, sorted, silty, occasional subrounded fine to medium gravel size pockets of black organic silt, strong organic odour, brownish grey, non-calcareous.

9.2.4 Surficial Geology

The surficial geology between KP 9.206 and KP 13.957 is highly variable characterised by outcrops of SEDIMENTARY ROCK with areas of SAND, GRAVEL and coarse SAND and DIAMICTON. The DIAMICTON is composed of sand, gravel, clay with cobbles and boulders. The SEDIMENTARY ROCK forms ridges at seabed and sediments infill the erosional surface of the bedrock. Glacial debris is prevalent between KP 9.206 and KP 14.372, with high density boulder fields. The last occurrence of SEDIMENTARY ROCK outcropping is at KP 15.520, here a thin ridge trends north from the route.

A large area of GRAVEL and coarse SAND occurs between KP 13.957 to KP 26.367 extending across the entire width of the corridor, north-south trending ribbons of SAND break up this area. There is a seabed ridge at KP 26.367, following the ridge the seabed sediment is composed primarily of SAND. Areas of ripples occur within the areas of GRAVEL and coarse SAND, ripple crests are orientated north to south in line with the prevailing storm wave base.

Detailed descriptions of the surficial geology are presented in Table 49 to Table 51.

9.2.5 Geotechnical Results

Ground Conditions

The geotechnical VC locations on the Bornholm2 (BH2) route are shown below (Figure 148). Seventeen VC were carried out with co-located CPT at every location. The investigated locations cover approximately 17.4 km, from KP 9.807 to KP 27.205.

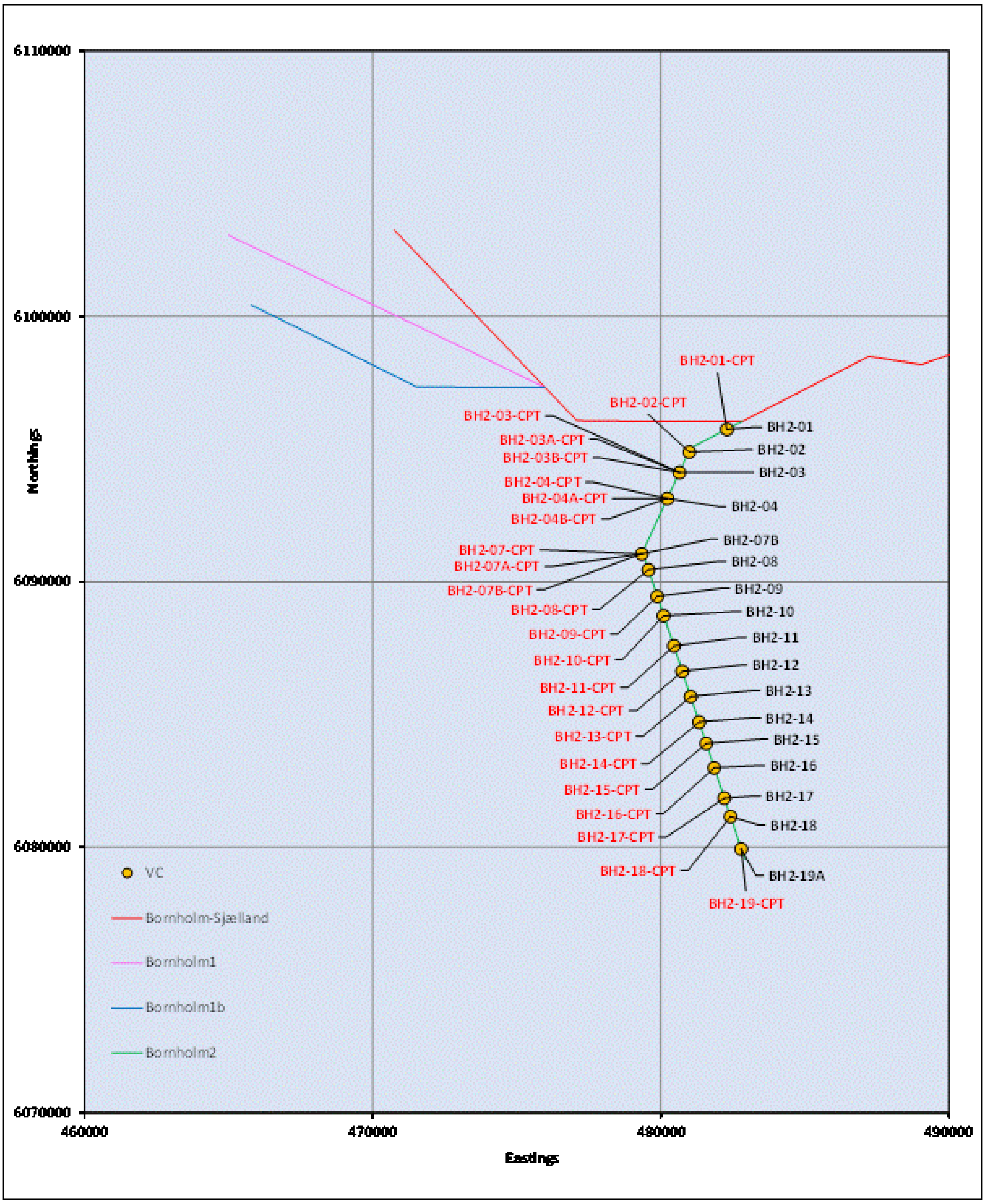
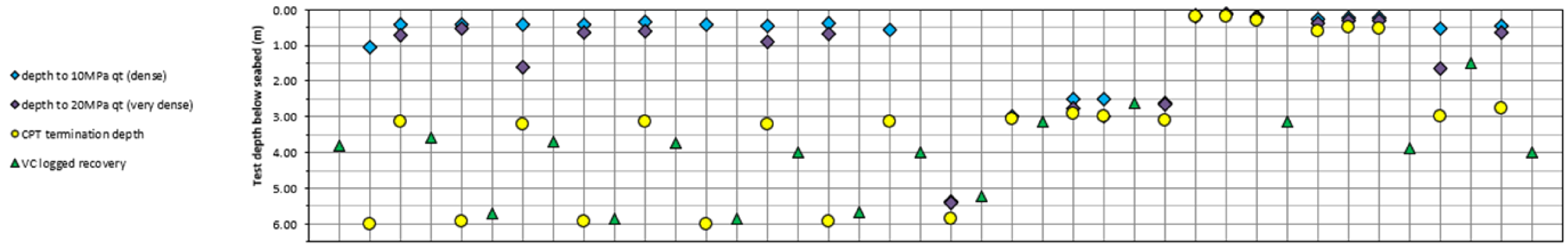


Figure 148 Geotechnical locations on the BH2 route, Part 1.

The assigned Seabed Sediment Index for the BH2 route is shown below (Figure 149).



Location ID	BH2-19A	BH2-19	BH2-18	BH2-18	BH2-17	BH2-17	BH2-16	BH2-16	BH2-15	BH2-15	BH2-14	BH2-14	BH2-13	BH2-13	BH2-12	BH2-12	BH2-11	BH2-11	BH2-10	BH2-10
Route KP	27.205	27.200	25.935	25.929	25.211	25.207	24.016	24.010	23.056	23.050	22.213	22.207	21.210	21.205	20.214	20.207	19.214	19.207	18.030	18.023
Location type	VC	CPT	CPT	VC	CPT	VC	CPT	VC	CPT	VC	CPT	VC	CPT	VC	CPT	VC	CPT	VC	CPT	VC
VC penetration	4.20			3.70		5.71		3.80		5.90		3.80		5.95		4.00		5.86		4.00
VC recovery	3.80			3.60		5.71		3.71		5.86		3.73		5.87		4.00		5.65		3.98
CPT termination depth		6.00	3.12		5.92		3.20		5.94		3.14		6.00		3.20		5.92		3.14	
Depth to 10 MPa (dense)		1.04	0.42		0.42		0.42		0.44		0.36		0.42		0.46		0.40		0.56	
Depth to 20 MPa (very dense)			0.72		0.54		1.60		0.66		0.60				0.92		0.68			

Location ID	BH2-09	BH2-09	BH2-08	BH2-08	BH2-07	BH2-07A	BH2-07B	BH2-07B	BH2-04A	BH2-04	BH2-04B	BH2-04	BH2-03A	BH2-03	BH2-03B	BH2-03	BH2-02	BH2-02	BH2-01	BH2-01
Route KP	17.262	17.256	16.213	16.206	15.574	15.569	15.568	15.564	13.330	13.330	13.325	13.321	12.256	12.256	12.252	12.250	11.418	11.411	9.812	9.807
Location type	CPT	VC	CPT	VC	CPT	CPT	VC	CPT	CPT	CPT	CPT	VC	CPT	CPT	CPT	VC	CPT	VC	CPT	VC
VC penetration		5.60		3.50			2.70					3.20				3.90		1.50		4.00
VC recovery		5.24		3.15			2.62					3.12				3.90		1.50		3.98
CPT termination depth	5.84		3.08		2.90	3.00		3.10	0.20	0.18	0.30		0.62	0.48	0.54		3.00		2.78	
Depth to 10 MPa (dense)	5.36		3.00		2.50	2.52		2.62	0.16	0.12	0.18		0.28	0.24	0.24		0.52		0.46	
Depth to 20 MPa (very dense)	5.40				2.76	2.98		2.66	0.18	0.14	0.22		0.38	0.30	0.32		1.64		0.64	

Depth below seabed (m)

Depth (m)	BH2-19A	BH2-19	BH2-18	BH2-18	BH2-17	BH2-17	BH2-16	BH2-16	BH2-15	BH2-15	BH2-14	BH2-14	BH2-13	BH2-13	BH2-12	BH2-12	BH2-11	BH2-11	BH2-10	BH2-10
0.5	7	7	5	5	5	5	5	5	5	5	5	5	5	5	5	5	5	5	6	6
1.0	6	6	3	3	3	3	6	6	3	3	3	3	5	5	3	3	3	3	5	6
1.5	5	5	3	3	3	3	5	5	3	3	3	3	6	6	5	5	5	5	6	6
2.0	8	8	3	3	3	3	3	3	3	3	3	3	5	5	5	5	5	5	6	6
2.5	8	8	3	3	3	3	5	5	3	3	3	3	6	6	6	6	5	5	6	6
3.0	8	8	3	3	3	3	6	6	5	5	5	3	6	6	6	6	5	5	6	6
4.0	8	8		3	3	3		6	5	5		3	6	6		6	6	6		6
5.0		8			3	3			5	5			5	5			6	6		
6.0		6			5	5			6	6			6	6			6	6		

Depth (m)	BH2-09	BH2-09	BH2-08	BH2-08	BH2-07	BH2-07A	BH2-07B	BH2-07B	BH2-04A	BH2-04	BH2-04B	BH2-04	BH2-03A	BH2-03	BH2-03B	BH2-03	BH2-02	BH2-02	BH2-01	BH2-01
0.5	6	6	6	8	6	6	6	6	3	3	3	3	3	3	3	3	5	5	3	3
1.0	6	6	6	6	6	6	7	7				3				3	5	5	3	3
1.5	8	6	6	6	6	7	4	7				3				3	3	3	3	3
2.0	8	8	8	8	4	4		4				3				3	3		3	3
2.5	8	8	4	4	5	5		4				3				3	3		3	3
3.0	8	8	6		3	3		3				3				3	3		3	3
4.0	4	4														3				3
5.0	6	4																		
6.0	3																			

SSI	Typical Seabed Sediment
1	Bedrock (CHALK)
2	Dense to very dense Glacial Deposits
3	Very dense granular
4	Medium to high strength cohesive (Glacial Till)
5	Dense granular
6	Medium dense granular
7	Loose granular
8	Low to medium strength cohesive
9	Very low to low strength cohesive
10	Extremely low strength cohesive
0	Organic material *sensu stricto* , containing PEAT

Figure 149 Seabed Sediment Index for BH2 route, Part 1.

The ground conditions from the recovered VC across this route are variable. At the start of the route, from KP 9.807 (location BH2-01) through to KP 13.330 (location BH2-04) the recovered material is entirely SAND. The SAND is slightly silty slightly gravelly to very gravelly, with the gravel component being of various lithologies. The SAND is non- to slightly calcareous. VC recovery was generally good, except at location BH2-02 where only 1.50 m penetration and recovery was achieved.

From KP 15.568 (location BH2-07) through to KP 17.256 (location BH2-09) Glacial Till is present at variable depths, from 1.47 m at location BH2-07, increasing to 4.37 m depth at location BH-09 (Figure 150). The Glacial Til is medium to high strength firm to stiff very silty sandy slightly gravelly CLAY. The gravel component is entirely of various lithologies and the CLAY is calcareous. Material overlying the Glacial Till is variable, from fine to coarse SAND and rare thin GRAVEL and SILT, through to low to intermediate plasticity, low to medium strength very silty sandy CLAY. The upper granular material is up to 1.81 m thick (location BH2-09), whilst SILT, present at location BH2-07B, is seen from 0.08 m to 1.20 m depth. The CLAY strata vary from 0.60 m to 1.70 m thick.

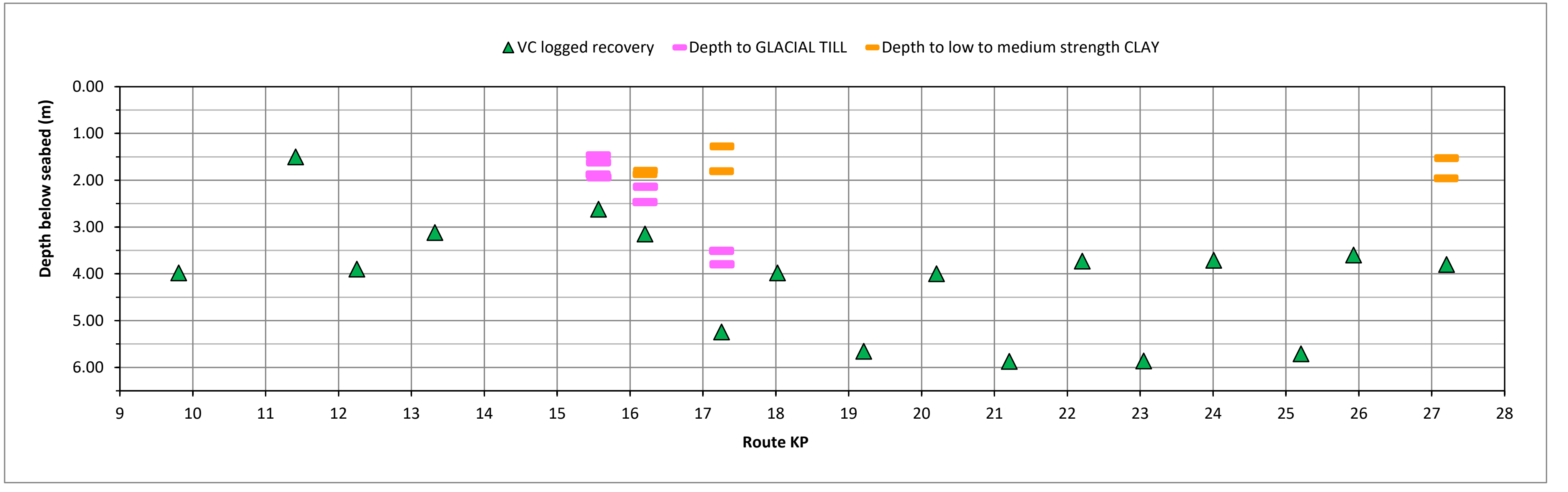


Figure 150 Plot of VC recovery and interpreted strata depths for route BH2, Part 1.

From KP 18.023 (location BH2-10) though to KP 25.929 m (location BH2-18), the recovered material is almost entirely SAND. The SAND is variable, from clayey very silty fine, through to slightly silty fine to medium, and gravelly fine to coarse. The SAND can be non-calcareous to calcareous, where a clay component is present. CLAY and SILT strata are rare, only being seen as very thin layers, up to 0.14 m thick, at locations BH2-12 and BH2-13.

At the final location on this route, BH2-19 at KP 27.205, CLAY is again present from 1.53 m depth, being low to high strength firm very silty slightly sandy slightly gravelly, with very closely to closely spaced thin laminae to very thin beds of grey clayey silt. The CLAY is a distinctive reddish brown colour and is slightly calcareous. The CLAY is not considered to be Glacial Till. Material overlying the CLAY from seabed level is SAND, being fine to medium, slightly clayey silty through to slightly silty slightly gravelly. The gravel component is various lithologies and the SAND is non-calcareous.

Laboratory Test Data

A summary table below (Table 48) details the quantities of laboratory testing carried out on material from the route BH2.

Table 48 Summary table of laboratory testing for the route BH2, Part 1.

Type		Quantity
Moisture Content (MC)		52
Bulk Density (BD)		47
Dry Density (DD)		47
Particle Density (PD)		8
Min/Max Dry Density (MM)		7
Atterberg Limits (AT)		5
Particle Size Distribution Analysis (PSD)		30
PSD sedimentation (SED)		10
Shear strength (Lab Vane, LV)		3
Shear strength (Torvane, TV)		13
Shear strength (Torvane, offshore TVO)		5
Shear strength (Pocket Pen., offshore PPO)		3
Shear strength (Unconsolidated undrained triaxial, UU)		-
Thermal (TR)		10
Chemical tests (CHEM)	Organic matter content:	-

A plot below shows the PSD data plotted schematically, in KP order, from the BH2 route (Figure 151). This shows the presence of CLAY in the tested material, with Glacial Till at locations BH2-07B to BH2-09 having total fines contents from 50 to 78 %. Gravel contents in the Glacial Till are generally low, in the range 0 to 10 %, with sand contents of 22 to 10 %. In the low to medium strength, high plasticity CLAY at location BH2-19, total fines contents are 95 %, with a low sand content of 5 %.

A single SILT stratum from location BH2-07B has a silt content of 78 % with clay content of 15 % and 7 % sand.

The tested SAND strata from this route have sand contents of 76 to 99 % with typically low total fines of 1 to 12 %. Elevated total fines in SAND of 24 % are seen at location BH2-11 and BH2-12. Gravel contents are generally low at < 10 % with only a single tested sample from BH2-01 having higher gravel contents of 24 %.

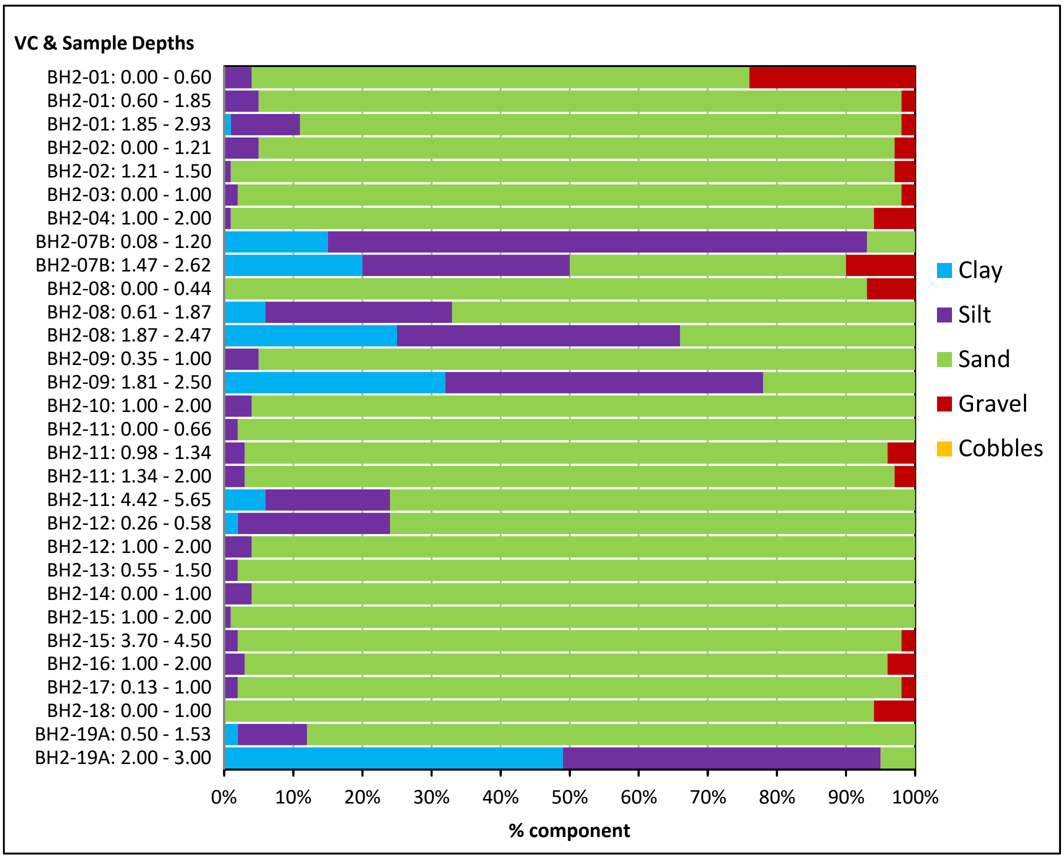


Figure 151 Schematic summary plot of PSD data for route BH2, Part 1.

PSD data for the tested material are also shown below (Figure 152).

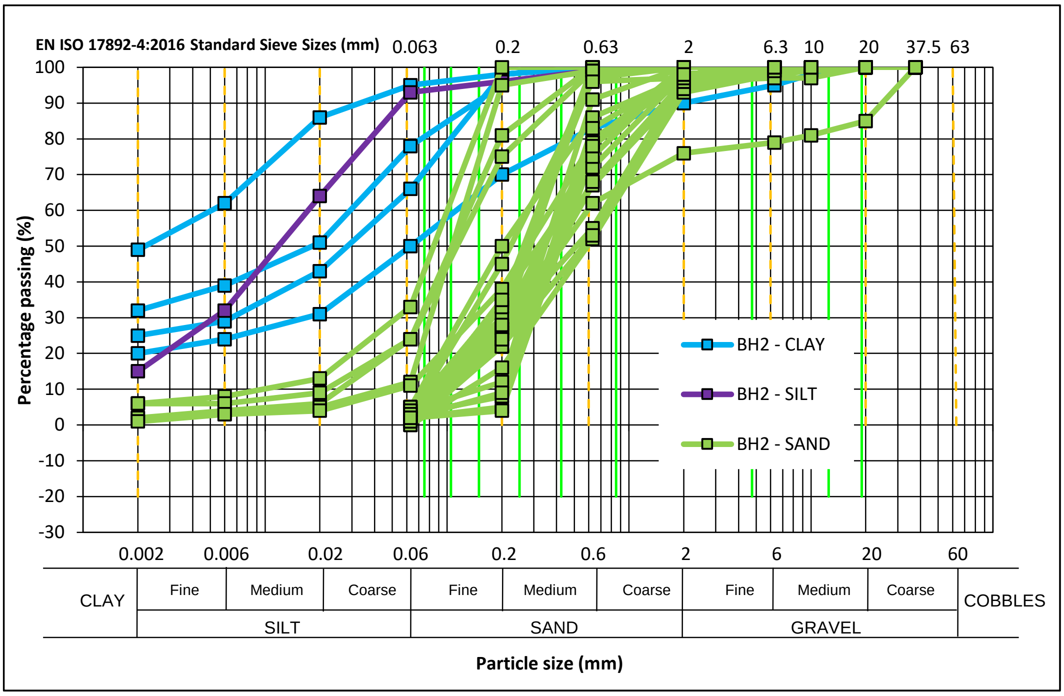


Figure 152 PSD plots for the tested material from route BH2, Part 1.

Laboratory test data are summarised below for granular material (Figure 153). The tested material have bulk and dry densities in the ranges from 1.48 to 2.10 Mg/m^3, and 1.12 to 1.85 Mg/m^3, respectively. There is a general increase in density with depth.

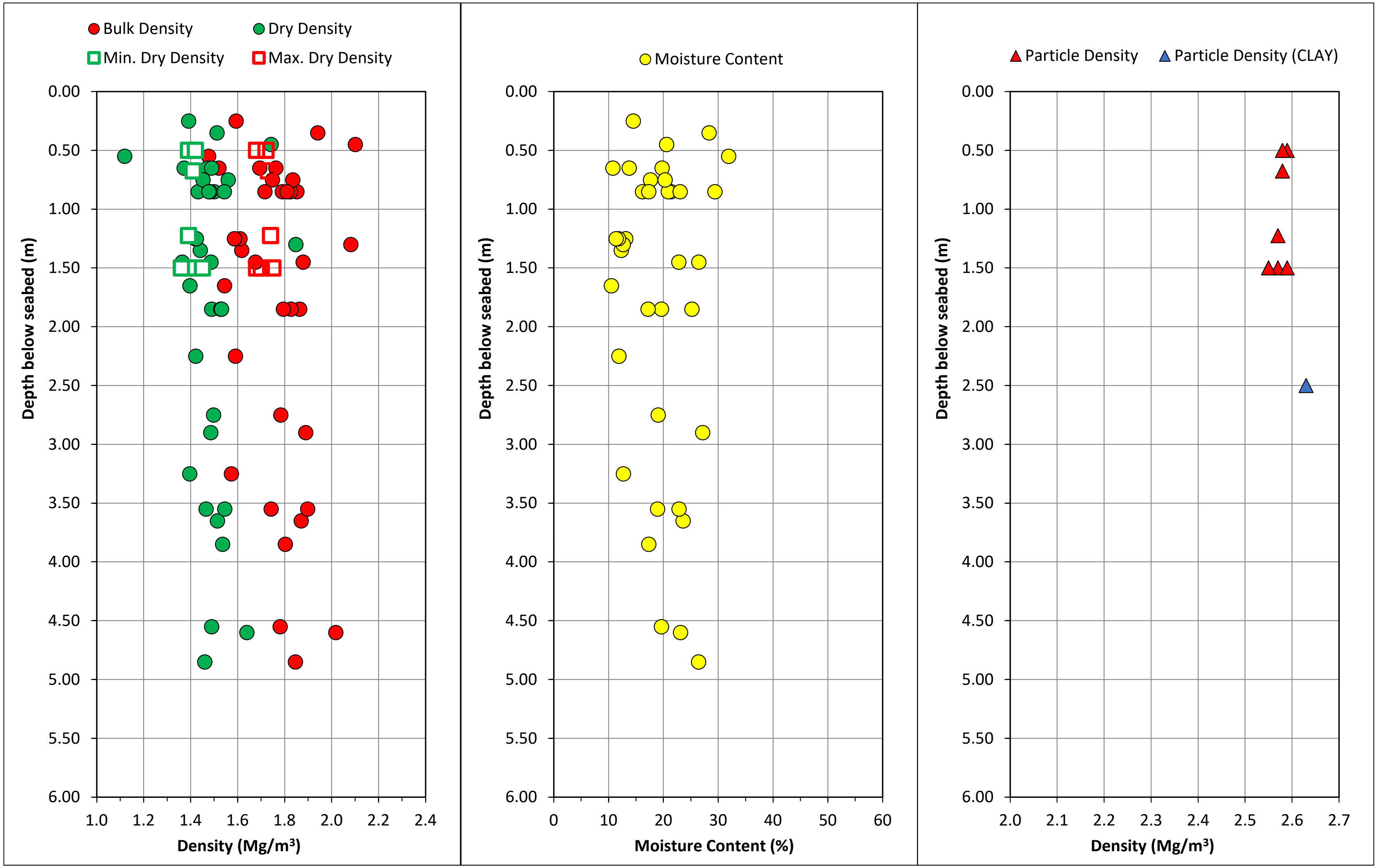


Figure 153 Laboratory test data for granular material, route BH2, Part 1.

Min and max dry densities are in the close ranges 1.36 to 1.45 Mg/m³, and 1.68 to 1.75 Mg/m³, respectively. Particle densities are in the range 2.55 to 2.59 Mg/m³. Moisture contents in granular material are in the range 11 to 32 %.

Laboratory density test data are summarised below for cohesive material (Figure 154). Bulk and dry densities for Glacial Till are in the ranges from 1.90 to 2.25 Mg/m³, and 1.55 to 1.97 Mg/m³, respectively. In lower strength CLAY bulk and dry densities are lower, in the ranges 1.72 to 2.15 Mg/m³, and 1.11 to 1.78 Mg/m³, respectively. A single particle density from low strength CLAY is 2.63 Mg/m³.

Determined moisture contents are also shown below for cohesive material. Glacial Till typically has moisture contents in the range 14 to 23 %, whilst lower strength CLAYs are more variable, from 21 to 55 %.

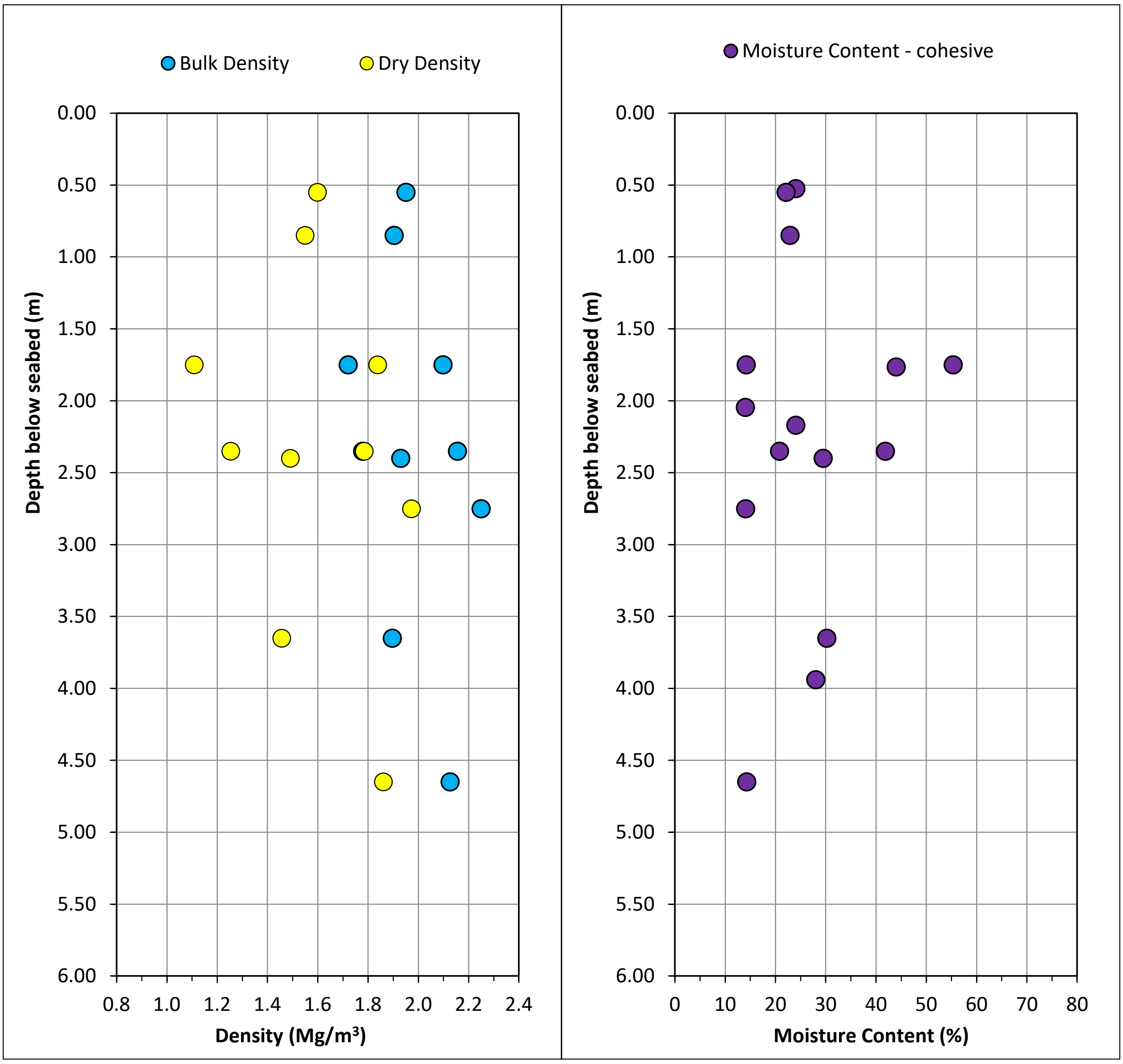


Figure 154 Laboratory test data for cohesive material, route BH2, Part 1.

Five Atterberg Limit tests were carried out on material from this route. The data are plotted below (Figure 155). Four of the tests returned as CLAY of low to intermediate plasticity with a single test returning as high plasticity. Glacial Till is low plasticity, whilst the lower strength CLAY returned as intermediate to high plasticity.

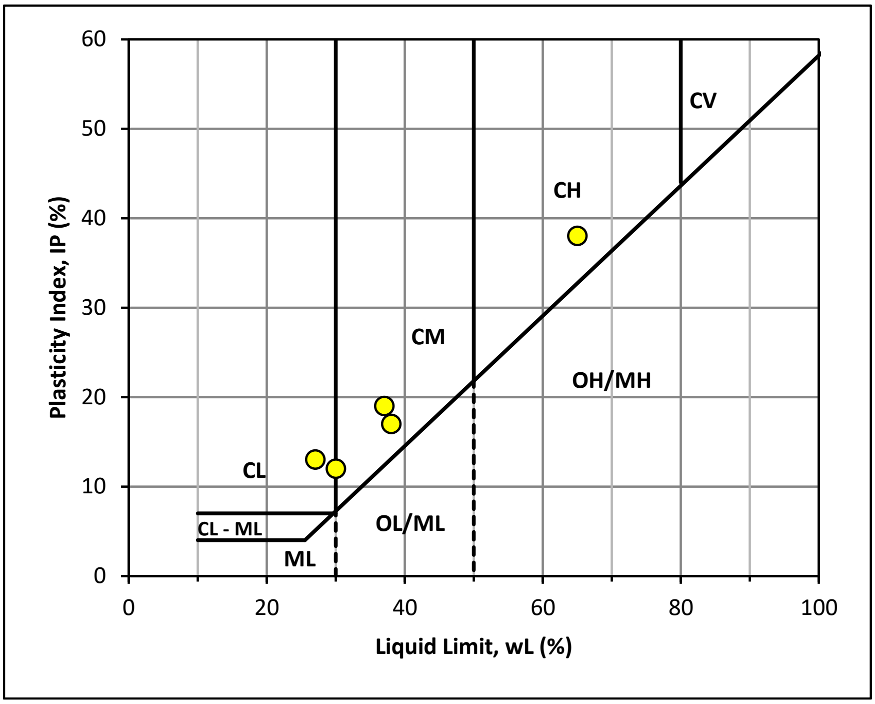


Figure 155 Plasticity Chart for route BH2, Part 1.

Laboratory shear strength data for cohesive material are shown below (Figure 156). The data indicates two groups. Stiff to very stiff CLAY, considered to be Glacial Till are typically in the medium to high strength ranges, whilst non-glacial CLAY is low to medium strength.

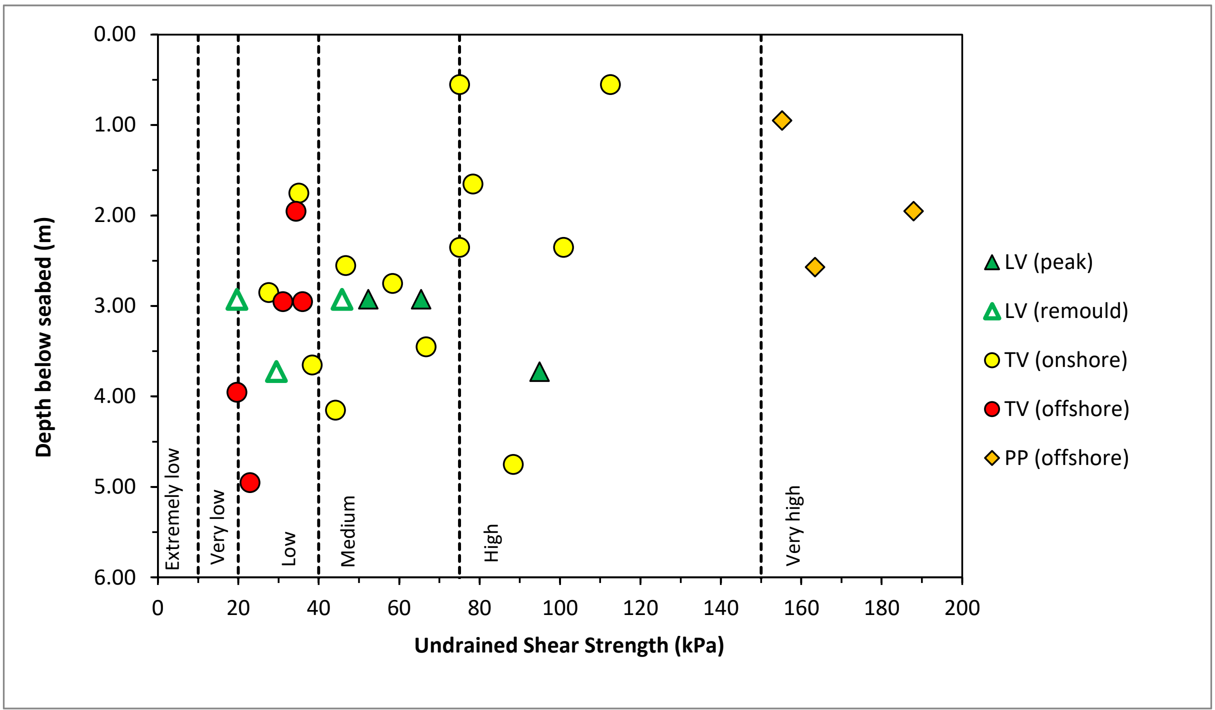


Figure 156 Laboratory shear strength data for route BH2, Part 1.

A summary of the acquired thermal resistivity data is shown below (Figure 157). The data for both cohesive and granular material mainly follow the expected trend of increasing resistivity with increasing moisture content. Three tests carried out on low moisture content SAND, which provide relatively high resistivities of 0.62 to 0.64 K m/W should be treated with caution.

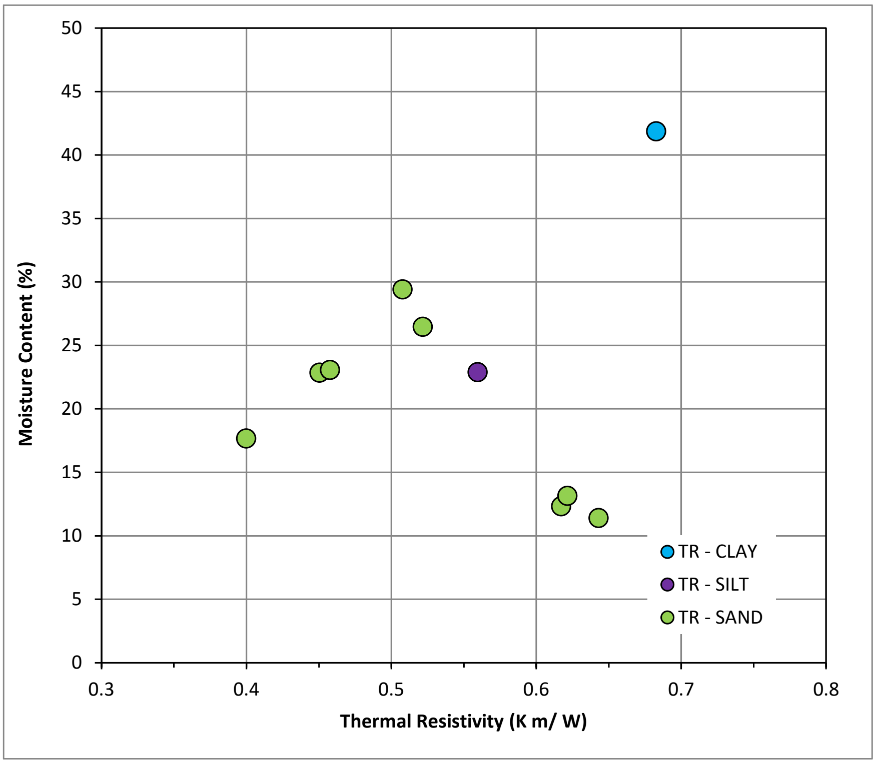


Figure 157 Summary of thermal data for route BH2, Part 1.

Cone Penetration Testing

Twenty three CPT were carried out at the seventeen locations on this route. Two re-attempts were carried out at three locations (BH2-03, BH2-04 and BH2-07). In the six attempts at locations BH2-03 and BH2-04, the deepest penetration achieved was only 0.62 m. The VC on the co-located positions achieved good recovery of 3.90 and 3.12 m, respectively, and it is not readily apparent why the CPT at these locations suffered shallow refusals.

Glacial Till was encountered from KP 15.568 (location BH2-07) through to KP 17.256 (location BH2-09), with the CPT penetrating to the required depth (Figure 158). At other locations across the route where granular material dominates, the depth to dense to very dense granular strata was generally shallow, at < 1.00 m. At the final location on the route at KP 27.200 (location BH2-19), low to medium strength CLAY was present from 1.96 m depth, overlain by medium dense to dense SAND. The measured cone responses were good with the resulting sediment interpretation being considered accurate and often close to the ground conditions in the co-located VC locations.

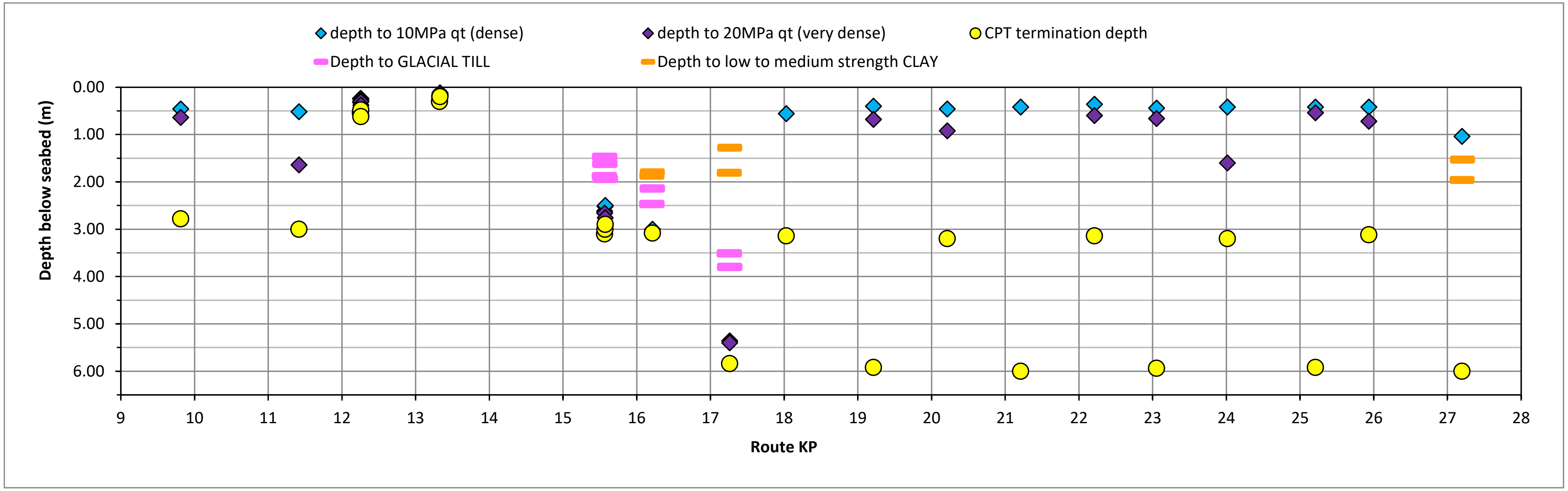


Figure 158 Plot of CPT test depths and interpreted stratum depths for route BH2, Part 1.

Measured cone resistances from the CPT are shown below (Figure 159). At locations BH2-03 and BH-04, the sharp increase in tip resistance at shallow depths, up to 50 MPa is clearly seen, indicating some localised shallow depth obstruction. In those tests where Glacial Till was encountered below granular material, cone resistances are low, < 2 MPa, with some sharp increases in tip resistances resulting in test termination, reflecting dense to very dense granular layers within the glacial deposits. At location BH2-19, loose to dense granular material extends to 1.96 m depth, with tip resistances in the low to medium strength CLAY below not exceeding 0.1 MPa.

Figure 160 below shows the calculated relative density profiles from the CPT data. The granular material is typically medium dense to very dense over the depth investigated. Very dense material is typically seen within the upper 1.00 m depth range. Figure 160 also shows the calculated shear strength profiles for the encountered CLAY, at an Nkt factor of 17.5. For the Glacial Till shear strengths are high, typically > 40 kPa. In the CLAY encountered at location BH2-19, calculated shear strengths are lower, generally in the range 20 to 40 kPa. The laboratory derived shear strength data are broadly consistent with the spread of CPT derived data from the two different types of CLAY encountered.

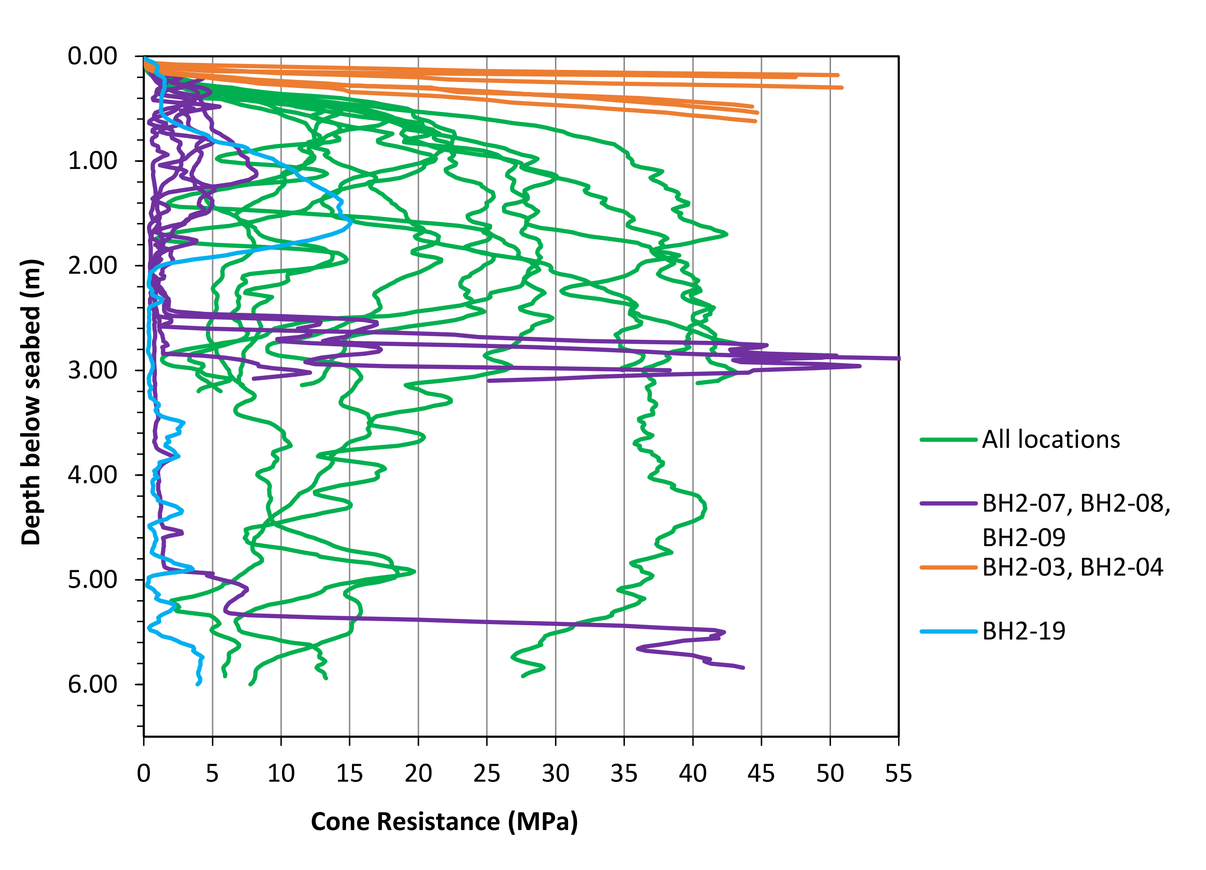


Figure 159 Plot of cone tip resistances for route BH2, Part 1.

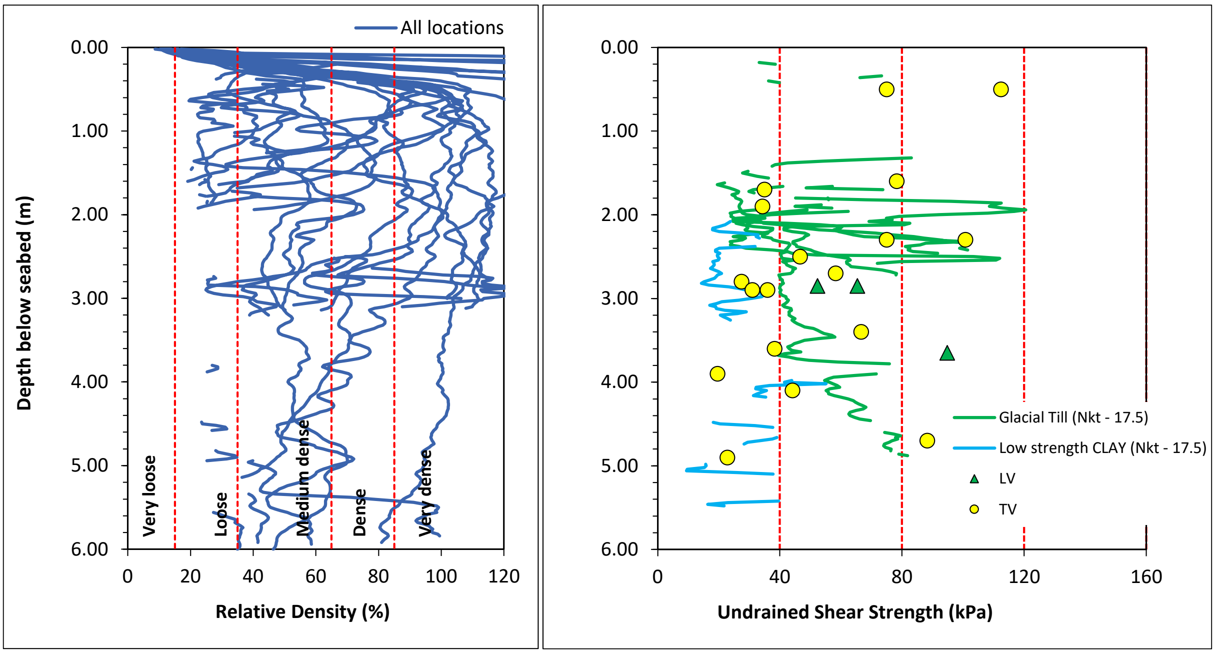


Figure 160 Plot of CPT derived parameters for route BH2, Part 1.

9.2.6 Shallow Geology

Several sedimentary units were identified in the sub-surface geology along the proposed route ERS Bornholm 2, down to a maximum depth of 15.0 m below the seabed. A detailed description of the changes in shallow geology observed along this route can be found in the shallow geology section presented in Table 49 to Table 51.

The start of the route, in the shallower nearshore area from KP 9.206 to KP 14.093, is largely dominated by SEDIMENTARY ROCK, either outcropping or present below thin veneers (< 1.0 m) of more recent SAND, GRAVEL or TILL, or below channels of SANDs and CLAYs. Between KP 0.000 and KP 14.100 there is significant uncertainty determining the top of Bedrock. This is due to the coarseness of the seabed sediments, weathered interface of the rock and very irregular rock bedding. Geotechnical points have been sited where there is sufficient sediment to sample. Caution should be taken extrapolating the depth of sediment cover between geotechnical sites. Please refer to report for more details and image examples. Where present, these veneers and channels have been identified as the units P1_H10 and P1_H45i respectively.

In the northern-central KP range from KP 14.093 to KP 17.773, the route is largely dominated by non-continuous units of silty gravelly SAND and firm to very stiff CLAY, typically undulating from the seabed to between 2.0 to 7.7 m thick, with SEDIMENTARY ROCK interpreted to be present below.

The uppermost, and youngest, SAND unit in this northern-central KP range has been confirmed to be recent Holocene silty gravelly SAND (P1_H10) based on the geotechnical sampling results, with some gradational lateral variation from silty SAND to silty sandy GRAVEL. The unit is predominantly classified as silty SAND or gravelly SAND on the profiles for simplification, with details of localised variations documented in Section 9.2.7. These sediments are often internally acoustically transparent, with the reflector at the base of this unit mostly flat and present from depths ranging from 0 – 0.5 m below seabed.

The next SAND unit identified in this northern-central KP range has been determined to be a Late/Post Glacial silty SAND, to silty gravelly SAND (P1_H20). This unit is primarily classified as a silty SAND on the profiles for the purpose of simplification, with details of localised variations documented in Section 9.2.7Table 49. This unit varies in thickness, with maximum thickness approximately 2.3 m, and is abundant in internal reflectors with varying in length, orientation, and amplitude. It also has a mostly flat, high amplitude basal reflector which separates it from the sediments below.

Identified below these SAND units in this northern-central KP range, is a Glacial CLAY unit (P1_H50). The Glacial CLAY unit has a slightly silty, sandy and gravelly composition which is variable across this section of the route. The unit predominantly displays a low to high amplitude chaotic internal structure in the SBP data. The geotechnical results confirm that the CLAY unit is predominantly firm to very stiff, as identified on the profiles. Beyond KP 17.773, the base of the CLAY unit is unable to be identified on the SBP data due to a decrease in amplitude of the basal reflector. In some places this Glacial CLAY unit is visible up to the seabed, where a GRAVEL and coarse SAND and/or TILL/DIAMICTION are observed. Caution should therefore be taken where this Glacial CLAY unit is encountered as geohazards such as boulders may be present in the shallow geology but not able to be identified in the SBP data.

Above the P1_H50 Glacial CLAY unit in the northern-central KP range, between KP 14.339 and KP 17.742, a non-continuous internal reflector has been used to identify areas of Late Glacial clayey, silty, gravelly SAND (P1_H35i). This is primarily classified as a Glacial Clayey SAND on the profiles for the purpose of simplification, with details of localised variations documented in Section 9.2.7. Above the reflector, a low-medium amplitude reflectivity is often observed, with occasional high amplitude internal reflectors, typically of a more silty to clayey composition. However, this is very similar to the acoustic character of the CLAY that is present below this, with the internal reflector often very low amplitude and only distinguishable with any certainty on the CL, in correlation with the geotechnical results. The geotechnical data confirms the Glacial SAND is occasionally visible up the seabed, but more commonly observed below the other more recent SAND units. It generally thickens from north to south along the route, with its base observed at 1.9 m BSB at KP 14.484 but at 7.7 m BSB by KP 17.742 in the south. Similarly, to the base of P1_H50, the reflector P1_H35i is unable to be identified on the SBP data beyond KP 17.742 due to a decrease in amplitude.

The centre-southern KP range from KP 17.773 to KP 26.400 is largely dominated by a thick unit of silty to silty gravelly SAND, with the base of SAND beyond the depth of SBP penetration, and/or below the end of the SBP record length. A veneer (< 0.6 m) of silty gravelly SAND (P1_H10), with some gradational lateral variation from silty SAND to silty sandy GRAVEL, is commonly observed above the thicker SAND unit in this KP range. The silty SAND, to silty gravelly SAND unit (P1_H20) with high amplitude internal reflectors has also been identified in this KP range, thickening towards the south.

In the end section of the route to the very South in the deeper water area from KP 26.400 to KP 27.605, the geology is again dominated by units of silty to silty gravelly SAND (P1_H10 and P1_H20) over the stiffer Glacial CLAY of P1_H50.

Overview maps of the distribution of interpreted SANDs and Glacial CLAY along the route can be seen in Figure 161.

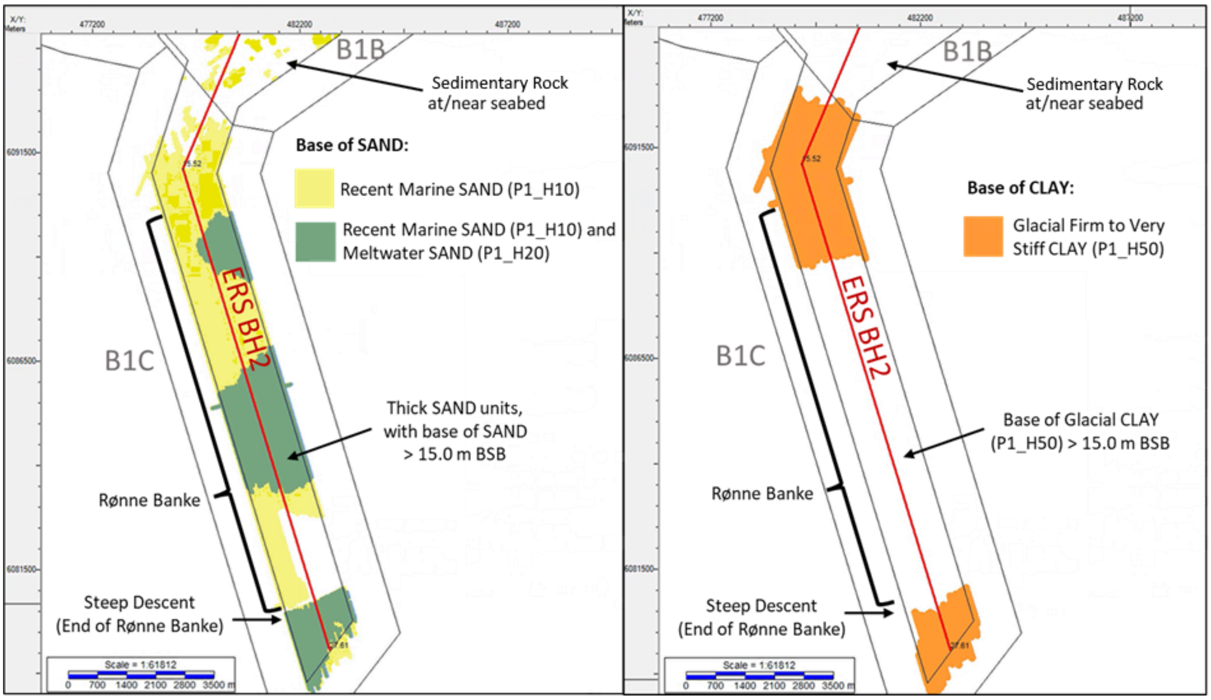


Figure 161 Overview maps of the distribution of interpreted geological units (Left – SAND distribution, Right – Glacial CLAY distribution) along ERS Bornholm 2 KP 12 to KP 27.

9.2.7 Detailed Description

A detailed presentation of the conditions and features of ERS Bornholm 2 Route are shown in Table 49 to Table 51 and associated figures.

Table 49 ERS Bornholm 2 detailed description for alignment chart 103971-ENN-OI-SUR-DWG-P1BH2001 (KP 9.206 - 16.596).

Alignment Chart 103971-ENN-OI-SUR-DWG-P1BH2001 (KP 9.206 - 16.596)	
Description (including min/max depth BSB to base of unit)	**Remark**
Bathymetry: Seafloor is sloping and highly irregular until it flattens at KP 14.000 and remains flat until KP 16.596.	Irregular, Very Steep slopes due to geology. Total Depth range = 10.64 m. Maximum slope of 26.15° on geological outcrop at KP 12.868. Minimum depth 10.6 m at KP 13.145. Maximum depth 21.24 m at KP 11.406.
Surficial Geology: Between 9.206 and KP 13.957 the seabed is characterised by SEDIMENTARY ROCK, ridges are formed where the rock outcrops. GRAVEL and coarse SAND and DIAMICTON infill the erosional surface of the bedrock (Figure 162 to Figure 165). The last occurrence of SEDIMENTARY ROCK outcropping is at KP 15.520, here a thin ridge trends north from the route. Between KP 13.957 and KP 16.596 the dominant seabed sediment is GRAVEL and coarse SAND, ribbons of north-south trending SAND are present from KP 15.330 (Figure 165). Ripples occur in most areas of GRAVEL and coarse SAND, crests are orientated north to south in line with the prevailing storm wave base (Figure 169). Between KP 9.206 and KP 14.372 is covered by glacial debris mostly falling under the high-density boulder field category. Patches where boulder numbers are low include ridges of rock outcrops and some areas within GRAVEL and coarse SAND. Following KP 14.372 boulders still occur but generally in low numbers, some small areas of boulder fields occur in the low to intermediate density category.	**Infrastructure:** Utility ID 07 (Pipeline, Baltic Pipe) detected on the MAG dataset. Pipeline is buried seabed disturbance observed on SSS dataset. Crossing at KP 14.597 (Figure 165). Utility ID 3 (cable, unknown) detected on the MAG dataset. Not seen on the SSS or MBES data. Crossing at KP 15.241. **Grab Samples:** 971-ENE-GR-GS-057 971-ENE-GR-GS-058 971-ENE-GR-GS-059 971-ENE-GR-GS-060 971-ENE-GR-GS-061 971-ENE-GR-GS-062 971-ENE-GR-GS-063 971-ENE-GR-GS-064 971-ENE-GR-GS-065 971-ENE-GR-GS-066

Alignment Chart 103971-ENN-OI-SUR-DWG-P1BH2001 (KP 9.206 - 16.596)	
Description (including min/max depth BSB to base of unit)	**Remark**
	971-ENE-GR-GS-067 971-ENE-GR-GS-068 971-ENE-GR-GS-069 971-ENE-GR-GS-070 971-ENE-DV-GS-100 971-ENE-DV-GS-101 971-ENE-DV-GS-102 971-ENE-DV-GS-103 971-ENE-DV-GS-104 971-ENE-DV-GS-105 971-ENE-DV-GS-106 971-ENE-DV-GS-107 971-ENE-DV-GS-108 971-ENE-DV-GS-109 971-ENE-DV-GS-126 971-ENE-DV-GS-127 971-ENE-DV-GS-134 971-ENE-DV-GS-135
Shallow Geology: KP 9.206 – KP 14.093 (Figure 166.): The shallow geology at the start of the route is dominated by SEDIMENTARY ROCK which is visible in the SBP data from the seabed to the end of the SBP record length at approximately 11.0 m BSB. The SEDIMENTARY ROCK is observed to be either outcropping at the surface or beneath a thin veneer (< 0.5 m BSB) of surficial sediments (P1_H10). The internal structure of the SEDIMENTARY ROCK is predominantly low amplitude reflectivity with high amplitude inclined reflectors. These reflectors vary in orientation and morphology throughout the KP range.	**Vibrocores and CPTs:** BH2-01 and BH2-01-CPT BH2-02 and BH2-02-CPT BH2-03 and BH2-03A-CPT BH2-04B and BH2-04B-CPT BH2-07B and BH2-07B-CPT BH2-08 and BH2-08-CPT

Alignment Chart 103971-ENN-OI-SUR-DWG-P1BH2001 (KP 9.206 - 16.596)	
Description (including min/max depth BSB to base of unit)	**Remark**
Within this KP range, three small isolated U to V shaped silty gravelly SAND filled Late to Post Glacial channels (P1_H45) have been interpreted to be present within the SBP data. These channels generally display a chaotic high amplitude reflectivity in the SBP data. Interpreted channel locations: KP 11.167 to KP 11.199 – Maximum depth 1.1 m BSB KP 11.294 to KP 11.497 – Maximum depth 5.5 m BSB KP 12.133 to KP 12.197 – Maximum depth 1.3 m BSB KP 14.093 to KP 14.339 (Figure 167): In this section of the route, the SEDIMENTARY ROCK unit can be observed to gradationally dip away from the seabed with a Glacial CLAY unit (P1_H50) above. The Glacial CLAY unit is firm to very stiff, silty, slightly sandy, slightly gravelly with chaotic high amplitude reflectivity on SBP data. It appears at the seabed at KP 14.093 and gradually thickens to 2.0 BSB by KP 14.339. KP 14.339 to KP 14.619 (Figure 167): A thin veneer (< 0.5 m BSB) of recent marine surficial sediments, likely silty gravelly SAND (P1_H10) is observed between KP 14.472 to KP 14.559. A localised region of Late Glacial clayey, silty SAND to clayey silty gravelly SAND (P1_H35i) is present from 0 – 2.0 m BSB. It displays a chaotic low-medium amplitude reflectivity with occasional high amplitude reflectors and its base is difficult to distinguish from sediments below. There is a gradational transition visible on the SBP data from this Glacial SAND into a firm to very stiff, silty, slightly sandy, slightly gravelly Glacial CLAY (P1_H50) with chaotic high amplitude reflectivity on SBP data. This Glacial CLAY is present with an average thickness of 1.2 m below the SAND (P1_H35i), approximately averaging 2.8 m BSB. SEDIMENTARY ROCK is interpreted to be present below this, with occasional inclined internal reflectors visible. KP 14.619 to KP 14.781:	

Alignment Chart 103971-ENN-OI-SUR-DWG-P1BH2001 (KP 9.206 - 16.596)	
Description (including min/max depth BSB to base of unit)	**Remark**
A firm to very stiff, silty, slightly sandy, slightly gravelly Glacial CLAY unit (P1_H50) with chaotic high amplitude reflectivity on SBP data is visible from the seabed to 2.6 m BSB. SEDIMENTARY ROCK is interpreted to be present below this, with occasional inclined internal reflectors visible. KP 14.781 to KP 14.950: A localised region of Late Glacial clayey, silty SAND to clayey silty gravelly SAND (P1_H35i) is present from 0 – 2.2 m BSB. It displays a chaotic low-medium amplitude reflectivity with occasional high amplitude reflectors and its base is difficult to distinguish from sediments below. There is a gradational transition visible on the SBP data from this Late Glacial SAND into a firm to very stiff, silty, slightly sandy, slightly gravelly Glacial CLAY (P1_H50) with chaotic higher amplitude reflectivity on SBP data. This Glacial CLAY is present with an average thickness of 1.2 m below the Late Glacial SAND (P1_H35i), approximately averaging 2.8 m BSB. SEDIMENTARY ROCK is interpreted to be present below this, with occasional inclined internal reflectors visible. KP 14.950 to KP 15.080: A firm to very stiff, silty, slightly sandy, slightly gravelly Glacial CLAY unit (P1_H50) with chaotic high amplitude reflectivity on SBP data is visible from the seabed to 2.7 m BSB. SEDIMENTARY ROCK is interpreted to be present below this, with occasional inclined internal reflectors visible. KP 15.080 to 16.596 (Figure 168): A thin veneer (< 0.5 m BSB) of recent marine surficial sediments, from silty gravelly SAND to silty sandy GRAVEL, (P1_H10) is observed between KP 15.445 to KP 16.596. A Late Glacial clayey, silty, gravelled SAND to clayey sandy SILT (P1_H35i) is observed to undulate from the seabed to between 0.4 – 2.6 m BSB. It displays a chaotic low-medium amplitude reflectivity with occasional high amplitude reflectors and its base is difficult to distinguish from sediments below. There is a gradational transition visible on the SBP data from this Late Glacial SAND into a firm to very stiff, silty, slightly sandy, slightly gravelly Glacial CLAY (P1_H50) with chaotic high amplitude reflectivity on SBP data. The	

Alignment Chart 103971-ENN-OI-SUR-DWG-P1BH2001 (KP 9.206 - 16.596)	
Description (including min/max depth BSB to base of unit)	**Remark**
Glacial CLAY is present with an average thickness of 1.0 m below the SAND (P1_H35i), approximately averaging 3.1 m BSB. SEDIMENTARY ROCK is interpreted to be present below this, with occasional inclined internal reflectors visible.	

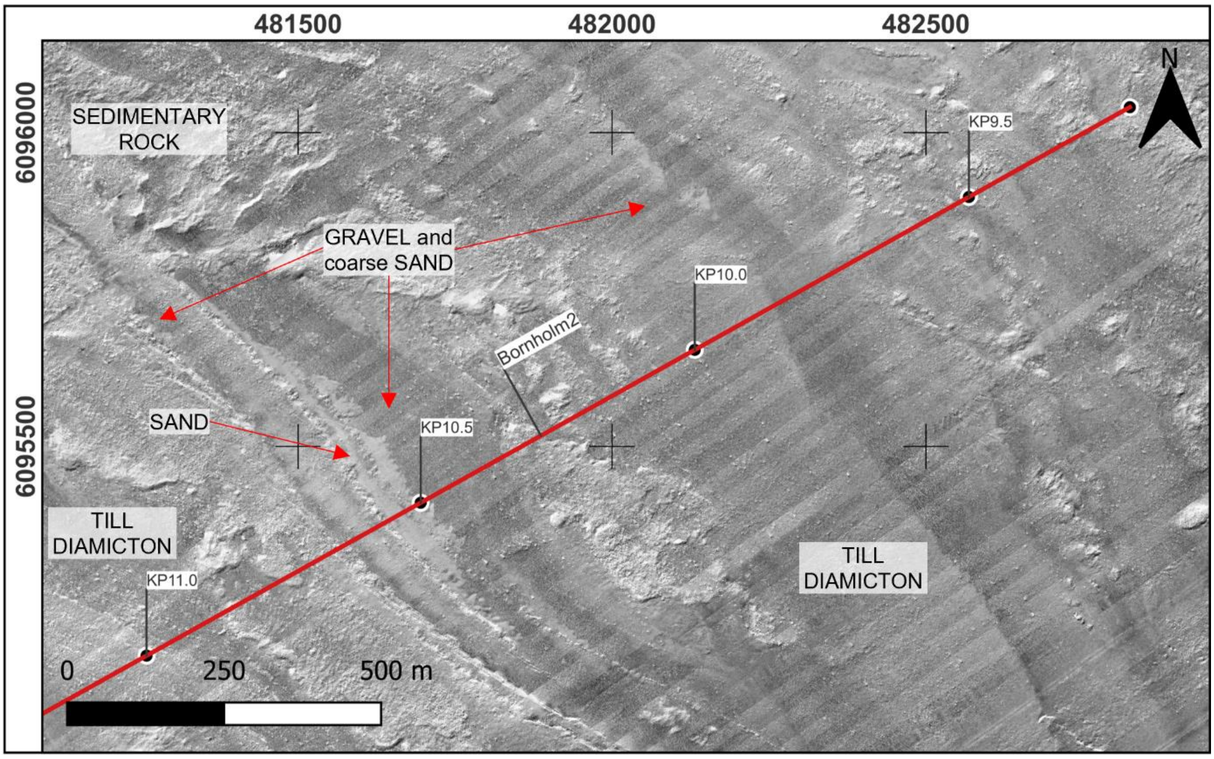


Figure 162 Overview of surficial geology from KP 9.2 to KP 11.2 as seen on SSS.

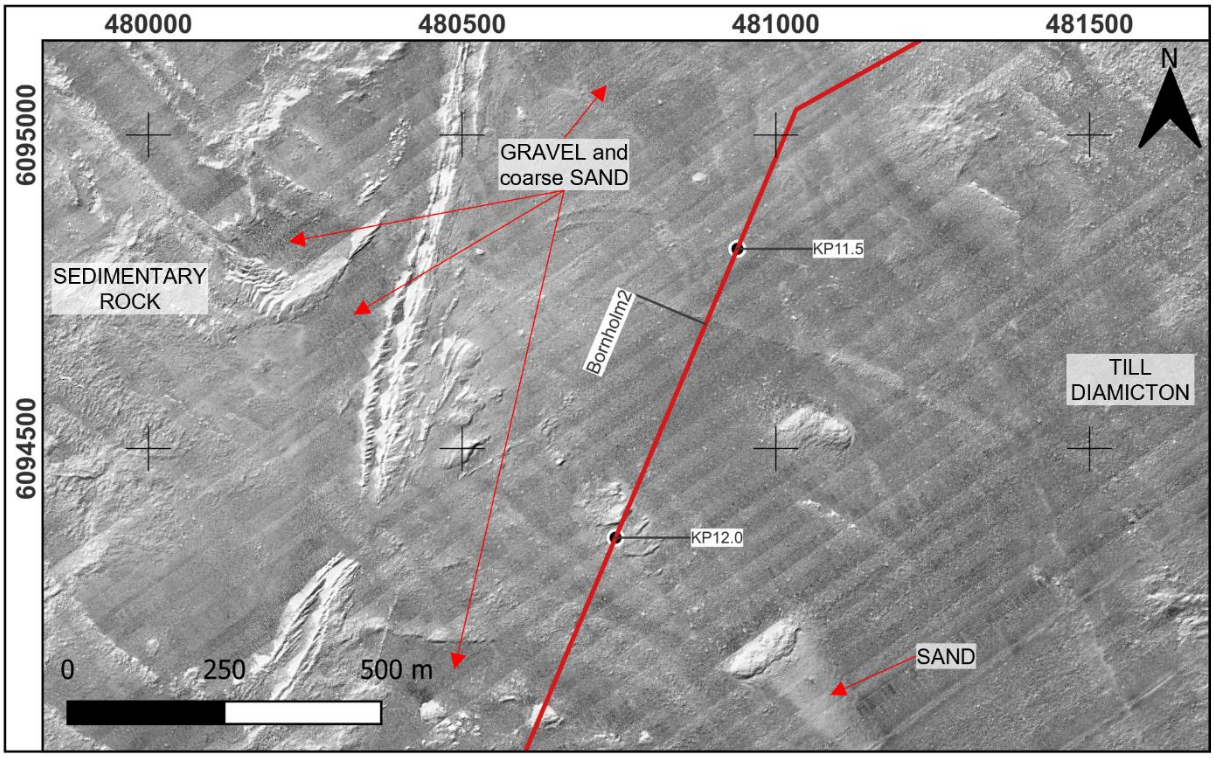


Figure 163 Overview of surficial geology from KP 11.0 to KP 12.4 as seen on SSS.

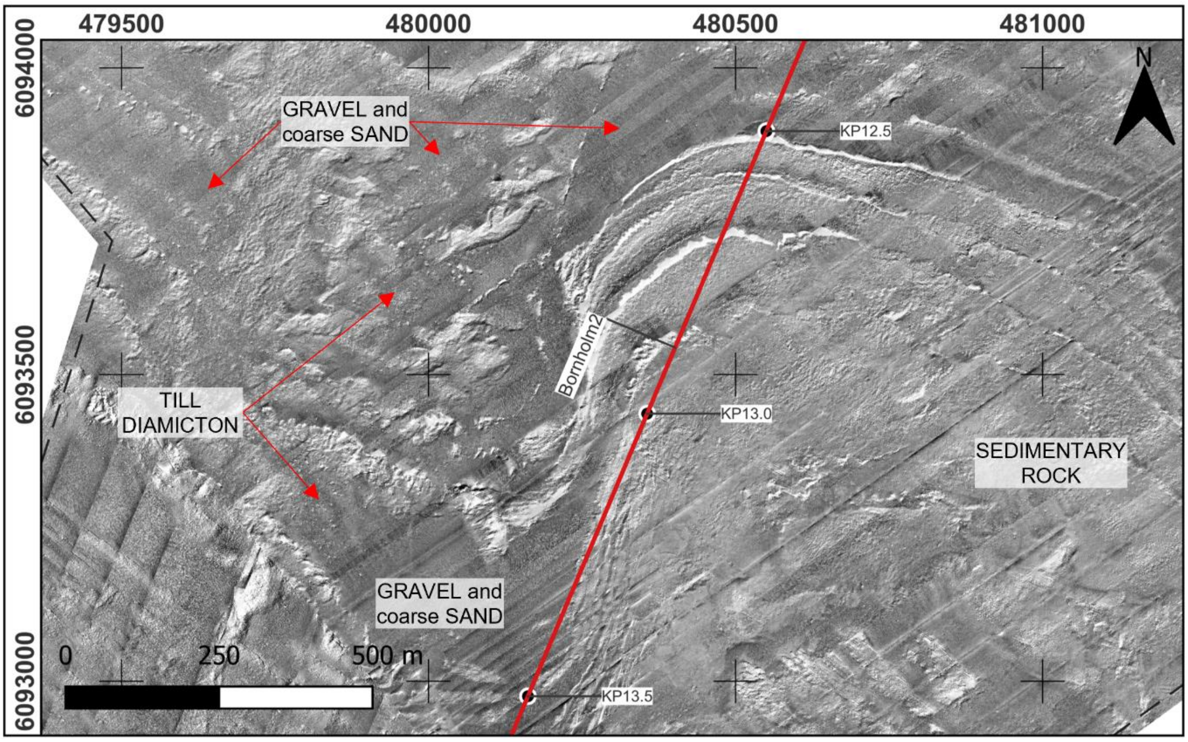


Figure 164 Overview of surficial geology from KP 12.2 to KP 13.6 as seen on SSS.

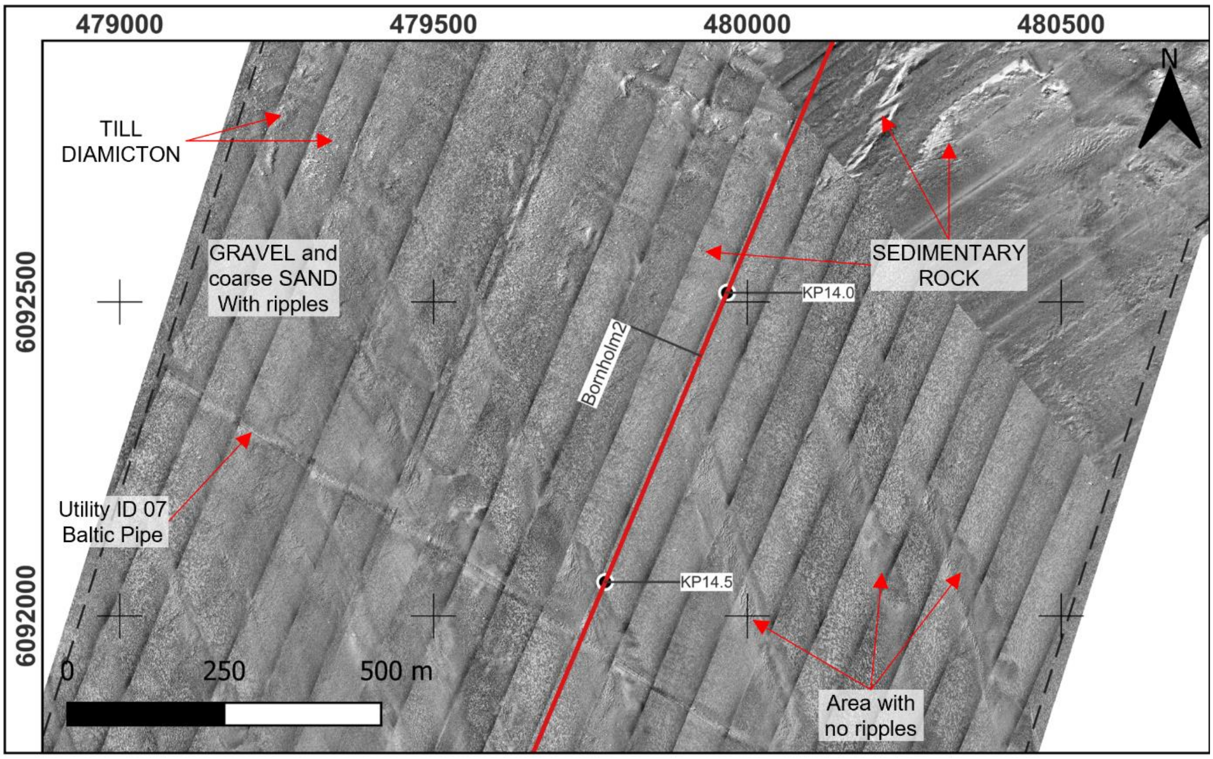


Figure 165 Overview of surficial geology from KP 13.5 to KP 14.8 as seen on SSS.

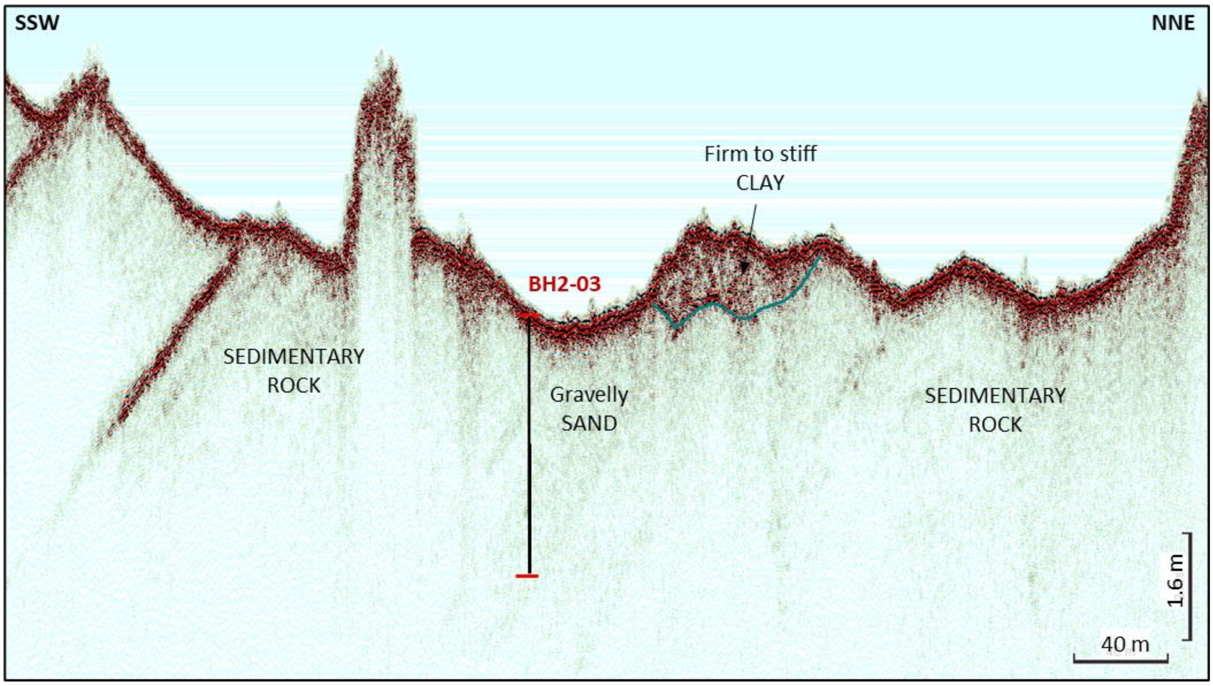


Figure 166 Innomar SBP data example from KP 12.480 (SSW) to KP 11.962 (NNE).

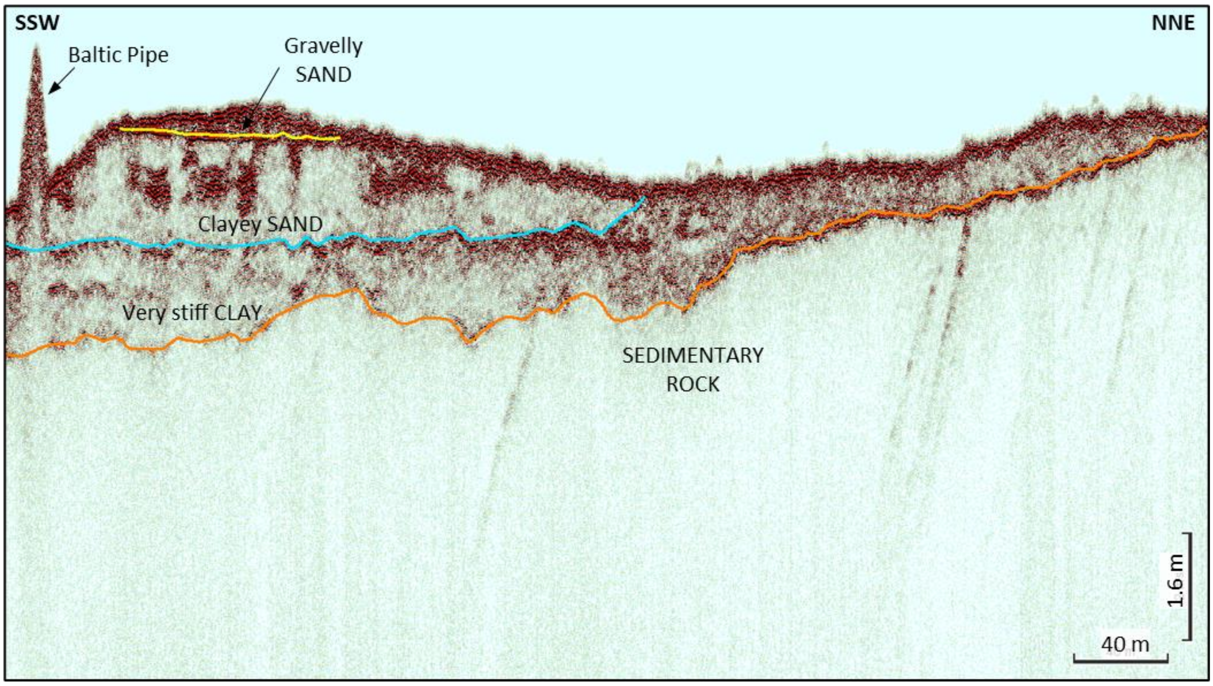


Figure 167 Innomar SBP data example from KP 14.612 (SSW) to KP 14.090 (NNE).

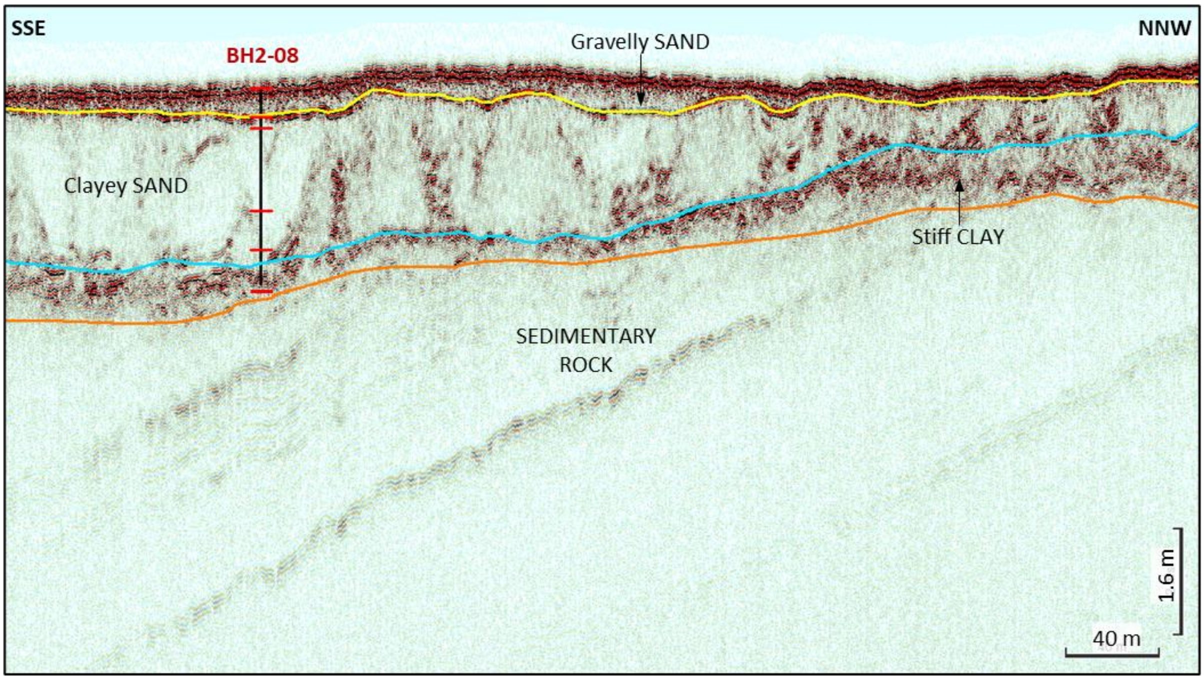


Figure 168 Innomar SBP data example from KP 16.318 (SSE) to KP 15.797 (NNW).

Table 50 ERS Bornholm 2 detailed description for alignment chart 103971-ENN-OI-SUR-DWG-P1BH2002 (KP 16.096 - 25.586).

Alignment Chart 103971-ENN-OI-SUR-DWG-P1BH2002 (KP 16.096 - 25.586)	
Description (including min/max depth BSB to base of unit)	**Remark**
Bathymetry: Relatively flat seabed with gentle to moderate slopes.	Depths range = 5.3 m. Maximum slope = 3.64° at KP 20.299. Minimum depth 13.96 m at KP 16.555. Maximum depth 19.22 m at KP 25.194.
Surficial Geology: Between KP 16.096 and KP 25.586 the dominant seabed sediment is GRAVEL and coarse SAND, ribbons of north-south trending SAND are present. Sand ribbons do not occur after KP 24.622. Ripples occur in most areas of GRAVEL and coarse SAND, crests are orientated north to south in line with the prevailing storm wave base (Figure 169) Boulders are present within the area but generally in low numbers, some small areas of boulder fields occur in the low to intermediate density category.	**Infrastructure:** Utility ID 05 (cable, unknown) detected on the MAG dataset but with low confidence due to few anomalies. Not detected on the SSS and MBES datasets or WPD. Crossing at KP 18.347. **Grab Samples:** 971-ENE-GR-GS-059 971-ENE-GR-GS-061 971-ENE-GR-GS-064 971-ENE-GR-GS-065 971-ENE-GR-GS-066
Shallow Geology: KP 16.096 to KP 17.187 (Figure 168): A thin veneer (< 0.5 m BSB) of recent marine surficial sediments, from silty gravelly SAND to silty sandy GRAVEL, (P1_H10) is observed at the seabed. A Late Glacial clayey, silty SAND to clayey silty gravelly SAND (P1_H35i) is observed to gradually increase in thickness below the surficial layer from 2.4m BSB at KP 16.096 to 4.7 m BSB at KP 17.187. It displays a chaotic low-medium amplitude reflectivity in the SBP data and its base is difficult to distinguish from sediments below.	**Vibrocores and CPTs:** BH2-08 and BH2-08-CPT BH2-09 and BH2-09-CPT BH2-10 and BH2-10-CPT BH2-11 and BH2-11-CPT BH2-12 and BH2-12-CPT BH2-13 and BH2-13-CPT BH2-14 and BH2-14-CPT

Alignment Chart 103971-ENN-OI-SUR-DWG-P1BH2002 (KP 16.096 - 25.586)	
Description (including min/max depth BSB to base of unit)	**Remark**
There is a gradational transition visible on the SBP data from this SAND into a thin layer of firm to very stiff, silty, slightly sandy, slightly gravelly Glacial CLAY (P1_H50) with chaotic high amplitude reflectivity on SBP data. The Glacial CLAY is present with an average thickness of 0.8 m below the SAND (P1_H35i), approximately averaging 4.0 m BSB. SEDIMENTARY ROCK is interpreted to be present below this, with occasional inclined internal reflectors visible. KP 17.187 to KP 18.104 (Figure 170): A thin veneer (< 0.5 m BSB) of recent marine surficial sediments, from silty gravelly SAND to silty sandy GRAVEL, (P1_H10) is observed at the seabed. Below this a late/post glacial washdown/meltwater silty SAND unit (P1_H20) with higher amplitude internal reflectors is observed to approximately 2.4 m BSB. A Late Glacial clayey, silty SAND to clayey silty gravelly SAND (P1_H35i) is observed to gradually increase in thickness to a maximum depth of 6.3 m BSB at KP 17.742. It displays chaotic low amplitude reflectivity in the SBP data. After KP 17.742, the low amplitude basal reflector decreases in amplitude further such that it is no longer distinguishable from the surrounding sediments. There is a gradational transition visible on the SBP data from this Late Glacial SAND into a thin layer of firm to very stiff, silty, slightly sandy, slightly gravelly Glacial CLAY (P1_H50) with chaotic high amplitude reflectivity on SBP data. The Glacial CLAY is present with an average thickness of 0.7 m below the Late Glacial SAND (P1_H35i), approximately averaging 5.6 m BSB. At KP 17.773, depth 7.6 m BSB, the basal reflector of the Glacial CLAY unit (P1_H50) decreases in amplitude such that it is no longer distinguishable from the surrounding sediments. SEDIMENTARY ROCK is interpreted to be present below the Glacial CLAY (P1_H50), where present, with a low amplitude reflectivity on the SBP data. KP 18.104 to KP 20.552:	BH2-15 and BH2-15-CPT BH2-16 and BH2-16-CPT BH2-17A and BH2-17-CPT

Alignment Chart 103971-ENN-OI-SUR-DWG-P1BH2002 (KP 16.096 - 25.586)	
Description (including min/max depth BSB to base of unit)	**Remark**
In this section of the route a thin unit (0.0 - 1.3 m BSB) which varies locally from a recent marine silty SAND to silty gravelly SAND (P1_H10) is observed in the SBP data as a low amplitude reflectivity unit with acoustic transparency. The base of this unit is defined by a mostly flat high amplitude reflector. Below this a thick Late Glacial silty SAND unit with no visible basal reflector interpreted as this is likely to be beyond the extent of the SBP data record length (approximately 15.0 m BSB). KP 20.552 to KP 23.450 (Figure 171): In this section of the route a thin unit (0.0 – 0.8 m BSB) which varies locally from a recent marine silty SAND to silty gravelly SAND (P1_H10) is observed in the SBP data as a low amplitude reflectivity unit with acoustic transparency. The base of this unit is defined by a mostly flat high amplitude reflector. Below this a late/post glacial washdown/meltwater silty SAND to silty gravelly SAND unit (P1_H20) with low to high amplitude internal reflectors is observed to gradually thicken through this KP range from 0.5 m BSB at KP 20.552 to 5.2 m BSB at KP 23.450. At KP 23.450, the base of the unit decreases in amplitude such that it is no longer distinguishable from the surrounding sediments. Below P1_H20 is likely to be continued thick silty SAND to silty gravelly SAND, with no visible basal reflector interpreted as this is likely to be beyond the extent of the SBP data record length (approximately 15.0 m BSB). KP 23.450 to KP 23.952 (Figure 172): In this section of the route a thin unit (0.0 – 0.6 m BSB) of recent marine silty gravelly SAND (P1_H10) is observed in the SBP data as a low amplitude reflectivity unit with acoustic transparency. The base of this unit is defined by a mostly flat high amplitude reflector. Below this, silty SAND to silty gravely SAND is interpreted to extend beyond the extent of the SBP data record length (approximately 15.0 m BSB). KP 23.952 to KP 25.586 (Figure 173): Silty SANDs to silty gravelly SANDs are interpreted to extend beyond the extent of the SBP data record length (approximately 15.0 m BSB).	

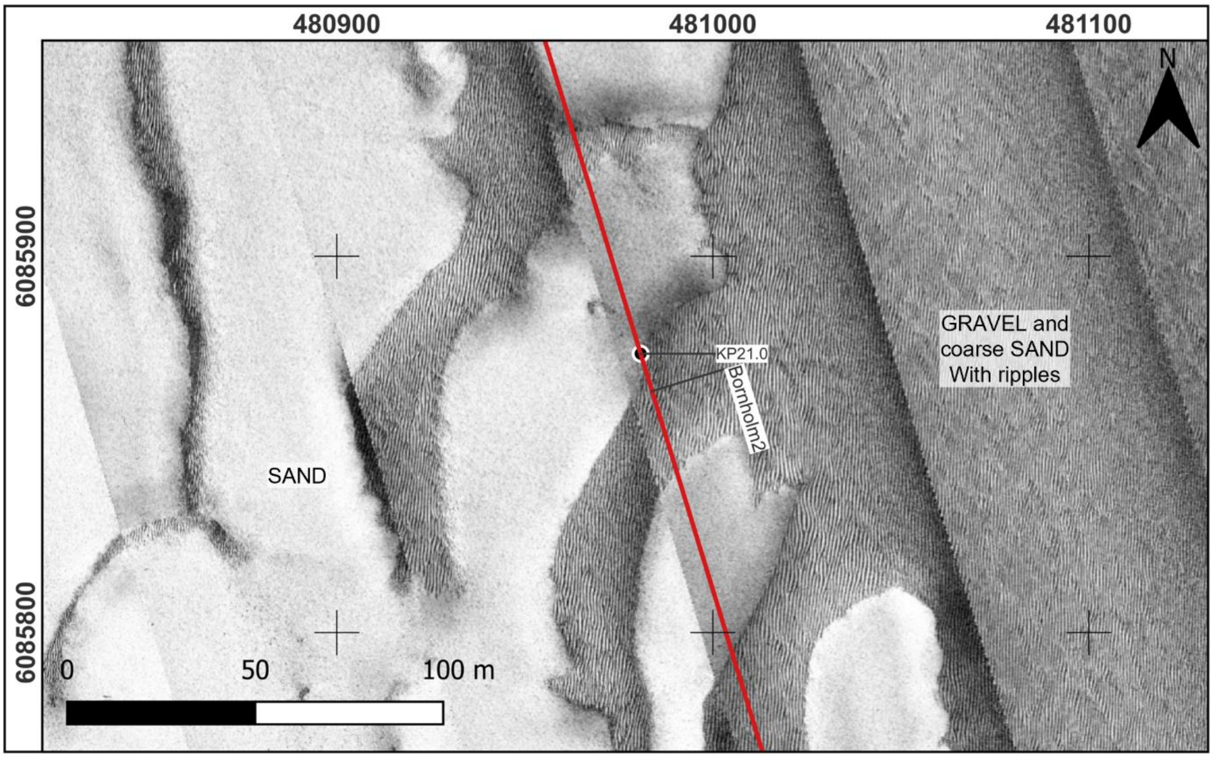


Figure 169 Overview of surficial geology at KP 21.0 as seen on SSS.

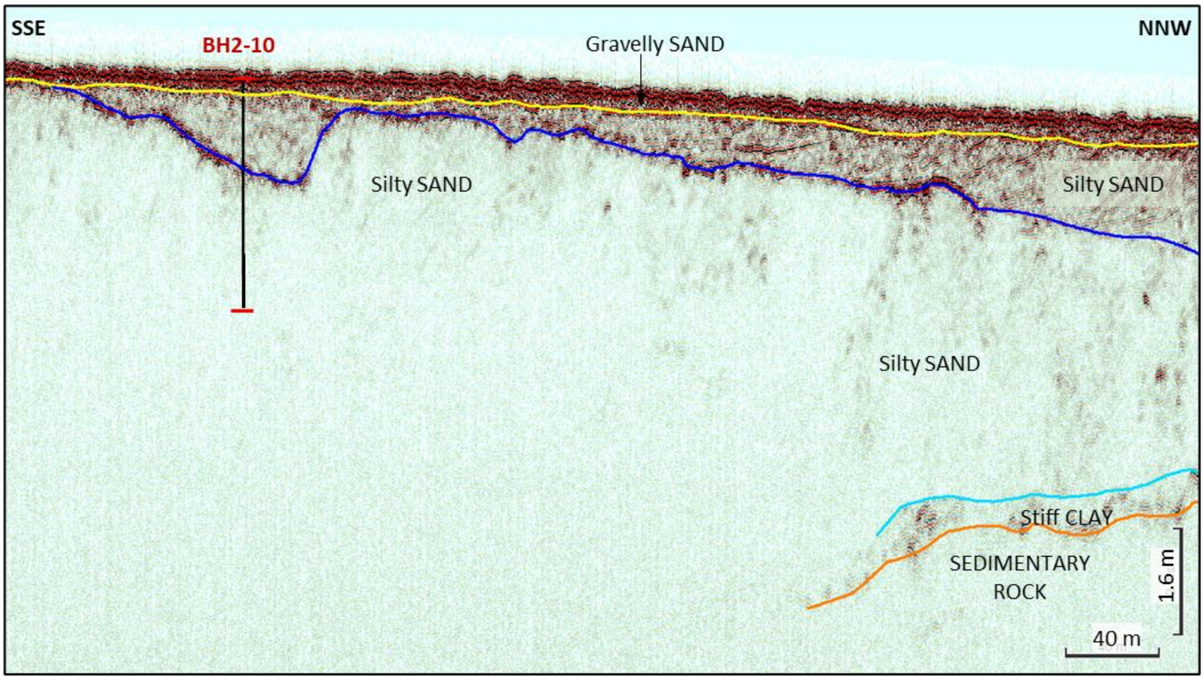


Figure 170 Innomar SBP data example from KP 18.128 (SSE) to KP 17.606 (NNW).

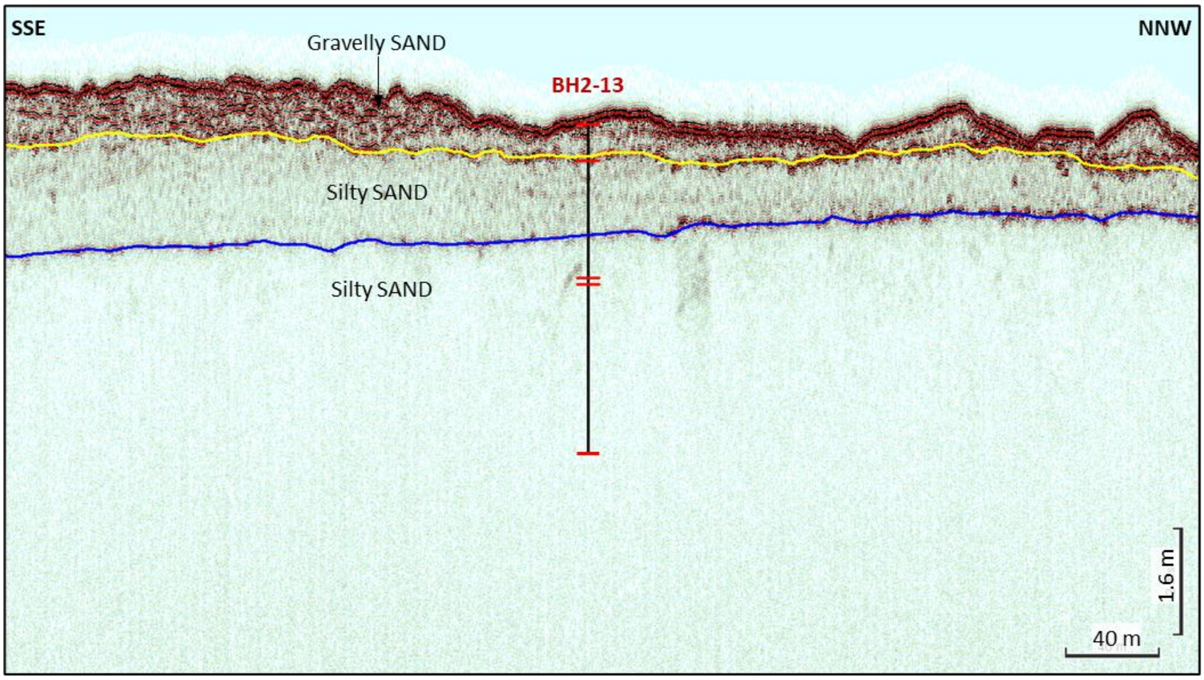


Figure 171 Innomar SBP data example from KP 21.464 (SSE) to KP 20.941 (NNW).

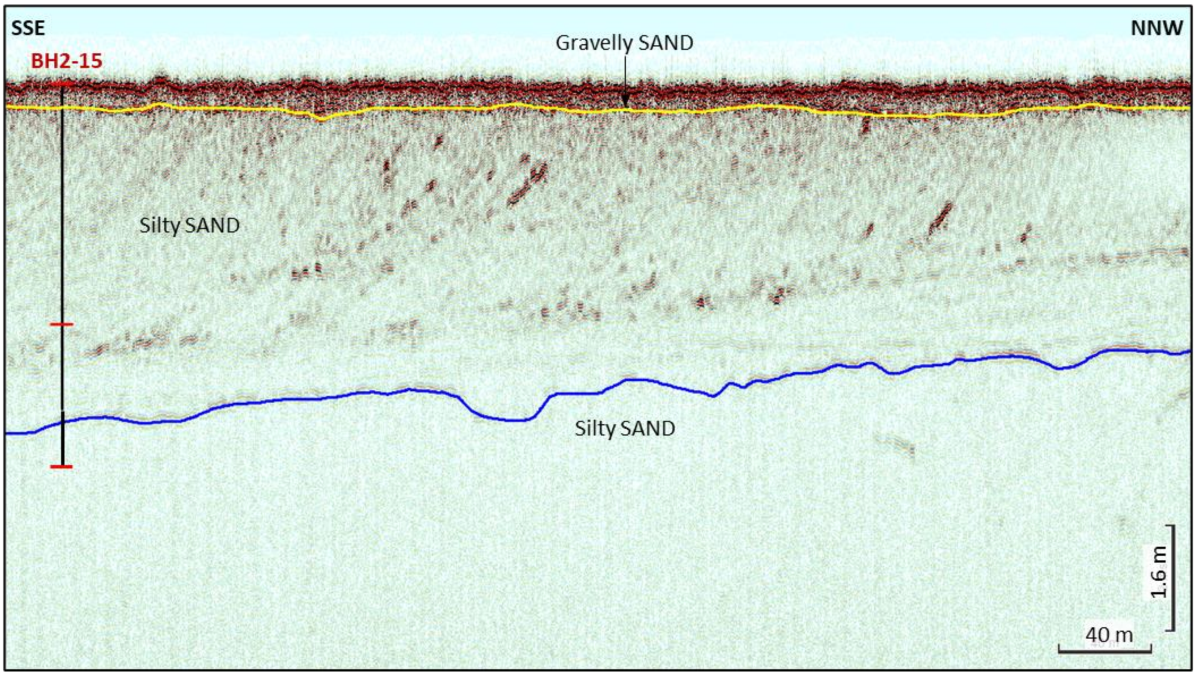


Figure 172 Innomar SBP data example from KP 23.075 (SSE) to KP 22.556 (NNW).

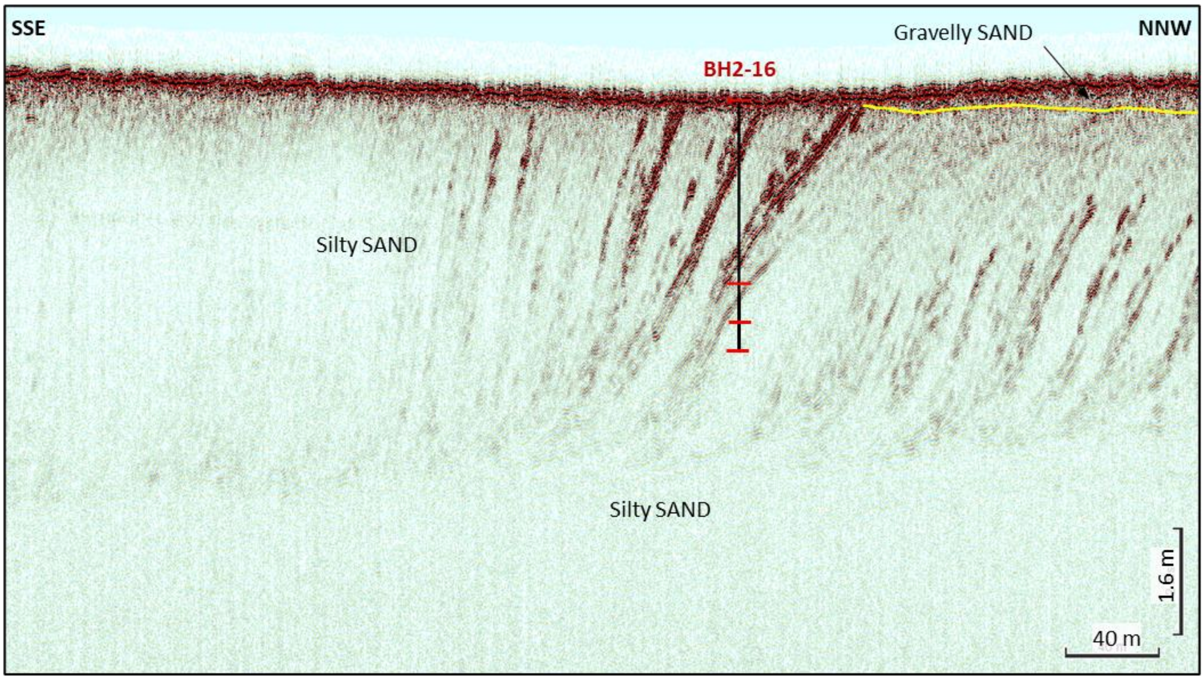


Figure 173 Innomar SBP data example from KP 24.330 (SSE) to KP 23.809 (NNW).

Table 51 ERS Bornholm 2 detailed description for alignment chart 103971-ENN-OI-SUR-DWG-P1BH2003 (KP 25.086 - 27.605).

Alignment Chart 103971-ENN-OI-SUR-DWG-P1BH2003 (KP 25.086 - 27.605)	
Description (including min/max depth BSB to base of unit)	**Remark**
Bathymetry: The seabed undulates gently over this section. Until KP 26.30 where the seafloor drops from 15 m to 27 m depth over 50 m (Figure 174).	Very Steep slope at KP 26.365 Depth range = 19.48 m. Maximum slope of 25.98° at KP 26.37. Minimum depth 13.96 m at KP 25.194. Maximum depth 33.44 m at KP 27.6.
Surficial Geology: Between KP 25.086 and KP 26.367 the dominant seabed sediment is GRAVEL and coarse SAND. Ripples occur in most areas of GRAVEL and coarse SAND, crests are orientated north to south in line with the prevailing storm wave base. An area with no ripples is present on the western side of the corridor. A seabed ridge occurs at KP 26.367 orientated west-south-west to east-south-east. South of the ridge the seabed sediment is composed of SAND (Figure 175). Isolated boulders are present within the area in low numbers.	**Grab Samples:** 971-ENE-GR-GS-067 971-ENE-GR-GS-068 971-ENE-GR-GS-069 971-ENE-GR-GS-070
Shallow Geology: KP 25.086 to KP 26.400: Silty SANDs to silty gravelly SANDs are interpreted to extend beyond the extent of the SBP data record length (approximately 15.0 m BSB). KP 26.400 to KP 27.605 (Figure 176):	**Vibrocores and CPTs:** BH2-17A and BH2-17-CPT BH2-18 and BH2-18-CPT BH2-19A and BH2-19-CPT

Alignment Chart 103971-ENN-OI-SUR-DWG-P1BH2003 (KP 25.086 - 27.605)	
Description (including min/max depth BSB to base of unit)	**Remark**
In this section of the route, after a decrease in water depth, a shallow recent marine SAND unit (0.0 – 1.2 m BSB), which varies locally from a silty SAND to silty gravelly SAND (P1_H10), is observed in the SBP data as a low-medium amplitude reflectivity unit. The base of this unit is defined by a mostly flat high amplitude reflector. Below this a late/post glacial washdown/meltwater silty SAND unit (P1_H20) with low to high amplitude internal reflectors is observed. This is present to approximately 2.6 m BSB and bounded at its base by a predominantly low amplitude basal reflector. Below these SAND units is interpreted to be a Glacial CLAY unit (firm, silty, slightly sandy, slightly gravelly) to 7.9 m BSB, defined as P1_H50. The Glacial CLAY unit (P1_H50) has a low amplitude erosional basal reflector.	

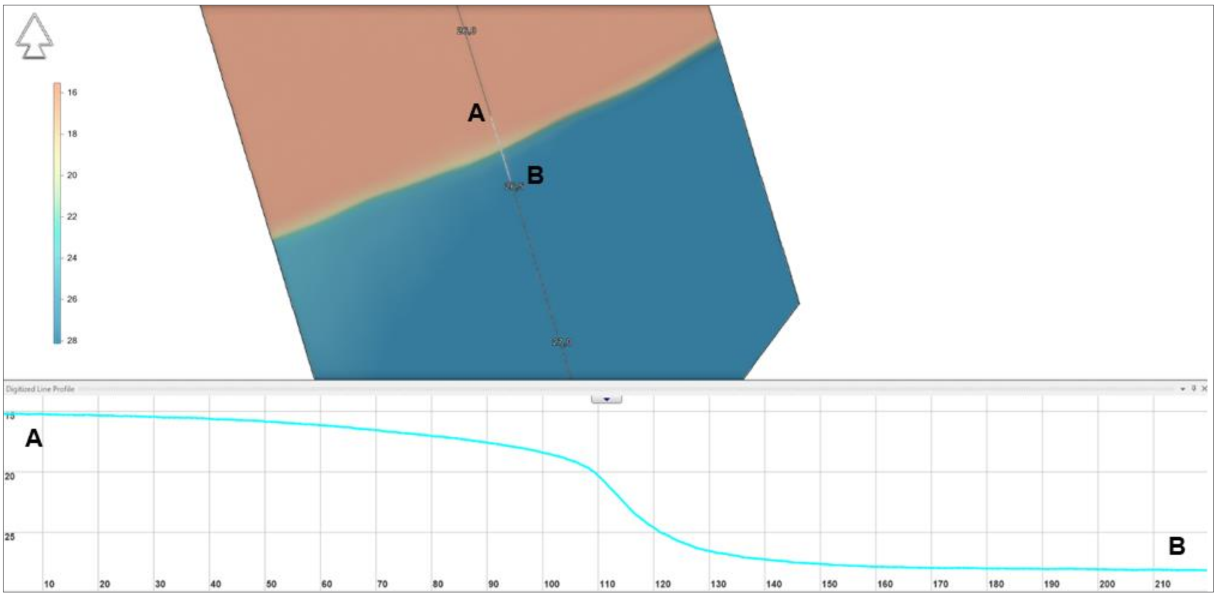


Figure 174 Showing very steep slope at KP 26.5. Vertical exaggeration of profile x3.2.

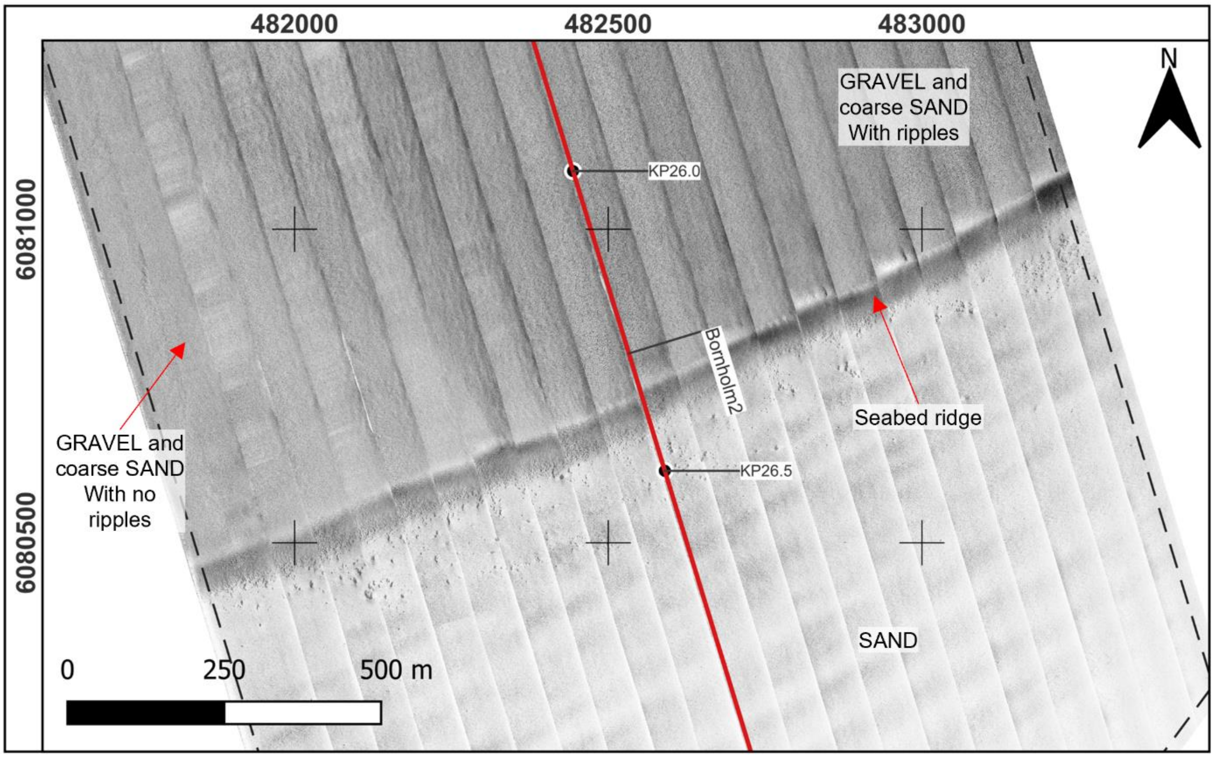


Figure 175 Overview of surficial geology from KP 25.7 to KP 27.0 as seen on SSS.

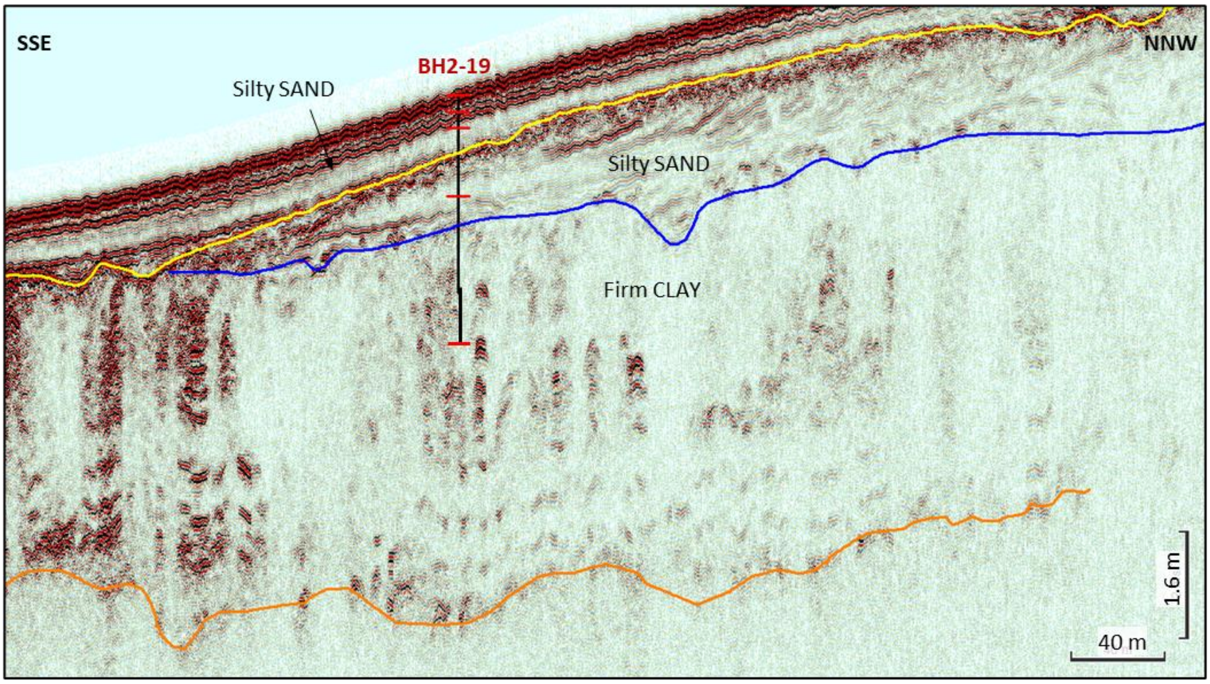


Figure 176 Innomar SBP data example from KP 27.526 (SSE) to KP 26.680 (NNW).

9.2.8 Integrated Seabed Index

Table 52 Integrated Seabed index for ERS Bornholm 2 KP 9.206 to KP 27.605

Location ID		BH2-01				BH2-02		BH2-03			BH2-04	BH2-04B						BH2-07B	BH2-07		BH2-08	BH2-08		BH2-09	BH2-09
Route KP	9.205	9.807	10.000	10.500	11.000	11.418	12.000	12.250	12.800	13.300	13.321	13.325	13.500	14.000	14.500	15.000	15.500	15.568	15.574	15.900	16.206	16.213	16.700	17.256	17.262
Data type	SBP	VC	SBP	SBP	SBP	CPT	SBP	VC	SBP	SBP	VC	CPT	SBP	SBP	SBP	SBP	SBP	VC	CPT	SBP	VC	CPT	SBP	VC	CPT
Depth below seabed (m)																									
0.5	1	3	1	1	1	5	1	3	3	3	3	3	1	1	6	4	6	6	6	8	8	6	6	6	6
1.0	1	3	1	1	1	5	1	3	3	3	3		1	1	7	4	7	7	7	6	6	6	6	6	6
1.5	1	3	1	1	1	3	1	3	1	3	3		1	1	7	4	7	4	6	4	6	6	6	6	8
2.0	1	3	1	1	1	3	1	3	1	3	3		1	1	4	4	4		4	4	8	8	8	8	8
2.5	1	3	1	1	1	3	1	3	1	3	3		1	1	4	1	4		5	1	4	4	8	8	8
3.0	1	3	1	1	1	3	1	3	1	3	3		1	1	1	1	4		3	1		6	4	8	8
4.0	1	3	1	1	1		1	3	1	1			1	1	1	1	1			1			4	4	4
5.0	1		1	1	1		1		1	1			1	1	1	1	1			1			1	4	6
6.0	1		1	1	1		1		1	1			1	1	1	1	1			1			1		3

Location ID		BH2-10	BH2-10			BH2-11	BH2-11		BH2-12	BH2-12		BH2-13	BH2-13		BH2-14	BH2-14		BH2-15	BH2-15		BH2-16	BH2-16	
Route KP	17.600	18.023	18.030	18.400	18.800	19.207	19.214	19.700	20.207	20.214	20.700	21.205	21.210	21.700	22.207	22.213	22.700	23.050	23.056	23.500	24.010	24.016	24.500
Data type	SBP	VC	CPT	SBP	SBP	VC	CPT	SBP	VC	CPT	SBP	VC	CPT	SBP	VC	CPT	SBP	VC	CPT	SBP	VC	CPT	SBP
Depth below seabed (m)																							
0.5	6	6	6	6	5	5	5	5	5	5	3	5	5	5	5	5	5	5	5	5	5	5	5
1.0	6	6	5	6	5	3	3	3	3	3	3	5	5	3	3	3	3	3	3	6	6	6	3
1.5	6	6	6	6	5	5	5	5	5	5	5	6	6	3	3	3	3	3	3	5	5	5	3
2.0	6	6	6	6	5	5	5	5	5	5	5	5	5	3	3	3	3	3	3	3	3	3	3
2.5	6	6	6	6	5	5	5	5	6	6	5	6	6	3	3	3	3	3	3	5	5	5	3
3.0	6	6	6	6	5	5	5	5	6	6	5	6	6	5	3	5	5	5	5	6	6	6	3
4.0	6	6		6	6	6	6	6	6		6	6	6	5	3		5	5	5	6	6		3
5.0	4			6	6	6	6	6			6	5	5	5			5	5	5	6			3
6.0	1			6	6	6	6	6			6	6	6	5			6	6	6	6			5

Location ID	BH2-17	BH2-17		BH2-18	BH2-18		BH2-19	BH2-19A
Route KP	25.207	25.211	25.600	25.929	25.935	26.500	27.200	27.205
Data type	VC	CPT	SBP	VC	CPT	SBP	CPT	VC
Depth below seabed (m)								
0.5	5	5	5	5	5	7	7	7
1.0	3	3	3	3	3	6	6	6
1.5	3	3	3	3	3	5	5	5
2.0	3	3	3	3	3	8	8	8
2.5	3	3	3	3	3	8	8	8
3.0	3	3	3	3	3	8	8	8
4.0	3	3	3	3		8	8	8
5.0	3	3	3			8	8	
6.0	5	5	5			6	6	

9.2.9 Seabed Features, Contacts and Anomalies

A total of 47 contacts were identified from the SSS data within the survey corridor on ERS Bornholm 2. The SSS contacts are summarised in Table 53. In addition to SSS contacts a total of 1 406 526 MBES boulders were identified within the defined boundary (Kabelrute OWF-BHM) at Bornholm.

A total of 54 magnetic anomalies were detected on ERS Bornholm. Of these, 83 are related to linear features or cables/Pipelines. The MAG targets are summarised in Table 54.

A total of 2 SSS contact positions correlated with detected magnetic anomalies.

Infrastructure detected:

- Utility ID 07 (Pipeline, Baltic Pipe) detected on the MAG dataset. Pipeline is buried seabed disturbance observed on SSS dataset. Crossing at KP 14.597 (Figure 107).
- Utility ID 3 (cable, unknown) detected on the MAG dataset. Not seen on the SSS or MBES data. Crossing at KP 15.241.
- Utility ID 05 (cable, unknown) detected on the MAG dataset but with low confidence due to few anomalies. Not detected on the SSS and MBES datasets or WPD. Crossing at KP 18.347.

Table 53 ERS Bornholm 2 SSS & MBES contacts.

CLASSIFICATION	NUMBER
Debris	41
Linear Debris	6
Total	**47**

Table 54 Summary of ERS Bornholm 2 magnetic anomalies.

CLASSIFICATION	NUMBER
Unclassified, possible objects	12
Linear anomalies	42
Total	54

9.3 ERS Bornholm 1B: KP 16.607 to KP 27.560

9.3.1 Overview

The route separates from the Bornholm – Sjælland route at KP 16.607 at which point the survey corridor is approximately 2.8 km wide. The Bornholm 1B route initially heads west before turning west-northwest at approximately KP 21.0. The corridor from this point to the end of the route at KP 27.560, maintains its 1.5 km width. The water gradually deepens from approximately KP 21.4 as the route departs the north-western side of the Ronne Banke (see Figure 177).

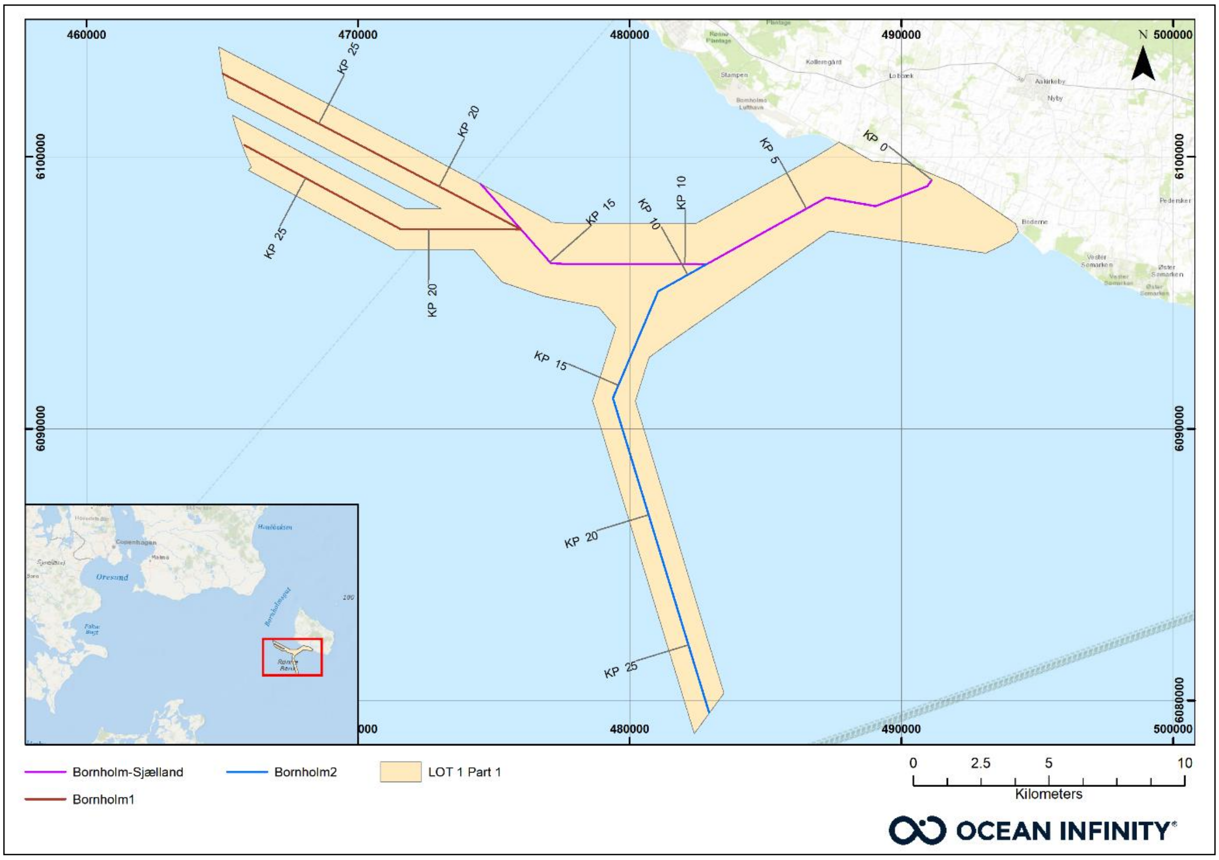


Figure 177 Overview image showing the cable routes and ECR within defined area of Part 1.

9.3.2 Bathymetry

This section begins with undulating seabed between KP 16.607 and KP 17.374 (Figure 196) which is apparent across the corridor. Typically, these undulations have a gentle gradient however some localised higher gradients are observed due to various seabed features such as boulders. From KP 17.374 these undulations give way to a gentle shallowing of the seabed as a sandbank intersects the southern side and central area of the corridor. This shallowing continues until KP 17.902 where the depth on the route reaches its minimum of 19.81 m.

From KP 17.902 to KP 18.102 the seabed deepens on a very gentle gradient along the route before levelling out with slight undulations up to KP 20.607. Over this section, the depth stays mostly the same along the route. However, the seabed deepens on a very gentle gradient across the corridor, perpendicular to the route, from south to north (Figure 197).

From KP 20.607 to the end of the section at KP 27.560 there is a general westward deepening on a very gentle gradient with some undulations in the seabed as the route crosses over the Ronne Banke which are crosscut by slightly deeper sections of seabed.

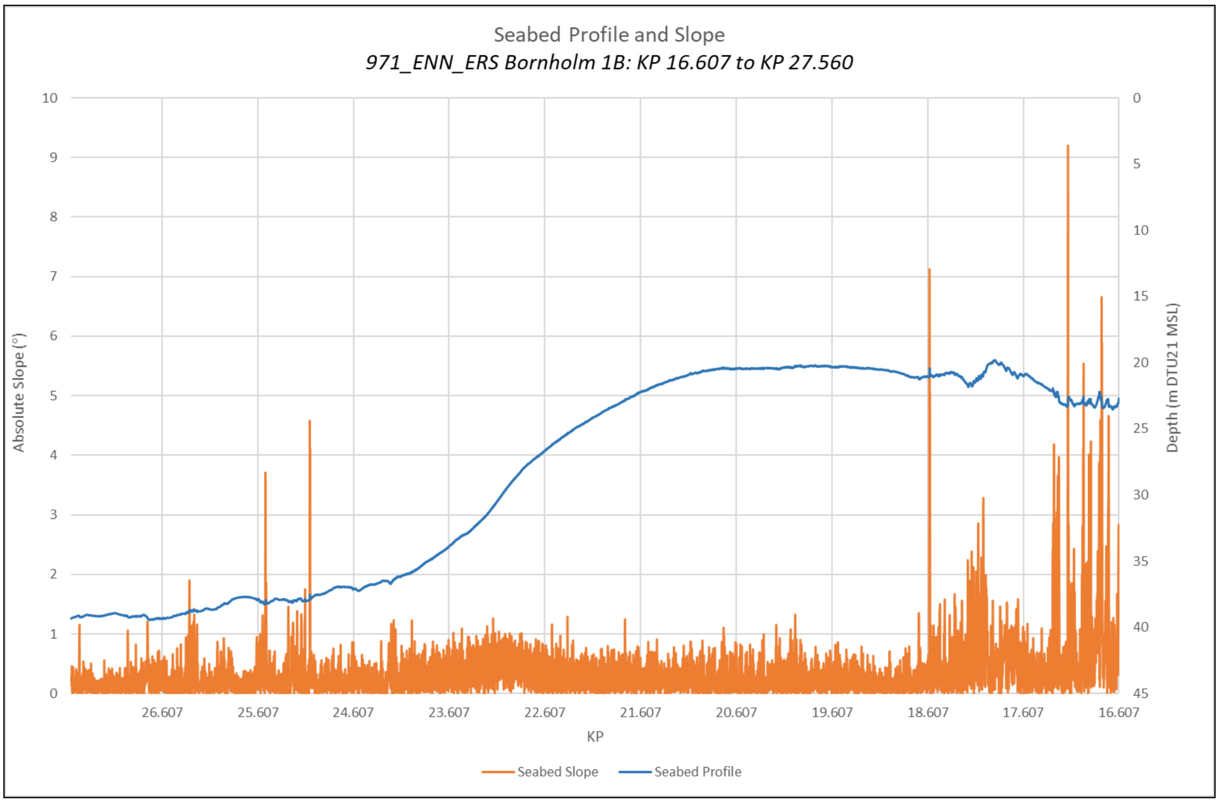


Figure 178 Route Bornholm 1B bathymetry longitudinal profile and slope.

Depth is in metres (with bathymetric depths positive below MSL datum) and slope is in degrees (absolute value for visualisation).

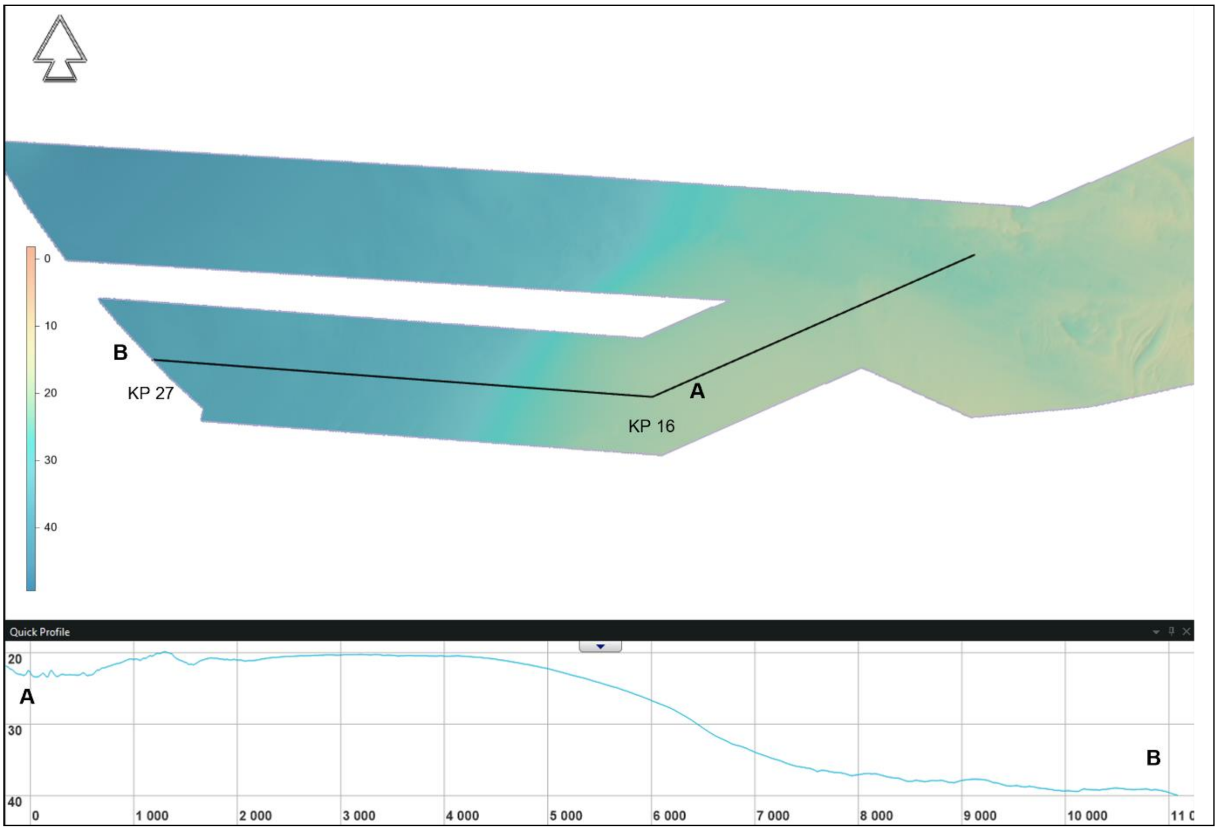


Figure 179 Overview image of ERS Bornholm 1B: KP 16.607 to KP 27.560 along Route Bornholm 1B.

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 x71.

9.3.3 Grab Sampling

The following grab samples were acquired, Figure 180 and Table 55. Full description of the grab sample results is contained in Appendix D.

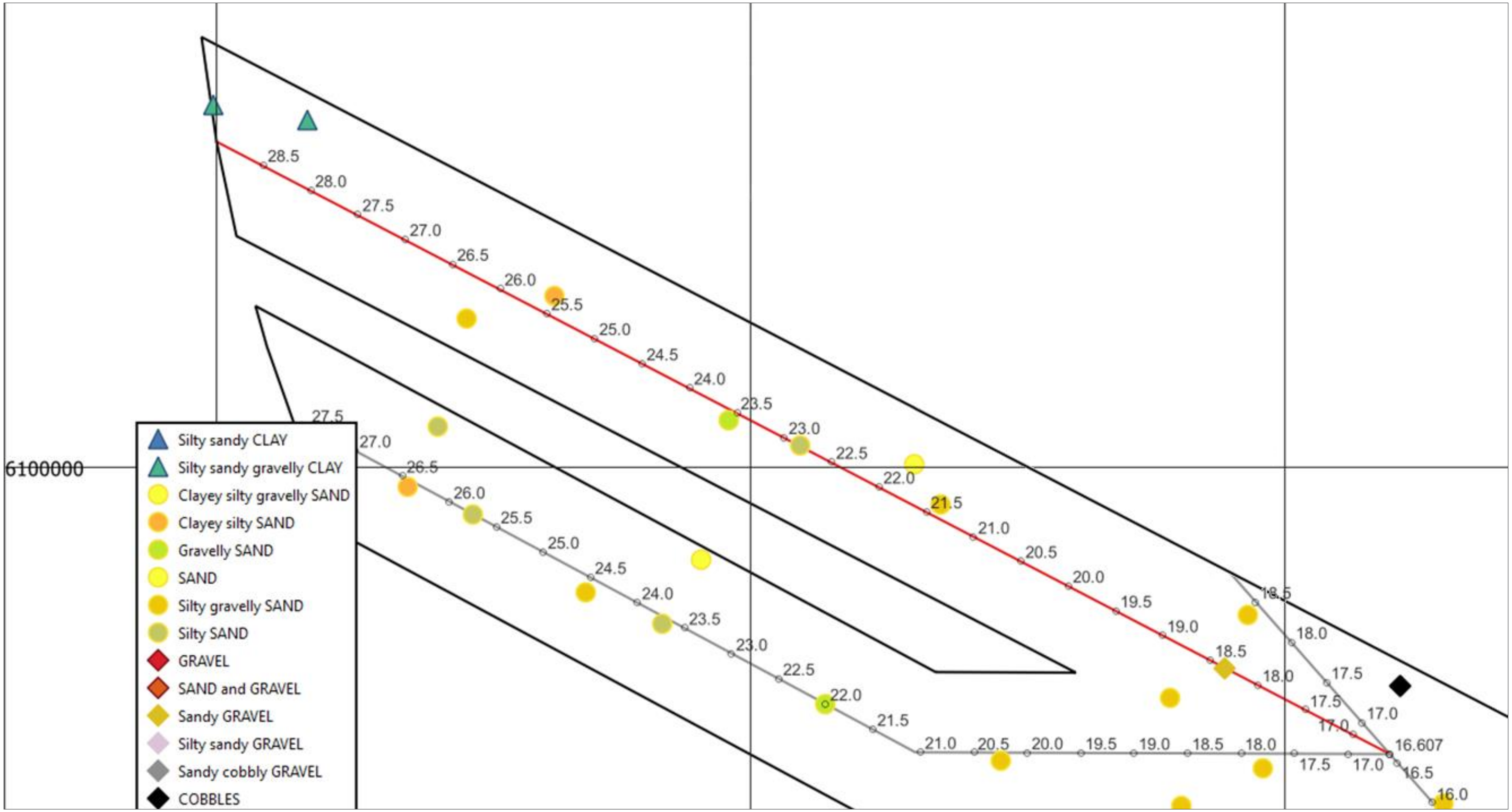


Figure 180 ERS Bornholm 1B grab sampling overview KP 16.607 to KP 27.560

Table 55 ERS Bornholm 1B grab sampling overview KP 16.607 to KP 27.560

ID	KP	DCC	Depth	Detailed Description
971-ENE-GR-GS-108	17.796	-136	20.6	SAND, fine to medium, sorted, slightly silty, slightly gravelly, gravel is 100% subangular fine shell fragments, light greyish brown, non-calcareous.
971-ENE-GR-GS-109	18.559	-491	20.2	SAND, fine to coarse, poorly sorted, slightly silty, very gravelly, gravel is 100% subrounded fine of various lithologies, light greyish brown, non-calcareous.
971-ENE-GR-GS-110	20.251	-71	20.4	SAND, fine to coarse, poorly sorted, slightly silty, slightly gravelly, gravel is 100% subrounded fine of various lithologies, light greyish brown, non-calcareous.
971-ENE-GR-GS-111	22.006	1	23.7	SAND, fine to coarse, poorly sorted, slightly gravelly, gravel is 100% subrounded fine of various lithologies, light greyish brown, non-calcareous.
971-ENE-GR-GS-113	23.669	632	35.5	SAND, fine to medium, poorly sorted, occasional subrounded fine to medium gravel size pockets of black silt, brown, non-calcareous.
971-ENE-GR-GS-112	23.703	-69	34.1	SAND, medium to coarse, poorly sorted, slightly silty, occasional subrounded fine gravel size pockets of dark grey silty sand, greyish brown, non-calcareous.
971-ENE-GR-GS-114	24.474	-138	36.8	SAND, fine to coarse, poorly sorted, slightly silty, slightly gravelly, gravel is 100% subangular fine shell fragments, occasional subrounded fine to medium gravel size pockets of black silt, greyish brown, non-calcareous.
971-ENE-GR-GS-115	25.742	0	37.8	SAND, fine to medium, sorted, slightly silty, frequent subrounded fine to medium gravel size pockets of black silty fine sand, slight organic odour, greyish brown, non-calcareous.
971-ENE-GR-GS-116	26.405	-70	39.2	SAND, fine to coarse, unsorted, slightly clayey, silty, frequent subrounded fine to medium gravel size pockets of black fine sandy silty, slight organic odour, dark grey, non-calcareous.
971-ENE-GR-GS-117	26.426	562	38.3	SAND, fine to coarse, poorly sorted, slightly silty, occasional subrounded fine gravel size pockets of black silt, dark orangish brown, non-calcareous.

9.3.4 Surficial Geology

The surficial geology in the area varies from Till DIMICTON, GRAVEL and COARSE SAND, SAND and Muddy SAND.

One isolated outcrop of SEDIMENTARY ROCK occurs between KP 16.782 and KP 16.836. Glacial debris is prevalent between KP 16.607 and KP 17.337, with high density boulder fields. Areas of ripples occur within the areas of GRAVEL and coarse SAND, ripple crests are orientated north to south in line with the prevailing storm wave base.

Detailed descriptions of the surficial geology are presented in Table 57 & Table 58.

9.3.5 Geotechnical Results

Ground Conditions

The geotechnical VC locations on the Bornholm1b (BH1B) route are shown below (Figure 181). Nine VC were carried out with co-located CPT at every location. The investigated locations cover approximately 9.9 km, from KP 17.630 to KP 27.513. The BH1B route runs parallel to the south of the BH1A route.

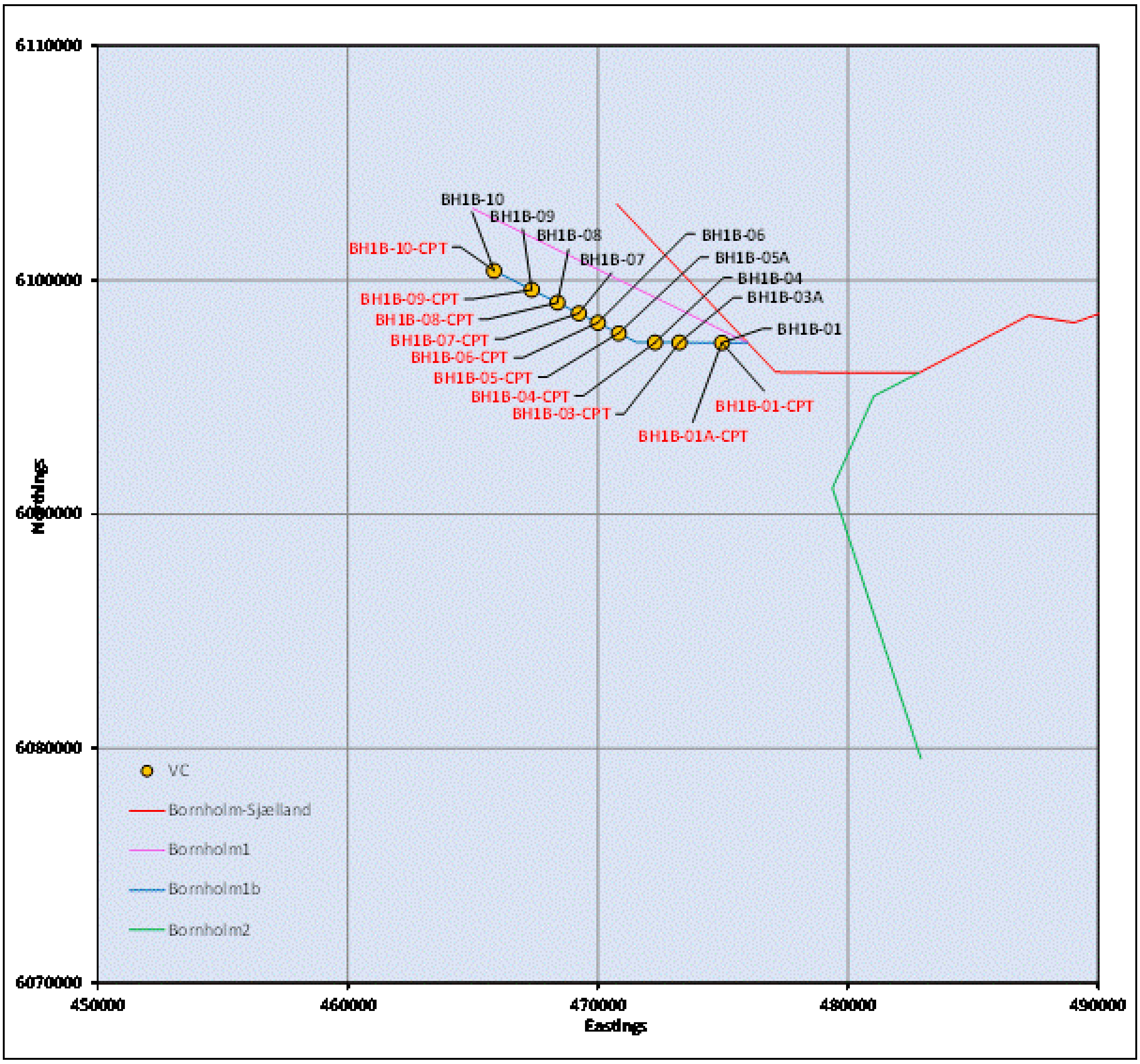
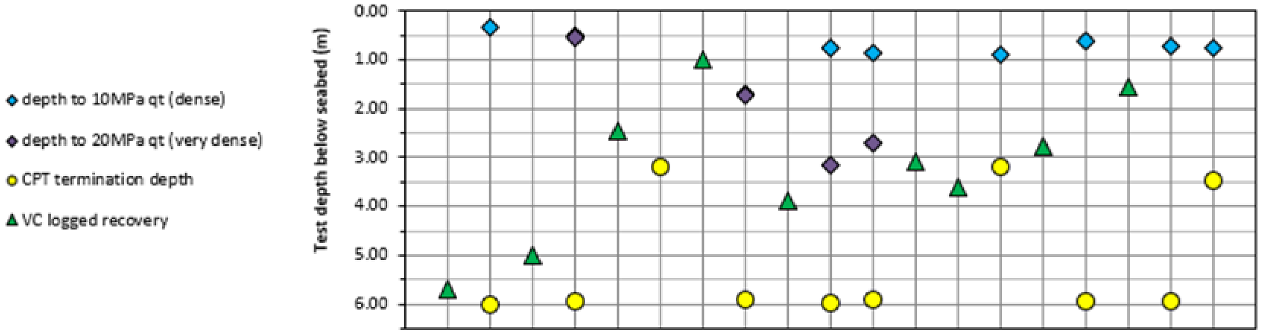


Figure 181 Geotechnical locations on the BH1B route, Part 1.

The assigned Seabed Sediment Index for the BH1B route is shown below (Figure 182).



Location ID	BH1B-10	BH1B-10	BH1B-09	BH1B-09	BH1B-08	BH1B-08	BH1B-07	BH1B-07	BH1B-06	BH1B-06	BH1B-05	BH1B-05A	BH1B-04	BH1B-04	BH1B-03A	BH1B-03	BH1B-01	BH1B-01A	BH1B-01
Route KP	27.513	27.511	25.799	25.792	24.635	24.628	23.669	23.663	22.807	22.800	21.867	21.861	20.308	20.302	19.335	19.329	17.636	17.632	17.630
Location type	VC	CPT	VC	CPT	VC	CPT	VC	CPT	VC	CPT	CPT	VC	VC	CPT	VC	CPT	VC	CPT	CPT
VC penetration	5.70		5.00		2.50		2.30		4.20			3.20	4.00		3.10		1.95		
VC recovery	5.70		5.00		2.47		1.00		3.90			3.10	3.60		2.77		1.56		
CPT termination depth		6.00		5.96		3.18		5.90		5.98	5.92			3.20		5.94		5.94	3.48
Depth to 10 MPa (dense)		0.34		0.50				1.70		0.76	0.86			0.90		0.60		0.72	0.74
Depth to 20 MPa (very dense)				0.56				1.74		3.16	2.72								

Depth below seabed (m)																			
0.5	5	5	5	5	4	4	6	6	6	6	6	6	6	6	6	6	6	6	6
1.0	5	5	6	6	4	4	4	4	5	5	5	5	5	5	5	5	5	5	5
1.5	5	5	9	9	4	6		4	5	5	5	5	5	5	5	5	4	4	5
2.0	6	6	9	9	4	4		4	5	5	5	5	6	6	6	6		4	4
2.5	9	9	9	9		4		4	5	5	6	6	6	6	4	4		4	4
3.0	9	7	9	9		4		4	5	5	4	4	4	4	4	4		4	
4.0	9	9	9	9				4	5	5	4					4		6	
5.0	9	8	9	9				4		4	4					6		6	
6.0	9	8		8				4		4	4					6		6	

SSI	Typical Seabed Sediment
1	Bedrock (CHALK)
2	Dense to very dense Glacial Deposits
3	Very dense granular
4	Medium to high strength cohesive (Glacial Till)
5	Dense granular
6	Medium dense granular
7	Loose granular
8	Low to medium strength cohesive
9	Very low to low strength cohesive
10	Extremely low strength cohesive
0	Organic material *sensu stricto*, containing PEAT

Figure 182 Seabed Sediment Index for BH1B route, Part 1.

The ground conditions from the recovered VC across this route are similar to those seen in the BH1A route. From KP 17.630 (location BH1B-01) through to KP 24.635 (location BH1B-08) the ground conditions are characterised by a varying thickness of SAND overlying Glacial Till (Figure 183). The SAND is typically fine to medium, slightly silty, varying to fine to coarse, slightly silty slightly to very gravelly at the seabed, with the gravel component being of various lithologies. The SAND is largely non-calcareous. Slightly silty sandy GRAVEL strata are rarely present, up to a maximum of 0.66 m thick (location BH1B-04). The thickness of granular material overlying Glacial Till varies, from only 0.50 m at location BH1B-08, to 3.90 m depth in the VC at location BH1B-06, where the Glacial Till is identified at 4.54 m depth in the co-located CPT. The VC recovery across this part of the route was reduced at some locations.

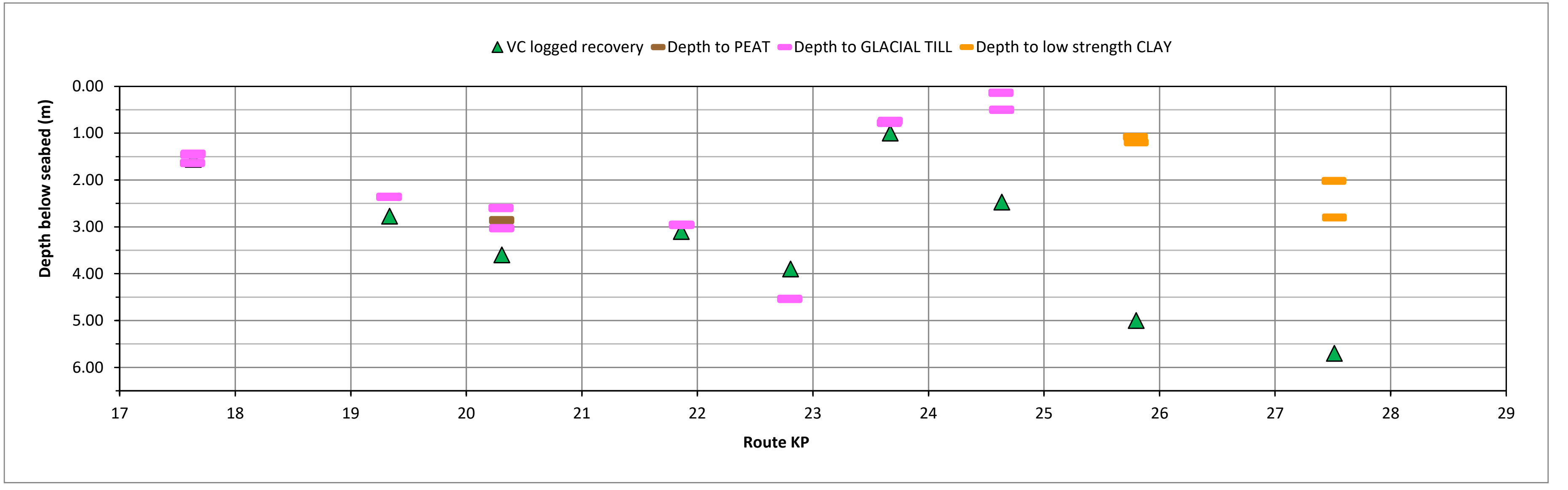


Figure 183 Plot of VC recovery and interpreted strata depths for route BH1B, Part 1.

A single thin PEAT layer is identified at location BH1B-04 at 2.86 to 2.93 m depth. The PEAT is overlain by GRAVEL and sits close to the top of the Glacial Till. The Glacial Till across the route is intermediate plasticity, medium to high strength stiff to very stiff, very silty sandy slightly gravelly CLAY. The gravel is entirely various lithologies. The CLAY is calcareous.

From KP 25.792 (location BH1B-09) through to the end of the route at KP 27.513 (location BH1B-10) Glacial Till is absent in the recovered material. At these two locations granular material is present from seabed level, to a depth of 2.20 m (BH1B-10). The SAND is typically fine to medium, silty to very silty, locally slightly gravelly. The gravel is generally shell fragments close to the seabed, becoming various lithologies with increasing depth. A thin GRAVEL stratum, 0.39 m thick, is present at location BH1B-09 at 0.46 m depth.

At both locations CLAY is present below the SAND. The CLAY is extremely low to low strength very soft to soft and slightly calcareous. The CLAY is slightly sandy very silty, locally slightly gravelly, with the gravel component being various lithologies. At location BH1B-10, a thin SAND stratum is seen within the CLAY at 3.17 to 3.60 m depth. VC recovery at these final two locations was good.

Laboratory Test Data

A summary table below (Table 56) details the quantities of laboratory testing carried out on material from the route BH1B.

Table 56 Summary table of laboratory testing for the route BH1B, Part 1.

Type		Quantity
Moisture Content (MC)		34
Bulk Density (BD)		30
Dry Density (DD)		30
Particle Density (PD)		1
Min/Max Dry Density (MM)		1
Atterberg Limits (AT)		4
Particle Size Distribution Analysis (PSD)		11
PSD sedimentation (SED)		3
Shear strength (Lab Vane, LV)		12
Shear strength (Torvane, TV)		16
Shear strength (Torvane, offshore TVO)		6
Shear strength (Pocket Pen., offshore PPO)		-
Shear strength (Unconsolidated undrained triaxial, UU)		2
Thermal (TR)		
Chemical tests (CHEM)	Organic matter content:	-

A plot below shows the PSD data plotted schematically, in KP order, from the BH1B route (Figure 184). This shows the presence of CLAY in the tested material, with Glacial Till at location BH1B-8 having a total fines content of 65 %, with a sand component of 25 % and 10 % gravel. By contrast the low strength CLAY seen at location BH1B-09 has total fines content of 90 %, with a low sand content of 9 % and 1 % gravel.

Tested SAND strata have sand contents of 80 to 99 %, with total fines contents in the range 1 to 8 %. A single sample from location BH1B-07 has a higher total fines content of 19 %, representing a slightly clayey very silty SAND. Gravel contents in SAND range from 0 to 10 %. A single tested GRAVEL stratum (location BH1B-04) has gravel content of 66 %.

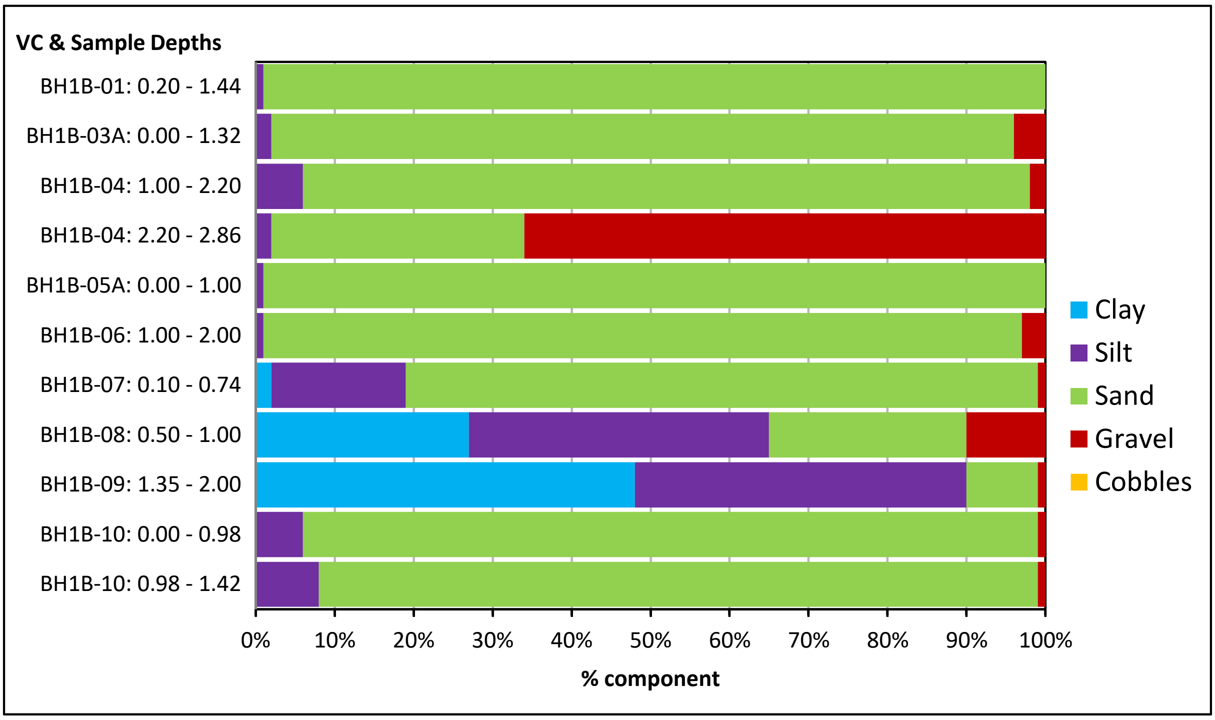


Figure 184 Schematic summary plot of PSD data for route BH1B, Part 1.

PSD data for the tested material are also shown below (Figure 185).

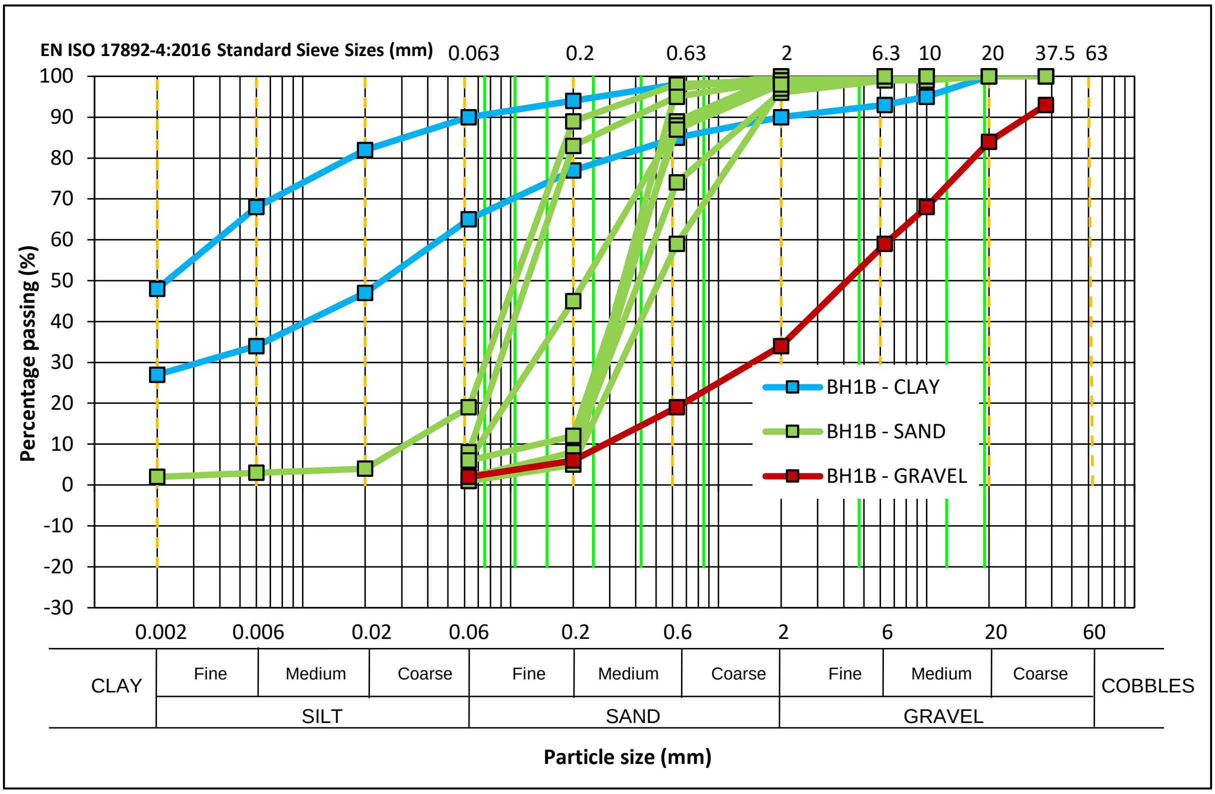


Figure 185 PSD plots for the tested material from route BH1B, Part 1.

Laboratory test data are summarised below for granular material (Figure 186). The tested material has bulk and dry densities in the ranges from 1.59 to 1.95 Mg/m^3, and 1.37 to 1.66 Mg/m^3, respectively. There is a general increase in density with depth. A single min and max dry density result is 1.45 Mg/m^3, and 1.69 Mg/m^3, respectively. A single particle density value is 2.64 Mg/m^3. Moisture contents in granular material are in the range 12 to 26 %.

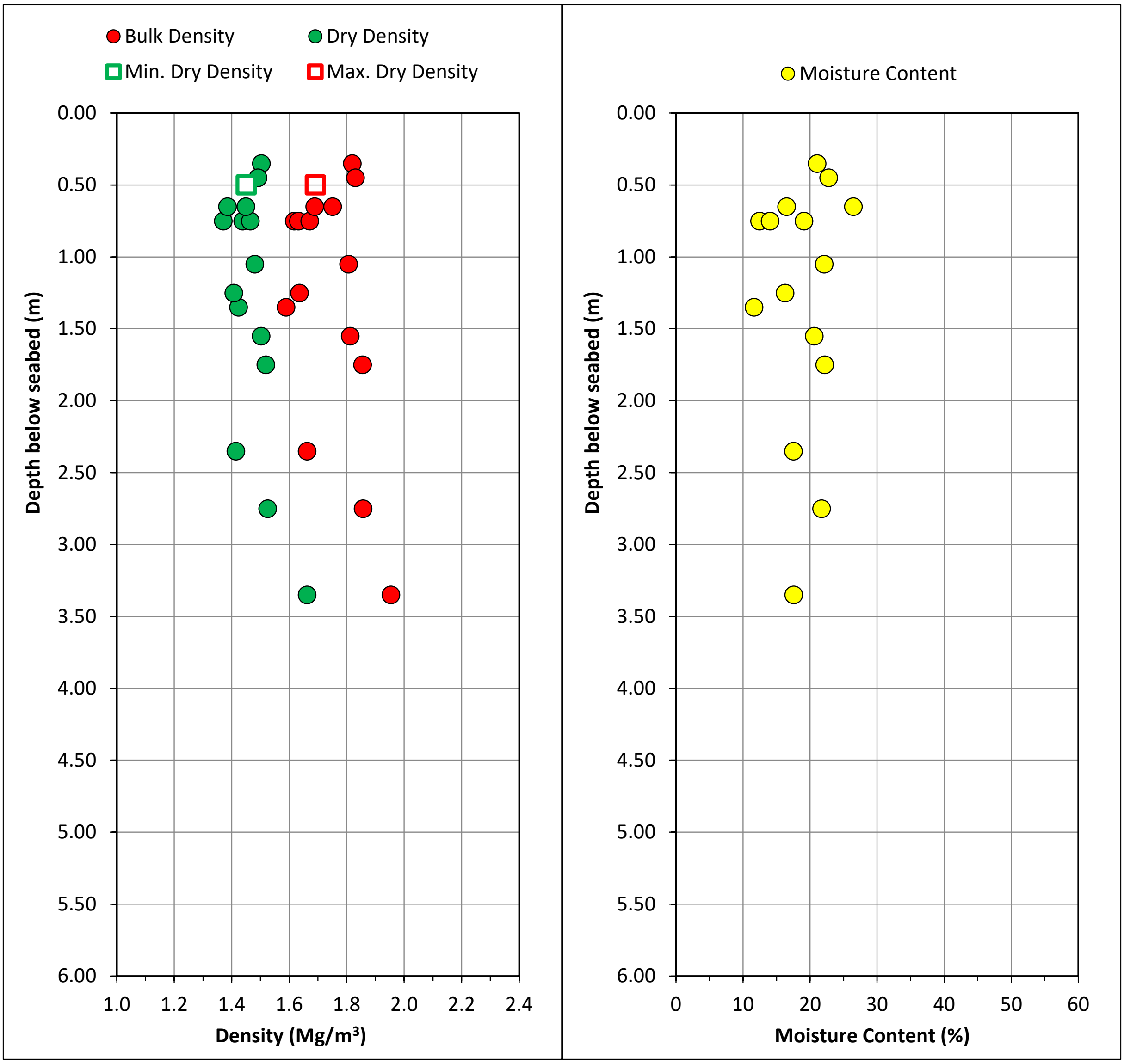


Figure 186 Laboratory test data for granular material, route BH1B, Part 1.

Laboratory density test data are summarised below for cohesive material (Figure 187). Bulk and dry densities for Glacial Till are in the ranges from 1.88 to 2.19 Mg/m^3, and 1.42 to 1.91 Mg/m^3, respectively. In lower strength CLAY bulk and dry densities are lower, in the ranges 1.55 to 1.96 Mg/m^3, and 1.03 to 1.56 Mg/m^3, respectively.

Determined moisture contents are also shown below for cohesive material. Glacial Till typically has moisture contents in the range 14 to 24 %, whilst lower strength CLAYs are more variable, from 25 to 63 %.

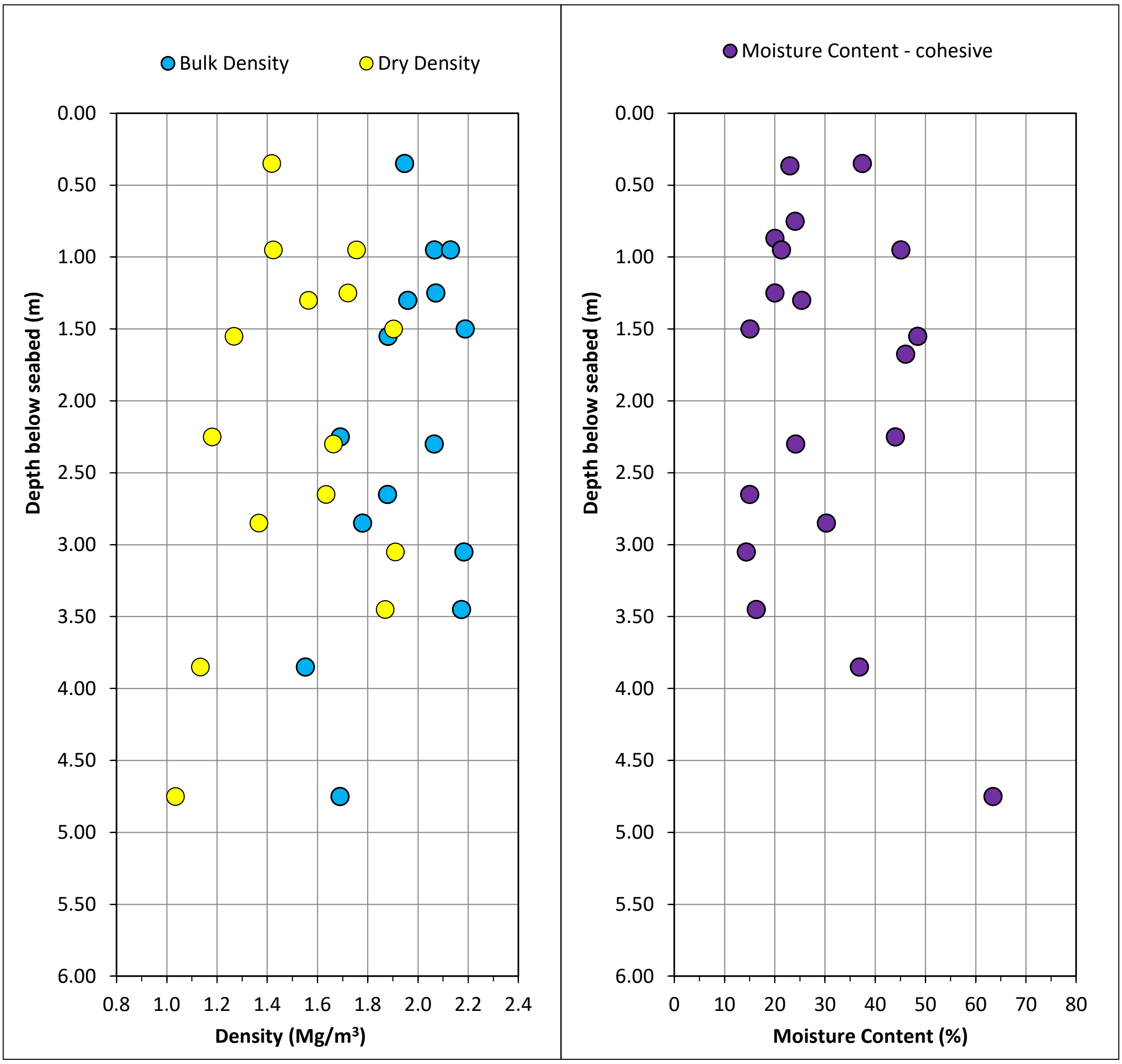


Figure 187 Laboratory test data for cohesive material, route BH1B, Part 1.

Four Atterberg Limit tests were carried out on material from this route. The data are plotted below (Figure 188). Three of the tests returned as CLAY of intermediate plasticity which represents the Glacial Till. A single lower strength CLAY returned as high plasticity.

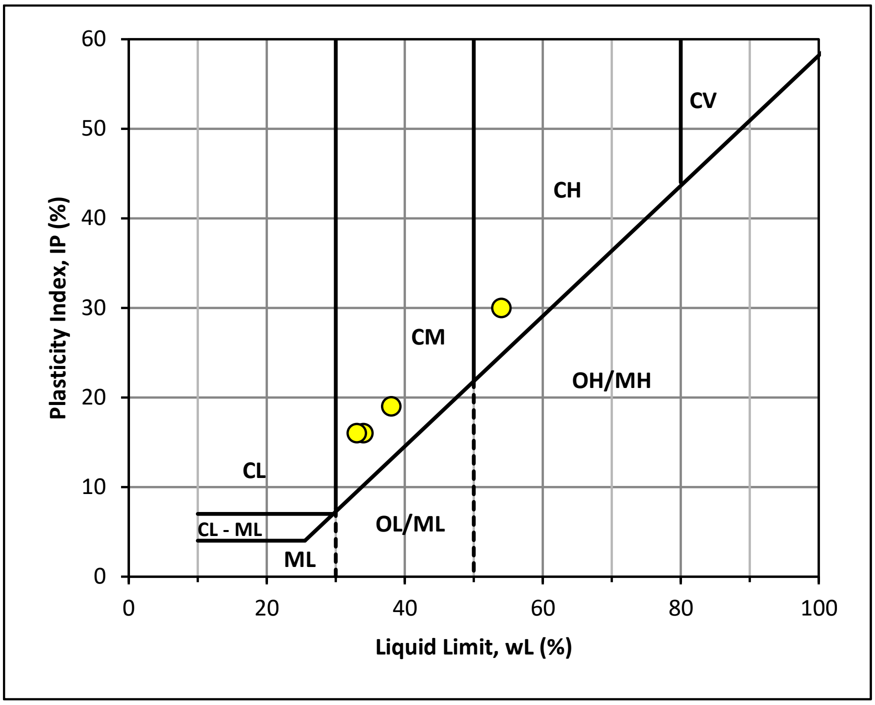


Figure 188 Plasticity Chart for route BH1B, Part 1.

Laboratory shear strength data for cohesive material are shown below (Figure 189). The data indicates two groups. Stiff to very stiff CLAY, considered to be Glacial Till are typically in the medium to high strength ranges, whilst non-glacial CLAY is generally extremely low to low strength. In most cores, there is a general increase in undrained shear strength with increasing depth.

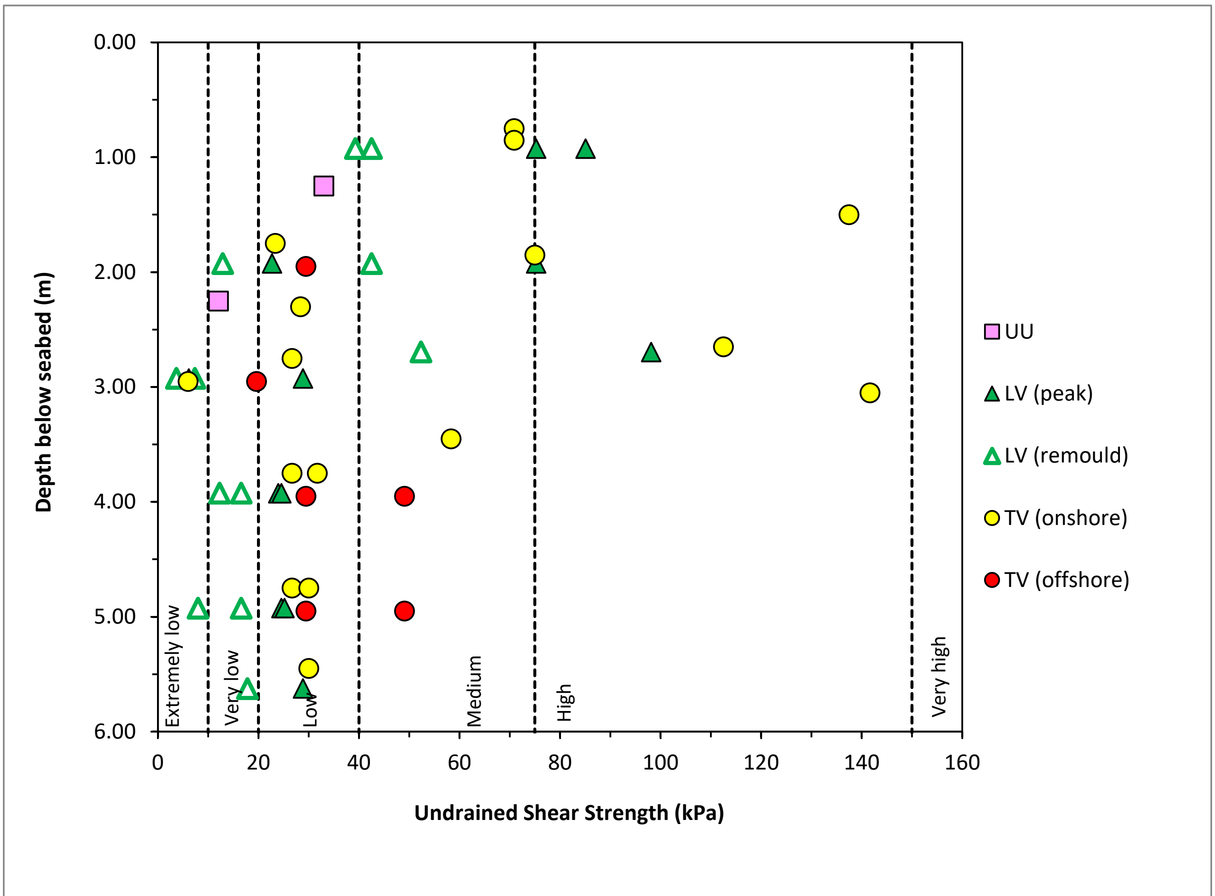


Figure 189 Laboratory shear strength data for route BH1B, Part 1.

A summary of the acquired thermal resistivity data is shown below (Figure 190). The data for both Glacial Till and granular material are mostly in the range 0.42 to 0.55 K m/W. A single low strength CLAY from location BH1B-09 does have a higher resistivity value of 0.92 K m/W.

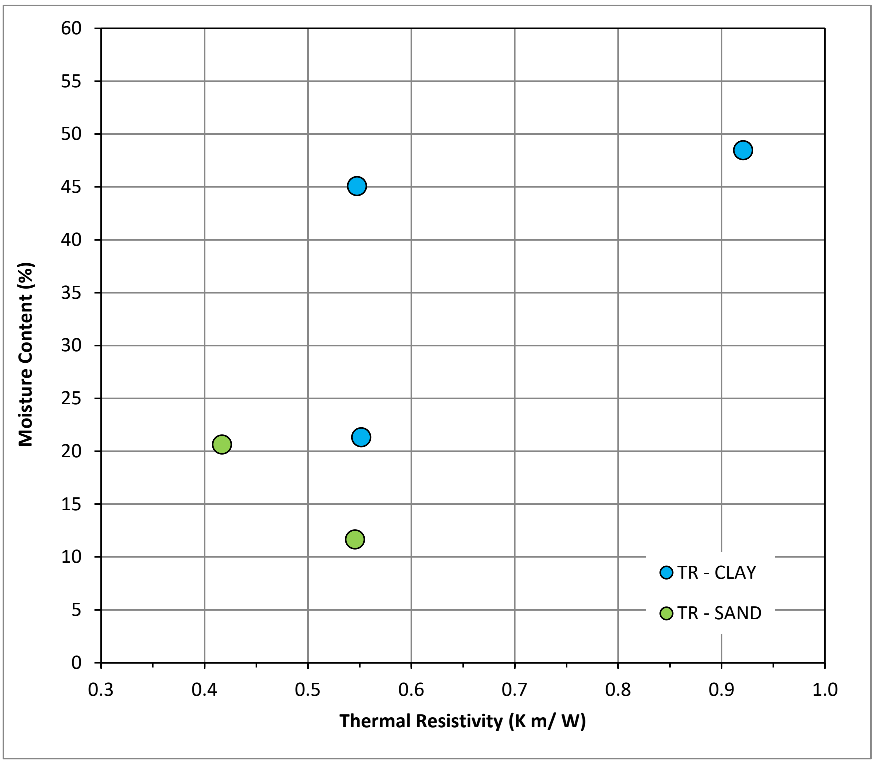


Figure 190 Summary of thermal data for route BH1B, Part 1.

Cone Penetration Testing

Ten CPT were carried out at the nine locations on this route. A single re-attempt was carried out at location BH1B-01, due to initial termination of the first attempt due to high tip resistance and high inclination. Glacial Till was encountered across most of this route, from KP 17.630 through to KP 24.635, at varying depths from 0.14 m to 4.54 m (see Figure 191). Penetration in the Glacial CLAY was generally good, with some very dense granular layers visible within the TILL strata at KP 23.663. Dense to very dense granular material overlying the Glacial Till was seen from KP 17.630 through to KP 22.800, typically at 0.60 to 0.90 m depth.

At the final two locations in this route where granular material overlies low strength CLAY, the CPT penetration was good, with both tests reaching the required 6 m depth. Some dense to very granular material was seen at depths from 0.34 to 0.56 m above the CLAY. The measured cone responses were good with the resulting sediment interpretation being considered accurate and often close to the ground conditions in the co-located VC locations.

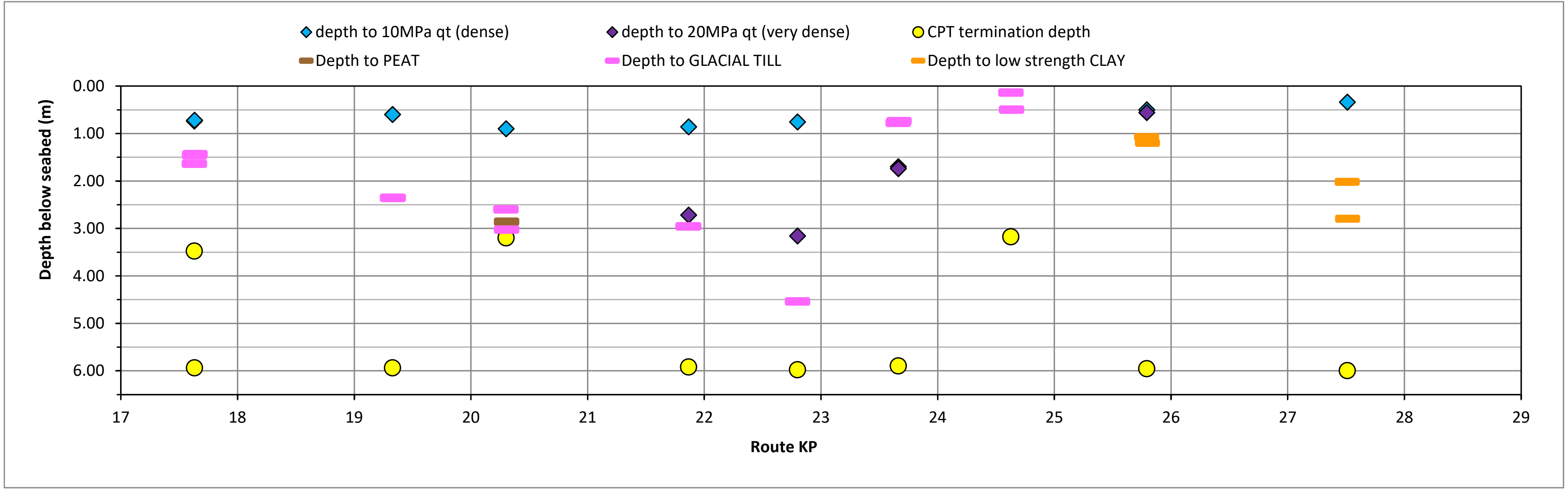


Figure 191 Plot of CPT test depths and interpreted stratum depths for route BH1B, Part 1.

Measured cone resistances from the CPT are shown below (Figure 192). Granular material overlying CLAY along the entire route shows generally high tip resistances in the range 5 to 15 MPa, in the upper 3.00 m depth range. At some locations denser granular material is indicated with tip resistances approaching 40 MPa (location BH1B-06).

Those tests where Glacial Till was encountered beneath the granular material show tip resistances in the range 1 to 5 MPa, whilst in the low strength CLAY the tip resistances are reduced, typically < 1 MPa.

Figure 193 below shows the calculated relative density profiles from the CPT data. The granular material is typically medium dense to dense at shallow depths, < 3.00 m, occasionally very dense. At some locations loose to medium dense SAND strata can be seen within the Glacial deposits at depths approaching 6.00 m (locations BH1B-01 and BH1B-03).

Figure 193 also shows the calculated shear strength profiles for the encountered CLAY, at an Nkt factor of 17.5. For the Glacial Till shear strengths are high, typically > 50 kPa, with some variability towards very high strengths, approaching 240 kPa. In the low strength CLAY at locations BH1B-09 and BH1B-10, calculated shear strengths are lower, generally in the range 20 to 40 kPa. The laboratory derived shear strength data are broadly consistent with the spread of CPT derived data from the two different types of CLAY encountered.

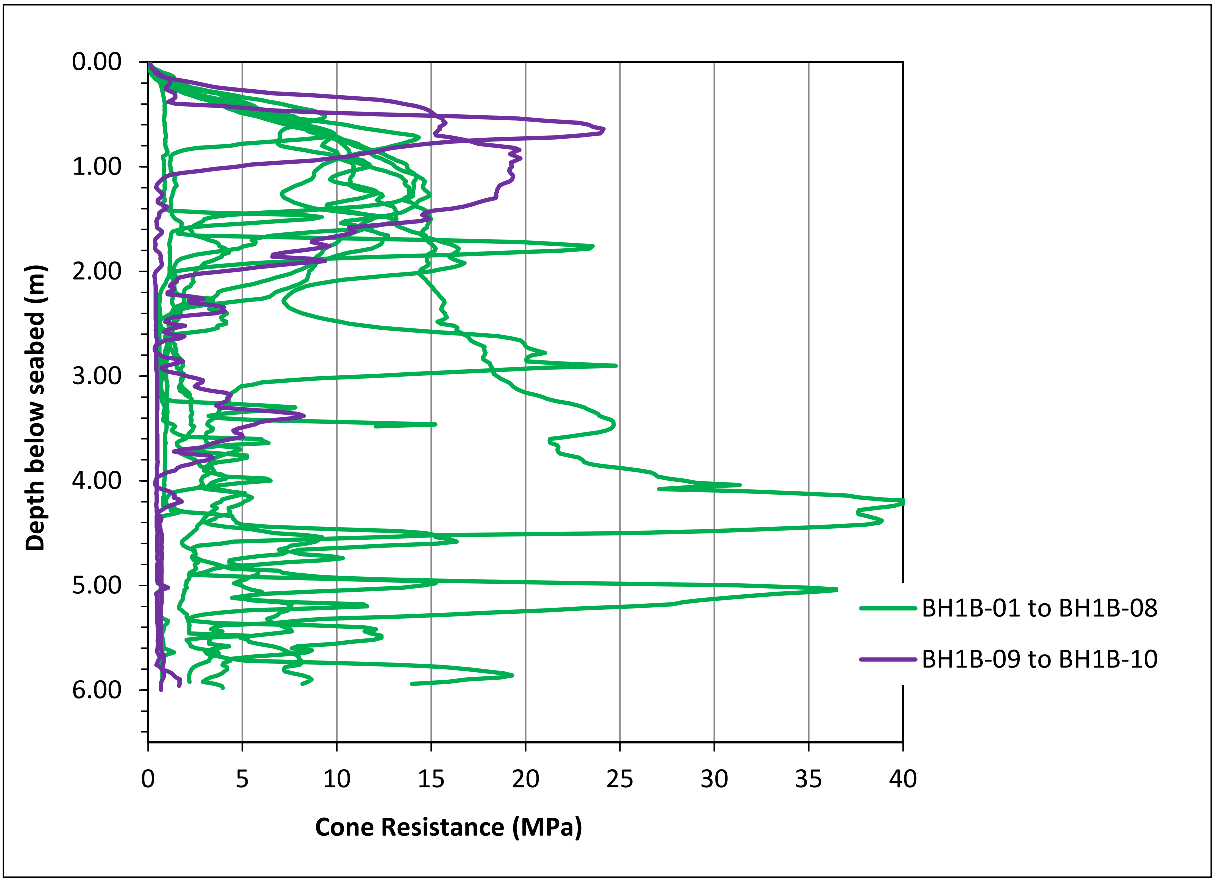


Figure 192 Plot of cone tip resistances for route BH1B, Part 1.

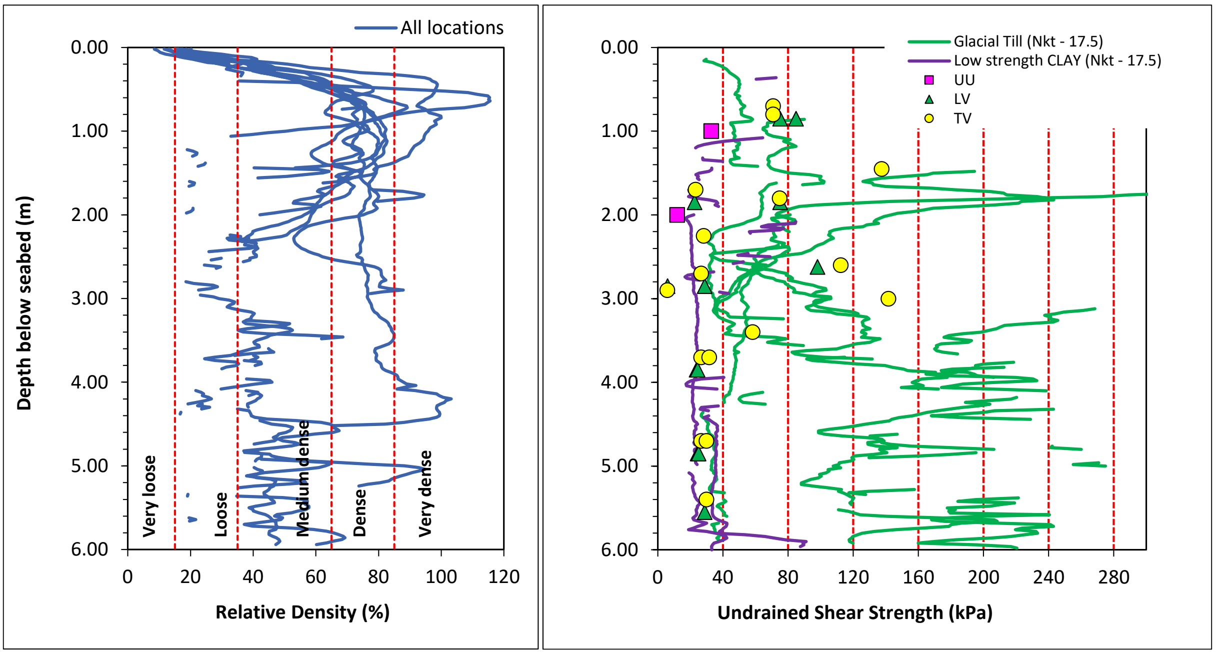


Figure 193 Plot of CPT derived parameters for route BH1B, Part 1.

9.3.6 Shallow Geology

A detailed description of the changes in shallow geology observed along the proposed route ERS Bornholm 1B can be found in the shallow geology section presented in Table 57 and Table 58.

A number of sedimentary units were identified in the sub-surface geology along this route, down to a maximum depth of 10.1 m below the seabed. The uppermost units along the majority of the route between KP 17.345 to KP 27.560 have been confirmed to be SANDs based on the geotechnical sampling results, with generally firm to stiff Glacial CLAYs below this. However, from KP 16.607 to KP 17.345, no upper SAND units are present and firm to stiff Glacial CLAYs are observed up to the seabed.

The uppermost, and youngest, unit along the majority of the route (KP 17.680 to KP 27.560) has been confirmed to be recent Holocene silty SAND based on the geotechnical sampling results, with some gradational lateral variation from silty gravelly SAND, gravelly SAND to GRAVEL. The unit is predominantly classified as silty SAND or gravelly SAND on the profiles for simplification, with details of localised variations documented in Section 9.3.7. The base horizon for this unit (P1_H10) is mostly flat and present from depths ranging from 0 – 3.6 m below seabed. These sediments are often acoustically transparent internally with occasional low-high amplitude internal reflectors interpreted to represent local changes in grain size from silty to gravelly, or vice versa. Where possible on the CL, these have been identified by the internal reflectors P1_H05i and P1_H06i.

Below this horizon are two further SAND units, each with distinctively different internal characteristics, as well as having different spatial distributions along the route. The first SAND unit (P1_H20) predominantly represents a Late/Post Glacial silty gravelly SAND and is spatially distributed along the western shallower end of route and along the steeper sloping section in the centre of the route from KP 17.345 to KP 23.816. The unit is predominantly classified as silty SAND on the profiles for simplification, with details of localised variations documented in Section 9.3.7. This unit is abundant in internal reflectors with varying in length, orientation, and amplitude and is primarily between 1.0 – 2.0 m thick. It also has a mostly flat, high amplitude basal reflector which separates it from the sediments below. At KP 20.308 (BH1B-04), despite no change in the consistent high reflectivity on the SBP data at the base of P1_H20, it should be noted that localised thin units of GRAVEL (2.20 – 2.86 m BSB) and Firm PEAT (2.86 – 2.93 m BSB) were identified in the geotechnical results.

The second SAND unit has been identified as P1_H30. This is non-continuously present in the deeper water section at the western end of the route primarily from KP 25.679 to KP 27.560. The unit is uniquely identifiable due to the abundance of internal high amplitude parallel reflectors visible in the SBP data, as well as its undulating basal reflector. The geotechnical sampling results confirm that these internal parallel reflectors are very closely to closely spaced thin to thick laminae of Late/Post Glacial clayey SILT. The unit is predominantly classified as silty SAND on the profiles for simplification, with details of localised variations documented in Section 9.3.7. This unit varies in thickness, but is predominantly between 0.2 m to 1.8 m thick along this route.

An overview of the interpreted SAND units along this route can be seen in Figure 194.

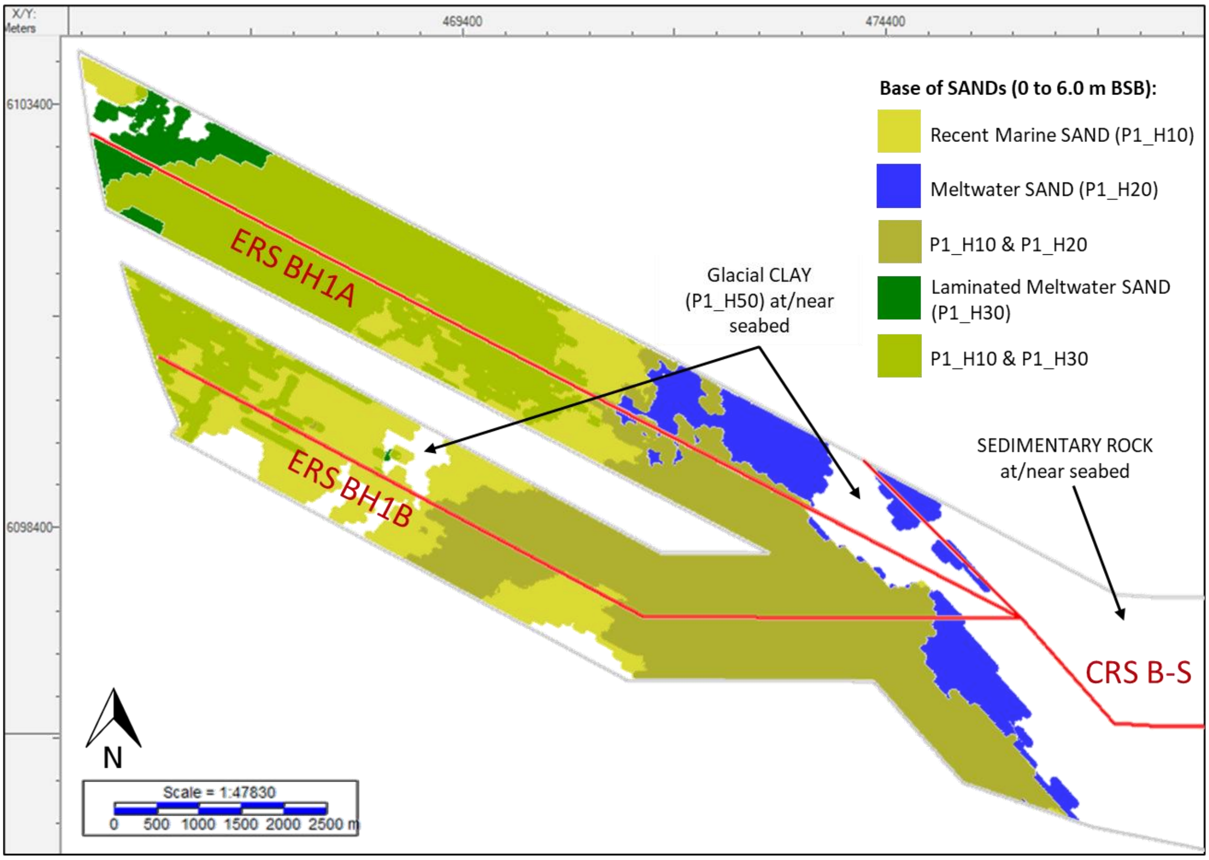


Figure 194 Overview map of the distribution of interpreted SAND units along ERS Bornholm 1B KP 16 to KP 19.

Below these SAND units, a Glacial CLAY unit (P1_H50) is present. The CLAY unit has a slightly silty, sandy and gravelly composition which is variable across the route, though this is not documented on the profiles for the purpose of simplification. The geotechnical results confirm that the CLAY unit is predominantly stiff to very stiff, but between KP 24.751 to KP 27.560 the CLAY is interpreted to be of Late Glacial Meltwater origin and is very soft to soft for the majority of the uppermost 0 to 7.0 m of the unit. Where possible, these change in stiffness properties have been delineated by an internal reflector (P1_H40i) on the CL only.

The P1_H50 Glacial CLAY unit predominantly displays a low to high amplitude chaotic internal structure in the SBP data, but in places high amplitude internal reflectors and laminations can be observed. From KP 16.607 to KP 19.711, the base of the CLAY can be observed as a non-distinct low amplitude erosional surface interpreted to lie on top of Upper Cretaceous SEDIMENTARY ROCK. From KP 19.711 to the end of the route at KP 27.560, the base of the CLAY unit is not able to be defined as the amplitude of the basal reflector decreases such that it is undistinguishable from the surrounding sediments. In some places this Glacial CLAY unit is visible up to the seabed, where a GRAVEL and coarse SAND and/or TILL/DIAMICTION are observed. Caution should therefore be taken where this Glacial CLAY unit is encountered as geohazards such as boulders may be present in the shallow geology but not able to be identified in the SBP data.

An overview of the distribution of the interpreted Glacial CLAY along this route can be seen in Figure 195.

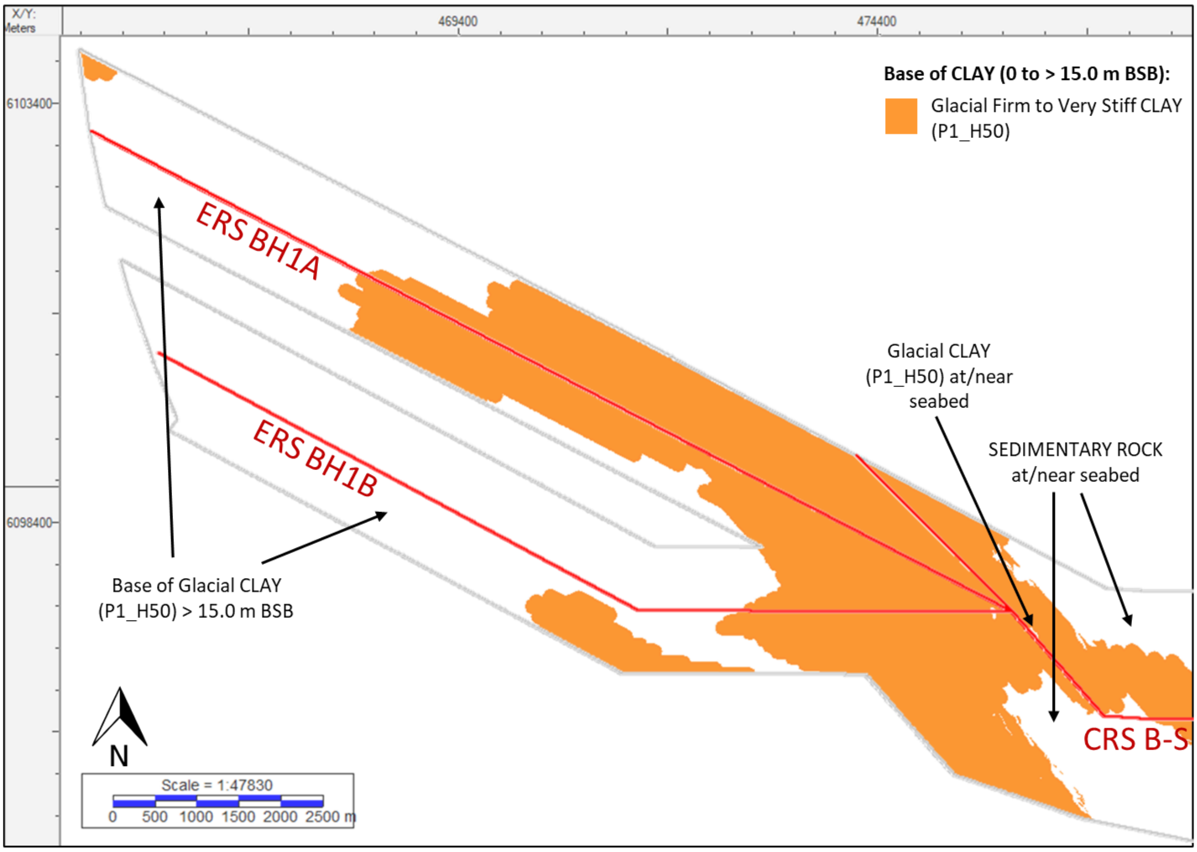


Figure 195 Overview map of the distribution of interpreted Glacial CLAY along ERS Bornholm 1B KP 16 to KP 19.

9.3.7 Detailed Description

A detailed presentation of the conditions and features of ERS Bornholm 1B are shown in Table 57 & Table 58 and associated figures.

Table 57 ERS Bornholm 1B detailed description for alignment chart 103971-ENN-OI-SUR-DWG-P1BH1B001 (KP 16.607 – 24.547).

Alignment Chart 103971-ENN-OI-SUR-DWG-P1BH1B001 (KP 16.607 – 24.547)	
Description (including min/max depth BSB to base of unit)	**Remark**
Bathymetry: Undulating seabed between KP 16.607 and KP 17.374 (Figure 196) Seabed then shallows on a gentle gradient up to the shallowest point on the route of 19.81 m at KP 17.902. Seabed deepens on a very gentle gradient from KP 17.902 to KP 18.102 before levelling out with slight undulations to KP 20.607. From KP 20.607 to KP 24.547 seabed exhibits a very gentle deepening.	Depth range along route = 17.42 m. Maximum slope of 9.1° at KP 17.140 related to the edge of a seabed formation. Minimum depth along route 19.81 m at KP 17.902. Maximum depth along route 37.23 m at KP 24.547.
Surficial geology: The surficial geology between KP 16.607 to KP 17.373 is dominated by DIAMICTON. One area of SEDIMENTARY ROCK outcrops along the route between KP 16.782 and KP 16.836 (Figure 198). From KP 17.373 to KP 18.783 the seabed varies between SAND and GRAVEL and coarse SAND. From KP 18.783 and KP 24.217 the seabed is composed of GRAVEL and coarse SAND. From KP 24.217 and KP 24.547 the seabed varies between SAND and GRAVEL and coarse SAND. Glacial debris is prevalent between KP 16.607 and KP 17.337, with high density boulder fields. Boulders occur within the rest of the area, generally these are isolated but some small areas of low, intermediate and high-density boulder fields occur. Areas of ripples occur within the areas of GRAVEL and coarse SAND, ripple crests are orientated north to south in line with the prevailing storm wave base.	**Infrastructure:** Utility ID 08 (Pipeline, Baltic pipe) crosses the route at KP 18.585 trending north-west to south-east (Figure 199). Utility ID 11 (cable, Bornholm-Rugen) detected MAG datasets, not detected on SSS or MBES dataset. Crossing route at KP 20.922. **Debris:** S_GR_WPA_B1D_0025 (associated with linear debris), KP 17.327 DCC 3.13 m. **Grab Samples:** 971-ENE-GR-GS-074 971-ENE-GR-GS-108 971-ENE-GR-GS-109 971-ENE-GR-GS-110 971-ENE-GR-GS-111 971-ENE-GR-GS-112 971-ENE-GR-GS-113 971-ENE-GR-GS-114 971-ENE-GR-GS-118 971-ENE-GR-GS-119

Alignment Chart 103971-ENN-OI-SUR-DWG-P1BH1B001 (KP 16.607 – 24.547)	
Description (including min/max depth BSB to base of unit)	**Remark**
Shallow Geology: KP 16.607 to KP 17.345 (Figure 200). At the start of the route, stiff silty slightly sandy slightly gravelly Glacial CLAY (P1_H50) is present from the seabed until approximately 1.4 m BSB, but due to the highly undulating nature of the basal reflector, the CLAY is in places present to a maximum depth of 4.7 m BSB. SEDIMENTARY ROCK is interpreted to be present below and extends beyond the extent of the SBP data. Occasional inclined reflectors are visible within the SEDIMENTARY ROCK. KP 17.345 to KP 21.369 (Figure 200, Figure 201): This section of the route contains two SAND units from the seabed to a maximum depth of 2.9 m BSB. The upper unit is comprised of recent marine slightly silty gravelly SAND (P1_H10) to a maximum depth of 1.6 m BSB, whereas the lower unit is a late/post glacial washdown/meltwater silty SAND (P1_H20) present to a maximum depth of 2.9 m BSB. Occasional high amplitude reflectors (P1_H06i) have been identified within the upper SAND unit, comprising of organic material (VC BH1B-03A). At KP 20.308 (BH1B-04), at the base of P1_H20, localised thin units of GRAVEL (2.20 – 2.86 m BSB) and Firm PEAT (2.86 – 2.93 m BSB) were identified in the geotechnical results. Below the SANDs is a stiff to very stiff silty slightly sandy slightly gravelly Glacial CLAY (P1_H50) which has a highly undulating basal reflector and is present to approximately 5.8 m BSB. At KP 18.837, the CLAY unit thickens to 10.1 m BSB by KP 19.711, at which point the base of Glacial CLAY reflector then decreases in amplitude such that it is no longer distinguishable from the surrounding sediments. The base of Glacial CLAY (P1_H50) was unable to be interpreted on the SBP data along the rest of the route. SEDIMENTARY ROCK is interpreted to be present below the CLAY, often beyond the extent of the SBP data. Occasional inclined reflectors are visible within the SEDIMENTARY ROCK. KP 21.369 to KP 23.944 (Figure 202, Figure 203, and Figure 204): This section of the route contains two SAND units from the seabed to 4.0 m BSB. The upper unit is a recent marine slightly silty, gravelly SAND unit (P1_H10) with a maximum depth of 3.1 m BSB. The lower	**Vibrocores and CPTs:** BH1B-01 and BH1B-01A-CPT BH1B-03A and BH1B-03-CPT BH1B-04 and BH1B-04-CPT BH1B-05A and BH1B-05-CPT BH1B-06 and BH1B-06-CPT BH1B-07 and BH1B-07-CPT

Alignment Chart 103971-ENN-OI-SUR-DWG-P1BH1B001 (KP 16.607 – 24.547)	
Description (including min/max depth BSB to base of unit)	**Remark**
unit is a late/post glacial washdown/meltwater silty, occasionally slightly gravelly, SAND (P1_H20), typically 0.9 m thick. Occasional continuous internal reflectors (P1_H06i) are visible within the upper SAND unit (P1_H10), delineating a change from a more gravelly SAND above to more silty SAND below. The lower SAND unit (P1_H20) is abundant in internals reflectors with varying length, orientation, and amplitude Below the SANDs is a thick unit of firm to stiff, slightly sandy, slightly gravelly Glacial CLAY. The base of this Glacial CLAY is not identifiable on the SBP data in this region. Neither SANDs are interpreted between KP 21.369 to KP 22.173, and instead Glacial CLAY is present at/just below seabed. KP 23.944 to KP 24.547: Firm to stiff, slightly sandy, slightly gravelly Glacial CLAY unit (P1_H50) is present from the seabed, or under thin (< 0.2 m) veneers of recent marine silty gravelly SAND (P1_H10). The base of Glacial CLAY is unable to be identified, likely as this is below the extent of the SBP data.	

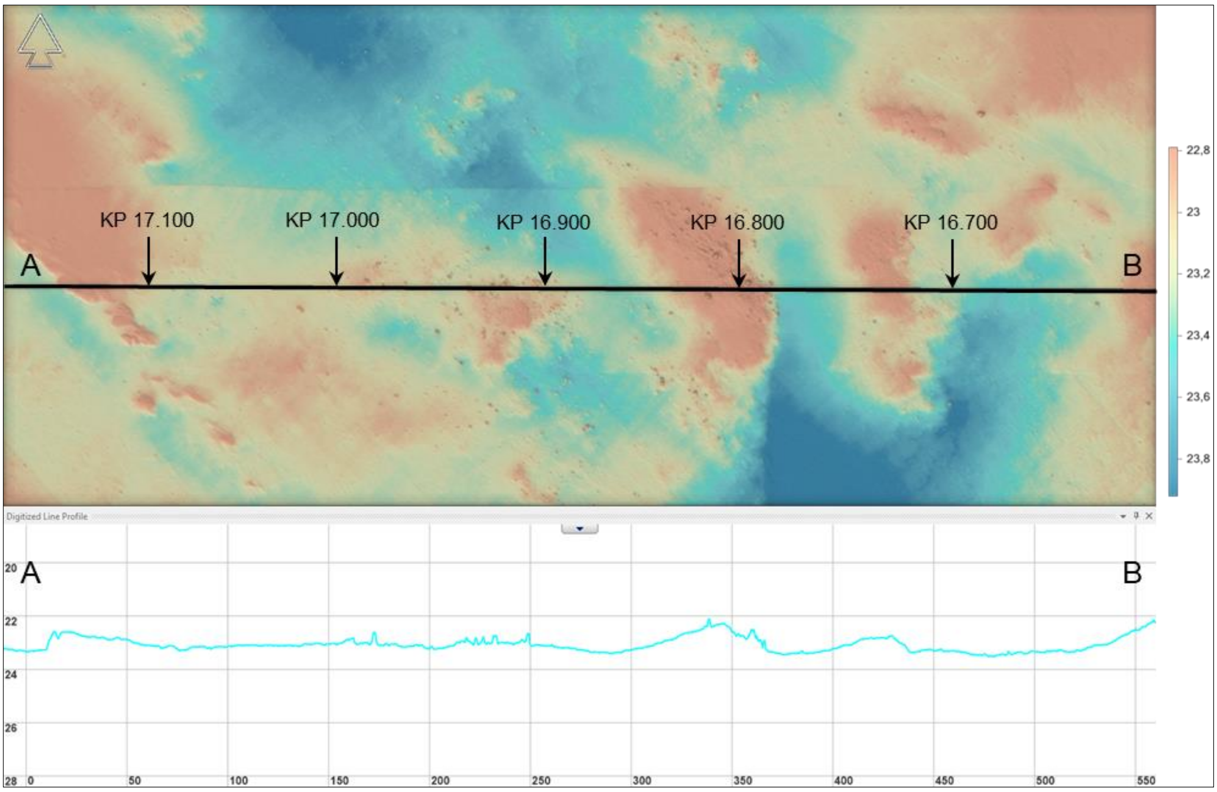


Figure 196 Bornholm 1B crossing over an area of undulating seabed between KP 16.596 and KP 17.164.

Depth convention in NaviModel presented positive down; vertical exaggeration of profile x13.2.

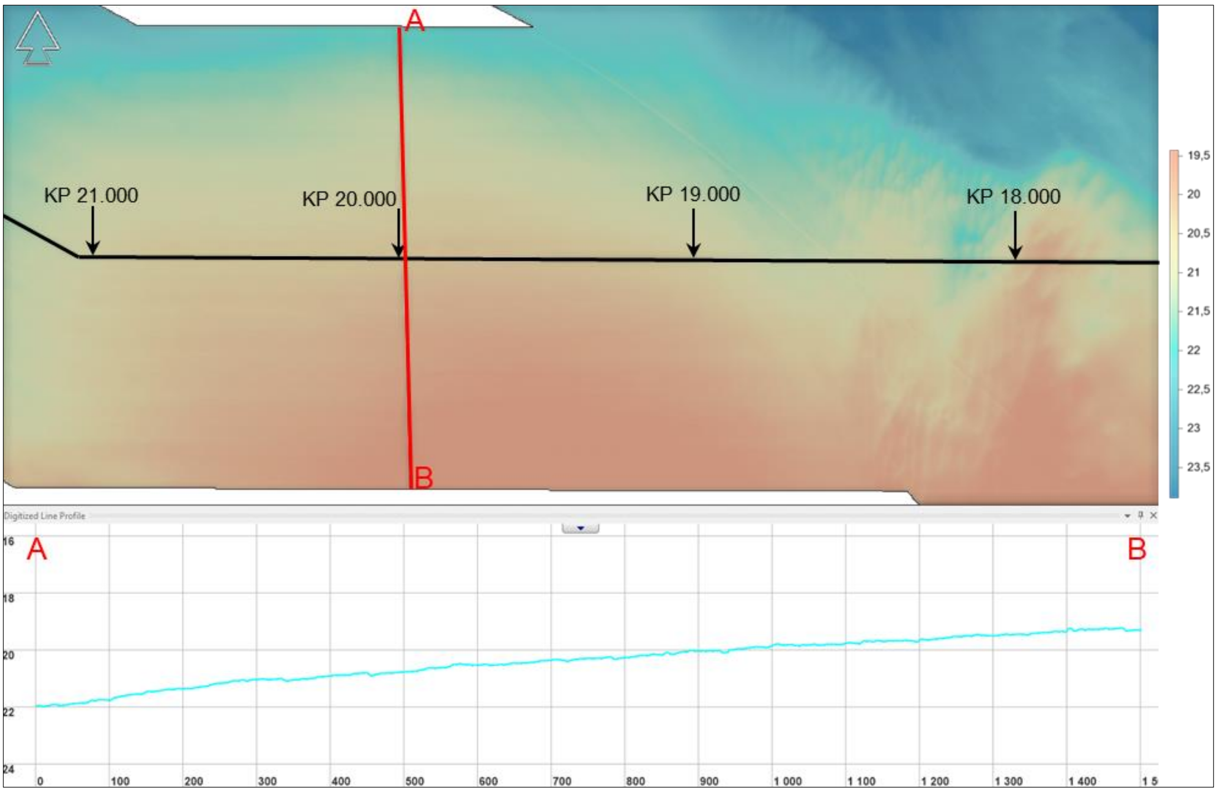


Figure 197 Very gently sloping seabed perpendicular to Bornholm 1B route at KP 19.997.

Depth convention in NaviModel presented positive down; vertical exaggeration of profile x38.4.

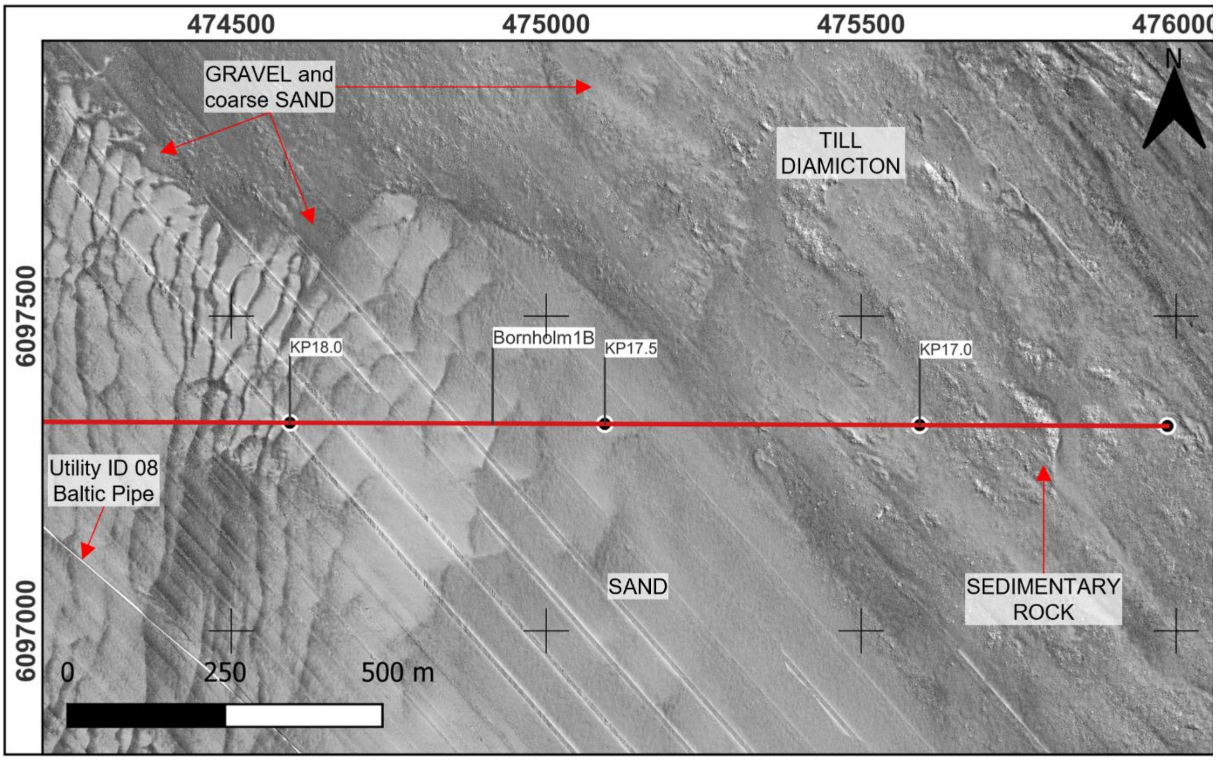


Figure 198 Overview of surficial geology from KP 16.607 to KP 18.500 as seen on SSS.

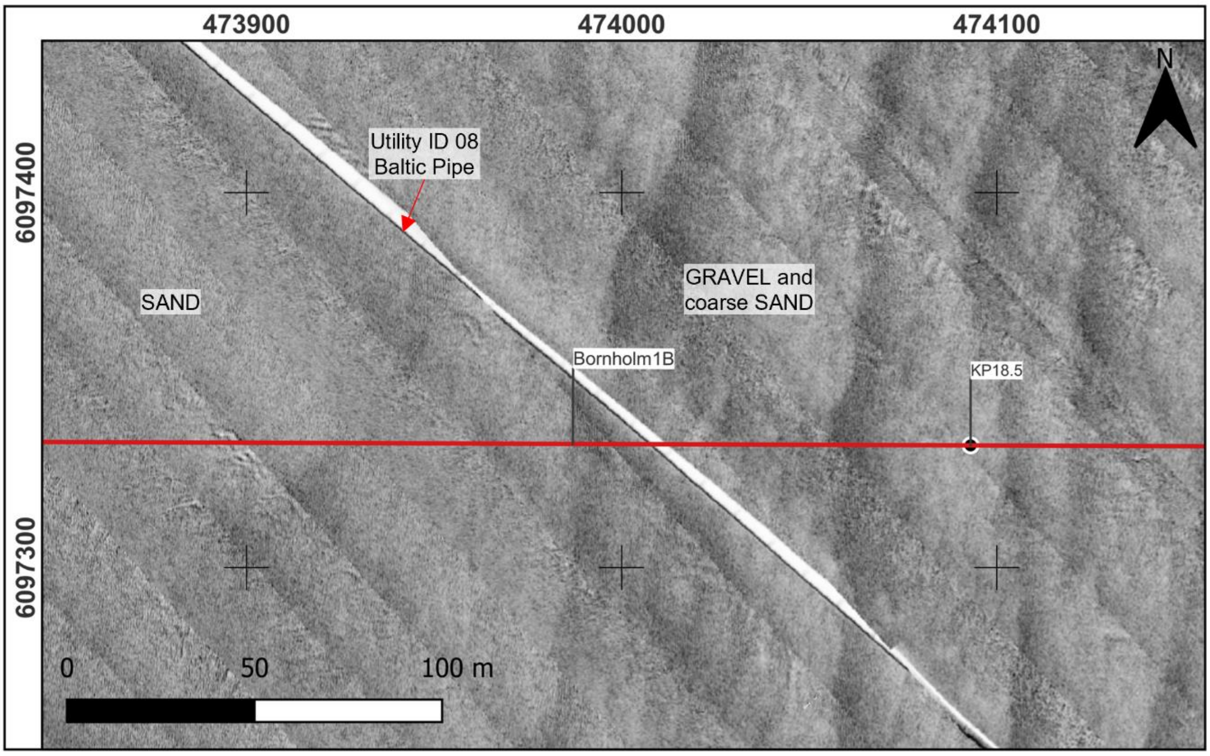


Figure 199 Baltic pipe crossing at KP 18.585

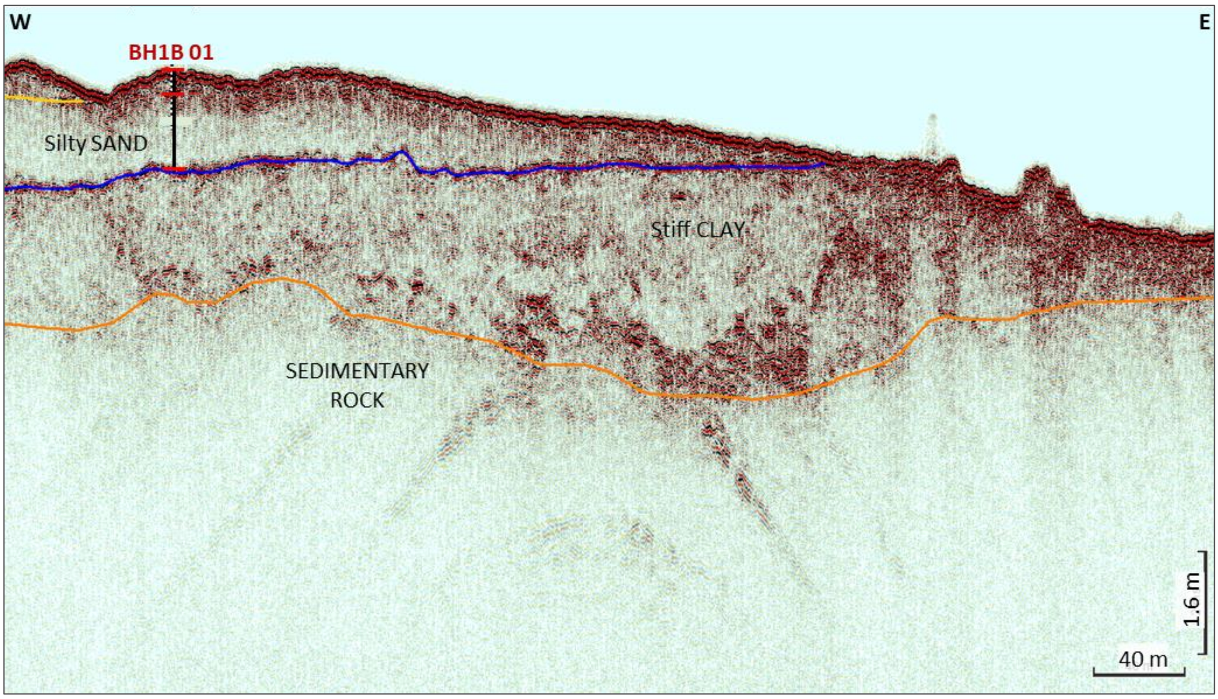


Figure 200 Innomar SBP data example from KP 17.712 (W) to KP 17.167 (E).

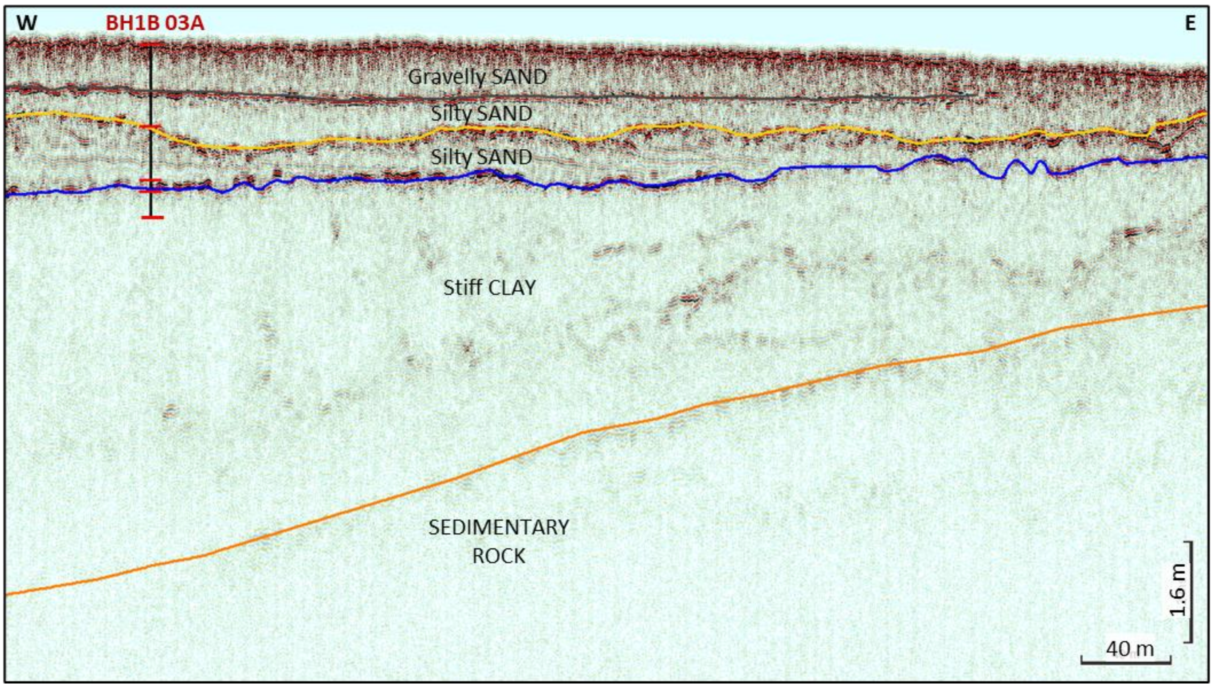


Figure 201 Innomar SBP data example from KP 19.401 (W) to KP 18.855 (E).

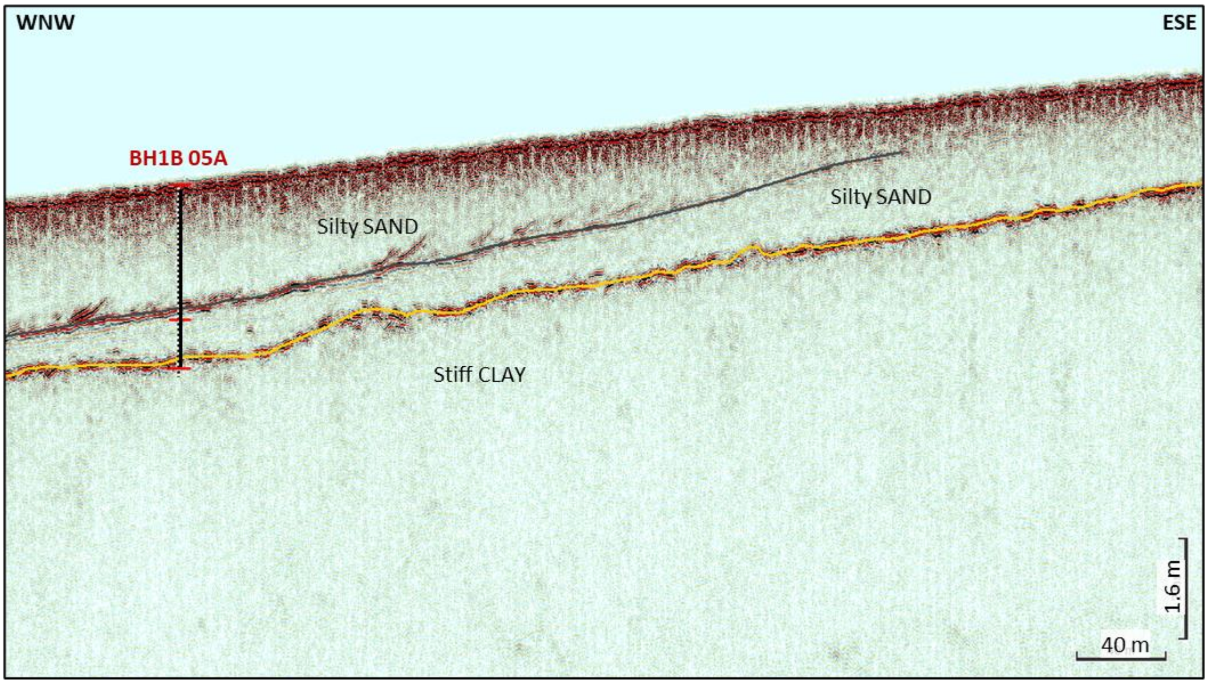


Figure 202 Innomar SBP data example from KP 21.939 (WNW) to KP 21.404 (ESE).

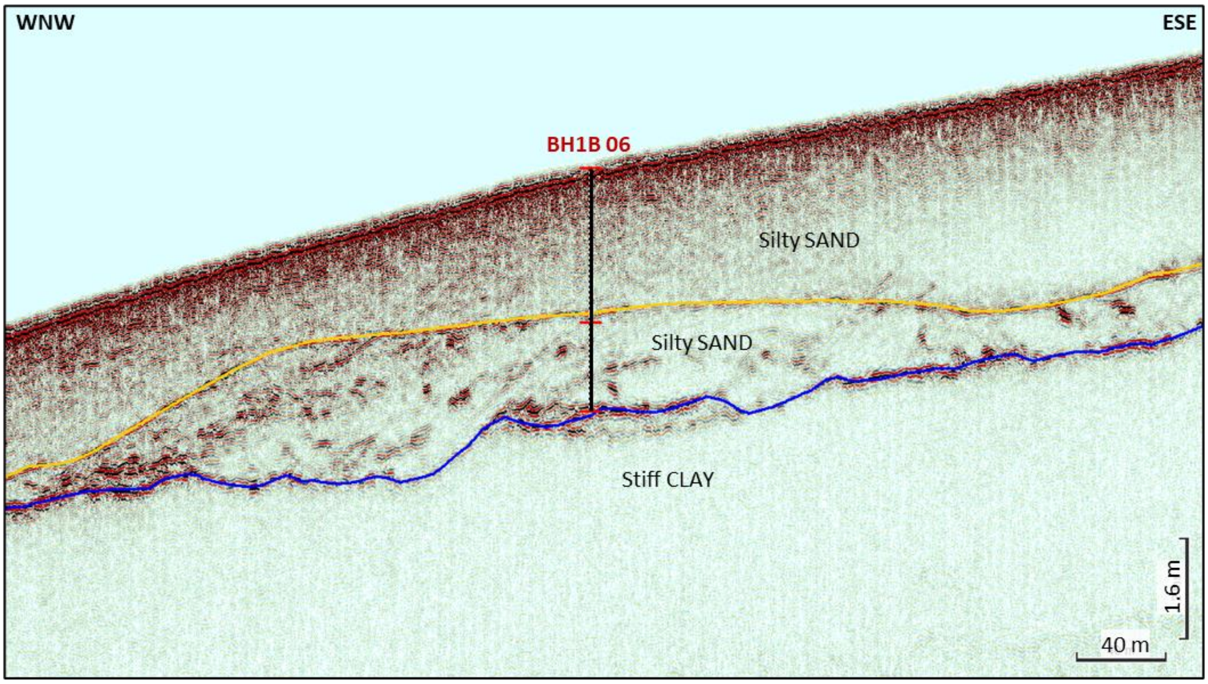


Figure 203 Innomar SBP data example from KP 23.073 (WNW) to KP 22.529 (ESE).

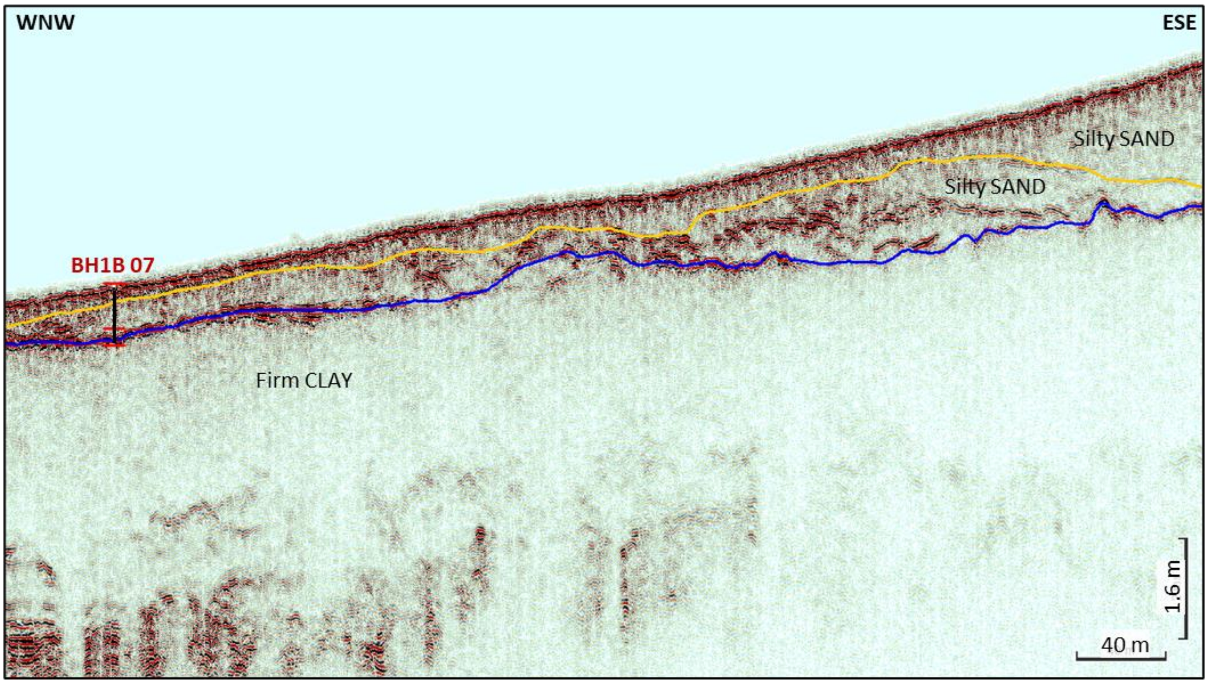


Figure 204 Innomar SBP data example from KP 23.722 (WNW) to KP 23.153 (ESE).

Table 58 ERS Bornholm 1B detailed description for alignment chart 103971-ENN-OI-SUR-DWG-P1BH1B002 (KP 24.047 – 27.560).

Alignment Chart 103971-ENN-OI-SUR-DWG-P1BH1B002 (KP 24.047 – 27.560)	
Description (including min/max depth BSB to base of unit)	**Remark**
Bathymetry: From KP 24.047 to KP 26.000 the seabed undulates with gentle gradients as the route crosses over broad banks which alternate with slightly deeper sections of seabed. From KP 26.000 to KP 27.560 the seabed flattens out with a general westward deepening on a very gentle gradient.	Depth range = 3.5 m. Maximum slope of 4.6° at KP 25.603 along route. Minimum depth 35.93 m at KP 24.048 along route. Maximum depth 39.43 m at KP 26.705 along route.
Surficial geology: The surficial geology from KP 24.047 to KP 27.560 varies between SAND and GRAVEL and coarse SAND (Figure 205). Boulders occur within the area, generally these are isolated but some small areas of low, intermediate and high-density boulder fields occur. Areas of ripples occur within the areas of GRAVEL and coarse SAND, ripple crests are orientated north to south in line with the prevailing storm wave base.	**Grab Samples:** 971-ENE-GR-GS-114 971-ENE-GR-GS-115 971-ENE-GR-GS-116 971-ENE-GR-GS-117
Shallow Geology: KP 24.047 to KP 25.679 (Figure 206): Thin (< 0.3 m) veneers of recent marine slightly silty, slightly gravelly SAND and GRAVEL (P1_H10) lie on top of a thick Glacial CLAY unit (P1_H50). From KP 24.047 to KP 24.751, the Glacial CLAY is firm to stiff, slightly sandy, slightly gravelly from the seabed, whereas from KP 24.751 to KP 25.679, the Glacial CLAY is soft, silty, slightly sandy slightly gravelly for the uppermost 2.6 m BSB, before likely increasing in stiffness to firm to stiff. The base of the Glacial CLAY unit is unable to be identified, likely as this is below the extent of the SBP data. KP 25.679 to KP 27.560 (Figure 207): Recent marine slightly silty, slightly gravelly SAND (P1_H10), with internal reflectors of GRAVEL (P1_H05i), is present from 0 – 1.4 m BSB. Below this, occasional regions of late/post glacial silty SAND (P1_H30) abundant in closely spaced thin to thick	**Vibrocores and CPTs:** BH1B-08 and BH1B-08-CPT BH1B-09 and BH1B-09-CPT BH1B-10 and BH1B-10-CPT

Alignment Chart 103971-ENN-OI-SUR-DWG-P1BH1B002 (KP 24.047 – 27.560)	
Description (including min/max depth BSB to base of unit)	**Remark**
laminae of clayey SILT are present. This unit is discontinuous throughout this KP range and has a highly undulating base, which can be seen to a maximum depth of 1.8 m BSB. Below these SAND units, Glacial CLAYs are observed to beyond the extent of the SBP data, with increasing strength with depth. The upper CLAY is Late Glacial, soft, silty sandy gravelly, with the base of the softer CLAY delineated by the internal reflector P1_H40i on the CL. The softer CLAY is observed to thicken with increasing KP (to the north-west) from 1.9 m BSB at KP 25.679 to 7.0 m BSB at the end of the route at KP 27.560. Below this the Glacial CLAY increases in stiffness, likely to a firm CLAY.	

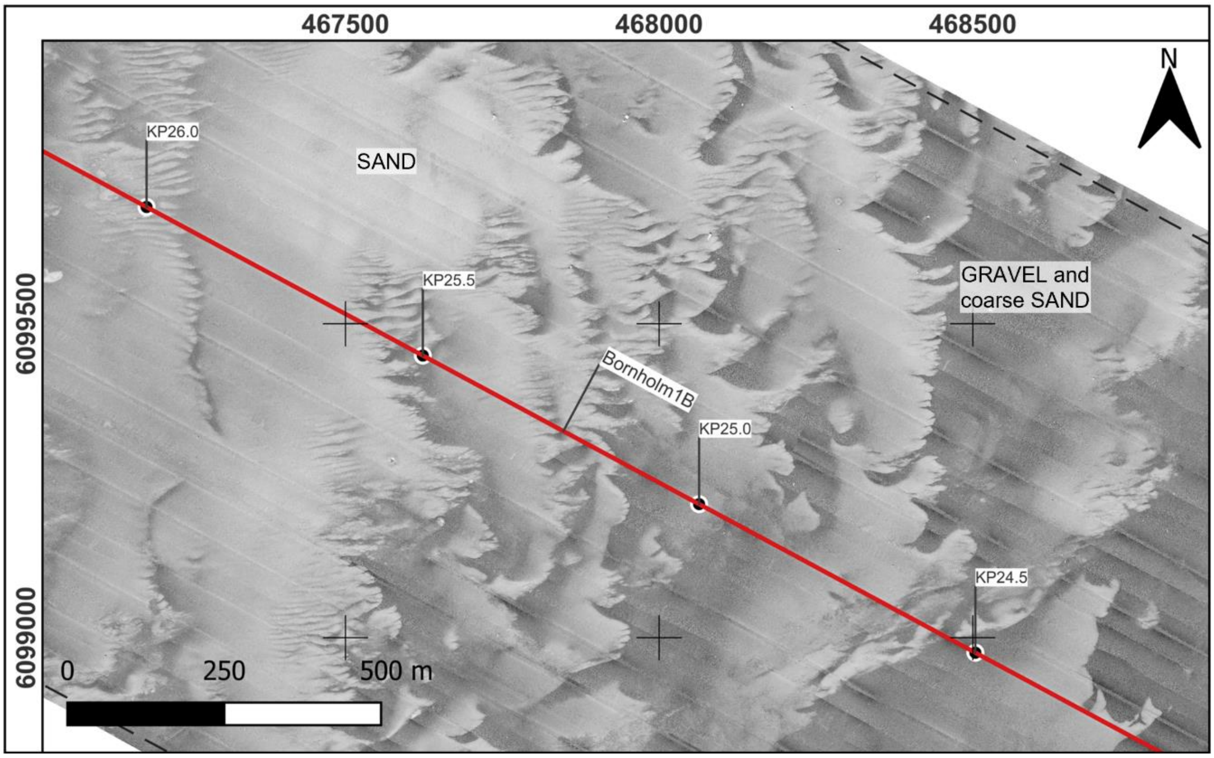


Figure 205 Overview of surficial geology from KP 24.0 to KP 26.2 as seen on SSS.

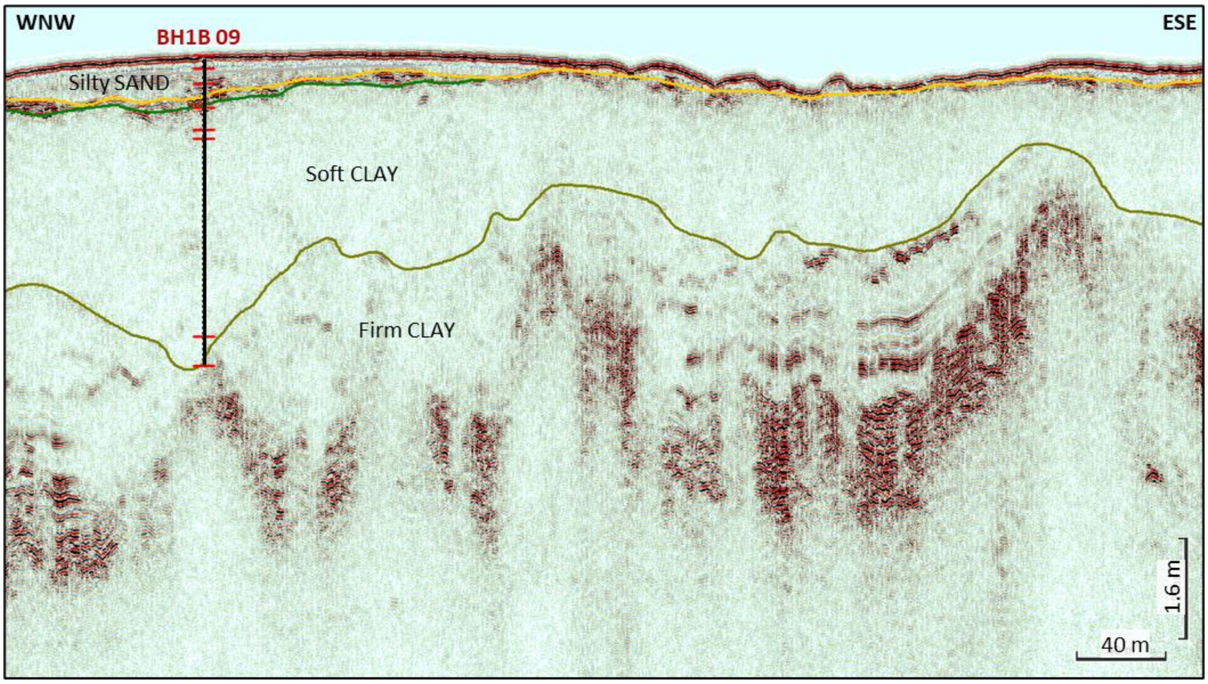


Figure 206 Innomar SBP data example from KP 25.887 (WNW) to KP 25.360 (ESE).

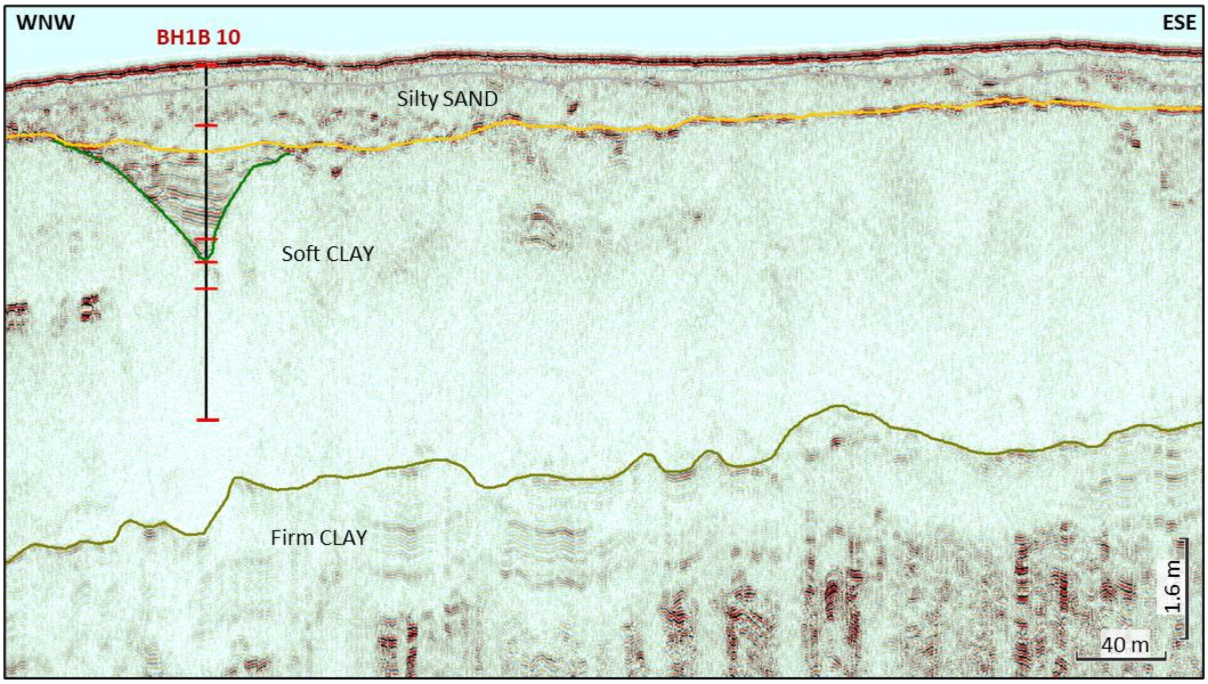


Figure 207 Innomar SBP data example from KP 27.560 (WNW) to KP 27.023 (ESE).

9.3.8 Integrated Seabed Index

Table 59 Integrated Seabed index for ERS Bornholm 1B KP 16.607 to KP 27.650

Location ID				BH1B-01A	BH1B-01				BH1B-03	BH1B-03A			BH1B-04	BH1B-04			BH1B-05A	BH1B-05
Route KP	16.606	17.100	17.600	17.632	17.636	18.000	18.400	18.800	19.329	19.335	19.500	20.000	20.302	20.308	20.800	21.300	21.861	21.867
Data type	SBP	SBP	SBP	CPT	VC	SBP	SBP	SBP	CPT	VC	SBP	SBP	CPT	VC	SBP	SBP	VC	CPT
Depth below seabed (m)																		
0.5	4	4	6	6	6	6	6	6	6	6	6	6	6	6	6	6	6	6
1.0	4	4	5	5	5	5	5	5	5	5	5	5	5	5	5	5	5	5
1.5	4	4	5	4	4	5	5	4	5	5	5	5	5	5	5	5	5	5
2.0	1	4	4	4		4	4	4	6	6	5	5	6	6	5	6	5	5
2.5	1	4	4	4		4	4	4	4	4	6	6	6	6	6	4	6	6
3.0	1	1	4	4		4	4	4	4	4	4	4	4	4	4	4	4	4
4.0	1	1	1	6		4	4	4	4		4	4			4	4		4
5.0	1	1	1	6		4	4	1	6		4	4			4	4		4
6.0	1	1	1	6		1	1	1	6		4	4			4	4		4

Location ID		BH1B-06	BH1B-06			BH1B-07	BH1B-07		BH1B-08	BH1B-08		BH1B-09	BH1B-09				BH1B-10	BH1B-10
Route KP	22.300	22.800	22.807	23.200	23.600	23.663	23.669	24.100	24.628	24.635	25.200	25.792	25.799	26.000	26.500	27.000	27.511	27.513
Data type	SBP	CPT	VC	SBP	SBP	CPT	VC	SBP	CPT	VC	SBP	CPT	VC	SBP	SBP	SBP	CPT	VC
Depth below seabed (m)																		
0.5	6	6	6	6	6	6	6	4	4	4	9	5	5	9	6	5	5	5
1.0	5	5	5	5	5	4	4	4	4	4	9	6	6	9	9	6	5	5
1.5	5	5	5	5	5	4		4	6	4	9	9	9	9	9	9	5	5
2.0	5	5	5	5	5	4		4	4	4	9	9	9	9	9	9	6	6
2.5	6	5	5	4	4	4		4	4		4	9	9	9	9	9	9	9
3.0	4	5	5	4	4	4		4	4		4	9	9	9	9	9	7	9
4.0	4	5	5	4	4	4		4			4	9	9	9	9	9	9	9
5.0	4	4		4	4	4		4			4	9	9	9	9	9	8	9
6.0	4	4		4	4	4		4			4	8		9	9	9	8	9

9.3.9 Seabed Features, Contacts and Anomalies

A total of 50 contacts were identified from the SSS data within the survey corridor on ERS Bornholm 1B. The SSS contacts are summarised in Table 60. In addition to SSS contacts a total of 1 406 526 MBES boulders were identified within the defined boundary (Kabelrute OWF-BHM) at Bornholm.

A total of 95 magnetic anomalies were detected on ERS Bornholm 1B. Of these, 78 are related to linear features or cables/Pipelines. The MAG targets are summarised in Table 61. A total of 6 SSS contact positions correlated with magnetic anomalies.

Infrastructure detected:

- Utility ID 08 (Pipeline, Baltic pipe) crosses the route at KP 18.585 trending northwest to southeast (Figure 144).
- Utility ID 11 (cable, Bornholm-Rugen) detected MAG datasets, not detected on SSS or MBES dataset. Crossing route at KP 20.922.

Table 60 Summary of ERS Bornholm 1B SSS & MBES contacts.

CLASSIFICATION	NUMBER
Debris	42
Linear Debris	4
Biogenic	3
Disturbed Seabed	1
Total	**50**

Table 61 Summary of ERS Bornholm 1B magnetic anomalies.

CLASSIFICATION	NUMBER
Unclassified, possible objects	17
Linear anomalies	78
Total	**95**

9.4 Cable and Pipeline Crossings

A detailed description of the utilities and unknown linear features is made in the 103971-ENN-OI-SUR-REP-CROSSWPD-02 crossing report.

9.5 Archaeology Considerations

During the survey there was no obvious archaeological findings observed. Three historic shipwrecks have been described in the relevant sections above. It is suggested that a full archaeology investigation be conducted on the data collected here by professionally qualified archaeologists to assess the possibility of palaeo landscapes that could have been occupied by early man.

10. Reservations and Recommendations

The results in this report, both geological descriptions and contact selection, are based on interpretations of geophysical data obtained during the survey. There is a natural limitation in the accuracy of interpretation. Results from grab sampling/ vibrocoring and CPTs 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 results have been extrapolated to constitute a base for verifications also in the surroundings.

The SBP and Magnetometer data is acquired with limited line spacing and so it is possible that features smaller than the line spacing may not have been detected by the data. This should be taken into consideration should deviations from the proposed routes be considered.

In some places, localised variations in sediment properties were observed in the geotechnical results, particularly in the near surface SAND unit, H10. The unit has regularly been observed in the geotechnical data to vary from silty SAND to silty gravelly SAND, and in some cases to a soft CLAY, however these local variations have not always been able to be interpreted on the SBP data due to no significant changes in the acoustic properties.

In some isolated areas, the basal reflectors of certain units or internal reflectors, for example, P1_H50 and P3_H50 in both proposed CRS Bornholm-Sjælland routes and P1_H35i along CRS Part 1 Bornholm 2, have been observed to gradationally transition into very low amplitude reflectors. In localised regions the base of these units can therefore become undistinguishable from the surrounding sediments due to similar acoustic properties and so caution should be taken along the routes in these areas.

Interpretation of CLAY strength should be restricted to the close proximity of the geotechnical sites only as it is expected that variations in this can be both temporal, as well as spatial across the full survey corridor width. Changes in CLAY strength is difficult to distinguish from acoustic properties of the SBP data alone.

The shallow water depths across the sites near landfall areas restricted the ability to acquire geotechnical data along the full extent of the proposed cable routes. The area affected as the beginning of CRS Part 1 Bornholm-Sjælland. The client should consider the use of a shallow draft platform such as a multicat for nearshore geotechnical sampling.

The shallow water in the above-mentioned areas also resulted in seabed multiples in the SBP data, masking the data below and therefore, in some places, inhibiting the interpretation.

It should be noted that not all existing contacts are detectable in the SSS data due to coarse terrain (i.e. boulderfields, bedrock and seagrass) in the nearshore sections.

The detection of magnetic anomalies is limited by line spacing and mag altitude. In Part 1 the background magnetic field is influenced by the large area of SEDIMENTARY ROCK and glacial debris, affecting the ability of the magnetometer to differentiate anomalies. Areas with localised background variation include:

- KP 0.0 to KP 17.748 in CRS Bornholm-Sjælland
- KP 9.206 to KP 14.372 on ERS Bornholm 2
- KP 16.607 to KP 19.417 on ERS Bornholm 1A
- KP 16.607 to KP 17.337 on Bornholm 1B

In the nearshore section of Part 1, the intertidal zone area proved challenging to achieve the bathymetric coverage and presented safety concerns, where large boulders dominated the surf zone. OI would recommend the LiDAR solution as an alternative to the standard small inshore vessel and topographic survey approach. The airborne LiDAR data set proved to be a better product than using a combination of standard topographic and inshore craft. The DTM produced was also of a higher quality and resulted in far fewer gaps than the standard approach could achieve. Also, the time taken to complete the LiDAR coverage (all three sites completed in one flight) was far quicker than what is generally achievable with conventional means.

A major consideration is the affect of the pycnocline on the sound velocity, especially in the warmer months, can be challenging and affect all geophysical datasets. This phenomenon is difficult to predict and is variable both in time and space. It has compromised some of the geophysical data and has resulted in significant re-runs.

Furthermore, OI's recommendations for future planning within the survey corridor areas of the proposed CRS and ERS routes would be to conduct a full pUXO survey along the designed cable route prior to the cable installation.

11. References

All references made are from GEUS 2021: Geological desk study Bornholm Windfarm cable transects. GEUS Rapport 2021/63.

Further supplementary papers and background reports specifically referenced in the text in this survey report are detailed below:

Andrén, T. & Expedition 347 participants 2014: Integrated Ocean Drilling Program Expedition 347 Preliminary Report. Baltic Sea Basin Paleoenvironment. Paleoenvironmental evolution of the Baltic Sea Basin through the last glacial cycle. Published by Integrated Ocean Drilling Program. http://publications.iodp.org/preliminary_report/347/347PR.PDF

Andrén, T, Jørgensen, B. B., Cotterill, C., Green, S. & Expedition 347 Scientists 2015: Baltic Sea palaeoenvironment. Proceedings of the IODP, Integrated Ocean Drilling Program 347. Integrated Ocean Drilling Program. Available at: http://publications.iodp.org/proceedings/347/347title.htm

Andrén, E., Andrén, T. & Sohlenius, G. 2000: The Holocene history of the southwestern Baltic Sea as reflected in a sediment core from the Bornholm Basin. Boreas 29, 233–250.

GEUS 2021: Geology desk study offshore Bornholm, Baltic Sea Windfarm investigations. GEUS Rapport 2021/18

Jensen, J.B. 1993: Late Weichselian deglaciation pattern in the southwestern Baltic: Evidence from glacial deposits off the island of Møn. Denmark. Bulletin of the Geological Society of Denmark 40, 314-331.

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12. Data Index

The deliverables listed in Table 62 accompany this report as digital and/or hard copy as specified.

Table 62 Deliverables.

Item	Group	Data Product
1	Bathy data	Bathymetry - Un-gridded soundings, (X,Y,Z) values in ASCII format.
2	Bathy data	Bathymetry - Gridded soundings, 0.25m resolution, (X,Y,Z) values in ASCII format (tiled following the UTM grid).
3	Bathy data	Bathymetry - Gridded soundings, 0.25m resolution, geotiff stored in esri file geodatabase (untiled).
4	Bathy data	Bathymetry - Gridded soundings, 1.00m resolution, (X,Y,Z) values in ASCII format (tiled following the UTM grid).
5	Bathy data	Bathymetry - Gridded soundings, 1.00m resolution, geotiff stored in esri file geodatabase (untiled).
6	Bathy data	Bathymetry - Gridded soundings, 5.00m resolution, (X,Y,Z) values in ASCII format (tiled following the UTM grid).
7	Bathy data	Bathymetry - Gridded soundings, 5.00m resolution, geotiff stored in esri file geodatabase (untiled).
8	Bathy data	Bathymetry - Bathymetric contour curves with 50cm interval, as TSG object CONTOURS_LIN
9	Bathy data	Bathymetry - Vessel tracks, as TSG object TRACKS_LIN, indicate equipment carrier and equipment type in attributes.
10	Bathy data	Bathymetry - TVU 1.00 m resolution, (X,Y, TVU) values in ASCII format
11	Bathy data	Bathymetry - TVU 1.00 m resolution, geotiff stored in esri file geodatabase
12	Bathy data	Bathymetry - THU 1.00 m resolution (X,Y,THU) values in ASCII format
13	Bathy data	Bathymetry - THU 1.00 m resolution, geotiff stored in esri file geodatabase
14	Bathy data	Bathymetry - backscatter 32bit geotiff stored in esri file geodatabase (amplitude populated channels)
15	Bathy data	Sound Velocity Profiles (SVP) in spreadsheet format for comparison
16	Bathy data	MBES - Anomaly target list, as TSG object MBES_ANOMALY_PTS, anomaly characteristics provided in attributes.
17	LIDAR	Delivered intergrated as a part of item 2: WP B – Nearshore and Landfall Survey - Gridded soundings, 0.25m resolution, (X,Y,Z) values in ASCII format.
18	LIDAR	Delivered intergrated as a part of item 3: WP B – Nearshore and Landfall Survey - Bathymetry - Gridded soundings, 0.25m resolution, geotiff stored in esri file geodatabase (untiled).
18a	LIDAR	ECW Files
19	LIDAR	Delivered intergrated as a part of item 8:

Item	Group	Data Product
		WP B – Nearshore and Landfall Survey - Bathymetry - Bathymetric contour curves with 50cm interval, as TSG object CONTOURS_LIN
20	SSS data	Side scan sonar data as XTF-files with corrected navigation, High frequency
21	SSS data	Side scan sonar data as XTF-files with corrected navigation, Low frequency
22	SSS data	Navigation files, CSV-format
23	SSS data	SSS instrument tracks, as TSG object TRACKS_LIN, indicate equipment carrier and equipment type in attributes
24	SSS data	SSS Anomaly target list, as TSG object SSS_ANOMALY_PTS, anomaly characteristics provided in attributes.
24a	SSS data	SSS Mosaics
24b	SSS data	SSS Coverage plot
25	SSS data	SonarWiz 7 project including the bottom tracked and suitably processed .XTF files and SSS and Magnetometer targets
26	Mag data	MAG measurements, CSV-format
27	Mag data	MAG instrument tracks, as TSG object TRACKS_LIN, indicate equipment carrier and equipment type in attributes.
28	Mag data	MAG Anomaly target list, as TSG object MAG_ANOMALY_PTS, anomaly characteristics provided in attributes
29	Mag data	Oasis montaj Project – if available
30	SBP data	Processed SBP recordings, SGY format
31	SBP data	Processed SBP recordings, as image-files (Tiff or PNG)
32	SBP data	SBP instrument tracks, as TSG object TRACKS_LIN, indicate equipment carrier and equipment type in attributes.
33	SBP data	SBP Anomaly target list, as TSG object SBP_ANOMALY_PTS, anomaly characteristics provided in attributes.
34	SBP data	Interpretation of the processed seismic data. These data include interpretation points for digitized horizons identified in the seismic recordings (point list file in CSV-format).
35	SBP data	Generated elevation grids relative to vertical datum for each interpreted horizon in 5 m resolution as GeoTIFF grid (provided in raster tsg)
36	SBP data	Generated elevation grids relative to vertical datum for each interpreted horizon in 5 m resolution as (X,Y,Z) values in ASCII format
37	SBP data	Generated depth below seabed (BSB) grids for each interpreted horizon in 5 m resolution as GeoTIFF grid (provided in raster tsg)
38	SBP data	Generated depth below seabed (BSB) grids for each interpreted horizon in 5 m resolution as (X,Y,Z) values in ASCII format (provided in raster tsg)

Item	Group	Data Product
39	SBP data	Generated Isochore (layer thickness) grids for each interpreted soil unit in 5 m resolution as GeoTIFF grid (provided in raster tsg)
40	SBP data	Generated Isochore (layer thickness) grids for each interpreted soil unit in 5 m resolution as (X,Y,Z) values in ASCII format (Z as the layer thickness in meter)
41	SBP data	Kingdom project
42	Grab sampling data	Grab sample positions, as TSG object GEOTECHNIC_PTS, indicate sampling characteristics in attributes.
43	Grab sampling data	Grab sample classification, MS-Excel spread sheet
44	Grab sampling data	Grab sample laboratory analysis, overview table and result tables, MS-Excel spread sheet.
45	Geotechnical data	Vibrocore and CPT sample positions, as TSG object GEOTECHNIC_PTS, indicate sampling
		characteristics in attributes
46	Geotechnical data	Geotechnical laboratory test, overview table and result tables, MS-Excel spread sheet
47	Geotechnical data	All CPT tests, Vibrocore, Piston core and laboratory test results provided as an AGS 4
		data file (see e.g. www.agsdataformat.com).
48	Integrated seabed interpretation data	Seabed Surface Geology, as TSG object SEABED_GEOLOGY_POL, indicate surface geological unit in attributes
49	Integrated seabed interpretation data	Seabed Surface Features, as TSG object SEABED_SURFACE_PTS, indicate surface forms in attributes
50	Integrated seabed interpretation data	Seabed Surface Features, as TSG object SEABED_SURFACE_LIN, indicate surface forms in attributes
51	Integrated seabed interpretation data	Seabed Surface Features, as TSG object SEABED_SURFACE_POL, indicate surface forms in attributes
52	Integrated seabed interpretation data	Seabed Substrate type, as TSG object SEABED_SUBSTRATE_POL, indicate substrate type in attributes.
53	Integrated seabed interpretation data	Man-Made-Objects, as TSG object MMO_PTS, indicate MMO type in attributes.
54	Integrated seabed interpretation data	Man-Made-Objects, as TSG object MMO_POL, indicate MMO type in attributes.

Item	Group	Data Product
55	Integrated seabed interpretation data	Man-Made-Objects, as TSG object MMO_LIN, indicate MMO type in attributes.
56	Report	Operations Reports. WPA, WPB, WPC
57	Report	Cable Route Survey Report
58	Charts	Charts

Appendix A Route Position Lists

Appendix B List of Produced Charts

Appendix C Contact and Anomaly List

Appendix D Geotechnical Report

Appendix E Benchmarks

Appendix F Integrated Seabed Index