Danish Offshore Wind 2030 Cable Route Survey

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Revision	Date	Description of Revision	Author	Checked	Approved

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REVISION HISTORY

The table on this page should be used to explain the reason for the report revision and what has changed since the previous revision. It is the holder's responsibility to check that they hold the latest validated version.

Rev.	Date	Reason for amendments	Section changes from previous version
0.0	13/05/2024	First draft	N/A
0.1	22/08/2024	Internal revision	Minor corrections
1.0	27/08/2024	For Client review	
2.0	29/11/2024	For Client review	Ref. "Deliverable_Register_DOW2030_NS_REPORT_ECR1_2_3_rev0.xlsx"

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DEFINITIONS AND ABBREVIATIONS

Throughout this document the following terminology is used:

Energinet *Energinet (Client)*

GEOxyz *GEOxyz Offshore (Consultant)*

GeoDK *Geo DK (Sub-contractor)*

Peak *Peak Processing (Sub-contractor)*

Field *Field Geospatial AS (Sub-contractor)*

BSL *Benthic Solutions Limited (Sub-contractor)*

Fielax *Fielax GmbH (Sub-contractor)*

OSC *Ocean Science Consulting Ltd (Sub-contractor)*

The abbreviations and units listed in the table below are used within this report. Where abbreviations used in this document are not included in this table, it may be assumed that they are either equipment brand names or company names.

Table 1: Abbreviations used in this document

Acronym	Description	Acronym	Description
ASV	Autonomous Surface Vehicle	MCA	Maritime and Coastguard Agency
BS	Backscatter	MCR	Mobilisation & Calibration Report
BSF	Below seafloor	MMO	Marine Mammal Observer/Man-Made Object
CMP	Common Mid-Point	MRU	Motion Reference Unit
CPT	Cone Penetration Test	mbsb	Metres below seabed
CPTU	Cone Penetration Test with Pore Pressure	MSL	Mean Sea Level
CTV	Crew Transfer Vessel	NS	North Sea
DGPS	Differential Global Positioning System	OWF	Offshore Wind Farm
DP	Dynamic Positioning	PAM	Passive Acoustic Monitoring
DTM	Digital Terrain Model	PG	Post Glacial
DTS	Desktop Study	QA	Quality Assurance
ECR	Export Cable Route	QC	Quality Control
EEZ	Exclusive Economic Zone	QINSy	Quality Integrated Navigation System
EGN	Empirical Gain Normalisation	QPS	Quality Positioning Services B.V.
EPSG	European Petroleum Survey Group	RPL	Route Position List
ETRS	European Terrestrial Reference System	RTK	Real Time Kinematic
FMGT	Fledermaus GeoCoder Toolbox	SBP	Sub Bottom Profiler
FO	Fiber Optic (telecom cable)	SOW	Scope Of Work
GIS	Geographical Information System	SSS	Side Scan Sonar
GL	Glacial	SVP	Sound Velocity Profile
GNSS	Global Navigational Satellite System	SVS	Sound Velocity Sensor

Acronym	Description	Acronym	Description
GOIV	Geo Ocean IV	SWL	Safe Working Limit
GS	Grab Sampling	TD	Target Depth
MCR	Mobilisation & Calibration Report	THU	Total Horizontal Uncertainty
GSV	Geo Surveyor V	TRT	Thermal Response Testing
H	Height	TVG	Time Variable Gain
HF	High Frequency	TVU	Total Vertical Uncertainty
IMU	Inertial Measurement Unit	UHR	Ultra-High-Resolution
INS	Inertial Navigation System	USBL	Ultra Short Base Line
KP	Kilometric Point	UTC	Universal Time Coordinated
L	Length	UTM	Universal Transverse Mercator
LF	Low Frequency	UXO	Unexploded Ordnance
LG	Late Glacial	VC	Vibrocore
MAG	Magnetometer	W	Width
MBES	Multi Beam Echo Sounder	WD	Water Depth

1 EXECUTIVE SUMMARY

<table>
<tr><th colspan="4">NS_ECR1</th></tr>
<tr><td rowspan="4">Survey dates</td><td rowspan="2">Geophysical survey</td><td>Start</td><td>20/08/2023</td></tr>
<tr><td>End</td><td>13/07/2024</td></tr>
<tr><td rowspan="2">Geotechnical survey</td><td>Start</td><td>06/03/2024</td></tr>
<tr><td>End</td><td>20/03/2024</td></tr>
<tr><td>Sensors and equipment</td><td colspan="3">Multibeam Echo Sounder (MBES), Side Scan Sonar (SSS), Magnetometer (MAG), Sub-Bottom Profiler (SBP), Grab Sampling (GS), Backscatter (BS), Vibrocore (VB), Cone Penetration Test (CPT), Thermal Response Testing (TRT), Lidar, Drone</td></tr>
<tr><td rowspan="2">Coordinate system</td><td colspan="2">Datum</td><td>European Terrestrial Reference System (ETRS89)</td></tr>
<tr><td colspan="2">Projection</td><td>UTM zone 32N (EPSG: 25832)</td></tr>
<tr><td colspan="4">Bathymetry and topography</td></tr>
<tr><td>Elevation</td><td colspan="3">24.94 m MSL (Topographic) – -28.61 m MSL (Bathymetric)</td></tr>
<tr><td>Site configuration</td><td colspan="3">The elevation levels across the North Sea ECR1 site range from 24.94 metres above Mean Sea Level (MSL) in the eastern landfall area to -28.61 metres below MSL towards the western boundary of the survey area.

Starting at landfall and moving eastwards from zero MSL towards KP 0.000 of the RPL, the gradient rises at approximately 2.3° over 41 metres, resulting in an elevation gain of 1.75 metres at the beginning of the RPL. Continuing landwards, there is a significant increase in the elevation with the gradient of 5.7° over 60 metres. Further inland, the survey area is characterised by gentle mounds / dunes with the highest point of 24.94 metres MSL located southern form the KP 0.000. The height of these mounds / dunes decreases when moving further eastwards.

The majority of the offshore area of North Sea ECR1 is characterized by gentle to moderate slopes, ranging from 1 to 10 degrees. In the eastern, nearshore part of the route from KP 0.000 towards KP 4.000 there is a sudden deepening of the seabed, ranging from 1.75 m MSL at the landfall to approximately -18.00 m MSL at KP 4.000. These initial KPs, near the coast, are characterized by steep slopes, reaching up to 56 degrees with dynamic seafloor, featuring ripples and sandwaves.

From KP 4.000 to approximately KP 10.000, the seabed depth flattens with gentle slopes and even shows a slight increase in the depth, of about 1.5 m. From KP 10.000 to the end of the RPL, there is dynamic variability in the sea depth, with a general tendency towards deepening to approximately -26 m MSL at the far end of the RPL.</td></tr>
<tr><td colspan="4">Seabed surface: Geology</td></tr>
<tr><td colspan="4">The seabed geology of the North Sea ECR1 area consists predominantly of sand, along with sediments such as gravel and coarse sand, muddy sand and till/diamicton.

The beginning of the route, from KP 0.000 to approximately KP 3.000, is mostly characterized by gravel and coarse sand, with patches of till/diamicton between KP 1.000 and KP 2.000. From KP 3.000 to KP 5.500, the seabed along the RPL primarily consists of muddy sand, after which from KP 5.000 to KP 10.000, the</td></tr>
</table>

NS_ECR1	
seabed is dominated by sand, corresponding to regions with very gentle slopes and a nearly level seabed elevation. Small patches of till/diamicton occur south of the RPL, around KP 11.500. Towards the west, from KP 10.000 to KP 15.000, sand and gravel and coarse sand dominate, whilst between KP 15.000 to KP 22.000 alternating muddy sand and sand are present. From KP 22.000 to the end of the RPL (and survey area), sand, and gravel and coarse sand alternate with smaller areas of muddy sand.	
Seabed surface: Morphology	
At the beginning of the NS_ECR1 route, from KP 0.000 to KP 0.360, sandwaves and ripples dominate the seafloor. The seabed dynamic is confirmed by the bathymetric profile, which also indicates steep slopes in the nearshore region. Between KP 1.350 and KP 2.000, there are patches of boulder fields which are predominantly high density, as well as an additional isolated boulder field at KP 0.800. The distribution of these boulder fields aligns with the till/diamicton regions of seabed geology. Between KP 2.000 and KP 5.500, the seabed morphology is primarily characterised by areas of ripples and patches of lower reflectivity as seen on the SSS data. These low reflectivity patches correlate to muddy sand in the seabed geology. Between KP 2.500 – KP 5.500 there are also some pitted seabed areas which are observed as isolated seabed depressions, possibly associated with scour around boulders. Similar seabed features are also observed between KP 16.000 – KP 17.000. From KP 5.500 to KP 9.600, the seabed is largely featureless, with the exception of boulders, and correlates with an area of sand in the surficial geology. From KP 9.500 to the end of the RPL, the seabed is mostly dominated by ripples or large ripples, which corresponds with more dynamic slope variability, including some steep slope values. These ripples exhibit wavelengths ranging from 0.5 m to up to 10 metres. Some patches of lower reflectivity as seen in the SSS data, and in correlation with areas of muddy sand in the surficial geology, are also observed in this western half of the route.	
Seabed surface: Man-made features and site-specific hazards	
Wrecks	No wrecks were identified within the NS_ECR1 site.
Metallic objects	One metallic linear contact was found within a 5 m radius of a magnetic anomaly. 43 point contacts were found within a 5 m radius of a magnetic anomaly.
Anchors	No anchors were identified within the site.
Other contacts	63 contacts were identified to be debris.
Rope	No ropes were identified within the site, though 3 linear contacts were identified to be possible rope fragments.
Cables	One cable crossing was identified in the background data but no associated anomalies were detected.
Pipelines	No pipelines were identified within or crossing the NS_ECR1 area.
Boulders	1797 boulders were identified within the site.
Sub-seabed soil units	
Unit I	Post Glacial - SAND with occasional GRAVEL, CLAY and GYTTJA/PEAT layers
Unit II	Periglacial, glaciomarine - Variable includes intervals of laminated CLAY, SAND-prone packages
Unit III	Periglacial, glaciomarine - Variable, includes intervals of laminated CLAY, SAND-prone packages

NS_ECR1	
Unit IV	Periglacial, glaciomarine - Variable, includes intervals of laminated CLAY, SAND-prone packages
Unit V	Glacial with localised direct ice contact - Variable, CLAY-prone, locally overconsolidated
Geology	
The area has a glacial to post-glacial sequence of relatively recent sediments over much older bedrock. Only the upper post glacial and glacial deposits are discussed along the ECR.	
Geohazards	
Unit I sediments are very weak and soft, with negligible bearing capacity, potentially causing retrieval difficulties related to the settlement of seabed frames. Units II, III, IV contains numerous cobbles and boulders. Unit V may exhibit variable levels of over-consolidation, as well as containing numerous cobbles and boulders. Some isolated patches of Gyttja and Peat have also been observed in the geotechnical data, though these have not presented as clear or continuous reflectors in the SBP data and hence are not mapped spatially away from the geotechnical locations. These present a possible geohazard relating to heat dissipation, as well as trenching considerations for Peat.	

NS_ECR2			
Survey dates	Geophysical survey	Start	20/08/2023
		End	13/07/2024
	Geotechnical survey	Start	06/03/2024
		End	20/03/2024
Sensors and equipment	Multibeam Echo Sounder (MBES), Side Scan Sonar (SSS), Magnetometer (MAG), Sub-Bottom Profiler (SBP), Grab Sampling (GS), Backscatter (BS), Vibrocore (VB), Cone Penetration Test (CPT), Thermal Response Testing (TRT), Lidar, Drone		
Coordinate system	Datum		European Terrestrial Reference System (ETRS89)
	Projection		UTM zone 32N (EPSG: 25832)
Bathymetry and topography			
Elevation	19.31 m MSL (Topographic) – -27.34 m MSL (Bathymetric)		
Site configuration	The elevation levels across the North Sea ECR2 site range from 19.31 metres above Mean Sea Level (MSL) in the eastern landfall area to -27.34 metres below MSL towards the northwestern area near the end of the RPL. Starting at the landfall and moving eastwards towards the KP 0.000 of the RPL of NS_ECR2, the gradient rises at approximately 2.7° over 62 metres, resulting in an elevation gain of 3.5 metres at the beginning of the RPL. Continuing landwards, there is an increase in the elevation with the gradient of 4.3° over 70 metres. Further inland the survey area is characterised by gentle mounds / dunes with the highest point of 19.31 metres MSL located northeastern form the KP 0.000. The height of these mounds / dunes decreases when moving further eastward and reach close to 0 m MSL in the vicinity of coastal lake Gammel Gab. The majority of the offshore NS_ECR2 area is characterised by very gentle to gentle slopes. However, in the eastern, nearshore part of the route from KP 0.000 towards		

NS_ECR2	
	KP 6.000 there is a sudden deepening of the seabed, ranging from 3.5 m MSL at the landfall to approximately -18 m MSL at KP 6.000. From KP 10.000 to KP 24.000, the seabed depth flattens. Around KP 25.250 there is a ridge approximately 1 meter high which separates the boulder fields area from a predominantly featureless area of seabed. From KP 25.000 to the KP 31.000 there is a slight raise in the seabed depth, measuring 0.5 metres. From KP 31.000 till the end of the RPL survey area, seabed deepens towards the 26.7 metres MSL at the end of the RPL. There is an increase in slope values in this part, from gentle to moderate slopes, correlating with areas of dynamic seabed such as ripples.
Seabed surface: Geology	
The seabed geology of the North Sea ECR2 survey area consists predominantly of sand, along with sediments such as gravel and coarse sand, muddy sand, Quaternary clay and silt and a few isolated areas till/diamicton. The beginning of the route, from KP 0.000 to approximately KP 6.000, is dominated by a mix of sediments including sand, patches of gravel and coarse sand, and muddy sand areas. From KP 5.400 to KP 5.750 there is an isolated area of till located approximately 40m north-east of the RPL. Between KP 6.000 and KP 10.500, sand covers the full width of the corridor, with the exception of three small patches of gravel and coarse sand. From KP 10.500 to KP 25.250, the seabed geology is primarily sand with some large patches of muddy sand, in correlation with a flatter area of seabed on the bathymetry data. Occasional smaller patches of Quaternary clay and silt were also interpreted along the RPL, in correlation with Vibrocore Top Geology (seabed) results between KP 19.800 and KP 21.900. From KP 25.250 to KP 27.000, the eastern side of the cable corridor is largely dominated by till and gravel and coarse sand, whilst the western side of the corridor is predominantly sand. From KP 27.00 to KP 30.500, sand is present along with an abundance of large linear patterned patches of Quaternary clay and silt. These are orientated in an NW-SE direction. From KP 30.500 to the end of the RPL, the route is dominated by large patches of muddy sandy and gravel and coarse sand, in correlation with the gentle to moderate slopes seen in the bathymetry and consistent with dynamic seabed features, such as ripples.	
Seabed surface: Morphology	
At the beginning of the NS_ECR2 route until KP 0.800, the seabed is dominated by ripples and megaripples. From KP 0.800 to KP 3.000, the seabed is further dominated by ripples, large ripples and areas of sediment waveforms. This indicates dynamic areas, which are also presented within the bathymetric and slope profile. From KP 3.000 to KP 6.250 the seabed is predominantly featureless, with the exception of boulders. There are also occasional isolated areas of patches of mottled seabed and areas of possible biostructures, off the RPL. From KP 5.400 to KP 5.750 there is an isolated boulder field area located approximately 40m north-east of the RPL, which correlates with an area of till in the seabed geology. An area of ripples, large ripples and erosional bedforms are also present, adjacent to the north-east of the boulder field. Between KP 6.250 to KP 28.200, the seabed is largely dominated by trawl marks, with some isolated large patches of featureless seabed also present. Occasional patches of lower reflectivity are also seen along	

NS_ECR2	
this section, in correlation with areas of muddy sand. From KP 25.250 to KP 27.000, the eastern side of the cable corridor is largely dominated by boulder fields and ripples, whilst the western side of the corridor remains either featureless, or trawl marks are observed. From KP 27.00 to KP 31.900, the seabed is featureless with the exception of boulders and an abundance of large linear patterned patches of lower reflectivity visible on the SSS data, that correlate to Quaternary clay and silt or muddy sand. These patches are predominantly orientated in an NW-SE direction. Between KP 31.900 and KP 39.400, the route is either featureless, with the exception of boulders, or is dominated by large areas of ripples and erosional bedforms. From KP 39.400 to the end of the RPL, the seabed is again, either featureless with the exception of boulders, or patches of lower reflectivity as seen on the SSS are again present.	
Seabed surface: Man-made features and site-specific hazards	
Wrecks	No wrecks were identified within the NS_ECR2 site.
Metallic objects	Three metallic linear contacts found within a 5 m radius of a magnetic anomaly. These were all identified to be cables within the survey area. 31 point contacts found within a 5 m radius of a magnetic anomaly.
Anchors	No anchors were identified within the site.
Other contacts	85 contacts were identified to be debris.
Rope	4 contacts related to possible soft rope item were identified.
Cables	7 cable crossings were detected in the survey area. 3 cable crossings were identified from background data only.
Pipelines	No Pipelines were identified within or crossing the NS_ECR 2 site.
Boulders	913 boulders were identified within the site.
Sub-seabed soil units	
Unit I	Post Glacial - SAND with occasional GRAVEL, CLAY and GYTTJA/PEAT layers
Unit II	Late Glacial - Variable, includes intervals of laminated CLAY and SAND-prone packages
Unit III	Glacial - Variable, SAND-prone, with CLAY and TILL locally overconsolidated
Geology	
The area has a glacial to post-glacial sequence of relatively recent sediments over much older bedrock. Only the upper post glacial and glacial deposits are discussed along the ECR.	
Geohazards	
Unit I sediments are very weak and soft, with negligible bearing capacity, potentially causing retrieval difficulties related to the settlement of seabed frames. Unit II contains numerous cobbles and boulders. Unit III may exhibit variable levels of over-consolidation and also contains numerous cobbles and boulders. Some isolated patches of Gyttja and Peat have also been observed in the geotechnical data, though these have not presented as clear or continuous reflectors in the SBP data and hence are not mapped spatially away from the geotechnical locations. These present a possible geohazard relating to heat dissipation, as well as trenching considerations for Peat.	

<table>
<tr><th colspan="4">NS_ECR3</th></tr>
<tr><td rowspan="4">Survey dates</td><td rowspan="2">Geophysical survey</td><td>Start</td><td>20/08/2023</td></tr>
<tr><td>End</td><td>13/07/2024</td></tr>
<tr><td rowspan="2">Geotechnical survey</td><td>Start</td><td>06/03/2024</td></tr>
<tr><td>End</td><td>20/03/2024</td></tr>
<tr><td>Sensors and equipment</td><td colspan="3">Multibeam Echo Sounder (MBES), Side Scan Sonar (SSS), Magnetometer (MAG), Sub-Bottom Profiler (SBP), Grab Sampling (GS), Backscatter (BS), Vibrocore (VB), Cone Penetration Test (CPT), Thermal Response Testing (TRT), Lidar, Drone</td></tr>
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<tr><td colspan="2">Projection</td><td>UTM zone 32N (EPSG: 25832)</td></tr>
<tr><td colspan="4">Bathymetry and topography</td></tr>
<tr><td>Elevation</td><td colspan="3">19.31 m MSL (Topographic) – -24.8 m MSL (Bathymetric)</td></tr>
<tr><td>Site configuration</td><td colspan="3">The elevation levels across the NS_ECR3 site range from a highest point of 19.31 metres above MSL in the eastern landfall area, to a deepest point of 24.80 metres below mean sea level (MSL) towards the northwestern boundary of the survey area.

Starting at the landfall and moving eastwards, the elevation increases gradually by 3.5 m, with a gradient of approximately 2.8°, over 59 metres. Continuing landwards, there is a further increase in elevation with the gradient of 4.3° over 70 metres. Further inland, the survey area is characterised by gentle mounds / dunes with the highest point of 19.31 metres MSL located northeastern from the KP 0.000. The height of these mounds / dunes decreases when moving further eastward and reach close to 0 MSL in the vicinity of coastal lake Gammel Gab.

The offshore area of the NS_ECR3 site is characterised by very gentle slopes on most of the cable survey area. The highest concentration of steep slopes located to the east of the KP 0.000, towards the inland areas.

In this nearshore part of the route, from KP 0.000 to KP 8.000, a significant deepening of the seabed, with steep slopes is observed. Between KP 2.000 and KP 3.000 there is a channel-type structure, corresponding to ripples, after which the seafloor continues to deepen towards the KP 8.000.

The area between KP 8.000 and KP 12.000 is characterised by almost flat seabed floor, without any changes in the depth. Following the KP 14.500 the seabed continues to deepen till the end of the RPL. There are sudden changes in elevation with differences reaching up to 2 m between around KP 19.000. This dynamic area corresponds to ripples and large ripples.</td></tr>
<tr><td colspan="4">Seabed surface: Geology</td></tr>
<tr><td colspan="4">The seabed geology of the North Sea ECR3 survey area consists predominantly of sand, along with sediments such as gravel and coarse sand, muddy sand and one isolated area of till/diamicton.

The beginning of the NS_ECR3 route, from KP 0.000 to approximately KP 6.000, is dominated by a mix of sediments including sand, patches of gravel and coarse sand, muddy sand and mud and sandy mud areas.</td></tr>
</table>

NS_ECR3	
From KP 5.400 to KP 5.750 there is an isolated area of till located approximately 440m north-east of the RPL, which correlates to a boulder field area in the seabed morphology. Between KP 6.000 and KP 10.900, sand covers the full width of the corridor, with the exception of one small patch of gravel and coarse sand just north of the RPL near KP 8.000. From KP 10.900 to the end of the RPL, the seabed geology is dominated by muddy sand and sand. The exception to this is between KP 18.750 and KP 19.850, where there are isolated patches of gravel and coarse sand near the RPL, and similarly between KP 21.600 and then the end of the route, along the northern edge of the corridor. These areas correlate with areas of large ripples and ripples.	
Seabed surface: Morphology	
At the beginning of the NS_ECR3 route until KP 0.800, the seabed is dominated by ripples and megaripples. From KP 0.800 to KP 3.000, the seabed is further dominated by ripples, large ripples and areas of sediment waveforms. This indicates dynamic areas, which are also shown within the bathymetric and slope data. From KP 3.000 to KP 6.250 the seabed is predominantly featureless, with the exception of boulders. There are also occasional isolated areas of patches of mottled seabed and areas of possible biostructures, off the RPL. From KP 5.400 to KP 5.750 there is an isolated boulder field area located approximately 440m north-east of the RPL, which correlates with an area of till in the seabed geology. An area of ripples, large ripples and erosional bedforms are also present, adjacent to the north-east of the boulder field. Between KP 6.250 to KP 9.400, the seabed is dominated by trawl marks before becoming featureless, with the exception of boulders, from KP 9.400 to KP 10.900. The end half of the route, from KP 10.900 to KP 22.966 is dominated by a mix of featureless seabed with the exception of boulders, linear seabed scars and patches of lower reflectivity as seen on the SSS data. Between KP 18.750 and KP 19.850, there are also isolated patches of ripples and large ripples near the RPL, and similarly between KP 21.600 and then the end of the route, along the northern edge of the corridor. These areas correlate with areas of gravel and coarse sand in the seabed geology.	
Seabed surface: Man-made features and site-specific hazards	
Wrecks	1 wreck was identified within the NS_ECR3.
Metallic objects	No metallic linear objects were found withing a 5 m radius of a magnetic anomaly. 10 point contacts were found withing a 5 m radius of a magnetic anomaly.
Anchors	No anchors were identified within the site.
Other contacts	24 contacts were identified to be debris.
Rope	18 contacts related to possible soft rope items were identified.
Cables	2 cable crossings were identified.
Pipelines	No pipelines were identified within or crossing NS_ECR3.
Boulders	394 boulders were identified within the site.
Sub-seabed soil units	
Unit I	Post Glacial - SAND with occasional GRAVEL, CLAY and GYTTJA/PEAT layers
Unit II	Late Glacial - Variable, includes intervals of laminated CLAY and SAND-prone packages
Unit III	Glacial - Variable, SAND-prone, with CLAY and TILL locally overconsolidated
Geology	

NS_ECR3
The area has a glacial to post-glacial sequence of relatively recent sediments over much older bedrock. Only the upper post glacial and glacial deposits are discussed along the ECR.
Geohazards
Unit I sediments are very weak and soft, with negligible bearing capacity, potentially causing retrieval difficulties related to the settlement of seabed frames. Unit II contains numerous cobbles and boulders. Unit III may exhibit variable levels of over-consolidation and also contains numerous cobbles and boulders. Some isolated patches of Gyttja and Peat have also been observed in the geotechnical data, though these have not presented as clear or continuous reflectors in the SBP data and hence are not mapped spatially away from the geotechnical locations. These present a possible geohazard relating to heat dissipation, as well as trenching considerations for Peat.

2 PROJECT INTRODUCTION AND BACKGROUND

2.1 PROJECT OVERVIEW

Following a decision in the Danish Parliament in 2022, Denmark is on the path to establish offshore energy infrastructure in the Danish North Sea to connect offshore wind energy to the Danish mainland. The location of the project is presented in Figure 1.

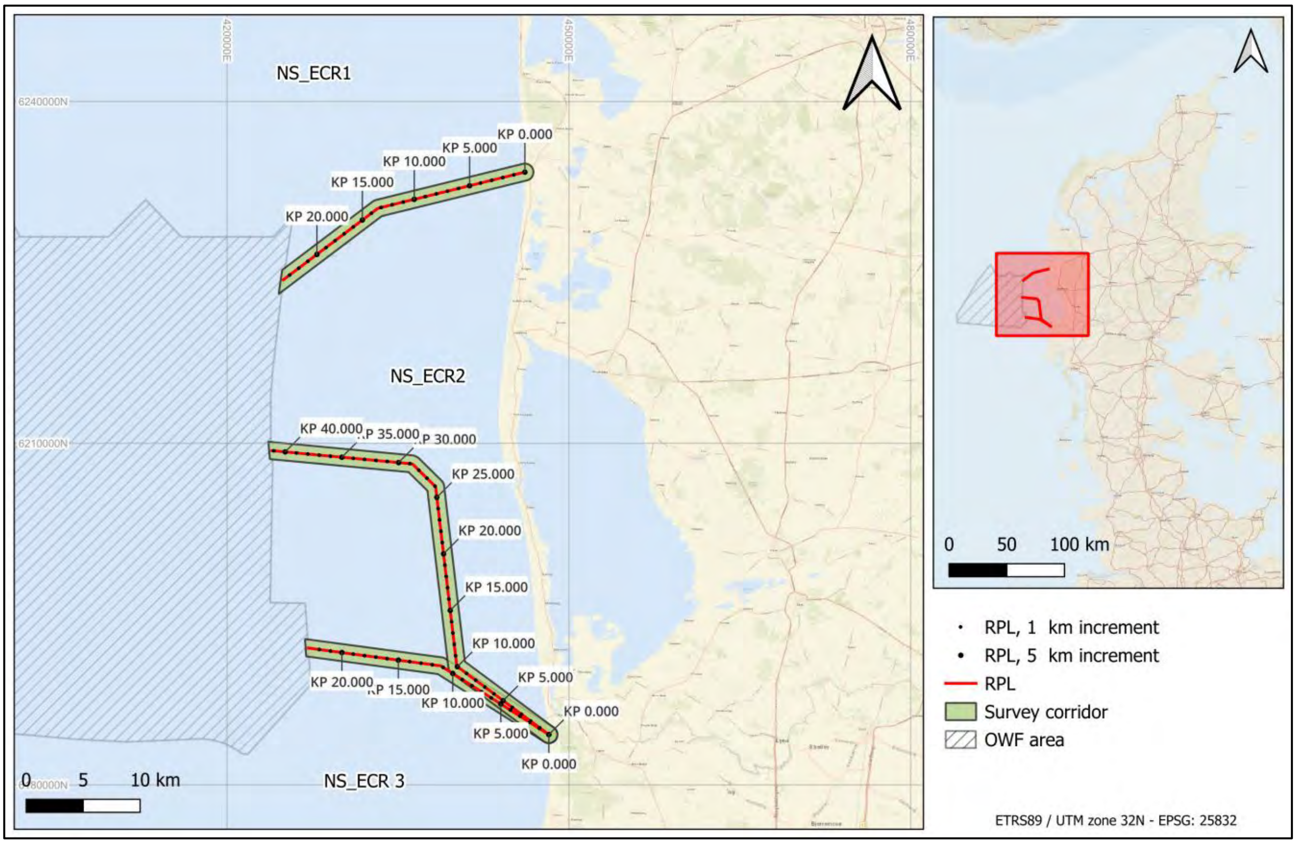


Figure 1: Project location overview – North Sea

It is anticipated that the North Sea development area at a later stage will be divided into multiple offshore wind farm project sites.

The Client has awarded GEOxyz a contract to provide surveys of the marine cable routes connecting the wind farm sites with land (Export Cable Routes, ECR). The overview of cable routes is presented in Table 2. The work includes geophysical survey and shallow geotechnical investigations. A detailed view on the survey area for cable NS_ECR1 and for cables NS_ECR2 and NS_ECR3 is presented in Figure 2 and Figure 3, respectively.

Table 2: Areas of investigation for the cable route surveys

Export Cable Route	Route length	Route width	Water depth
NS_ECR1	23 km	1500 m	0 - 27 m
NS_ECR2	41 km	1500 m	0 - 28 m
NS_ECR3	23 km	1500 m	0 - 24 m

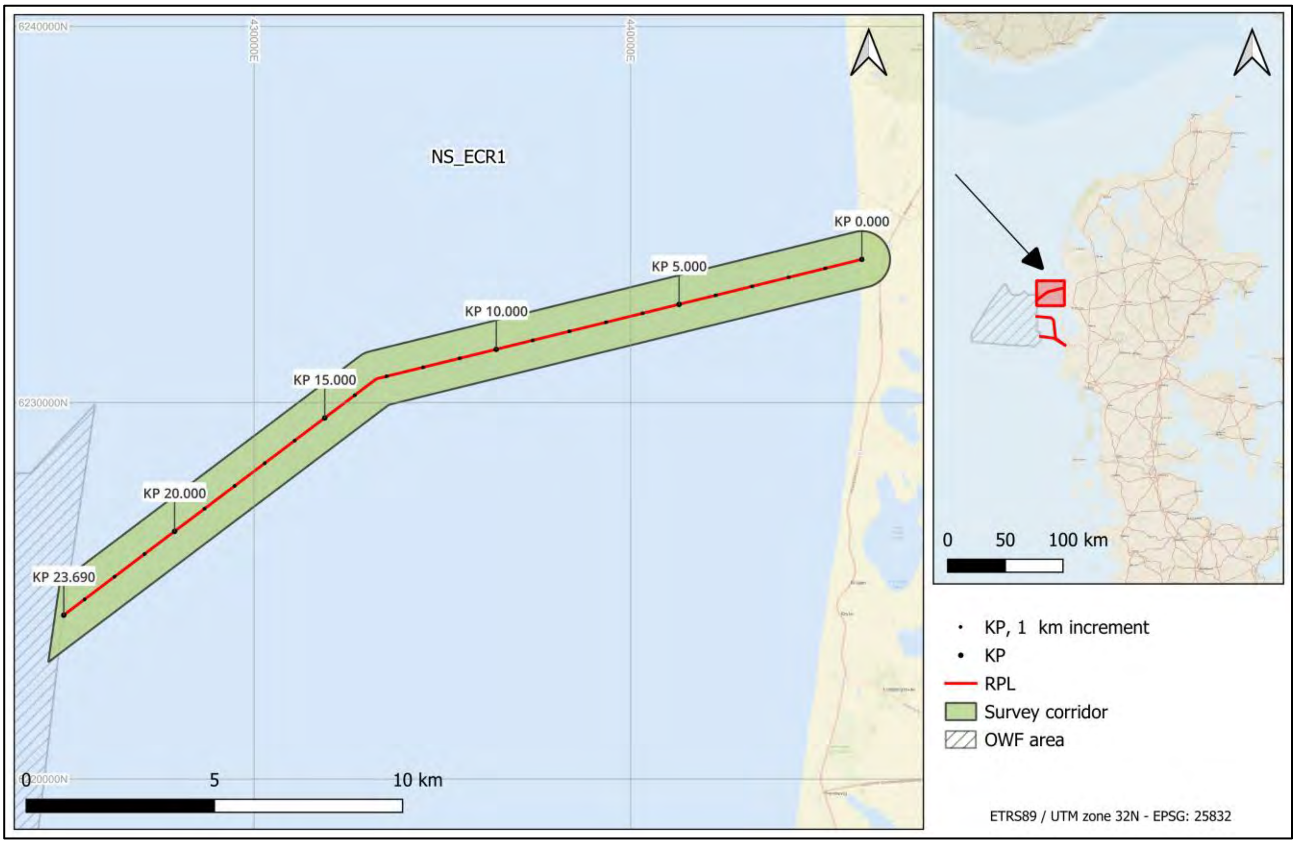


Figure 2: Detailed view on the NS_ECR1 survey area

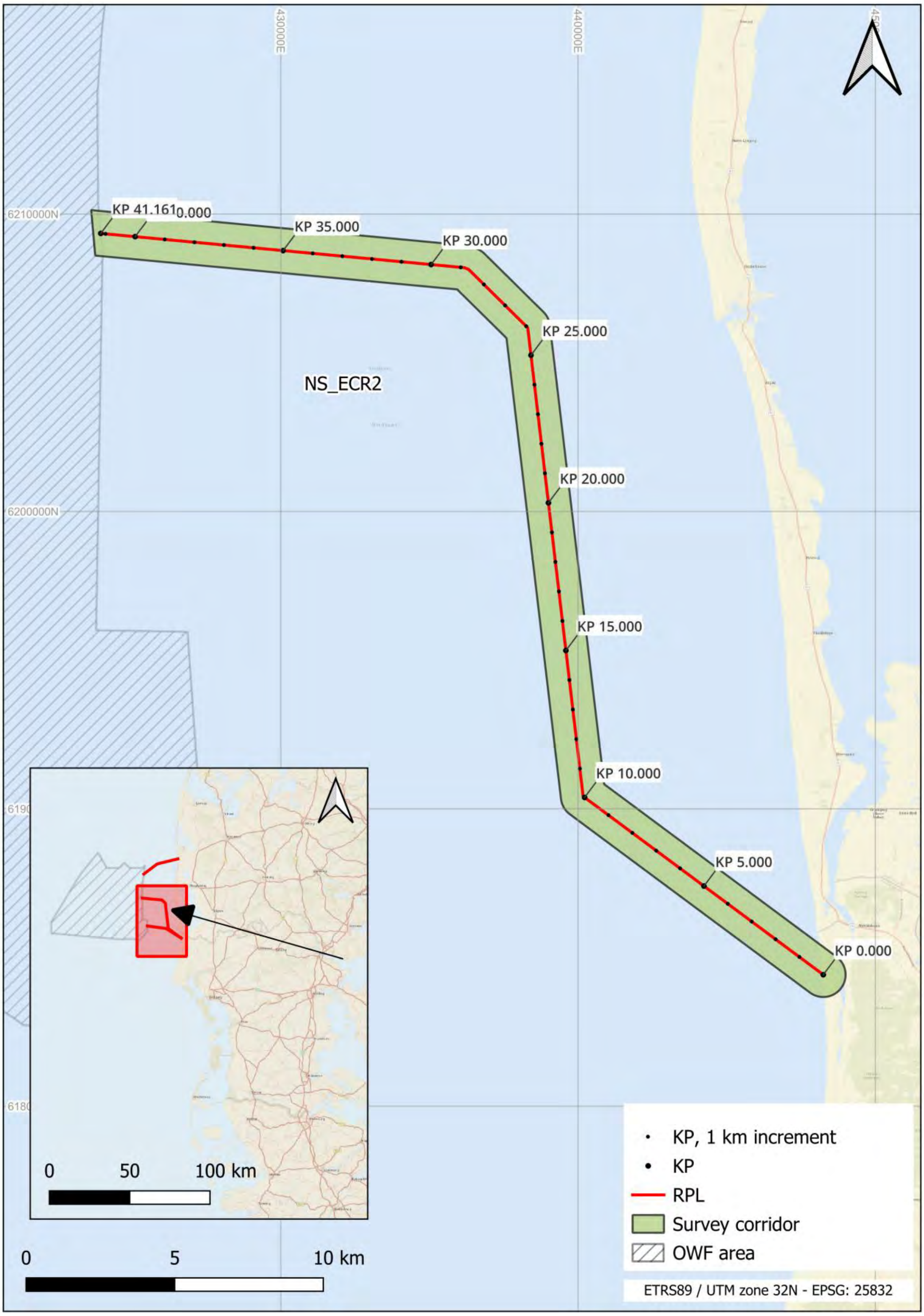


Figure 3: Detailed view on the NS_ECR2 survey areas

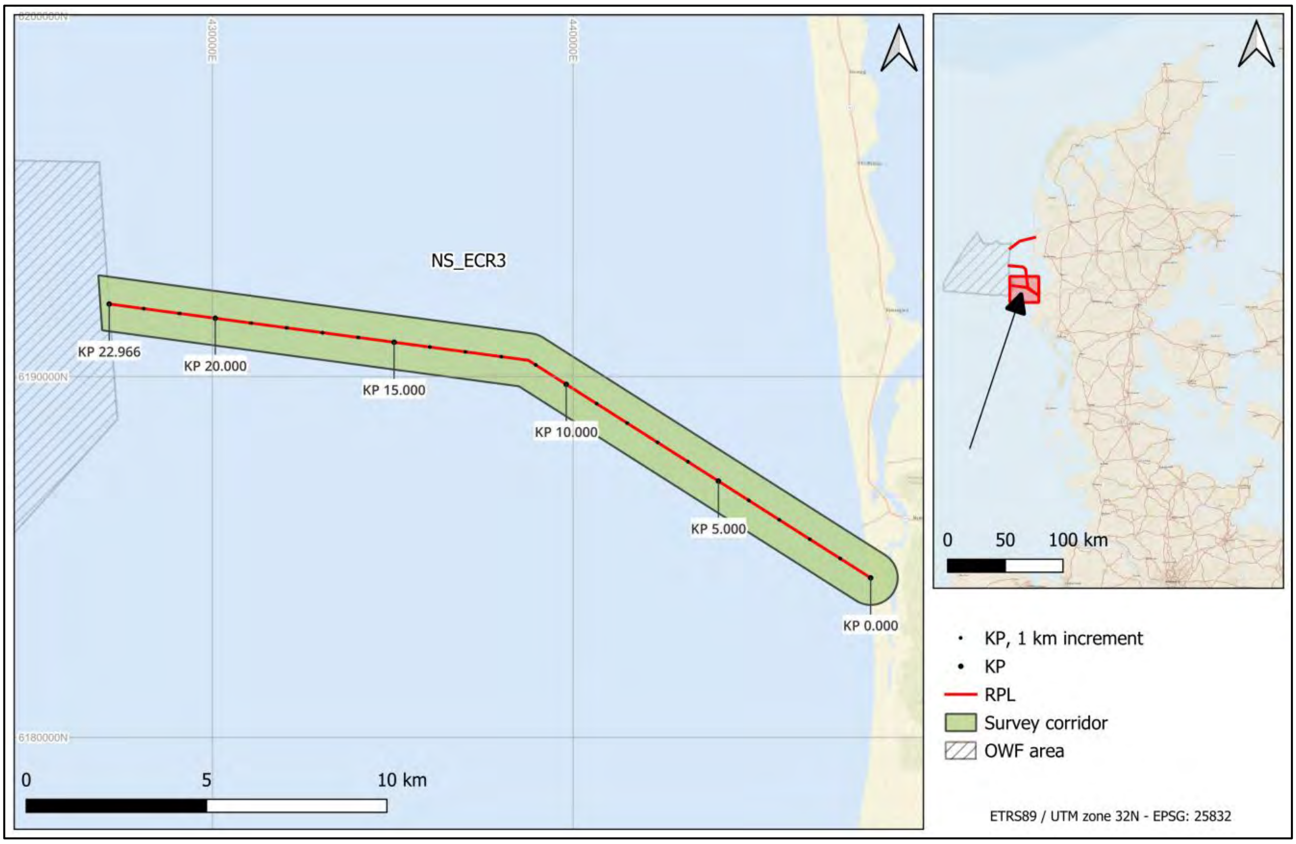


Figure 4: Detailed view on the NS_ECR3 survey areas

2.2 CABLE ROUTES

The survey extents of the planned North Sea cables NS_ECR1, NS_ECR2, and NS_ECR3 are situated in the Danish North Sea, connecting planned North Sea I OWF to the Danish mainland. A summary of coordinates is displayed in Figure 5 and Table 3. The landfall for the North Sea cable NS_ECR1 is planned at Vedersø Klit (Figure 6). The landfall for North Sea cables NS_ECR2 and NS_ECR3 is planned at Nymindegab (Figure 7, and Figure 8).

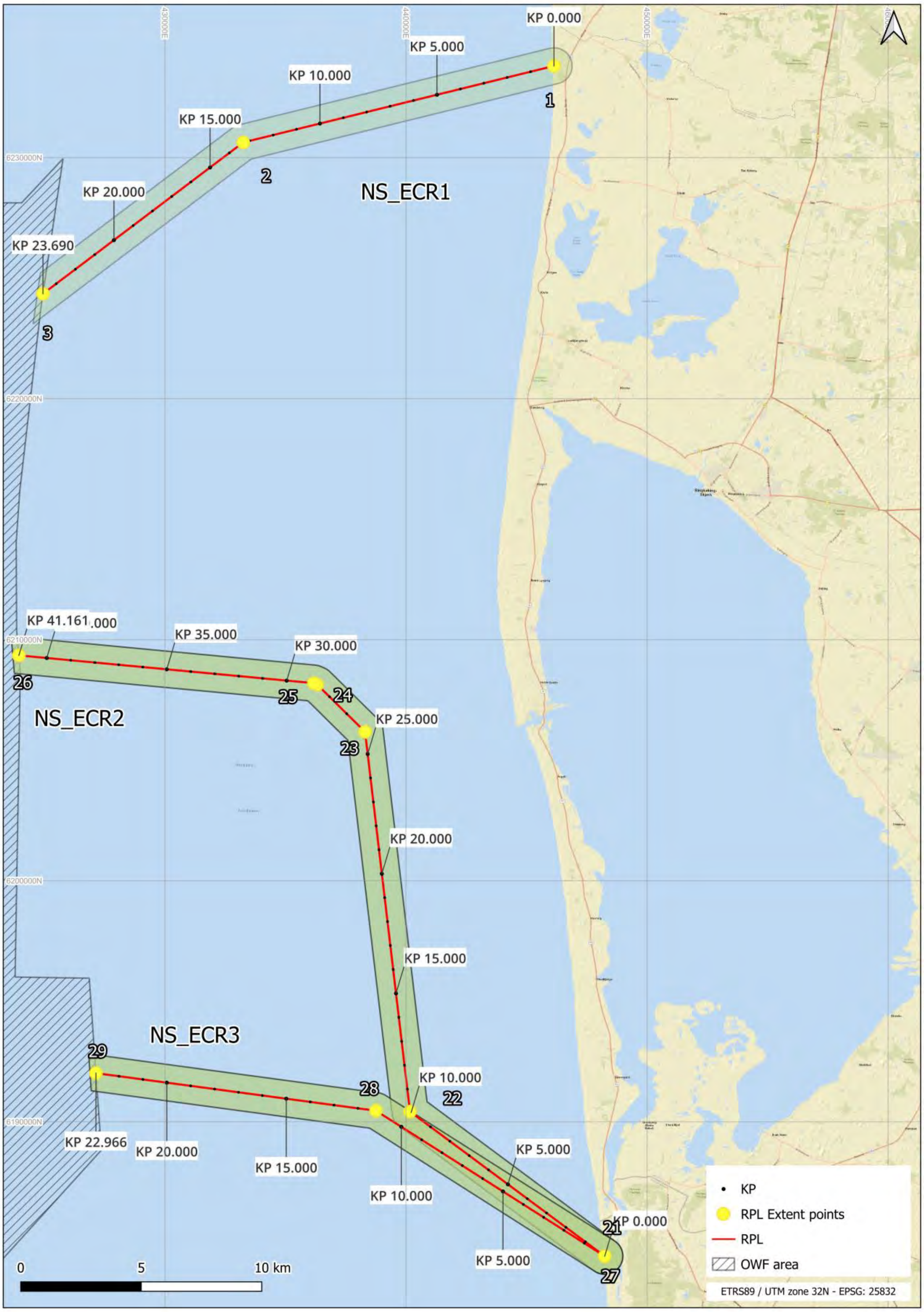


Figure 5: Overview of NS_ECR1, NS_ECR2 and NS_ECR3 cable extents

Table 3: Coordinates of the North Sea cables (projection UTM 32N, datum: ETRS89)

	Point ID	Point KP	Easting	Northing	Longitude	Latitude
ECR1	1	0.000	446143.38	6233808.48	8° 7.855' E	56° 14.765' N
	2	13.278	433250.46	6230635.09	7° 55.423' E	56° 12.957' N
	3	23.691	424943.54	6224355.79	7° 47.494' E	56° 9.498' N
ECR2	21	0.000	448246.91	6184422.00	8° 10.463'E	55° 48.158'N
	22	10.061	440169.00	6190420.00	8° 2.653' E	55° 51.335' N
	23	25.929	438305.69	6206177.50	8° 0.652' E	55° 59.815' N
	24	28.716	436321.91	6208136.00	7° 58.716' E	56° 0.855' N
	25	28.871	436180.31	6208197.50	7° 58.579' E	56° 0.887' N
	26	41.161	423943.85	6209350.35	7° 46.785' E	56° 1.401' N
ECR3	27	0.000	448246.91	6184422.00	8° 10.463' E	55° 48.158' N
	28	11.242	438760.91	6190455.00	8° 1.303' E	55° 51.343' N
	29	22.966	427140.83	6192015.56	7° 50.143' E	55° 52.088' N

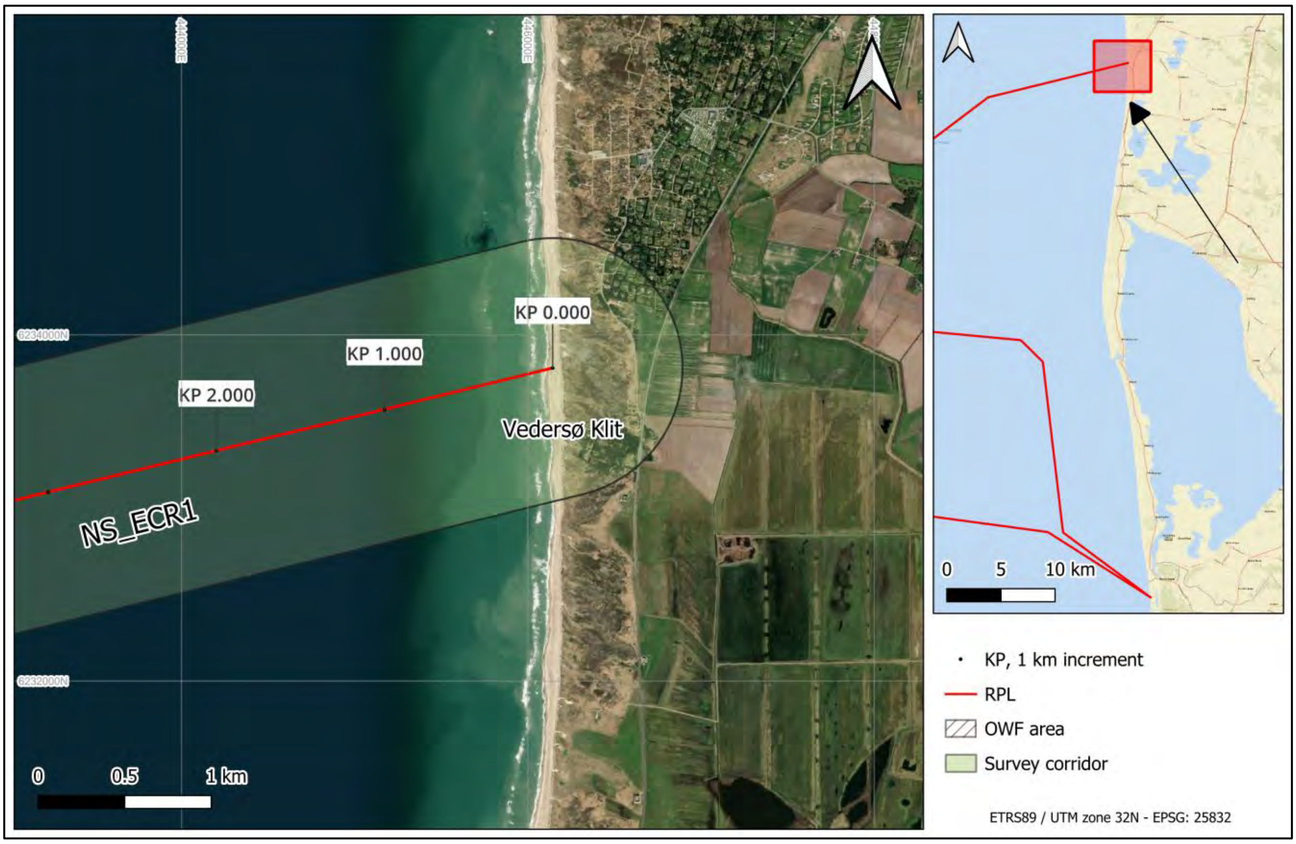


Figure 6: Landfall location overview NS_ECR1 – Vedersø Klit

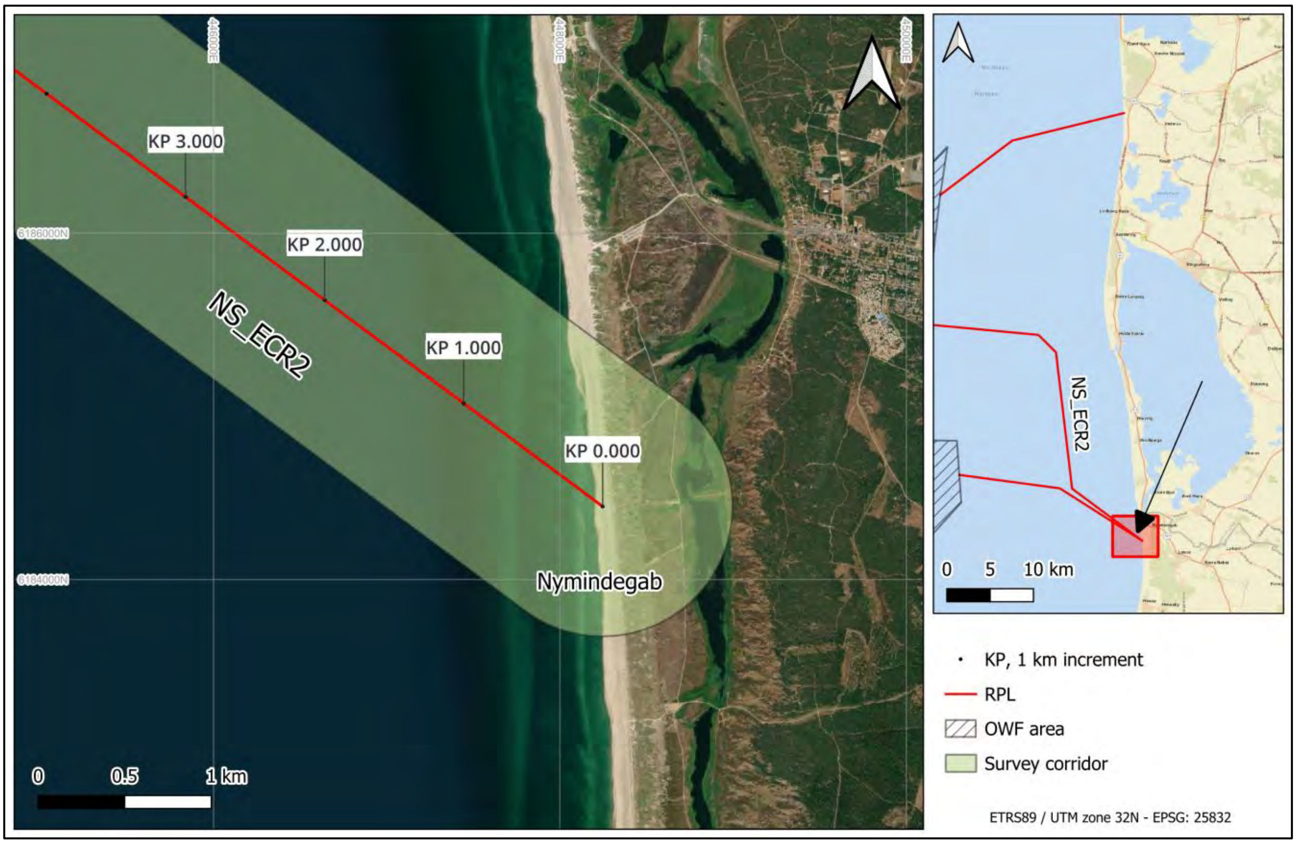


Figure 7: Landfall location overview NS_ECR2 – Nymindegab

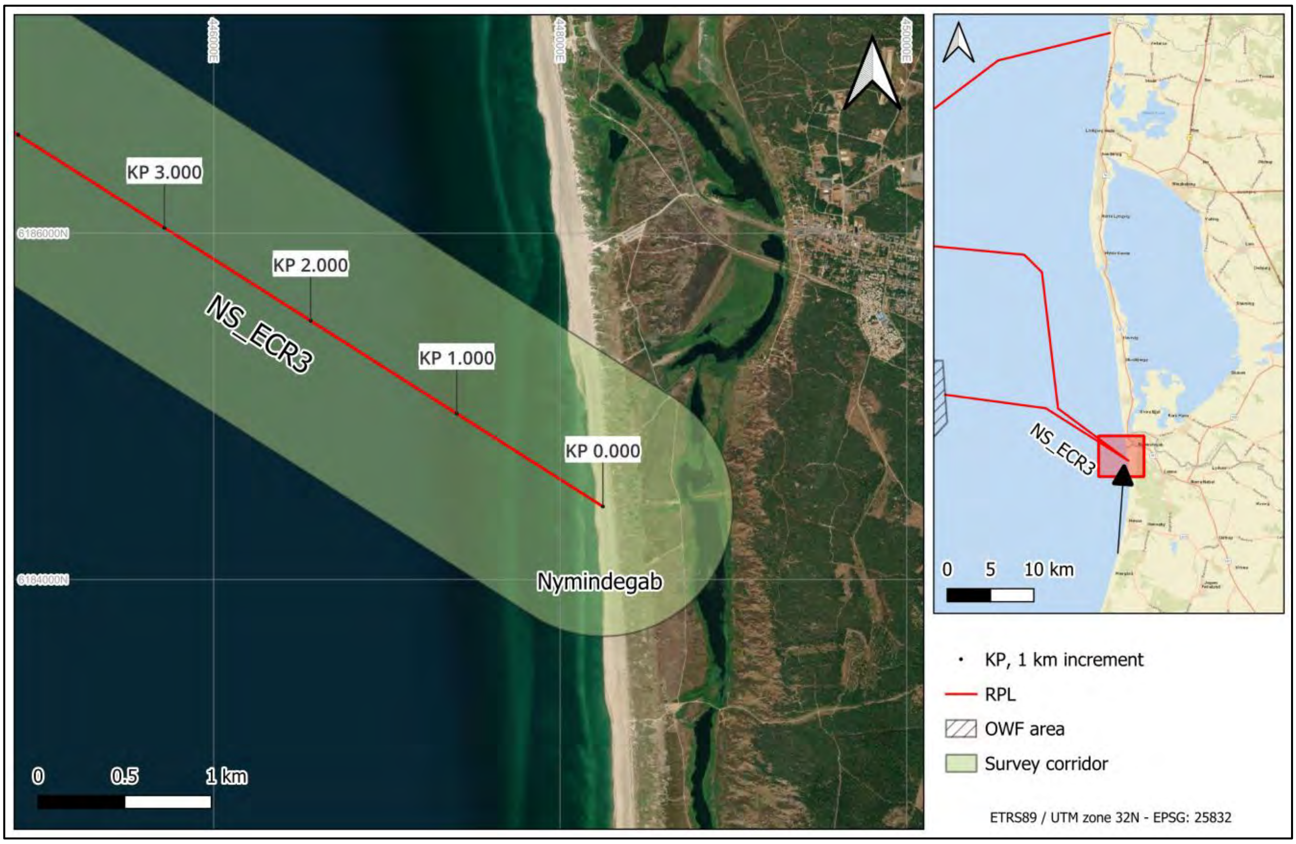


Figure 8: Landfall location overview NS_ECR3 – Nymindegab

2.3 EXISTING INFRASTRUCTURE

In North Sea ECR 1, there is one crossing of ODIN 2, a fibre optic telecom cable, at KP 13.653. This same cable, ODIN 2, also crosses North Sea ECR 2 at KP 23.340 and KP 31.091. Further crossings in North Sea ECR 2 include the Havfrue cable crossing at the KP 11.526 and TAT-14 between KP 25.167 and 25.248, and between KP 29.335 and KP 29.374. No crossings over the North Sea ECR 3 RPL were identified, though the Havfrue and Havhingsten (stub) are present along the edges of the western half of the North Sea ECR 3 survey corridor. Overview maps showing where this existing infrastructure crosses the North Sea survey areas are presented in the figures below.

These crossings were identified with a desktop study (Ref. "0699462_GeoXYZ_DanishCablesDS_v1.0") and supplementary research from EMODnet and HELAS databases. Additionally, these crossings were also surveyed as part of the Crossings Survey (WPD) scope of this project. The findings of this survey can be found in the Crossing Report (Ref. "BE5950H-771-CSR-02-2.0 Crossings Survey Report - North Sea").

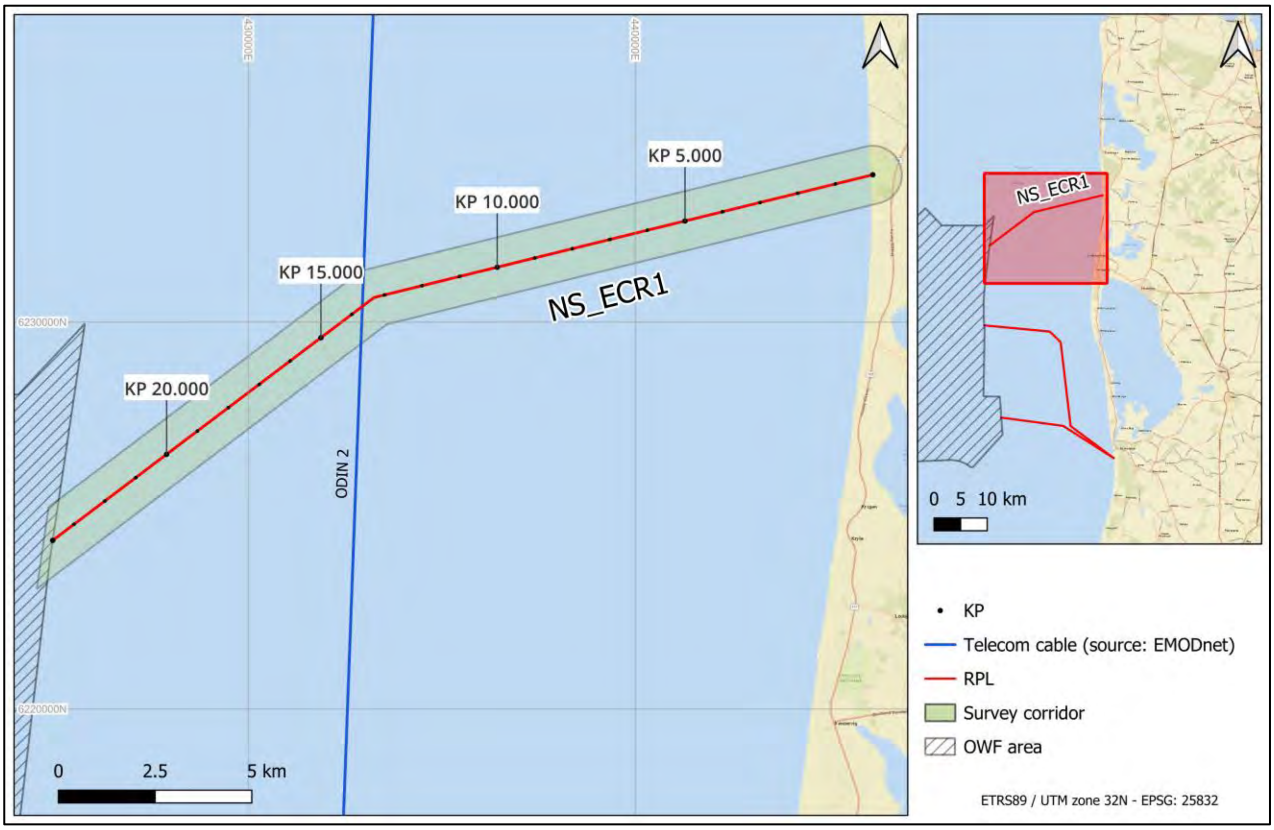


Figure 9: Existing infrastructure within the NS_ECR1 survey area

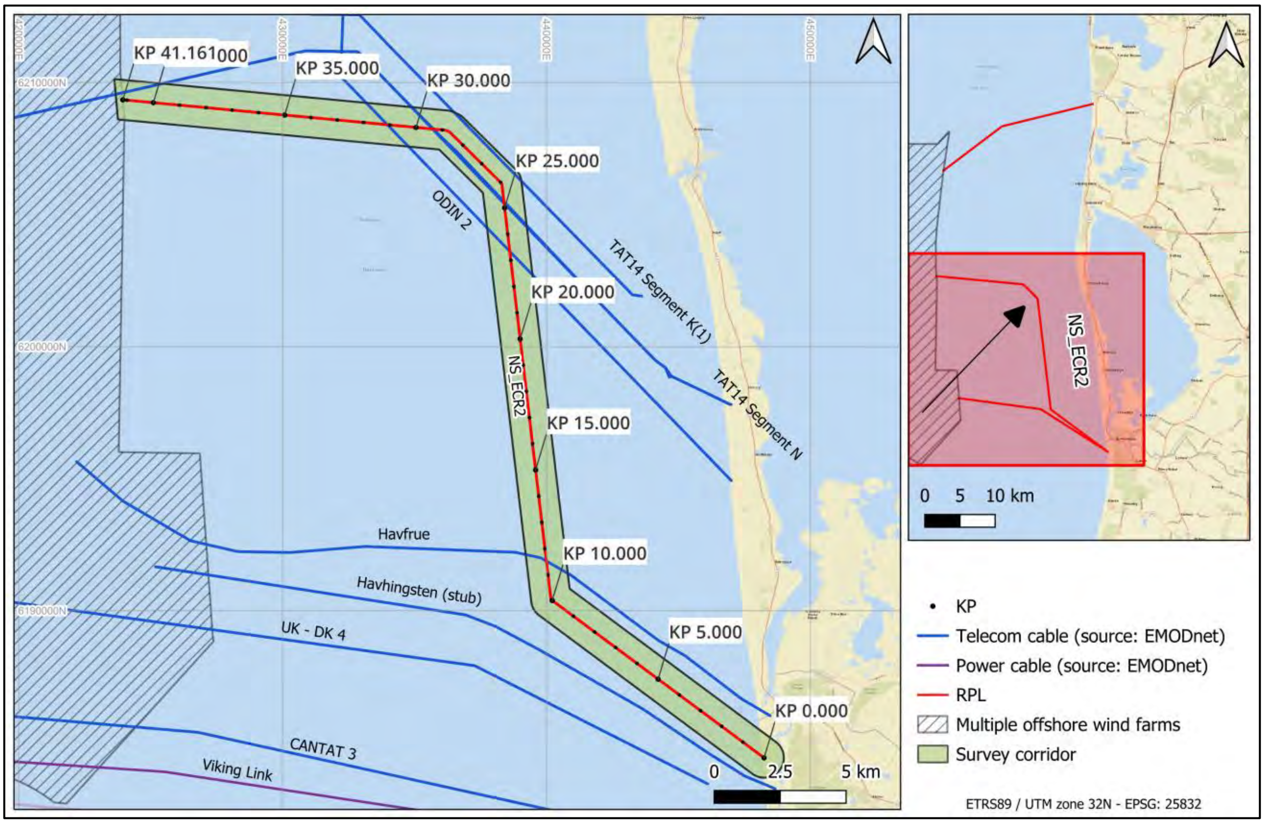


Figure 10: Existing infrastructure within the NS_ECR2

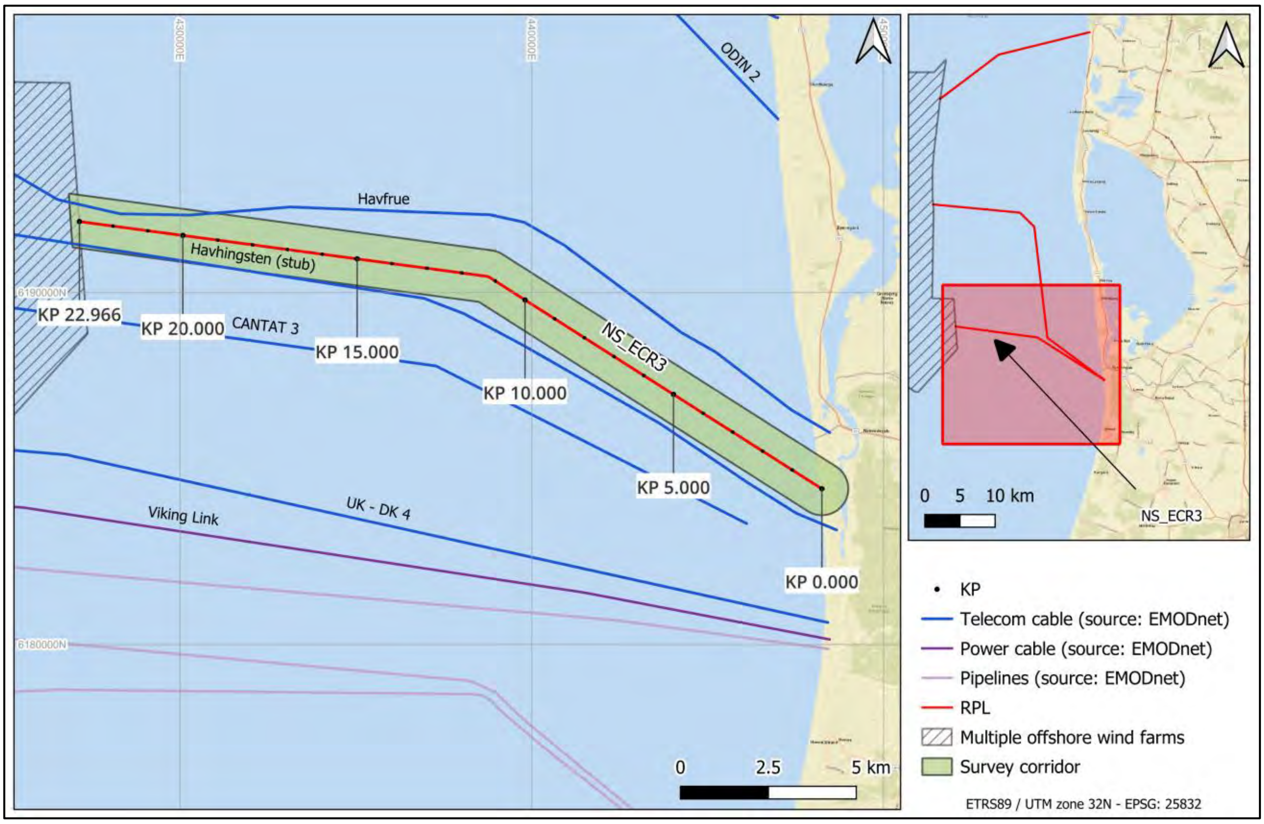


Figure 11: Existing infrastructure within the NS_ECR3

2.4 PARTIES INVOLVED

The parties involved in the project are represented by the organogram given in Figure 12.

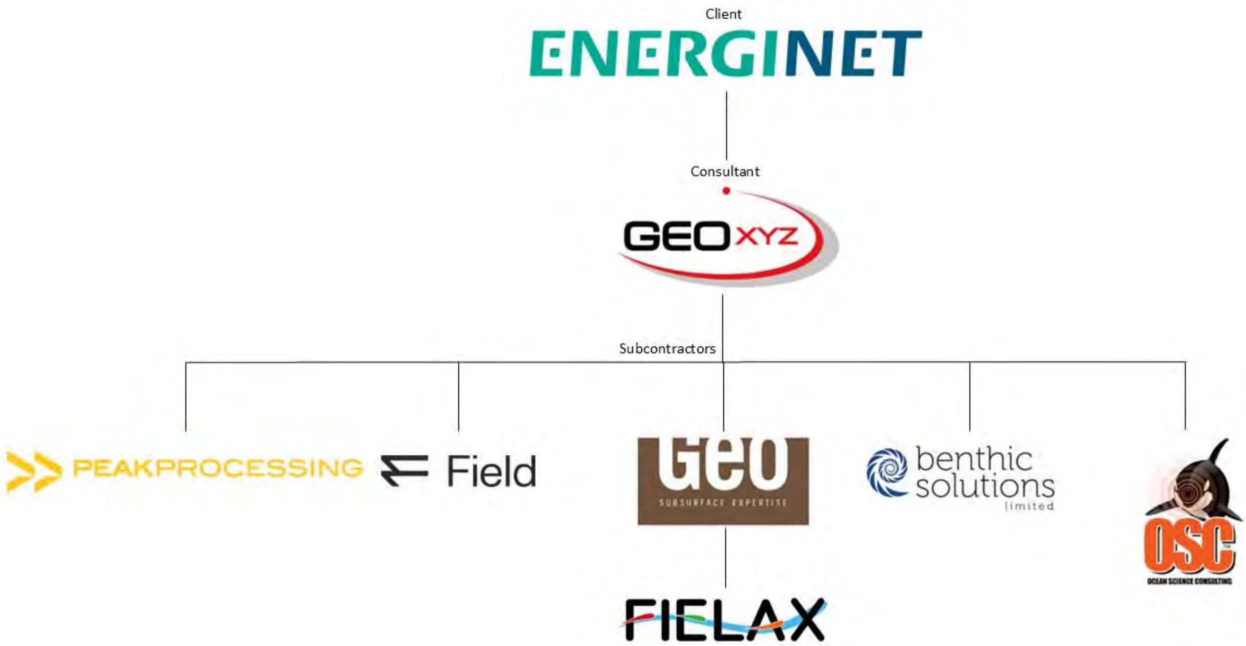


Figure 12: Parties involved in the project

A summary of the involvement of the subcontractors used by GEOxyz to facilitate the project is:

- Peak Processing – To process and interpret the SBP data
- Field – To acquire the Lidar data in the landfall areas of the sites
- Geo and Fielax – To process and interpret the Geotechincal data, with Fielax to support with TRT data analysis.
- Benthic Solutions – To process and interpret the Grab Sample data, as well as provide visual surveys and subsequent interpretation for Marine Mammal Reporting and Analysis
- OSC – To provide visual surveys and subsequent interpretation for Marine Mammal Reporting and Analysis

2.5 SCOPE OF WORK

2.5.1 Geophysical survey

A comprehensive geophysical offshore, nearshore, and landfall site survey was conducted, encompassing MBES (Multibeam Echo Sounding) including backscatter, SSS (Side Scan Sonar), magnetometer, and SBP (Sub-Bottom Profiler) to map the bathymetry, static and dynamic elements of the seabed surface, and the subsurface geological soil layers to a depth of at least 10 m below the seabed. Grab sampling was also performed to support the interpretation of the seabed surface geology.

In the terms of the water depths, nearshore and landfall surveys referred to the land and underwater areas with depths up to a 10 metres MSL, whilst offshore survey refers to the underwater areas deeper than 10 m MSL.

The functional requirements of the work included the following acquisitions:

- A Multibeam Echo Sounding survey with full bathymetric coverage, where the data quality allowed for the preparation of digital elevation models (DTMs) of the bathymetry with a 25 cm spatial resolution (minimum 4 pings per 25 cm²).
- A dual frequency side scan sonar with over 200 % coverage to ensure overlap with the nadir of adjacent survey lines, detecting all objects greater than 0.5 m.
- A single magnetometer towed behind the vessel along all survey lines.
- Sub-bottom profiling using a high-resolution and relatively high-frequency single-channel system to a depth of 10 m along all survey lines.
- Horizontal positioning uncertainty less than 0.5 m for vessels.
- Horizontal positioning uncertainty less than 2.0 m for towed equipment.
- Vertical positioning uncertainty meeting IHO S-44 Special Order standards of less than 0.2 m.
- Grab sampling at an approximate rate of one sample per route kilometre.

2.5.2 Line planning

For the offshore geophysical survey, the survey lines comprised of main lines spaced at 30 or 50 m, depending on the water depth, and cross lines, for MBES and SBP, spaced every 2000 m. The nearshore and landfall survey comprised of lines spaced every 10 metres. Both offshore and nearshore areas have a minimum overlap of 250 m.

Schematic diagrams of the line plans for the geophysical surveys for NS_ECR1, NS_ECR2 and NS_ECR3 are presented in Figure 13, Figure 14, and Figure 15.

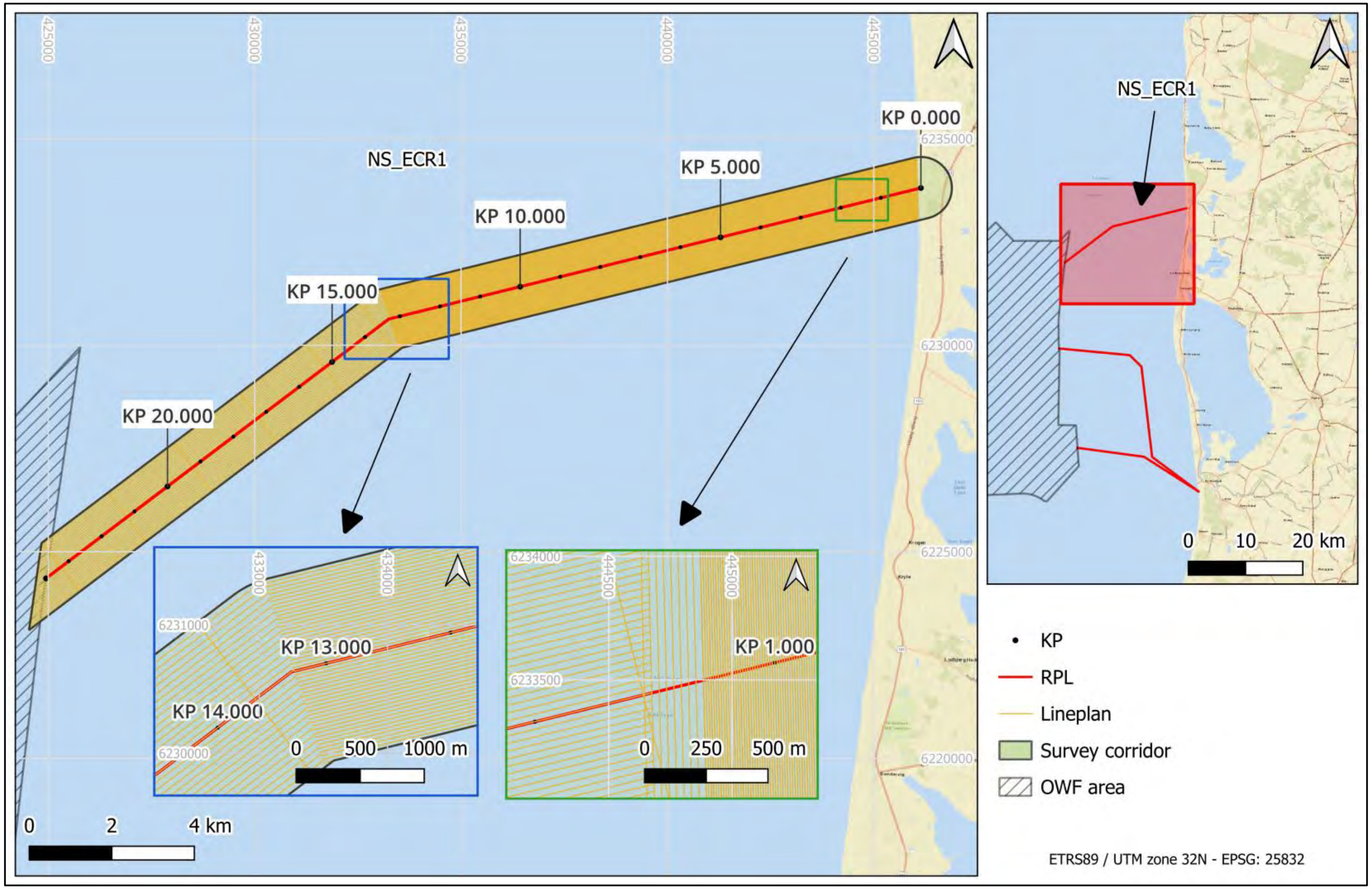


Figure 13: NS_ECR1 line plan

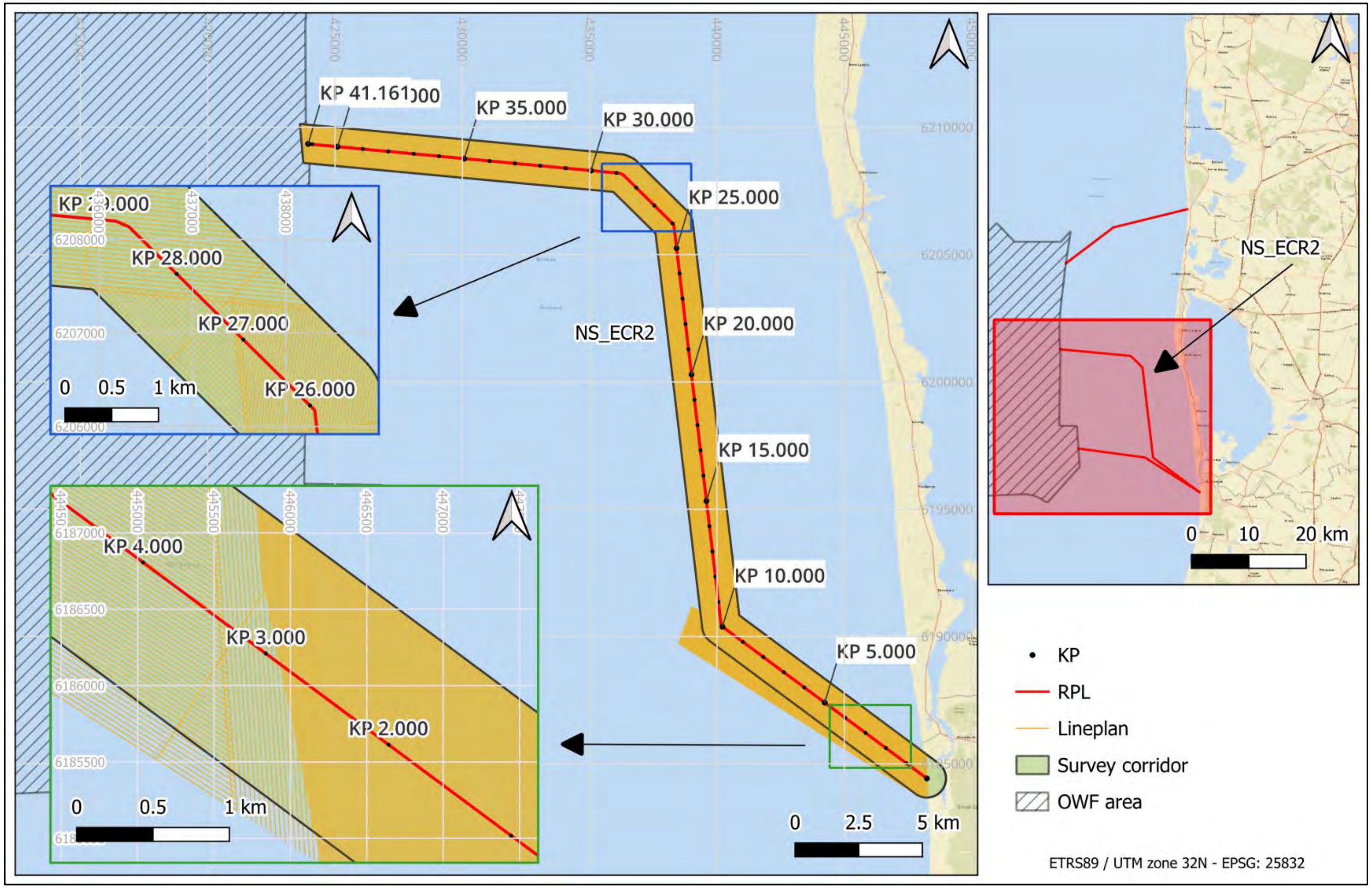


Figure 14: NS_ECR2 line plan

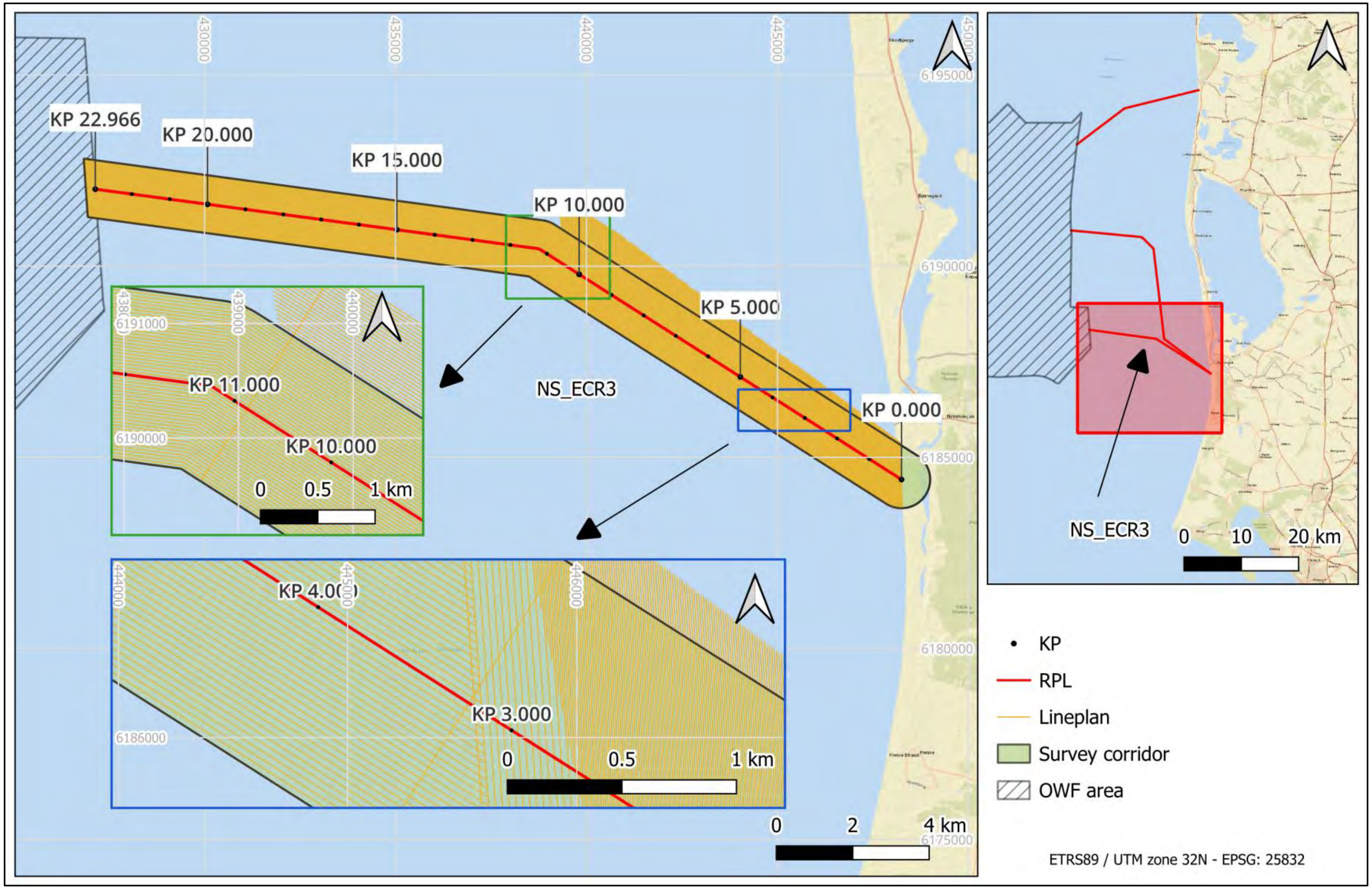


Figure 15: NS_ECR3 line plan

2.5.3 Geotechnical survey

The geotechnical survey of the North Sea export cables was performed from the 6th to the 20th of March 2024. Geotechnical investigations were carried out in water depths greater that 10 metres due to vessel limitations and limited gain of additional samples within the nearshore section.

Investigation consisted of the following field work:

1) Cone Penetration Test with pore pressure (CPTU) with a target depth of 3 and 6 mbsb

2) Vibrocore (VC) sampling with target depth of 3 and 6 m*

3) In-situ Thermal Response Testing (TRT)

4) Offshore field descriptions of VC section ends and undrained shear strength testing.

5) Onshore laboratory testing of VCs including core splitting, photography and geological description of entire core

6) Various geotechnical tests at selected sub-samples

7) Reporting

The number of tests carried out for each investigation is summarized in Table 4 and overview of geotechnical locations is presented in Figure 16 to Figure 24. A detailed overview of geotechnical locations is presented in Appendix B.

Table 4: Geotechnical works summary

Type of test	Target depth (mbsb)			Planned tests			Processed tests		
	NS_ECR1	NS_ECR2	NS_ECR3	NS_ECR1	NS_ECR2	NS_ECR3	NS_ECR1	NS_ECR2	NS_ECR3
CPTU	3	3	3	11	19	12	11	19	12
	6	6	6	9	26	11	11	27	12
VC	3	3	3	11	20	12	11	20	12
	5.7	5.7	5.7	9	25	11	9	25	11
In-situ TRT	5.7	5.7	5.7	5	11	6	5	12	6

** Maximum penetration depth is 5.7 m when In-Situ TRT equipment is mounted on VC*

Figure 16: NS_ECR1 CPT locations overview

Figure 17: NS_ECR1 TRT / VC locations overview

Figure 18: NS_ECR1 VC locations overview

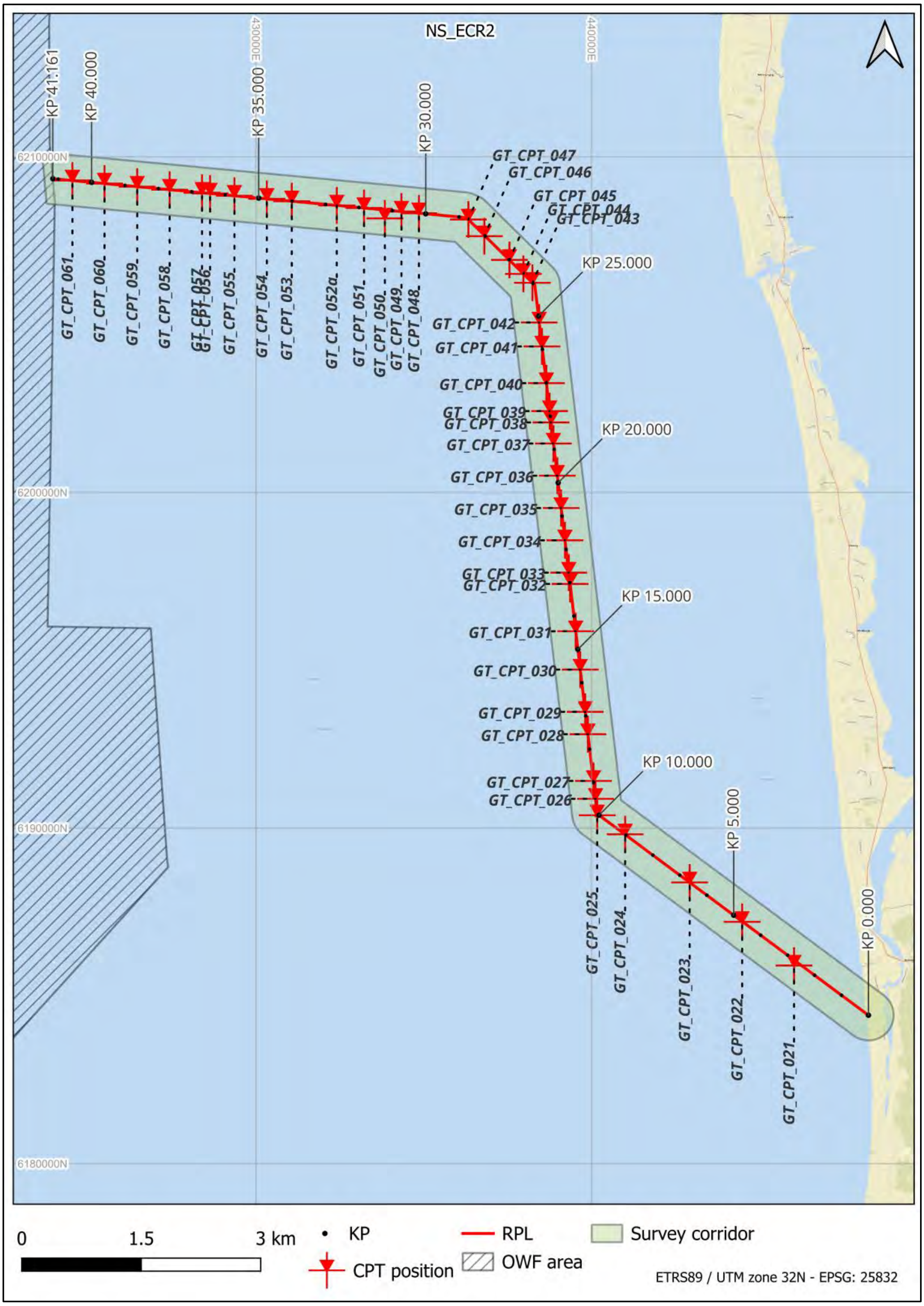


Figure 19: NS_ECR2 CPT locations overview

Figure 20: NS_ECR2 TRT/VC locations overview

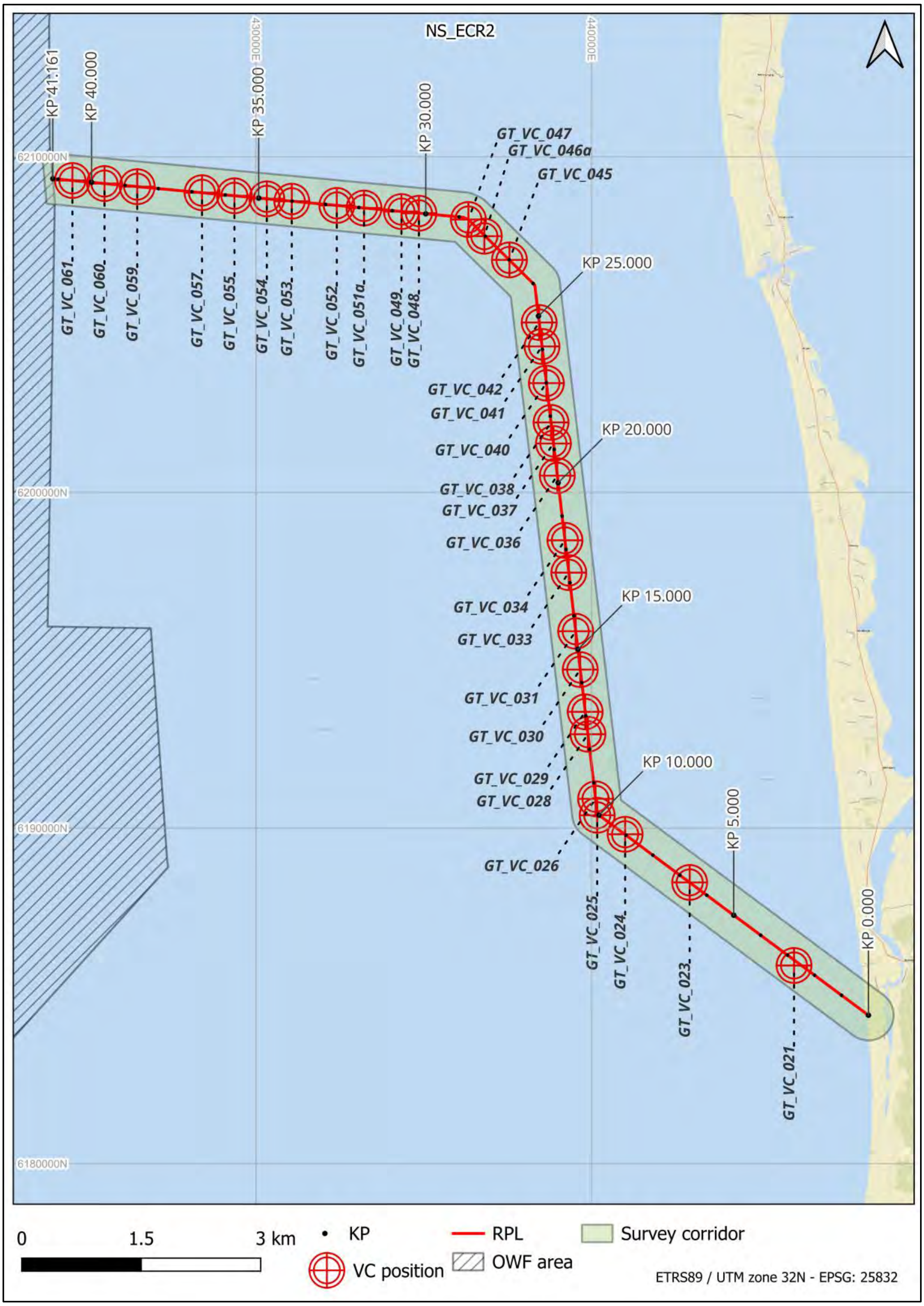


Figure 21: NS_ECR2 VC locations overview

Figure 22: NS_ECR3 CPT locations overview

Figure 23: NS_ECR2 TRT/VC locations overview

Figure 24: NS_ECR3 VC locations overview

2.5.4 General survey objectives

The scope of work of the project consisted of geophysical surveys, grab sampling and geotechnical site investigations of the export cable route. The results of the survey will be able to be used for:

- Verification of the feasibility of the investigated cable routes.
- Initial marine archaeological site assessment.
- Planning of environmental investigation and assessment of environmental conditions.
- Design of subsea cable burial.
- Assessment of conditions for installation and maintenance.
- Providing site information to be enclosed in the tender for offshore cable and installation.

2.5.5 Deviations from survey planning

Survey operations within the North Sea ECR2 route corridor presented some challenges at the time of acquisition due to the presence of the existing and developing Vesterhav Syd (Vattenfall) wind farm site and installed environmental monitoring buoys.

Full data coverage within the planned corridor of North Sea ECR2 was not possible to achieve due to the presence of Vesterhav Syd. Operations onboard the GOIV continued to the limits that safety would allow approaching the windfarm with vessel towed array system, however due to exclusion zone limitations and presence of Wind Turbine Generator (WTG) pylons, the vessel could not approach closer leaving a section within block ECR02E of the ERC2 corridor without coverage for all sensors.

Similarly, the presence of environmental monitoring buoys located within the North Sea ECR2 route corridor meant acquisition with towed sensors on the planned survey line had careful considerations and was planned accordingly with regards to safety of equipment and personnel. A data coverage gap was thus present in ECR02C where the presence of an environmental monitoring buoy impeded data acquisition leaving a coverage gap. A client concession was made for this which is covered in field memo '*BE5950H-771-FM-04-0.1 Field Memo - Coverage concession NS_ECR02C MMO Buoy'*. Two similar gaps were also present in ECR02E, just south of the gap caused by the presence of the Vesterhav Syd wind farm site.

The gaps can be seen in Figure 25 below, as well as in the data coverage maps presented in Figure 25.

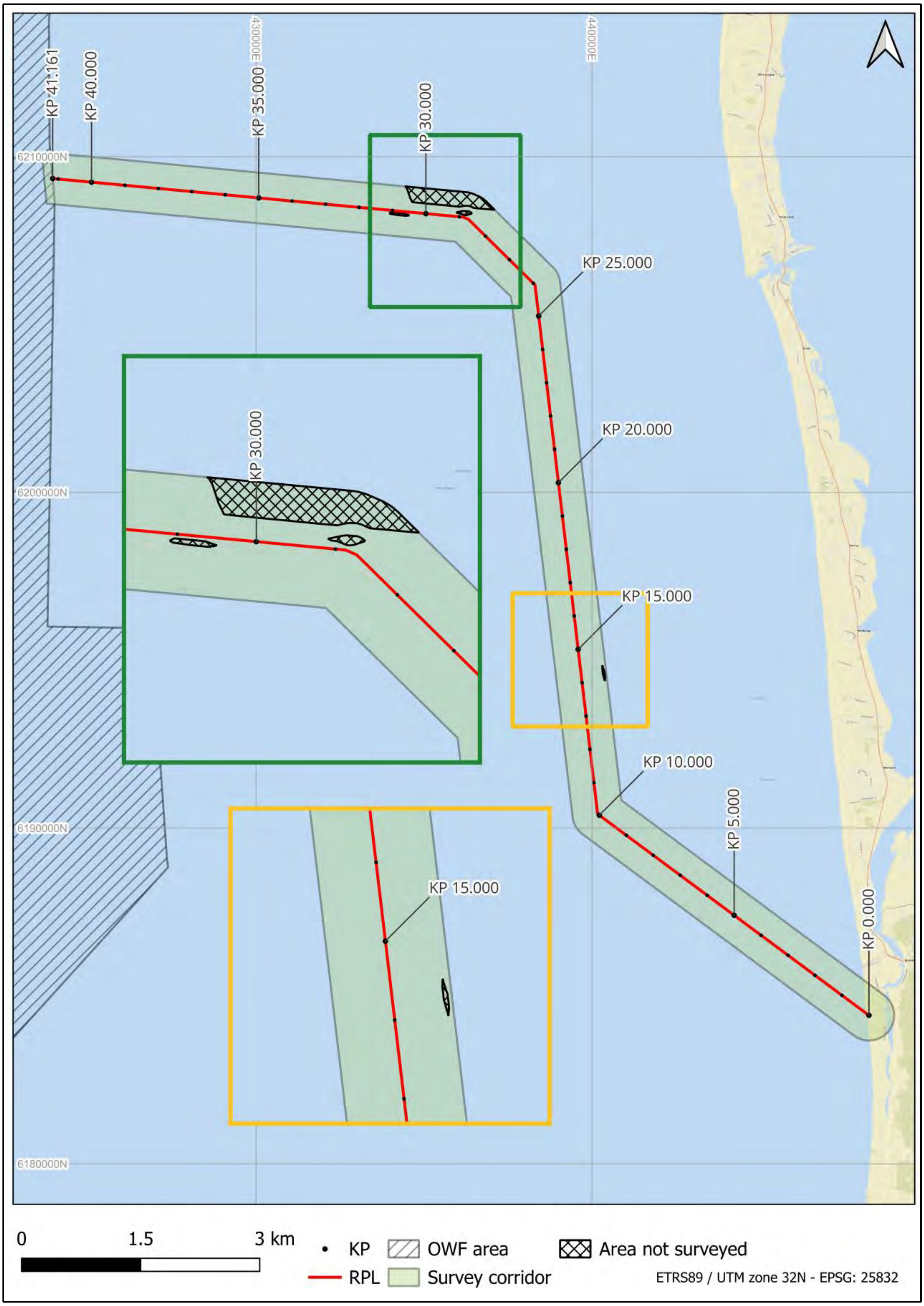


Figure 25: NS_ECR2 deviations from the survey planning

2.6 REFERENCE DOCUMENTATION

Key project and corporate documentation are listed below.

Client reference documents

Documentation provided by the Client is presented in Table 5.

Table 5: Client reference documentation

Document Code/Category	Title
23/00573-5	Scope of Services – Lot 1
22/00573-6	Scope of Services – Enclosure 1 – Technical Requirements
22/00573-7	Scope of Services – Enclosure 2 – Standards of Deliverables
16/19566-2	Scope of Services – Enclosure 3 – Standards of Deliverables Annex 1
23/00573-8	Scope of Services – Enclosure 4 – HSE Requirements
23/00573-9	Scope of Services – Enclosure 5 – Quality Management Requirements

Company and project documents

Key project and corporate documentation are listed in Table 6 below.

Table 6: Company and project documentation

Title
Project Execution Plan
Data Deliverables List
MBES Data Processing
SSS Data Processing
SBP Data Processing
Backscatter Data Processing
Processing Flow - Energinet Geophysical survey

Other references

Other references relevant to the project are listed below.

Table 7: Other references

Title	Resource
SN2023_027_NS_ECR1_Export_cable_route_v1.shp	RPL shapefile
SN2023_027_NS_ECR2_Export_cable_route_v1.shp	RPL shapefile
SN2023_027_NS_ECR3_Export_cable_route_v1.shp	RPL shapefile
0699462_GeoXYZ_DanishCablesDS_v1.0	Crossing DTS
BE5950H-771-MP-01-3.0_Northsea Noise Monitoring Logs	Noise Monitoring Logs
EMODnet	Online database
HELAS	Online database

Title	Resource
Jensen, J. B., Petersen, K. S., Konradi, P., Kuijpers, A., Bennike, O.,Lemke, W. & Endler, R. 2002: Neotectonics, sea-level changes and biological evolution in the Fennoscandian Border Zone of the southern Kattegat Sea. Boreas, Vol. 31, pp. 133–150. Oslo.	Academic paper
Larsen and Andersen (2005). Late Quaternary stratigraphy and morphogenesis in the Danish eastern North Sea and its relation to onshore geology. Netherlands Journal of Geosciences, 84 (2005), pp. 113-128	Academic paper
Houmark-Nielsen, M. (2003). The Pleistocene of Denmark: a review of stratigraphy and glaciation history. In: Ehlers, J. & Gibbard, P. (eds): Quaternary Glaciation-extend and chronology. Vol. 1 Europe. Elsevier (Amsterdam): 321-336	Academic paper
Larsen G., et. al. (1995) A guide to engineering geological soil description. DGF-Bulletin 1. Danish Geotechnical Society	Book
National drilling database (Jupiter database), GEUS. Borings DGU 550711.12, DGU 550711.18, DGU 560722.3 https://data.geus.dk/Jupiter-WWW/index.jsp	Online database
Ocean Infinity (2024) Danish Offshore Wind 2030 LOT 4, Work Package C, Area 1, Geophysical Survey – SN2023_010 North Sea, Danish Sector. 104287-ENN-OI-SUR-REP-LOT4WPCA1, rev04	Ocean Infinity Report

Project reports

Table 6 lists all the reports delivered as part of this survey, with this report highlighted in bold.

Table 8: Project reports

Title	Type of Report
Mobilisation and Calibration Report – GOIV	Mobilisation and Calibration Report
Mobilisation and Calibration Report – GSV	Mobilisation and Calibration Report
Mobilisation and Calibration Report - Geo-X	Mobilisation and Calibration Report
DOW2030 NS_ECR1-2-3_OPS_Report_Offshore_Survey_Geophysical-rev1.2	Offshore Operational Report
DOW2030 NS_ECR1-2-3_OPS_report_Nearshore_survey_Geophysical-rev1.3	Nearshore Operational Report
Danish Offshore Wind 2030 - WPC, North Sea, Operational Report, Rev. 00, 2024-04-17	Geotechnical Operational Report
DOW2030 - WPC, North Sea, Factual Report, Rev. 01, 2024-11-12 REPORT	Geotechnical Report
BE5950H-771-MP-01-1.0_MMO PAM report Northsea Geo Ocean IV	Offshore MMO/PAM Report
OSC_2023_Geophysical_Vesselbased_v2.2, OSC_2024_Geophysical_Landbased_v2.7	Nearshore MMO/PAM Reports
Crossings Survey Report - North Sea	Crossings Survey Report
BE5950_LiDAR_Production_Report	Topographic Report
North Sea – Cable Route Integrated Report	**Results Report**

3 GEODETIC PARAMETERS AND TRANSFORMATIONS

3.1 HORIZONTAL DATUM

The datum parameters for the survey are described in Table 9, and the projection parameters are given in Table 10.

Table 9: Datum parameters

Parameter	Details
Name	European Terrestrial Reference System 1989 (ETRS89)
EPSG Datum Code	6258
EPSG Coordinate Reference System	4258
Spheroid	GRS80
EPSG Ellipsoid Code	7019
Semi-Major Axis	6378137.000
Semi-Minor Axis	6356752.314140
Flattening	1/298.2572221010
Eccentricity Squared	0.00669428002290

Table 10: Projection parameters

Parameter	Details
Area of Use	North Sea
EPSG Coordinate Reference Code	25832
EPSG Map Projection Code	16032
Projection	UTM
UTM Zone	32N
Central Meridian	9° East
Latitude of Origin	0°
False Easting	500000.00 m
False Northing	0.00 m
Scale Factor at Central Meridian	0.9996
Units	Metres

3.2 VERTICAL REFERENCE

The vertical datum for the project is Mean Sea Level (MSL) as defined by the Technical University of Denmark geoid model DTU21MSL. Height data were acquired relative to the ellipsoid and reduced to the project vertical datum.

The onshore Datum for the project is defined as DVR90 however the reporting for all onshore works was referenced as per the offshore datum.

3.3 SURVEY UNITS

The following survey units were used during the project:

- Linear units will be expressed in international metres (m)
- Angular units will be expressed in degrees (°)

3.4 TIME REFERENCE

Local time was used for record keeping during the project (including the Daily Progress Reports unless stated otherwise). The vessels also maintained local time for operations.

Data time-tagging and synchronization used UTC (Universal Time Coordinated). All data recorded in the online navigation software was time stamped where appropriate using the time string and the pulse-per-second (PPS) from the GNSS.

4 SURVEY RESOURCES

4.1 SURVEY VESSELS

4.1.1 Offshore geophysical survey

For the geophysical surveys, the survey vessel Geo Ocean IV (GOIV) was utilised to complete the work across the offshore cable route survey area. The specifications of the GOIV are summarised in Table 11.

Table 11: GOIV survey vessel specification

<table>
<tr><th>Geo Ocean IV</th><th colspan="2">Specifications</th></tr>
<tr><td rowspan="8">
</td><td>Owner:</td><td>GEOxyz</td></tr>
<tr><td>Length:</td><td>41.9 m</td></tr>
<tr><td>Width:</td><td>9.1 m</td></tr>
<tr><td>Maximum draught:</td><td>5.53 m</td></tr>
<tr><td>Cruising speed:</td><td>5 knots</td></tr>
<tr><td>Propulsion:</td><td>High screw CP-propeller</td></tr>
<tr><td>Endurance:</td><td>24 h day operations (20 days)</td></tr>
<tr><td>Accommodation:</td><td>23</td></tr>
</table>

4.1.2 Nearshore geophysical survey

Survey operations for nearshore area were carried out using the Geo X and Geo Surveyor V (GSV). Their specifications are summarised in the Table 12 and Table 13.

Table 12: Geo X survey vessel specification

<table>
<tr><th>Geo X</th><th colspan="2">Specifications</th></tr>
<tr><td rowspan="8"></td><td>Owner</td><td>GeoGroup</td></tr>
<tr><td>Length</td><td>16.5 m</td></tr>
<tr><td>Width</td><td>4.8 m</td></tr>
<tr><td>Maximum draught</td><td>1.5 m</td></tr>
<tr><td>Cruising speed</td><td>14 knots</td></tr>
<tr><td>Propulsion</td><td>Main diesel engines MAN 2 x 325 kW;
Aux Engine 28 kVA</td></tr>
<tr><td>Endurance</td><td>24 hr (2x 12 hr shift pattern)</td></tr>
<tr><td>Accommodation</td><td>4</td></tr>
</table>

Table 13: GSV survey vessel specification

Geo Surveyor V	Specifications	
	Owner	GEOxyz
	Length	7.2 m
	Width	2.45 m
	Maximum draught	0.75 m
	Cruising Speed	5 knots
	Propulsion	2x outboard motorblock
	Endurance	< 12-hour operations, day vessel
	Accommodation	6

Additional bathymetric data were acquired in the intertidal area using the Geo Drone 1800 (Table 14).

Table 14: Geo Drone 1800 specification

Geo Drone 1800	Specifications	
	Owner	GEOxyz
	Length	1.80 m
	Width	0.66 m
	Draught	0.15 m
	Operational depth below waterline	0.30 m
	Weight	35 kg
	Max. payload	40 kg
	Steering	Autopilot line steering
	Survey speed	3 knots
	Autonomy	5 hours

4.1.3 Landfall topographic survey

Lidar data on the landfall was acquired by the sub-contractor Field. More details on the acquisition of the topographic data can be found in the topographic Operations Report (Ref. “BE5950_LiDAR_Production_Report.pdf”).

4.1.4 Geotechnical survey

The geotechnical activities were carried out from the Dynamic Positioning (DP II) vessel Connector, supplied by Geo DK, presented in Table 15.

Table 15: DP II Connector vessel specifications

Connector	Specifications	
	Owner	Geo DK
	Length	90.2 m
	Width	7.0 m
	Maximum draught	5.53 m
	Cruising speed	16 knots
	Propulsion	Fixed Pitch Propellors
	Endurance	24 h day operations (20 days)
	Accommodation	60

4.2 SURVEY SYSTEMS

The survey equipment used onboard the vessel GOIV are listed in Table 16.

Table 16: GOIV geophysical survey equipment specifications

System	Manufacturer & model	Equipment specifications
GNSS	2 x Trimble BX992 (1 x XP2 and 1 x G4 corrections)	RTK: < 0.05 m; DGNSS: <0.10 m
INS (motion, heading)	IXBlue Phins II / Octans IV	H: 0.05°; R&P: 0.01°; Heave: 0.05 cm
SVP	Valeport – Swift	0.02 m/s
MBES	Kongsberg 2040, dual head, dual swath system	Freq: 200 - 400 kHz Focus: 0.4° x 0.7° at 400 kHz
USBL	Kongsberg HiPAP 351p	0.02 m range detection accuracy or < 0.3 % of slant range
Magnetometer	Geometrics G882	Accuracy: < 2 nT throughout range. Freq: up to 40 Hz
SSS	Edgetech 4205MP 300/900kHz	Horizontal beamwidth: 0.5°@300 kHz, 0.26°@600 kHz, 0.3°@900 kHz Resolution Across Track: 3 cm @ 300 kHz, 1.5 cm @ 600 kHz, 1 cm @ 900 k Hz
SBP	Innomar SES-2000 Medium	3.5-15 kHz 1 – 5 cm resolution
Grab	Day grab/Dual Van Veen grab	1 x 0.1 m^2 sample size

The GEO X vessel was mobilized with the equipment listed in Table 17.

Table 17: Geo X survey equipment

System	Manufacturer – Model
DGPS	Septentrio AstRx-m2a RTK-
MRU	iXBlue Hydrins
Gyrocompass	iXBlue Hydrins
SVS	N/A
SVP	Valeport – Swift
MBES	T50-R IDH
SSS	Edetech 4200 300/900kHZ
SBP	Innomar SES Quattro
Mag	G882 magnetometer
USBL	Sonardyne Mini Ranger II
Grab	Van Veen Grab

GSV was mobilised using the equipment listed in Table 18.

Table 18: GSV survey equipment

System	Manufacturer – Model	Equipment specifications
Primary GNSS	Trimble BD992-INS	Horizontal: RTK: 0.008m; DGNSS: 0.25m Vertical: RTK: 0.015m; DGNSS: 0.50m
INS (motion, heading)	iXblue Phins II	Hdg: 0.01°; roll & pitch: 0.01°; heave: 2.5 cm
SVP	Valeport Swift	0.02 m/s
MBES	Edgetech 6205 s2	Freq: 520 kHz
Magnetometers	Geometrics G-882 magnetometer	Accuracy: < 2 nT throughout the range. Sampling rate: up to 20 Hz
SSS	Edgetech 6205 s2 (520/850 kHz)	Horizontal beamwidth: 0.36° @ 520kHz, 0.29° @ 850 kHz Resolution Across Track: 1cm @ 520 kHz, 0.9cm @ 850 kHz
SBP	Innomar SES-2000 Medium	2-22kHz - 1-5cm resolution

The Geo Drone 1800 was mobilised using the equipment listed in Table 19.

Table 19: Geo Drone 1800 survey equipment

System	Manufacturer – Model
Positioning & motion sensor	SBG Apogee
MBES	Norbit WMBS

The equipment onboard the Connector vessel is listed in Table 20.

Table 20: Connector survey equipment

System
POSMV Ocean master INS navigation system, with GNSS aided gyro

System
POSMV IMU (type 320)
Trimble BX992 navigation system, with GNSS heading
TSS IMU on CPT platform
CPTU/VC rig, GeoCeptor

An overview of the equipment used to acquire the topographic lidar data is presented Table 21 below.

Table 21: Topographic survey equipment

System	Manufacturer – Model
Drone	Cessna 208B Grand Caravan LN-TER
LiDAR sensor	Teledyne Optech CZMIL SuperNova
GNSS	Trimble Applanix POS AV 610 med PPRTX
Digital camera	Phase One iXM-RS 150F

4.3 SOFTWARE

The primary software installed on GOIV, Geo X and GSV used to acquire and process the data is listed in Table 22.

Table 22: Primary software list

Type	Software	Related equipment
Acquisition	QPS QINSy	Navigation, MBES, GNSS, SSS, MAG
	BeamworkX NavAQ	Navigation, MBES, GNSS, MAG
	Edgetech Discover	SSS Edgetech
	Innomar SESwin	SBP
Processing	Beamworx AutoClean	MBES
	QPS Qimera	MBES
	QPS FMGT	Backscatter
	Sonarwiz	SSS
	Oasis Montaj	MAG
	Silas	SBP
	QGIS	GIS
	TerraPos, vendor, Terrasolid	Lidar

4.4 TOWED PASSIVE ACOUSTIC MONITORING SYSTEM

The PAM System is a stand-alone marine mammal acoustic system for the accurate detection and monitoring of marine mammal vocalisations. The system is towed and utilizes high bandwidth hydrophones to identify and track whale, dolphin and porpoise species.

Towed passive acoustic monitoring system was used in all area's when visibility was reduced and during hours of darkness to establish the presence of marine mammals prior to the commencement of acoustic geophysical operations.

4.5 MARINE MAMMAL REPORTING AND ANALYSIS

GEOxyz provided a full survey report of the findings from the visual surveys and subsequent interpretation (Ref. “MMO-PAM Report North Sea Geo Ocean IV”) for the offshore survey, and for the nearshore scope: “OSC 2023 Geophysical Landbased”, “OSC 2023 Geophysical Vesselbased”, “OSC 2023 MarineMammalFormsGeoX”, “OSC 2023 MarineMammalFormsGSV”, “OSC 2023 Noise Monitoring GeoX”, “OSC 2023 Noise Monitoring GSV”).

4.6 GENERAL SURVEY TIMELINE

A summary of the survey operations is listed in Table 23 below. More details on the mobilization and survey operations can be found in the Mobilisation and Calibration Reports and Operations Reports, respectively.

Table 23: General survey timeline

Section	Vessel	Dates	Activity
Offshore	Geo Ocean IV	02/10/2023 – 08/10/2023	Mobilisation and calibrations
		16/10/2023 – 01/11/2023	Survey operations
		12/11/2023 – 21/11/2023	
		29/11/2023 – 15/12/2023	
		06/01/2024 – 08/01/2024	
		08/01/2024	Demobilisation
Nearshore	Geo X	05/08/2023 08/08/2023	Mobilisation and calibrations
		11/08/2023 – 23/08/2023	
		31/08/2023	
		24/08/2023 - 28/08/2023	Survey operations
		31/08/2023 - 10/09/2023	
		10/09/2023	Demobilisation
	Geo Surveyor V	04/08/2023 - 06/08/2023	Mobilisation and calibrations
		13/08/2023 - 15/08/2023	
		20/08/2023 - 28/08/2023	Geophysical operations
		28/08/2023	Demobilisation
	Geo Drone 1800	09/07/2024	Mobilisation and calibrations
		09/07/2024 - 13/07/2024	Geophysical operations
Geotechnical	Connector	08/02/2024 (port of Frederikshavn, Denmark) 04/03/2024 – 08/03/2024 (port of Esbjerg, Denmark) 06/03/2024	Mobilisation and calibrations
		06/03/2024 – 20/03/2024	Geotechnical operations
		26/03/2024	Demobilisation
Topographic survey	Cessna 208B Grand Caravan	01/06/2024	Geophysical operations

5 DATA PROCESSING AND WORKFLOW

5.1 LIDAR

5.1.1 Data acquisition

Lidar data were acquired using the Cessna 208B Grand Caravan LN-TER with a Phase One iXM-RS 150F camera. More details can be found in the topographic operations report (Ref. “BE5950_LiDAR_Production_Report.pdf”).

5.1.2 Processing

Processing of navigation data was performed with the TerraPos software. Observations from inertia sensor (IMU) and GNSS were combined in a Kalman filter by so-called "tightly coupled" processing. Together with a subsequent backward filter recursion ("RTS-smoother"), it provided a statistically optimal parameter estimation.

Using the vendor’s software, a point cloud was generated. The resulting LAS-files was first outputted in WGS84 deliverables and later transformed to the project’s projection.

To make the final deliverables, the laser data were processed by classifying the point cloud to isolate hits on seabed and ground. The lidar data were classified as follows:

1) Unclassified
2) Ground
7) Noise
40) Seabed
41) Water surface
45) Unclassified bathymetric points (seaweed, objects, etc.)

Terrasolid OY software was used for point cloud classification and deliverables generation, while QGIS software was used to handle shapefile attributes. Finally, orthophoto mosaics were produced.

5.1.3 Data quality assessment

The North Sea landing sites have areas where the bathymetry indicates developed coastal sandbanks with subsequent erosional troughs running parallel with the coast, which the light laser could not penetrate and record seabed depths. This zone is dynamic and experiences significant wave energy, increased seabed mobility and colouration of mixing sediments within the water (Bathy LiDAR data gap approx. 70-180 m wide running North - South and crossing the corridor extents).

Due to a combination of surface wave action causing light laser reflection (rather than penetration), the waters sub-surface turbidity causing suspension of particles within the water column and depth of water within the parallel running through areas between the sandbanks and the intertidal zone, the Bathy LiDAR could not achieve 100 % coverage in the Results sections.

Therefore, to 'bridge the gap' between nearshore vessel MBES and aerial TOPO LiDAR data, the GEOxyz GeoDrone ASV was actioned to acquire depth and bathymetry within the area that could not be achieved using the Bathy LiDAR.

In addition, not all 0.25 cm grid cells had lidar points which resulted in many nodata cells in the gridded output. Nodata values were set to -9999 in the GEOTIFF delivery.

5.2 MULTIBEAM ECHOSOUNDER

5.2.1 Data acquisition

Bathymetric data was acquired following the Special Order, as defined in the IHO standard S-44, with the additional specifications listed in Table 24.

Table 24: MBES Client specifications

Item	Client Specification
Data density	16 hits/m^2
MBES mode	Equi-distant
Gridded	0.25 m cell size
Hit count survey	4 hits per 0.25 m^2 after processing (97.5 % of site)
THU/TVU	Follow IHO special order
Coverage	100 %
Target size detecting	1 m (height, width and length)

The MBES acquisition settings onboard the GOIV, Geo X and GSV are presented in Table 25, Table 26 and Table 27, respectively.

Table 25: GOIV MBES acquisition settings

General parameters		
System type	Kongsberg 2040, TX, dual RX, dual swath	
Survey speed	4.2 knots	
Frequency	400 kHz	
Bottom sampling	High density dual swath (1024 beams)	
Coverage swath	50 m	
Power	Maximum	
Pulse length	Auto	
Calibration parameters	**Head 1 Rx port**	**Head 2 Rx stbd**
Pitch	0.577°	0.322°
Roll 1	-39.464°	41.014°
Roll 2	-39.564°	41.172°
Heading	-2.118°	-0.768°
Sector width	70°	70°

General parameters	
Ping rate	13 Hz (WD 40 m), dependent on range

Table 26: Geo X MBES acquisition settings

General parameters	
System type	Teledyne Reson Seabat T50-R
Survey speed	Average 4.5 knots
Frequency	400kHz
Bottom sampling	Equi-distant (1024 beams)
Range	Variable
Power	193 db
Pulse length	50 µs
Patch test roll	-2.30°
Patch test pitch	-1.66°
Patch test heading	0.99°
Sector width	100-120° depending on WD
Ping rate	25 Hz, fixed

Table 27: GSV MBES acquisition settings

General parameters	
System type	Edgetech 6205 s2
Survey speed	Average 4.5 knots
Opening angle	55-60 degrees
Power	Maximum
Pulse length	Auto
Beam spacing	Equidistant
Number of beams	2 x 400
Trigger	External trigger (slave) from SBP to avoid interference

5.2.2 MBES processing

All MBES data were processed following the below steps outlined in Table 28 to Table 31. Figure 26 displays the general MBES processing workflow. A processing checklist was populated while processing.

Table 28: Data import into Qimera and initial QC

Step 1	Data import Qimera and QC
1.1 Set up project	Load in RAW multibeam files (*.db) as recorded by QINSy in a new project, grid cell size 0.25 x 0.25 m
1.2 QC of coverage	Check completeness of data by cross-referencing the imported files with the Survey Log.

Step 1	Data import Qimera and QC
1.3 QC of raw data	Check the update rate and accuracy of Gyro/MRU data. Check for systematic noise (i.e. interference). Check for any positioning jumps/inconsistencies.

Table 29: Positioning QC

Step 2	Positioning QC
2.1 SVP correction	Applying the most recent SVP into the data set. Consider using the 'Nearest in time' or 'Nearest in distance' sound velocity strategy in Qimera.
2.2 Comparison with old data set	Compare the positioning with previous data set of the area. Check if there is any mismatch in the overlap parts with the adjacent blocks.
2.3 Create full block surface	Generate a dynamic surface at 1 x 1 m cell size.
2.4 Overall statistics	Run Standard Deviation statistics. The standard deviation must be < 0.2 m, unless exceeded due to the significant changes in the seabed morphology.
2.5 Create positioning QC surfaces	Generate THU and TVU surfaces from the 1 x 1 m grid.
2.6 Verify horizontal positioning and THU	Apply the correct colour map and review the data to make sure the horizontal positioning quality is within the client specifications. The surface needs to be updated and a new export can be done.
2.7 Verify vertical positioning and TVU	Apply the correct colour map and review the data to make sure the vertical positioning quality is within the client specifications. The surface needs to be updated and a new export can be done.

Table 30: Data de-spiking

Step 3	Data de-spiking
3.1 Manual de-spiking	Manually remove remaining substantial spikes using the 2D / 3D views and the slice editor. Correct where necessary.
3.2 Filter de-spiking	Run any filter profiles to provide an optimal surface, ensuring the features and the data density are not affected by filter (filter profiles to be adjusted and optimised by processor).
3.3 SVP refraction correction	Apply any required SVP refraction corrections.

Table 31: Data QC

Step 4	QC
4.1 Coverage gaps	Ensure there are no gaps caused by excessive manual or filtered de-spiking.
4.2 Shallowest/deepest areas	Special attention is needed for these areas to verify all spikes are removed.
4.3 Check for steps in data	Change plan view to the mean depth colour data to verify no steps are present in the data.
4.4 Statistics control	Run Standard Deviation, Density, Total Horizontal Uncertainty (THU) and Total Vertical Uncertainty (TVU) statistics. The standard deviation must be < 0.25 m and density ≥ 16 hits per 1 m². Ensure the THU and TVU requirements are met (depth dependant).

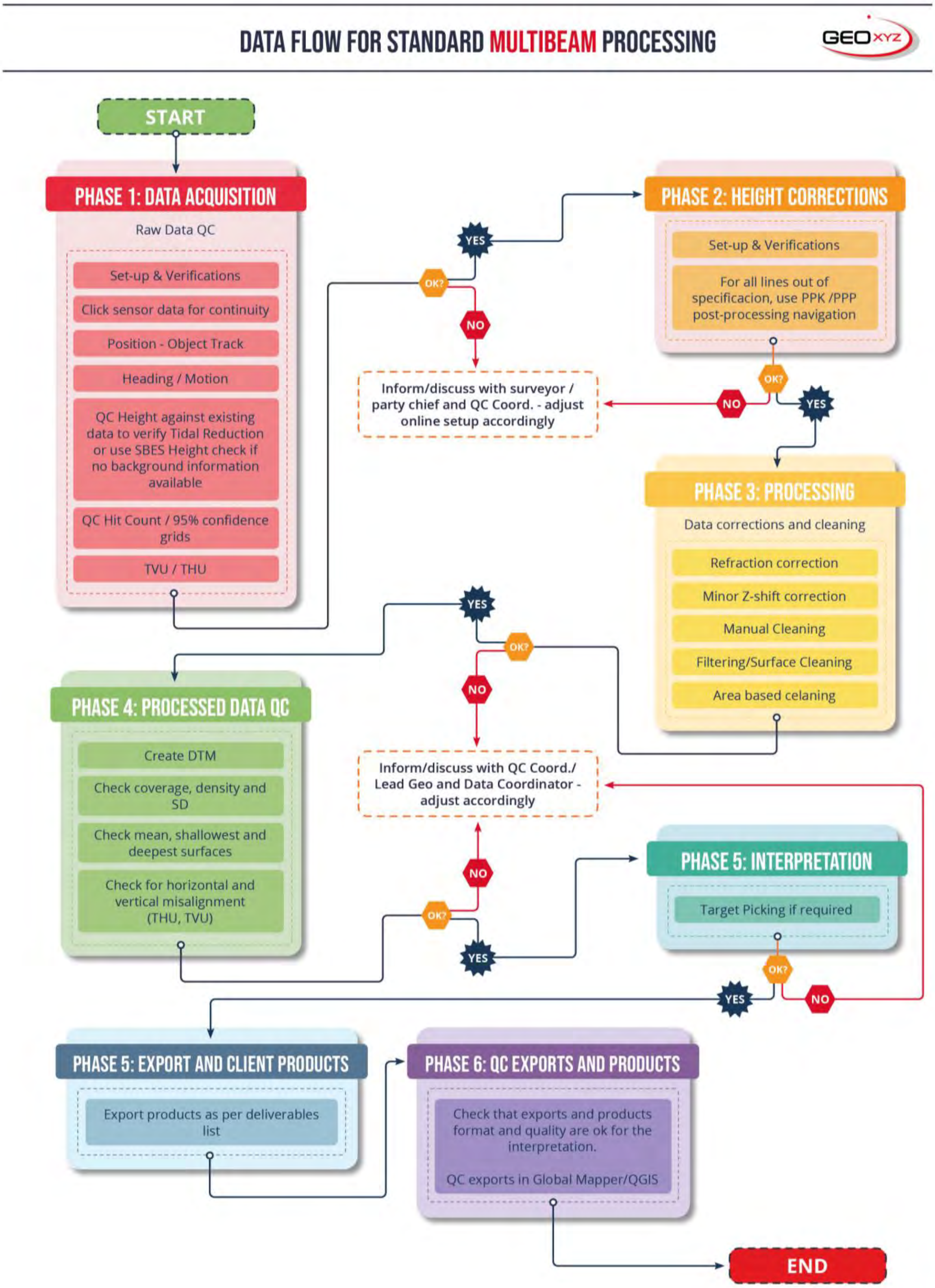


Figure 26: MBES processing workflow

Backscatter data were recorded on all lines and the data were processed and delivered with all other digital deliverables. The backscatter data were processed and exported, using QPS Fledermaus GeoCoder Toolbox (FMGT) software.

Backscatter processing was carried out on the fully cleaned and processed MBES data files, from previous steps in the Qimera software. Combined GSF (both heads exported in the same file) were exported and then imported in FMGT along with a MBES reference surface.

The gain was modified to normalize the intensity over the survey area. It was also optimized to enhance changes in seabed sediment composition and morphological features on the seafloor.

5.2.3 MBES target picking

MBES target picking was carried out after processing, using the automatic tool in BeamworX AutoClean software. Only targets larger than 1 metre were flagged, and vessel names were added to the target IDs.

Targets were detected based on a reference grid, which automatically measures the targets in Length x Width x Height. The detection process was fully automated and based on input parameters. These parameters could change per area depending on data quality, target numbers, size, and seabed complexity, but always in accordance with the specification of the project relative to minimum size and their interpretation as per TSG requirement. Detection and accuracy are greatly dependent on data quality. Artefacts such as thermocline, vertical alignment and complex morphology could impact the detectability of potential targets.

After running the detection process, a manual QC was conducted and any amendment were applied if needed e.g. false positives are removed, false negatives are added, and target dimensions were adjusted manually if required. The automated routine combined with a manual QC gave this output a reliable result.

Finally, a target correlation was done with the SSS and MAG contacts, and a final QC was done to ensure consistency on the target classification across the sites. SSS and MBES targets were correlated if within 2 m of each other (as per the positional accuracy specification of the project). MBES and MAG targets were correlated if within 5 m of each other.

5.2.4 MBES and backscatter data quality assessment

In general, the data quality for all vessels and areas was good and within the project specifications. However, some issues were faced to achieve the final stage of the project deliverables. The following is a brief description of the quality of the data for each area and each vessel, as well as some examples of the problems encountered.

Geo Ocean IV data

The data is overall of good quality in both MBES and backscatter. Refractions problems were detected in some areas, especially in block NS_ECR3A, as presented in Figure 27. These problems were solved processing line by line with refraction correction filters in Qimera and AutoClean.

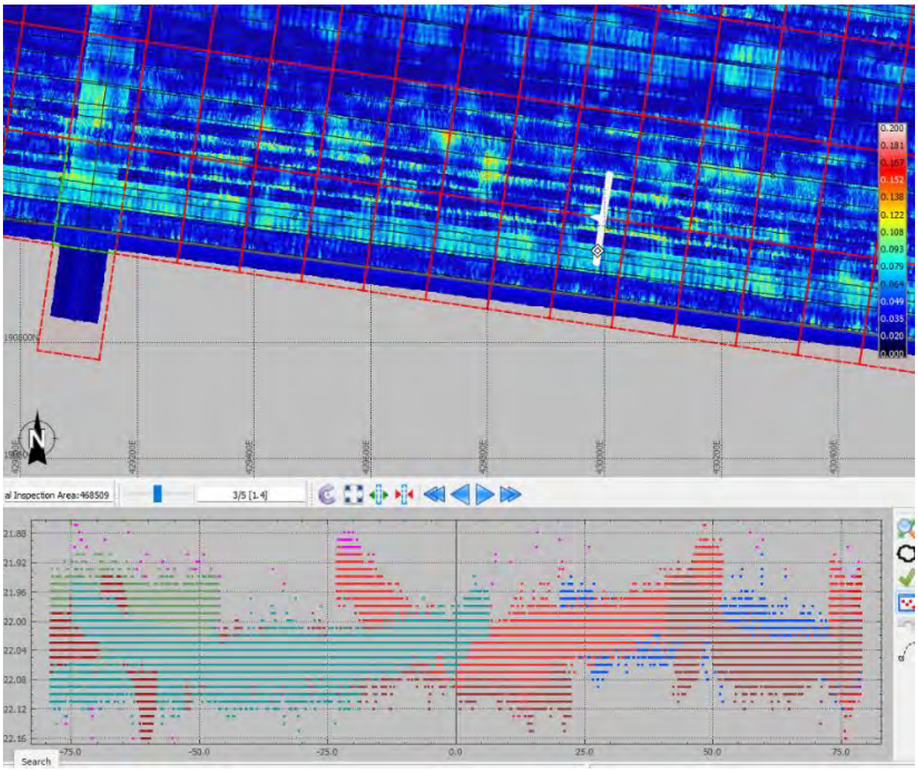


Figure 27: Example within MBES dataset showing refraction problems

Geo X data

The data is overall of good quality in both MBES and backscatter. There are slight differences in values scale compared against GOIV data, but within expectations as they are different vessels.

Geo Surveyor V data

Overall, the data is of good quality. The data was noisier compared to the data obtained from deeper areas, yet this is to be expected given the characteristics of the ship and the shallow depth of the nearshore part. Given the characteristics of the coupled system (MBES-SSS), the backscatter data came from SSS raw files, resulting in a different values scale compared to backscatter from MBES of the rest of vessels.

The TVU coverage maps of the survey area for NS_ECR1, ECR2, and ECR3 are shown in Figure 28, Figure 29, and Figure 30, respectively. The THU coverage maps of the survey area for NS_ECR1, ECR2, and ECR3 are presented in Figure 31, Figure 32, and Figure 33, respectively.

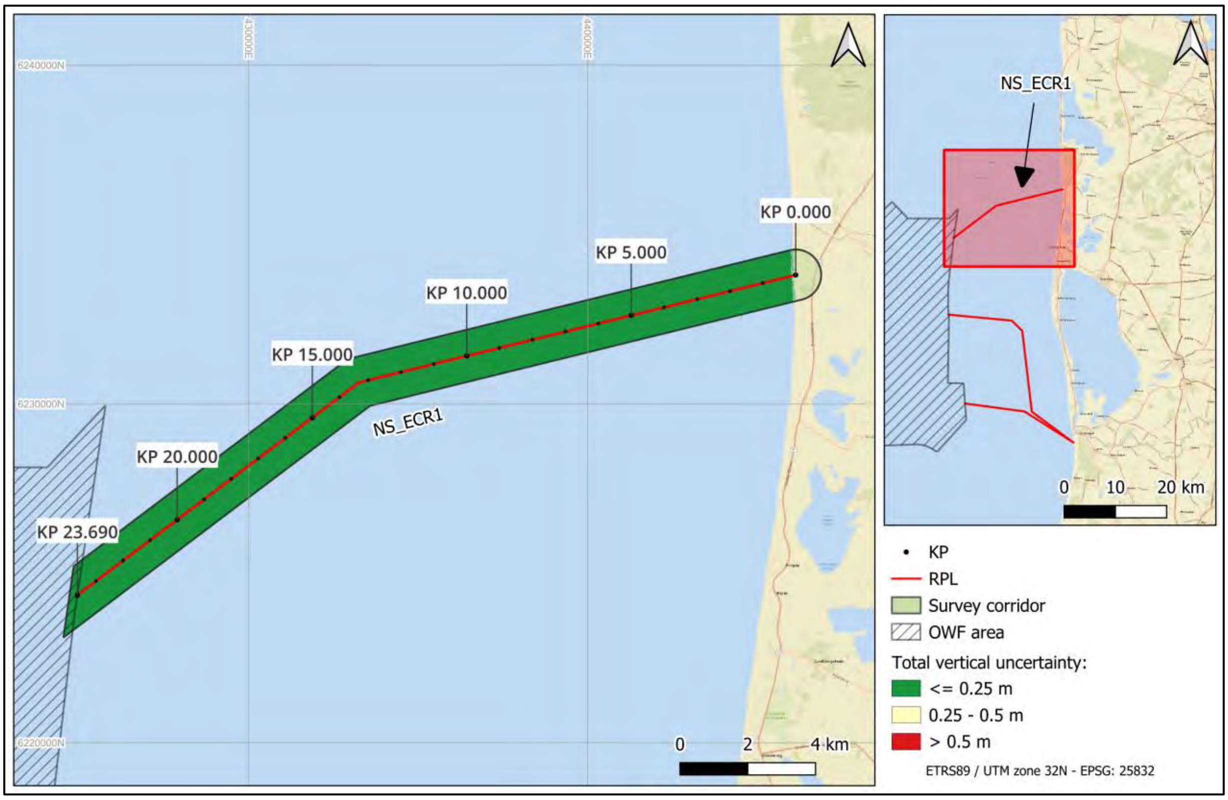


Figure 28: TVU coverage map of the survey area NS_ECR1

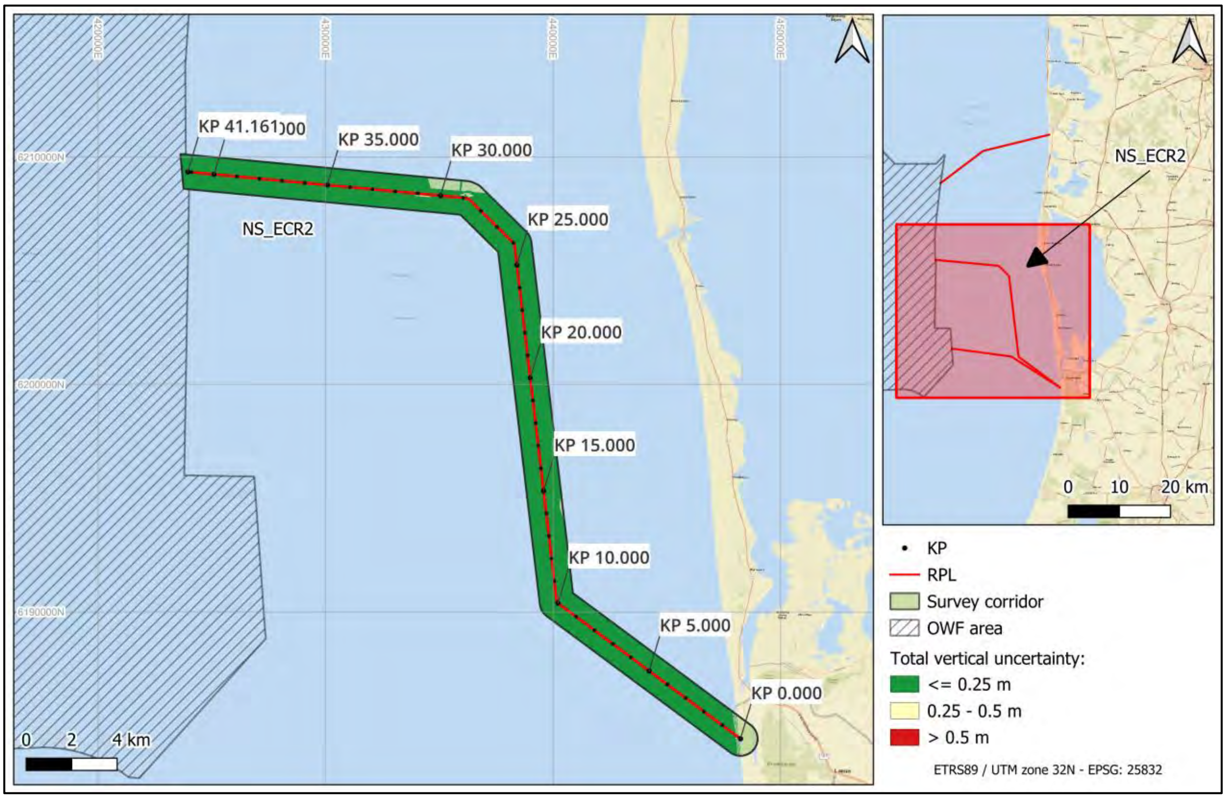


Figure 29: TVU coverage map of the survey area NS_ECR2

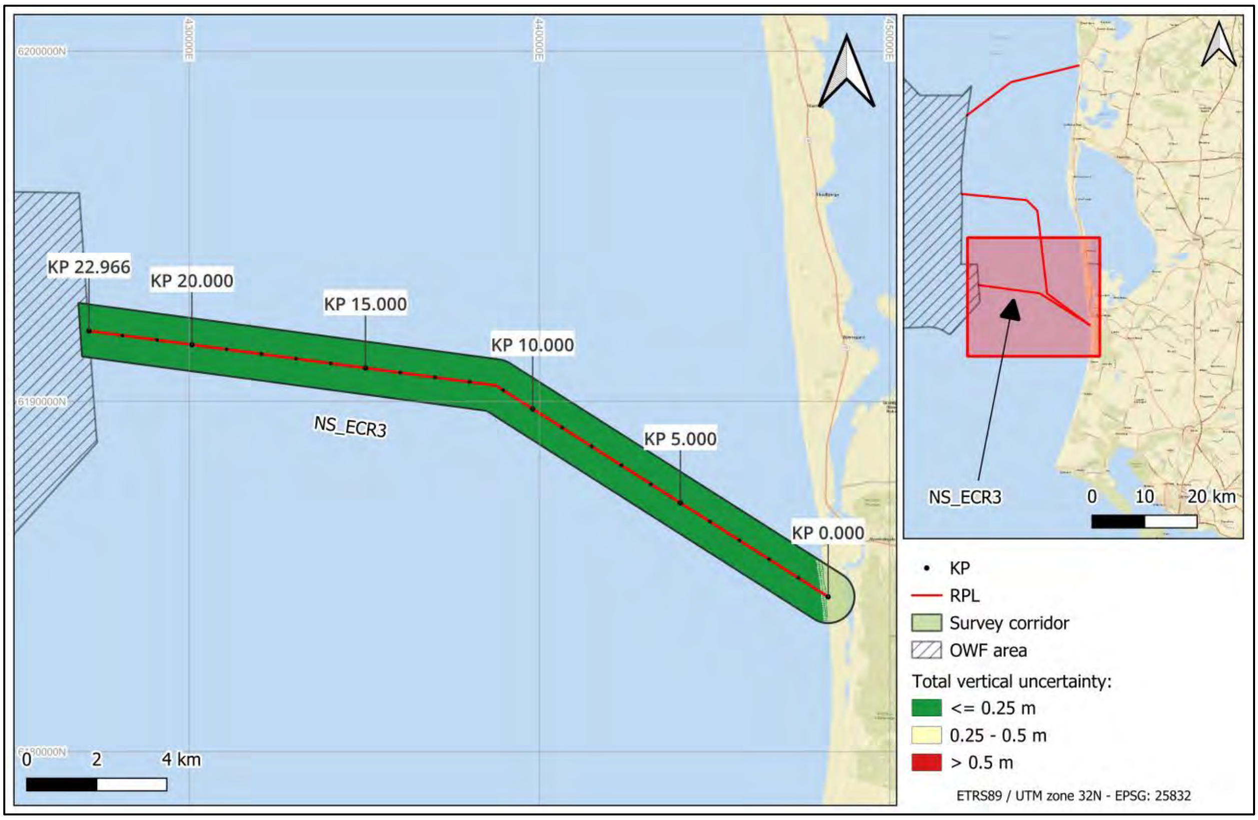


Figure 30: TVU coverage map of the survey area NS_ECR3

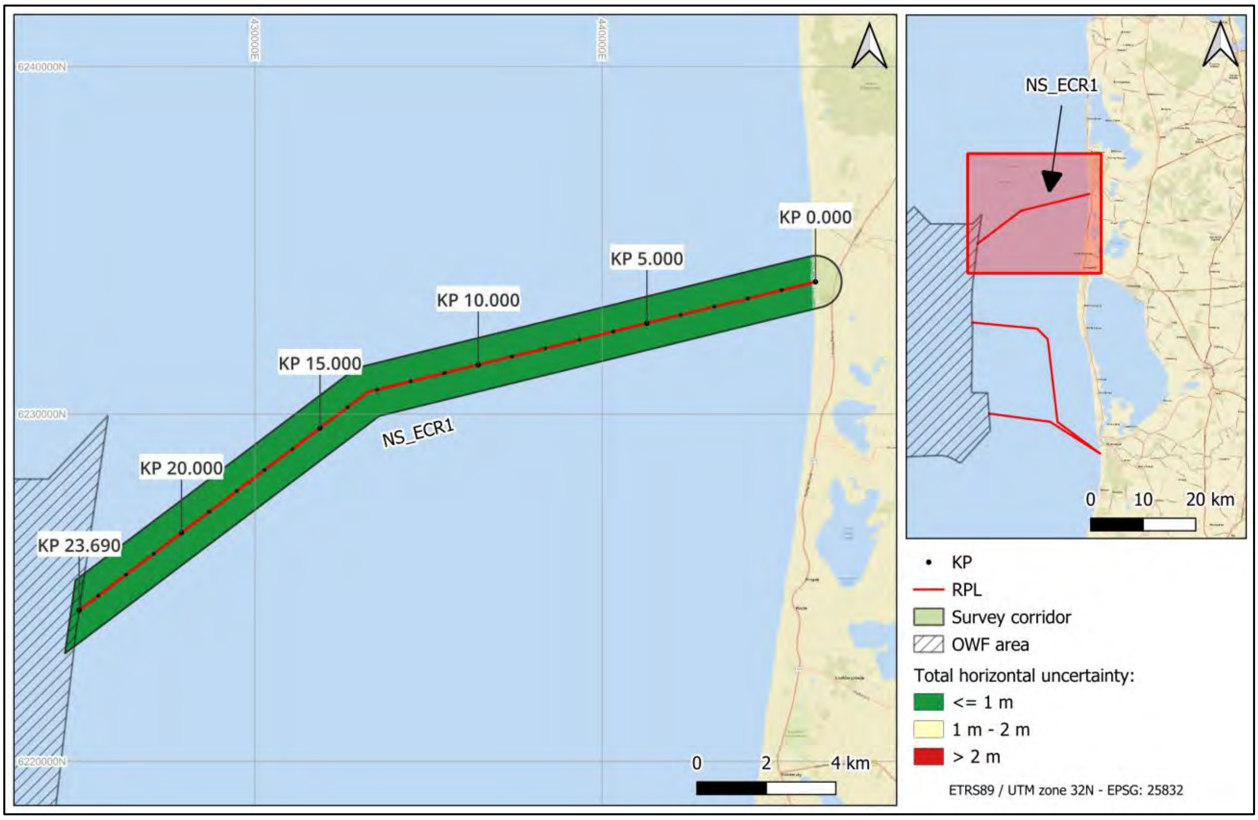


Figure 31: THU coverage map of the survey area NS_ECR1

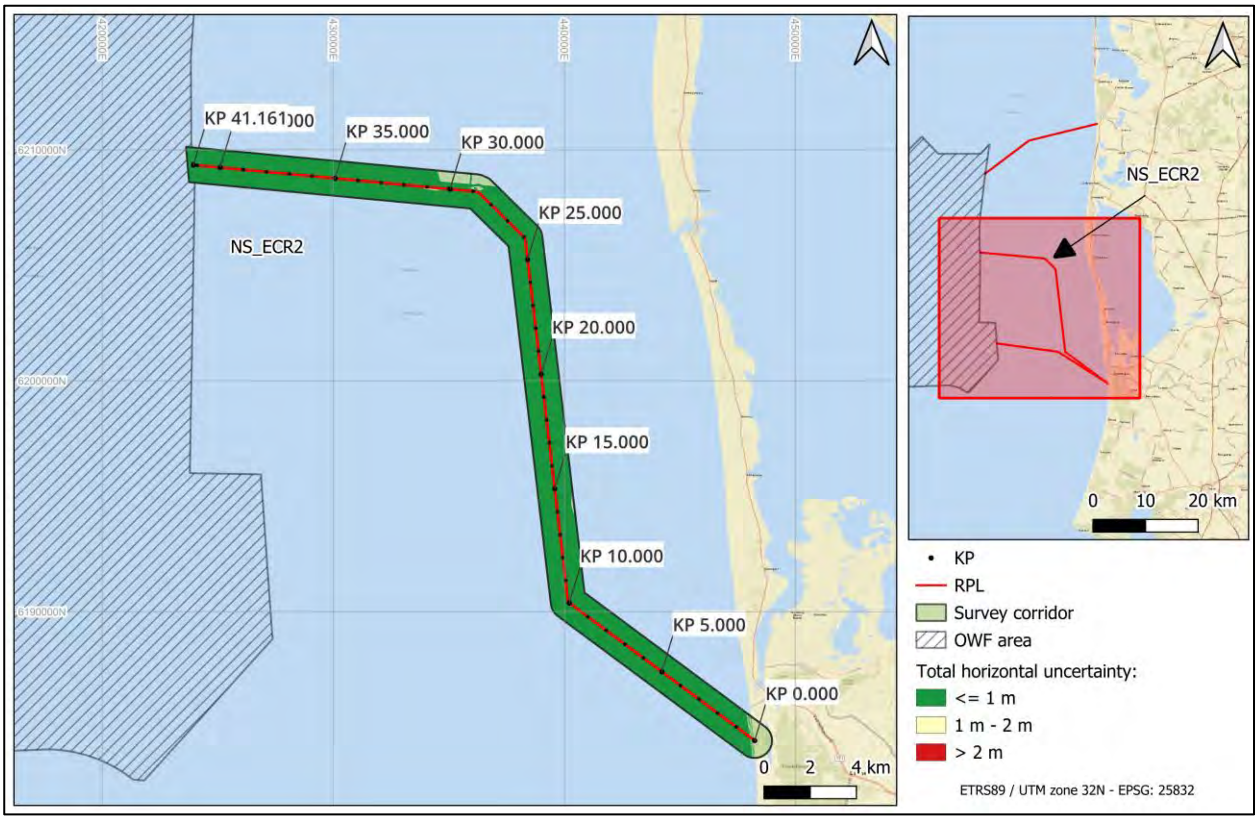


Figure 32: THU coverage map of the survey area NS_ECR2

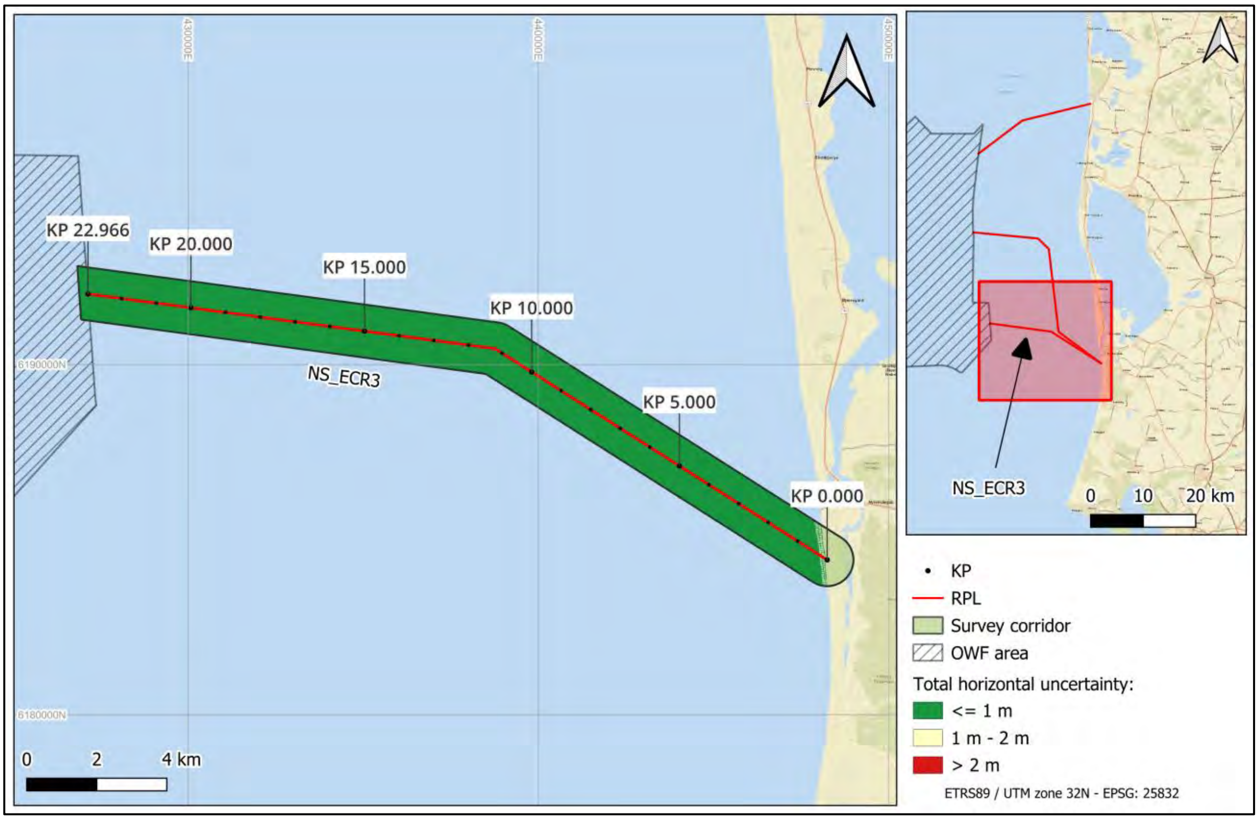


Figure 33: THU coverage map of the survey area NS_ECR3

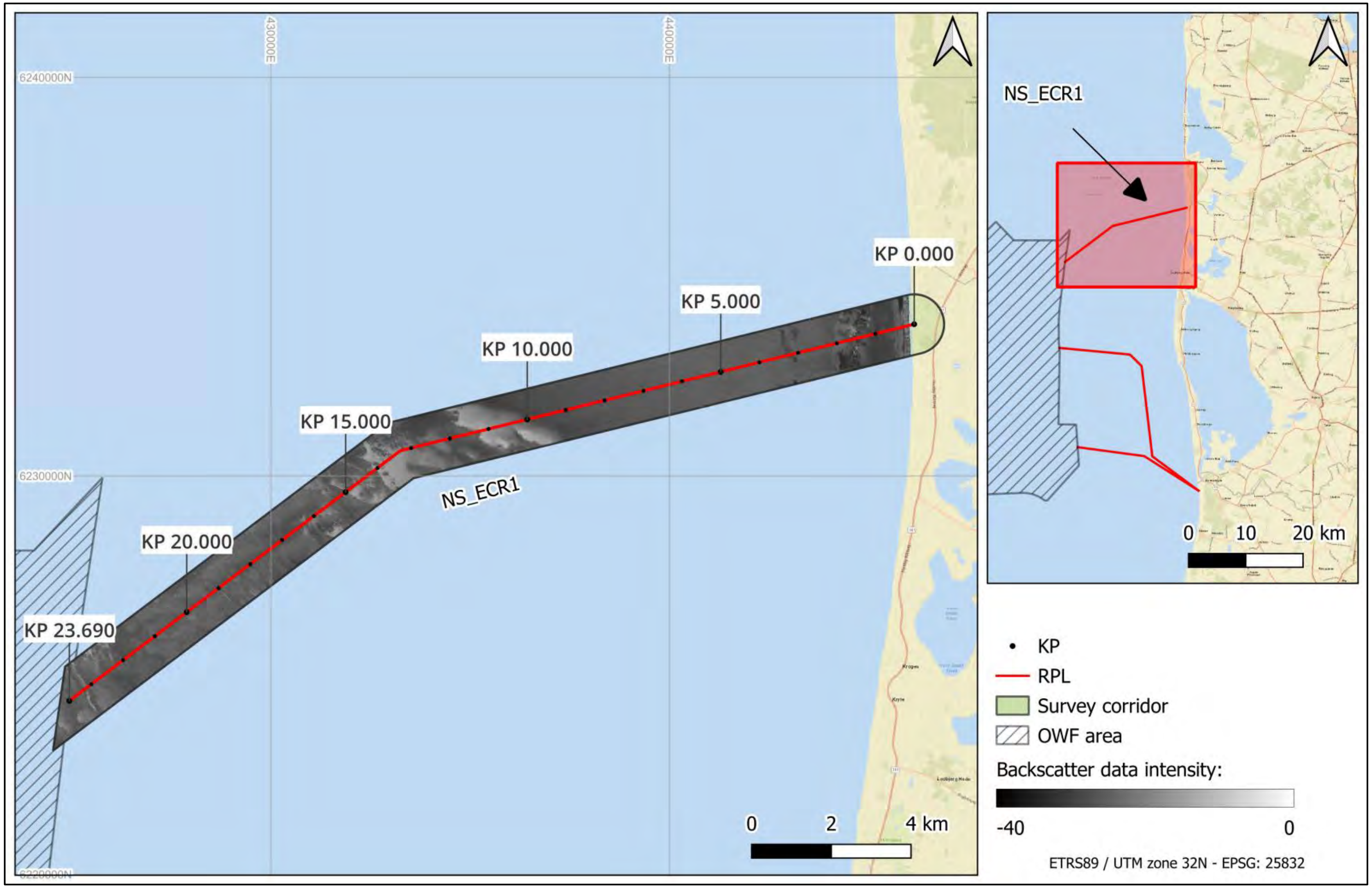


Figure 34: Backscatter data intensity within the survey area for NS_ECR1

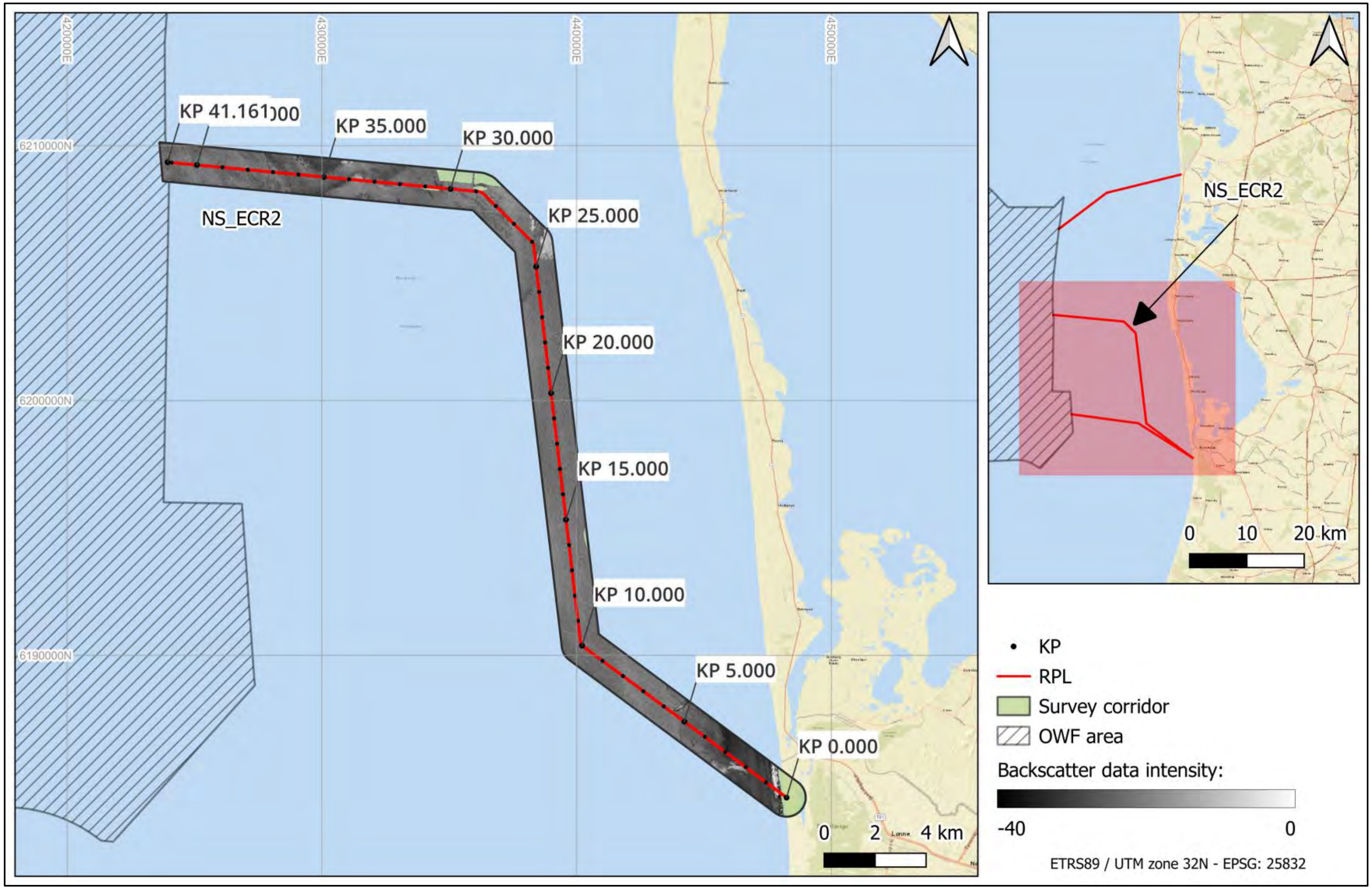


Figure 35: Backscatter data intensity within the survey area for NS_ECR2

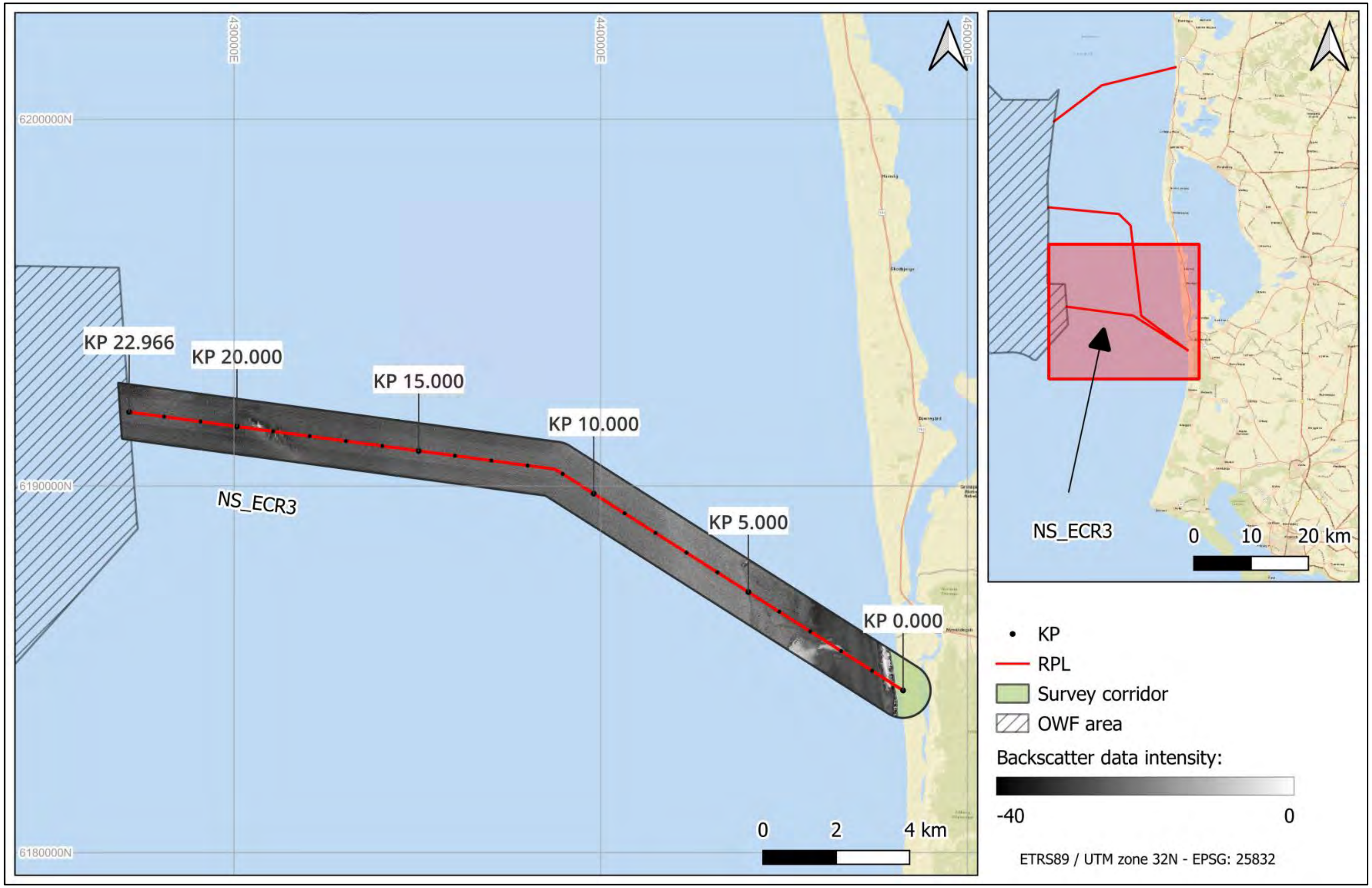


Figure 36: Backscatter data intensity within the survey area for ECR 3

5.3 SIDE SCAN SONAR

5.3.1 Data acquisition

Side scan sonar data was acquired following specifications listed in Table 32.

Table 32: SSS Client specifications

Item	Client specification
Low frequency	1 m
High frequency	0.1 m
Coverage	200 % (100 % nadir coverage for pycnocline- thermocline affected data)
Target picking	1 m (height, width and length)
Position accuracy	±2 m (using vessel course-over-ground and USBL) between SSS lines and compared to MBES
SSS range	70 m
Frequency SSS use	Dual frequency 300/600 kHz

The primary SSS system settings used for the project are outlined in Table 33, Table 34, and Table 35, split per vessel.

Table 33: SSS system settings – GOIV

Item	Settings
System type	Edgetech 4205MP 300/900kHz
Survey speed	Average 4.5 knots
Positioning	HiPAP 351 USBL
Mean fish altitude	8-12 % of sonar range
Trigger	High frequency = master
TVG/Gain	Recording RAW (*.jsf)
Range	75 m/55 m
Mode	High Definition mode

Table 34: SSS acquisition settings – Geo X

Item	Settings
System type	Edgetech 4200 300/900kHz
Survey speed	Average 4.5 knots
Positioning	Sonardyne Miniranger II
Mean fish altitude	Between 3 -4 m
Trigger	High Frequency = Master
TVG / Gain	Recording RAW (*.jsf)
Range	HF = 35 m / LF = 35 m
Mode	High Definition Mode

Table 35: SSS acquisition settings – GSV

Item	Settings
System type	Edgetech 6205 s2 (520/850 kHz)
Survey speed	Average 4.5 knots
Positioning	GNSS
SSS altitude	Pole mounted
Trigger	External trigger (slave) from SBP to avoid interference
TVG / gain	Recording RAW (*.jsf)
Range	35 m

5.3.2 SSS processing

Side Scan Sonar (SSS) data were processed and interpreted using Chesapeake SonarWiz software. The SSS processing steps are outlined in Table 36 to Table 42.

Figure 37 outlines the SSS processing workflow used for the project.

Table 36: Importing SSS data into SonarWiz

Step 1	Importing data: overview of the acquired lines
Set up project	The raw sonar files (*.jsf) had corrected navigation applied, using the SonarWiz NavInjectorPro utility, before being imported into Chesapeake SonarWiz software. The navigation data was de-spiked and exported from QINSy validator, to provide a smoothed position, with a bearing to towpoint heading solution. The processed sonar files (*.jsf) were imported into the SonarWiz project with the appropriate file type specific settings, as those were determined during the mobilization and calibration tests. A smoothing filter of 100 pings was applied during import. Once the parameters were agreed and checked with the Employer's Offshore Supervisor, they were used for the remainder of the dataset.
Bottom track	Using the automatic bottom tracking feature, SSS data were bottom tracked, line by line, and then, if needed, bottom track was manually adjusted.

Table 37: Navigation correction in SonarWiz

Step 2	Navigation correction
Check position	The SSS data were checked for positional accuracy against the MBES data, by locating clearly distinguishable features and contacts in both datasets and comparing their positions. If needed, the navigation data were re-processed and re-exported from QINSy as new navigation files (x, y, heading) and injected into the SSS data, using the SonarWiz NavInjectorPro utility. After that, positional accuracy was checked again.
Navigation	The towfish heading source was set to the fish heading to tow point. Using the SonarWiz ZEdit utility, navigation spikes were corrected and the positional accuracy was checked. The towfish heading was QC'd for small data jumps or artifact "vortex" effects.

Table 38: SSS signal processing

Step 3	Signal processing
EGN (Empirical Gain Normalization)	An EGN (Empirical Gain Normalization) table was calculated and applied to the data, creating a normalised gain, both along track and across track.

Step 3	Signal processing
TVG (Time Variable Gain)	If the EGN table applied to the data did not have the desired effect, an Auto TVG was used.

Table 39: SSS infill assessment

Step 4	SSS infill assessment
Manual check for gaps	Manual check for data gaps, overlap and data loss during QC/QA.
Check for pycnocline interference	Quality control check for pycnocline interference towards swath edges. Affected areas were marked for infill and re-run if required.
SonarWiz coverage	Checked for 200 % coverage (100 % nadir coverage for pycnocline-thermocline affected data), using SonarWiz Coverage report.

Table 40: SSS contact picking

Step 5	SSS target picking
Target picking	Must include: H-L-W measurements Description of the target Confidence level The interpretation of contacts was performed in SonarWiz digitizing mode, in accordance with the specifications. Contacts were digitized alongside MBES data and confidence level was updated accordingly. Wrecks and cables were correlated to relevant databases.
Criteria of object detection	Minimum of 1 m (height, width or length) Object is identified as deviation from natural seabed forms The object is verified in wing line side scan image Position is verified with MBES data Man-made objects or very clear objects (even if only detected on one line only) Contact classification criteria defined with the Reporting Coordinator and sent to the Data Coordinator onshore.
Image picture	Colour grey inverted
Confidence level (Low, Medium, High)	Every contact has a confidence level attributed to it based on its detection in: • 1 SSS line -> Low, • 2 or more SSS lines -> Medium • 1 or more SSS lines and MBES data -> High
Boulder fields	Within 50 m x 50 m area, the boulder zone defining criteria are: • 0 – 10 boulders: Not a boulder zone. Targets > 1 m in any direction picked. • 10 – 20 boulders: Intermediate boulder density. Targets > 2 m in any direction picked. • > 20 boulders: High boulder density. Targets > 2 m in any direction picked.

Table 41: SSS mosaic creation

Step 6	SSS mosaic creation (HF and LF)
Adjust SSS line drawing order	SSS lines drawing order was adjusted to optimize the exported seabed image
Line grouping	Lines were grouped in: Approved, Rejected, Trials or Other

Step 6	SSS mosaic creation (HF and LF)
EGN and gain check	Final QC of EGN and gains was performed. If required, new EGNs and gains were recalculated and reapplied.
Inter file gap check	Data was checked for small inter-file gaps. SonarWiz inter-file gap tool was used when required.
Range check	Range was adjusted for optimized quality without compromising the 200 % data coverage.
Mosaic export	SSS mosaics were exported using the standardised project tile size and arrangement.

Table 42: SSS seabed classification

Step 7	Seabed classification
Seabed features	Seabed features have been created and QC'd using the exported SSS LF mosaics. SSS HF mosaics and the MBES exports were also taken into account.
Seabed geology	The SSS LF and HF mosaics, as well as the MBES data and the SBP contours were used in order to outline the sediment differences, as those are represented by the reflectivity changes mainly on the SSS mosaics. Grab samples were the most useful for editing and confirming the outlined sediment boundaries.

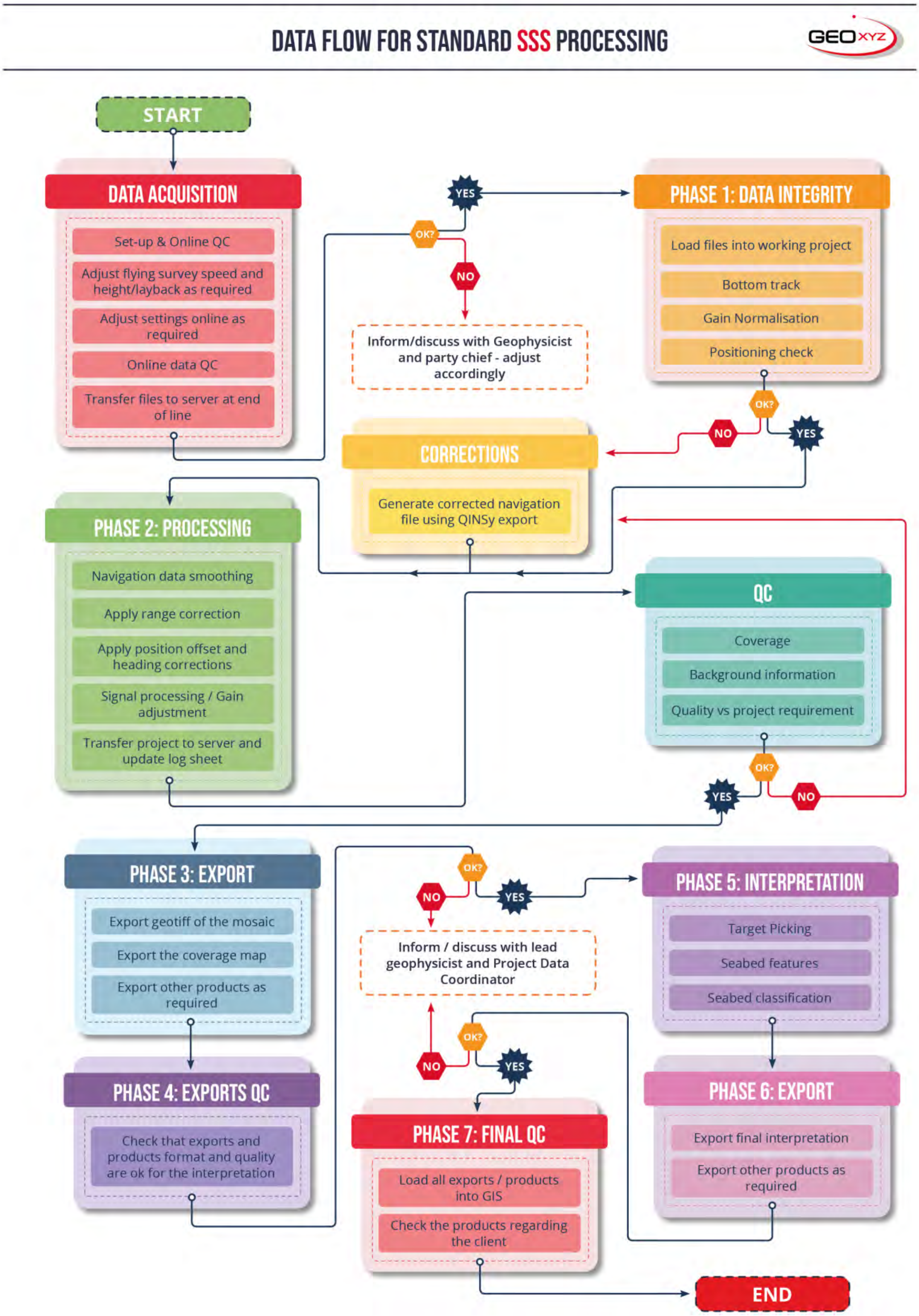


Figure 37: SSS data processing workflow

5.3.3 SSS target picking

As defined in TQ-012-Boulder Picking clarification:

- Boulders zones were mapped with the automatic tool for boulders > 0.5 m (height/length/width).
- Individual boulders/blocks within boulder zones were mapped with the automatic tool for boulders > 2 m (height/length/width).
- Rocks/blocks outside boulder zones were mapped by manual method on boulders > 1 m (height/length/width).
- Quality of automatic boulder picking tool was demonstrated with a comparison between automatic versus manually mapped boulders (Comparison is done in boulder field area 100 x 100 m).

Within 50 m x 50 m area, boulder zones were defined using the following criteria:

- 0 – 10 boulders = not a boulder zone. Targets > 1 m in any direction picked
- 10 – 20 boulders = intermediate boulder density. Targets > 2 m in any direction within the zone picked
- > 20 boulders = High boulder density. Targets > 2 m in any direction within the zone picked

The primary sensor for target identification was the MBES (in terms of positioning), as it has greater positional accuracy. Therefore, targets seen on MBES were classed as ‘High’ in confidence. SSS targets were classed ‘Medium’ when the targets were identified on multiple SSS lines and ‘Low’ confidence levels were assigned to targets which were only resolved within one SSS line.

SSS target measurements were determined in Sonar Wiz. The lengths and width are manually measured and the heights were automatically calculated within SonarWiz. The software takes into account the manually measured target shadow length, towfish altitude and range to auto- calculate the height. Due to limitations in the software, is possible that some target heights may exceed what is listed. Due to occasional stretching of the data in the far ranges, this sometimes results in elongated representation of contacts. Contact picking was verified over multiple lines and data where possible to report accurate measurements, however some elongated contacts may still be visible within the mosaic.

The steps of target identification are presented in Table 43.

Table 43: Target identification workflow

Step	Procedure
1.	Once the MBES data was clean and ready, the AutoClean boulder picking algorithm was executed.
2.	The shapefile from AutoClean was extracted and imported into QGIS.
3.	In QGIS, a density function was applied to determine boulder field classification areas using Kernel Density estimation, resulting in a new raster hit map.
4.	The density hit map in QGIS was vectorised.
5.	Individual boulders larger than 2 metres within boulder areas and larger than 1 metre outside the boulder field polygons were filtered. The SSS automatic boulder picking script from Hidrocibalae was run.
6.	The results were imported into the SW project.
7.	Individual boulders larger than 2 metres within boulder areas and larger than 1 metre outside the boulder polygons were filtered. Individual boulders were plotted in QGIS.
8.	2-metre buffers around MBES-identified individual boulders were created, and SSS boulders that fall within these buffers were identified.

Step	Procedure
9.	Correlation between the MBES and SSS boulders in QGIS via a model was done.
10.	The same method was applied to MAG anomalies using the same technique and a residual grid was applied.

The detection process, as presented in Figure 38, was performed on each individual SSS line, and for each target the automated detection yielded a polygon that outlines the reflection and a line that outlines the shadow. When requested to identify the same target from several SSS lines, a specifically developed tool compared target position and dimension on different lines and created average values for one representative target. This task was especially challenging inside high-density boulder fields where target reflection varied between the lines and shadows overlaps between contacts.

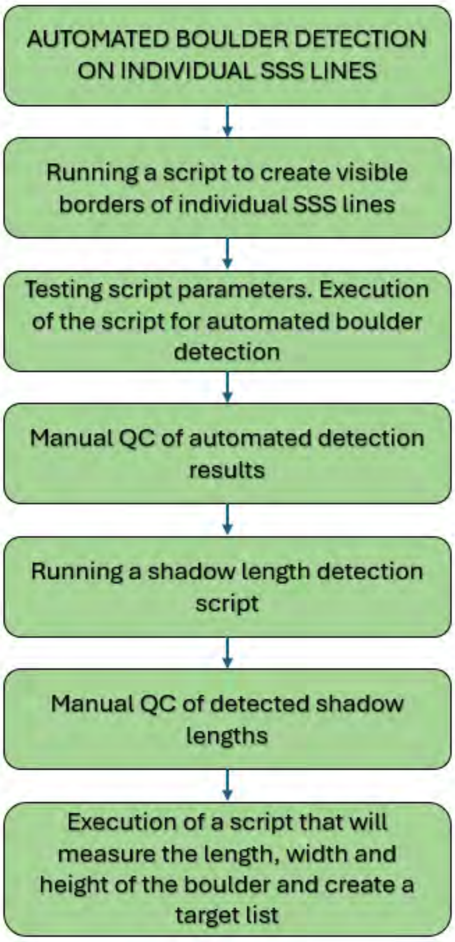


Figure 38: Automated boulder detection progress

A QC process was manually performed by a processor to check whether the detection results correspond to the real target by size and location, making adjustments if necessary to avoid false positive target detections. Manual quality control enabled the processor to ensure accurate and reliable detection results, adjust the results where needed, and improve the overall quality of the detection process.

Once the algorithm was run and the QC was finished, a SSS boulder shapefile was exported and correlated with the MBES and MAG contacts. SSS and MBES targets were correlated if within 2 m of each other. SSS and MAG targets were correlated if within 5 m of each other. A final QC by the Lead Geo was done to assure the correct definition of contact.

5.3.4 SSS data quality assessment

Overall, the SSS data quality was monitored throughout the survey and was of high quality, achieving Client specifications.

The nearshore data acquired by the Geo Surveyor V and Geo X was of high quality and no significant presence of the pycnocline was observed. This can be seen in the data examples below of NS_ECR1 (Figure 39) and NS_ECR2 and NS_ECR3 (Figure 40).

Figure 39: NS_ECR1 (Nearshore) SSS HF Mosaic (0.5 m Cell Size)

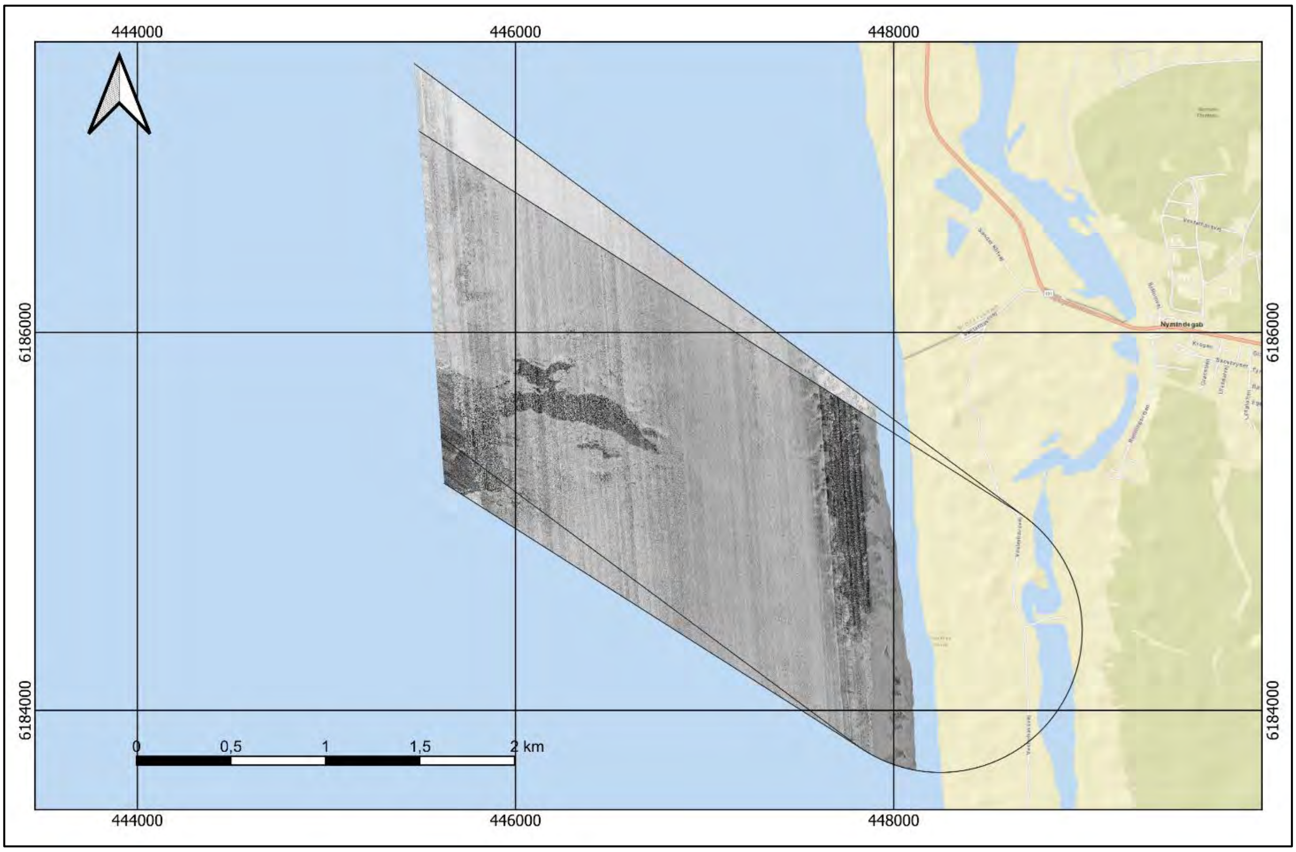


Figure 40: NS_ECR2 and NS_ECR3 (Nearshore) SSS HF Mosaic (0.5 m Cell Size)

The offshore data quality was generally of high quality. However, the presence of a pycnocline was observed within some of the data obtained by the Geo Ocean IV which resulted in marginal or reduced data quality in the outer ranges in some sections of the SSS lines. The affected sections were removed during processing and good quality data was used for mosaic exports and target picking.

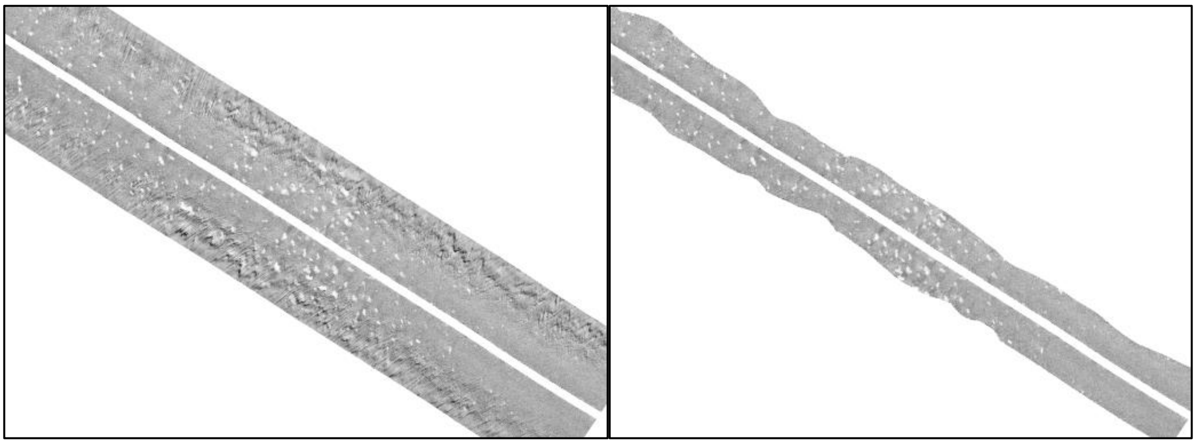


Figure 41: Pycnocline artefact before (left image) and after (right image) removal in the SSS dataset

Figure 42, Figure 43, and Figure 44 below show the achieved SSS data coverage within North Sea ECR1, ECR2 and ECR3, respectively.

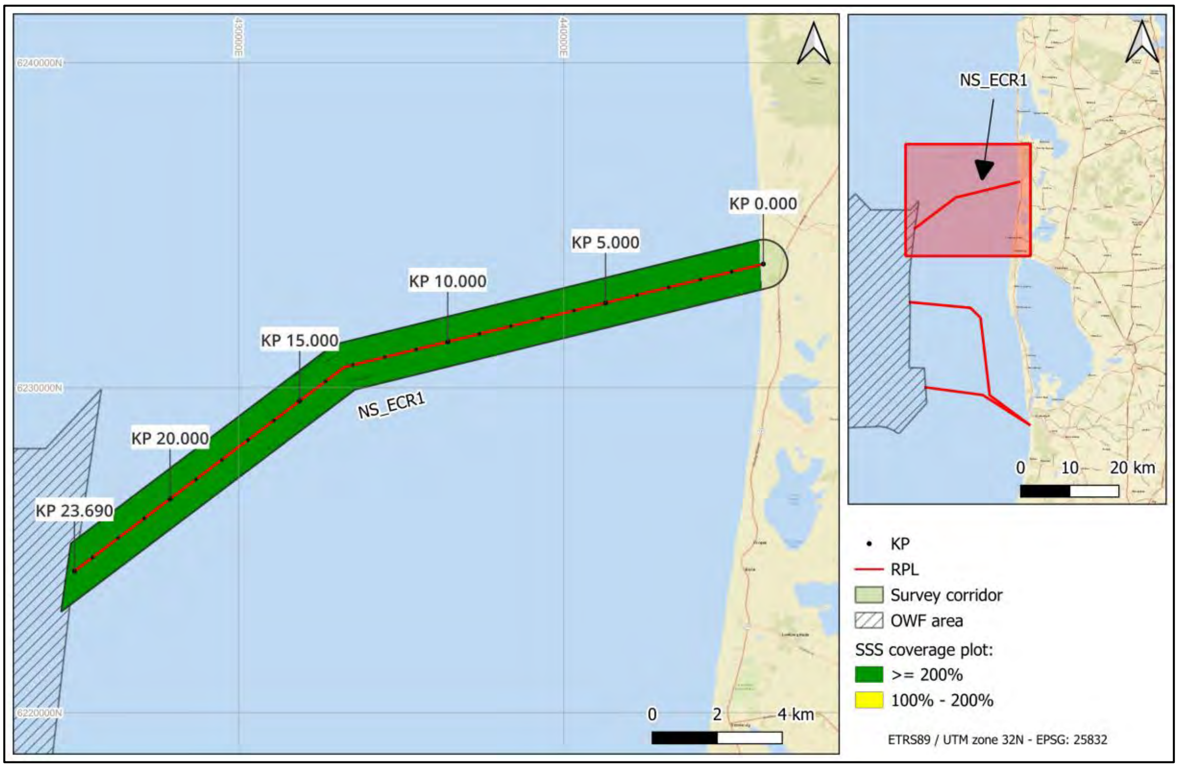


Figure 42: NS_ECR1 - SSS coverage plot

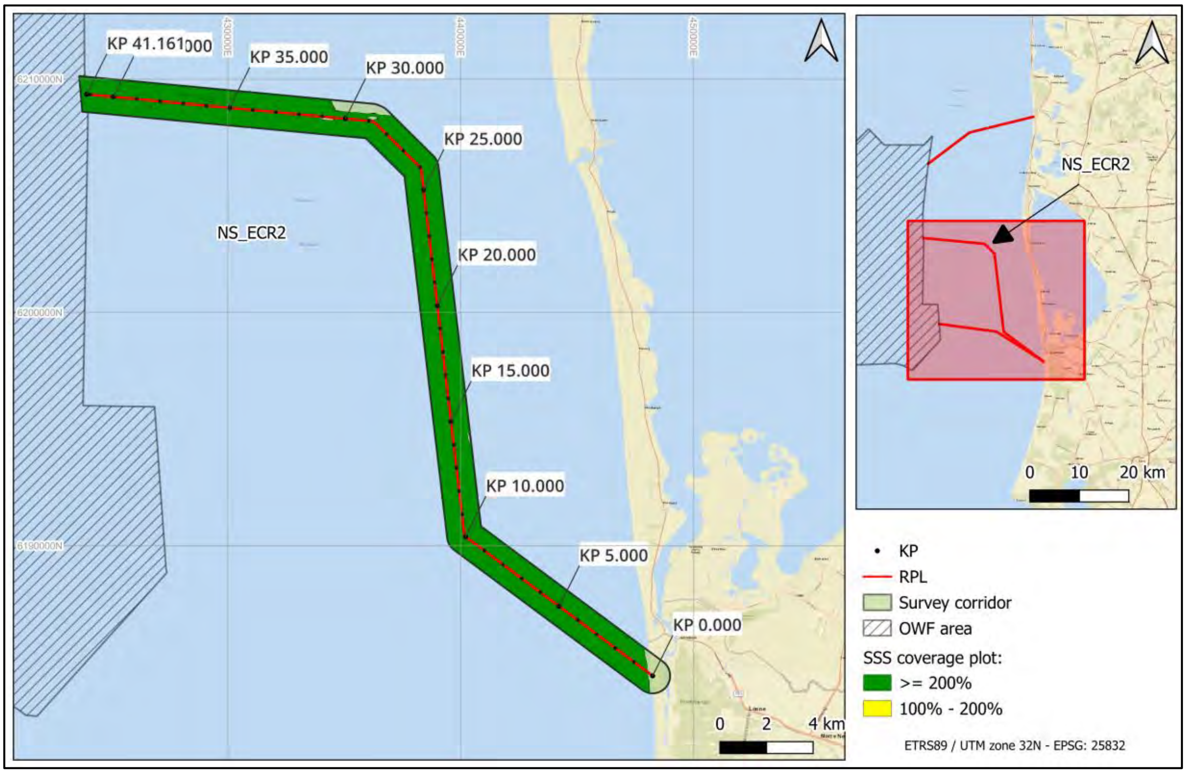


Figure 43: NS_ECR2 - SSS coverage plot

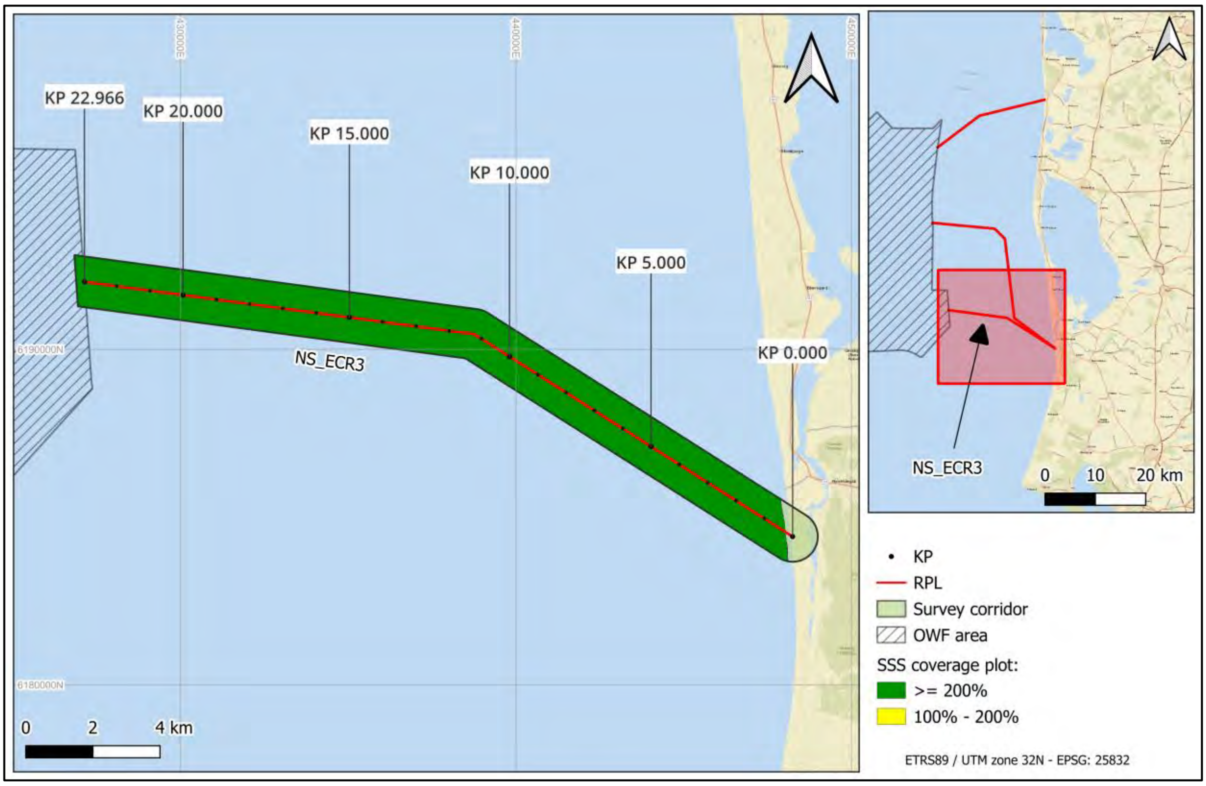


Figure 44: NS_ECR3 - SSS coverage plot

5.4 MAGNETOMETER

5.4.1 Data acquisition

Magnetometer data was acquired following specifications listed in Table 44 below.

Table 44: MAG specifications

Item	Client Specification
Measurement sensitivity	0.01 nT
Seabed altitude(max)	≤ 5.0 m
Seabed altitude (min)	2 m
Coverage	100 % by line
Minimum nT target detecting	10 nT on analytical signal grid
MAG frequency	1-20 Hz (selectable)
Position accuracy	2.5 m in two lines in opposite direction (GEOxyz specs)
Noise level	≤ 2 nT
Blanking distance	5 m

The primary settings that were used onboard the GOIV, GSV and Geo X are presented in Table 45, Table 46 and Table 47, respectively.

Table 45: MAG acquisition settings – GOIV

Geometrics G882	
Survey speed	4.2 knots
Positioning	HiPAP 351 USBL
Magnetometer altitude	Below 5 m
Frequency	10 Hz

Table 46: MAG acquisition settings - GSV

Geometrics G882	
Survey speed	Average 4.5 knots
Positioning	Layback
Magnetometer altitude	ca. 3 m
Frequency	10 Hz

Table 47: MAG acquisition settings – Geo X

Geometrics G882	
Survey speed	Average 4.5 knots
Positioning	Sonardyne Miniranger II USBL system
Mean fish altitude	Variable – similar or lower than SSS altitude
Frequency	10 Hz

5.4.2 MAG processing

The magnetometer data were processed using GeoSoft Oasis Montaj following the below processing steps:

- QC Raw Navigation
- Process Navigation
- Process Altitude
- Process Total Field / Calculate Residual
- Generate Final XY

Processing scripts with associated database views to easily QC the results were developed to streamline the magnetometer processing. Navigation and altimeter data were first de-spiked and smoothed. A residual was derived by subtracting a background field, derived using a set of non-linear and smoothing filters, from the Total field. Total field and residual grids were created using a cell size of 50 cm. From the residual grid an analytical signal grid was derived and was primarily used for target picking.

The general workflow is outlined in Figure 45, and processing steps used for the project are outlined from Table 48 to Table 53.

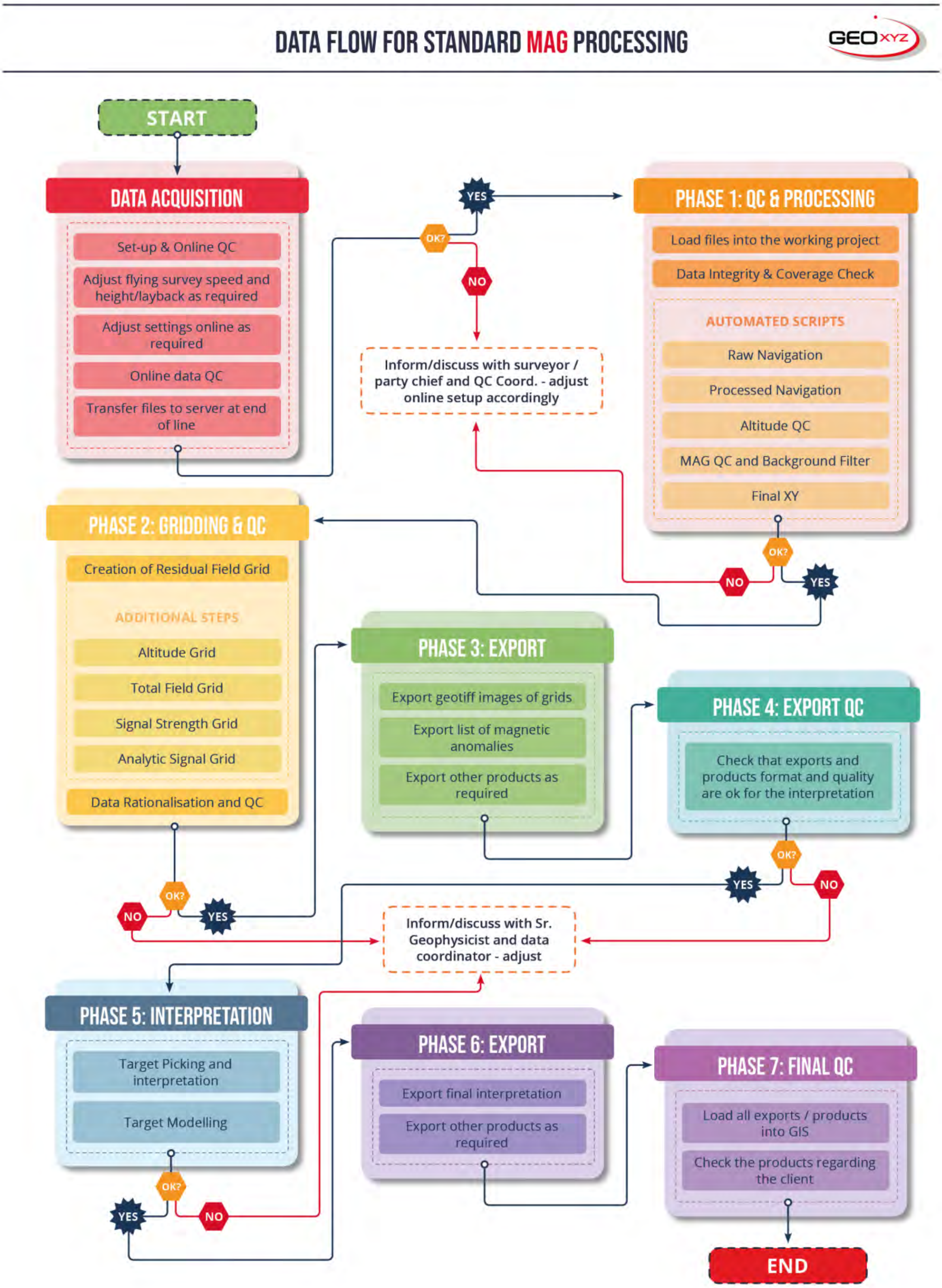


Figure 45: Magnetometer data processing workflow

Table 48: Magnetometer navigation processing

Step 1	Magnetometer navigation processing
Backup of "Easting" and "Northing"	The raw easting and northing were copied; all subsequent navigation processing were performed upon these copies.
De-spiking	Data windowed for survey site Non-linear filter applied, with a fiducial width of 5 (and tolerance of 1.5 m). The filter was used to remove small spikes present in the data.
Back up of smoothed navigation	The smoothed/interpolated/de-spiked data were backed up.
Projection	Project projection is set.
Distance	Calculates the total distance along the track for each fiducial.
Distance separation	The distance between each fiducial is calculated. This was done by applying a convolution filter to the distance. The settings were -1, 1, 0. The results were written to the *Dist_QC* channel. This helped to monitor the frequency (10 Hz) of the magnetometer, it helped to spot any "freezes" in the data acquisition. It was compared to the magnetometer signal. Any large jumps in distance separation could have caused a spurious anomaly or missed data.
Comparison	The raw navigation, de-spiked navigation, smoothed navigation, the distance separation and magnetometer signal had their profile plotted together within Oasis Montaj. This allowed the quality control (QC) of the navigation and its processing. The database view plots these profiles against each other.

Table 49: Magnetometer altitude processing

Step 2	Magnetometer altitude processing
De-spiking	The raw altitude was de-spiked. The filter stripped out any data spike that is above 5 m. This was done within Oasis Montaj using channel tools and channel mathematics.
Interpolation	The interpolation restored the gaps created by removing the altitude spikes. This was done using a linear interpolation, for gaps over ten fiducials (approximately 2 m).
Smoothing filters	A set of filters (low pass and B-spline) was applied to the de-spiked/interpolated altitudes to produce a smooth, more realistic values for altitude.
Alt cut-off	Clipped any data above 5 m and below 2 m.
Clip X and Y with Alt masked	Clipped the position according to the altitude cut-off.
Copy mask of interpolated altitudes to Easting and Northings	Not done at this step.
Comparison	The raw altitudes, de-spiked, smoothed altitudes, averaged altitudes and smoothed average altitudes, the distance separation and magnetometer signal had their profile plotted together within Oasis Montaj. This allowed QC of the altitude and the processing.

Table 50: Magnetometer data QC

Step 3	Magnetometer data QC
De-spiking	A de-spiking filter was applied to the total magnetic TMF values.
Non-linear filtering	A non-linear filter was applied to attenuate any noise present in the data.

Step 3	Magnetometer data QC
B-spline smoothing	A “B Spline” filter was applied to the non-linear filter. This helped to make the signal to appear more realistic (smooth).
Copy mask of interpolated TMF values and poor magnetic signal to Easting and Northings	The stripped magnetic data is used to mask the eastings and northings. The data gaps that are present in the interpolated TMI values were reintroduced by using these TMI values to mask the eastings and northings. This is done because original gaps may have been reduced due by the previous smoothing filters.
Comparison	All the processing steps for the TMI are plotted along with the magnetometer signal for QC.

Table 51: Magnetometer background calculation

Step 4	Magnetometer background calculation
Background	To obtain the background magnetometer signal, a series of non-linear filters were applied. These were as per GEOxyz’s procedures. An additional geological filter was produced by using a variation of filter parameters to attenuate magnetic anomalies.
B-Spline	A “B Spline” filter was applied to the final non-linear filters to smooth the result.
Compare	The final data were compared with the raw data to identify over or under filtering of the data.

Table 52: Magnetometer residual field calculation

Step 5	Magnetometer residual field calculation
Residual (Anomalies)	Filtered magnetometer data minus the background signal (anomaly and geology).
Residual (Geology)	An additional geological residual field was also calculated using an additional non-linear filter set.
Gridding	Data were gridded using Minimum Curvature with a Cell Size of 0.5 m and a blanking distance of 5 m.

Table 53: Magnetometer target picking

Step 7	Magnetometer target picking
Analytic signal	AS grids were produced using a 0.5 m cell size, blanking distance set at 5 m.
Target picking	Anomalies were picked from the analytical signal grid. The residual field was checked against the total field to help determine anomalies. Mag anomalies with a peak to peak value of less than 10 nT from the analytical signal were kept if they were also clearly seen in the residual field.
De-duplication of targets	Compare targets with Altitude and Residual and TMI profiles. Targets were de-duplicated as required.
Target list	Magnetometer target list was compiled, as per client requirements

5.4.3 MAG target picking

Magnetometer was used for screening larger ferrous objects, crossing cables, and pipelines. MAG list includes magnetic linear anomalies indicative of ferrous masses greater than 50 kg, buried up to 2 metres below the seabed surface, including wrecks, potential UXO, fishing gear, man-made objects. Contact list was completed at the GEOxyz office and involves checking for all targets and seabed features mentioned above.

5.4.4 MAG data quality assessment

Both the offshore and nearshore datasets acquired within the North Sea area maintained high quality with no deviations from the normal processing workflow. All data is within project requirements, with noise thresholds below the acceptable level and altitude at the required flying height (Figure 46).

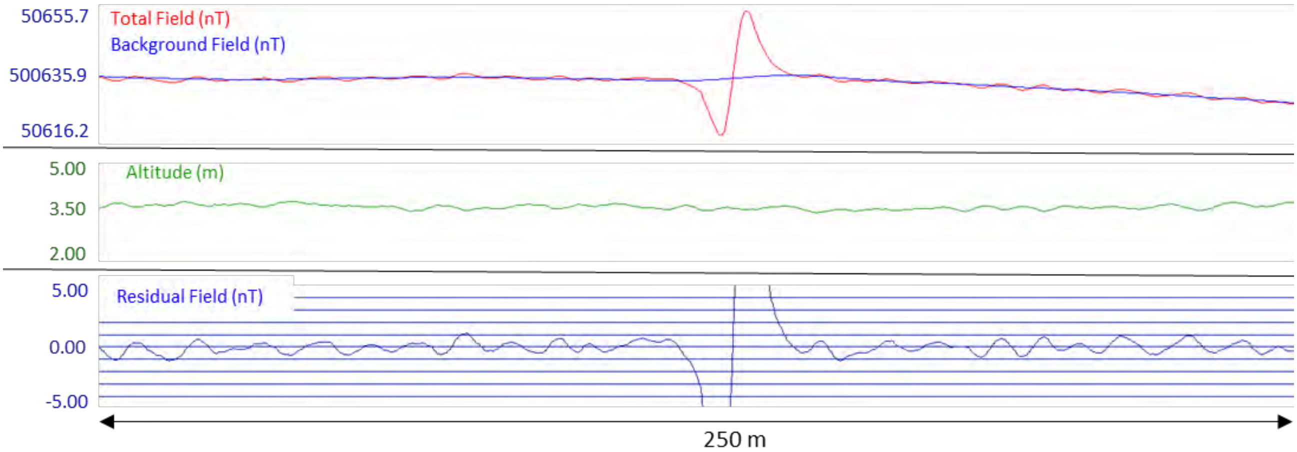


Figure 46: Example of magnetometer data in profile view, from line "0136-5950_B_NS-3_GeoX_L071V_230825", ECR2/3 nearshore section

5.5 SUB-BOTTOM PROFILER

5.5.1 Data acquisition

SBP data was acquired following specifications listed in Table 54 below.

Table 54: SBP specifications

Item	Client Specification
Penetration	10 m
Vertical resolution	0.3 m

The acquisition settings that were used onboard the GOIV, Geo X and GSV are presented in Table 55, Table 56 and Table 57.

Table 55: GOIV SBP acquisition settings

General parameters GOIV	
System type	Innomar SES-2000 Medium 100
Survey speed	4.2 knots
Source frequency	8 kHz
Power setting	100 %
LF gain	4 dB
LF pulse	1

Table 56:Geo X SBP acquisition settings

General parameters Geo X	
System type	Innomar SES Quatro
Survey speed	Average 4.5 knots
Source Frequency	8 kHz
Power Setting	100 %
LF Gain	6
LF Pulse	1

Table 57: GSV SBP acquisition settings

General parameters GSV	
System type	Innomar SES-2000 Standard
Survey speed	Average 4.5 knots
Source Frequency	10 kHz
Power Setting	100 %
LF Gain	-6
LF Pulse	1

Sub-Bottom Profiler (SBP) data was recorded as '.ses3' files then processed with Silas processing software. Incoming data was monitored for quality during recording before secondary QC of both SBP and navigation data. An acquisition log was kept of all settings and observations.

Position was sent via QINSy to SESWIN24, and raw files were tide corrected. Heave was corrected when converting the .ses3 files in SEG-Y using 'SES Convert' software. SEG-Y files were imported to Silas software. Sound velocity was set and processed MBES data (tide corrected) was compared to ensure correct seabed arrival time. Since the raw SEG-Y recorded, time was rounded to 1 ms, the trigger delay was corrected up to 2 decimal precisions to ensure the seabed matched the bathymetry. The bottom was tracked over the centre beams using Silas Auto Tracing. Processed SEG-Y in 32-bit padded format was then exported.

5.5.2 SBP processing

The main SBP processing steps used for the QC are outlined in Table 58 and Table 59. SBP processing workflow diagram is presented in Figure 47.

Table 58: SBP data import and data QC

Steps	SBP data import and QC
Import of SEG-Ys	Import SEG-Y Tide file applied
Data Quality	Lines checked for: No empty pings Correct bottom detection No motion influence No noise in the data No artefacts in data

Steps	SBP data import and QC
	Good reflector visibility Good penetration (5 m)
Position check	Lines checked for: Data coverage Verification of the absolute height by importing the MBES grid (no manual offset is accepted, after tide/heave correction applied online)

Table 59: SBP acquisition and processing methodology

High frequency shallow sub-bottom profiler (SBP)	
Objective	• To characterise and map the sediment architecture and structure down to 10 metres beneath the seabed, in order to obtain a detailed understanding of the uppermost soil/geological conditions of the survey area • To identify geological or manmade hazards down to 5 metres beneath the seabed, such as lithological heterogeneities, organic-rich soils/peat shallow gas, buried objects, etc
Equipment	• System: Innomar SES-2000 Standard • Acquisition software: SESWIN recording software • SBP processing software: ISE, SES Convert and Stema Silas • SBP interpretation software: IHS Kingdom seismic interpretation software

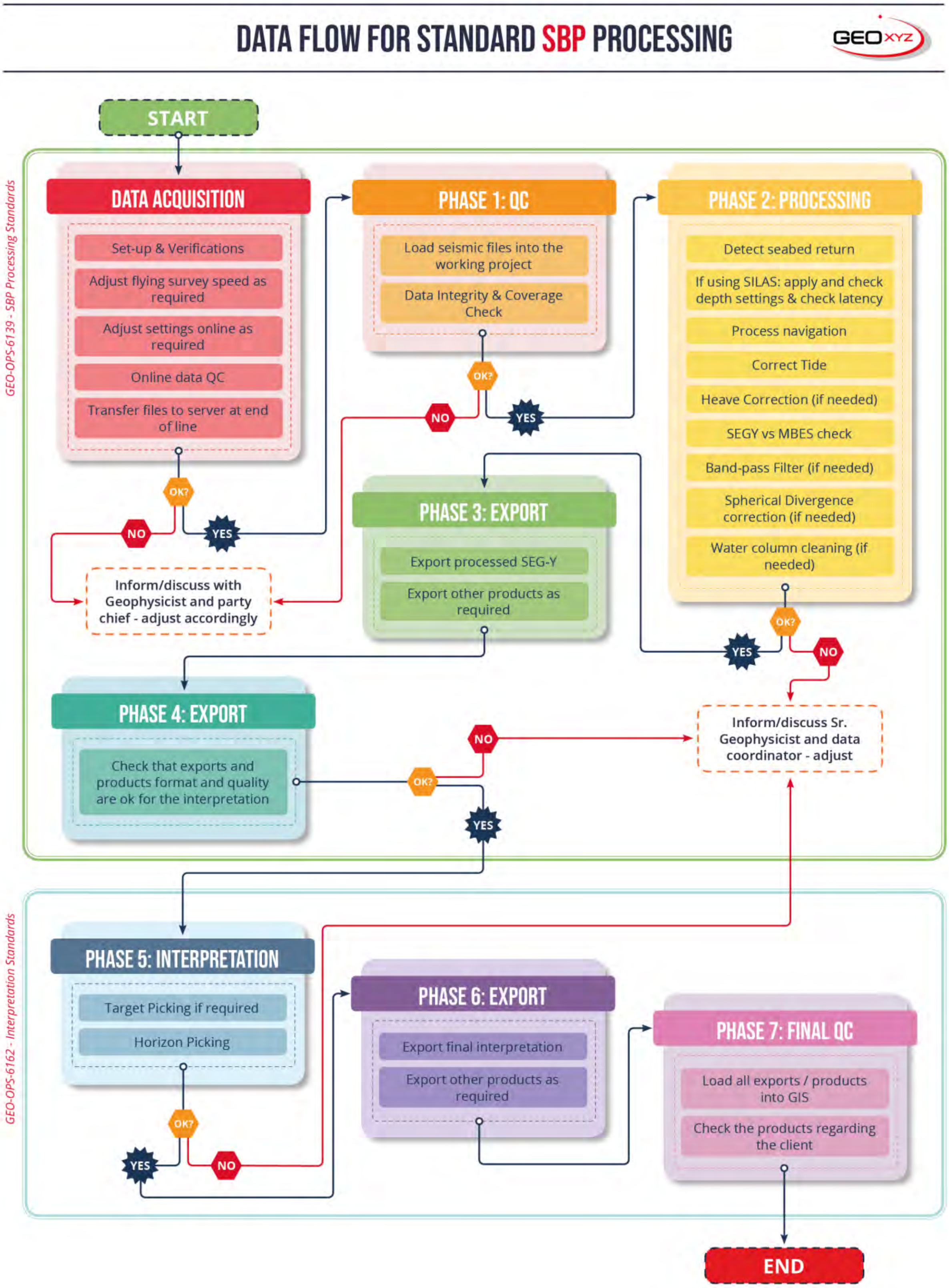


Figure 47: SBP data processing workflow

5.5.3 Geology interpretation

Once processed, the SBP data were loaded into an IHS Kingdom project for interpretation. The data are of good quality and are uniform across the different vessels used in acquisition. The vertical resolution allows separation of surfaces ~0.15 m apart.

The picked horizons were gridded to 5 m lateral resolution using the IHS Kingdom Flex Gridding algorithm default settings. The final project datum depth grids were created from thickness horizons, which were then added to the MBES bathymetry. This was to remove the effect of any static misties and to provide the best gridded surface possible.

Sub-bottom data and interpretations were depth converted using a velocity of 1650 m/s. A velocity of 1650 m/s was chosen as not only does it follow on from the velocity selected for the windfarm sites, but it was assumed that the shallow geology would mainly be Sandy CLAY. Therefore, this velocity is in between the velocities of these two sediment types. CLAY being 1600 m/s and SAND being 1700 m/s.

5.5.4 SBP data quality assessment

The data quality along the survey lines is generally good, with all intended horizons mapped across the entire survey area. Penetration is more limited by the underlying geology and the multiple masking data in certain shallow regions, particularly where the glacial till is close to the seabed, rather than due to the SBP system's failure to reach the desired depth. The data is uniform across the different vessels used in acquisition

Data examples for each vessel are presented below.

Data acquired by GOIV vessel is presented in Figure 48. The data shows clear image with minimal noise or artifacts which would interfere with processing and interpretation. Data penetration is good ranging from 4 meters to 10 meters, in some areas. Where interpreted till/coarser sediments are expected close to the surface, penetration has been limited by geology. The resolution is excellent, and fine laminations are visible (left side of dataset). Minor ambient noise is present in the water column.

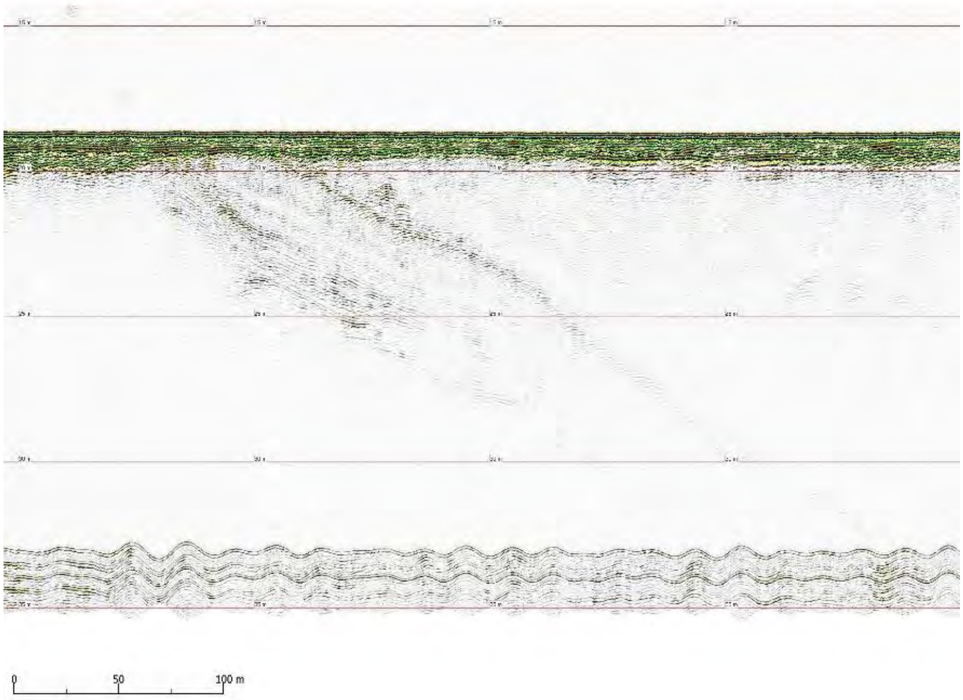


Figure 48: Line 0660-5950_A_NS-ECR01B_GOIV_L49V from vessel GOIV

Data acquired by GEO X is shown in Figure 49. The quality of data is good with occasional noise from the vessel appearing as short vertical bursts. These occurrences don't interfere with data processing and interpretation as the layers are clearly visible. Resolution is good and fine lamination can be seen (left side of data example). Notable reflector near surface, interpreted as till, has limited data penetration with a range of approximately 2 to 7 metres, approaching 10 m in isolated locations.

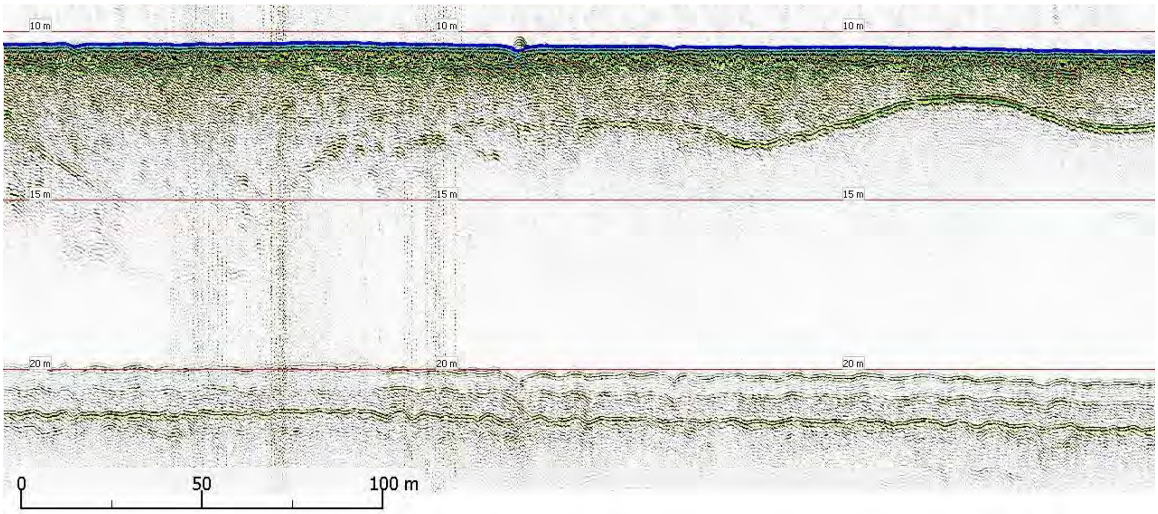


Figure 49:Line 0498_NS-1_GeoX_L232 from vessel GeoX

Data acquired by GSV is presented in Figure 50, which shows some very small bursts of noise in the dataset caused by the vessel. Resolution is good with fine lamination showing. Penetration has been limited by the presence of till/coarse sediments as well as the first multiple, present within the first 10 m of the dataset due to the shallow water, but good reflections are observed in the figure below to the limit that the multiple allows. Some swell noise in affecting data along a few lines, however not to the extent to prevent interpretation of the data.

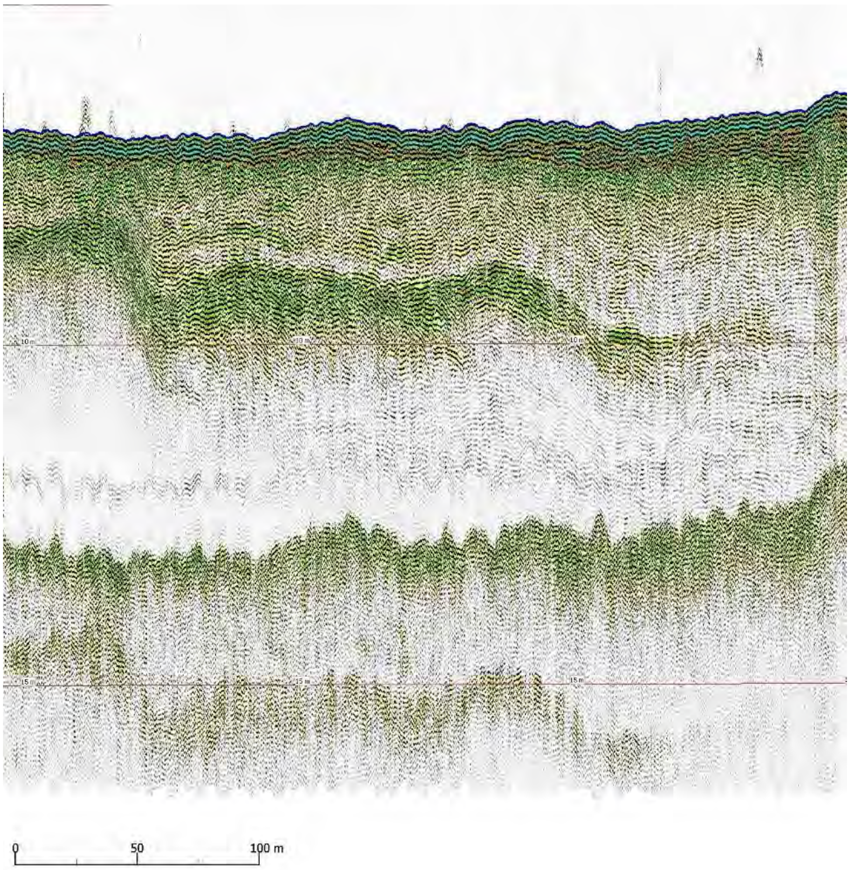


Figure 50: Line 0252_5950_B_NS_ERC0 from vessel GSV

5.5.5 Depth SBP data

The SBP depth data are based on the final time SEG-Y files. The water column and recorder delay are depth converted at the water velocity. This velocity INTERVAL extends from the top of the record to a point just above the picked water bottom. This small offset ensures that the seabed return signal is not distorted by the transition from one interval velocity to another. Due to the large range of water velocities observed across the site and between vessels, an average water velocity of 1492 m/s was used for time/depth conversion of the water column.

The remainder of the record is converted at an assumed velocity of 1650 m/s. This is because these shallow penetrating data only image normally consolidated, uncompacted sediments and there are no associated processing velocities to consider.

This sub-seabed interval velocity was also applied to the thickness conversion of the interpretation of the upper two units: the depth SBP data match the supplied thickness/depth grids for units I and II.

The depth SEG-Y lines are in the Kingdom projects as multiversions of the parent timelines. All interpretation is of the time data. These time interpretations have been thickness and depth converted and can be displayed on the depth lines as grids. The depth data/interpretation show some very minor artefacts (<0.3 m) related to busts between adjacent lines. These artefacts are primarily caused by the high density of survey lines and slight variations in horizon picking between these lines.

5.6 GRAB SAMPLING

Grab sampling was carried out to support the interpretation of the seabed surface geology.

Only grab samples comprising a minimum of 40 % grab capacity or minimum 5 kg of material with no evidence of wash-out was accepted.

All sampling operations were logged during operations both on deck and independently in the laboratory. This allowed quality control and cross-checking of operations on completion of the project.

After a preliminary visual geological description of the soil, the samples were stored on the vessel for potential later transportation to an onshore laboratory for further testing.

All grab samples were subject to a geological characterization according to Larsen et al. (1995).

All grab samples were described regarding:

- Lithology
- Depositional environment
- Geological age

Grab samples were subject to the following geotechnical classification tests:

- Particle size, Sieve analysis
- Particle size, Hydrometer analysis
- Organic content, Loss on ignition

All field observations were made in accordance with Dansk Geologisk Forening (DGF) detailed in Larsen et al. (1995). However, laboratory analysis was conducted in accordance to BS EN ISO 17892-4 which uses the Wentworth scale for particle size analysis. An overview of the sampling locations for NS ECR 1, NS ECR 2 and NS ECR 3 are presented in Figure 51, Figure 52, and Figure 53, respectively.

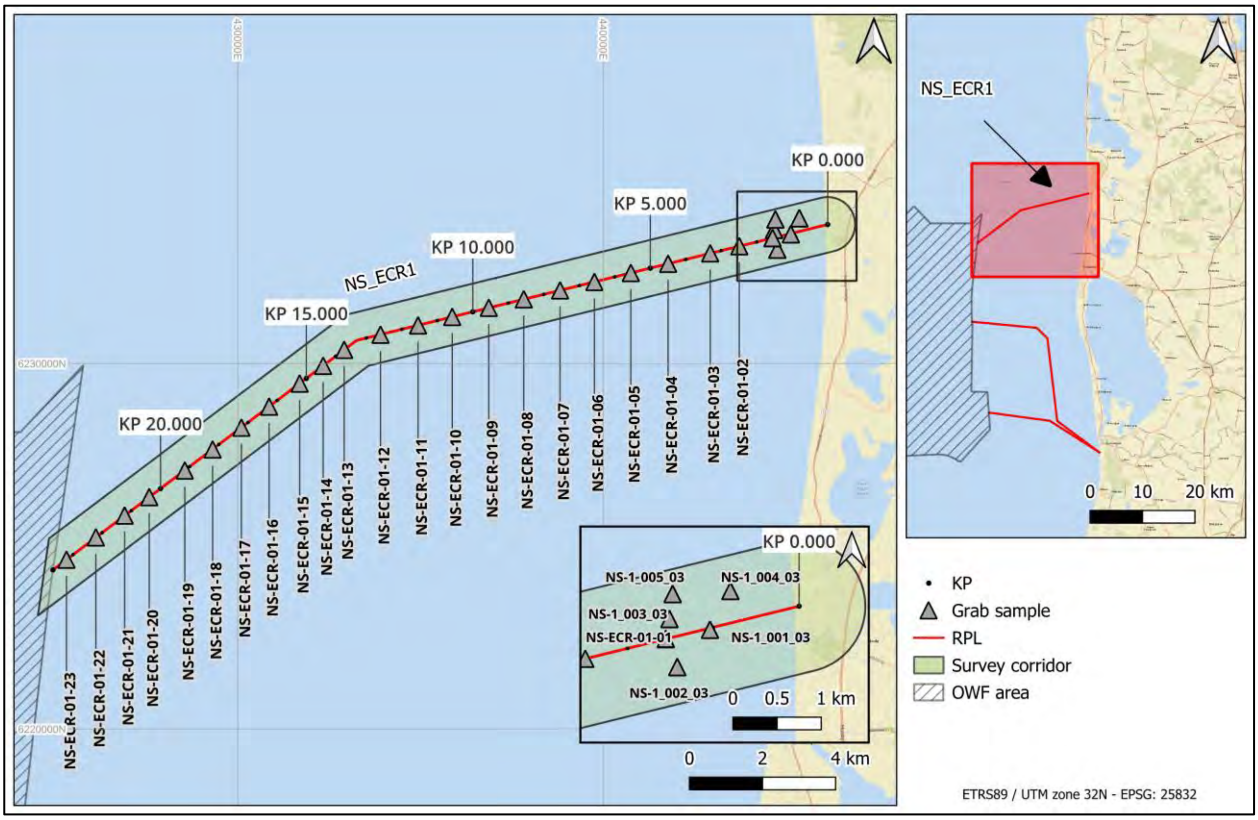


Figure 51: Grab sampling locations overview NS_ECR1

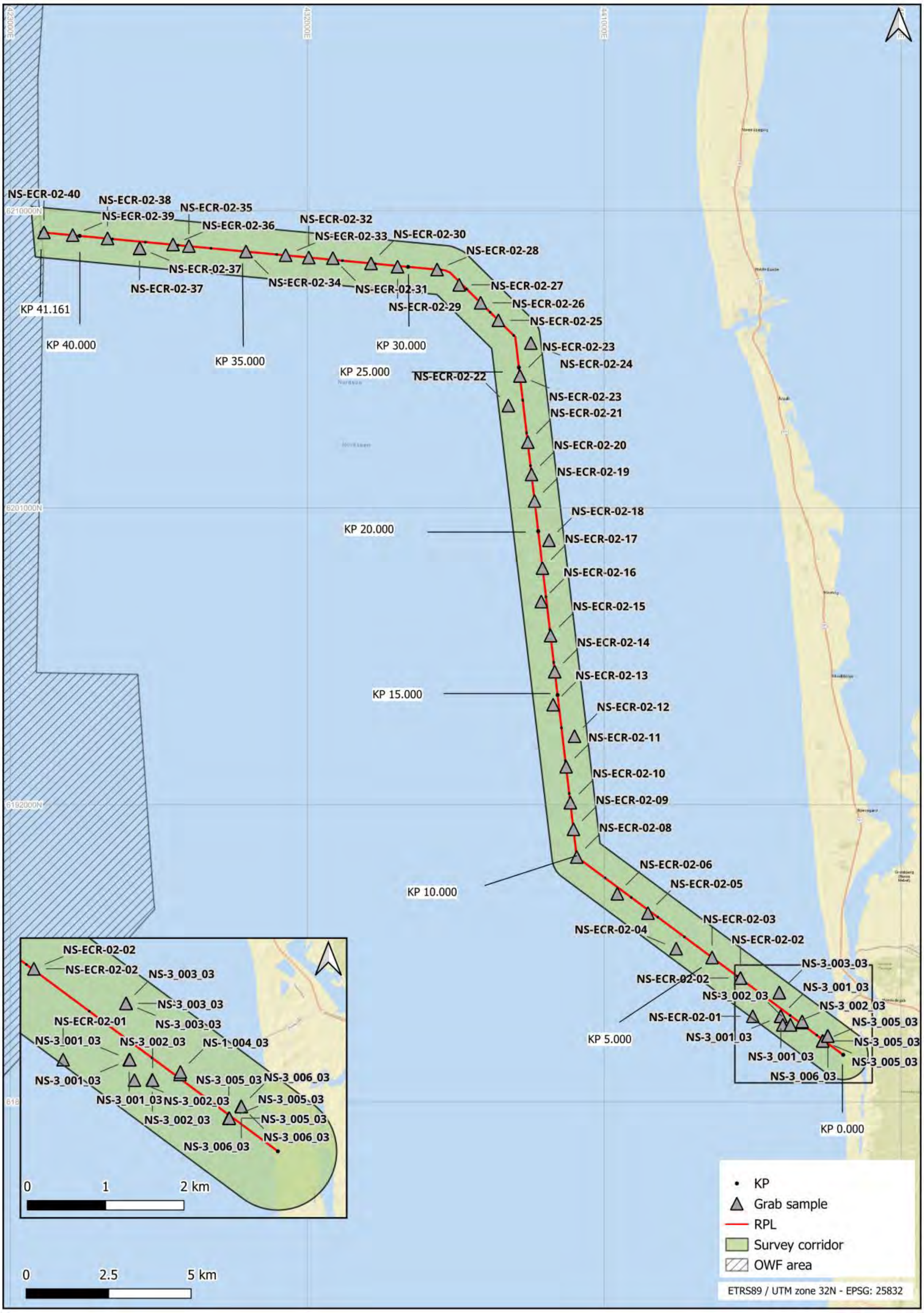


Figure 52: Grab sampling locations overview NS_ECR2

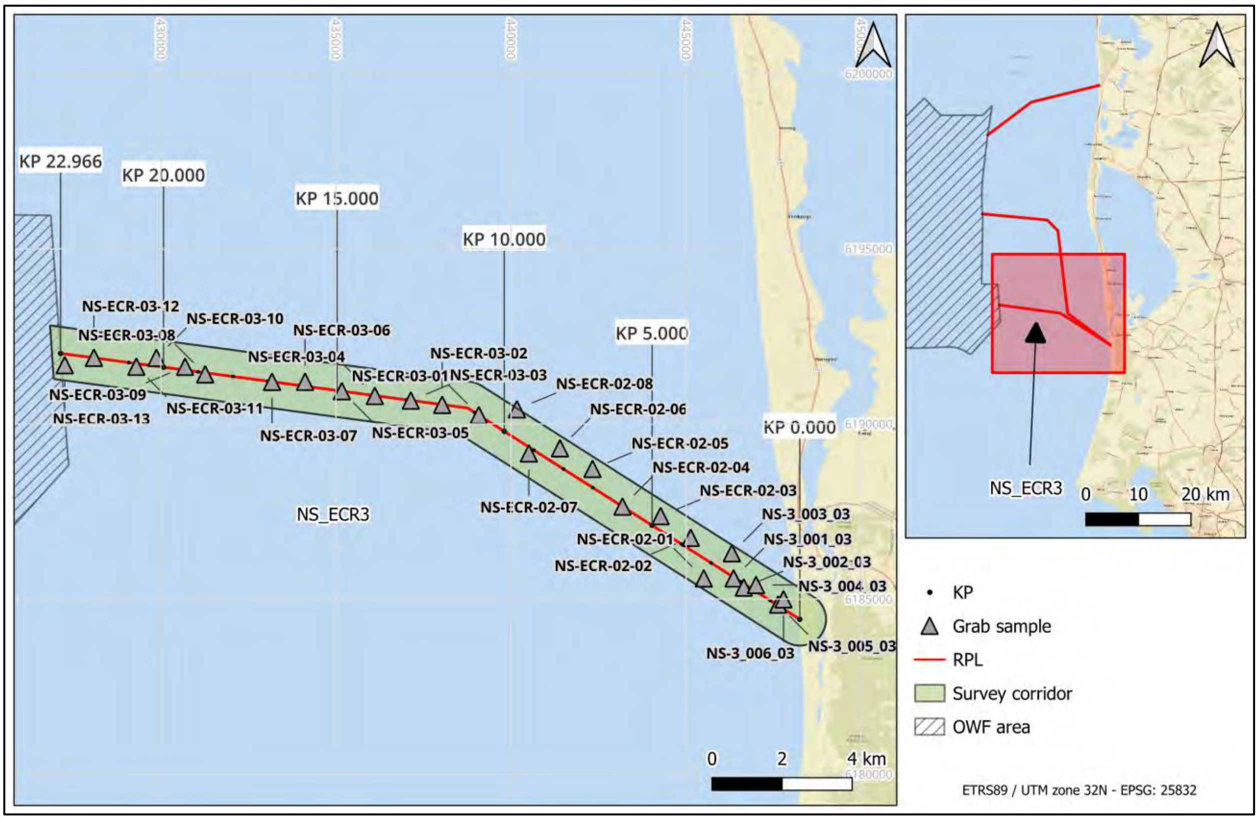


Figure 53: Grab sampling locations overview NS_ECR3

5.7 GEOTECHNICAL SAMPLING AND TESTING

The offshore geotechnical survey was conducted from the DP II vessel Connector and included 79 locations for CPTU, VC, and in-situ TRT. The survey was executed using Geo DK’s combined seabed rig GeoCeptor, capable of performing CPTU, VC, and in-situ TRT in a single deployment (Figure 54). The CPTU unit and VC unit were located 80 cm apart.

Sampling locations were carefully selected by the client through an evaluation of survey data, including SBP, MAG, SSS, and MBES data. An overview of the exact CPTU, VC and TRT test quantities, outlined per cable route, can be found in Section 2.5.3.

Summaries of the selected results from the geotechnical investigation for NS_ECR1, NS_ECR2, and NS_ECR3, are presented in the Geotechnical results sections 6.6, 8.6, and 10.6 respectively.

A detailed account of the geotechnical dataset can be found in the geotechnical report. For full access to the results from the geotechnical investigation, please refer to the external document as Appendix C (DOW2030 - WPC, North Sea, Factual Report, Rev. 01, 2024-11-12 REPORT”).

Figure 54: GeoCeptor - Combined Vibrocore and CPTU rig

5.7.1 CPT testing

A total of 82 seabed CPTUs were performed across 79 locations, with target depths of 3 m and 6 m. Penetration depths ranged from a minimum of 3.20 mbsb to maximum 6.40 mbsb, with an average penetration of 5.8 mbsb for tests targeting 6 m and 3.4 mbsb for tests targeting 3 m. Three re-runs were conducted due to unsatisfactory results or failure to reach target depth on the initial attempt. Re-runs were identified by appending "a" or "b" to the original location ID.

5.7.2 Vibrocore sampling

A total of 91 VCs were performed across the 79 geotechnical locations, with target depths of 3 m and 6 m. (maximum target depth for VC is 5.7 when TRT equipment is mounted), including 12 re-runs, achieving penetration depths between 1.0 mbsb and 5.8 mbsb. As for CPTs, re-runs were identified by appending "a" or "b" to the original location ID. The average recovery was 4.0 m, with individual recoveries ranging from 0.8 m to 5.9 m. VC samples were transported to Geo DK's laboratory in Lyngby, Denmark, for further analysis.

5.7.3 In-Situ TRT

TRT was planned on 20 locations and successfully conducted at 21 of the CPTU/VC locations. Geo DK's subcontractor, Fielax, performed the testing using their Vibroheat equipment, providing thermal property data of the seabed materials.

5.7.4 Laboratory testing

Following the fieldwork, laboratory tests were conducted to evaluate soil conditions and determine key geotechnical characteristics. Table 60 provides types and amounts of laboratory testing performed on recovered sample.

Table 60: Overview of classification test on VC samples

Test type	Quantity	Sediment type	Standard
Geological Description and Classification	n/a	All	A guide to engineering geological soil description. G. Larsen et. al. DGF-Bulletin 1
Tor Vane	116	Cohesive	ASTM D8121/D8121M_9
Pocket Penetrometer	79	Cohesive	ISO 19901-8:2014(F)
Geotester	40	Cohesive	ISO 19901-8:2014(F)
Moisture Content	39	All	ISO 17892-1:2014
Bulk / Dry Density	344	All	EN ISO 17892-2:2014
Particle Size Distribution	157	All	DS/EN ISO 17892-4:2016
Atterberg Limits	45	Cohesive	DS/EN ISO 17892-12:2018 |
Max. and Min. dry density	32	All	DGF Bulletin 15
Thermal Conductivity	79	All	ASTM D5334-14
Loss on Ignition	145	Organic	ASTM D2974-20
Particle density	165	All	DS/EN ISO 17892-4:2016
C14 dating	16	Organic	In-house procedure by Beta Analytical Inc.

Particle Size Distribution (PSD)

The characterization of soil types along the route was achieved by integrating visual descriptions of split VC samples with PSD analyses (Figure 71, Figure 72, Figure 123, Figure 124, Figure 188, and Figure 189). A total of 157 sieve analyses and 92 hydrometer analyses were conducted, with visual VC sample descriptions updated based on PSA results. Sieve analyses included all material components, with gravel content potentially incorporating shells, fragments, and organic debris. Hydrometer tests were performed when fines exceeded 10 %. Combined results provided detailed data on D10, D30, D50, D60, D90, Cu, and the percentages of clay, silt, sand, and gravel, as documented in the geotechnical report.

Thermal conductivity

Thermal conductivity tests have been carried out on both intact VC samples and reconstituted specimens. Forty-seven tests were measured directly in the VC samples just after opening of the core, and the corresponding classification parameters were determined in proximity to the conductivity test. The samples were kept at room temperature before the measurements. All tests were conducted using the MP-2 controller from Thermtest and the needle TLS100. Thirty-two tests have been carried out on granular samples as reconstituted tests. The specimens are reconstituted to a target density based on the relative density obtained from the CPTU and maximum and minimum dry density tests. For some specimens the relative density derived from the CPTUs was lower than 35 %. The low relative density led to a lower target density, which made the reconstitution process of the specimen difficult to achieve during specimen preparation.

Consequently, these samples were tested assuming a relative density of 35 %. For other specimens there were no value of relative density detected at the CPTUs. These specimens were tested based on a relative density of 35 % or more.

Tor Vane

Tor Vane has been carried out both onshore and offshore on cohesive material for determination of undrained shear strength. Notably, the maximum value that can be measured by the tor vane is 250 kPa.

Geotester / Pocket Penetrometer

Pocket Pen has been carried out both onshore and offshore on cohesive material for determination of undrained shear strength. It should be noted that the maximum value that can be measured by the pocket penetrometer is 1000 kPa.

Moisture Content

Moisture content is an accredited test and has been determined if Bulk and Dry Density test was not possible. The values range from lowest 1.9 % in SAND to highest 273.7 % in PEAT sediment type.

Bulk and Dry Density

Bulk and dry density measurements have been conducted onshore across all soil types. The highest values were recorded in SAND, where the bulk density reached 2.53 g/cm³ and the dry density measured 2.23 g/cm³ at the depth of 0.10 metres below seabed.

Atterberg Limits

The liquid and plastic limits were determined on 45 specimens. The plasticity index for 42 of the specimens varies between 7 and 64 %. Three samples were non-plastic (VC_014 specimen 2.2D, VC_039 specimen 1.1D and VC_076 specimen 3.1D).

Organic Content

Tests has been conducted on all types of material indicating a content of organic matter. The organic content in these samples varies between 0.2 – 65 %. The results of the organic content determination tests are considered reliable, and representative of the material encountered across the site.

C14 Dating

C14 dating were performed at Beta Analytical Inc. according to an in-house standard. The "Conventional Radiocarbon Age" was calculated using the Libby half-life (5568 years) and was corrected for total isotopic fraction and was used for calendar calibration where applicable. The Age is rounded to the nearest 10 years and is reported as radiocarbon years before present (BP), “present" = AD 1950. Results greater than the modern reference are reported as percent modern carbon (pMC). The modern reference standard was 95 % of the 14C signature of NIST SRM-4990C (oxalic acid). Dating has been conducted on all types of material indicating a content of organic matter.

Details about geotechnical methods and sampling/testing results are provided in Table 61 and APPENDIX C and are discussed alongside SBP data in the Sub-surface geology sections of each route.

5.7.5 Ground truthing for acoustic data interpretation

Geotechnical parameters reported in Table 61 have been correlated with the acoustic dataset to support ground truthing:

- Seabed nature: Determined based on the description of the upper sections of the VC samples and CPT result
- Sub-seabed units: Interpreted using data from VC, CPT, and laboratory test results.

The results of the integration between geotechnical data and geophysical interpretation are discussed in Sections 6.6 (NS_ECR1 Route), 8.6 (NS_ECR1 Route) and 10.6 (NS_ECR1 Route).

Table 61: Analysis on vibrocores and CPTs integrated in our results

Analysis	Description
Bulk density	Dry weight of soil per unit volume of soil.
Moisture Content (%)	Mass of water which can be removed from the soil, usually by drying, expressed as a percentage of the dry mass.
D50 percentile value	Median diameter of particle size distribution, value of the particle diameter at a 50 % in the cumulative distribution.
D90 percentile value	Grain size of the 10 % “coarse" fraction of the sample
Cone resistance (Qc)	Cone resistance presented in MPa
Friction resistance (Fc)	Sleeve friction resistance in MPa

5.8 CLASSIFICATION CRITERIA

5.8.1 Seabed gradient classification criteria

Seabed gradient has been classified as per Table 62 below.

Table 62: Slope classification

Classification	Slope
Very Gentle	< 1°
Gentle	1° - 5°
Moderate	5° - 10°
Steep	10° - 15°
Very Steep	> 15°

5.8.2 Confidence interval classification for targets

Confidence interval classification for targets has been classified as per Table 63.

Table 63: Confidence interval classification for targets

Confidence interval	Criteria
Low	Visible on a single SSS line
Medium	Seen on more than one SSS line
High	Seen on one or more SSS lines and MBES

5.8.3 Boulder field classification

Boulders zones were mapped with the automatic tool for boulders > 0.5 m (height/length/width). Individual boulders/blocks within boulder zones were mapped with the automatic tool for boulders > 2 m (height/length/width). Any rocks/blocks outside boulder zones were mapped by manual method on boulders > 1 m (height/length/width).

Boulder fields were classified as per Table 64 below.

Table 64: Boulder field classification

Number of targets within 50 x 50 m area	Boulder Identified	Class
0 – 10	>1 m in any direction	Not a boulder field
10 – 20	>2 m in any direction	Intermediate
> 20	>2 m in any direction	High density

5.8.4 Mobile bedform classification

Nomenclature for mobile bedform classification is presented in Table 65 below. The bedforms were measured off the MBES data and classified accordingly. They were classified based on whichever of the two, height or wavelength, fall into the larger category, e.g. for example, if wavelength of the ripple was 3 m but height was 0.3 m then it was classified as a large ripple.

Table 65: Bedform classification

Bedform classification	Height (m)	Wavelength (m)
Ripples	< 0.1	< 5
Large ripples	0.1 – 1.0	5 – 15
Megaripples	1.0 – 3.0	15 – 50
Sand waves	3.0 – 5.0	50 – 200

5.8.5 Sediment classification

The sediments across the survey areas have been described using a combination of the DGF, GEUS and Wentworth classifications.

For the grab sample analysis, the definition of the particle sizes followed the Wentworth scale. The sediment classifications in the seabed geology polygon shapefile deliverable were then made by correlating the observations seen in the MBES, backscatter and SSS data with the grab and geotechnical results and were described according to the DGF classification and GEUS Sediment Classes for Danish surface seabed sediments.

Details of the Wentworth scale for classifying sediments are presented in Figure 55, with the GEUS seabed sediment classification for Danish waters in Table 66.

Major Grade	Phi (Φ) limits		Wentworth size class
	Lower	Upper	
gravel	<-8	-8	boulder
	-8	-6	cobble
	-6	-2	pebble
	-2	-1	granule
sand	-1	0	very coarse sand
	0	1	coarse sand
	1	2	medium sand
	2	3	fine sand
	3	4	very fine sand
mud	4	5	coarse silt
	5	6	medium silt
	6	7	fine silt
	7	8	very fine silt
	8	>8	clay

Scale by Wentworth (1922) classifying sediment particles according to the diameter expressed in units of N (phi, the negative log 2 of the diameter in millimeters).

Figure 55: Wentworth Scale – classifying sediment particles

Table 66: GEUS Seabed Sediment Classification for Danish Waters

GEUS Sediment Class	GEUS Sediment Description for Danish Waters
Quaternary clay	Marine, meltwater or lake deposits of clay. Often laminated with sand/silt and/or peat layers, in some cases covered by few cm of lag sediments (sand, gravel or pebbles). The deposit is often related to the Yoldia Clay (Kattegat), The Baltic Icelake (The Baltic Sea) or Holocene clay (The North Sea).
Mud	Soft and fine-grained sediment with more than 10 % fine organic matter and less than a few percent coarser material. Very high water content. Often with shells and plant remains. Related to accumulation and basin areas in the inner Danish waters.
Sandy Mud / Muddy Sand	A mixed sediment type composed of variable content of sand and mud. Deposited at the rim of basins or as a thin cover layer in erosion areas.
Sand	Homogeneous layer of loose, well-sorted sand. Often combined with ripples and/or sand waves due to current or wave action.
Sand, Gravel and Pebbles	Mixed sediments of more than 0.50 m thickness. Lag sediments covering till, meltwater deposits or fossil coastal deposits.
Till	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.
Sedimentary bedrock	Not observed in this survey area.

6 NS_ECR1 ROUTE OVERVIEW

6.1 RESULTS

This report section provides a detailed analysis of the findings within the NS_ECR1 survey area from topographic data, bathymetric data, side scan sonar data, sub-bottom profiling, and magnetometer surveys conducted within the survey area.

Datasets were reduced to MSL, which involved applying the DTU21MSL geoid separation model during post-processing.

Listings for all sonar, magnetometer and sub-bottom contacts and linear targets across the site are presented within each relevant section of the text. A confidence level is assigned to sonar contacts as presented previously in Section 5.8.

6.2 BATHYMETRY AND TOPOGRAPHY

The elevation levels across the NS_ECR1 site range from a highest point of 24.94 metres above mean sea level (MSL) near 446241 mE, 6233511 mN in the eastern landfall area, to a deepest point 28.61 metres below MSL near coordinates 424657 mE, 6223773 mN towards the western boundary of the survey area. Figure 56 presents a comprehensive overview of the NS_ECR1 1 survey area, merging both topographic and bathymetric data to illustrate the general morphology.

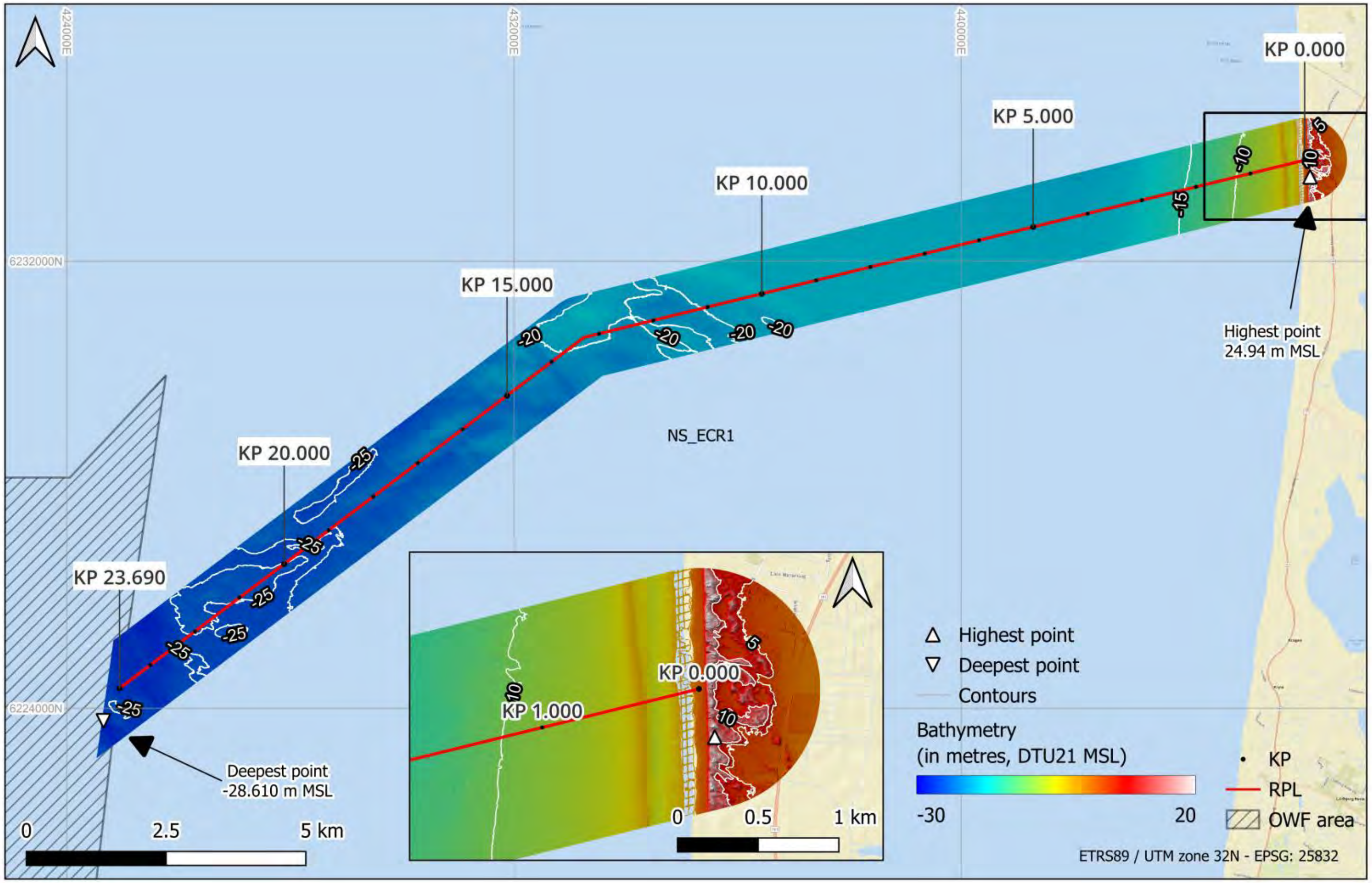


Figure 56: Bathymetry and topographic combined overview NS_ECR1

6.2.1 Landfall and topography

Starting at landfall and moving eastwards from zero MSL towards KP 0.000 of the RPL, the gradient rises at approximately 2.3° over 41 metres, resulting in an elevation gain of 1.75 metres at the beginning of the RPL. Continuing landwards, there is a significant increase in the elevation with the gradient of 5.7° over 60 metres (i.e., distance from the KP 0.000 to the closest approximate highest point on land). Further inland, the survey area is characterised by gentle mounds / dunes with the highest point of 24.94 metres MSL located southern form the KP 0.000. The height of these mounds / dunes decreases when moving further eastwards. General topographic overview is provided in Figure 57, and a detailed overview is shown in Figure 58.

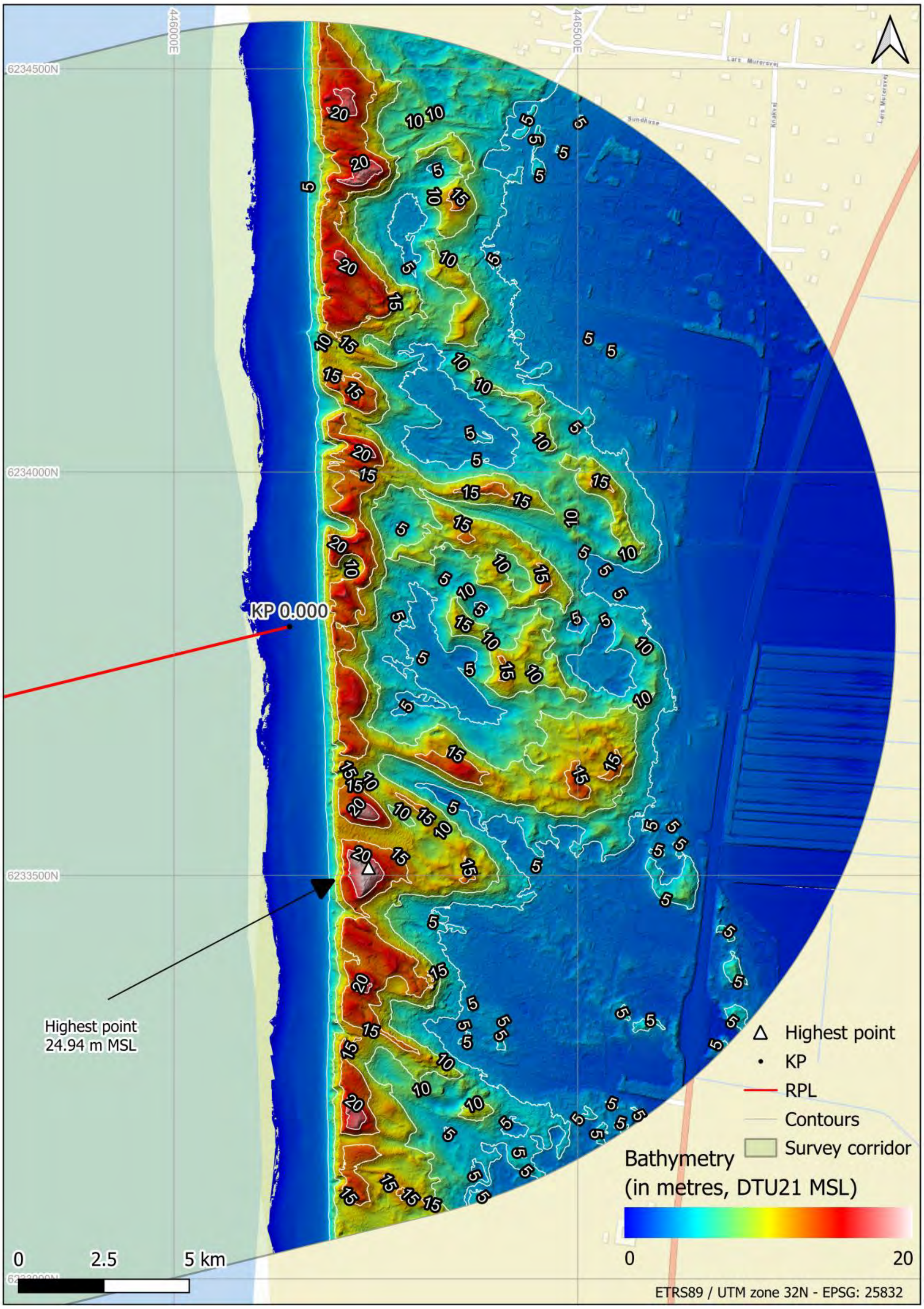


Figure 57: Topographic overview NS_ECR1

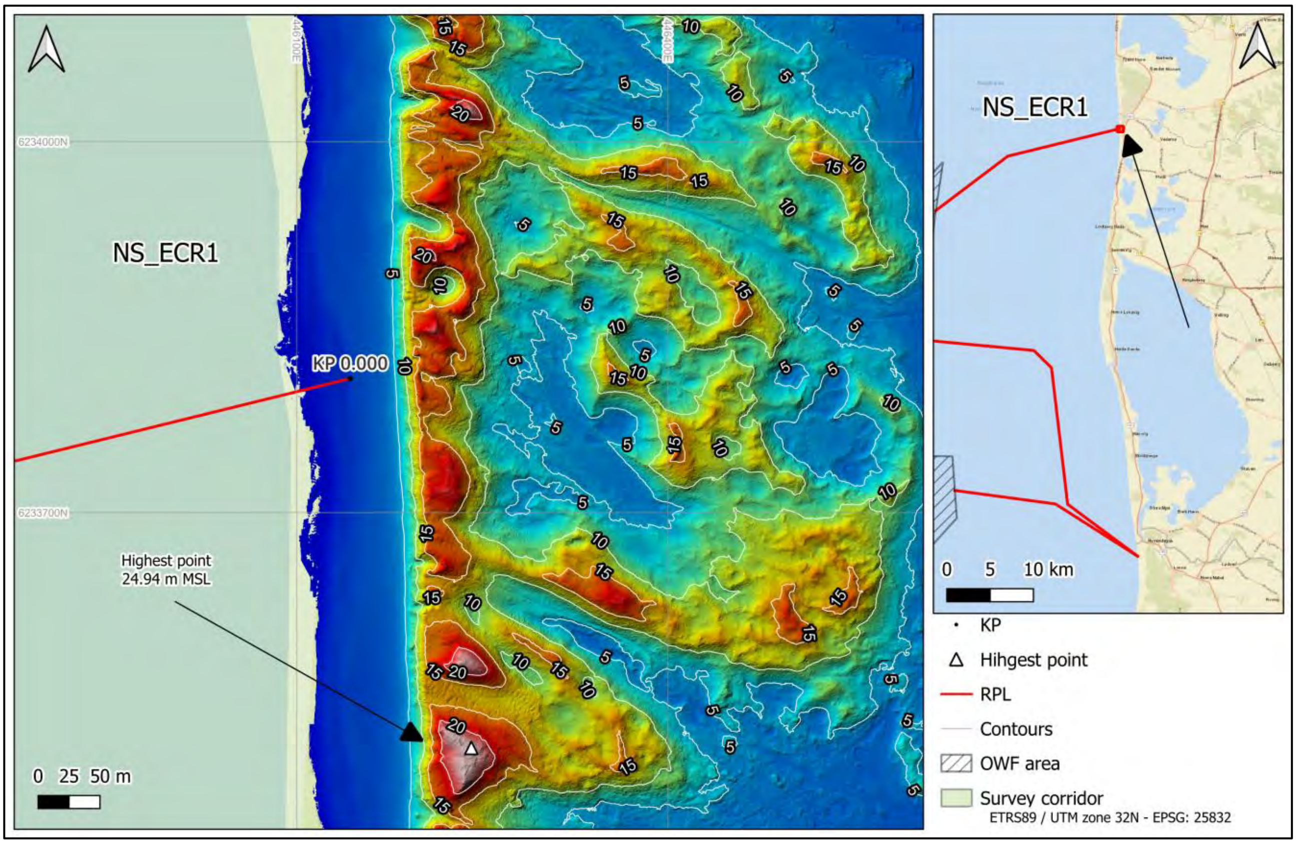


Figure 58: NS_ECR1, landfall, detailed overview

6.2.2 Bathymetry overview

A comprehensive overview of the bathymetry within the NS_ECR1 survey area is illustrated in Figure 59, while a detailed bathymetry profile along the Route Position List (RPL) is depicted in Figure 60.

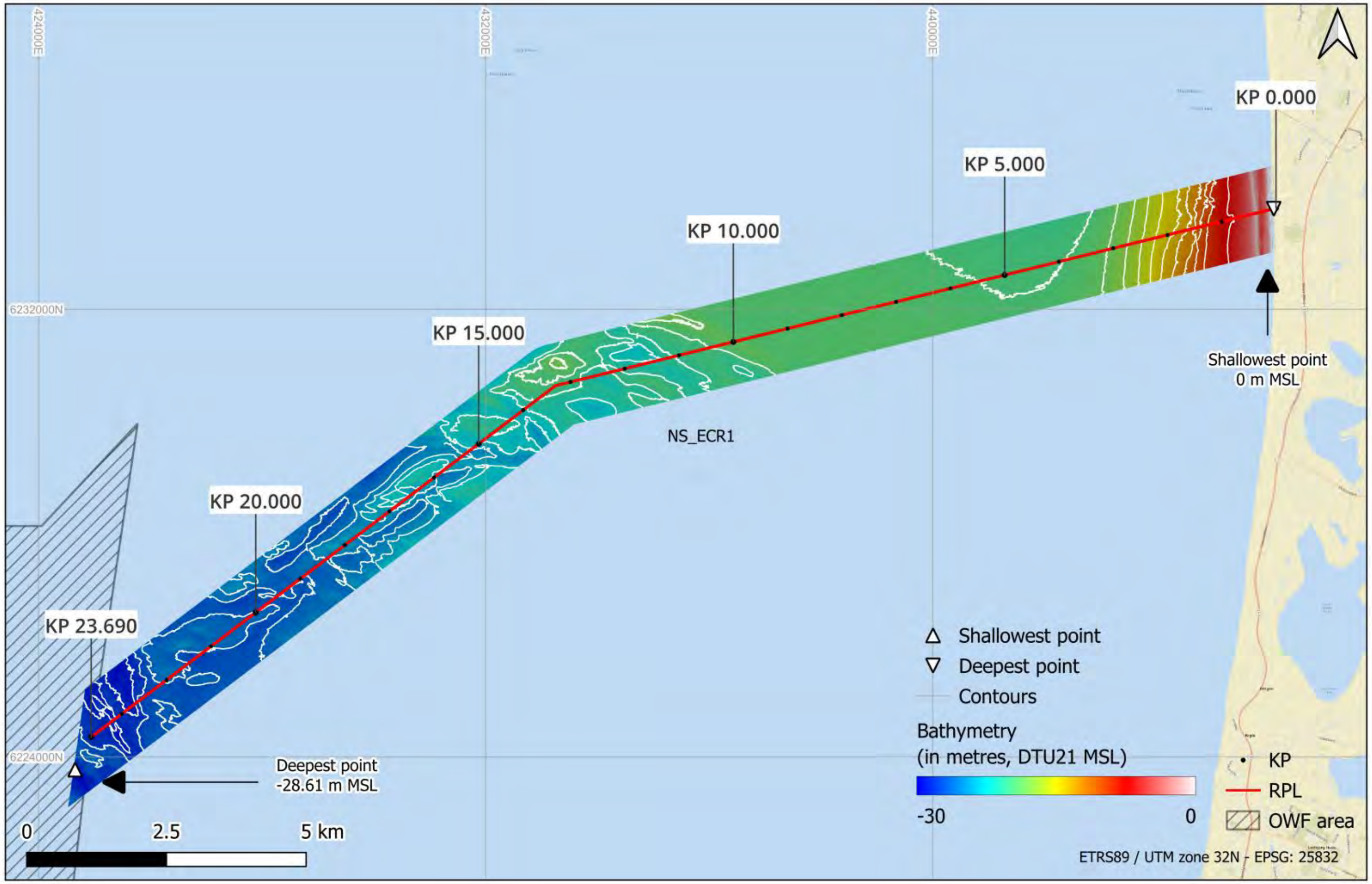


Figure 59: Bathymetry overview for NS_ECR1

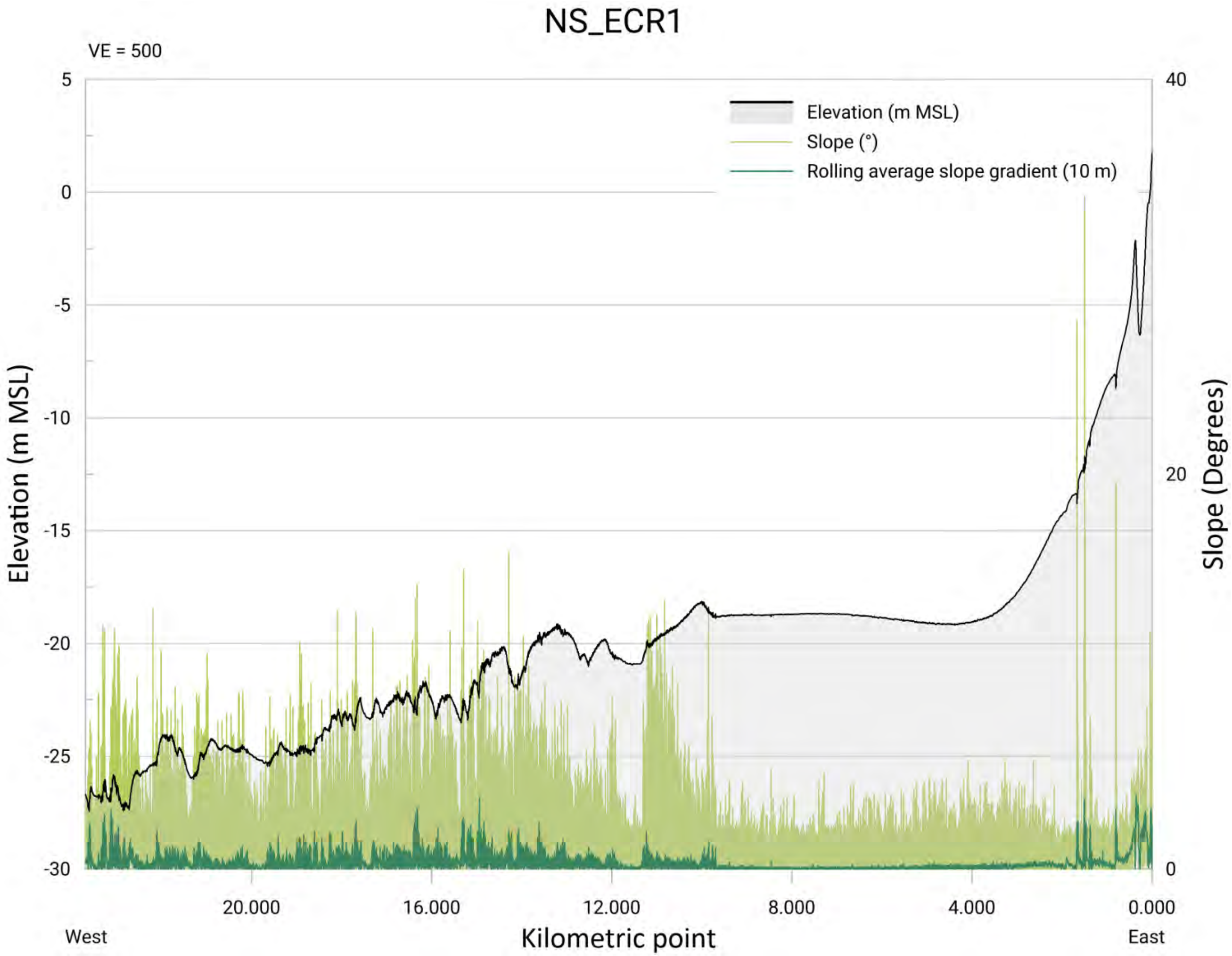


Figure 60: Depth and slope profile along the NS_ECR1 (created from 0.25 m grid)

Overall, the majority of the NS_ECR1 area is characterized by gentle to moderate slopes, ranging from 1 to 10 degrees. The highest concentration of steep slopes located near KP 0.000, towards the inland areas. In the eastern, nearshore part of the route from KP 0.000 towards KP 4.000 there is a sudden deepening of the seabed, ranging from 1.75 m MSL at the landfall to approximately -18 m MSL at KP 4.000. These initial KPs, near the coast are characterized by steep slopes, reaching up to 56 degrees and rolling average slope gradient indicating morphologically dynamic seafloor, featuring ripples and sandwaves. From approximately KP 1.000 to KP 2.000 there is increase of the slope dynamics, up to very steep slopes. This area correlates with a boulder field area, as seen in Figure 61.

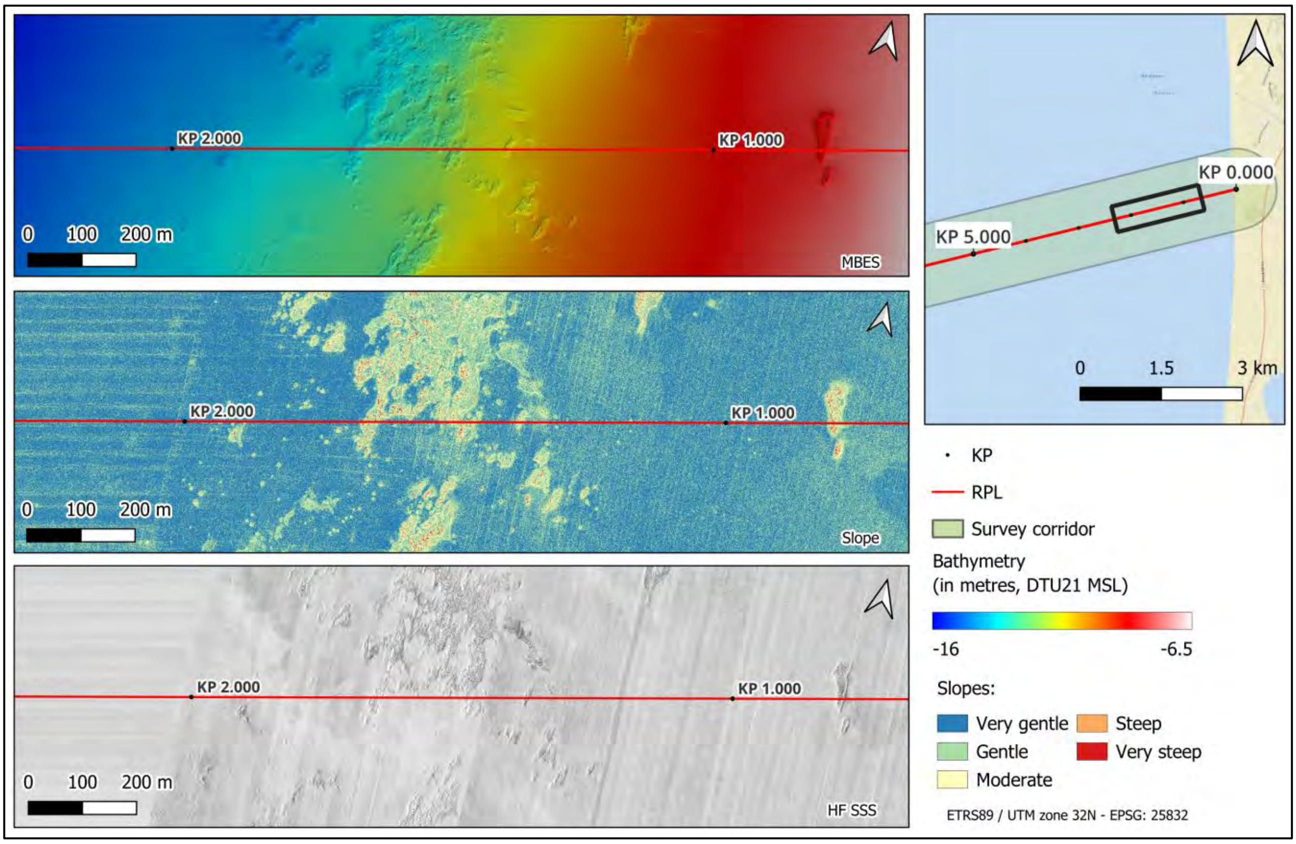


Figure 61: NS_ECR1, boulder field class 1 (MBES, slope, HF SSS)

From KP 4.000 to approximately KP 10.000, the seabed depth flattens and even shows a slight increase in the depth, for about 1.5 m. The low rolling average slope gradient values within this segment suggest a more stable seabed morphology with gentle slopes. This area correlates mostly with the sand sediments. From KP 10.000 to the end of the RPL, there is dynamic variability in the sea depth, with a general tendency towards deepening to approximately -26 m MSL at the far end of the RPL. Here, the slopes are mostly gentle to moderate, with steep slope areas corresponding to large ripples.

Figure 62 displays overall slope overview with inset maps:

A, B – steep slopes - corresponding to the large ripple areas

C – steep slopes corresponding to boulder field areas

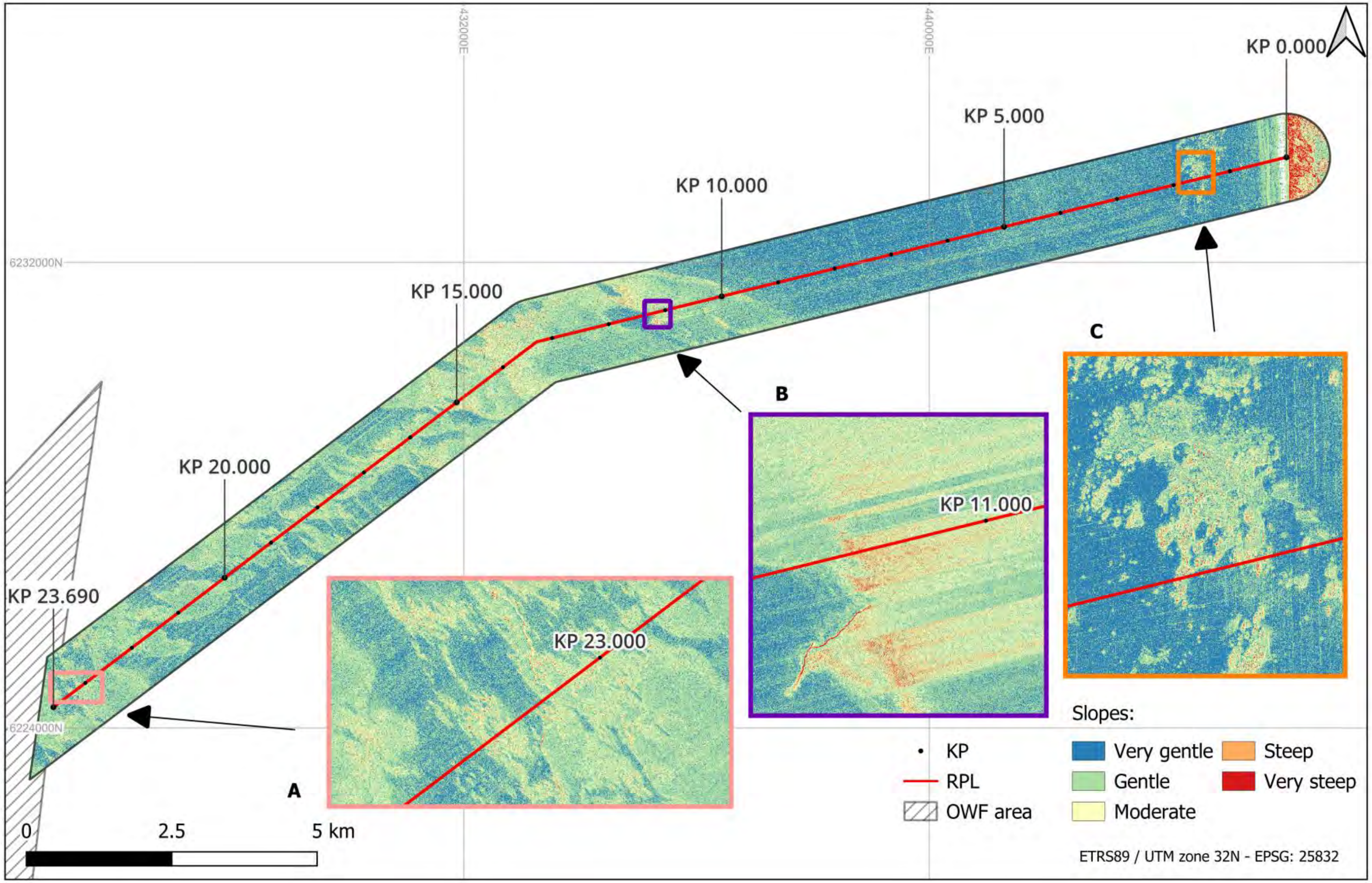


Figure 62: Slope overview of the NS_ECR1

6.3 SEABED SURFACE GEOLOGY

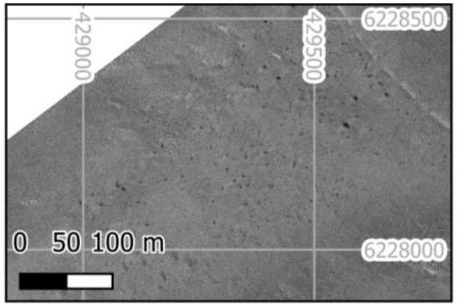
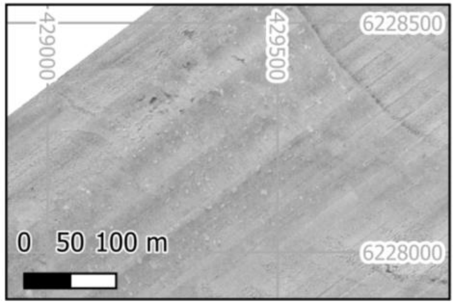
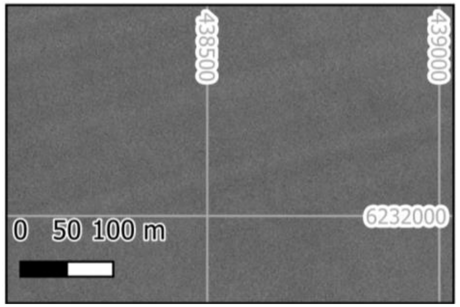
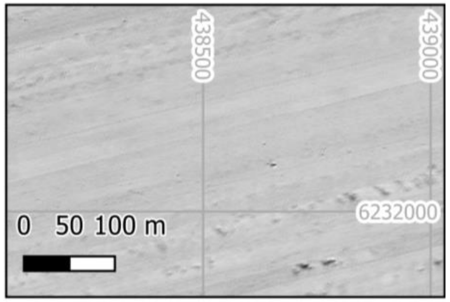
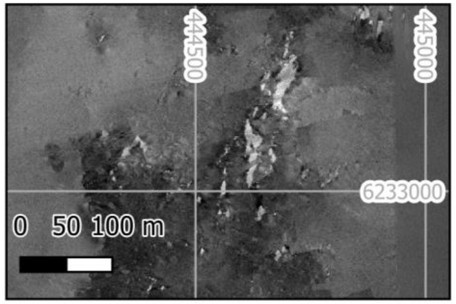
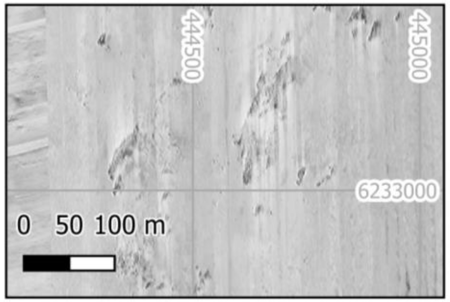
The seabed geology for the North Sea ECR1 survey area was evaluated from the interpretation of the low and high frequency SSS data, the backscatter imagery and the MBES dataset. Data analysis and classification was performed using the seabed acoustic characteristics, such as reflectivity and backscatter strength, as well as the seafloor relief and the overall pattern. During the interpretation of the SSS data, higher reflectivity areas – higher intensity sonar returns (darker grey to black colours) have been related to relatively coarse-grained sediments and lower reflectivity areas – lower intensity sonar returns were related to relatively fine-grained sediments (Table 67). Bathymetric data aided the interpretation mainly in outlining of possible outcrops and the boulder field delineation. As detailed in section 5.8.5, GEUS terminology was used to define the identified seafloor sediments in the survey area.

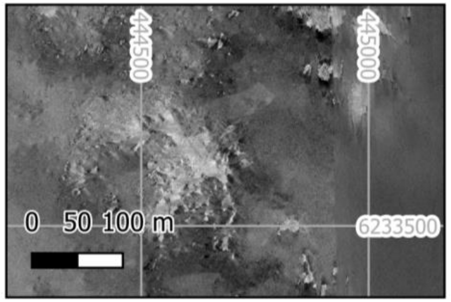
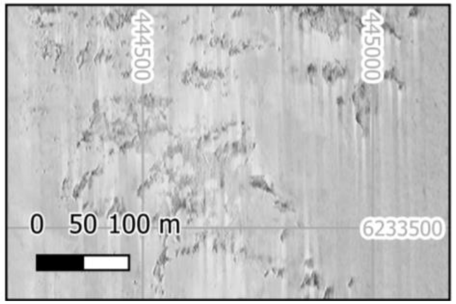
The resultant seabed surface geology has been correlated to the soil description of the surficial grab samples. Field descriptions of the grab results were in accordance to DGF however for the laboratory analysis, the definition of the particle sizes followed the Wentworth scale (Figure 55) in accordance to BS EN ISO 17892-4. Seabed geology was also correlated to Vibrocore Top Geology (seabed) results.

It should be noted that not only the grab samples (that might not be representative of the entire area outlined), but also SSS reflectivity, MBES relief, backscatter data, sub-surficial geology and the EMODnet classification have been considered for the Geology polygons.

Finally, seafloor sediment classification has been integrated to the sub-seabed geology data.

Table 67: Acoustic characteristics of the sediment types within the NS_ECR1 survey area

Geological interpretation	Colour and code	Sediment interpretation	Acoustic description	Backscatter image	LF SSS image
Muddy sand	13	Predominately sand with significant fractions of mud and muddy sand. May contain minor fractions of gravel	Low to medium reflectivity		
Sand	12	Predominately sand. May contain minor fractions of mud and/or gravel	Medium reflectivity		
Gravel and coarse sand	11	Mixed sediment. Predominately gravel and sand. May contain mud.	Medium to High reflectivity. Patches of high reflectivity interspersed in areas of low to medium reflectivity		

Geological interpretation	Colour and code	Sediment interpretation	Acoustic description	Backscatter image	LF SSS image
Till/diamicton	41	Mixed sediment. Constituents range between mud and boulders.	Low to High reflectivity. Patches of high reflectivity interspersed in areas of low to medium reflectivity. Usually, positive relief in MBES data		

The seabed geology of the North Sea ECR1 survey area consists predominantly of sand, along with sediments such as gravel and coarse sand, muddy sand and till/diamicton (Figure 63).

The beginning of the route, from KP 0.000 to approximately KP 3.000, is mostly characterized by gravel and coarse sand, with patches of till/diamicton between KP 1.000 and KP 2.000. From KP 3.000 to KP 5.500, the seabed along the RPL primarily consists of muddy sand, after which from KP 5.000 to KP 10.000, the seabed is dominated by sand, corresponding to regions with very gentle slopes and a nearly level seabed elevation. Small patches of till/diamicton occur south of the RPL, around KP 11.500.

Towards the west, from KP 10.000 to KP 15.000, sand and gravel and coarse sand dominate, whilst between KP 15.000 to KP 22.000 alternating muddy sand and sand are present. From KP 22.000 to the end of the RPL (and survey area), sand, and gravel and coarse sand alternate with smaller areas of muddy sand.

Figure 63 displays seabed surface geology overview with inset maps:

A – Sand, gravel and coarse sand and till/diamicton

B – Sand, muddy sand and gravel and coarse sand

C – Sand, muddy sand and gravel and coarse sand

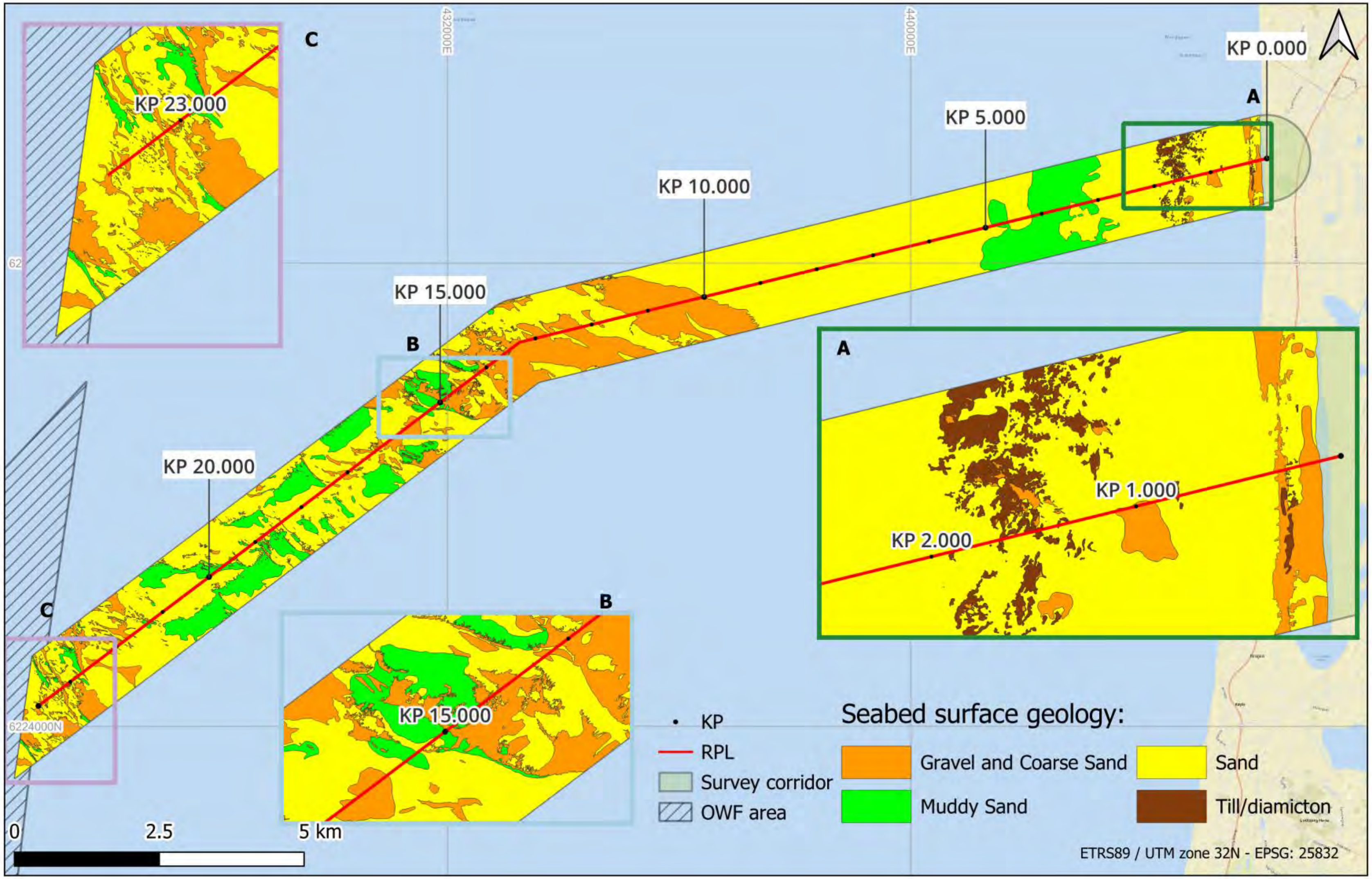


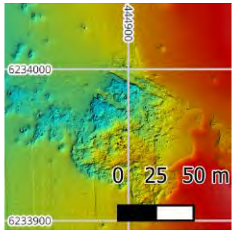
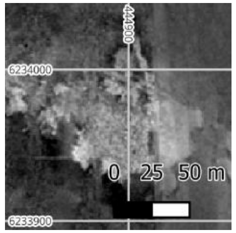
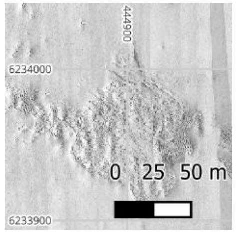
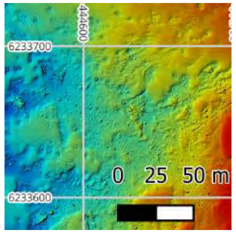
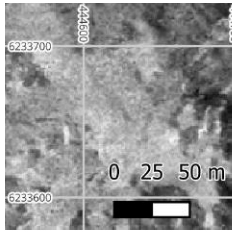
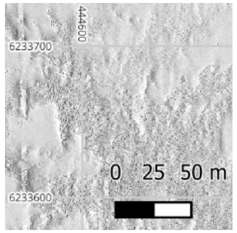
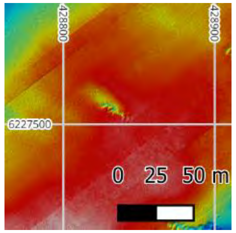
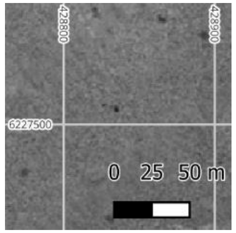
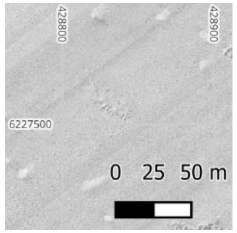
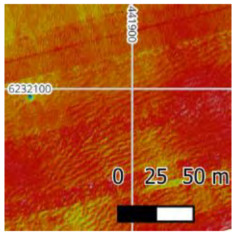
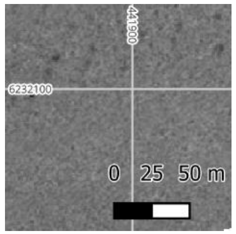
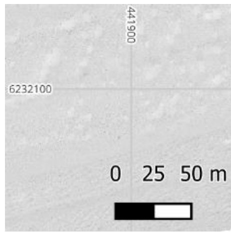
Figure 63: Seabed surface geology classification of NS_ECR1

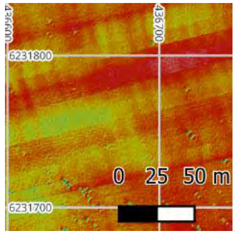
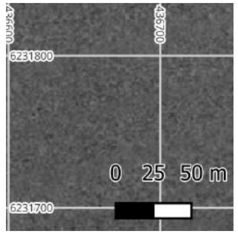
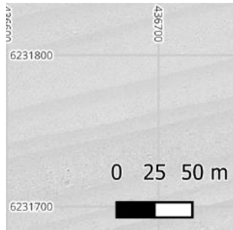
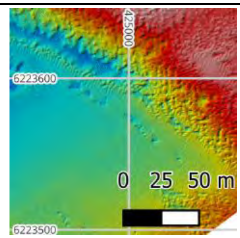
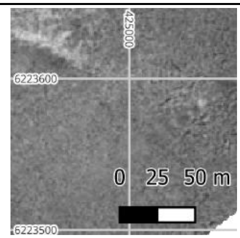
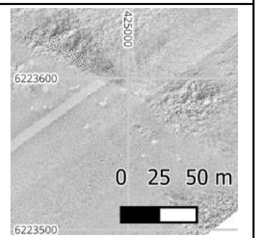
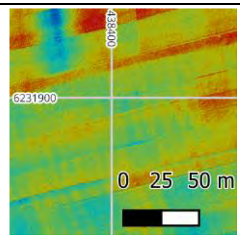
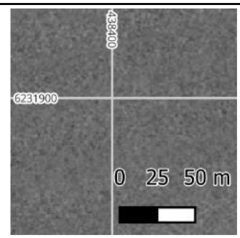
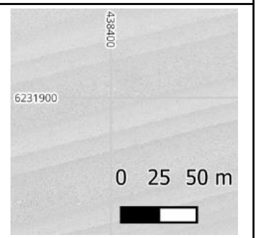
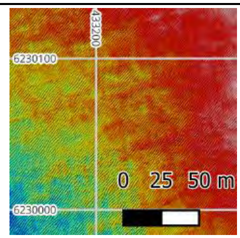
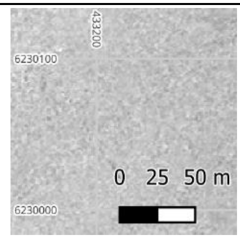
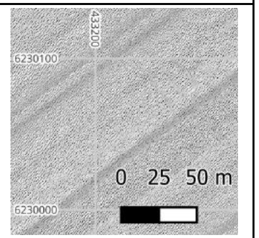
6.4 SEABED SURFACE MORPHOLOGY

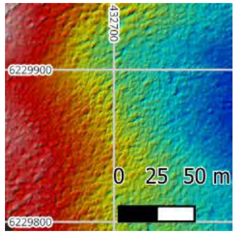
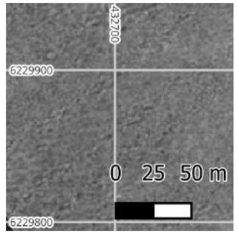
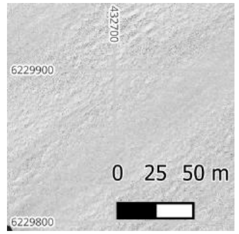
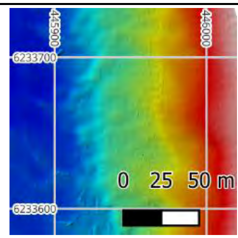
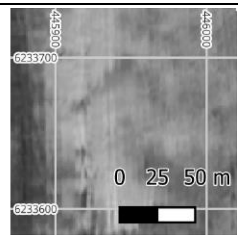
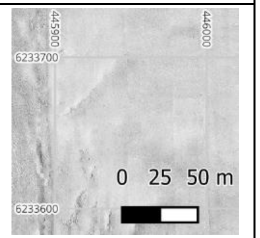
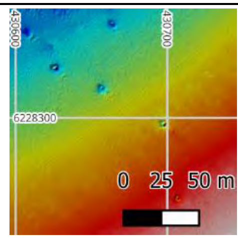
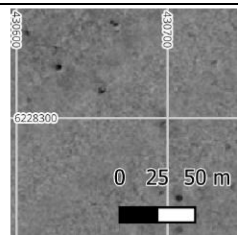
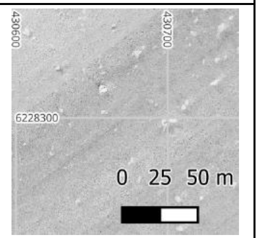
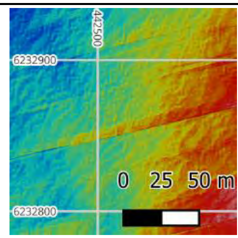
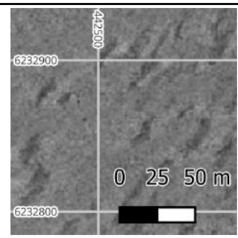
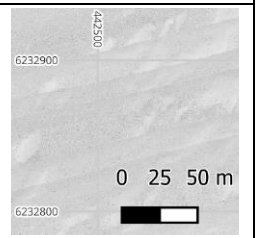
The seafloor morphology and seabed features were analysed using SSS (Side Scan Sonar), BS (Backscatter), and MBES (Multibeam Echo Sounder) datasets, with additional insights derived from SBP (Sub-Bottom Profiler) data. The acoustic characteristics of the interpreted seabed features at the NS_ECR1 site are depicted in Table 68.

A variety of morphological seabed features of differing dimensions were identified. These features reflect a diverse geological environment influenced by both historical and current hydrodynamic conditions associated with sea level fluctuations (e.g. areas of boulders, ripples). Ripples were classified based on their wavelengths and heights. Ripples were classified based on whichever of the two, height or wavelength, fall into the larger category, e.g. for example, if wavelength of the ripple was 3 m but height was 0.3 m then it was classified as a large ripple.

Table 68: Morphological interpretation – NS_ECR1

Seabed Feature	Symbology	Description	MBES image	Backscatter image	HF SSS image
Boulder Field - intermediate density (Class 1)		High reflectivity contacts of intermediate density (10 to 20 boulders in a 50 x 50 m box), visible in MBES			
Boulder Field - high density (Class 2)		High reflectivity contacts of high density (more than 20 boulders in a 50 x 50 m box), visible in MBES			
Disturbed seabed		Low to medium reflectivity, evidence of unnatural seabed disturbance			
Other - Bedforms. Sediment waveforms		Low to medium reflectivity linear scars forming a pattern, visible in MBES			

Seabed Feature	Symbology	Description	MBES image	Backscatter image	HF SSS image
Other - Erosional bedforms		Low to medium reflectivity features formed from sediment removal. Possibly early-stage ripple formation			
Other - Textured seabed		Medium reflective features, likely change in seabed sediment type			
Other - Featureless seabed		Areas of no significant seabed features (exception of boulders)			
Ripples		Low to high reflectivity alternating areas. Clear in MBES. Wavelength (<5 m) and height <0.01 m - 0.1 m) are the primary classifiers			

Seabed Feature	Symbology	Description	MBES image	Backscatter image	HF SSS image
Large Ripples		Low to high reflectivity alternating areas. Visible in MBES. Wavelength, 5 m - 15 m, height 0.1 m – 1 m.			
Sandwaves		Low to high reflectivity alternating areas. Visible in MBES. Wavelength, 50 m -200 m, height 3 m -5 m.			
Pitted seabed		Medium reflectivity circular depressions, possibly formed by scour around boulders			
Unknown – Patches of lower reflectivity, not visible on MBES		Low reflectivity irregular patches, distinguishable only in SSS.			

The resulting seabed surface morphology interpretation in North Sea ECR1 is presented Figure 64 and the distribution of these features are detailed below. The route does not exhibit any significant seabed features of concern, aside from the presence of boulder fields and areas of dynamic seabed, such as sandwave areas.

From KP 0.000 to KP 0.360, sandwaves and ripples dominate the seafloor. The seabed dynamic is confirmed by the bathymetric profile, which also indicates steep slopes in the nearshore region. Between KP 1.350 and KP 2.000, there are patches of boulder fields which are predominantly high density, as well as an additional isolated boulder field at KP 0.800. The distribution of these boulder fields aligns with the till/diamicton regions of seabed geology.

Between KP 2.000 and KP 5.500, the seabed morphology is primarily characterised by areas of ripples and patches of lower reflectivity as seen on the SSS data. These low reflectivity patches correlate to muddy sand in the seabed geology. Between KP 2.500 – KP 5.500 there are also some pitted seabed areas which are observed as isolated seabed depressions, possibly associated with scour around boulders. Similar seabed features are also observed between KP 16.000 – KP 17.000.

From KP 5.500 to KP 9.600, the seabed is largely featureless, with the exception of boulders, and correlates with an area of sand in the surficial geology.

From KP 9.500 to the end of the RPL, the seabed is mostly dominated by ripples or large ripples, which corresponds with more dynamic slope variability, including some steep slope values. These ripples exhibit wavelengths ranging from 0.5 m to up to 10 metres. Some patches of lower reflectivity as seen in the SSS data, and in correlation with areas of muddy sand in the surficial geology, are also observed in this western half of the route.

Figure 64 presents an overview of the NS_ECR1 seabed surface morphology, with detail views of the:

A - nearshore sandwaves and boulder fields

B - areas of pitted seabed and areas containing patches of lower reflectivity as seen on SSS data

C - dynamic area with ripples and large ripples at the end of the RPL

Figure 65 displays locations of the four linear seabed features (seabed scars) detected within the NS_ECR1 cable survey area.

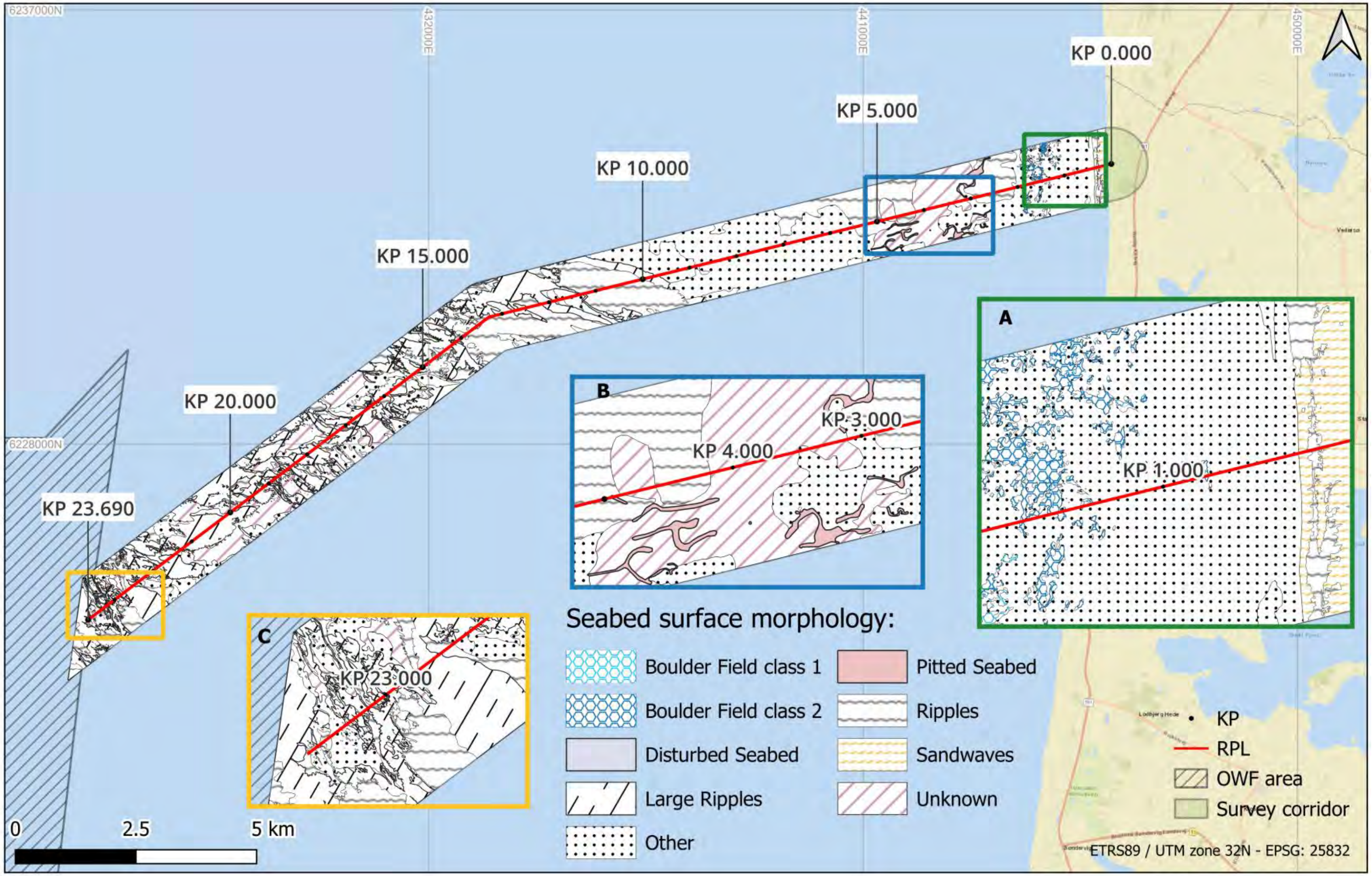


Figure 64: Seabed surface morphology overview, NS_ECR1

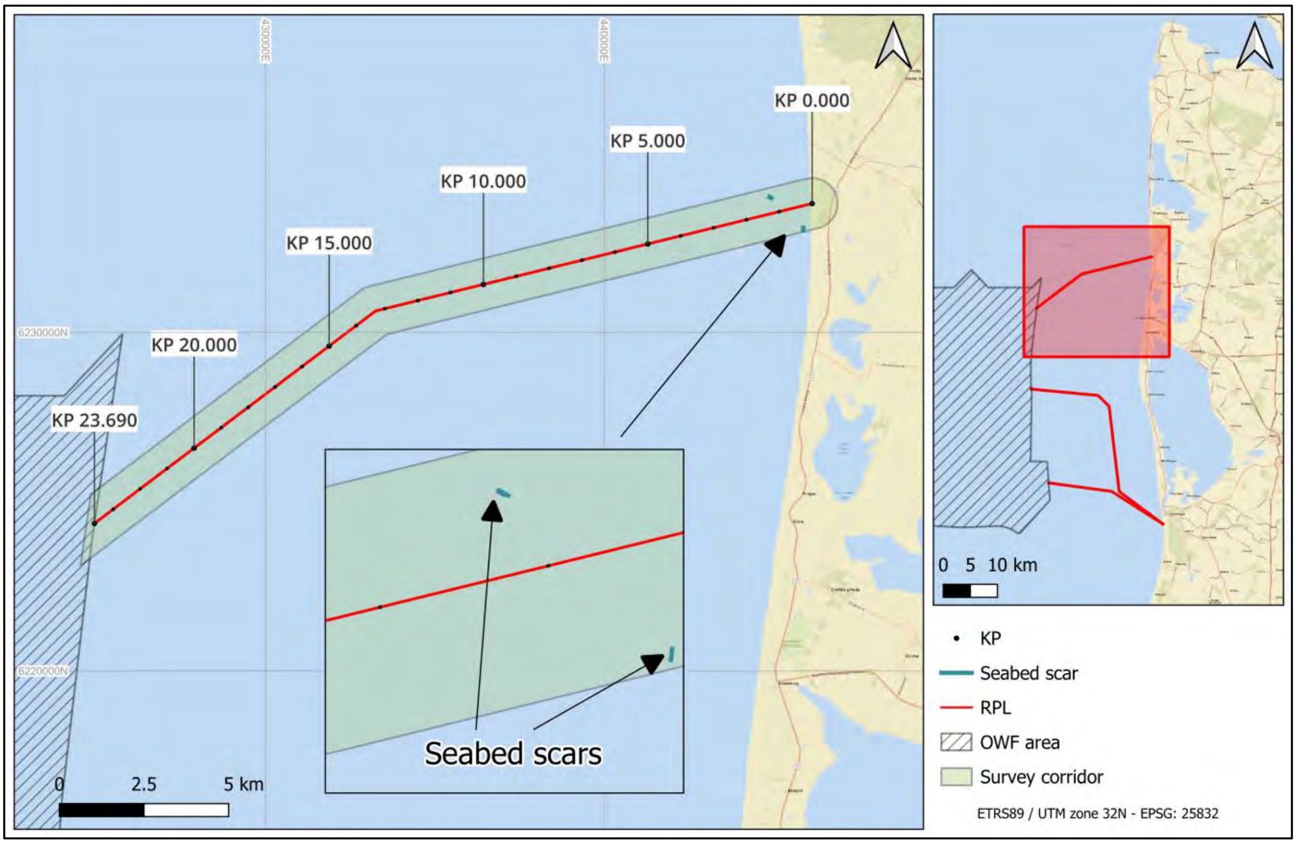


Figure 65: Seabed surface morphology overview - linear features, NS_ECR1

6.5 SEABED SURFACE FEATURES

Seabed surface objects which are determined to be man-made objects (MMO) in NS_ECR1 are outlined in Table 69 and Table 70, in both linear and point contacts.

Point seabed features for NS_ECR1 have been determined as a Master target list, without the man- made object point features. Linear features have been determined from MBES and SSS data. Polygon features have been detected from SSS and MBES data. No polygonal MMO's were observed in NS_ECR1.

A total of 4 MMO linear objects were identified though the interpretation of the MBES, SSS, and MAG datasets in NS_ECR1. All of these objects were detected in multiple sensors. One additional cable crossing was detected in the background data but no associated anomalies were detected. There are an additional 4 linear seabed features identified as seabed scars.

A total of 1903 point contacts were detected in NS_ECR1 through the interpretation of the MBES, SSS, and MAG datasets within the survey area. 106 contacts are identified within the MMO point file and 1797 are identified within the seabed features point file and interpreted as boulders. It should be noted that some MMOs could be classified into more than one feature type (e.g. two objects have been classified as both linear and point contacts). Therefore, the sum of the amounts found in Table 69 and Table 70 does not amount to the total number of objects.

Table 69: Summary of linear contact man-made objects in NS_ECR1

Feature type	Total amount	Comment
Wrecks	0	No shipwrecks were identified on site.
Metallic	1	Possible rope/cable/wire fragment attached to object. Located within a 5 m radius of a magnetic anomaly.
Ropes	0	No ropes contacts were identified on site but three possible rope fragments have been identified as 'Other' contacts.
Other contacts	3	Possible rope fragments.
Cable/pipeline	1	Cable crossing the survey area identified from background data only.

Table 70: Summary of point contact man-made objects in NS ECR1

Feature type	Total amount	Comment
Wrecks	0	No shipwrecks were identified on site.
Metallic	43	43 metallic contacts found within a 5 m radius of a magnetic anomaly.
Anchor	0	No anchors were found within the site.
Ropes	0	No ropes were identified on site but three 'Other' contacts are associated with possible rope fragments.
Other contacts	63	There were 63 contacts found.
Cable/pipeline	0	There was no cable crossing point contact identified on site.

6.5.1 Wrecks

No wrecks were identified within the NS_ECR1 site.

6.5.2 Cables, wires, and ropes

There were five linear objects detected within the NS_ECR1. Three of them are classified as possible rope, one is metallic object classified as possible rope, cable or linear fragment.

The fifth object is ODIN 2, fibre optic cable crossing the NS_ECR1 at the KP 13.653. This cable is detected in the background data, cable databases and nautical charts and was not detected by the magnetometer or visible in any other sensor.

Distribution of these linear man-made objects is presented in Figure 66.

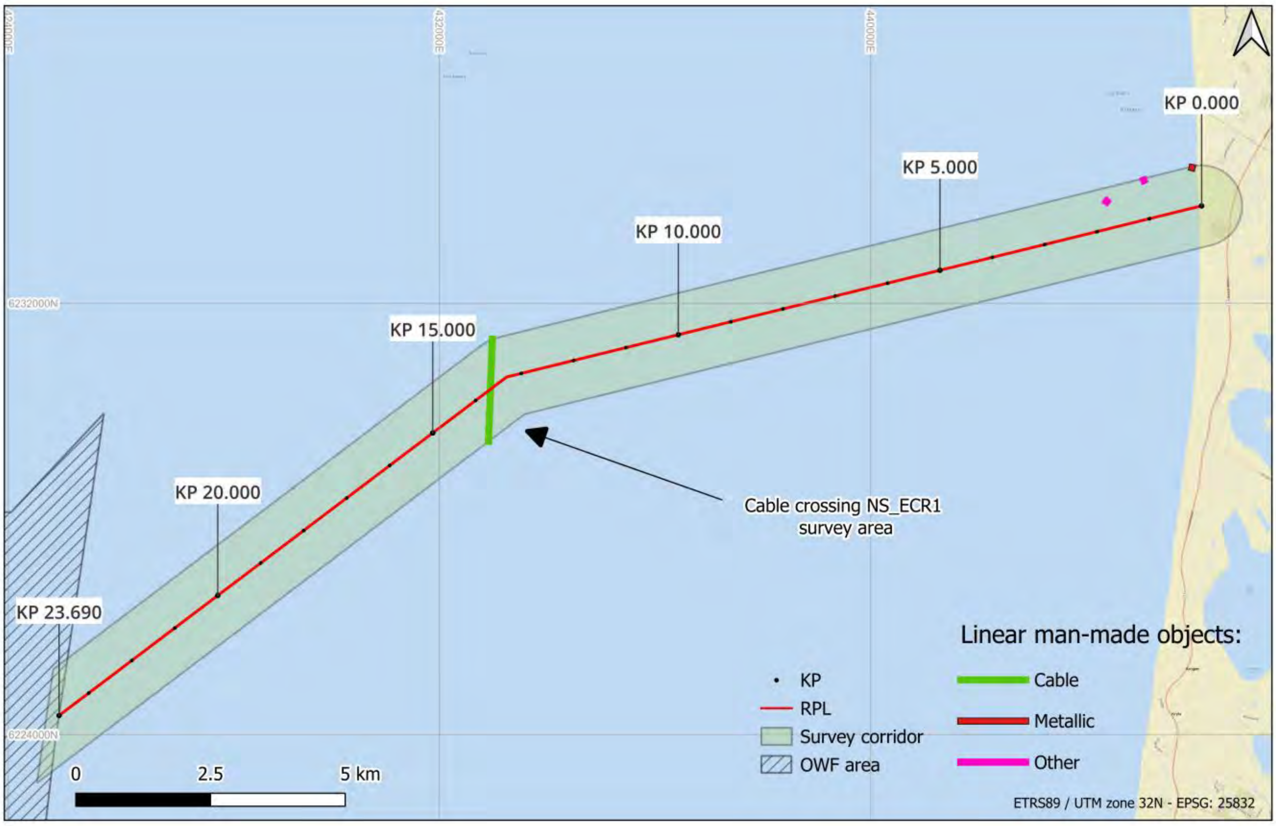


Figure 66: Overview of linear MMO found within the NS_ECR1 survey area

6.5.3 Pipelines

No pipelines were identified within or crossing the within the NS_ECR1 area.

6.5.4 Debris

An object identified from SSS and MBES, confirmed to be within a 5-metre radius of a magnetic anomaly, is classified as a metallic object. There were 43 metallic objects found within the NS_ECR1 survey area. The majority of these metallic objects are concentrated within the KP 1.000 to KP 2.000 cable survey area.

The distribution of the metallic objects is presented in the Figure 67.

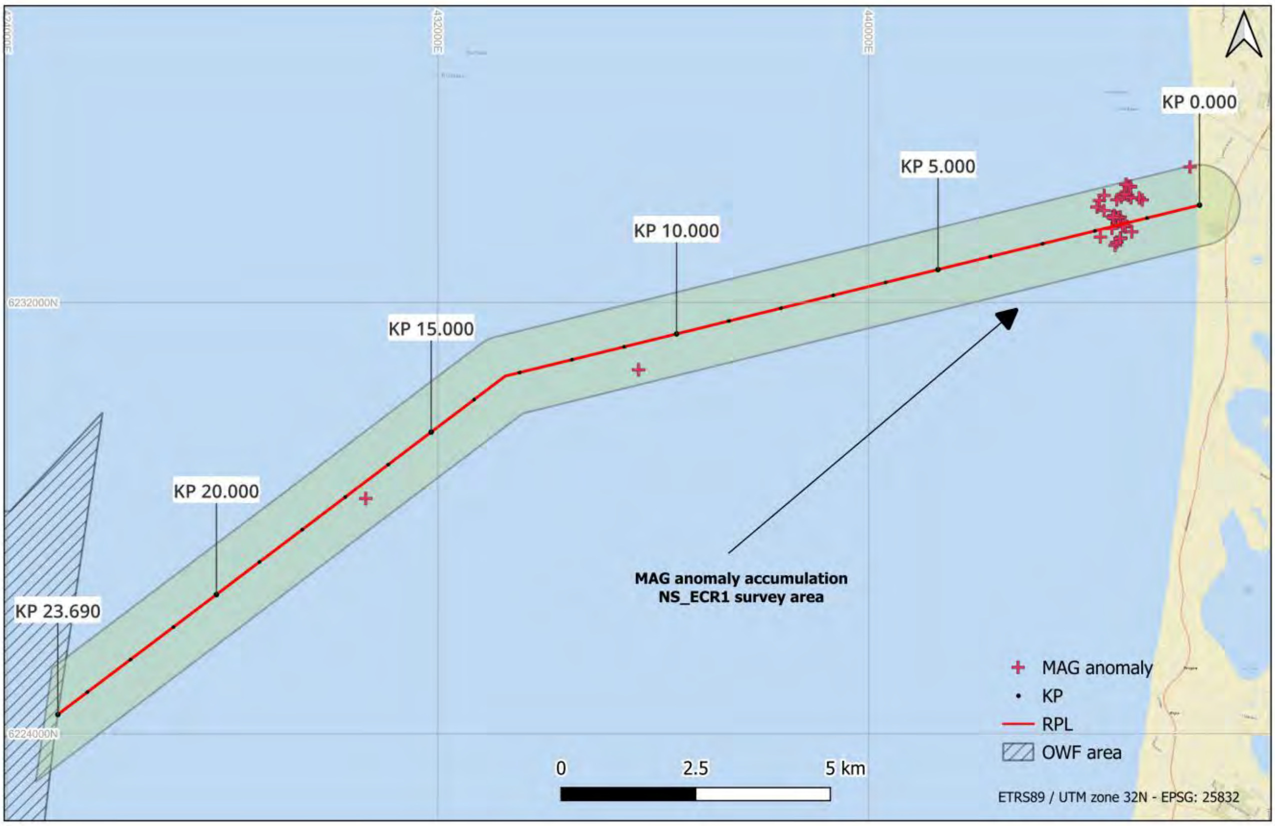


Figure 67: Overview of debris items within NS_ECR1

A total of 63 Other/Debris point contacts were observed within the site. All of these were interpreted as non-ferrous objects.

Figure 68 presents two objects detected: one NS_ECR1_MMO_PTS_0028 detected as metallic object, possible rope, cable or wire fragment attached to object; the second (NS_ECR1_MMO_PTS_0016) is debris, detected on SSS and MBES data.

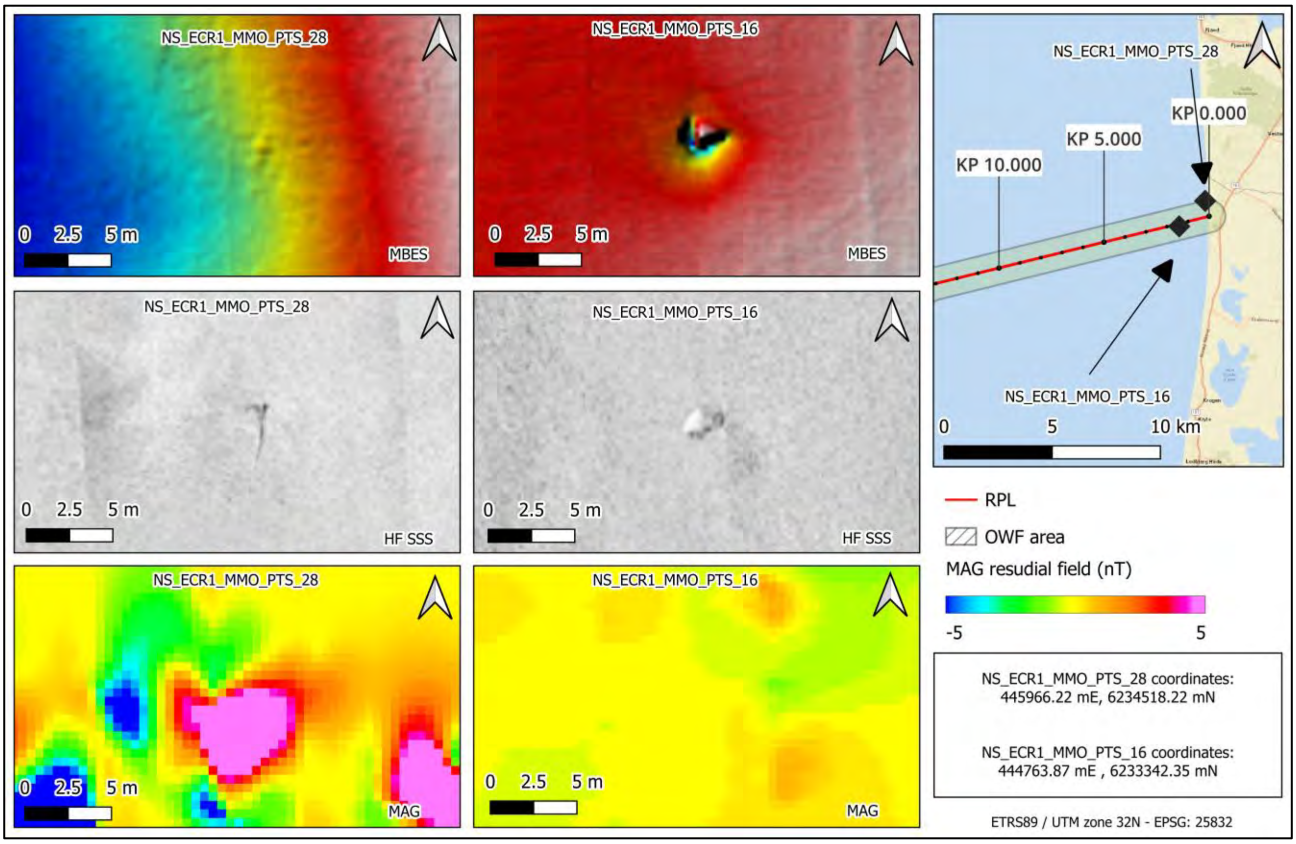


Figure 68: Debris examples, NS_ECR1_MMO_PTS_0028 and NS_ECR1_MMO_PTS_0036

6.5.5 Items related to fishing activities, and seabed disturbances

Seabed scars and ropes identified within the NS_ECR1 cable survey area are highly likely to be related to fishing activities.

6.5.6 Archaeological findings

No anthropogenic contacts identified have been associated with archaeological significance within the North Sea ECR1 site.

GEOxyz is not specialised in providing archaeological services. As such, the findings in this report are based on an interpretation of the data, which is a matter of opinion on which professionals may differ.

6.6 GEOTECHNICAL RESULTS

The following section presents a summary of the selected results from the geotechnical investigation conducted along the NS_ECR1 route. Figure 69 and Figure 70 displays the locations of CPT and VC measurements, along with the achieved penetration depth.

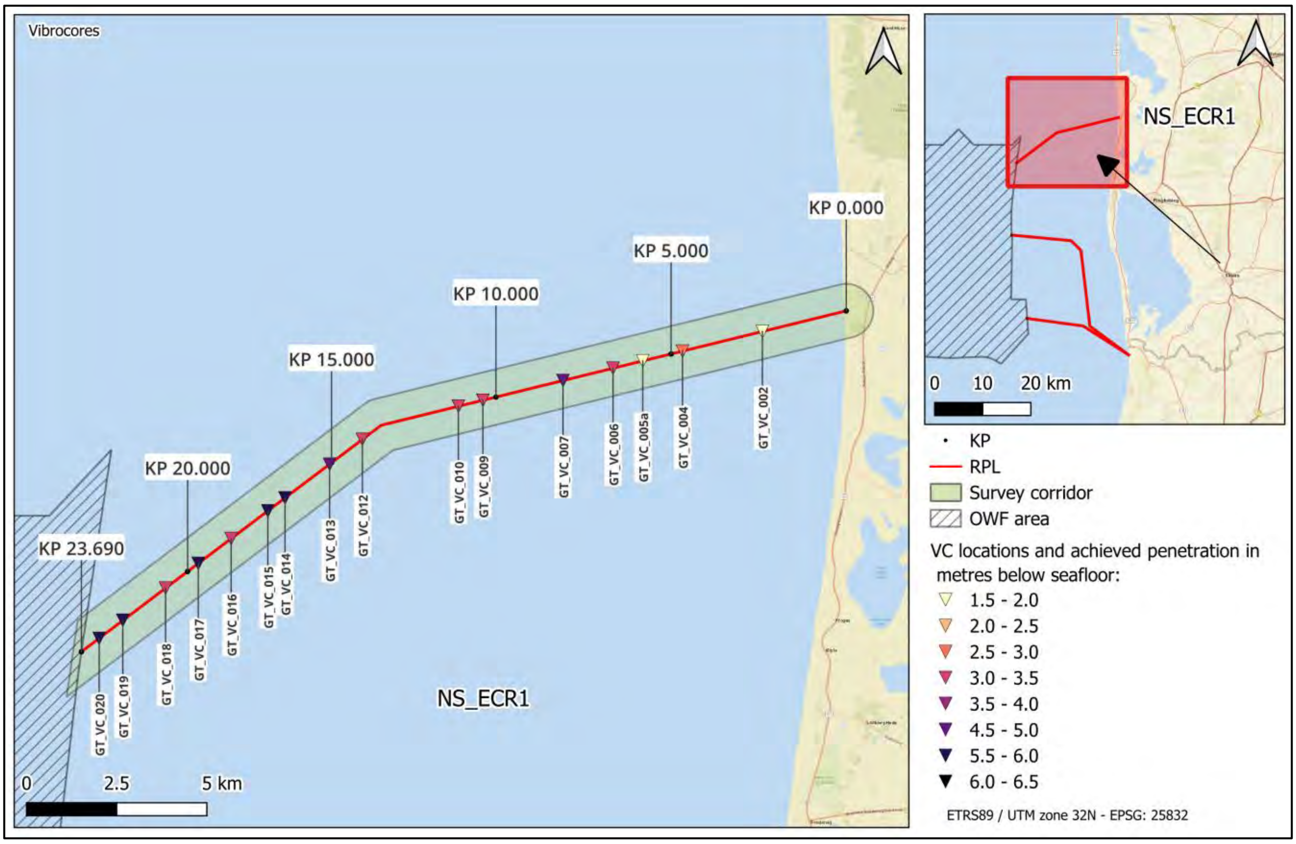


Figure 69: VC locations overview with achieved depths below seabed

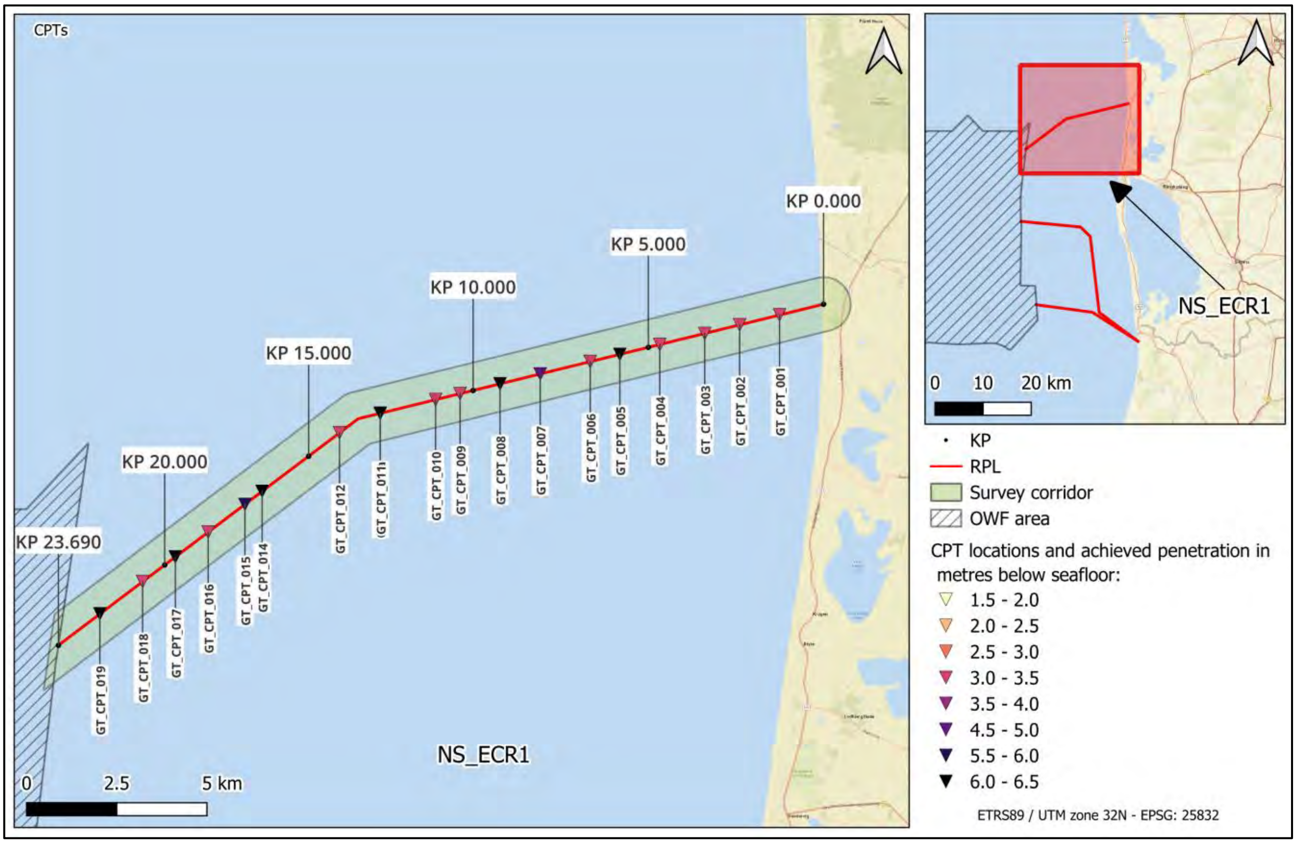


Figure 70: CPT locations overview with achieved depths below seabed

Figure 71 to Figure 73 provide the sample analysis results for each vibrocore, including:

- Description of the soil type
- D50 percentile value
- D90 percentile value
- Bulk density
- Water content

Figure 74 presents the cone resistance and friction resistance measurements for each CPT location along the route.

In Figure 75, the percentage of clay and the thermal resistivity values along the route are presented.

A detailed account of the geotechnical dataset can be found in the geotechnical report. For full access to the results from the geotechnical investigation, please refer to the external document as Appendix C (DOW2030 - WPC, North Sea, Factual Report, Rev. 01, 2024-11-12 REPORT").

6.6.1 Particle size distribution and soil type analysis

Visual and PSD analyses of VC samples reveal a sand dominance along the entire NS_ECR1 route, starting at GT-002 on. D50 and D90 values derived from PSD analyses indicate that sand is predominantly fine to medium from GT-001 to GT-006. In contrast, coarser sand, occasionally gravelly, is observed in the upper 1 to 2 metres from GT-009 to GT-018 (Between GT-003 and GT-012, Horizon H07 marks the base of thin to medium clay or gyttja beds and likely represents the lower limit of the periglacial deposits comprising Unit II, as detailed in Section 6.7 (Figure 71 and Figure 72). The combined results of visual and PSD analyses also allowed differentiation between varying degrees of silt presence within the sand. Mostly clean sand was recovered at GT-002, GT-003, and from GT-014 to GT-020, while silty sand was identified at the surface between GT-006 and GT-009 and below clean sand deposits between GT-011 and GT-013 (Figure 76).

At GT-001, the easternmost location, the soil is composed entirely of clay. Thin to medium clay beds, often associated with thin layers of gyttja, are also present between GT-003 and GT-011, below 4.5 mbsb at GT-014, and in the shallowest depths at GT-019.

Clay-dominated glacial till was identified exclusively at GT-019, below 4.8 mbsb (Figure 71Figure 71).

6.6.2 Moisture content, bulk density and dry density

The highest moisture content values, exceeding 75 %, were observed within the gyttja layers. These layers also correspond to the lowest bulk density recorded, below 1.80 g/cm³ (Figure 73).

The relationship between bulk density and moisture content further highlights the differentiation in silt content within the sands, as described in the previous section. Clean sand is characterized by low moisture content, generally below 10%, and low bulk density, typically less than 1.80 g/cm³, as observed, for example, at GT-010. In contrast, silty sand displays higher moisture content, ranging from 10 % to 20 %, and a higher bulk density, exceeding 2.1 g/cm³ in some locations, such as GT-009 (Figure 76).

Clay recovered in the VCs, such as at GT-005, shows intermediate moisture content, between 20 % and 35 %, and bulk density values ranging from 1.8 to 1.95 g/cm³.

The complete dataset of moisture content measurements and derived dry density values is provided in the geotechnical report for further reference.

6.6.3 Thermal resistivity from TRT measurements

Thermal resistivity measurements from TRT conducted at five geotechnical stations (GT_005a, GT_007, GT_011, GT-015, and GT-019) illustrate the thermal response of different soil types encountered along the RPL, with values ranging from 0.2 to over 1.4 mK/W. Additional resistivity values were taken as discrete samples from selected vibrocore core samples. The lowest thermal resistivity values (<0.3mK/W) were recorded at the base of GT_019 where medium sands started to give way to glacial till (clayey), and on GT_015 in gravelly medium SAND. The highest thermal resistivity values (>1 mK/W) were recorded on GT_019 within a layer of 1.5 m thick GYTTJA.

Generally, the near surface (<1m below seabed) TRT and lab resistivity showed low resisitivity (<0.5 mK/W) in the near surface due to the sandy and loose nature of the upper post glacial sediments. Increases in resistivity then occurred at depths >1m or where post glacial sediments were thin, where clays and more compacted soils were present in the subsurface. This is particularly evident on the lab test for GT_010 which indicated a resistivity of 1.4 mK/W at the seabed where PEAT was found in the vibrocores under a veneer of SAND.

All in-situ and lab thermal testing have been plotted on the 3 km profile panels presented in the route analysis section.

6.6.4 Correlation between derived CPT parameters, soil types and geophysical units

Undrained shear strength and relative density data derived from CPT measurements were correlated with soil type information from VC samples, enabling further characterization of the subsurface and validation of SBP-interpreted units (Figure 76).

Cone resistance (Qc) measurements were generally below 20 MPa in the upper 0–3 m across all geotechnical stations. Higher values were recorded below 4 m at specific locations, with Qc reaching up to 75 MPa at GT-009 and GT-010, and generally exceeding 40 MPa below 3 mbsb from GT-015 to GT-020 (excluding GT-019, where a medium gyttja layer was recovered in the VC). Friction ratio values were consistently low across all stations, ranging from 0.1 to 0.2 MPa. Detailed CPT readings are provided in the geotechnical report (Figure 74).

In general, relative density and undrained shear strength show a sharp increase corresponding to the rise in Qc values below the upper 0–3 m of sediments. This transition is marked by a shift from low to medium undrained shear strength for clays and loose to medium-dense relative density for sands, to high to very high undrained shear strength and dense to very dense relative density. This change corresponds to Horizon H05 in the seismic interpretation, which marks the lower boundary of post-glacial sediments Unit I (see Section 6.7).

Silty sand beds tend to exhibit lower relative density compared to clean sands, often falling between drained and undrained conditions and displaying medium to high undrained shear strength values. In contrast, clays and gyttja layers are characterized by medium to very high undrained shear strength, reflecting their greater consolidation.

Between GT-003 and GT-012, Horizon H07 marks the base of thin to medium clay or gyttja beds and likely represents the lower limit of the periglacial deposits comprising Unit II, as detailed in Section 6.7.

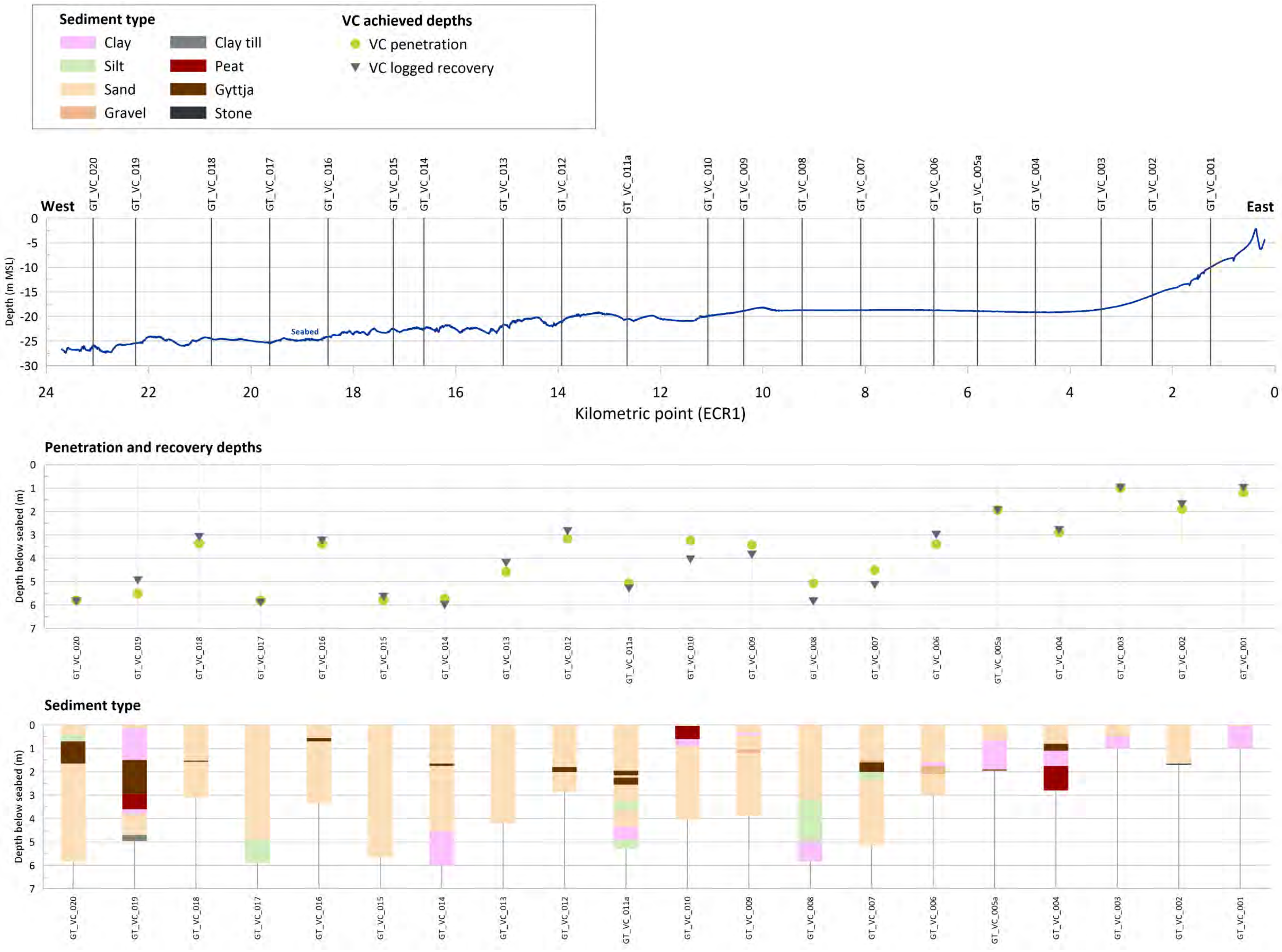


Figure 71: Sample analysis showing achieved depths and soil type distribution

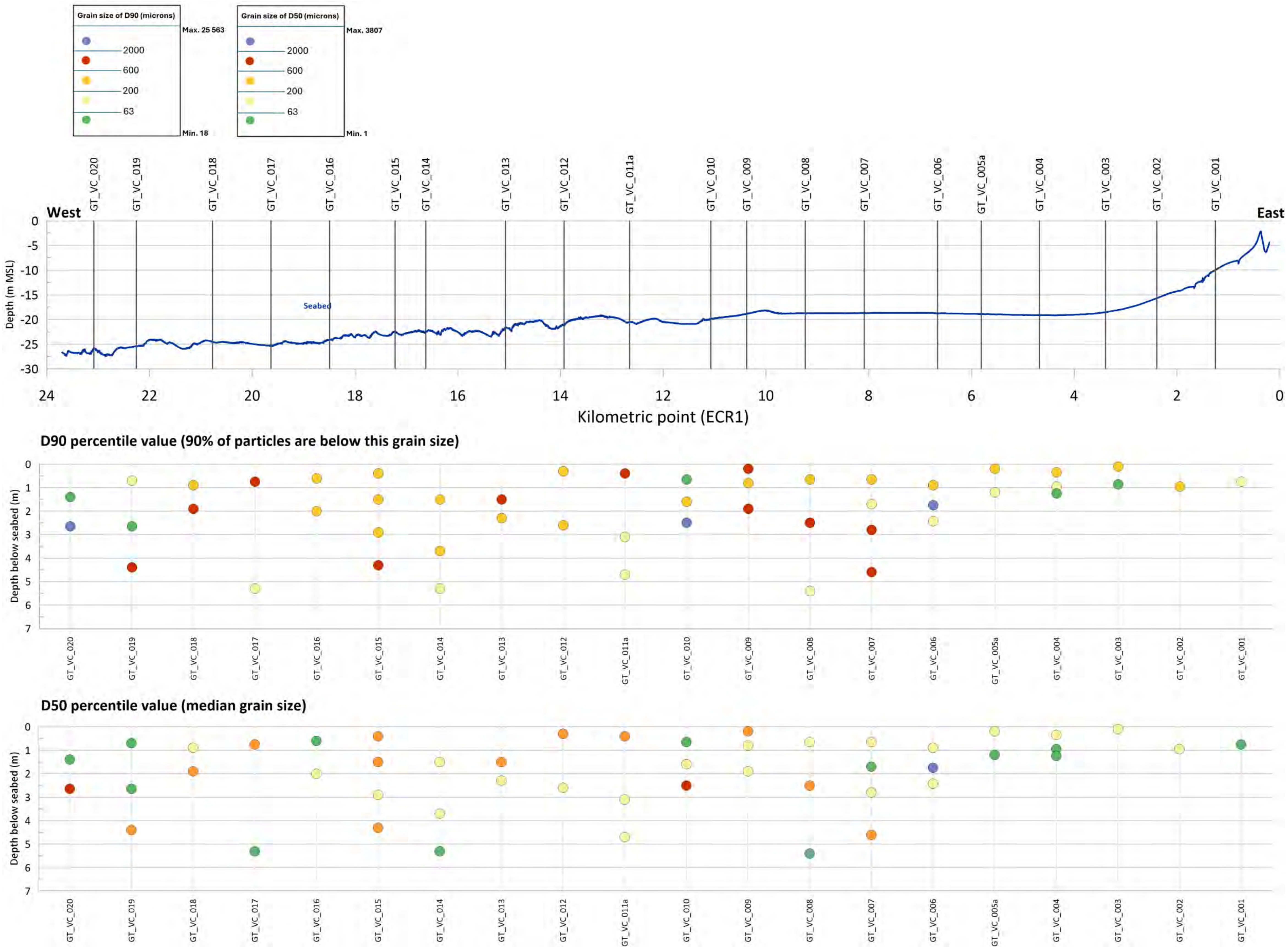


Figure 72: Sample analysis showing D50 and D90 grain size diameters

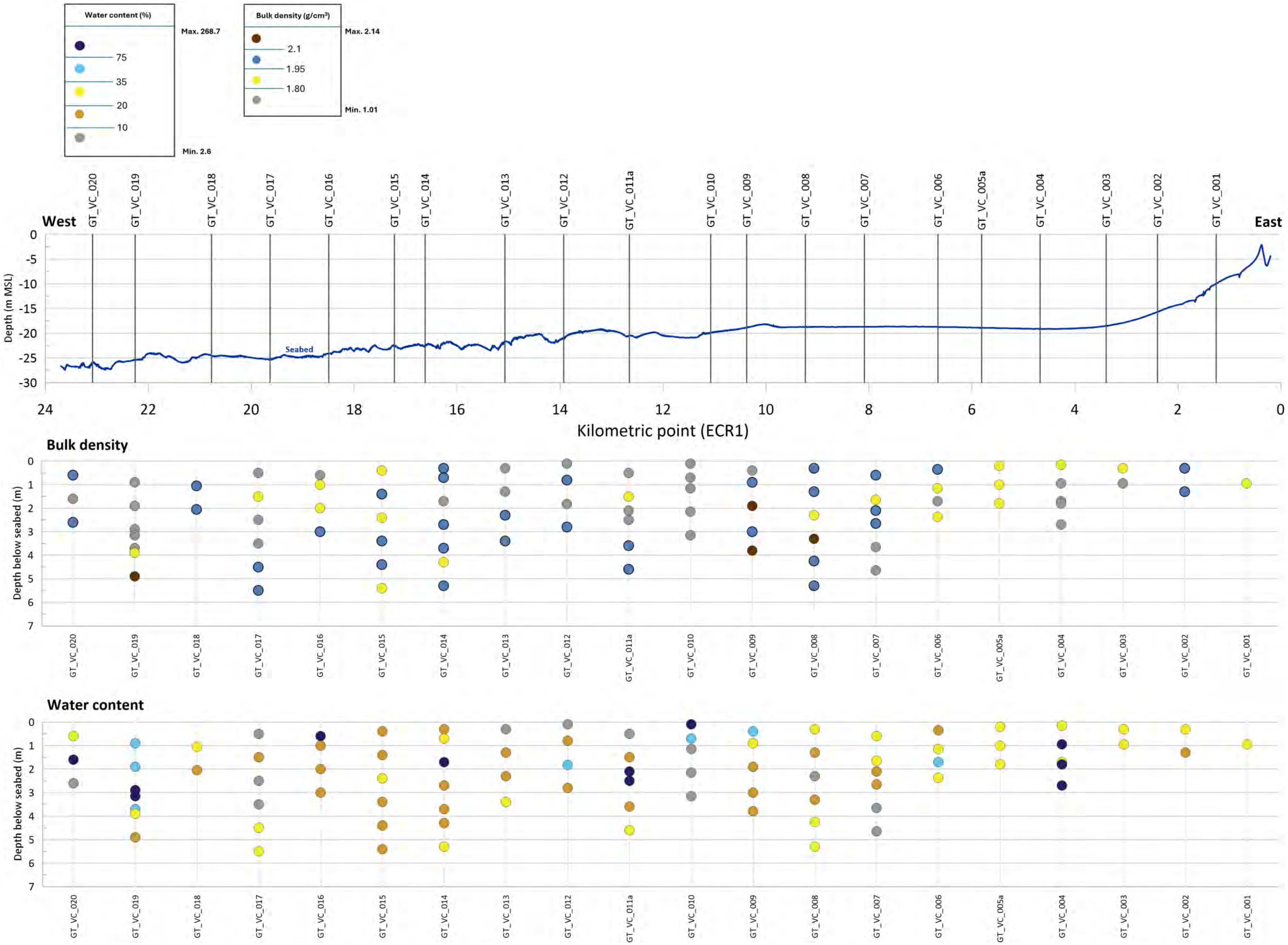


Figure 73: Sample analysis presenting bulk density (g/cm³) and water content (%)

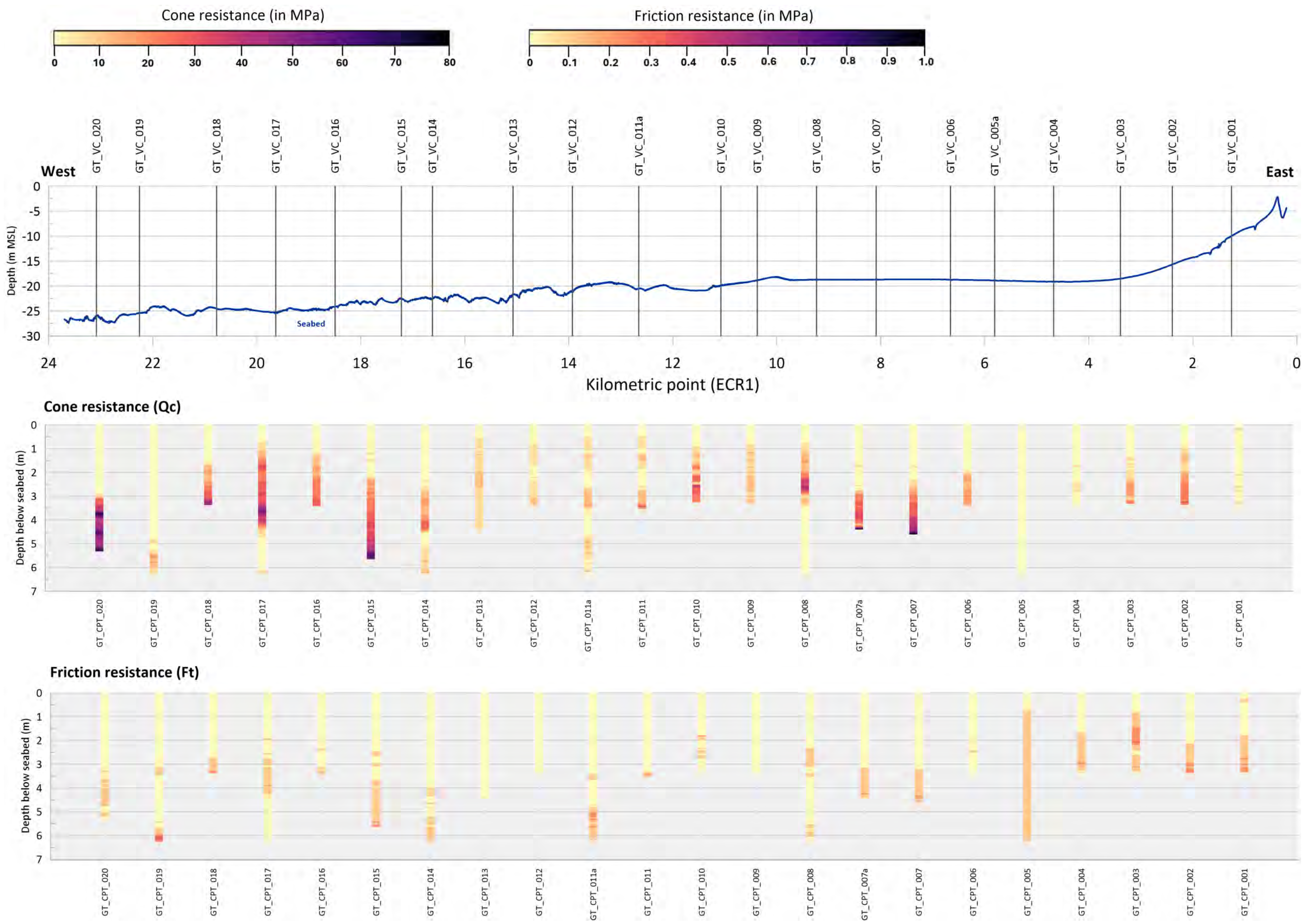


Figure 74: Sample analysis showing cone resistance and friction resistance in MPa

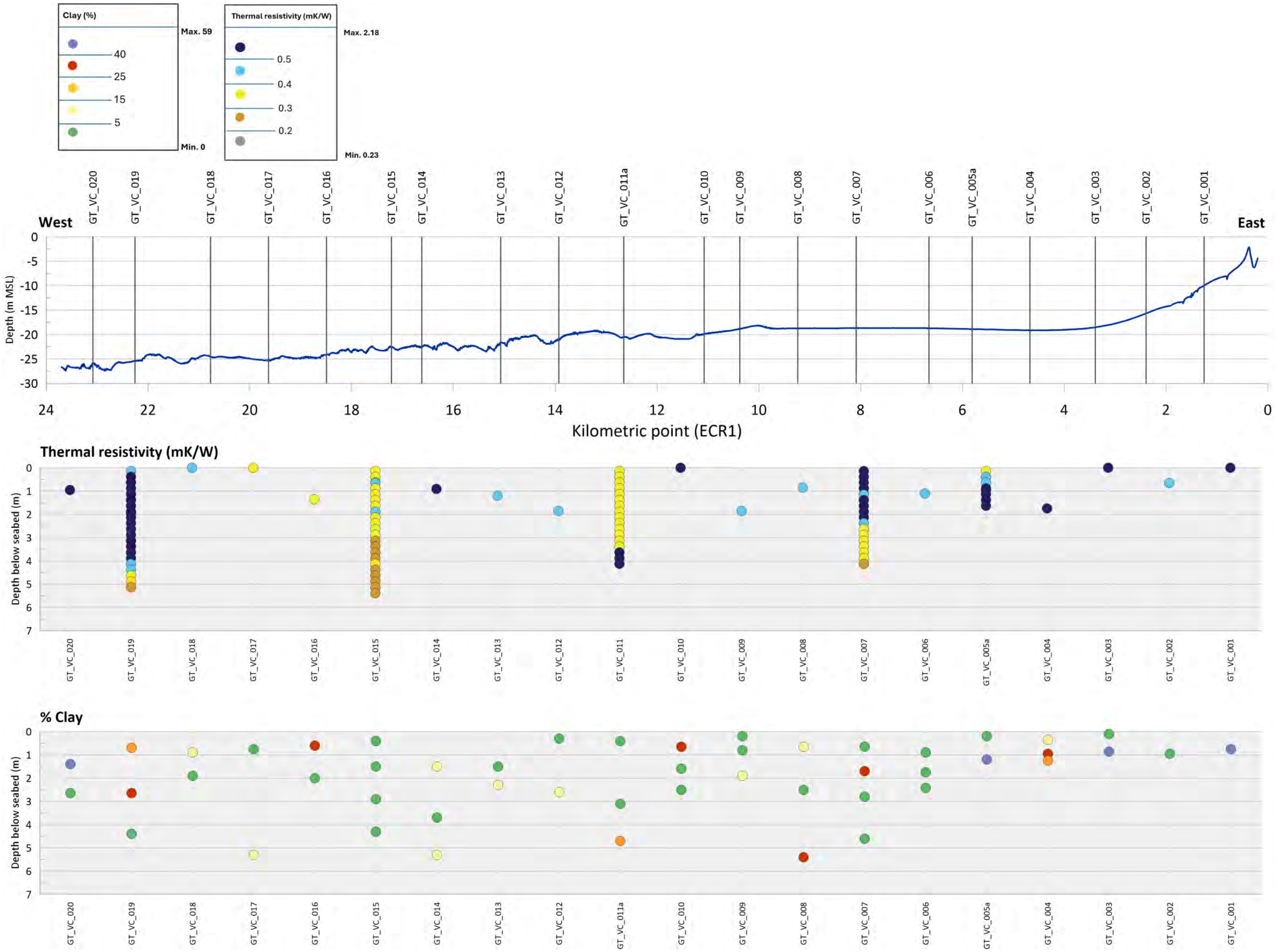


Figure 75: Sample analysis presenting clay (%) and thermal resistivity

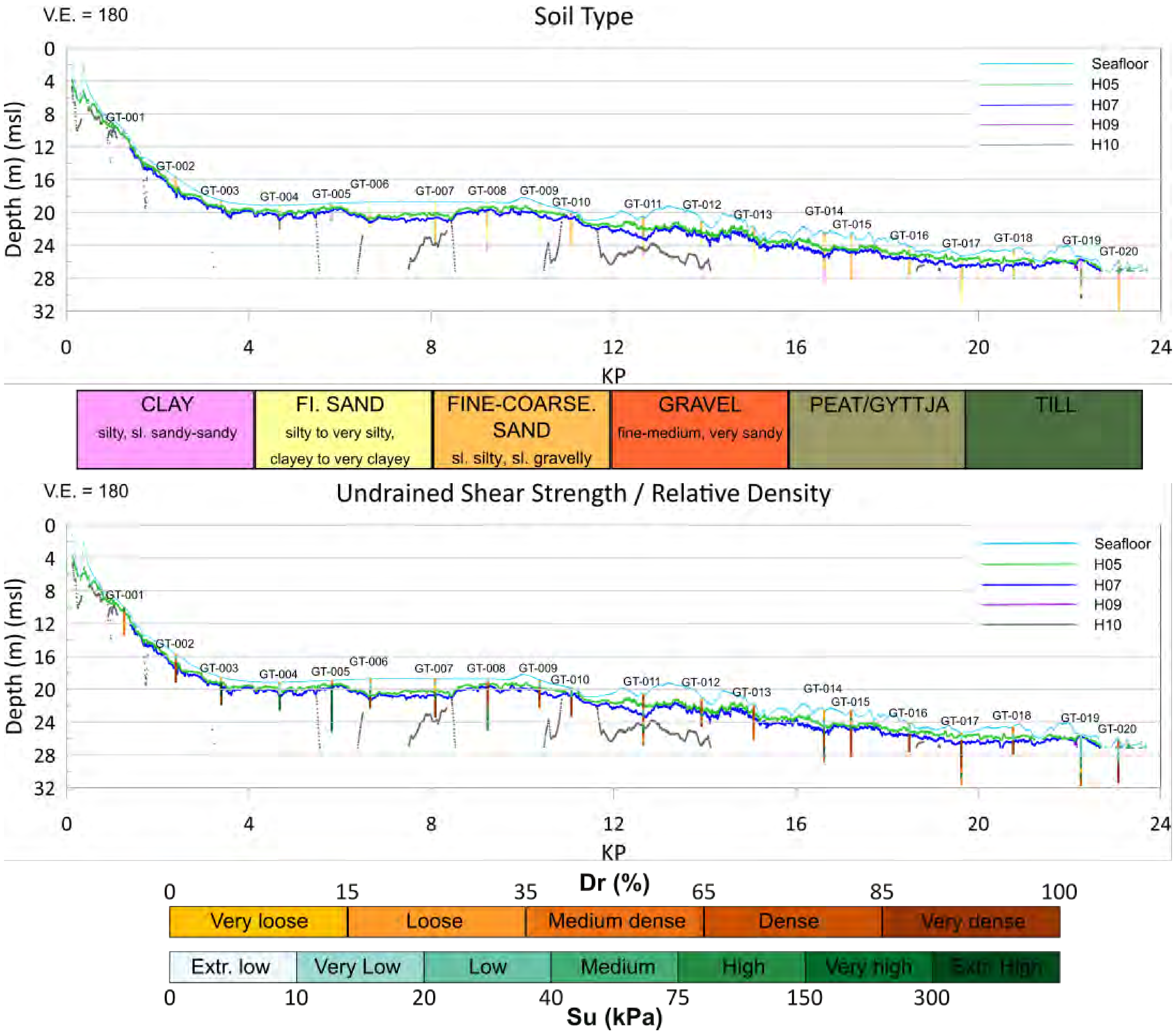


Figure 76: Soil types derived from VC and CPT data (top) and CPT parameters (bottom) compared with key horizons from SBP interpretation

6.7 SUB-SURFACE GEOLOGY

6.7.1 Regional geological history

The geological interpretation along the proposed ECR is based upon the geophysical and geotechnical datasets acquired with reference to the supplied GEUS desk study. This desk study applies a stratigraphic model developed by Jensen et al. (2002) in conjunction with archive seismic data and limited ground truth information. In general, there is a good correspondence between shallow geology imaged in this project's sub-seabed data and the desk study. In addition to the DTS, reports for the OWF have been considered (Fugro 2024, Ocean Infinity 2024), to aid interpretation of observed horizons.

Overall, the area has a glacial to post-glacial sequence of sediments over much older bedrock. Only the upper post glacial and glacial deposits are discussed along the ECR. The bedrock is deeper than the installation zone of interest and not imaged on the SBP data.

The Quaternary consists of glacial and interglacial deposits overlain by a variable cover of Post Glacial marine deposits. Above the pre-Quaternary surface is a lower glacial unit of Saalian and/or older age glacials (Larsen & Andersen (2005). The lower glacial unit forms a bank about 30 km offshore Blåvands Huk (Vovov hill island) and between the bank and the shore, the surface of the Saalian glacial landscape forms a wide depression c. 50 m below sea level. This basin has controlled deposition in the area since the late Saalian and is filled with sediments of late Saalian (glacial), Eemian (interglacial), Weichselian (glacial) and Holocene (interglacial) age. Close to the coast northwest of Ringkøbing Fjord the seaward extension of another Saalian glacial hill island (Skovbjerg Bakkeø) occurs. Here glaciotectonised Miocene clayey deposits commonly occur right up to the seabed. In the central parts of the basin, a 10-20 m thick layer of late Saalian meltwater sediments was deposited followed by up to 13 m of Eemian marine deposits of silty clay and sandy silt corresponding to a sea level high-stand, where the sea covered almost the entire area, except the Saalian glacial deposits at the Vovov hill island and the Skovbjerg Bakkeø. In the lowermost part of the Eemian succession freshwater deposits occasionally has been observed. During the Weichselian, the sea level dropped again, and the area became land with rivers and lakes. A schematic diagram of the geology expected adjacent to the North Sea survey area is presented in Figure 77, showing a profile of units north of Horns Rev approximately 30 km south of NS_ECR2/NS_ECR3 and 70 km south of NS_ECR1.

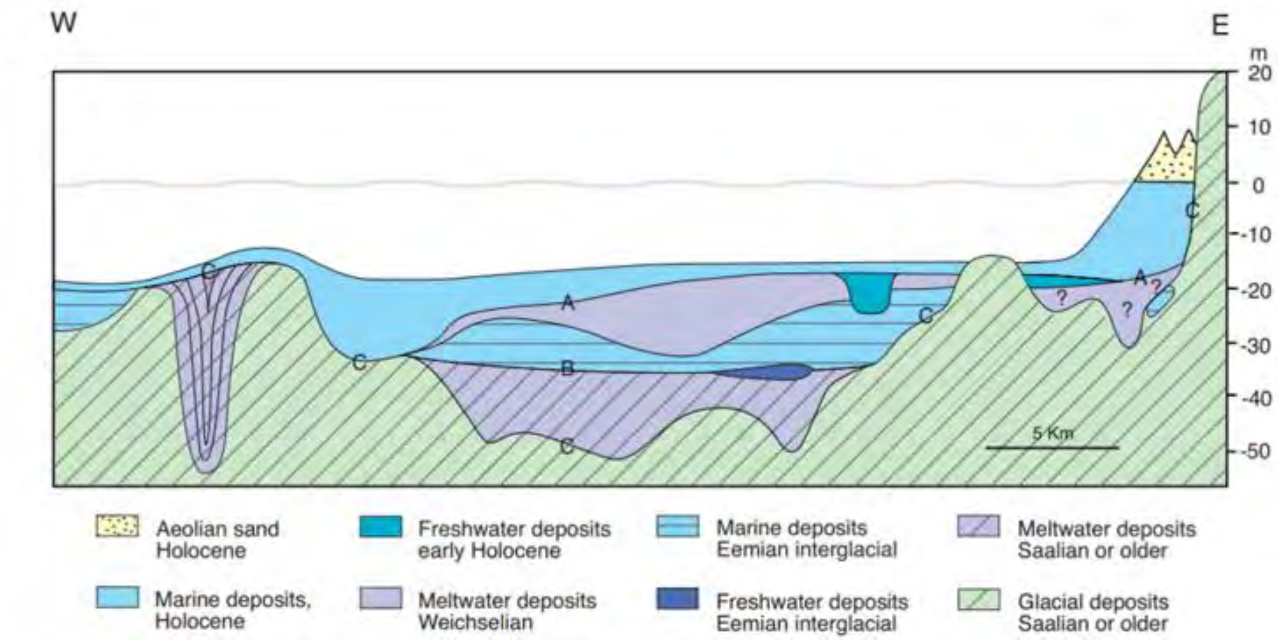


Figure 77: Schematic W-E profile across the wide basin in the Saalian landscape north of Horns Rev (Extract from GEUS DTS,2023)

The Weichselian ice sheet did not reach the southern part of the Danish North Sea, but it is generally assumed that the large alluvial outwash plains west of the ice margin in central Jutland extended into the North Sea area through valleys between hills in the old Saalian landscape (Houmark-Nielsen, 2003). Thus, Weichselian meltwater sediments partly eroding or covering the Eemian deposits in the area are probably remnants of distal alluvial fans mostly fed from north and east. Following the final ice sheet retreat and general climate amelioration, a tundra landscape in the late glacial period was followed in the Holocene by a forest covered landscape with local rivers and streams. From about 9000-7000 years BP the area was progressively transgressed by the North Sea.

During the first thousand years, the relatively shallow sea in the area may have been characterised by an isthmus and islands of higher-lying glacial deposits causing local sheltered marine- to brackish sea areas. However, as the sea rose, the entire area was inundated, and by establishment of the Jutland Coastal Current and increasing exposure to the harsh wind and wave conditions from the North Sea, the seabed was exposed to selective erosion and deposition of late Holocene mobile sand units, which are intricately related to the circulation and dynamic sediment transport pattern around Horns Rev.

6.7.2 Shallow geological overview

Depths quoted below seabed have been converted from time using an assumed seismic velocity of 1650 m/s which is considered suitable for the sediments present along the route.

The interpretation has been carried out based on the seismic acoustic nature of the SBP data, the adjoining Offshore windfarm survey results and report and the GEUS desk study. Geotechnical data, acquired by Geo DK were later available and confirmed the age and depositional environments of the sediments. Table 71 summarizes the interpretation, geological units and depositional environments.

Table 71: Shallow geological units

Unit	Upper Surface	Lower Surface	Main Soil Description	Depositional Environment
I, Post Glacial (P)	Seabed	H05	SAND with occasional GRAVEL, CLAY and GYTTJA/PEAT layers	Post-glacial marine
II, Late Glacial (LG)	Seabed/H05	H07	Variable, includes intervals of laminated CLAY, SAND-prone packages	Periglacial, glaciomarine
III, Late Glacial (LG)	H07	H09	Variable, includes intervals of laminated CLAY, SAND-prone packages	Periglacial, glaciomarine
IV, Late Glacial (LG)	H07/H09	H10	Variable, includes intervals of laminated CLAY, SAND-prone packages	Periglacial, glaciomarine
V, Glacial (GL)	H10		Variable, CLAY-prone, locally overconsolidated	Glacial with localised direct ice contact

6.7.3 Stratigraphy and general arrangement of units

Figure 78 shows the arrangement of units along the proposed NS_ECR1. Table 71 shows the basic characteristics of the stratigraphic units. Key surfaces are the top of Unit V (H10) which is the top of potentially overconsolidated deposits. Sediments within Units I to IV are less well consolidated, with fewer cobbles and boulders present than found in Unit V. The top of Unit V, marked by H10 is only mapped sporadically within the survey area as it is generally beneath the depth of acoustic penetration required to accurately map the surface. Lower frequency sources, such as those used in the windfarm area (UHR dataset) would allow for more extensive mapping of the surface; however, this is likely to be beyond the requirement for an export cable route survey.

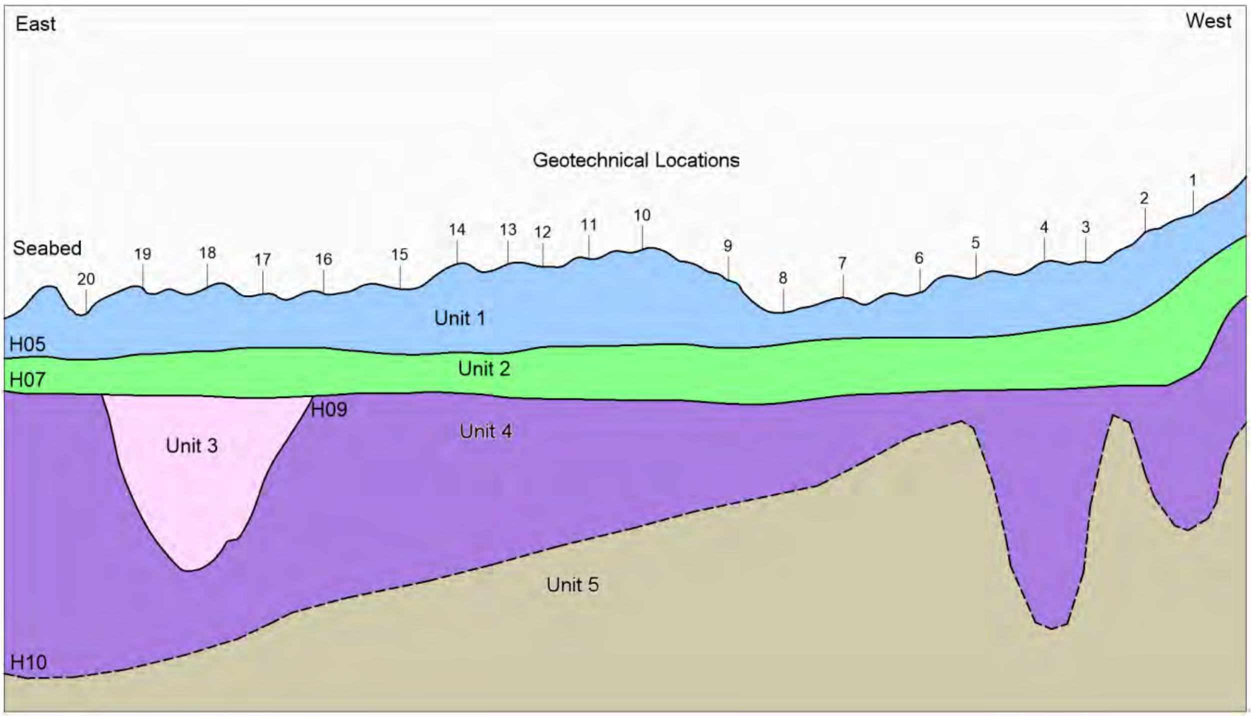


Figure 78: Geological schematic, general arrangement of units with approximate geotechnical locations

6.7.4 Quaternary deglaciation history / stratigraphic units

These bullet points are largely derived from information in the GEUS desk study. Here the stratigraphic units have been linked to the changing paleoenvironments.

- In Denmark the Scandinavian Ice Sheet reached its maximum extent about 22,000 years BP followed by retreat with evidence for short-lived advances over the following 4,000 years. **Unit V was laid down in association with this ice sheet.**
- Marine transgression began around 18,000 years BP leading to rapid deglaciation and establishment of glaciomarine conditions. An isostatic regression occurred shortly after 18,000 years BP. This was followed by renewed marine transgression related to the wasting of the Baltic Ice Stream. **Unit II-IV was laid down over this complex period.**
- After deglaciation the area generally experienced high-stand conditions, though glacio-isostatic rebound outstripped background sealevel rise around 11,000 years ago, driving a local regression. **Unit I was deposited in this marine environment.**

a Post Glacial geology

Unit I is a package predominantly of post-glacial SAND with occasional layers of GRAVEL, CLAY and GYTTJA/PEAT which is less than 3 m thick over large parts of the site. The interval includes a veneer of sandier seabed sediments, though this is interpreted to be very thin and not resolvable in the SBP data. The post glacial sediments are widely distributed over the cable route corridor, varying from absent to less than 3 m over much of the route, as seen in Figure 80. It increases in thickness at the nearshore end, reaching a maximum observed thickness of 4.4 m at KP 1.300. It may be thicker even further inshore, but the horizon is obscured by the seabed multiple.

The geotechnical interpretation from the vibrocores or CPTs is shown on the relevant data examples. These indicate that there is a lot of lateral variation in the lithology within all units. Occasional pockets of peat and gyttja are observed in the geotechnical logs, but there is no obvious seismic expression noted in the SBP data.

The base post glacial marine deposits are mapped as H05 and the deposit varies between 0.2 and 4.4 m thick along the route corridor. There are small areas where the base reflector (H05) could not be distinguished from the seabed pulse. In these areas the unit is either thin or absent and the underlying sediments of Late Glacial age are outcropping at seabed.

Acoustically the interval is quiet but there are higher amplitude point reflectors, interpreted as representing shell fragments or small cobbles and locally there are very subtle unconformities. These may represent sea level variations related to the interplay of isostatic rebound and background sea level rise as well as shoreline transgressions and regressions. There are very occasionally bright spots which may possibly be organic material.

The erosion at H05 may be related to the final regression of the area ~11,000 years ago when sea level dropped, potentially allowing storm erosion of the contemporary seabed.

The location of seismic profiles, which are presented throughout the report, are displayed in Figure 79 below.

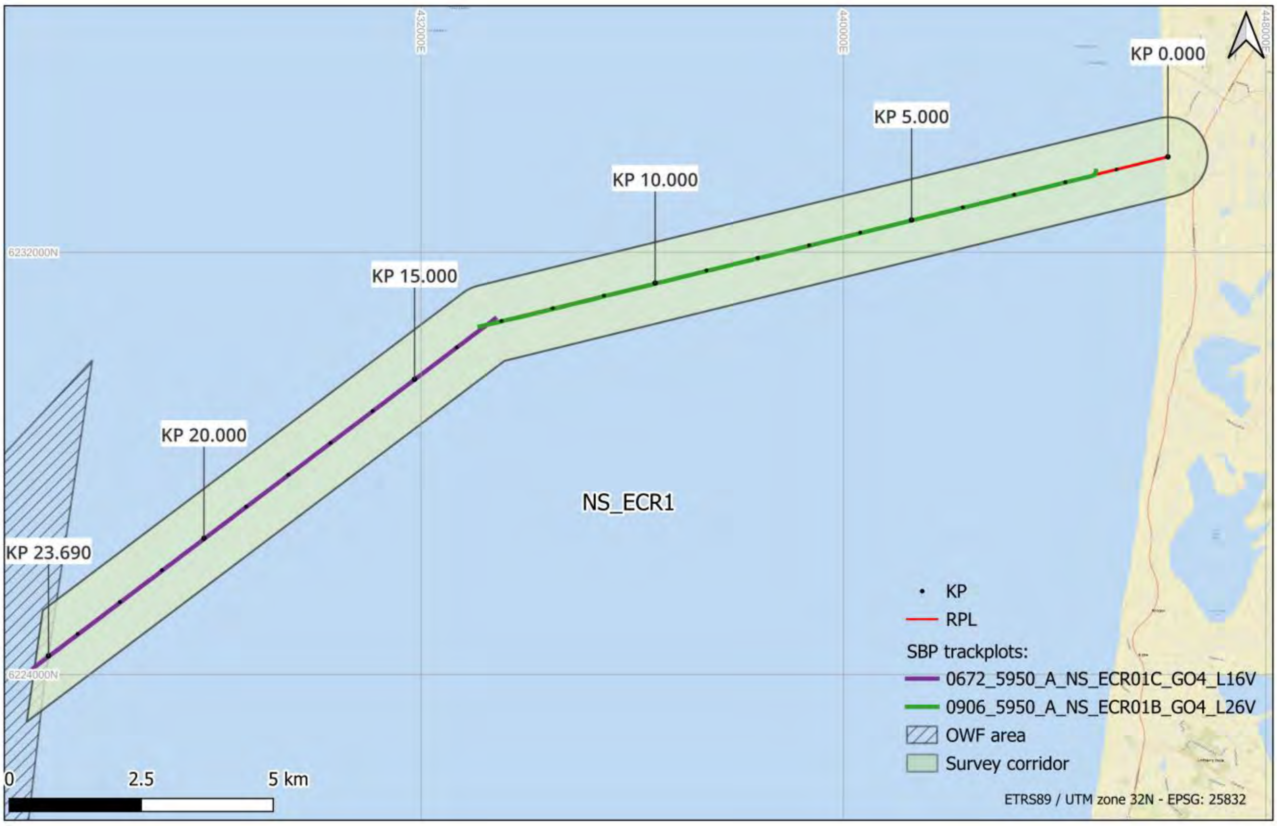


Figure 79: Location of the seismic profiles along NS_ECR1 shown throughout the report

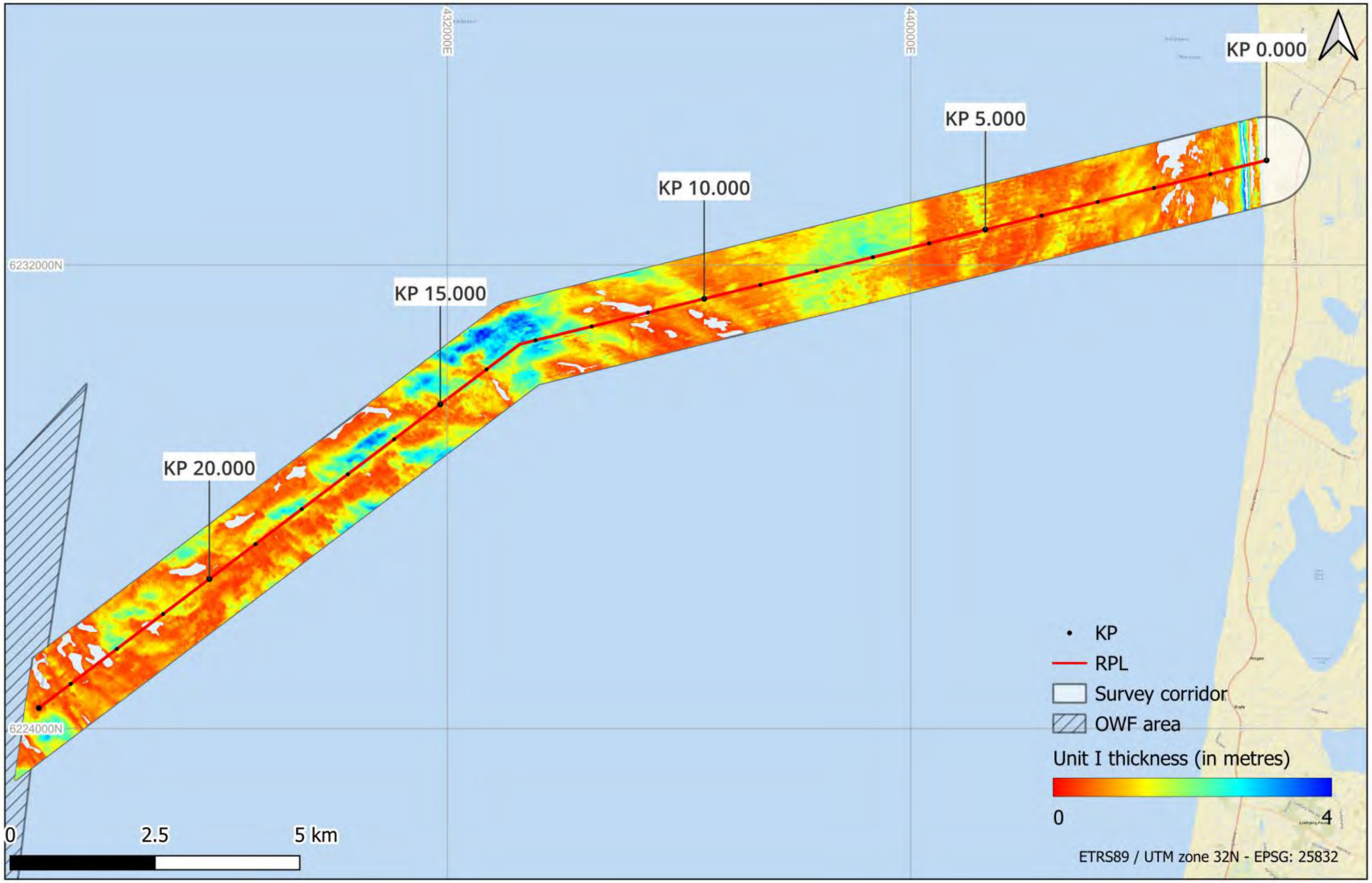


Figure 80: Distribution and thickness of Unit I

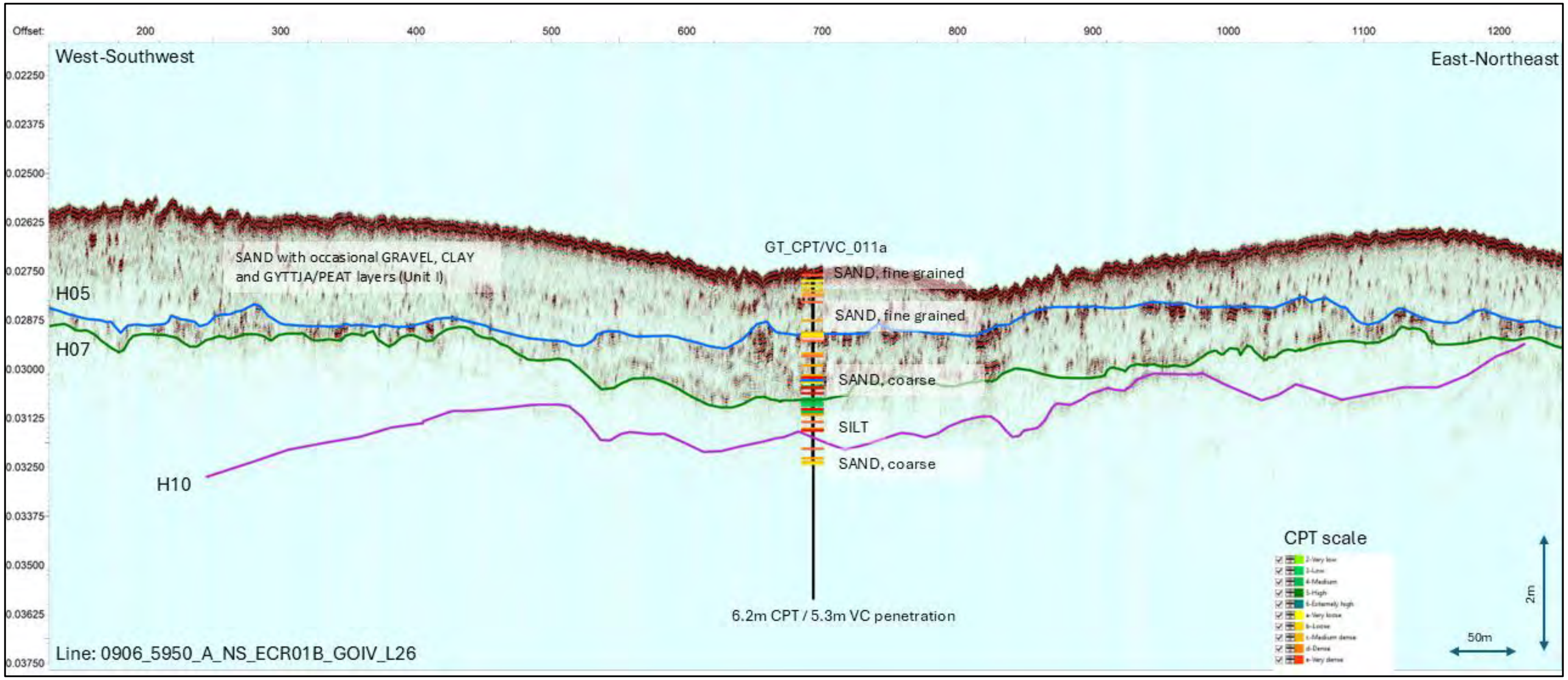


Figure 81: Seismic example showing acoustic character of Units – CPT011a

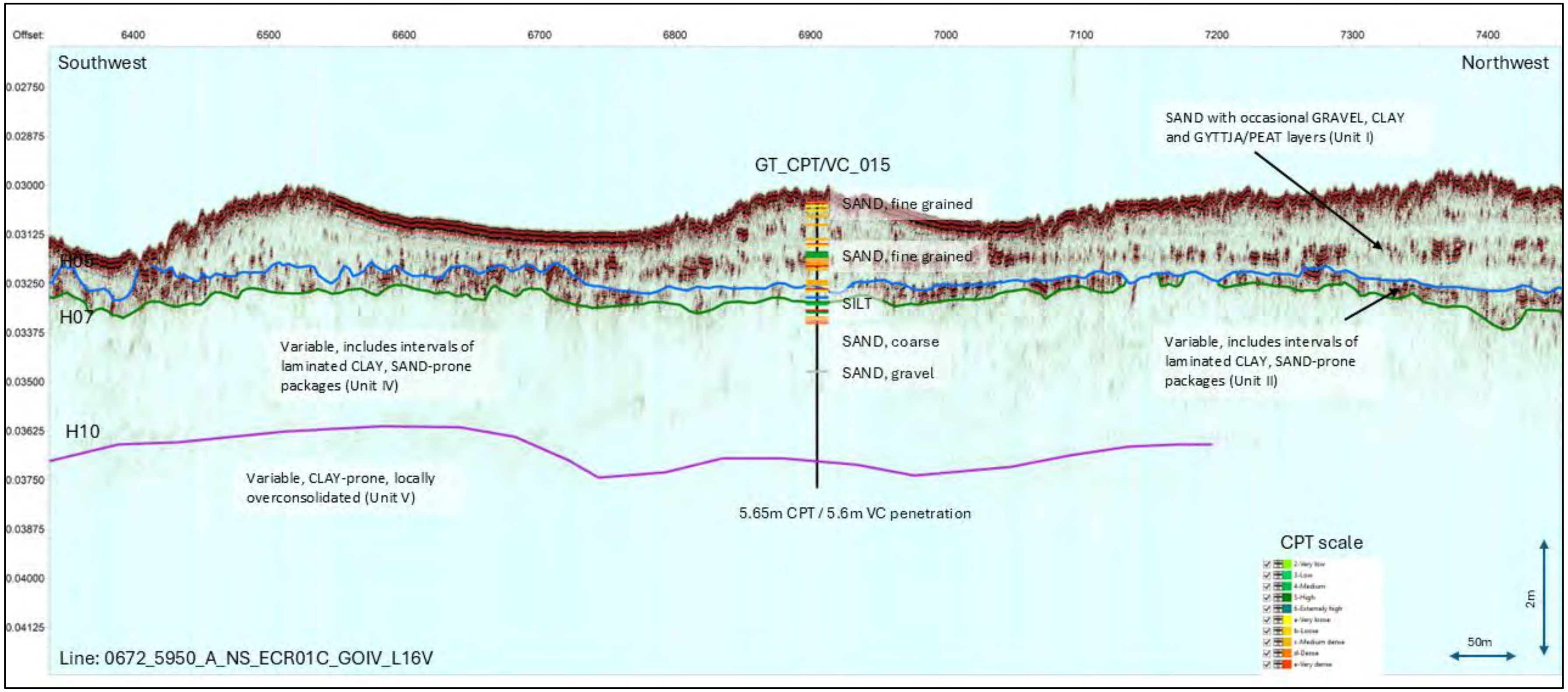


Figure 82: Seismic example illustrating sediments in Unit I and Unit II

b Quaternary geology

Unit II, III and IV, Late Glacial deposits

This interval is very complex due to the area's range of environmental conditions during the Late Weichselian and earliest Holocene. Some intervals show laminations indicative of clays and silts, others may represent sandy beach-type deposits. Along the cable route corridor these sediments have been subdivided into three units. This is because they vary greatly in seismic acoustic character and geotechnically.

Unit II is mapped with H07 at its base. It consists of higher amplitude sediments, interpreted as a coarser sediment layer. This is fairly continuous along the route and occurs between 0.2 m below seabed at the start of the route at KP 0.200 and 4.8 m between KP 13.000 and KP 14.000.

Unit III is a small channel towards the end of the route, between KP 22.100 and KP 23.500. The unit is generally mapped with H09 at its base.

Unit IV is mapped with H10 as its base. Below H07, and H09 where present, the data appears acoustically quiet throughout. This makes mapping the base of Unit IV difficult because it is not clear if H10 shows little acoustic impedence with the sediments above or if it is actually beyond the limit of penetration on the Innomar SBP system. The acoustically quiet package of Unit IV does not help make this difference any clearer. The extents and interpretation of H10 is tentative, which has resulted in a sparser and more intermittent gridded result towards the offshore.

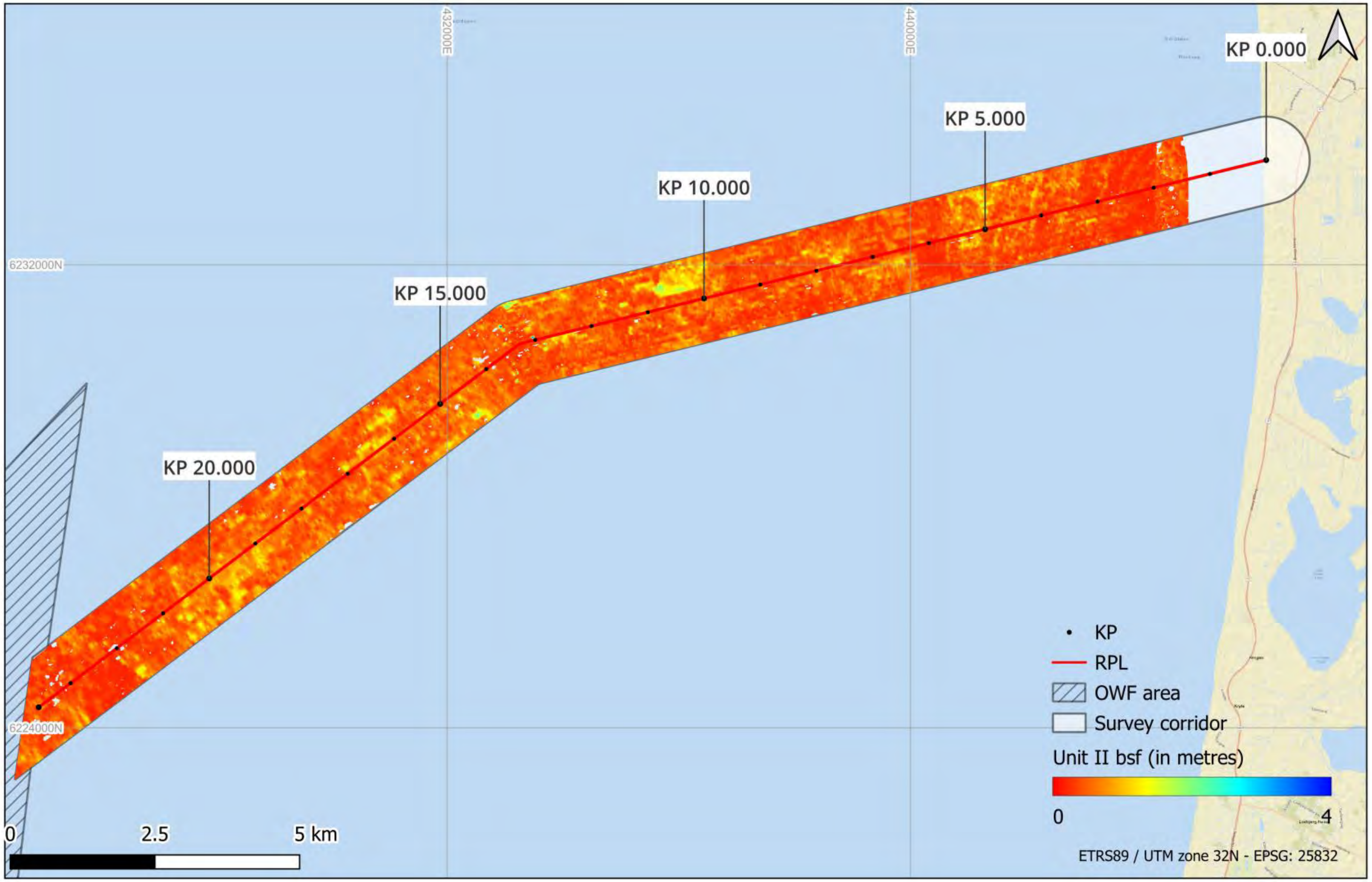


Figure 83: Distribution and depths below seabed of Unit II

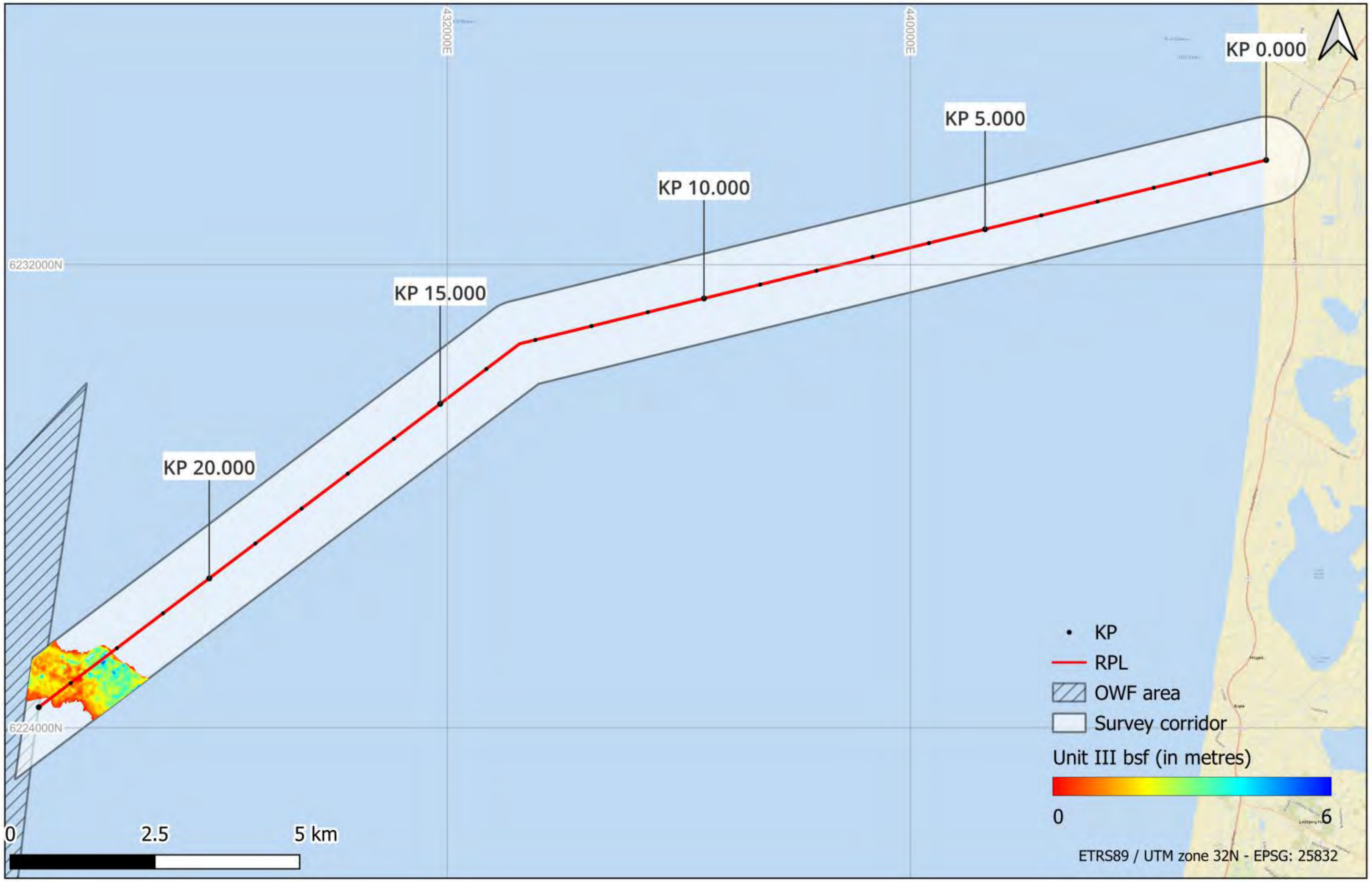


Figure 84: Distribution and depths below seabed of Unit III

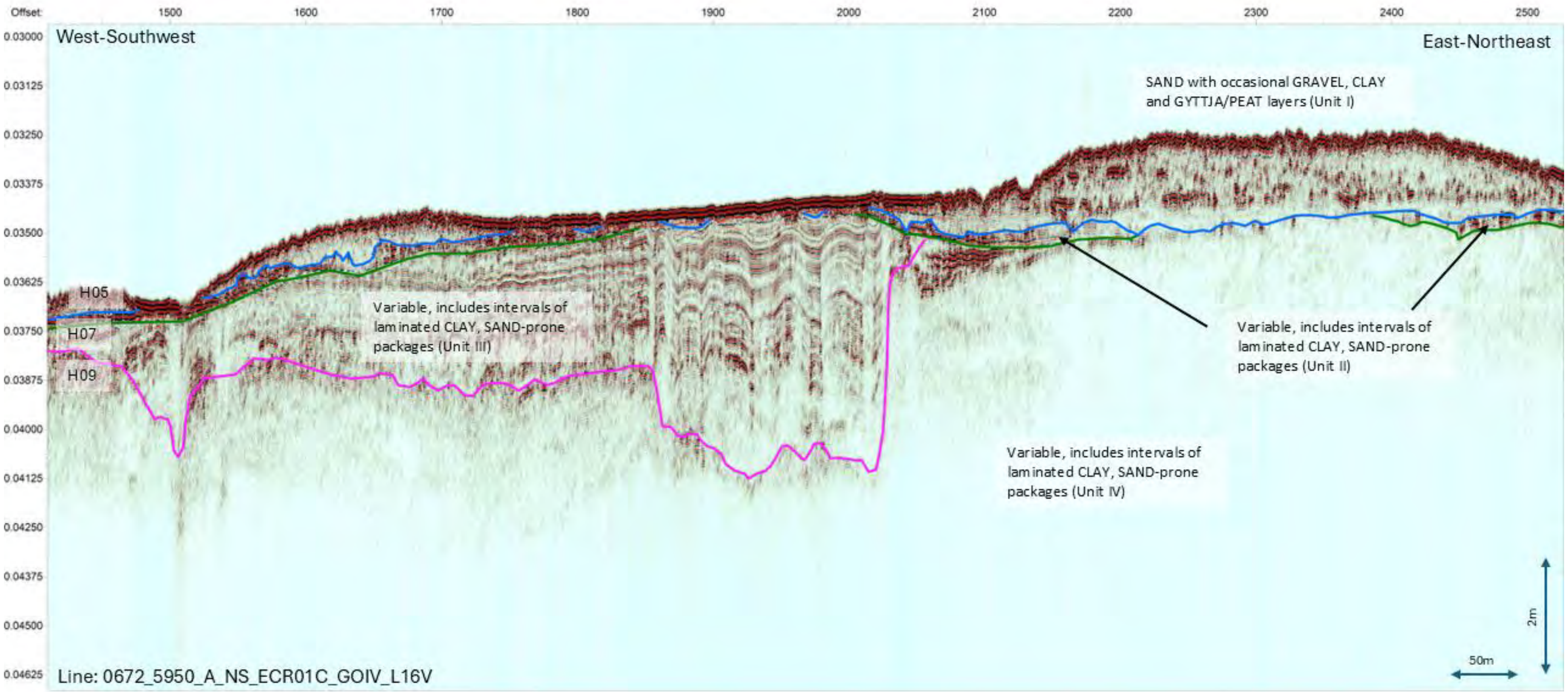


Figure 85: Seismic example illustrating Unit III

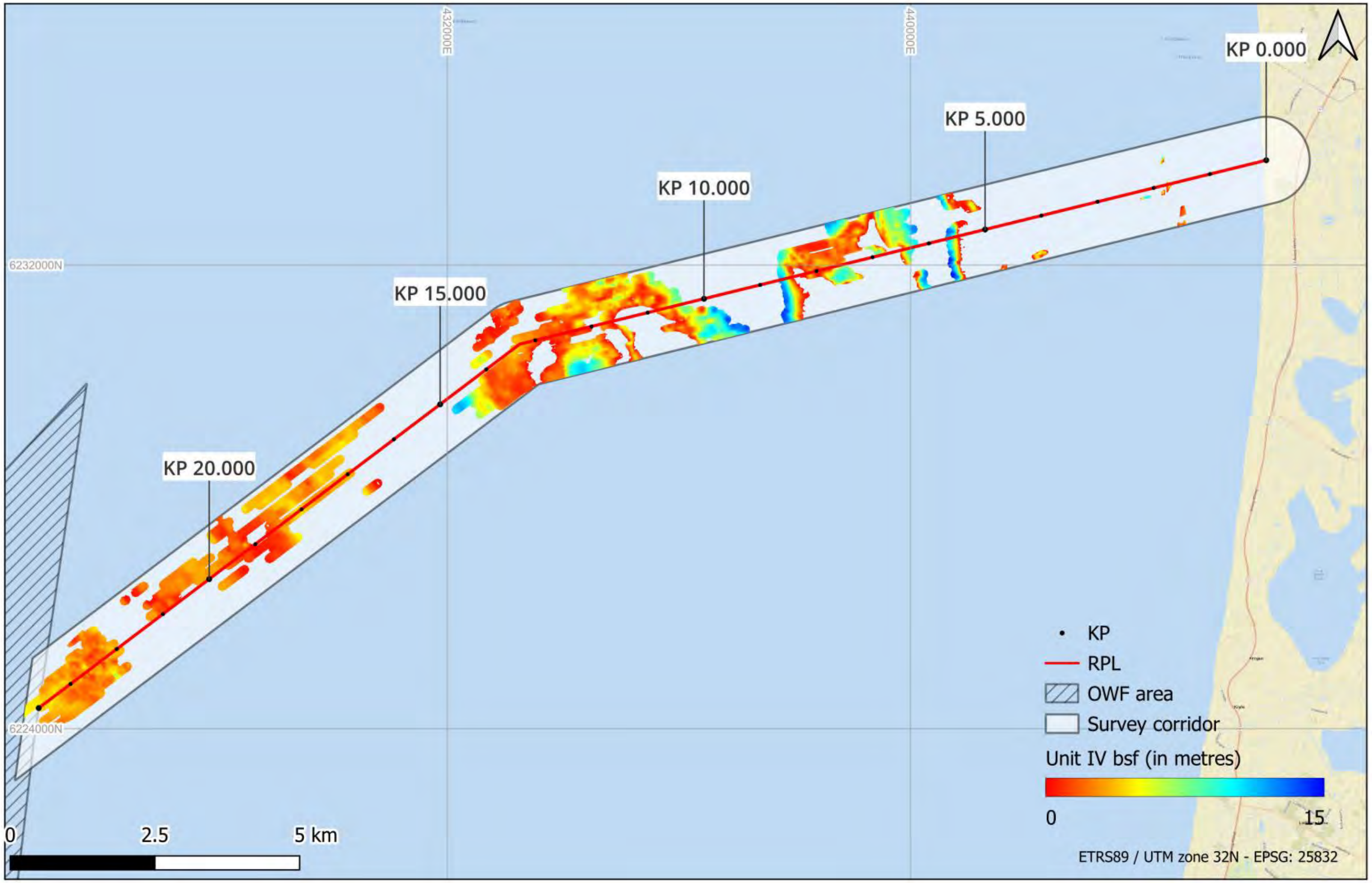


Figure 86: Distribution and depths below seabed of Unit IV

Unit V, Glacial deposits

Unit V deposits occur along the route corridor. Unit V is interpreted to be a till laid down in association with the last major ice advance over the area, approximately 22,000 years ago. The till forms a relatively thick blanket, to deeper than the depth of interest for cable burying. The base of the till/ top bedrock is not imaged within the export route corridor but the unit is marked by either H10 (where Unit IV is present) or it directly underlies Unit II so is present within the top 5 m of seabed over much of the route. Any geotechnical data that penetrates into this unit shows little conclusive evidence of the sediment type.

Unit V is generally a glacial till which has been subjected to direct ice contact, though the unit contains other facies which may have been laid down in ice-marginal environments during oscillations of the ice front. The ice-contact facies may comprise a clay-prone diamicton which is likely to contain subordinate silt, sand, gravel, cobbles and boulders and will be overconsolidated. Consolidation levels may significantly vary over short distances. Seismically, the ice contact facies are structureless with a very irregular upper surface, which probably forms a series of ridges.

6.7.5 C14 Analysis

Carbon 14 analysis to determine soil age has been undertaken on six locations along the NS ECR01 route. Figure 135 shows the C14 sample locations along the route corridor.

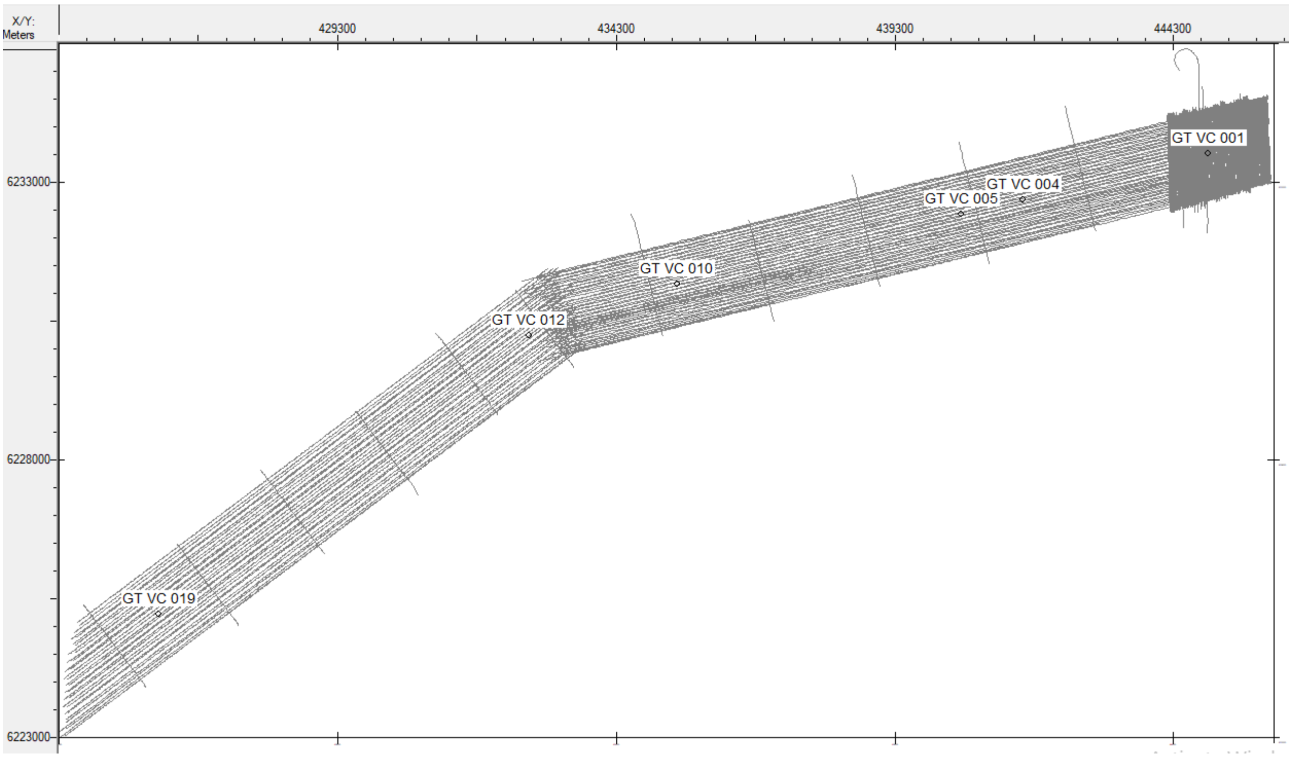


Figure 87: Locations of C14 sampling on ECR01

Figure 136 shows the C14 result at VC_001 plotted on the SBP data. The sample appears to be taken just below the post glacial interface (H05) and correlates with the expected glacial unit beneath, away from the interpreted channel of late glacial material adjacent to the vibrocore (H10). The derived age of > 43,500 BP, which is the practical limit of the C14 methodology utilised in this lab analysis, infers that the interpretation and C14 aging agree that glacial sediments are present at this location.

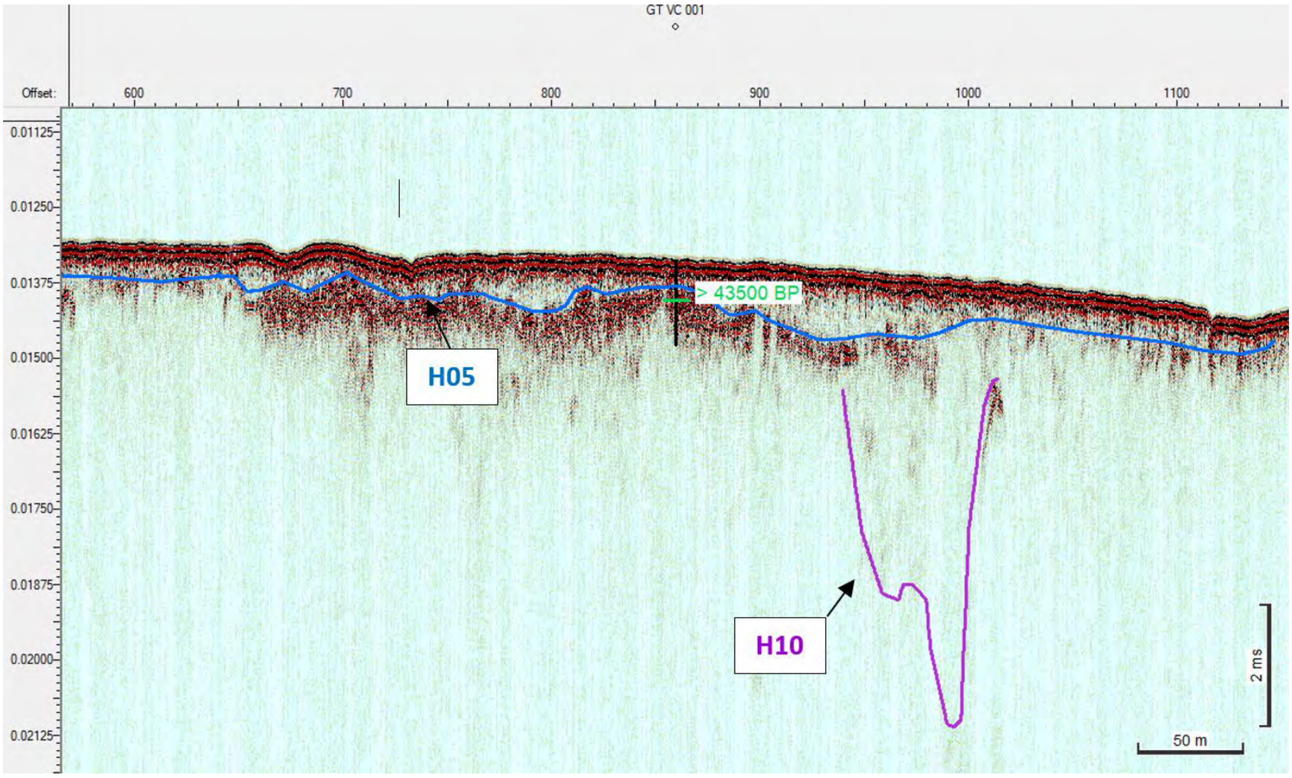


Figure 88: C14 result on SBP profile at VC_001

Figure 137 shows C14 results for VC_004 and VC_005. The C14 sample for VC_004 has been taken below all interpretation, placing it within the glacial till unit, which agrees with the derived age measured at > 43,500 BP. The C14 results on VC_005 shows a younger age at 36,220 ±330 BP, which resides within a channel bounded by the interpretation of H10 shown in the figure showing the eastern bank of the channel extending to depth. H10 marks the late glacial, and so it is expected that the sediments within the channel feature should be younger as part of the late glacial units.

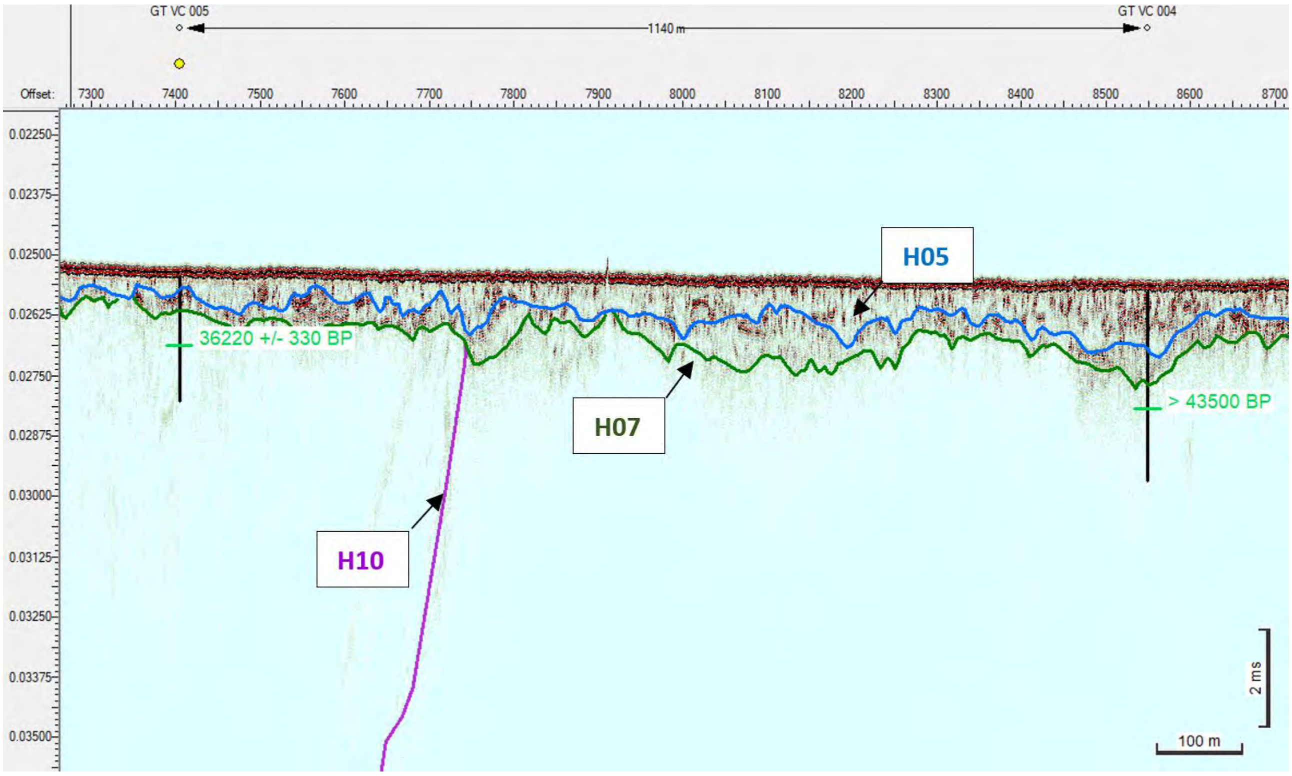


Figure 89: C14 result on SBP profile at VC_004 and VC_005

Figure 138 shows C14 results for VC_010 and VC_012. VC_010 lies at a location where SBP interpretation becomes uncertain as the H05 reflector shoals. The C14 result of 9,340 ± 30 BP at this location indicates late post glacial sediments are like at this location at a depth of 0.4 m below seabed. At VC_012 much younger soils have aged at 1.85 m below seabed which is beneath the interpreted post glacial base. This conflict may indicate that the post glacial base in this locale might be closer to the interpretation made for H07 which was interpreted to follow a band of higher amplitude reflections beneath the interpreted base of post glacial. The difference at this location between the two reflectors is small, at 0.4m. It is also possible that the sample depth may have errors induced by vibrocoring and obtaining clean C14 samples across decimetre distance. There is also the ~5,000-year difference between soils tests at VC_010 and VC_012, where the younger sediment is found deeper and beneath key reflectors in the SBP that may indicate error in the C14 measurement.

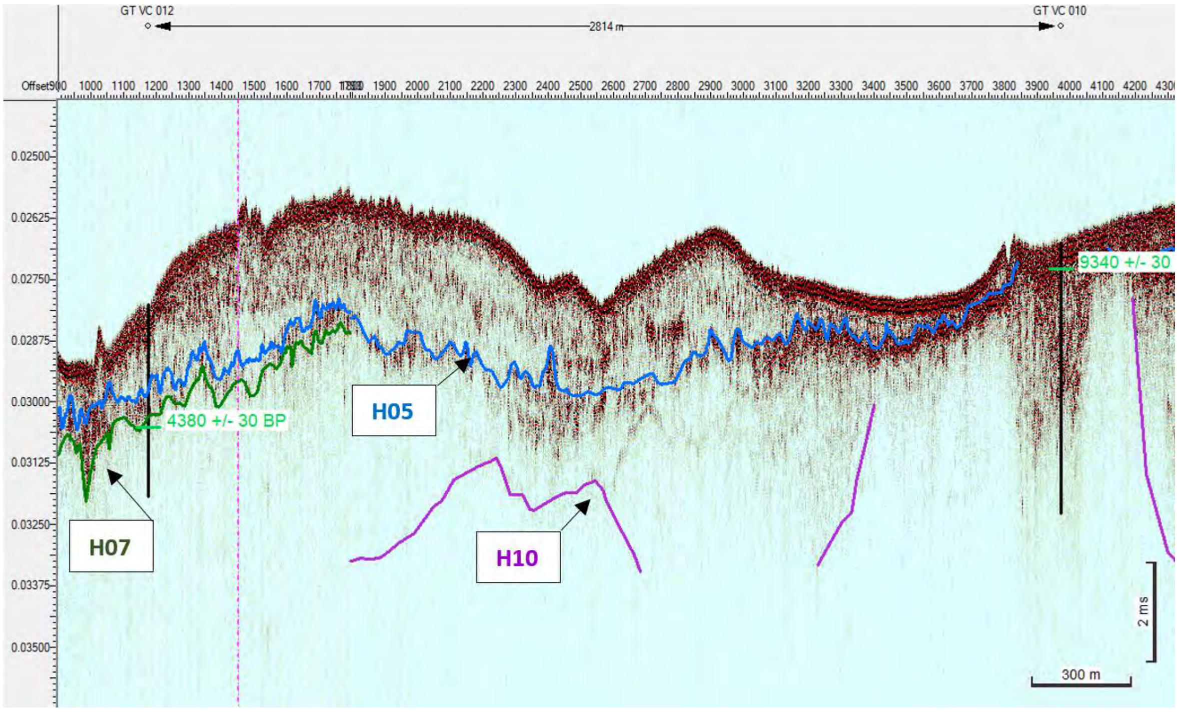


Figure 90: C14 result on SBP profile at VC_010 and VC_012

Figure 138 shows the C14 results for VC_019. This result shows an age of 8920 ±30 BP at a depth of 3.25m below seabed. The H05 horizon marking the interpreted base of post glacial material is conflicting with the C14 result at this location, however the structure has been interpreted as more akin the those found in the late glacial sediments, as well as the unit interpreted above H05 being consistent with the character observed for the post glacial sediments across the rest of the site.

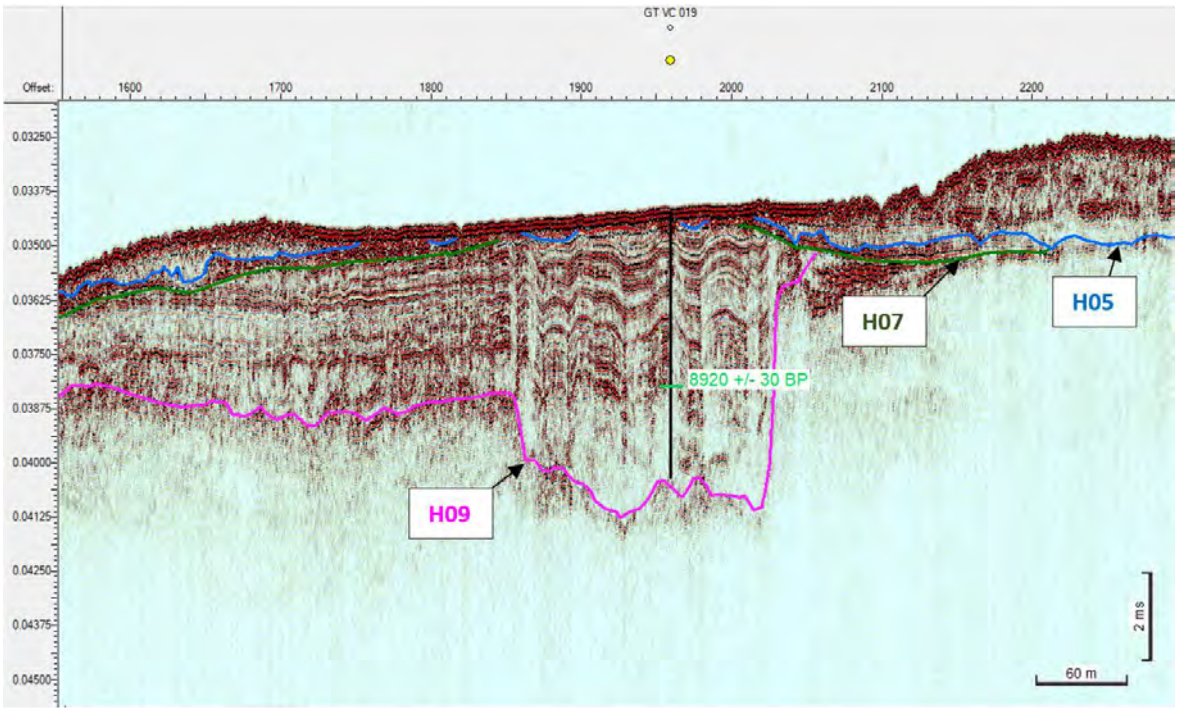


Figure 91: C14 result on SBP profile at VC_019

7 NS_ECR1 ROUTE ANALYSIS

A summarized route analysis along the NS_ECR1 cable route, subdivided in 3 km sections, is displayed in Table 72, below. SBP images with geomodelling, in 3 km sections, are presented in Appendix E. The route analysis is based on correlation between geotechnical and geophysical data.

Table 72: NS-ECR1 Overview per 3 km interval

From KP	To KP	Seabed Geology	Seabed Features	Seabed Topography	Shallow Geology	Environmental and geotechnical	
0	3	The seabed geology is a mix of SAND, Gravel and Coarse SAND and occasional patches of Till until KP 0.360. From KP 0.360 to KP 1.350, the geology is predominantly SAND with an isolated patch of TILL at KP 0.800 and an area of Gravel and Coarse SAND at approx. KP 1.000. From KP 1.350 to KP 2.000, the geology is predominantly a mix of Till and SAND. KP 2.000 to KP 3.000 consists of SAND.	Sandwaves and ripples are present until KP 0.360. The seabed is then predominantly featureless until KP 1.350, other than a small high density boulder field on the RPL at approx. KP 0.800. From KP 1.350 to KP 2.000, high and intermediate density boulder fields dominate the survey corridor. From KP 2.000 to KP 3.000, the northern half of the survey corridor is dominated by ripples, whereas the southern half is primarily featureless.	The nearshore area is characterised by steep slopes. Seabed slope from KP 0.000 to KP 0.500 drops by 5-6 metres, with a ridge of elevation of up to 3 metres in height in the centre. The slope from KP 0.500 to KP 3.000 steeply declines by 12 metres.	H05 and H10 present	Geotechnical	VC001 VC002 CPT001 CPT002
						Grab samples	NS-1_001_03 NS-1_002_03 NS-1_003_03 NS-1_004_03 NS-1_005_03 NS-ECR-01-01 NS-ECR-01-02
3	6	Predominantly Muddy SAND until KP 5.000 where the geology turns to SAND.	From KP 3.000 to KP 4.200, the seabed is largely dominated by isolated patches of lower reflectivity visible on SSS only but is otherwise primarily featureless, other than a small	From KP 3.000 to KP 6.000 the seabed forms a gentle slope. The slope gradually decreases by 1 metre.	H05 present	Geotechnical	VC003 VC004 VC005a CPT003 CPT004 CPT005

From KP	To KP	Seabed Geology	Seabed Features	Seabed Topography	Shallow Geology	Environmental and geotechnical	
			high density boulder field approx. 400 m south of the RPL at KP 3.600, and small isolated areas of pitted seabed. KP 4.200 to KP 5.500 is largely dominated by ripples to the north of the RPL, and patches of lower reflectivity and areas of pitted seabed to the south. KP 5.500 to KP 6.000 is primarily featureless, other than some ripples to the north of the RPL at the edge of the survey corridor.			Grab samples	NS-ECR-01-03 NS-ECR-01-04 NS-ECR-01-05
6	9	SAND is present throughout the survey corridor in this KP range.	The seabed is primarily featureless, with the exception of boulders and occasional patches of erosional bedforms. Ripples can also be found along the northern edge of the survey corridor from KP 6.000 to KP 7.000.	From KP 6.000 to KP 9.000 the seabed flattens with minimal changes in bathymetry.	H5 and H10 present	Geotechnical	VC006 VC007 CPT006 CPT007
						Grab samples	NS-ECR-01-06 NS-ECR-01-07 NS-ECR-01-08
9	12	From KP 9.000 to 10.000 and KP 11.250 to KP 12, SAND dominates the seabed geology. Gravel and Coarse SAND and Sand are present between KP 10.000 to 11.250.	Ripples and large ripples dominate this part of route. Erosional bedforms can also be found, primarily between KP 9.000 and KP 9.750. One small high density boulder	Seabed slope from KP 9.000 to KP 12.000 gradually declines by 2 metres. From KP 11.000 to KP 11.500 in the middle there are local elevation (large	H5 and H10 present	Geotechnical	VC008 VC009 VC010 CPT008 CPT009 CPT010

From KP	To KP	Seabed Geology	Seabed Features	Seabed Topography	Shallow Geology	Environmental and geotechnical	
		Three small patches of Till are present to the south of the RPL near KP 11.400.	field is found 700 m south of RPL at approx. KP 10.500.	ripple crests) up to 0.5 -1 metre high.		Grab samples	NS-ECR-01-09 NS-ECR-01-10 NS-ECR-01-11
12	15	Predominantly Gravel and Coarse SAND and SAND, with a few patches of Muddy Sand present mainly between KP 14.100 to KP 15.000.	Ripples and large ripples dominate this part of the route. Occasional isolated areas of erosional bedforms and featureless seabed are found towards the outer edges of the survey corridor.	Seabed slope from KP 12.000 to KP 13.000 slightly increases by 1 metre and from KP 13.000 to KP 15.000, the seabed slope gradually decreases by 2 metres with large ripple crests up to 1 metre heigh.	H5 and H10 present	Geotechnical	VC011 VC012 CPT011a CPT012
						Grab samples	NS-ECR-01-12 NS-ECR-01-13 NS-ECR-01-14
15	18	Gravel and Coarse SAND and SAND are the most represented along the RPL, with large patches of Muddy SAND towards the outer edges of the survey corridor.	Ripples and large ripples dominate this part of the route. Areas of featureless seabed and patches of lower reflectivity on the SSS data are largely found away from the RPL.	Seabed slope from KP 15.000 to KP 18.000 gradually decreases by 1.5 metres with large ripples crests present.	H5 and H10 present	Geotechnical	VC013 VC014 VC015 CPT013 CPT014 CPT015
						Grab samples	NS-ECR-01-15 NS-ECR-01-16 NS-ECR-01-17

From KP	To KP	Seabed Geology	Seabed Features	Seabed Topography	Shallow Geology	Environmental and geotechnical	
18	21	Predominantly Muddy SAND and SAND, with smaller isolated patches of Gravel and Coarse SAND.	Large ripples dominate this part of the route. Areas of featureless seabed, ripples and patches of lower reflectivity on the SSS data are largely found away from the RPL.	Seabed slope from KP 18.000 to KP 20.000 slope gradually decreases by 1.5 metres. From KP 20.000 to KP 21.000 there is a slope with an increase of 0.5 m.	H5 and H10 present	Geotechnical	VC016 VC017 VC018 CPT016 CPT017 CPT018
						Grab samples	NS-ECR-01-18 NS-ECR-01-19 NS-ECR-01-20
21	23.691	Predominantly SAND and Gravel and Coarse SAND. Some isolated patches of Muddy SAND are present near	Ripples and large ripples dominate this part of the route. Areas of featureless seabed, erosional bedforms	From KP 21.000 to KP 21.250 the slope decreases by 1.3 m. There is a slope increase of 1.9 m from KP 21.250 to KP	H5 and H10 present	Geotechnical	VC019 VC020 CPT019 CPT020

From KP	To KP	Seabed Geology	Seabed Features	Seabed Topography	Shallow Geology	Environmental and geotechnical	
		KP 21.350 and between KP 22.750 and KP 23.500.	and patches of lower reflectivity on the SSS data are largely found away from the RPL.	22.000. From KP 22.000 to KP 22.750 the seabed slope decreases by 3 metres. From KP 22.750 to KP 23.691 the seabed is predominately flat with large ripple crests up to 1 meter heigh.		Grab samples	NS-ECR-01-21 NS-ECR-01-22 NS-ECR-01-23

7.1 KP 0.000 – KP 3.000

Two VCs, two CPT's and three grab samples were acquired in this section.

Unit I (bounded by H5) is present throughout the section which varies in thickness between 1 and 2 m but forms a channel reaching around 3 m deep around KP 0.4. Acoustically it is opaque but with numerous high amplitude discrete features which may represent coarser/firmer deposits or potentially dropstones.

Geotechnical samples VC001, VC002, CPT001 and CPT002 and three grab samples were acquired, showing the sediments to comprise fine to coarse (gravelly in VC001) SAND over sandy CLAY at VC001 and STONE at VC002. Both VC stations had limited penetration, however, the CPT stations extended into Units II and IV.

Unit I directly overlies Unit IV to around KP 1.4 whereafter Unit II is present overlying Unit IV/V.

H10 (Base of unit IV) is present and has only been mapped intermittently over this section due to the seismic data not being sufficiently defined to fully trace. It is unclear in this section where the boundary is between units IV and V therefore there may be over consolidated sediments present within the top 5 m of sediments.

CPT001 penetrates Unit IV and is interpreted to comprise fine SANDS, SILT and silty CLAYS. CPT002 penetrates both Unit II and Unit IV and Unit II is recorded as SILT mixtures with Unit IV as clayey SILT to silty CLAY.

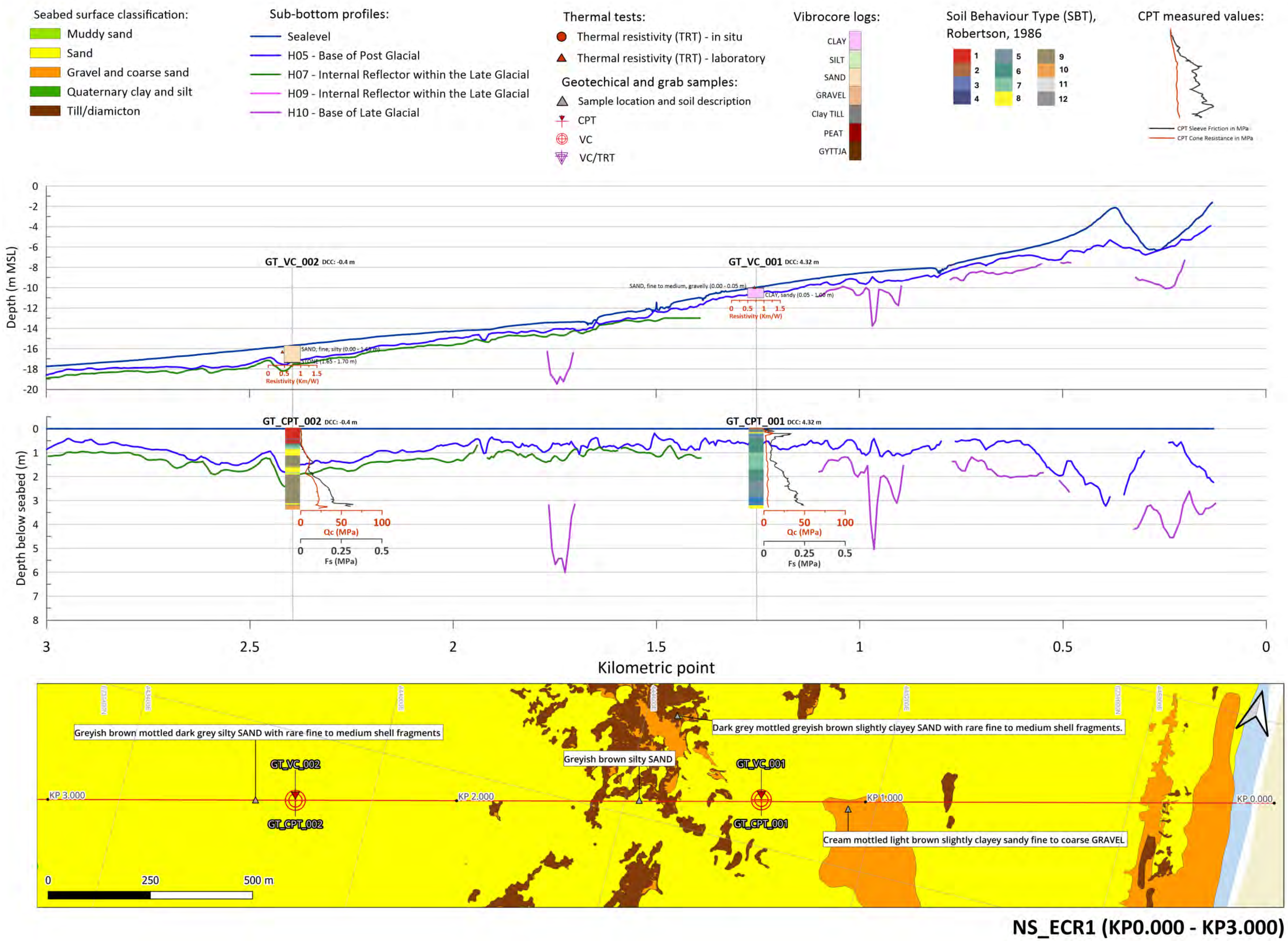


Figure 92: Integrated geotechnical panel KP 0.000 – KP 3.000

7.2 KP 3.000 – KP 6.000

Three VCs, three CPTs and three grab samples were acquired in this section.

Unit I (bounded by H05) is present throughout the section which varies in thickness between 0.5 to 1 m. Acoustically, it is opaque but with numerous high amplitude discrete features which may represent coarser/firmer deposits or potentially dropstones.

Geotechnical samples VC003, VC004, VC005a, CPT003, CPT004 and CPT005 and three grab samples were acquired, all penetrating Unit I which is represented by fine, clayey, silty SAND. However, VC004 has a 30 cm layer of GYTTJA at the base. This is not observed as a change in signal on the seismic data.

Unit II underlies Unit I throughout this section and is a thin unit of less than 1 m primarily comprising silty, sandy CLAY. It is higher amplitude on the seismic data, showing a more chaotic response to the sediments above and below it.

Units III and IV are not present along most of this section so Unit II overlies Unit V. Only one VC (VC004) penetrated Unit V and PEAT was recorded. CPT's 003 and 004 penetrated UNIT V and are described as predominantly SAND and SILTS. Although this unit is described as Glacial – Variable, clay prone, it is possible that locally over-consolidated sediments are present in some areas.

A channel fill of Unit IV sediments is interpreted between KP 5.45 and KP 5.75 which is penetrated by VC005a and CPT005 and VC presents fine sandy CLAY with sandy GYTTJA at the base (at 1.95 m) and CPT005 presents a mix of SILT dominant sediments to the base of the push at 6.2 m.

As the boundary between units IV and V is not always apparent on seismic data in this section there may be over consolidated sediments present within the top 5 m of sediments.

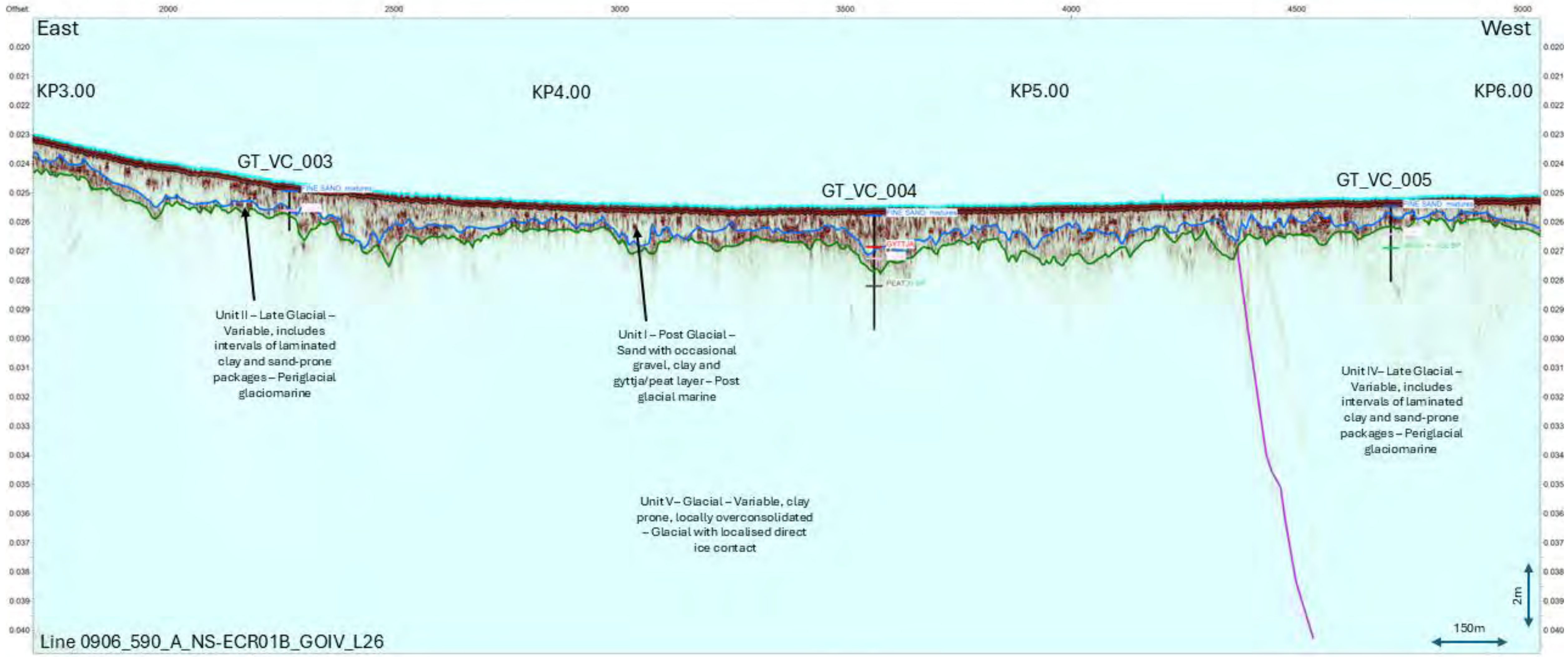


Figure 93: SBP and Geotech, KP 3.000 – KP 6.000

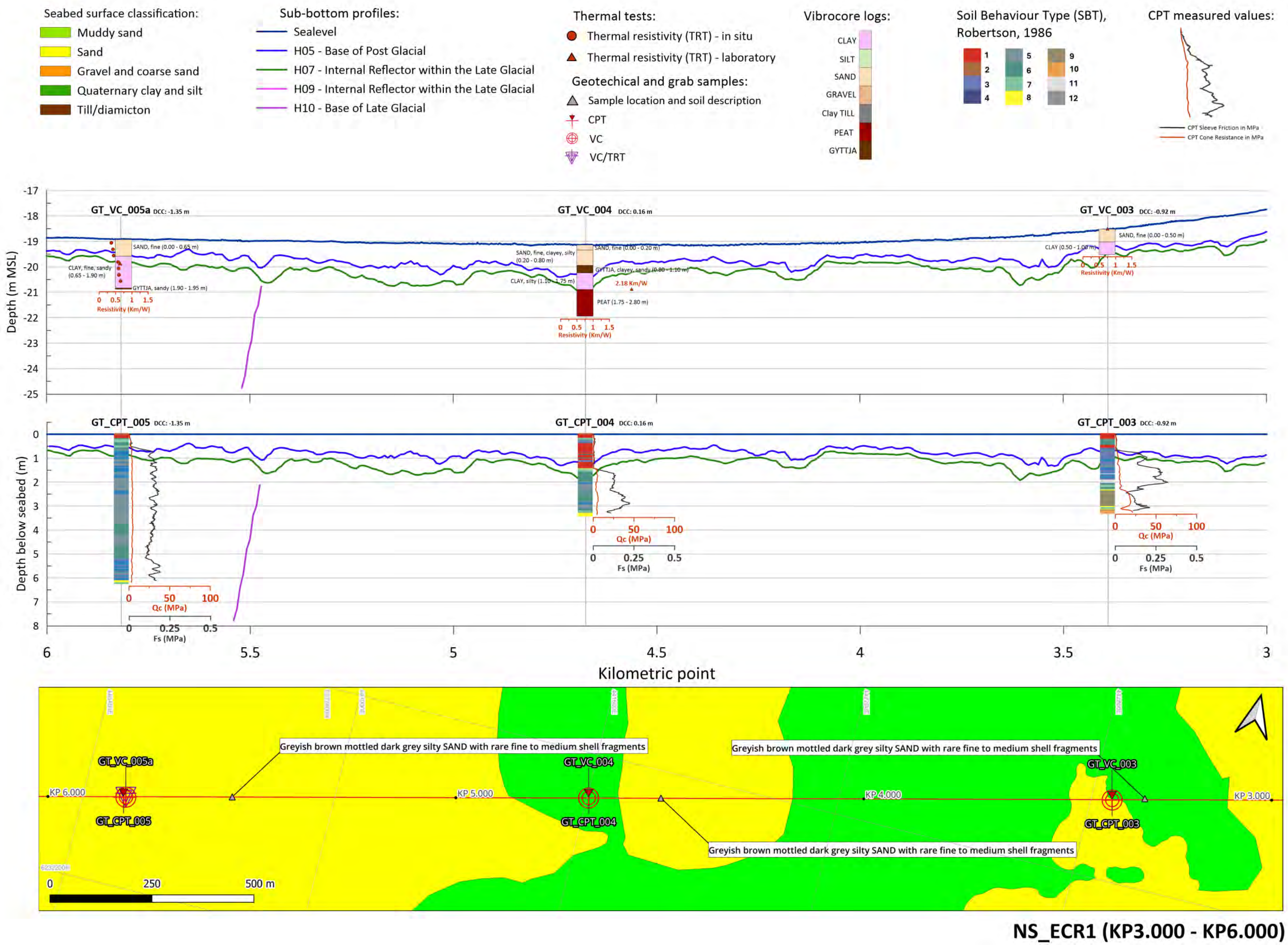


Figure 94: Integrated geological panel 3.000 – KP 6.000

7.3 KP 6.000 – KP 9.000

Two VCs, two CPTs and three grab samples were acquired in this section.

Unit I (bounded by H05) is present throughout the section which varies in thickness between 1 to 2 m. Acoustically it is opaque but with numerous high amplitude discrete features which may represent coarser/firmer deposits or potentially dropstones.

Geotechnical samples VC006, VC007, CPT006 and CPT007 and three grab samples were acquired, all penetrating Unit I which is represented by fine to medium silty SAND; however, VC006 has a thin layer of sandy CLAY at the base of Unit I.

Unit II underlies Unit I throughout this section and is a thin unit of less than 1m primarily comprising a thin layer of GRAVEL at the top overlying GYTTJA (VC007) and fine silty SAND (VC006).

Units III is not present along this section however there are channels of Unit IV (bounded by H10) present. VC007 and CPT007 penetrated Unit IV and present as sandy SILT layer overlying fine to medium SAND although the CPT is noted as having GRAVEL mixtures. Where Unit IV is not present Unit II overlies Unit V. VC and CPT06 penetrated Unit V and fine silty SAND was recorded (although the CPT describes a coarser SAND).

As the boundary between units IV and V is not always apparent on seismic data in this section there may be over consolidated sediments present within the top 5 m of sediments.

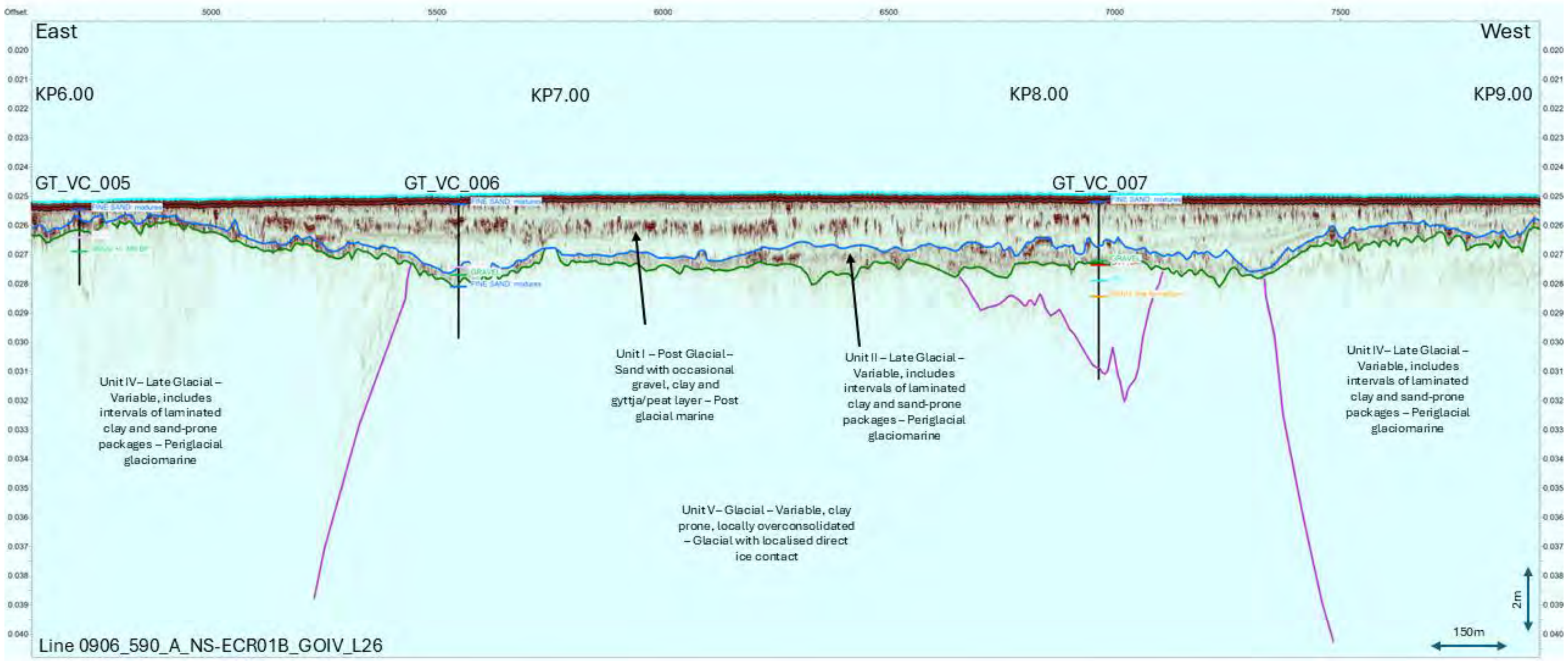


Figure 95: SBP and Geotech, KP 6.000 – KP 9.000

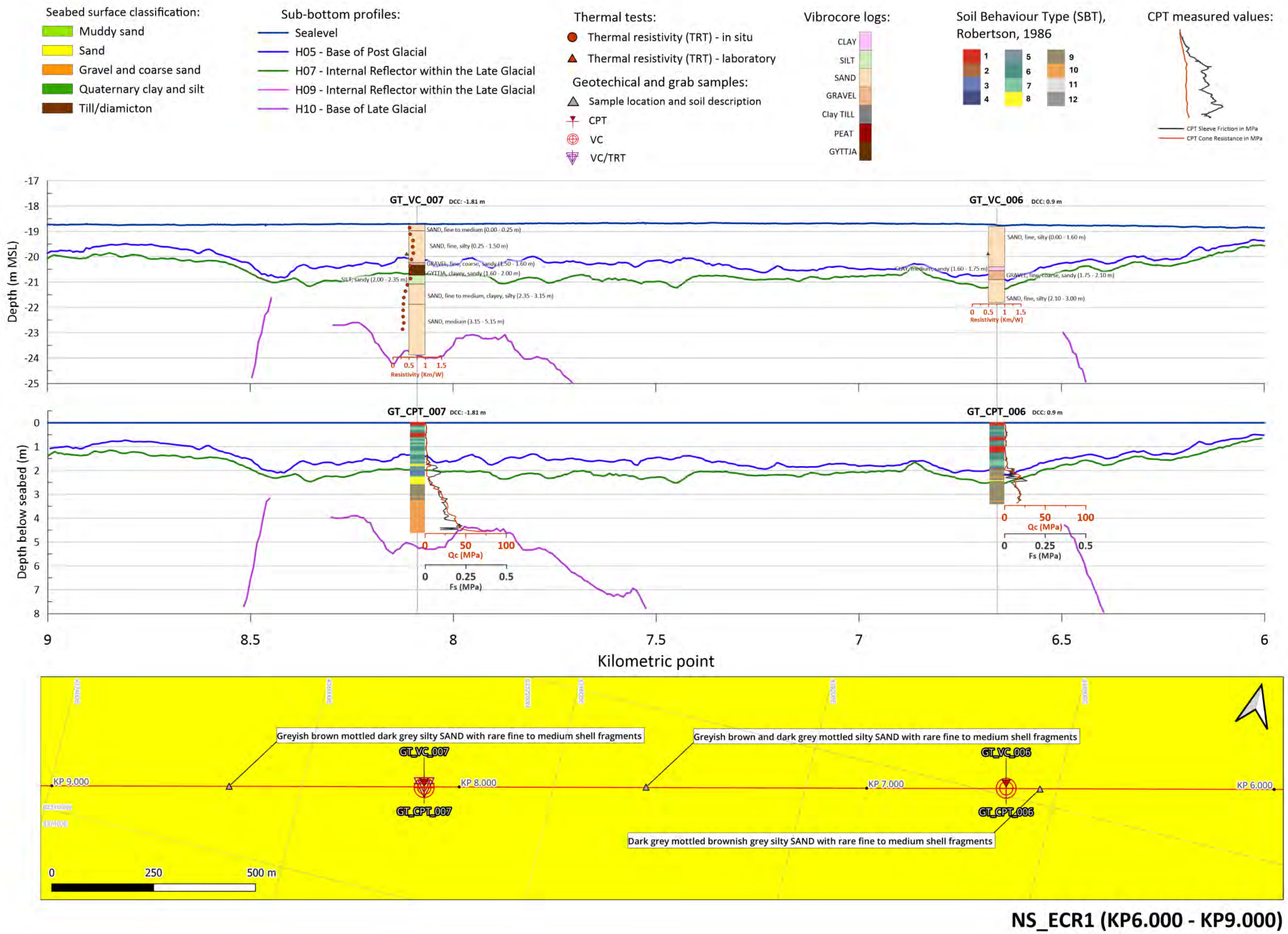


Figure 96: Integrated geotechnical panel KP 6.000 – KP 9.000

7.4 KP 9.000 – KP 12.000

Three VCs, three CPTs and three grab samples were acquired in this section.

Unit I (bounded by H05) is present throughout the section which varies in thickness between < 1 m to 1.2 m. There is a short section around geotechnical station 10 where H05 has not presented sufficient impedance to map. Acoustically, it is opaque but with numerous high amplitude discrete features which may represent coarser/firmer deposits or potentially dropstones.

Geotechnical samples VC008, VC009, VC010, CPT008, CPT009 and CPT010 and three grab samples were acquired, all penetrating Unit I which is represented predominantly by fine to coarse SAND; however, some thin layers of sandy CLAY are recorded in VC009 and VC010 presents a coarser SAND overlying PEAT.

Unit II underlies Unit I throughout this section and is a thin unit of less than 1 m primarily comprising a mix of GRAVEL, sandy CLAY and gravelly SAND.

Units III is not present along this section however there are channels of Unit IV (bounded by H10) present. Only VC and CPT009 are within a Unit IV channel and present as clayey, silty, gravelly coarse to medium SAND.

VC008/CPT008 and VC010/CPT010 penetrated Unit V and present as fine to medium gravelly SAND which overlies a sandy SILT layer, overlying a sandy CLAY layer in VC008.

As the boundary between units IV and V is not always apparent on seismic data in this section there may be over consolidated sediments present within the top 5 m of sediments.

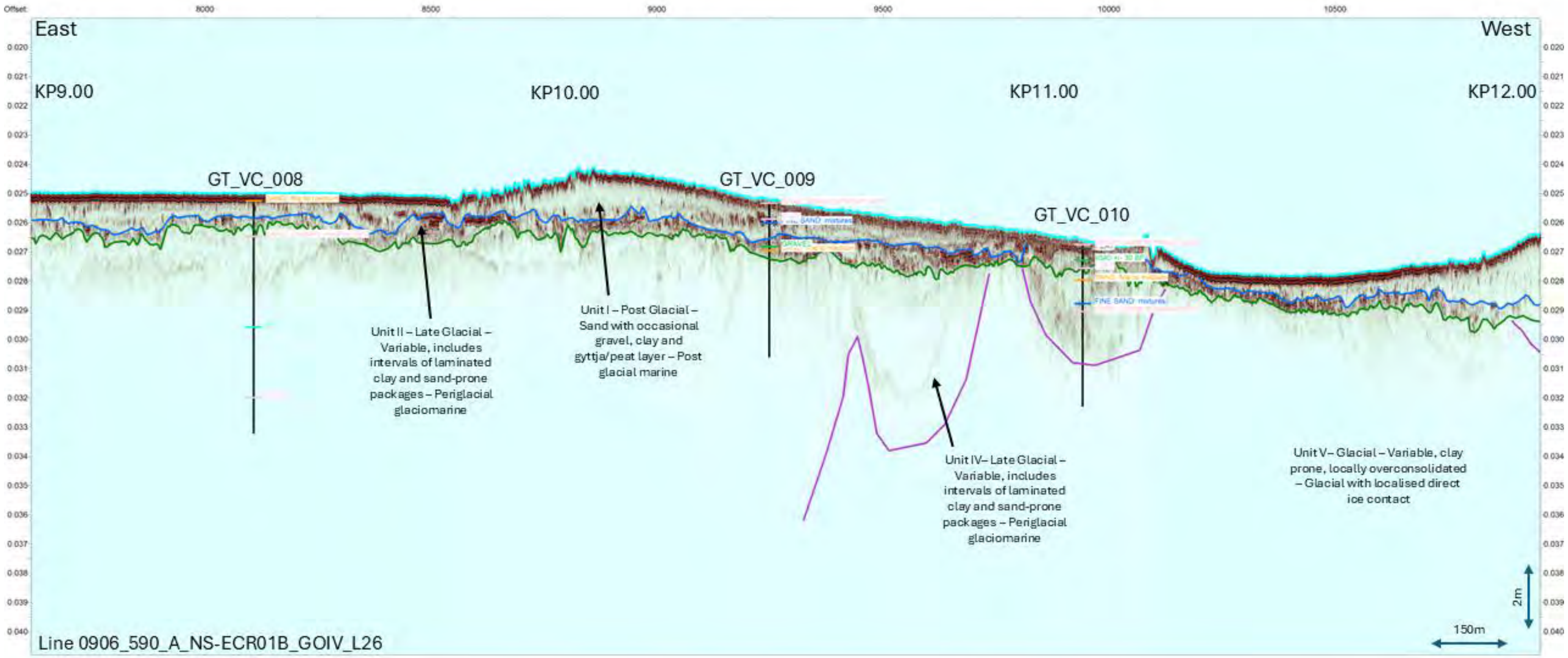


Figure 97: SBP and Geotech, KP 9.000 – KP 12.000

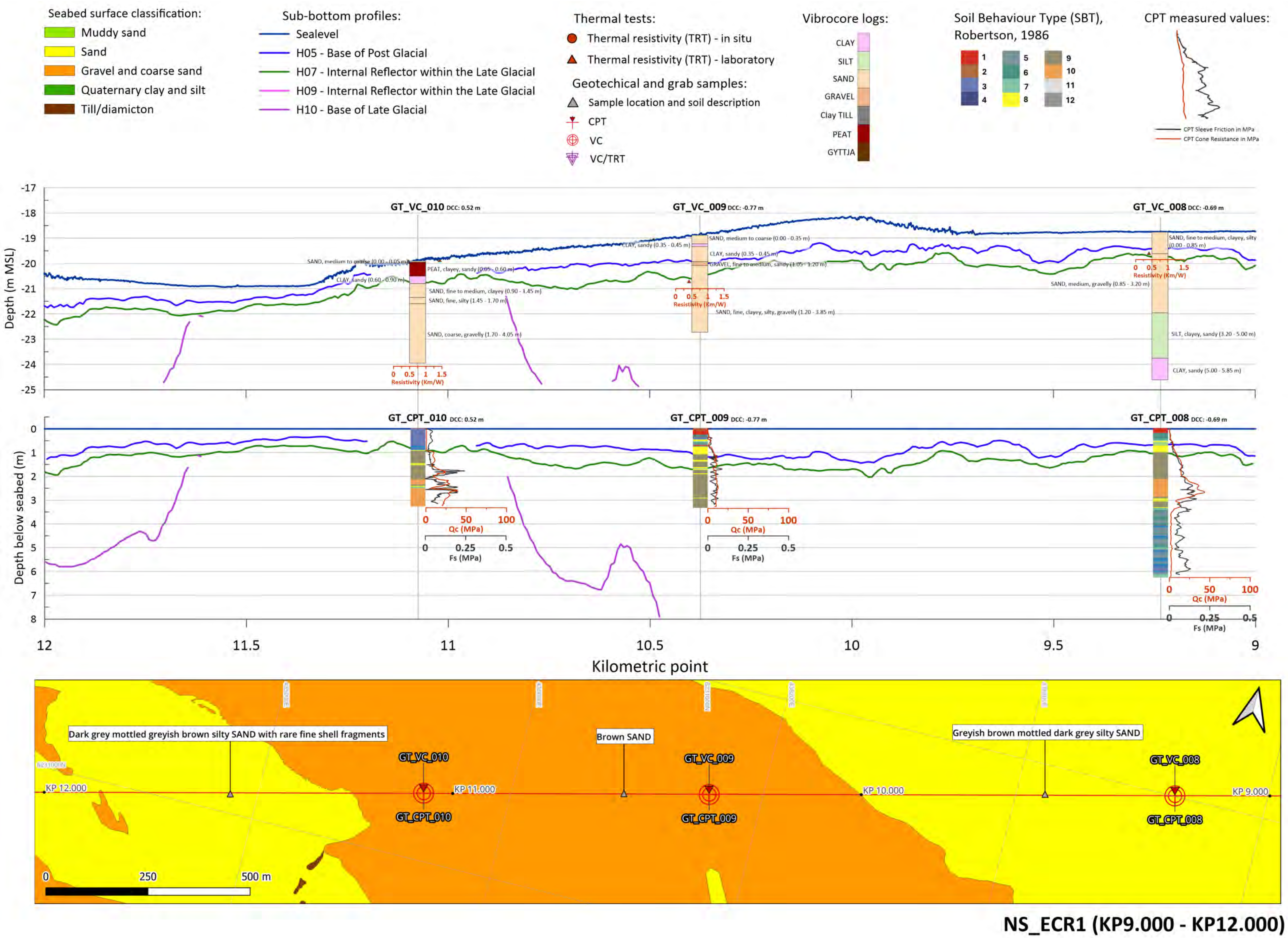


Figure 98: Integrated geotechnical panel KP 9.000 – KP 12.000

7.5 KP 12.000 – KP 15.000

Two VCs, two CPTs and three grab samples were acquired in this section.

Unit I (bounded by H05) is present throughout the section which varies in thickness between < 1 m to 2.8 m. Acoustically it is opaque but with numerous high amplitude discrete features which may represent coarser/firmer deposits or potentially dropstones.

Geotechnical samples VC011, VC012, CPT011a, and CPT012 and 3 grab samples were acquired, all penetrating Unit I which is represented predominantly by fine to medium SAND.

Unit II underlies Unit I throughout this section and is a thin unit of less than 1 m primarily comprising a mix of fine to medium SAND with layers of GYTTJA towards the base.

Units III is not present along this section however there are channels of Unit IV (bounded by H10) present over most of this section. Both stations penetrated Unit IV and present as clayey, silty, gravelly coarse to medium SAND with a layer of sandy SILT recorded at the base of Unit IV in station 011.

VC011/CPT011a penetrated to Unit V recorded fine to medium gravelly SAND, sandy CLAY overlying sandy SILT.

As the boundary between units IV and V is not apparent on seismic data in part of this section there may be over consolidated sediments present within the top 5 m of sediments.

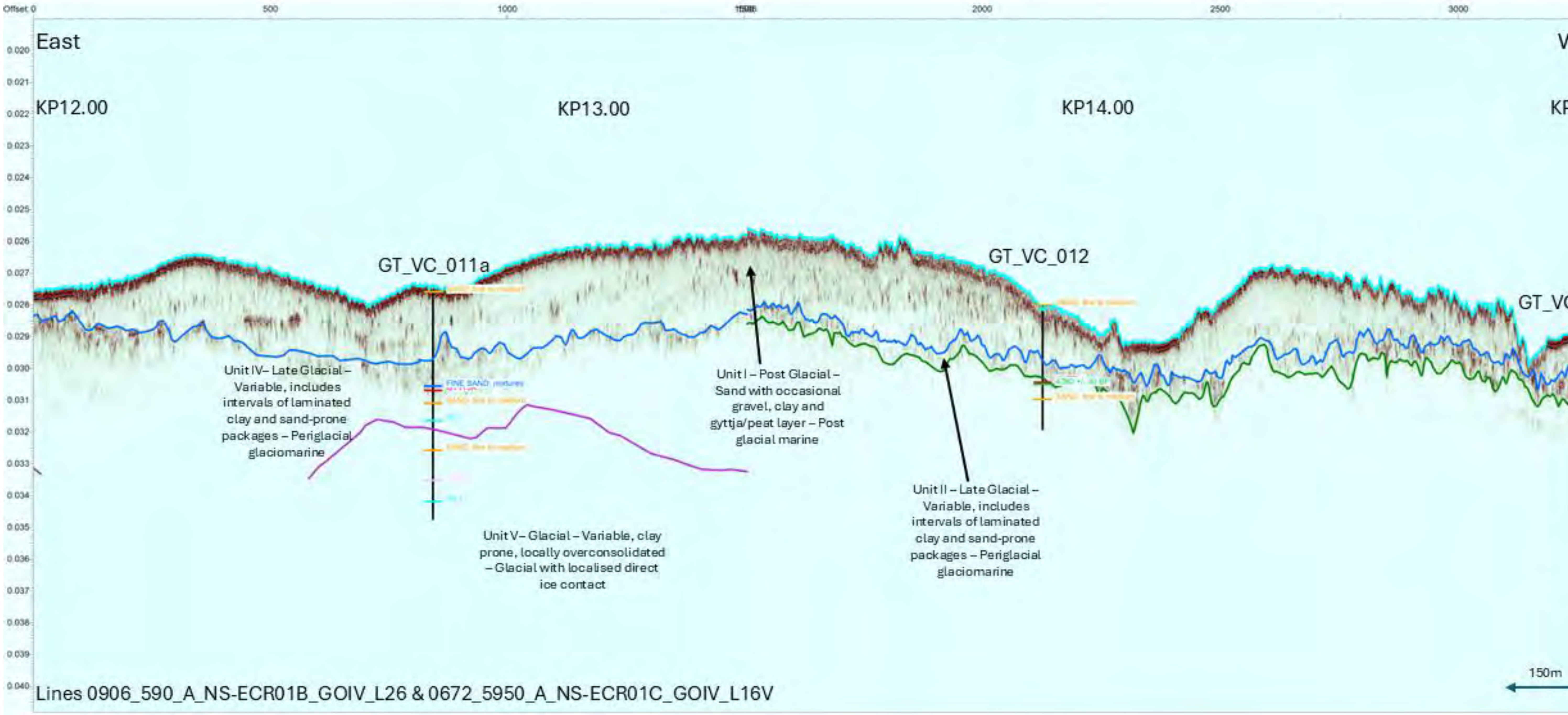


Figure 99: SBP and Geotech, KP 12.000 – KP 15.000

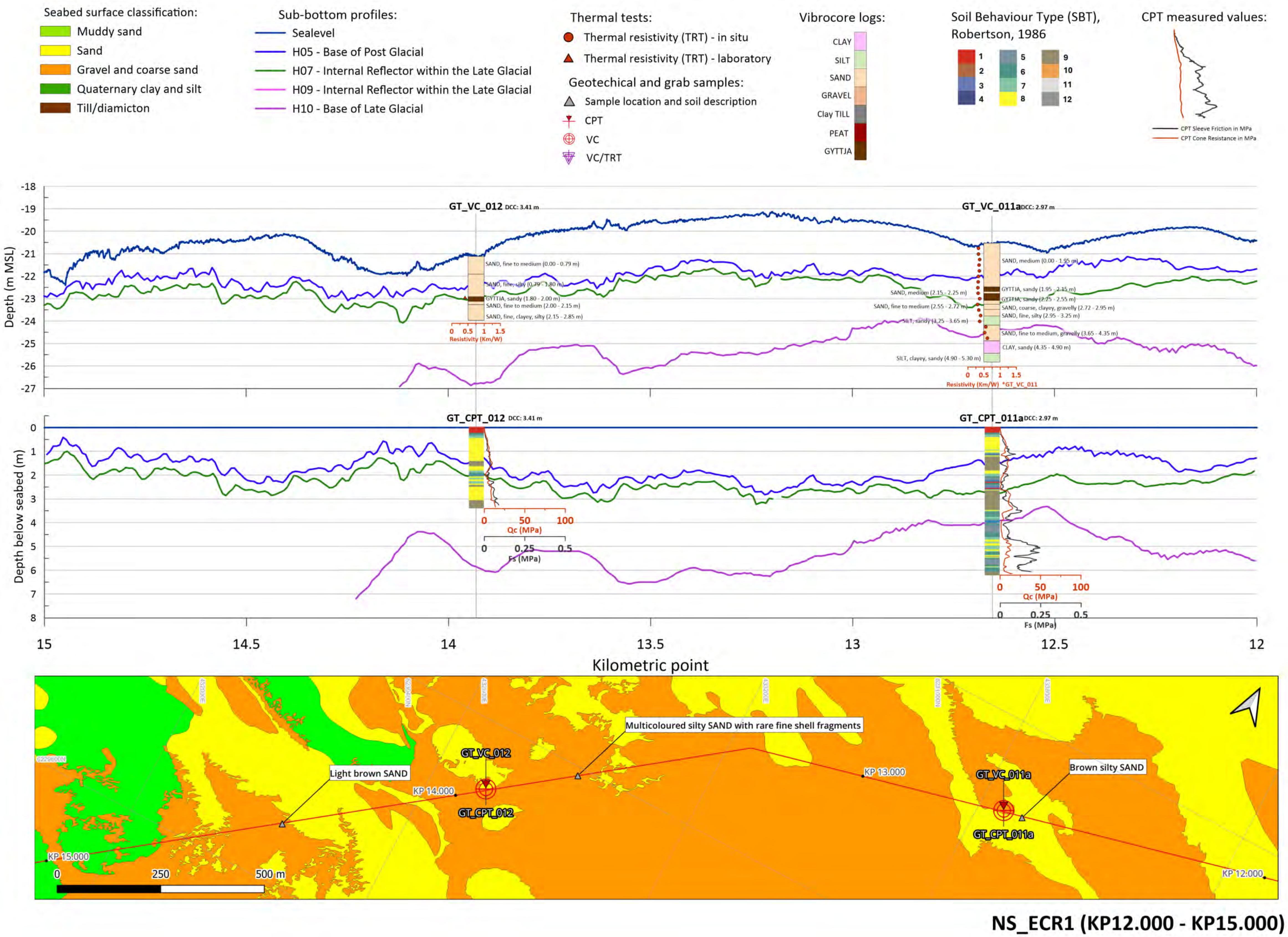


Figure 100: Integrated geotechnical panel KP 12.000 – KP 15.000

7.6 KP 15.000 – KP 18.000

Three VCs, three CPTs and three grab samples were acquired in this section.

Unit I (bounded by H5) is present throughout the section which varies in thickness between < 1 m to over 2 m. Acoustically, it is opaque but with numerous high amplitude discrete features which may represent coarser/firmer deposits or potentially dropstones.

Geotechnical samples VC013, VC014, VC015, CPT013, CPT014 and CPT015 and three grab samples were acquired, all penetrating Unit I which is represented predominantly by fine to medium clayey, silty SAND (VC014 records a layer of GYTTJA towards the base).

Unit II underlies Unit I throughout this section and is a thin unit of less than 1 m primarily comprising a mix of fine to medium SAND.

Units III is not present along this section. Unit IV (bounded by H10) is present from KP 16.8 present to the end of this section. Station 015 penetrated Unit IV and presents as fine to medium gravelly SAND.

VC/CPT013 and VC/CPT014 penetrated to Unit V and recorded fine to coarse silty, gravelly SAND, overlying silty CLAY at station 014.

As the boundary between units IV and V is not apparent on seismic data in part of this section there may be over consolidated sediments present within the top 5 m of sediments.

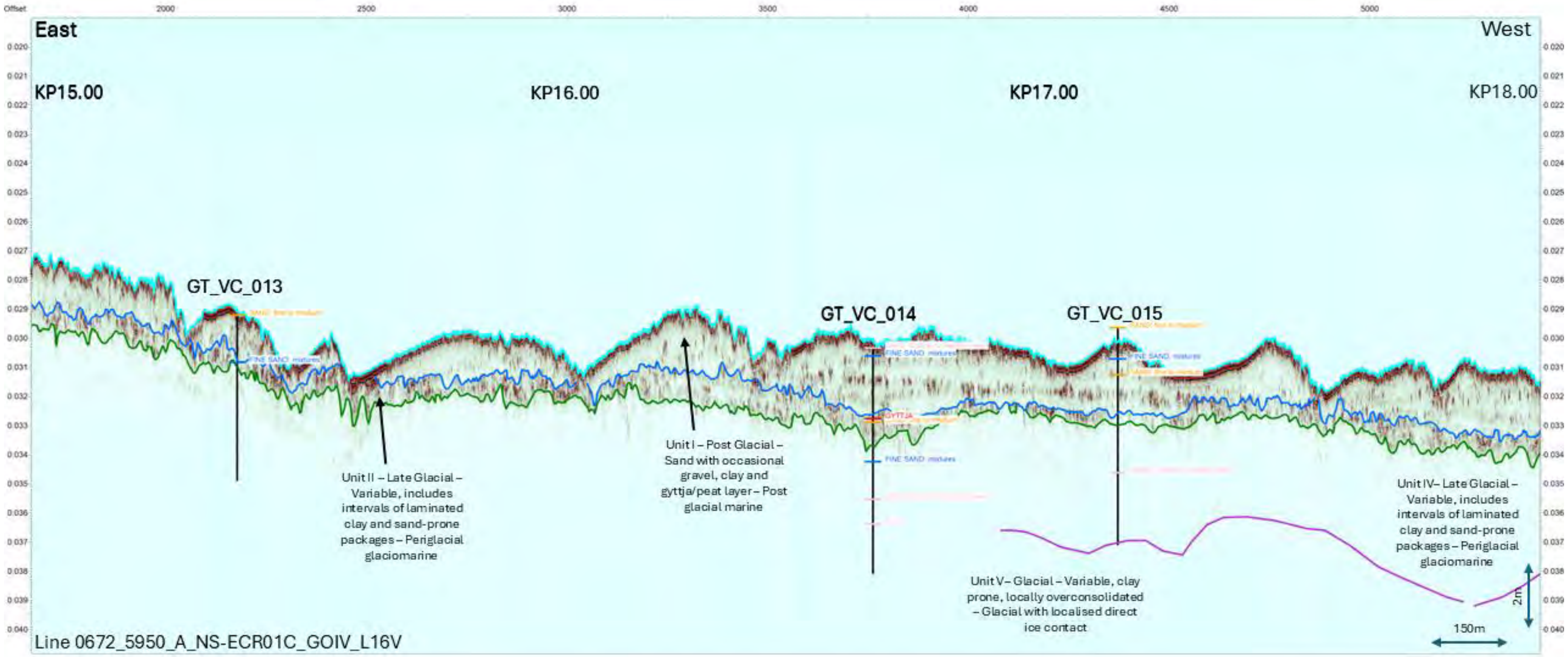


Figure 101: SBP and Geotech, KP 15.000 – KP 18.000

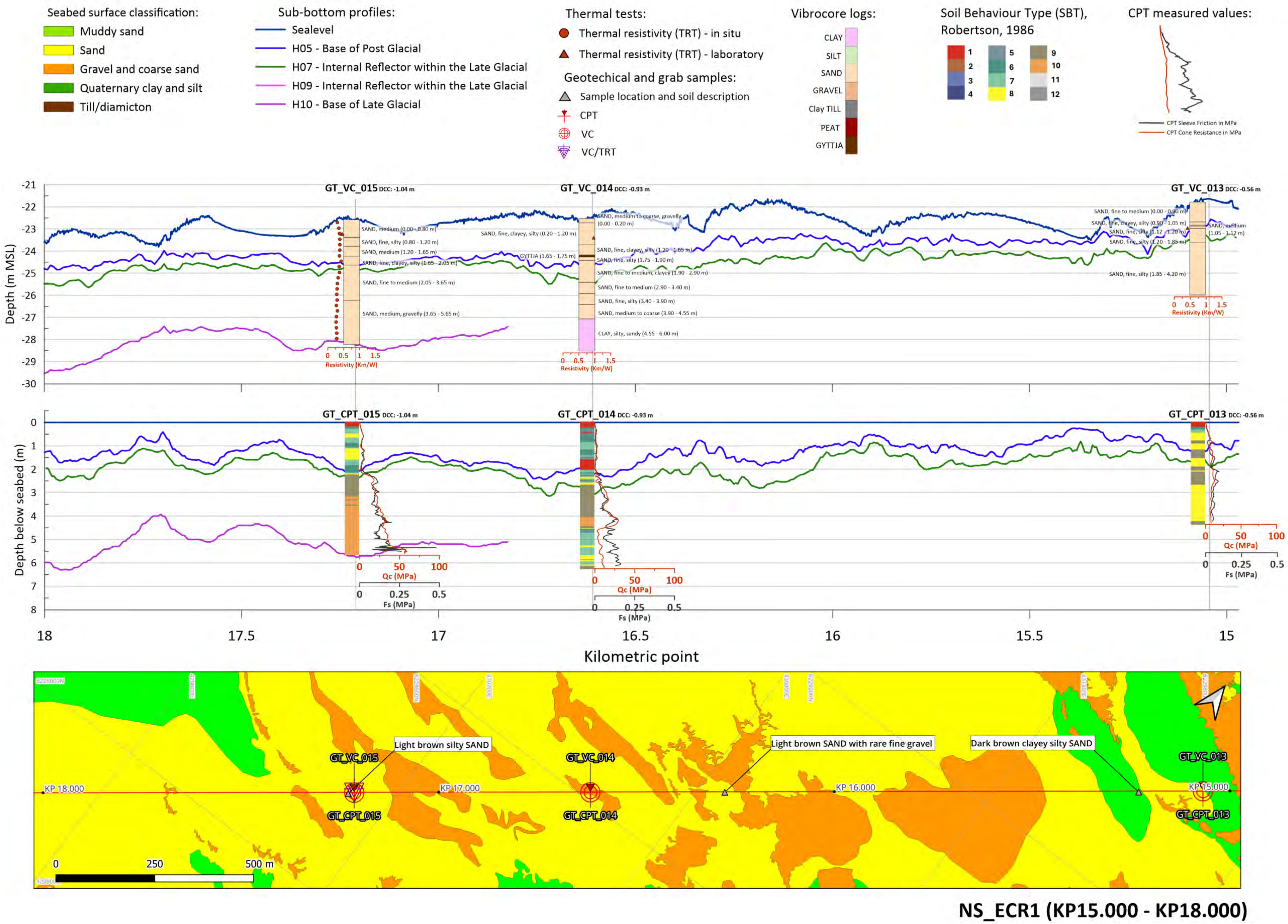


Figure 102: Integrated geotechnical panel KP 15.000 – KP 18.000

7.7 KP 18.000 – KP 21.000

Three VCs, three CPTs and three grab samples were acquired in this section.

Unit I (bounded by H5) is present throughout the section which varies in thickness between < 1 m to almost 2 m. Acoustically, it is opaque but with numerous high amplitude discrete features which may represent coarser/firmer deposits or potentially dropstones.

Geotechnical samples VC016, VC017, VC018, CPT016, CPT017 and CPT018 and three grab samples were acquired, all penetrating Unit I which is represented predominantly by fine to medium clayey, silty SAND (VC016 records a layer of GYTTJA towards the base).

Unit II underlies Unit I throughout this section and is a thin unit of less than 1 m primarily comprising a mix of fine to medium SAND with a thin layer of clayey GYTTJA at the top of this unit in VC018.

Unit III is not present along this section. Unit IV (bounded by H10) is mostly in this section and all stations penetrated Unit IV and presents as fine to medium gravelly SAND.

As the boundary between units IV and V is not apparent on seismic data in part of this section there may be over consolidated sediments present within the top 5 m of sediments.

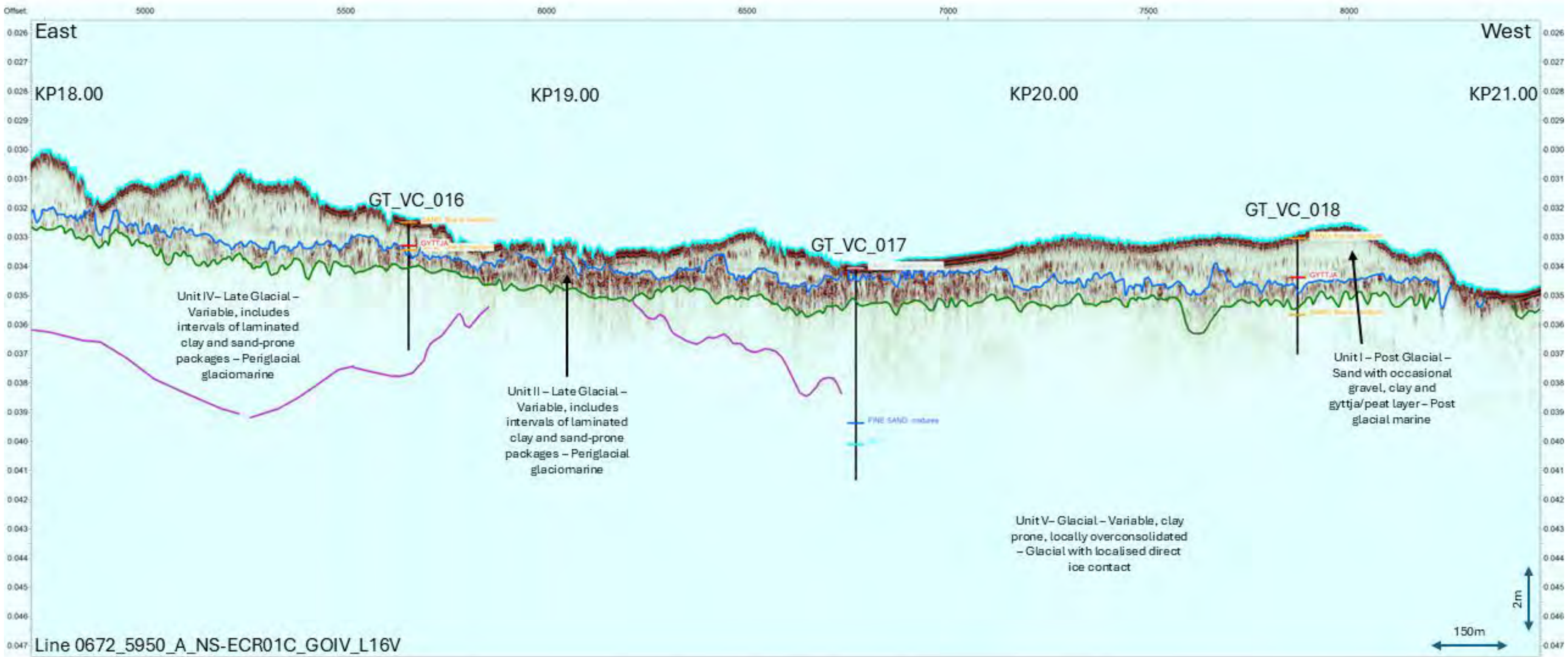


Figure 103: SBP and Geotech, KP 18.000 – KP 21.000

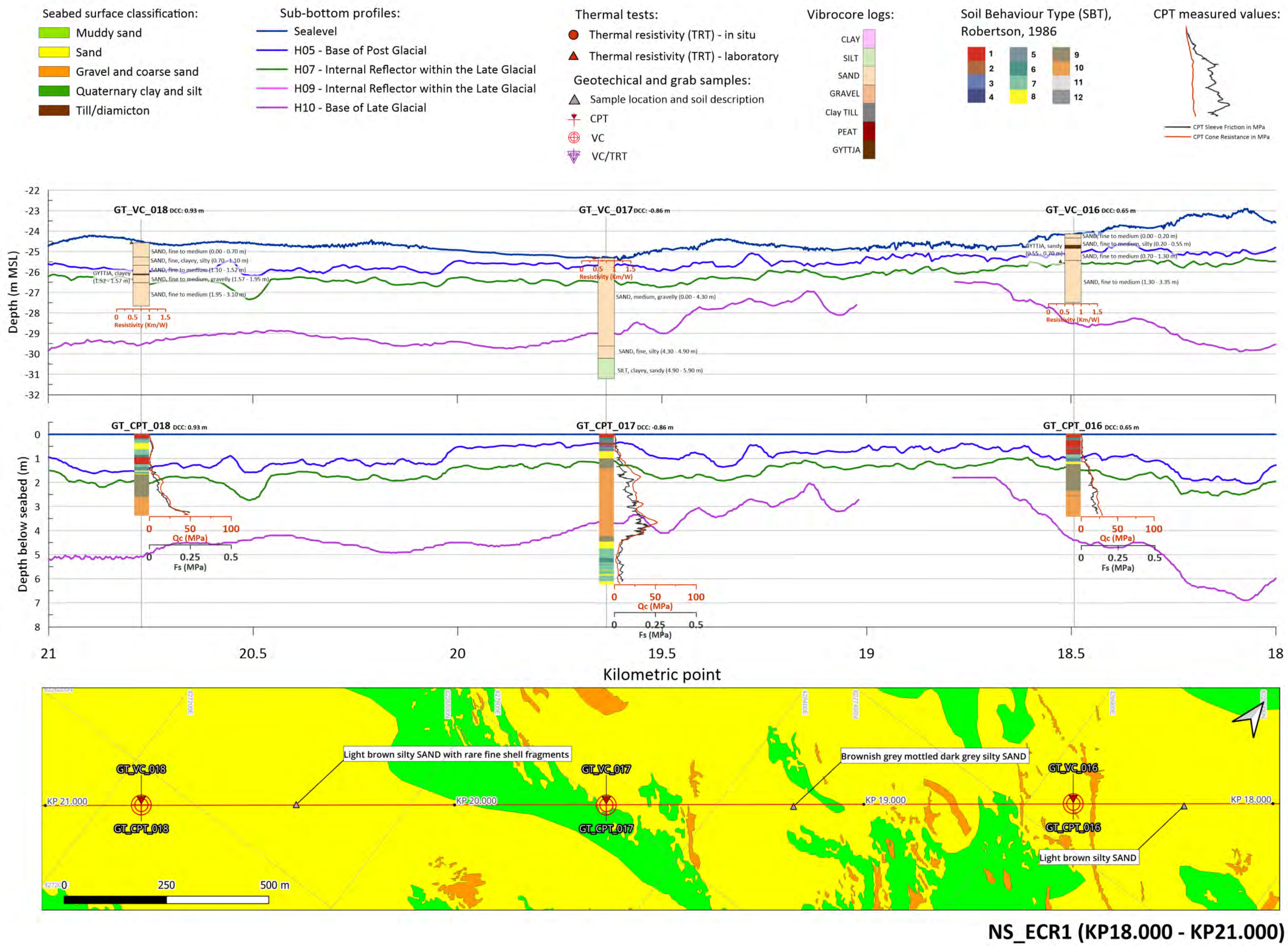


Figure 104: Integrated geotechnical panel KP 18.000 – KP 21.000

7.8 KP 21.000 – KP 23.691

Two VCs, two CPTs and three grab samples were acquired in this section.

Unit I (bounded by H5) is present throughout the section which varies in thickness mostly less than 1 m thick deepening around KP 21.5 to KP 22 to 2 m. Acoustically, it is opaque but with numerous high amplitude discrete features which may represent coarser/firmer deposits or potentially dropstones.

Geotechnical samples VC019, VC020, CPT019 and CPT020 and three grab samples were acquired, all penetrating Unit I which is represented predominantly by fine to medium SAND (VC26 records the SAND overlying a layer of sandy SILT overlying GYTTJA towards the base and extending into Unit II).

Unit II underlies Unit I throughout this section and is a thin unit of less than 1 m primarily comprising a mix of fine to medium SAND with a layer of clayey GYTTJA in VC020.

Unit III is present along this section from KP 22.1 to KP 23.5 and is interpreted as a late glacial channel feature with lateral bedding on the seismic data. Both geotechnical stations penetrated this unit and VC/CPT020 comprises medium to coarse gravelly SAND whereas a short distance away VC/CPT019 comprises a mix of clayey SAND, GYTTJA, PEAT, CLAY and TILL.

Unit IV (bounded by H10) is present along this whole section and VC/CPT020 penetrated Unit IV and presents as medium to coarse gravelly SAND.

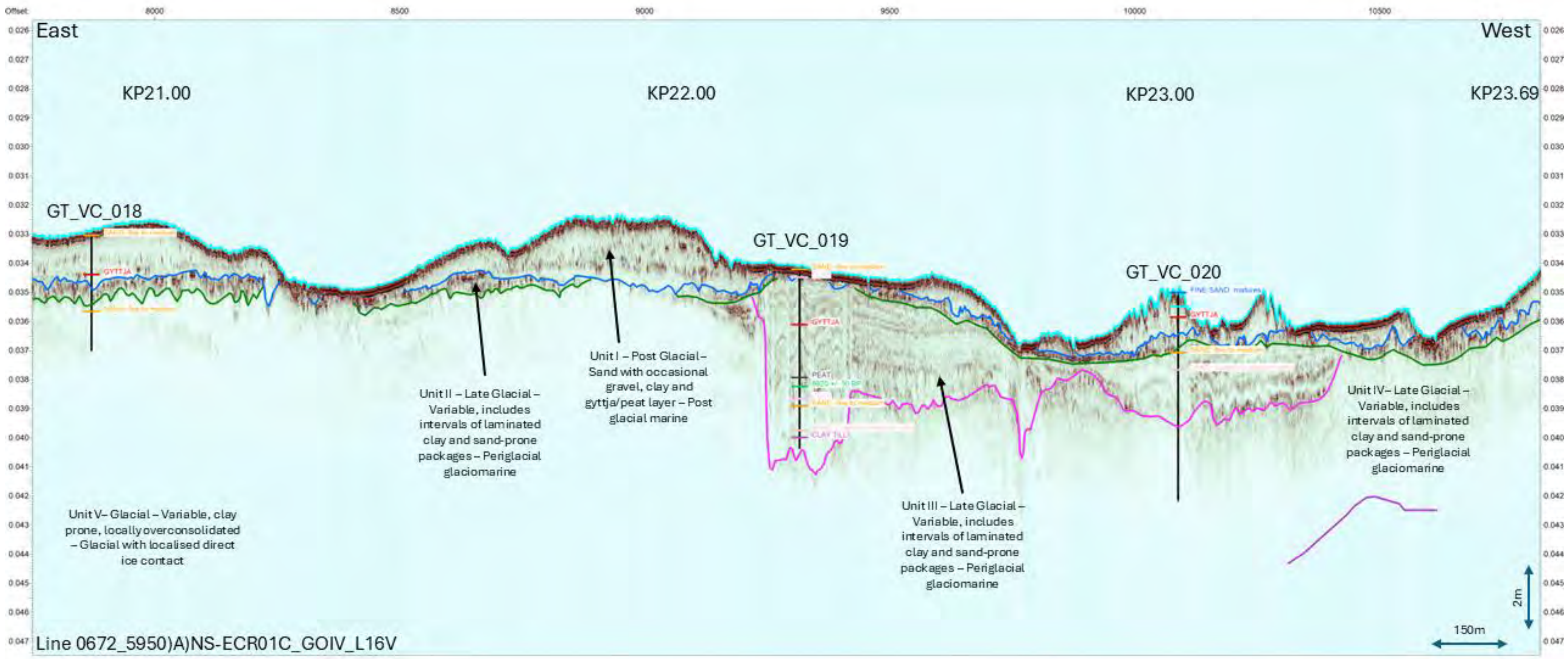


Figure 105: SBP and Geotech, KP 21.000 – KP 23.691

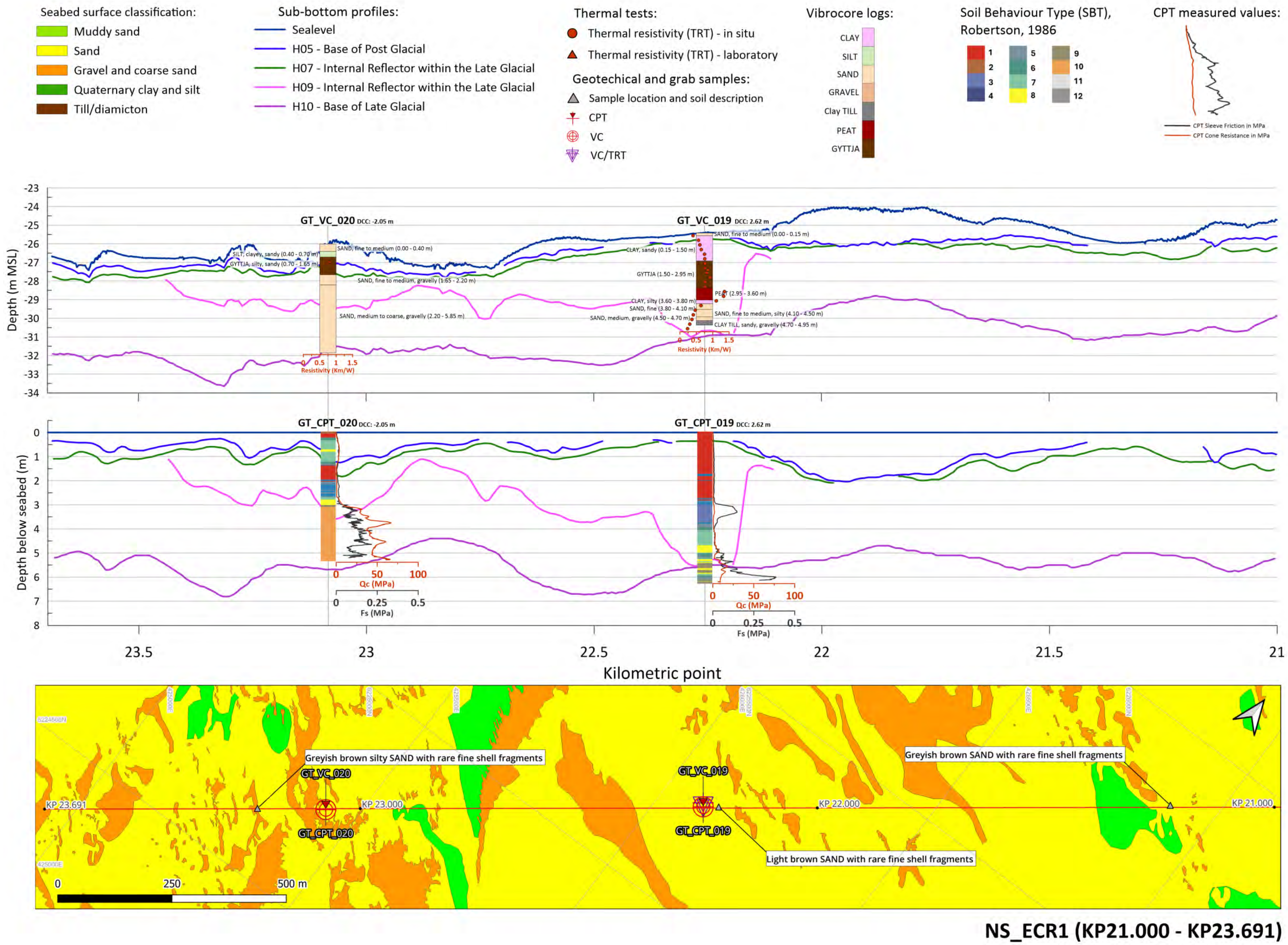


Figure 106: Integrated geotechnical panel KP 21.000 – KP 23.691

7.9 SHALLOW GEOLOGICAL INSTALLATION CONSTRAINTS AND GEOHAZARDS

Unit I sediments are very weak/soft. Their bearing capacity will be negligible and could cause retrieval difficulties related to settlement of seabed frames etc. The sediments in this Unit I may also contain diffuse organic material.

Units II, III, IV and V contain numerous cobbles and boulders.

Unit V may have variable levels of overconsolidation.

7.9.1 Cobbles and Boulders

There are occasional indications of boulders within the sub-bottom profiler data. These data have been optimized to resolve the shallow stratigraphy and do not readily generate diffraction hyperbola, which are the usual seismic indication of point contacts in the sub-surface. A further complication is that the units most likely to contain boulders, Units II, III, IV and V, have been deformed and compressed by ice confusing any returns from individual point contacts.

Due to these circumstances, appearance of clear hyperbolae that could be interpreted as isolated individual point targets relating to buried boulders have not been observed.

7.9.2 Organic Material

GYTTJA and PEAT layers have been observed in geotechnical data within ECR01, which have been presented and described in the route analysis. However, these have not presented as clear or continuous reflectors in SBP data, and hence are not mapped spatially, away from GT locations. These present a possible geohazard relating to heat dissipation as well as trenching considerations for PEAT.

7.10 COMPARISON BETWEEN SEABED AND SUB-SEABED FINDINGS

In the later stage of interpretation, surficial geology has been correlated to the SBP results. Where sub-seabed Unit V (i.e. base of H05/H07/H09/H10) identified as a glacial till is at or near the seabed in proximity to the landfall there is an abundance of boulders, these areas are delineated by “intermediate” boulder fields seabed features (Figure 64) and as “Till/diamicton” in the seabed geology (Figure 63). Inversely there is a strong correlation between the presence of sub-seabed Unit I/II/II/IV (Figure 80/Figure 83/Figure 84) and the “Gravel and Coarse SAND”, “SAND” and “Muddy SAND” surficial substrates. There is a strong correlation between the occurrence of magnetic anomalies (Figure 67) and the Till/diamicton seabed geology/ near seabed glacial till.

7.11 CONCLUSIONS

The elevation levels across the North Sea ECR1 site range from 24.94 metres above Mean Sea Level (MSL) in the eastern landfall area to -28.61 metres below MSL towards the western boundary of the survey area.

Starting at landfall and moving eastwards from zero MSL towards KP 0.000 of the RPL, the gradient rises at approximately 2.3° over 41 metres, resulting in an elevation gain of 1.75 metres at the beginning of the RPL. Continuing landwards, there is a significant increase in the elevation with the gradient of 5.7° over 60 metres (i.e., distance from the KP 0.000 to the closest approximate highest point on land). Further inland, the survey area is characterised by gentle mounds / dunes with the highest point of 24.94 metres MSL located southern form the KP 0.000. The height of these mounds / dunes decreases when moving further eastwards.

The majority of the offshore area of North Sea ECR1 is characterized by gentle to moderate slopes, ranging from 1 to 10 degrees. In the eastern, nearshore part of the route from KP 0.000 towards KP 4.000 there is a sudden deepening of the seabed, ranging from 1.75 m MSL at the landfall to approximately -18.00 m MSL at KP 4.000. These initial KPs, near the coast, are characterized by steep slopes, reaching up to 56 degrees with dynamic seafloor, featuring ripples and sandwaves.

From KP 4.000 to approximately KP 10.000, the seabed depth flattens with gentle slopes and even shows a slight increase in the depth, of about 1.5 m. From KP 10.000 to the end of the RPL, there is dynamic variability in the sea depth, with a general tendency towards deepening to approximately -26 m MSL at the far end of the RPL.

The seabed geology in NS_ECR1 consists predominantly of sand, along with sediments such as gravel and coarse sand, muddy sand and till/diamicton. The beginning of the route, from KP 0.000 to approximately KP 3.000, is mostly characterized by gravel and coarse sand, with patches of till/diamicton between KP 1.000 and KP 2.000. From KP 3.000 to KP 5.500, the seabed along the RPL primarily consists of muddy sand, after which from KP 5.000 to KP 10.000, the seabed is dominated by sand, corresponding to a flatter seabed with gentle slopes. Small patches of till/diamicton occur south of the RPL, around KP 11.500. Towards the west, from KP 10.000 to KP 15.000, sand and gravel and coarse sand dominate, whilst between KP 15.000 to KP 22.000 alternating muddy sand and sand are present. From KP 22.000 to the end of the RPL (and survey area), sand, and gravel and coarse sand alternate with smaller areas of muddy sand consistent with a dynamic seabed such as areas of ripples.

The seabed morphology in NS_ECR1 from KP 0.000 to KP 0.360 is dominated by sandwaves and ripples, as confirmed in the bathymetric profile. Between KP 1.350 and KP 2.000, there are patches of boulder fields which are predominantly high density, as well as an additional isolated boulder field at KP 0.800. The distribution of these boulder fields aligns with the till/diamicton regions of seabed geology. Between KP 2.000 and KP 5.500, the seabed morphology is primarily characterised by areas of ripples and patches of lower reflectivity as seen on the SSS data. These low reflectivity patches correlate to muddy sand in the seabed geology. Between KP 2.500 – KP 5.500 there are also some pitted seabed areas which are observed as isolated seabed depressions, possibly associated with scour around boulders. Similar seabed features are also observed between KP 16.000 – KP 17.000. From KP 5.500 to KP 9.600, the seabed is largely featureless, with the exception of boulders, and correlates with an area of sand in the surficial geology. From KP 9.500 to the end of the RPL, the seabed is mostly dominated by ripples or large ripples, which corresponds with more dynamic slope variability, including some steep slope values. These ripples exhibit wavelengths ranging from 0.5 m to up to 10 metres. Some patches of lower reflectivity as seen in the SSS data, and in correlation with areas of muddy sand in the surficial geology, are also observed in this western half of the route.

A total of 1,903 point contacts were detected in NS_ECR1, with 106 of these attributed to be man-made (MMO) point targets and 1,797 point targets interpreted as boulders. A total of four MMO linear objects were identified by multiple sensors. Three of these were classified as possible rope, and the forth was a metallic object classified as possible rope, cable or linear fragment. One additional fibre optic cable crossing (ODIN 2) was detected in the background data in NS_ECR1 at KP 13.653 but no associated anomalies were detected. There were an additional 4 linear seabed features identified as seabed scars. There were 43 metallic objects found within the NS_ECR1 survey area. The majority of these metallic objects are concentrated within the KP 1.000 to KP 2.000 cable survey area. Additionally, 63 items of the debris point contacts were observed within the site. All of these were interpreted as non-ferrous objects. There were no wrecks or pipelines identified within the NS_ECR1 site.

The geological interpretation along the proposed ECR is based upon the geophysical and geotechnical datasets acquired with reference to the supplied GEUS desk study. Details of specific correlations between the geophysical and geotechnical datasets can be found in the 3 km route analysis sections of the report.

Overall, the area has a glacial to post-glacial sequence of relatively recent post glacial sediments over much older bedrock. Only the upper post glacial and glacial deposits are discussed along the ECR. The bedrock is deeper than the installation zone of interest and not imaged on the SBP data.

The post glacial unit (Unit I) is a package predominantly of post-glacial SAND with occasional layers of GRAVEL, CLAY and GYTTJA/PEAT which is less than 2 m thick over large parts of the site. The interval includes a veneer of sandier seabed sediments, though this is interpreted to be very thin and not resolvable in the SBP data. The post glacial sediments are widely distributed over the cable route corridor (Figure 55) varying from absent to less than 3 m over the majority of the route. It increases in thickness at the nearshore end, reaching a maximum observed thickness of 5.2 m at KP 1.300. It may be thicker even further inshore, but the horizon is obscured by the seabed multiple. From background knowledge of the depositional environments of the area there is expected to be much mixing of the sediments. It is therefore not expected to be as clear as 'sand' or 'clay' within each sample, but a mix of all and a general change along the route. The geotechnical interpretation from the vibrocores or CPTs is shown on the relevant data examples. These indicate that there is a lot of lateral variation in the lithology within all units. Occasional pockets of peat and gyttja are observed in the geotechnical logs, but there is no obvious seismic expression noted in the SBP data.

The late glacial deposits (Unit II, III and IV) are very complex due to the area's range of environmental conditions during the Late Weichselian and earliest Holocene. Some intervals show laminations indicative of clays and silts, while others may represent sandy beach-type deposits. Along the cable route corridor these sediments have been subdivided into three units. This is because they vary greatly in seismic acoustic character and geotechnical properties. Unit II is mapped with H07 at its base. It consists of higher amplitude sediments, interpreted as a coarser sediment layer. This is fairly continuous along the route and occurs between 0.2 m below seabed at the start of the route at KP 0.200 and 4.8 m between KP 13.000 and KP 14.000. Unit III is a small channel towards the end of the route, from KP 22.000 onwards. The unit is generally mapped with H09 at its base.

Unit IV is mapped with H10 as its base. Below H07, and H09 where present, the data appears acoustically quiet, though this may be due to a lack of penetration into the harder sediments. The extents and interpretation of H10 is tentative, and the geotechnical samples show little consistency within this unit. The glacial deposits (Unit V) occur along the route corridor and are interpreted to represent a till laid down in association with the last major ice advance over the area, approximately 22,000 years ago. The till forms a relatively thick blanket, deeper than the depth of interest for cable burying. The base of the till/top bedrock is not imaged within the export route corridor. Unit V is generally a glacial till which has been subjected to direct ice contact, though the unit contains other facies which may have been laid down in ice-marginal environments during oscillations of the ice front. The ice-contact facies may comprise a clay-prone diamicton which is likely to contain subordinate silt, sand, gravel, cobbles and boulders and will be overconsolidated. Consolidation levels may significantly vary over short distances.

Unit I sediments are very weak and soft, with negligible bearing capacity, potentially causing retrieval difficulties related to the settlement of seabed frames. Units II, III, IV contains numerous cobbles and boulders. Unit V may exhibit variable levels of over-consolidation, as well as containing numerous cobbles and boulders. Some isolated patches of Gyttja and Peat have also been observed in the geotechnical data, though these have not presented as clear or continuous reflectors in the SBP data and hence are not mapped spatially away from the geotechnical locations. These present a possible geohazard relating to heat dissipation, as well as trenching considerations for Peat.

8 NS_ECR2 ROUTE OVERVIEW

8.1 RESULTS

This report section provides a detailed analysis of the findings within the NS_ECR2 survey area from topographic data, bathymetric data, side scan sonar data, sub-bottom profiling, and magnetometer surveys conducted within the survey area.

Datasets were reduced to MSL, which involved applying the DTU21MSL geoid separation model during post-processing.

Listings for all sonar, magnetometer and sub-bottom contacts and linear targets across the site are presented within each relevant section of the text. A confidence level is assigned to sonar contacts as presented previously in Section 5.8.

8.2 BATHYMETRY AND TOPOGRAPHY

The elevation levels across the NS_ECR2 site range from a highest point of 19.31 metres above mean sea level (MSL) near 448361 mE, 6184519 mN in the eastern landfall area, to a deepest point of 27.34 metres below MSL near coordinates 425314 mE, 6208598 mN, towards the northwestern boundary of the survey area. Figure 107 presents a comprehensive overview of the NS_ECR2 survey area, merging both topographic and bathymetric data to illustrate the general morphology.

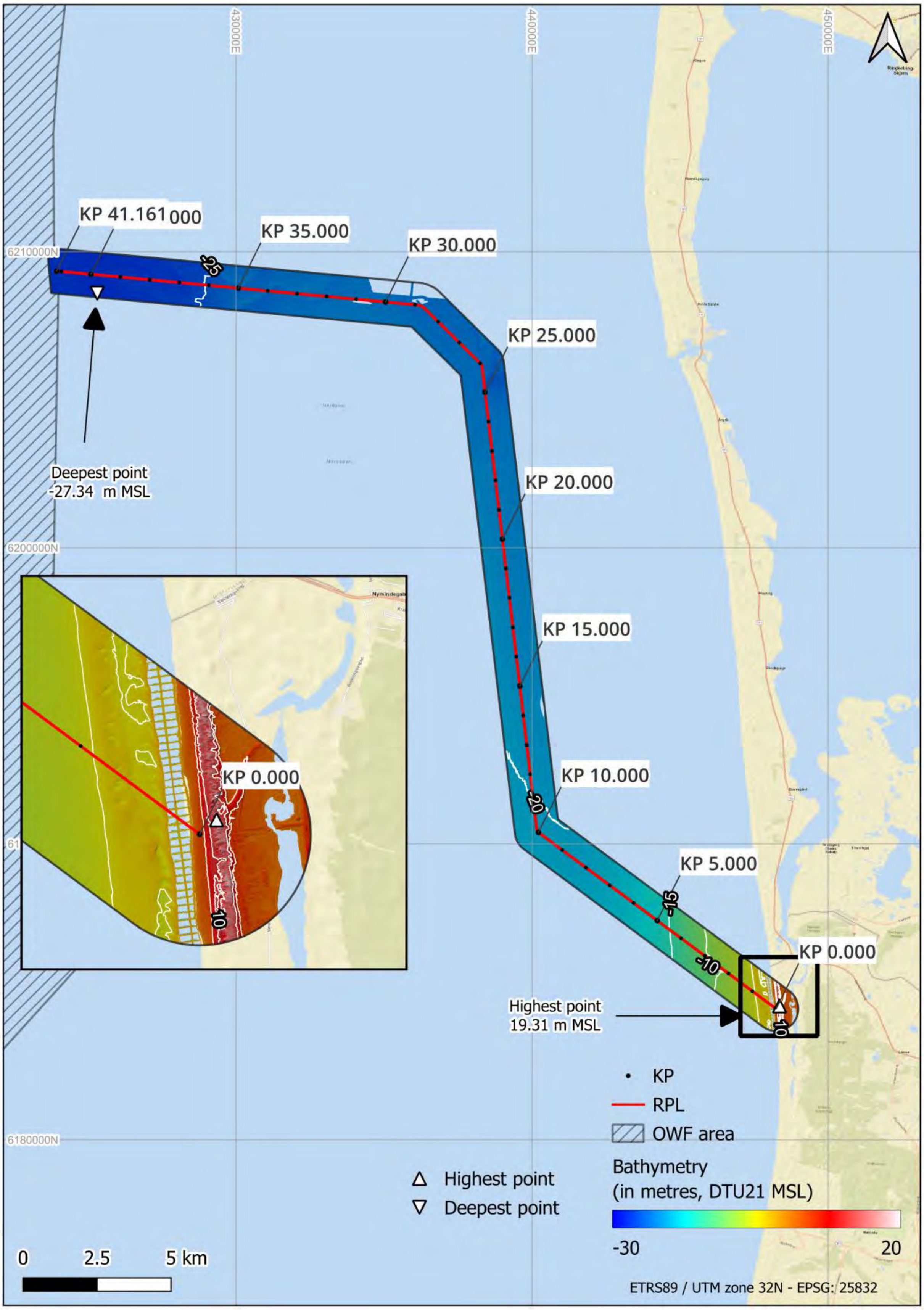


Figure 107 : Bathymetry and topographic combined overview in NS_ECR2

8.2.1 Landfall and topography

Starting at the landfall and moving eastwards towards the KP 0.000 of the RPL of NS_ECR2, the gradient rises at approximately 2.7° over 62 metres, resulting in an elevation gain of 3.5 metres at the beginning of the RPL. Continuing landwards, there is an increase in the elevation with the gradient of 4.3° over 70 metres (70 metres is the distance from the KP 0.000 to the closest approximate highest point on land). Further inland the survey area is characterised by gentle mounds / dunes with the highest point of 19.31 metres MSL located northeastern form the KP 0.000. The height of these mounds / dunes decreases when moving further eastward and reach close to 0 m MSL in the vicinity of coastal lake Gammel Gab. The topographic overview is provided in Figure 108, while a detail of the landfall is provided in Figure 109.

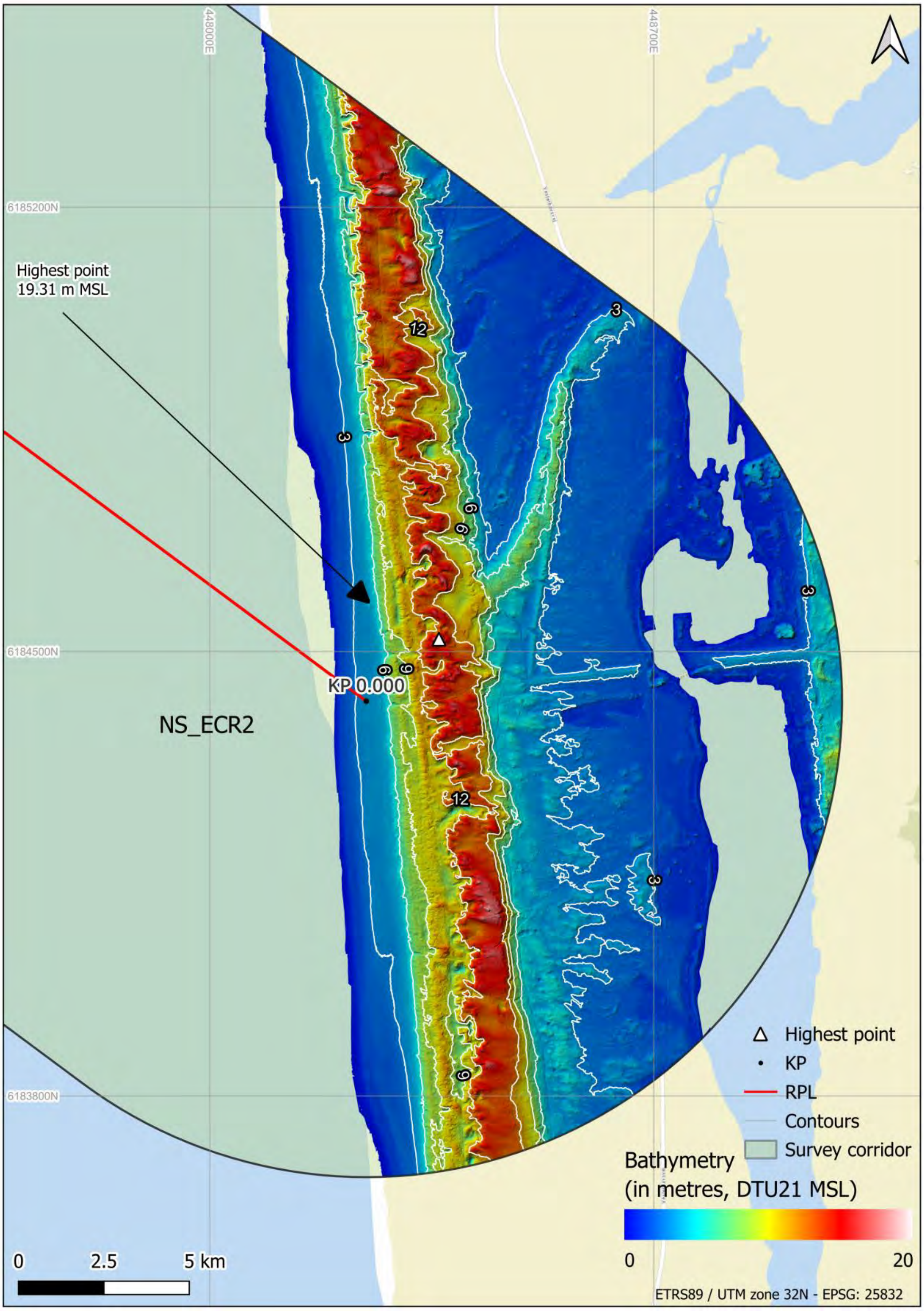


Figure 108: Topographic overview of NS_ECR2

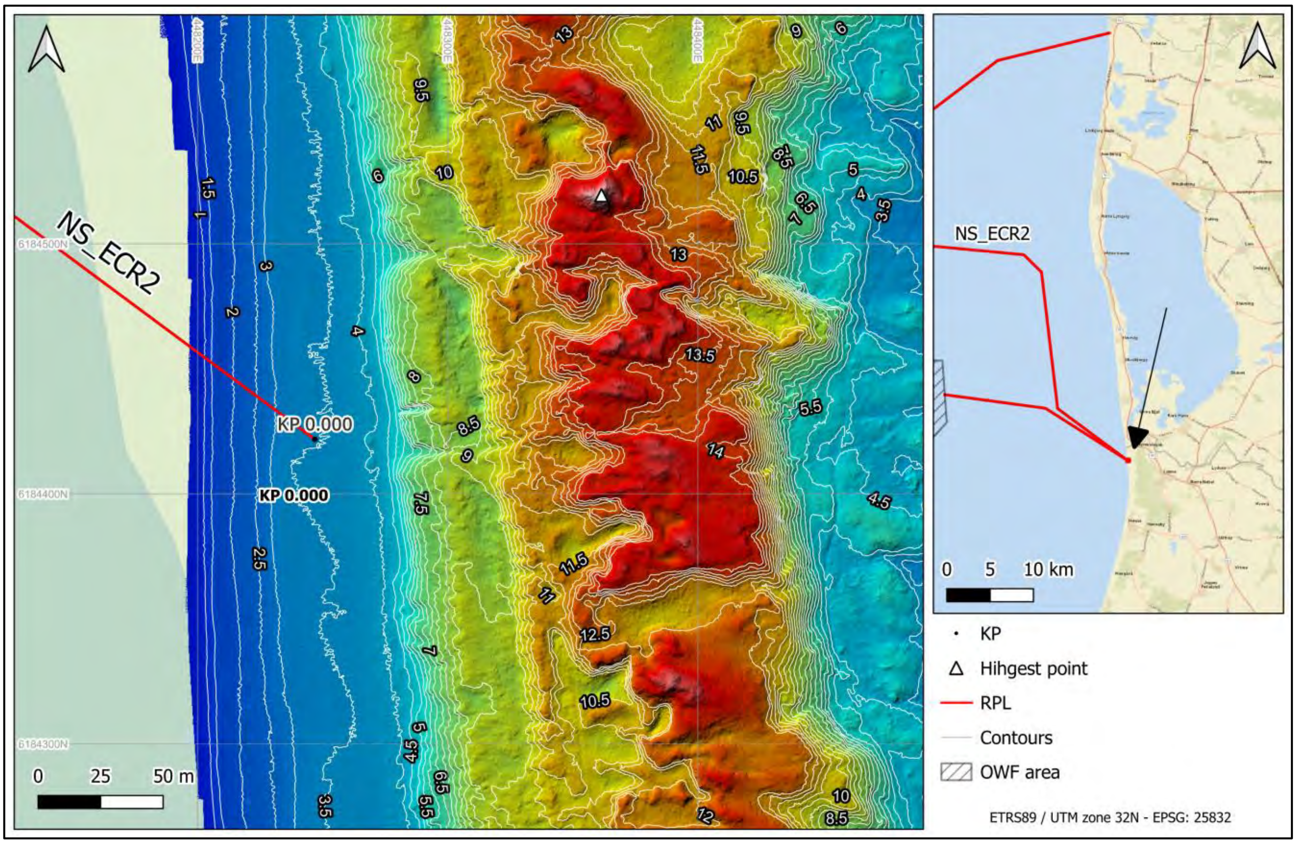


Figure 109: NS ECR2, landfall, detailed overview

8.2.2 Bathymetry overview

A comprehensive overview of the bathymetry within the NS_ECR2 survey area is illustrated in Figure 110, while a detailed bathymetry profile along the Route Position List (RPL) is depicted in Figure 111.

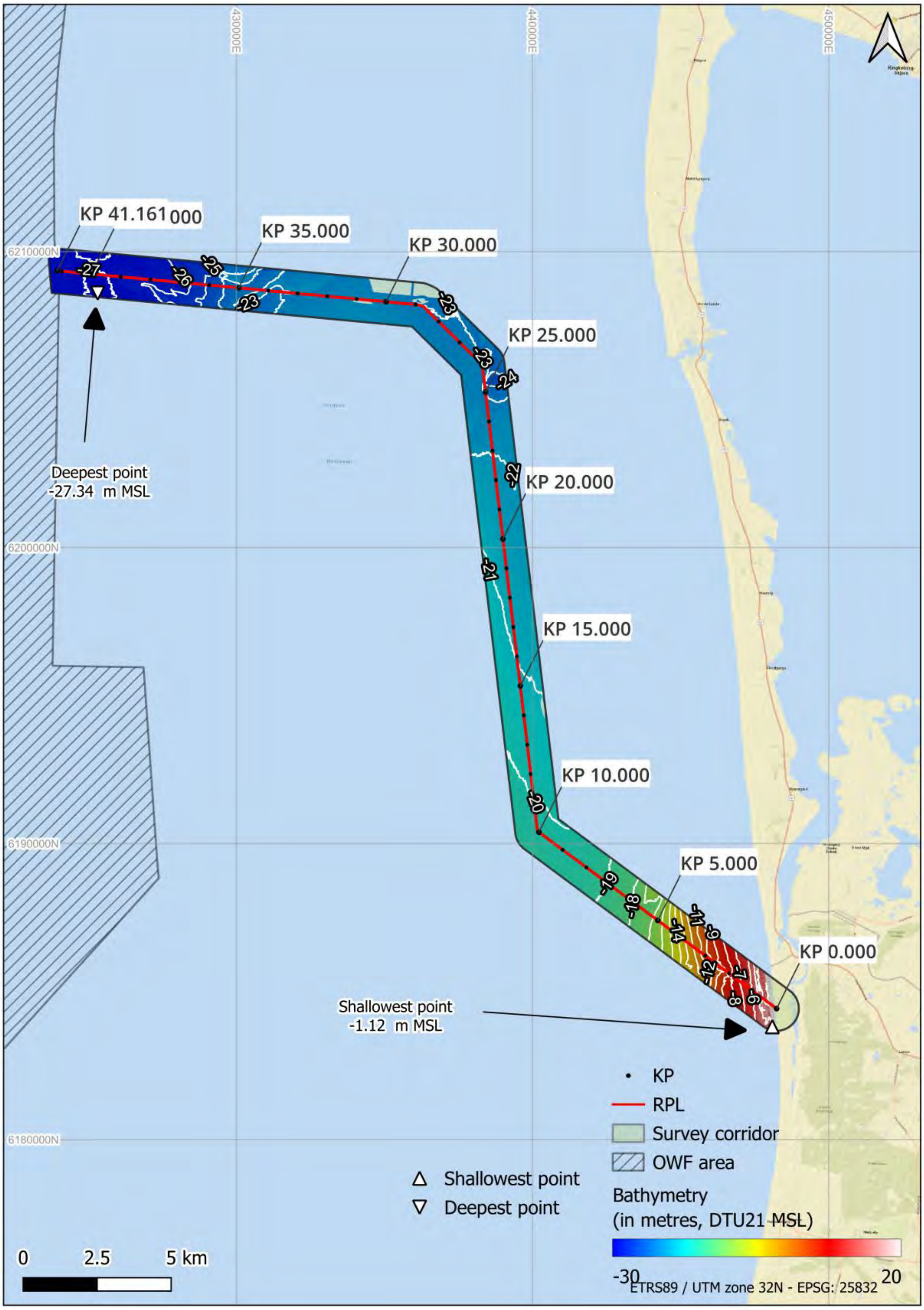


Figure 110: Bathymetry overview up to the landfall in NS_ECR2

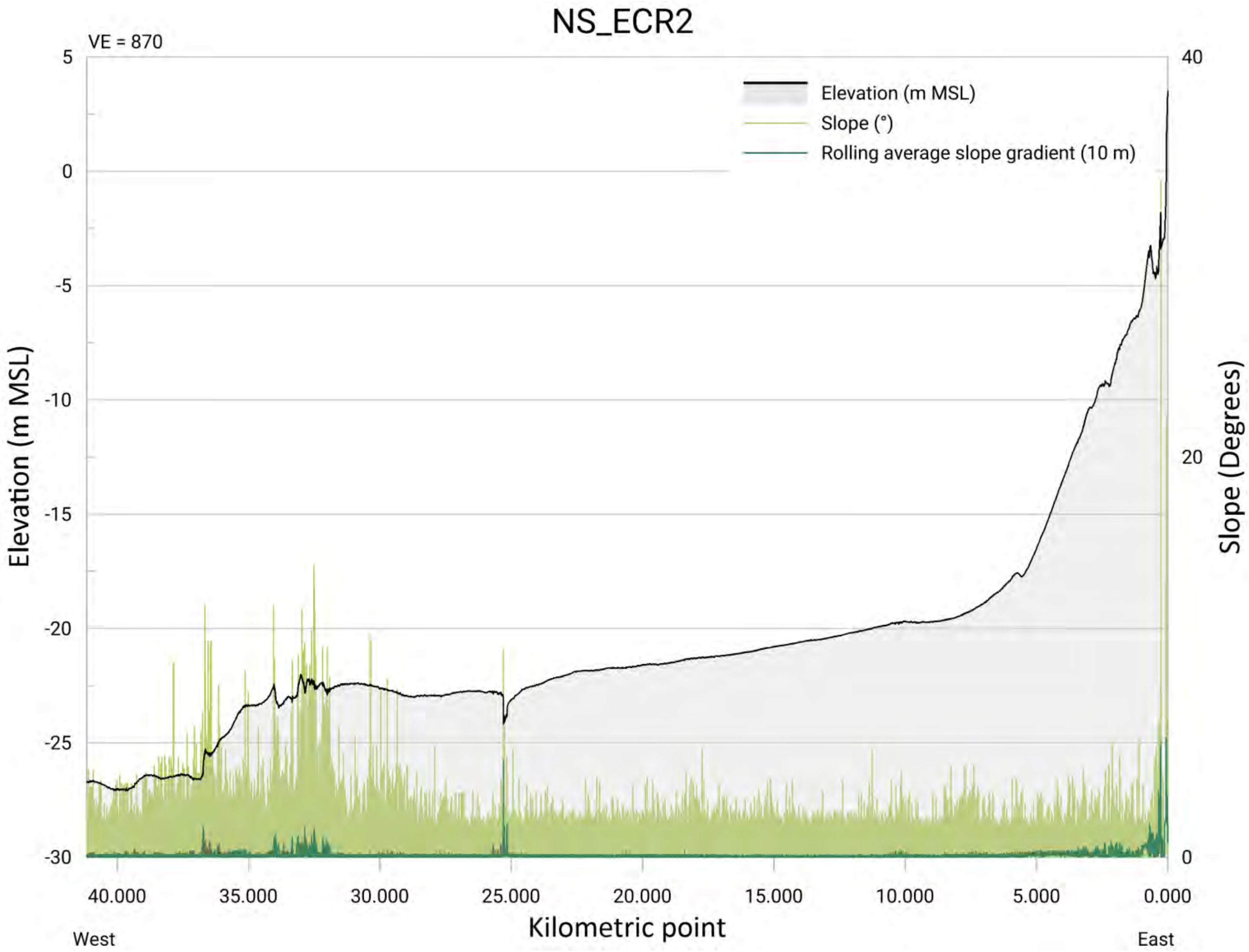


Figure 111: Depth and slope profile along the NS_ECR2 (created form 0.25 m grid)

Overall, the majority of the NS_ECR2 area is characterised by very gentle to gentle slopes. The highest concentration of steep slopes is located near KP 0.000, towards the inland areas.

In the eastern, nearshore part of the route from KP 0.000 towards KP 6.000 there is a sudden deepening of the seabed, ranging from 3.5 m MSL at the landfall to approximately -18 m MSL at KP 6.000.

From KP 10.000 to KP 24.000, the seabed depth flattens. Around KP 25.250 there is a ridge approximately 1 metre high which separates the boulder fields area from a predominantly featureless area of seabed, Figure 112.

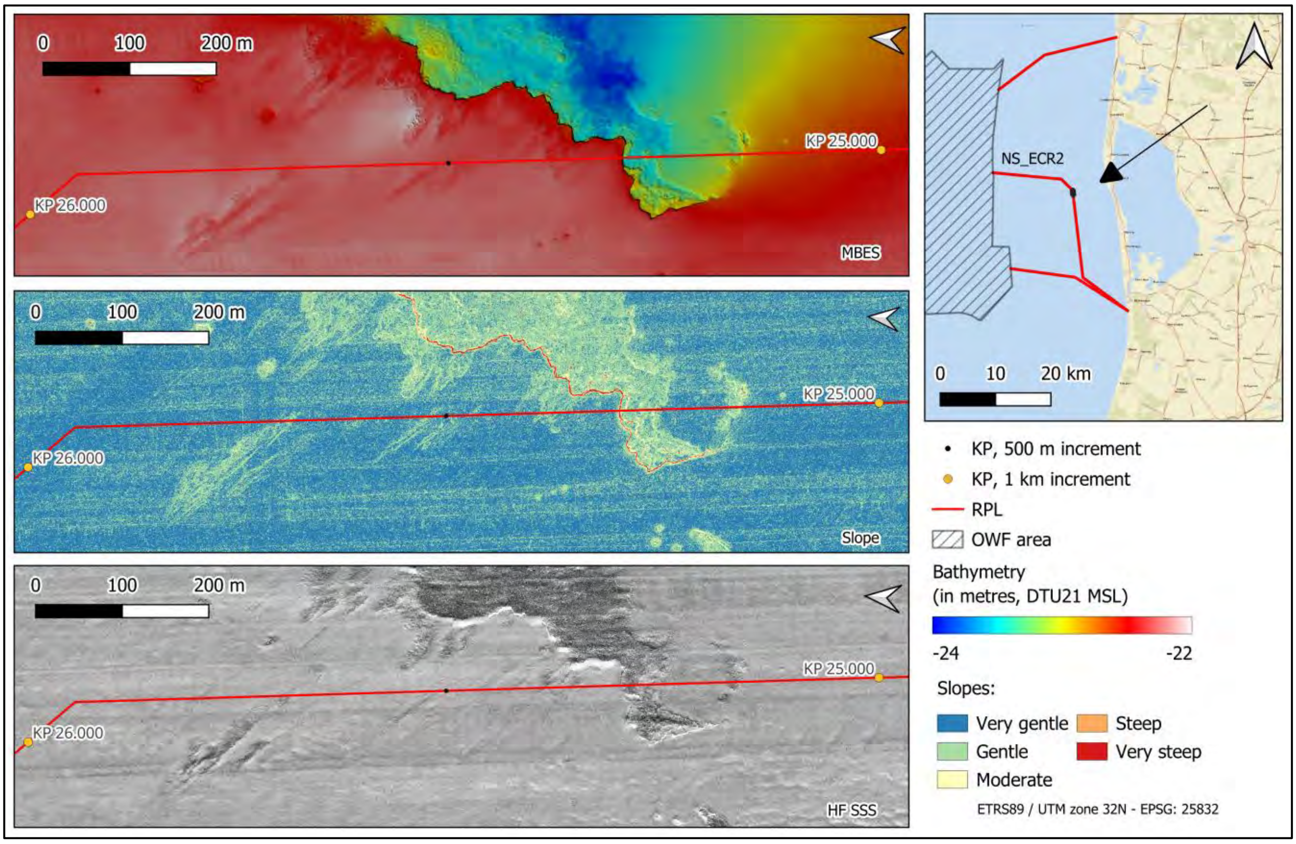


Figure 112: Change in bathymetry and slope, KP 25.000 - KP 26.000 of NS_ECR2

From KP 25.000 to the KP 31.000 there is a slight raise in the seabed depth, measuring 0.5 metres.

From KP 31.000 till the end of the RPL survey area, seabed deepens towards the 26.7 metres MSL at the end of the RPL. There is an increase in slope values in this part, from gentle to moderate slopes, correlating with areas of dynamic seabed such as ripples.

Figure 113 displays overall slope overview with inset maps:

A – gentle to moderate slope values correlating with ripple areas.

B – slight raise in seabed depth correlating with boulder field areas.

C – steep slopes in the nearshore area towards landfall.

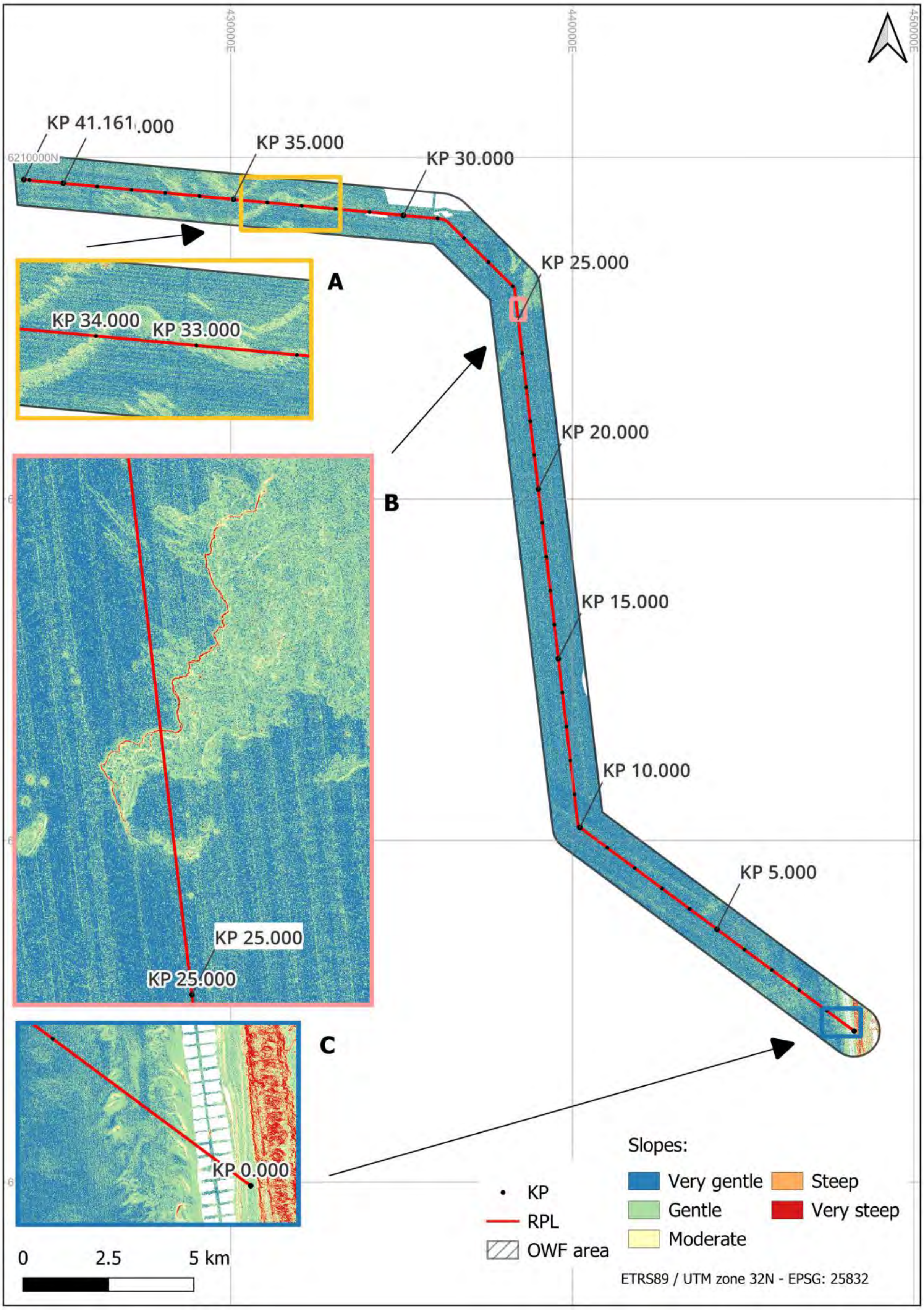


Figure 113: Slope overview of the NS_ECR2 route

8.3 SEABED SURFACE GEOLOGY

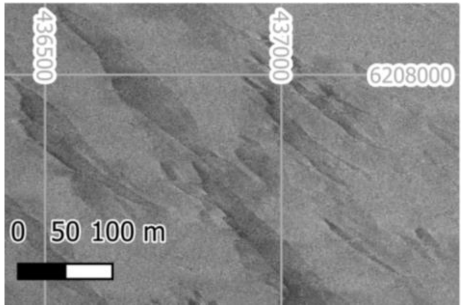
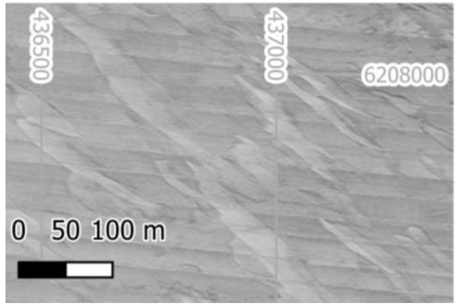
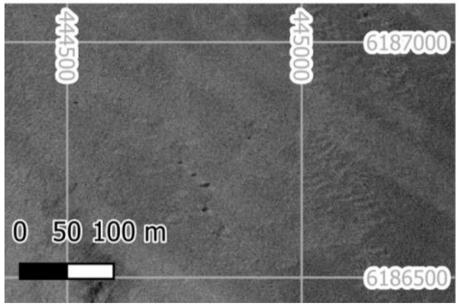
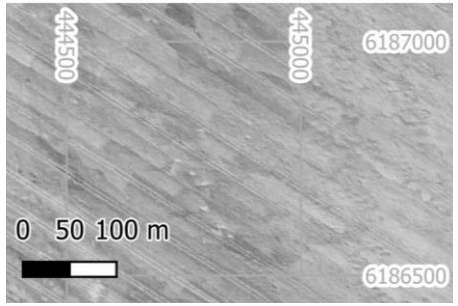
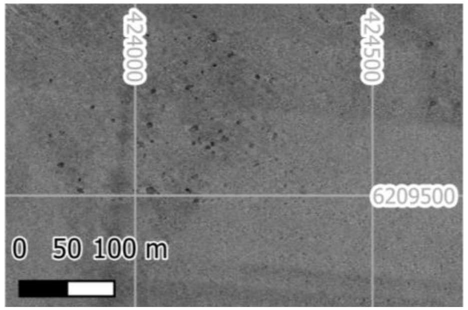
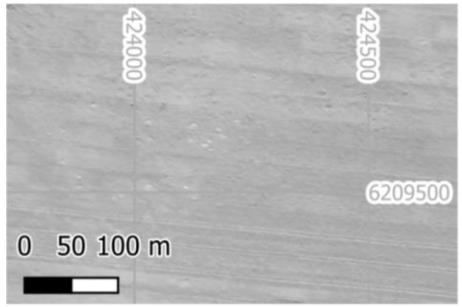
The seabed geology for the NS_ECR2 site was evaluated from the interpretation of the low and high frequency SSS data, the backscatter imagery and the MBES dataset. Data analysis and classification was performed using the seabed acoustic characteristics, such as reflectivity and backscatter strength, as well as the seafloor relief and the overall pattern. During the interpretation of the SSS data, higher reflectivity areas – higher intensity sonar returns (darker grey to black colours) have been related to relatively coarse-grained sediments and lower reflectivity areas – lower intensity sonar returns have been related to relatively fine-grained sediments (Table 73). Bathymetric data aided the interpretation mainly in outlining of possible outcrops and the boulder field delineation. As detailed in section 5.8.5, GEUS terminology was used to define the identified seafloor sediments in the survey area.

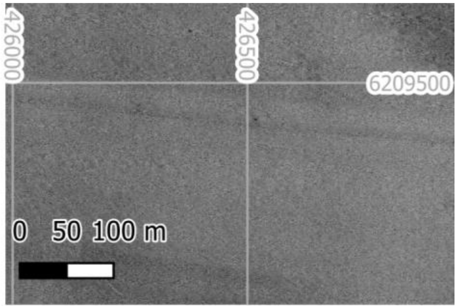
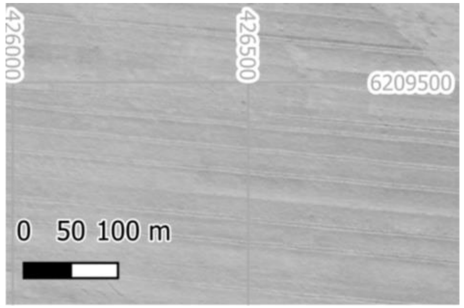
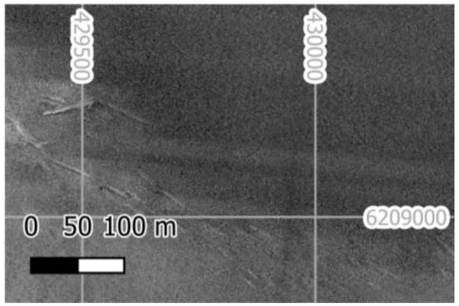
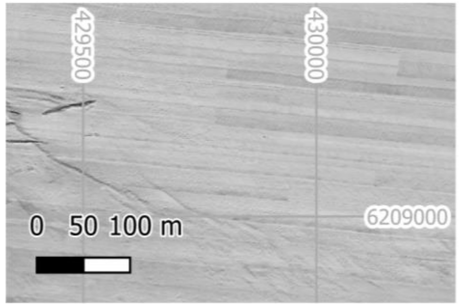
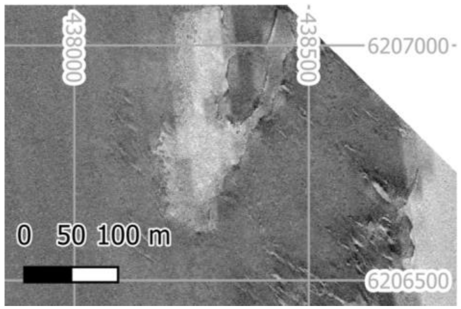
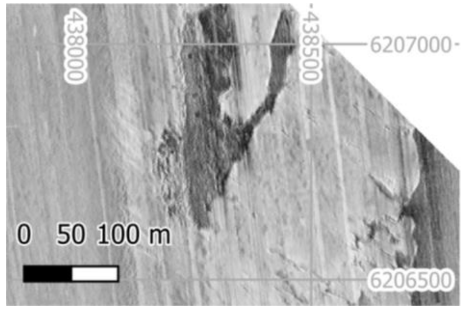
The resultant seabed surface geology has been correlated to the soil description of the surficial grab samples and the onshore laboratory results. Field descriptions of the grab results were in accordance to DGF however the laboratory analysis, the definition of the particle sizes followed the Wentworth scale (Figure 55) in accordance to BS EN ISO 17892-4. Seabed geology was also correlated to Vibrocore Top Geology (seabed) results.

It should be noted that not only the grab samples (that might not be representative of the entire area outlined), but also SSS reflectivity, MBES relief, backscatter data, sub-surficial geology and the EMODnet classification have been considered for the Geology polygons.

Finally, seafloor sediment classification has been integrated to the sub-seabed geology data.

Table 73: Acoustic characteristics of the sediment types within NS_ECR2

<table>
<tr><th>Geological interpretation</th><th>Colour and code</th><th>Sediment interpretation</th><th>Acoustic description</th><th>Backscatter image</th><th>LF SSS image</th></tr>
<tr><td>Quaternary clay and silt</td><td>31</td><td>Predominantly silt or silty sand with patches of clay.</td><td>Patches of medium reflectivity interspersed in areas of low to medium reflectivity. Clay often found in linear patterns.</td><td>
</td><td>
</td></tr>
<tr><td>Mud and sandy mud</td><td>21</td><td>Predominately mud with minor to significant fractions of sand. May contain minor fractions of gravel</td><td>Low reflectivity</td><td>
</td><td>
</td></tr>
<tr><td>Muddy Sand</td><td>13</td><td>Predominately sand with significant fractions of mud and muddy sand. May contain minor fractions of gravel</td><td>Low to medium reflectivity</td><td>
</td><td>
</td></tr>
</table>

Geological interpretation	Colour and code	Sediment interpretation	Acoustic description	Backscatter image	LF SSS image
Sand	12	Predominately sand. May contain minor fractions of mud and/or gravel	Medium reflectivity		
Gravel and coarse sand	11	Mixed sediment. Predominately gravel and sand. May contain mud.	Medium to High reflectivity. Patches of high reflectivity interspersed in areas of low to medium reflectivity		
Till/diamicton	41	Mixed sediment. Constituents range between mud and boulders.	Low to High reflectivity. Patches of high reflectivity interspersed in areas of low to medium reflectivity. Usually, positive relief in MBES data		

The seabed geology of the North Sea ECR2 survey area consists predominantly of sand, along with sediments such as gravel and coarse sand, muddy sand, Quaternary clay and silt and a few isolated areas till/diamicton.

The beginning of the route, from KP 0.000 to approximately KP 6.000, is dominated by a mix of sediments including sand, patches of gravel and coarse sand, and muddy sand areas. From KP 5.400 to KP 5.750 there is an isolated area of till located approximately 40 m north-east of the RPL.

Between KP 6.000 and KP 10.500, sand covers the full width of the corridor, with the exception of three small patches of gravel and coarse sand. From KP 10.500 to KP 25.250, the seabed geology is primarily sand with some large patches of muddy sand, in correlation with a flatter area of seabed on the bathymetry data. Occasional smaller patches of Quaternary clay and silt were also interpreted along the RPL, in correlation with the Vibrocore Top Geology (seabed) results at VC_036, VC_037 and VC_038 between KP 19.800 and KP 21.900.

From KP 25.250 to KP 27.000, the eastern side of the cable corridor is largely dominated by till and gravel and coarse sand, whilst the western side of the corridor is predominantly sand. From KP 27.00 to KP 30.500, sand is present along with an abundance of large linear patterned patches of Quaternary clay and silt. These are orientated in an NW-SE direction. From KP 30.500 to the end of the RPL, the route is dominated by large patches of muddy sandy and gravel and coarse sand, in correlation with the gentle to moderate slopes seen in the bathymetry and consistent with dynamic seabed features, such as ripples.

Figure 114 displays seabed surface geology overview with inset maps:

A – Sand and gravel and coarse sand, with smaller patches of muddy sand.

B – Patches of Quaternary clay and silt, and muddy sand within an otherwise predominantly sand-rich area.

C – A mix of sediments including sand, patches of gravel and coarse sand, and muddy sand areas. Area of till near KP 5.500 is also visible.

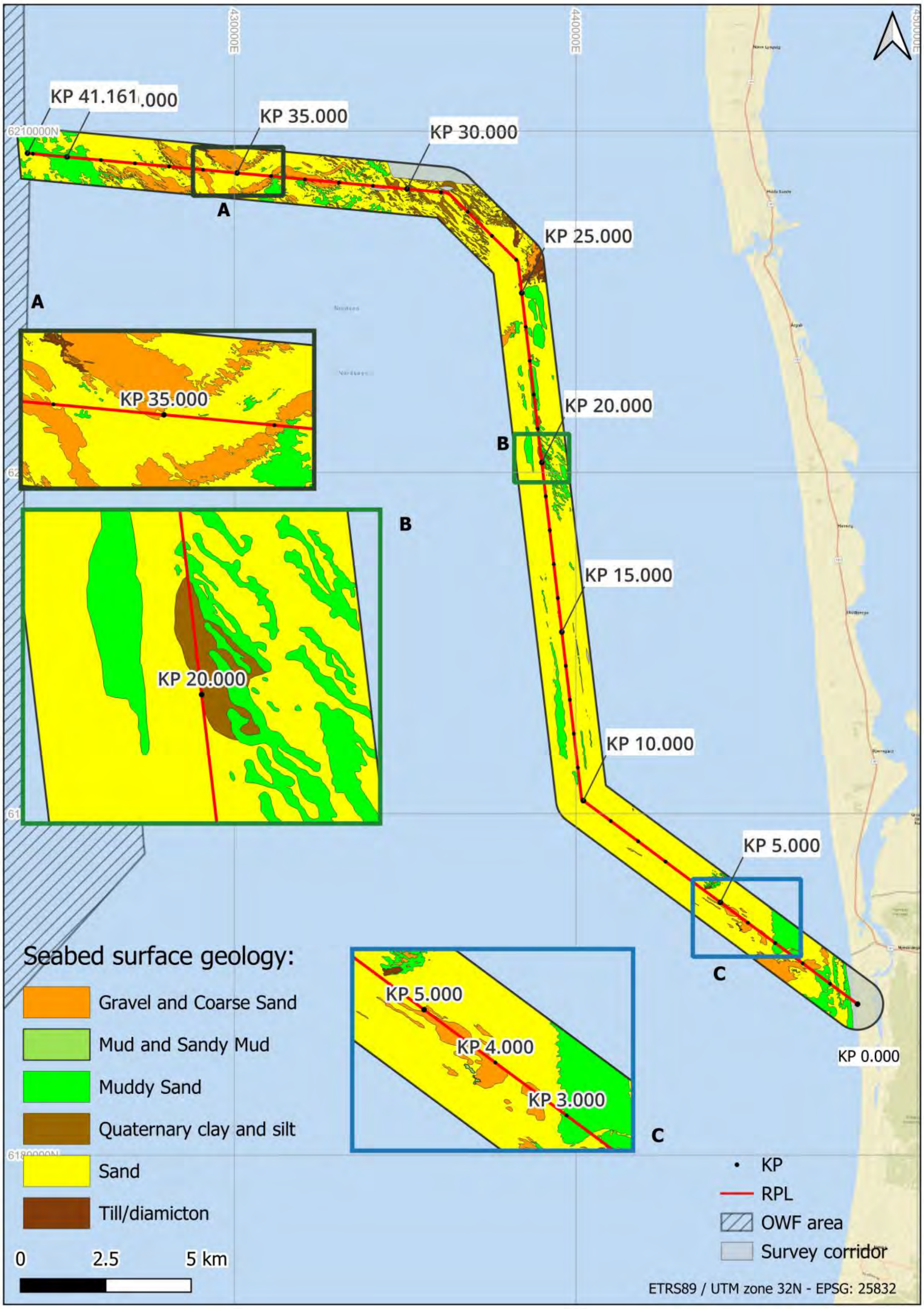


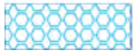
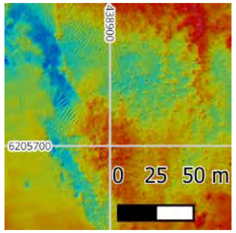
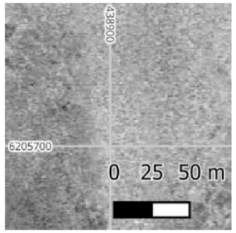
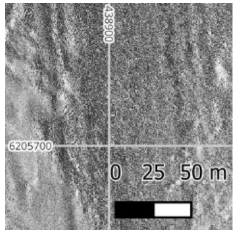
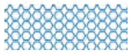
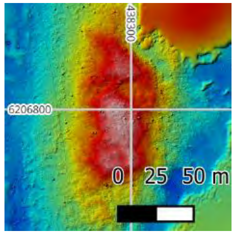
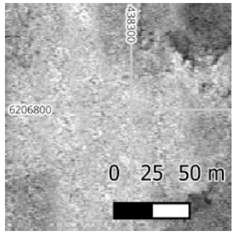
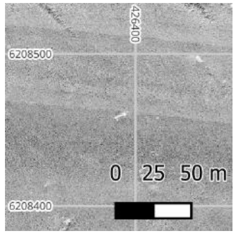
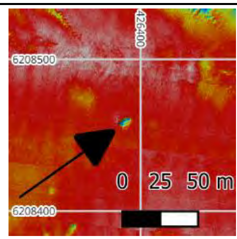
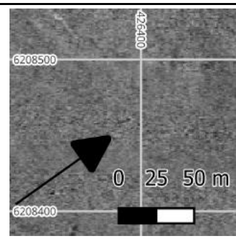
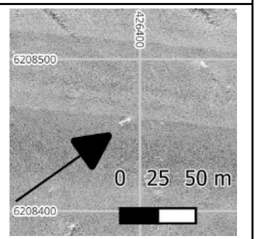
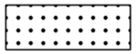
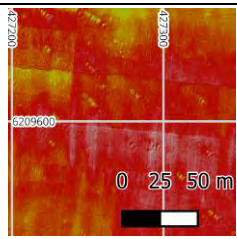
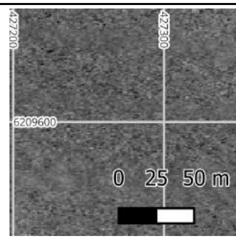
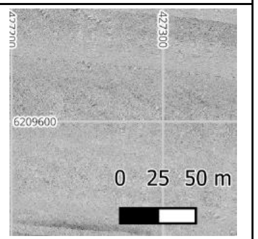
Figure 114: Seabed surface geology classification in NS_ECR2

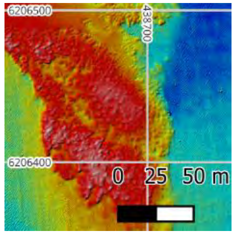
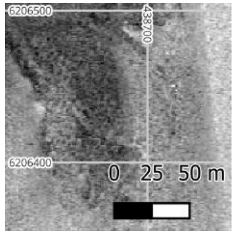
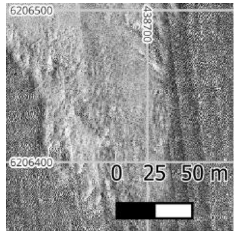
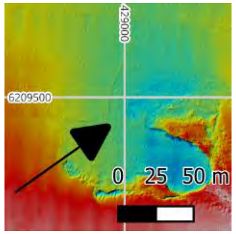
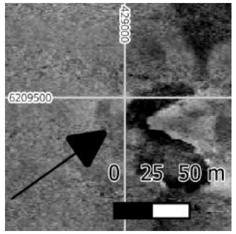
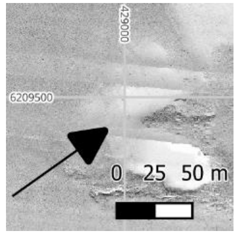
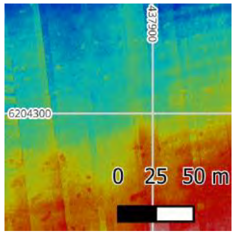
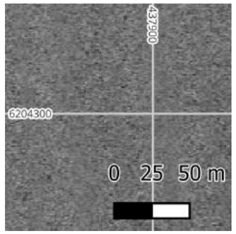
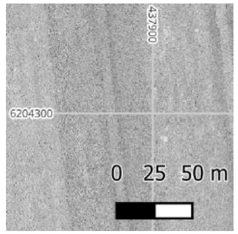
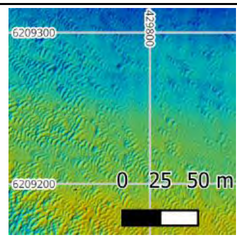
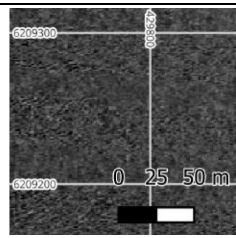
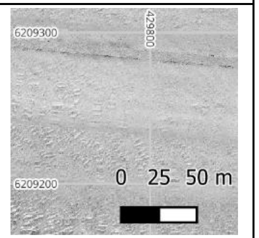
8.4 SEABED SURFACE MORPHOLOGY

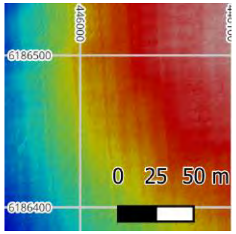
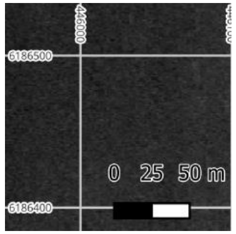
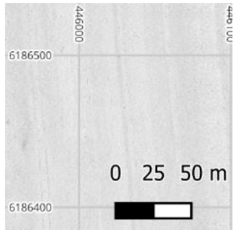
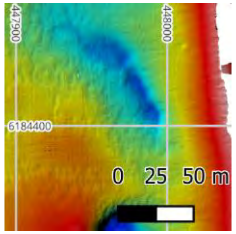
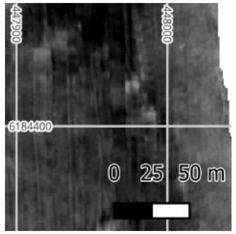
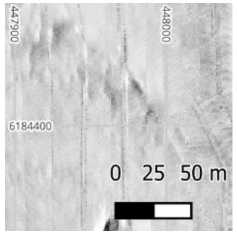
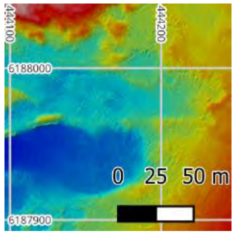
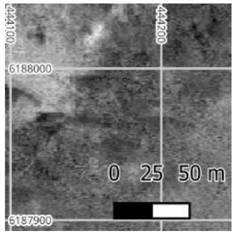
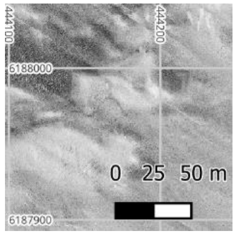
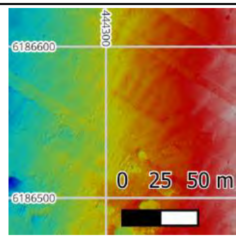
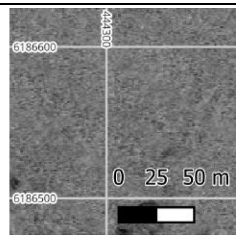
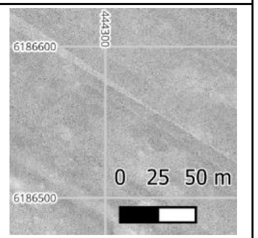
The seafloor morphology and seabed features were analysed using SSS (Side Scan Sonar), BS (Backscatter), and MBES (Multibeam Echo Sounder) datasets, with additional insights derived from SBP (Sub-Bottom Profiler) data. The acoustic characteristics of the interpreted seabed features at the NS_ECR2 site are depicted in Table 74.

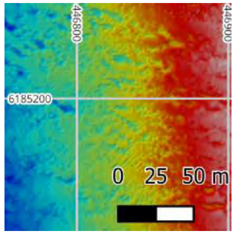
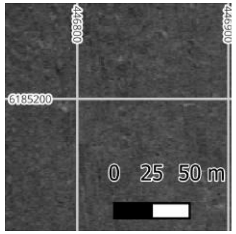
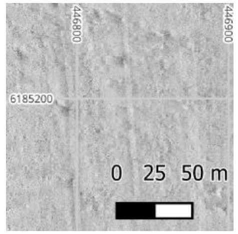
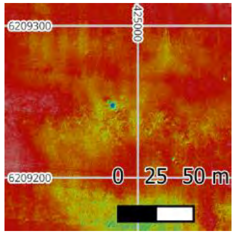
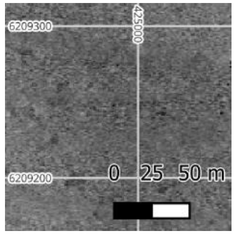
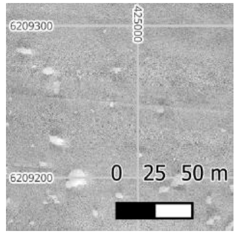
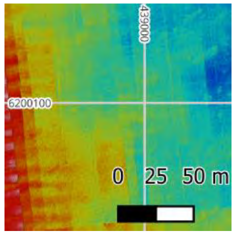
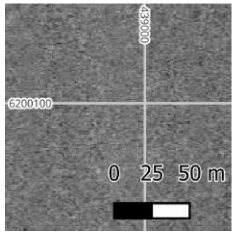
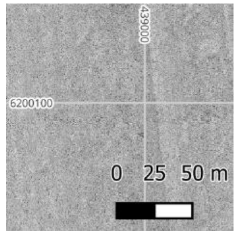
A variety of morphological seabed features of differing dimensions were identified. These features reflect a diverse geological environment influenced by both historical and current hydrodynamic conditions associated with sea level fluctuations (e.g. areas of boulders, ripples). Ripples were classified based on their wavelengths and heights. Ripples were classified based on whichever of the two, height or wavelength, fall into the larger category, e.g. for example, if wavelength of the ripple was 3 m but height was 0.3 m then it was classified as a large ripple. Additionally, some features have anthropogenic origins, such as trawl marks.

Table 74: Morphological interpretation – NS_ECR2

Seabed Feature	Symbology	Description	MBES image	Backscatter image	HF SSS image
Boulder Field - intermediate density (Class 1)		High reflectivity contacts of intermediate density (10 to 20 boulders in a 50 x 50 m box), visible in MBES			
Boulder Field - high density (Class 2)		High reflectivity contacts of high density (more than 20 boulders in a 50 x 50 m box), visible in MBES			
Disturbed seabed		Low to medium reflectivity, evidence of unnatural seabed disturbance			
Other – Erosional bedforms		Low to medium reflectivity features formed from sediment removal. Possibly early-stage ripple formation			

Seabed Feature	Symbology	Description	MBES image	Backscatter image	HF SSS image
Other – Bedforms. Sediment waveforms		Low to medium reflectivity linear scars forming a pattern, visible in MBES			
Other – Textured seabed		Medium reflective features, likely change in seabed sediment type			
Other – Featureless seabed		Areas of no significant seabed features (exception of boulders)			
Ripples		Low to high reflectivity alternating areas. Clear in MBES. Wavelength (<5 m) and height <0.01 m - 0.1 m) are the primary classifiers			

Seabed Feature	Symbology	Description	MBES image	Backscatter image	HF SSS image
Large Ripples		Low to high reflectivity alternating areas. Visible in MBES. Wavelength, 5 m -15 m, height 0.1 m - 1 m.			
Mega Ripples		Low to high reflectivity alternating areas. Visible in MBES. Wavelength, 15 m -50 m, height 1 m -3 m.			
Unknown – Possible erosional bedform features		Low to medium reflectivity features formed from sediment removal. Possibly early-stage ripple formation			
Unknown – Possible biostructures		Low to medium reflectivity patches, visible in MBES			

Seabed Feature	Symbology	Description	MBES image	Backscatter image	HF SSS image
Unknown – Mottled seabed (erosional)		Low reflective, circular, raised patches of seabed, surrounded by medium reflective seabed.			
Unknown – Patches of lower reflectivity		Patches of likely finer sediment deposited in areas of surrounding coarser sediment			
Trawl mark area		Area of linear scours caused by trawling related fishing activity			

The resulting seabed surface morphology interpretation for North Sea ECR2 is presented in Figure 115. The route does not exhibit any significant seabed features of concern, aside from the presence of occasional boulder fields. The morphology and distribution of these features are detailed below.

At the beginning of the route until KP 0.800, the seabed is dominated by ripples and megaripples. From KP 0.800 to KP 3.000, the seabed is further dominated by ripples, large ripples and areas of sediment waveforms. This indicates dynamic areas, which are also presented within the bathymetric and slope profile in Figure.

From KP 3.000 to KP 6.250 the seabed is predominantly featureless, with the exception of boulders. There are also occasional isolated areas of patches of mottled seabed and areas of possible biostructures, off the RPL. From KP 5.400 to KP 5.750 there is an isolated boulder field area located approximately 40m north-east of the RPL, which correlates with an area of till in the seabed geology. An area of ripples, large ripples and erosional bedforms are also present, adjacent to the north-east of the boulder field.

Between KP 6.250 to KP 28.200, the seabed is largely dominated by trawl marks, with some isolated large patches of featureless seabed also present. Occasional patches of lower reflectivity are also seen along this section, in correlation with areas of muddy sand. From KP 25.250 to KP 27.000, the eastern side of the cable corridor is largely dominated by boulder fields and ripples, whilst the western side of the corridor remains either featureless, or trawl marks are observed. From KP 27.00 to KP 31.900, the seabed is featureless with the exception of boulders, isolated seabed scars and an abundance of large linear patterned patches of lower reflectivity visible on the SSS data, that correlate to Quaternary clay and silt or muddy sand. These patches are predominantly orientated in an NW-SE direction.

Between KP 31.900 and KP 39.400, the route is either featureless, with the exception of boulders, or is dominated by large areas of ripples and erosional bedforms. From KP 39.400 to the end of the RPL, the seabed is again, either featureless with the exception of boulders, or patches of lower reflectivity as seen on the SSS are again present.

Figure 115 displays NS_ECR2 seabed surface morphology overview with detailed views of:

A – Large ripples.

B – Boulder field area and adjacent areas of ripples, large ripples and erosional bedforms.

C – Boulder fields and ripples to the east of the corridor, with featureless seabed or trawl mark area to the west.

Figure 116 displays overview of the linear seabed features within the NS_ECR2 survey area.

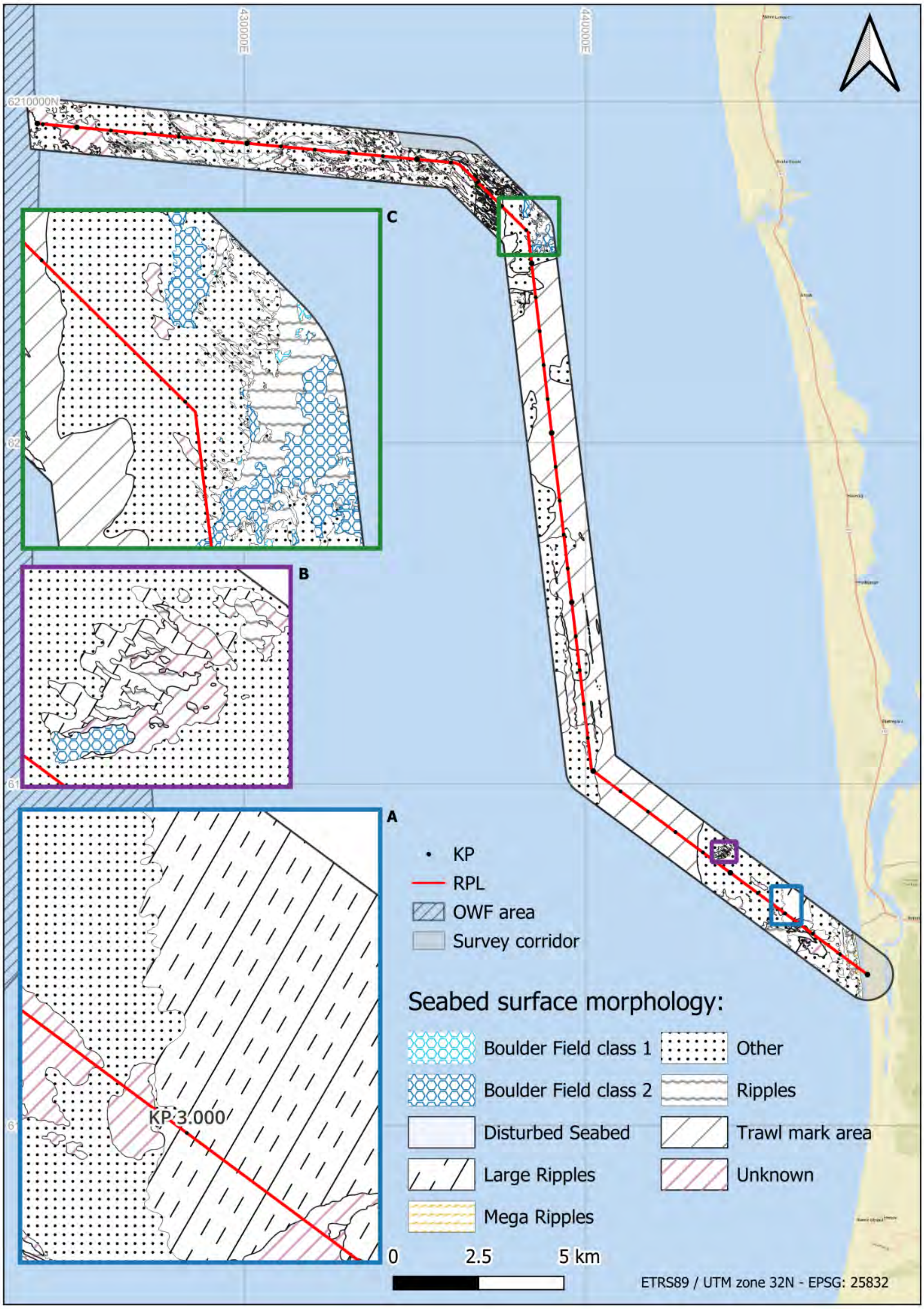


Figure 115: Seabed surface morphology overview, NS_ECR2

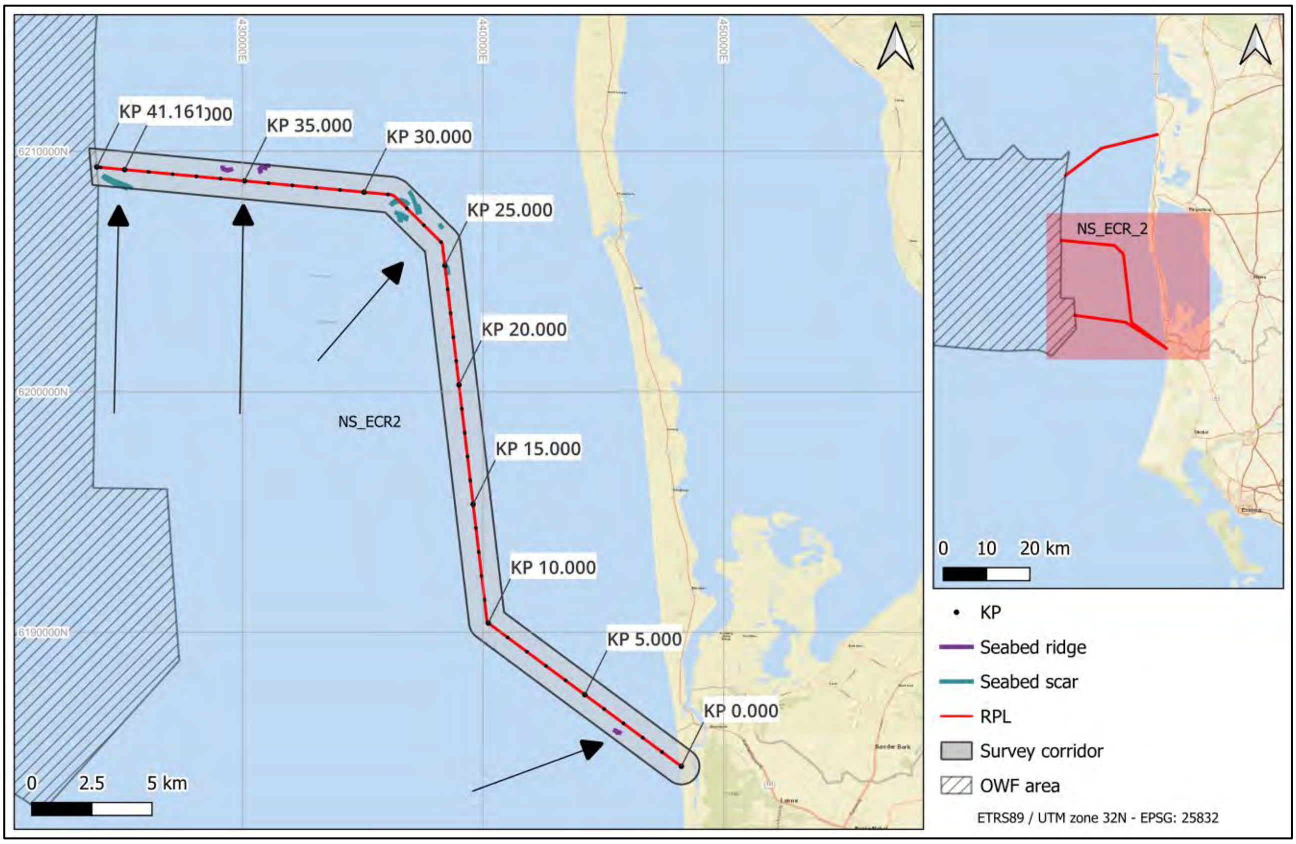


Figure 116: Seabed surface morphology overview - linear features, NS_ECR2

8.5 SEABED SURFACE FEATURES

Seabed surface objects which are determined to be man-made objects (MMO) in NS_ECR2 are outlined in Table 75 and Table 76, in both linear and point contacts. Polygonal man-made objects are summarised in Table 77.

Linear features have been determined from MBES and SSS data. Point seabed features have been determined as a Master target list without the man-made object point features. Polygon features have been detected from SSS and MBES data.

A total of 18 MMO linear objects were identified though the interpretation of the MBES, SSS, and MAG datasets in NS_ECR2. Only one of these objects (a cable crossing) was detected in multiple sensors. Of these linear objects, 7 of these were determined to be cable crossings within NS_ECR2. However, three of these were detected in the background data only and no associated anomalies were detected. There are an additional 14 linear seabed features identified as seabed scars and a further 8 linear seabed features identified as seabed ridges.

A total of 1034 point contacts were detected in NS_ECR2 through the interpretation of the MBES, SSS, and MAG datasets within the survey area. 121 contacts are identified within the MMO point file and 913 are identified within the seabed features point file and interpreted as boulders. It should be noted that some MMOs could be classified into more than one feature type (e.g. two objects have been classified as both linear and point contacts). Therefore, the sum of the amounts found in Table 75 and Table 76 does not amount to the total number of objects.

Table 75: Summary of linear contact man-made objects

Feature type	Total amount	Comment
Wrecks	0	No shipwrecks as were identified on site.
Metallic	0	No linear objects were detected within a 5m radius of a magnetic anomaly, other than 3 cable contacts.
Soft rope	4	3 contacts related to possible soft rope item and 1 was a free span rope.
Other contacts	7	There were 7 other linear objects detected.
Cable/pipeline	7	6 cable crossings and 1 telecom cable were identified. 3 of these were only identified in the background data.

Table 76: Summary of point contact man-made objects

Feature type	Total amount	Comment
Wrecks	0	No shipwrecks were identified on site.
Metallic	31	There were 31 metallic objects found, three of them are possible clusters of metallic debris. All were located within a 5m radius of a magnetic anomaly.
Anchor	0	No anchors were identified on site.
Soft rope	4	3 contacts related to possible soft rope item and one free span rope.
Other contacts	85	There were 85 other contacts found identified to be debris.
Cable/pipeline	1	There was one Telecom cable point contact detected on site.

Table 77: Summary of polygonal contact man-made objects

Feature type	Total amount	Comment
Other	1	One debris field was identified on site.

8.5.1 Wrecks

No wrecks were identified within the NS_ECR2 site.

8.5.2 Cables, wires, and ropes

There were a total of 18 linear man-made objects (MMOs) detected within the NS_ECR2 cable survey area. Four of these features were identified as soft ropes, most likely related to fishing activities, and seven of them were other linear contacts. None of these features were detected using magnetometer. There were additional six cable crossings recorded – all of them detected in the background data, cable databases and nautical charts and three of them were detectable by magnetometer. Telecom cable KB1029 was detected by SSS and not on magnetometer.

Distribution of these linear man-made objects is presented in Figure 117. Figure 118 presents target NS_ECR2_MMO_LIN_0008 - Telecom cable KB1029, which can be seen most clearly on the MBES image in the figure, and target NS_ECR2_MMO_LIN_0015, which can be seen mostly clearly on the MAG image in the figure.

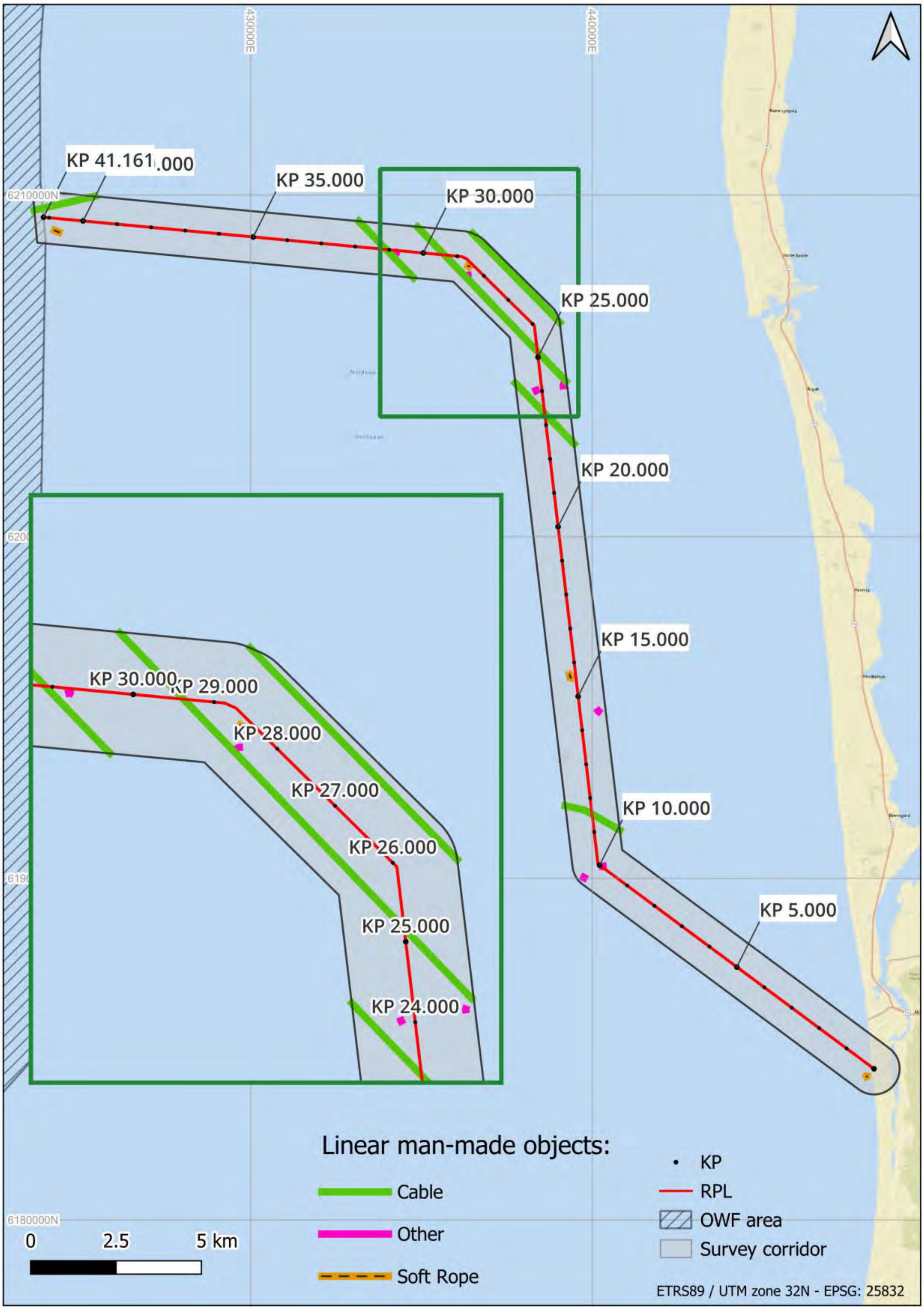


Figure 117: Overview of linear MMO found within the NS_ECR2 survey site

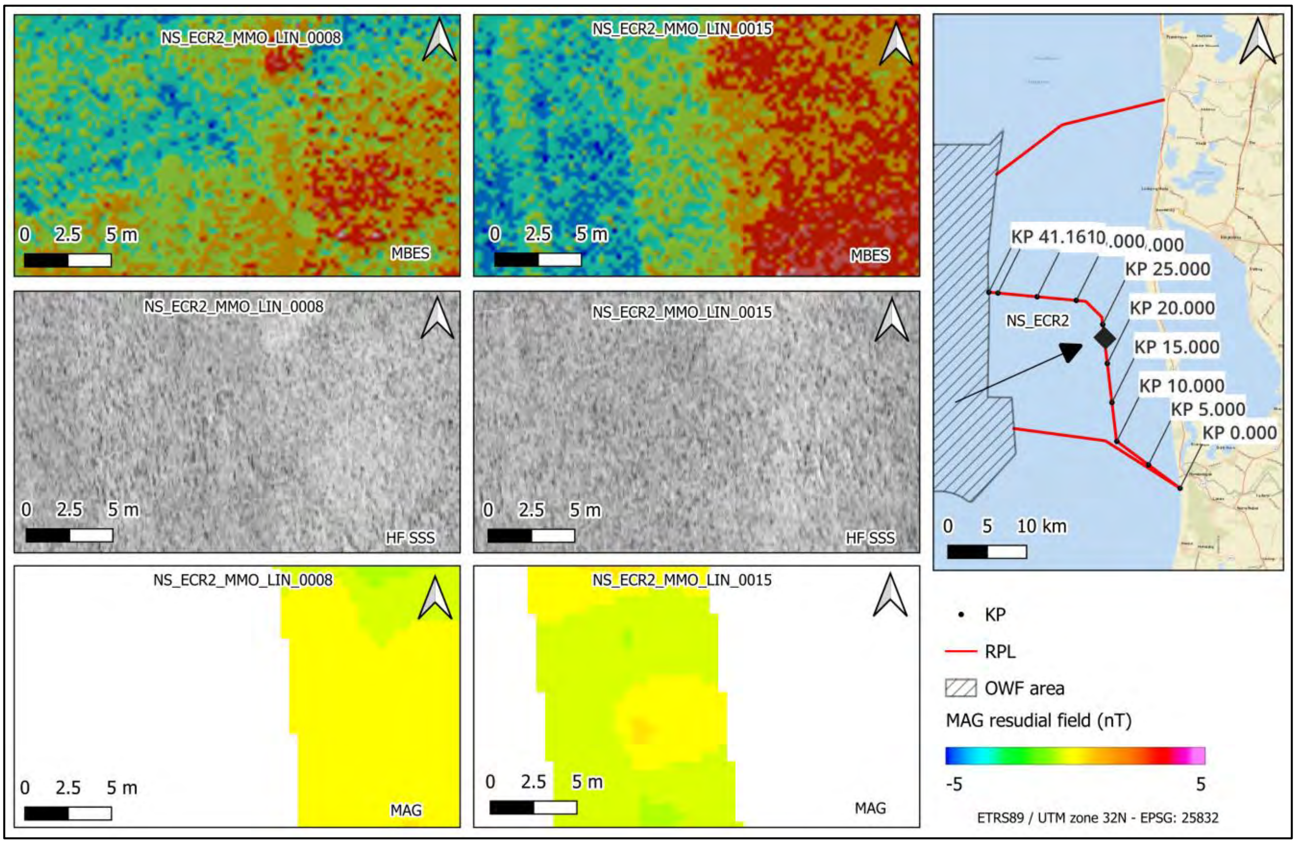


Figure 118: NS_ECR2_MMO_LIN_0008 (Telecom cable KB1029) and NS_ECR2_MMO_LIN_0015 on MBES, HF SSS and MAG

8.5.3 Pipelines

No pipelines were identified within or crossing the within the NS_ECR2 area.

8.5.4 Debris

An object identified from SSS and MBES, confirmed to be within a 5-metre radius of a magnetic anomaly, is classified as a metallic object. There were 31 metallic objects found within the NS_ECR2 survey area, all of which have associated SSS anomalies. The highest density of these metallic objects is located between KP 25.250 to KP 27.000 on the eastern side of the cable survey area.

The distribution of the metallic objects is presented in the Figure 119.

Figure 119: Overview of debris items within the NS_ECR2 survey area

Additional 85 items of the debris point contacts were observed within the site. All of these were interpreted as non-ferrous objects and detected in the SSS or MBES data.

Figure 120 there are NS_ECR2_MMO_PTS_0091 detected as debris field and NS_ECR2_MMO_PTS_0010 detected as possible cluster of metallic debris. Both are represented on MBES, HF SSS and MAG background.

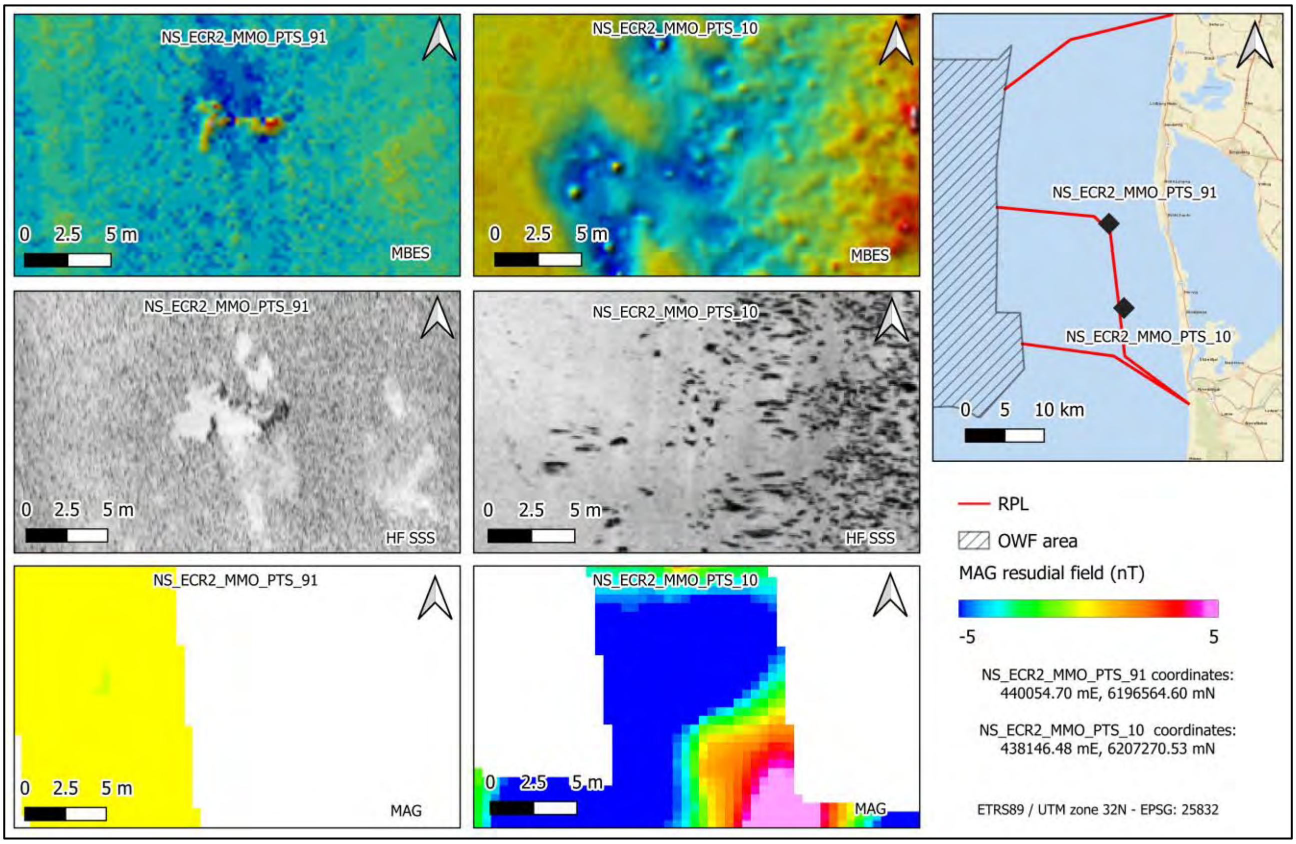


Figure 120: NS_ECR2_MMO_PTS_0091 - debris field and NS_ECR2_MMO_PTS_0010 - possible cluster of metallic debris

8.5.5 Items related to fishing activities, and seabed disturbances

Trawl marks, seabed scars, and ropes identified within the NS_ECR2 cable survey area are highly likely related to fishing activities.

8.5.6 Archaeological findings

No anthropogenic contacts identified have been associated with archaeological significance within the North Sea ECR2 site.

GEOxyz is not specialised in providing archaeological services. As such, the findings in this report are based on an interpretation of the data, which is a matter of opinion on which professionals may differ.

8.6 GEOTECHNICAL RESULTS

The following section presents a summary of the selected results from the geotechnical investigation conducted along the route.

Figure 121 and Figure 122 illustrate the locations of VC and CPT measurements, along with the achieved penetration depth.

Figure 123 to Figure 128 display the sample analysis results for each vibrocore, including:

- Description of the soil type
- D50 percentile value
- D90 percentile value
- Bulk density
- Water content

Figure 126 presents the cone resistance and friction resistance measurements for each CPT location along the route.

In Figure 127, the percentage of clay and the thermal resistivity values along the route are presented.

A detailed account of the geotechnical dataset can be found in the geotechnical report. For full access to the results from the geotechnical investigation, please refer to the external document provided in Appendix C.

Figure 121: VC locations overview with achieved depths below seabed

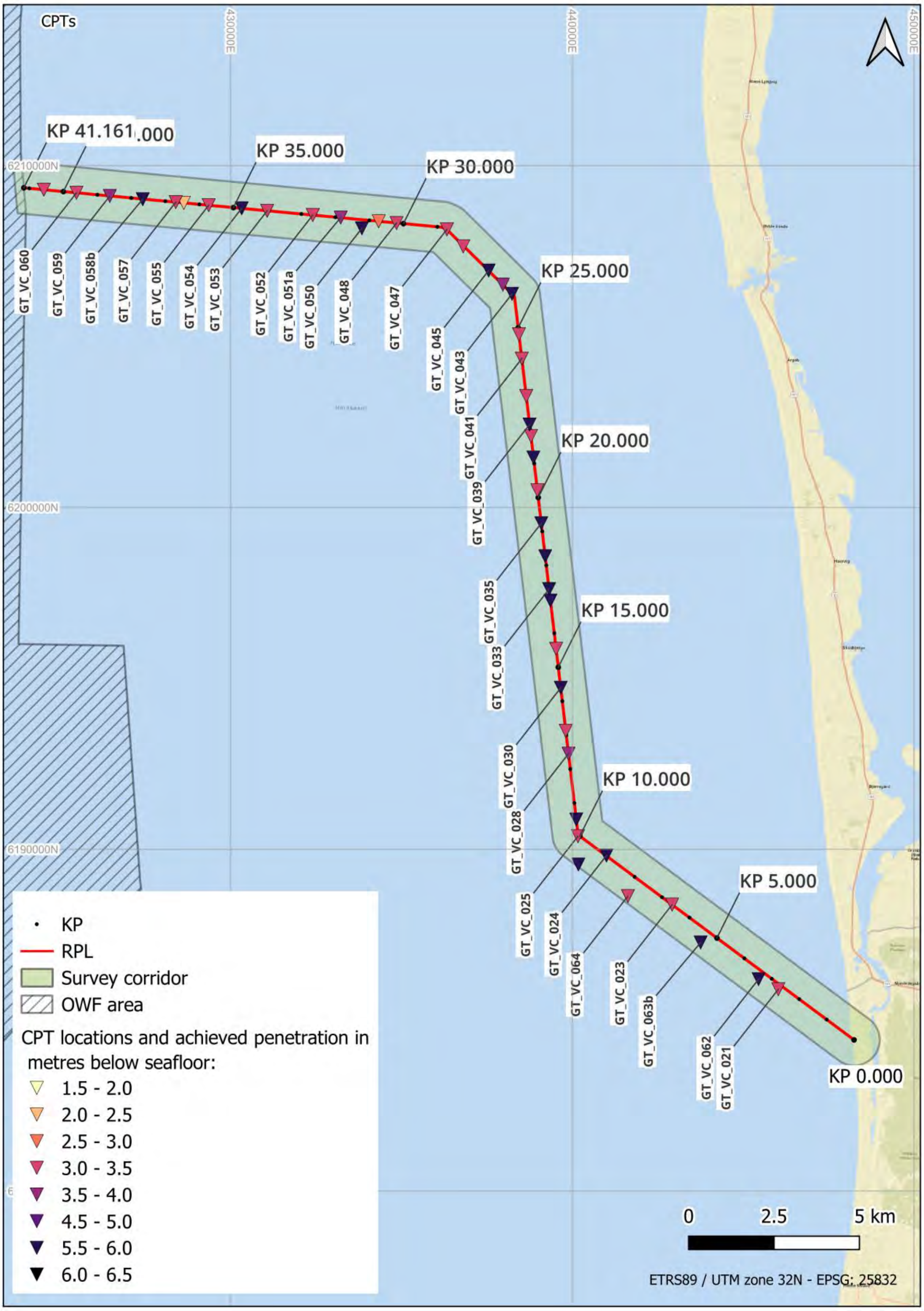


Figure 122: CPT locations overview with achieved depths below seabed

8.6.1 Particle size distribution and soil type analysis

Visual and PSD analyses of VC samples reveal sand and clay as the predominant soil types recovered along the route. Sand, occasionally interbedded with thin to medium gravel beds, dominates the sediment distribution from GT-021 to GT-024, GT-028 to GT-043, and GT-053 to GT-061. In between those geotechnical station (GT-065 to GT-027 and GT-044 to GT-052), the VCs recovered clay, topped by a thin to medium bed of sand.

In the westernmost sector, GT-064 is the only VC along the route to recover glacial till, found below approximately 2 mbsb.

PSD analysis indicates that while VCs from GT-021 to GT-063 consist almost entirely of clean, medium sand, the western portion of the route is capped by a 1–2 m layer of fine silty sand, extending up to GT-055. Beyond this, VCs from GT-055 to GT-061 predominantly recovered fine sand with minimal silt content.

VCs from GT-033 and GT-034 reveal shallow, medium beds of gyttja, overlain by only a few centimetres of fine silty sand. The comparison of D50 and D90 values consistently indicates the presence of gravel, associated primarily with intervals of medium to coarse clean sand.

8.6.2 Moisture content, bulk density and dry density

As observed along the NS_ECR1 route (Figure 125), the highest water content values (greater than 75%) and the lowest bulk densities (below 1.80 g/cm³) were measured in thin beds of gyttja recovered at GT-033, GT-034, and GT-056. In contrast, clean sands were characterized by lower water content, generally below 20 %, and bulk densities below 1.95 g/cm³.

Silty sands, such as those at GT-054, exhibited water content values between 25 % and 35 % and bulk densities ranging from 1.95 to 2.1 g/cm³, which are comparable to the measurements recorded for clay.

The complete dataset of moisture content measurements and derived dry density values is provided in the geotechnical report for further reference.

8.6.3 Thermal resistivity from TRT measurements

Thermal resistivity measurements from TRT conducted at 12 geotechnical stations (GT_022, GT_027, GT_032, GT_035, GT_039, GT_043, GT_044a, GT_050, GT_056a, GT_058, GT058b, and GT_063b) illustrate the thermal response of different soil types encountered along the RPL, with values ranging from 0.25 to 1.7 mK/W. Additional resistivity values were taken as discrete samples from selected vibrocore core samples. The lowest thermal resistivity values (<0.3 mK/W) were recorded on GT_022, GT035, GT_035, GT_43, GT_050, and GT_058b, correlating where soil types were medium SAND or coarser, up to gravel. The highest thermal resistivity values (>1 mK/W) were recorded on GT_056a within a layer of 1.7 m thick PEAT bed.

Generally, the near surface (<1 m below seabed) TRT and lab resistivity showed low to moderate resistivity (<0.7 mK/W) in the near surface due to the sandy and loose nature of the upper post glacial sediments. Increases in resistivity then occurred at depths >1 m or where post glacial sediments were thin, where clays and more compacted soils were present in the subsurface. The only deviation to this was GT_056a where PEAT was observed very close to the seabed and hence resistivity values rose rapidly upon entering the shallow peat layer to values >1.5 mK/W within the first metre of the subsurface.

All in-situ and lab thermal testing have been plotted on the 3km profile panels presented in the route analysis section.

8.6.4 Correlation between derived CPT parameters, soil types and geophysical units

Undrained shear strength and relative density data derived from CPT measurements were correlated with soil type information from VC samples, enabling further characterization of the subsurface and validation of SBP-interpreted units (Figure 128).

Cone resistance (Qc) values were generally below 15 MPa within the shallowest 2 m of soil along the entire route. Localized intervals of high Qc were observed at GT-022, where values exceed 50 MPa starting from 4 mbsb, and between GT-032 and GT-039, corresponding to clean sand intervals identified in the VC samples. Friction readings were consistently low, ranging between 0.1 and 0.2 MPa across most of the route (Figure 126). Detailed CPT readings are provided in the geotechnical report.

Similar to the findings from the NS_ECR1 route, relative density and undrained shear strength show a marked increase 1 to 2 mbsb, indicating a sharp transition in compaction. This shift corresponds to Horizon H10, which marks the bottom limit of the Holocene post-glacial Unit I. Sand transitions from loose to medium-dense at the surface to dense/very dense below Horizon H10. Similarly, clays transition sharply from low to high or very high undrained shear strength. The post glacial sediments are predominantly composed of silty fine sand, transitioning to fine to medium clean sand between GT-021 and GT-063 and again from GT-055 to GT-059 (Figure 128).

Below Horizon H10, the periglacial Unit II consists of an alternation of clean fine to medium sand, including sporadic thin beds of gravel, and clay, as described in Section 8.7. Horizon H15 appears to delineate the boundary between clay and sand sediments within Unit II, as observed at GT-028 and GT-030. Another horizon within Unit II, H12, corresponds to a medium bed of gyttja identified at GT-033 and GT-034. This correspondence is particularly evident in the derived CPT parameter plot, where a shift from undrained shear strength to relative density indicates that Horizon H12 likely represents the base of the gyttja layer (Figure 128).

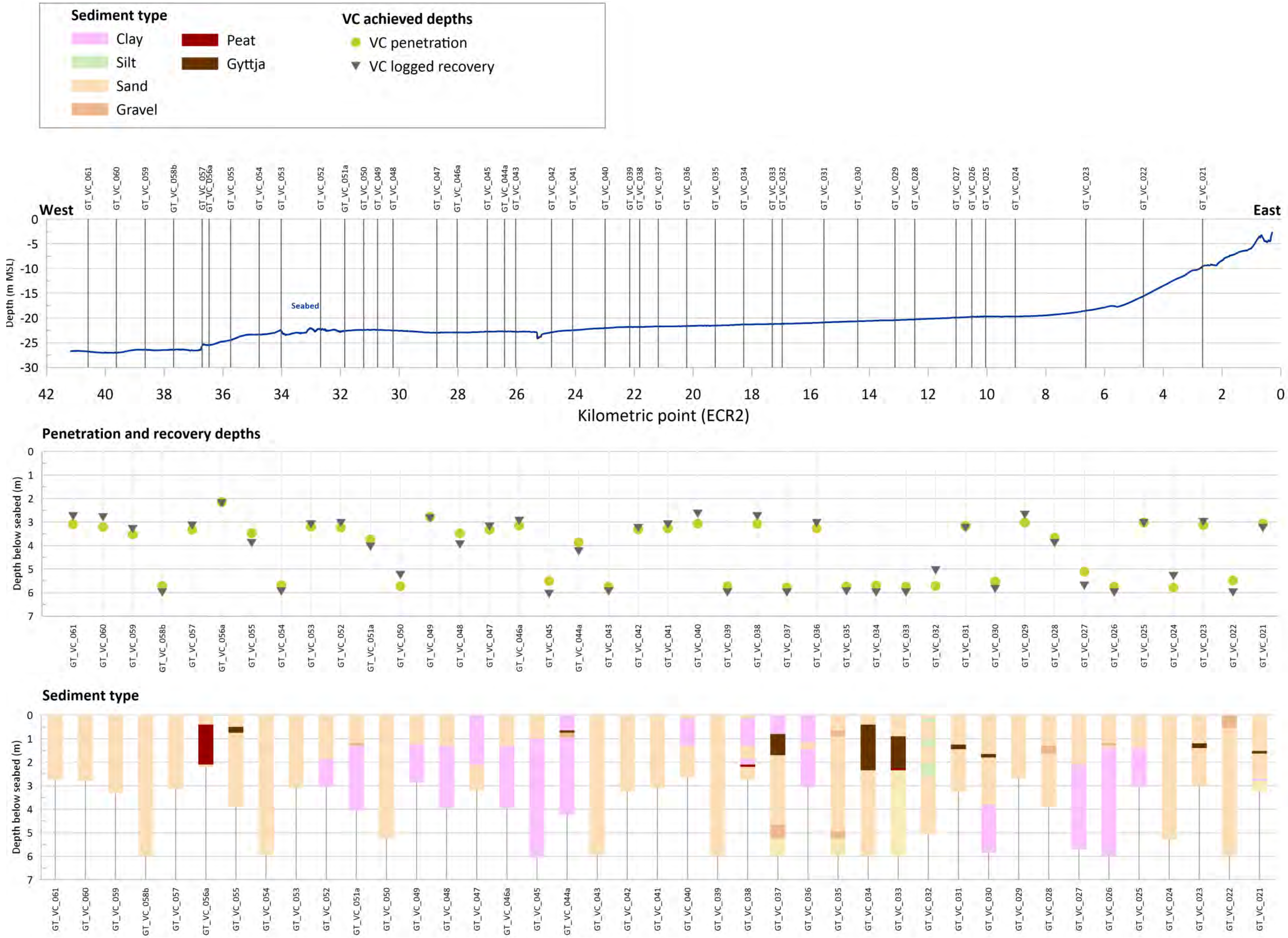


Figure 123: Sample analysis showing achieved depths and soil type distribution

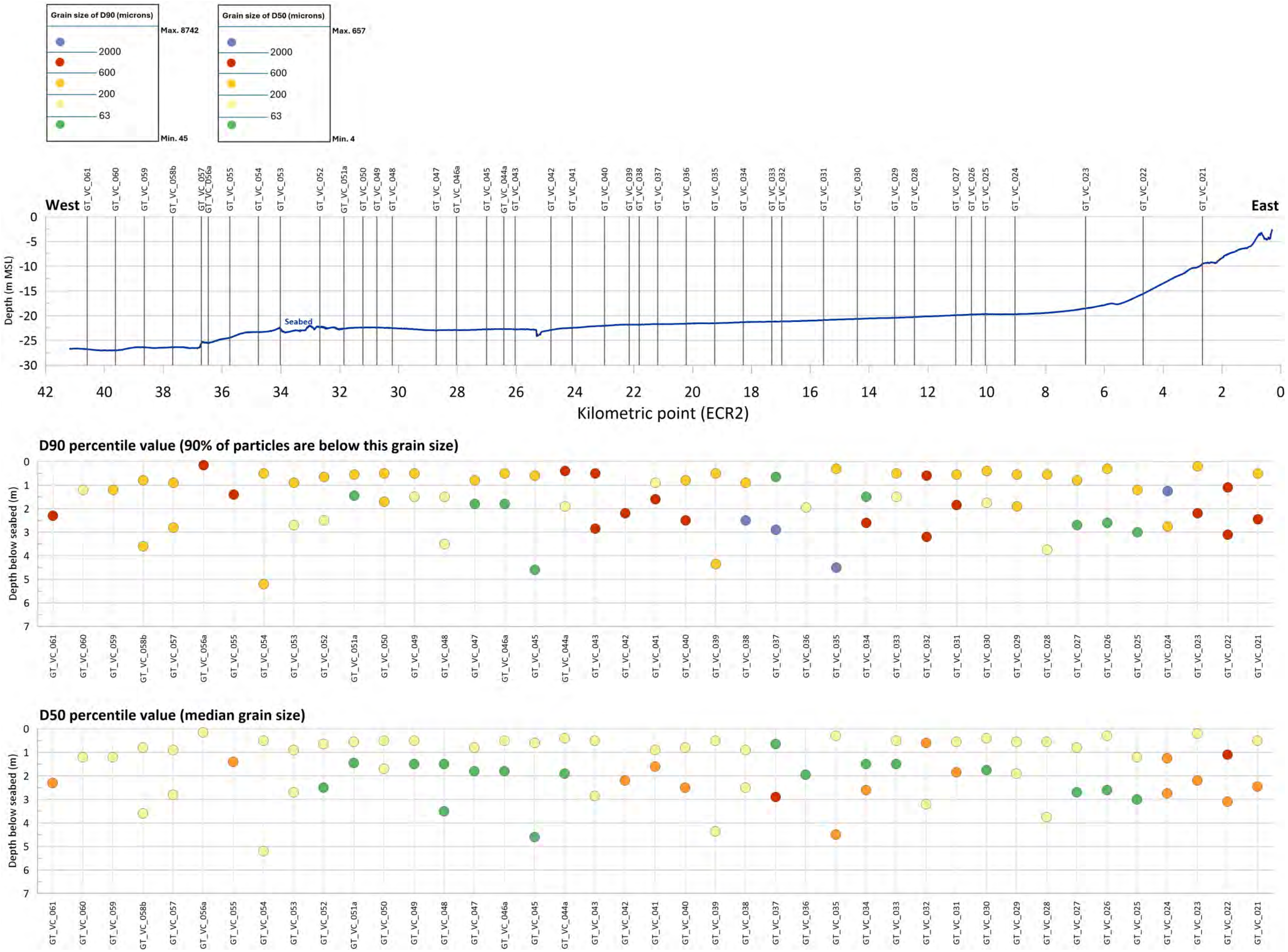


Figure 124: Sample analysis showing D50 and D90 grain size diameters

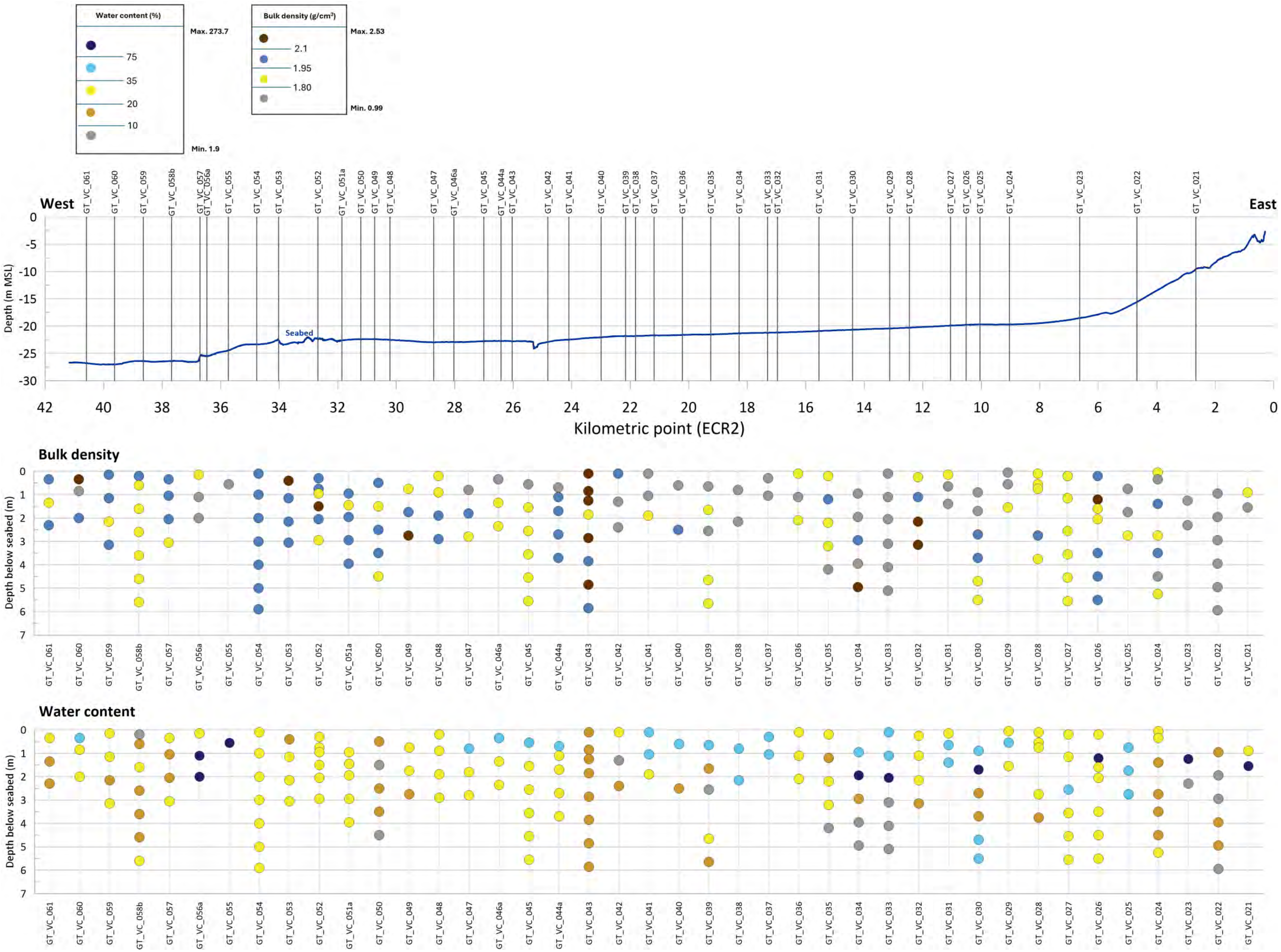


Figure 125: Sample analysis presenting bulk density (g/cm³) and water content (%)

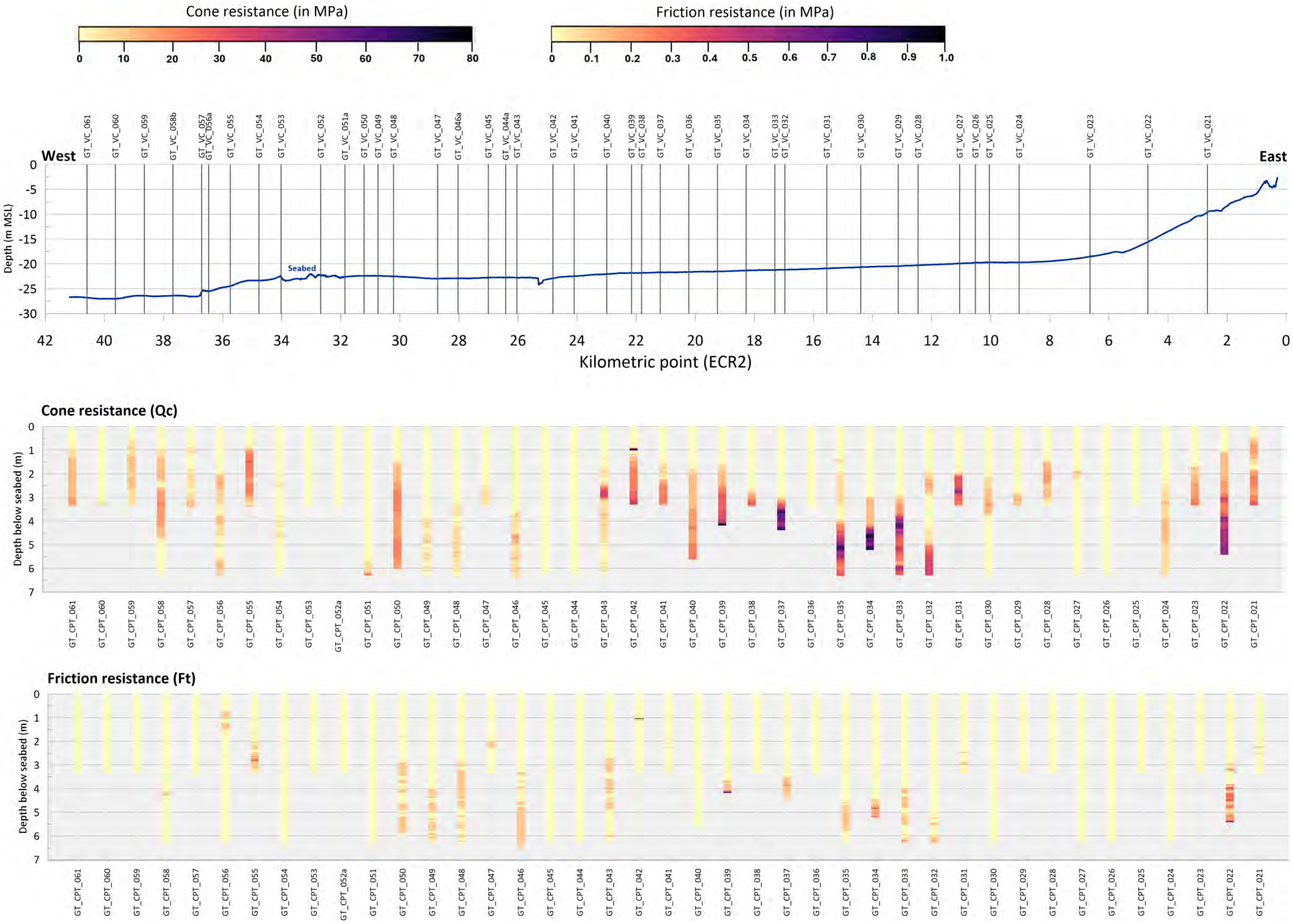


Figure 126: Sample analysis showing cone resistance and friction resistance in MPa

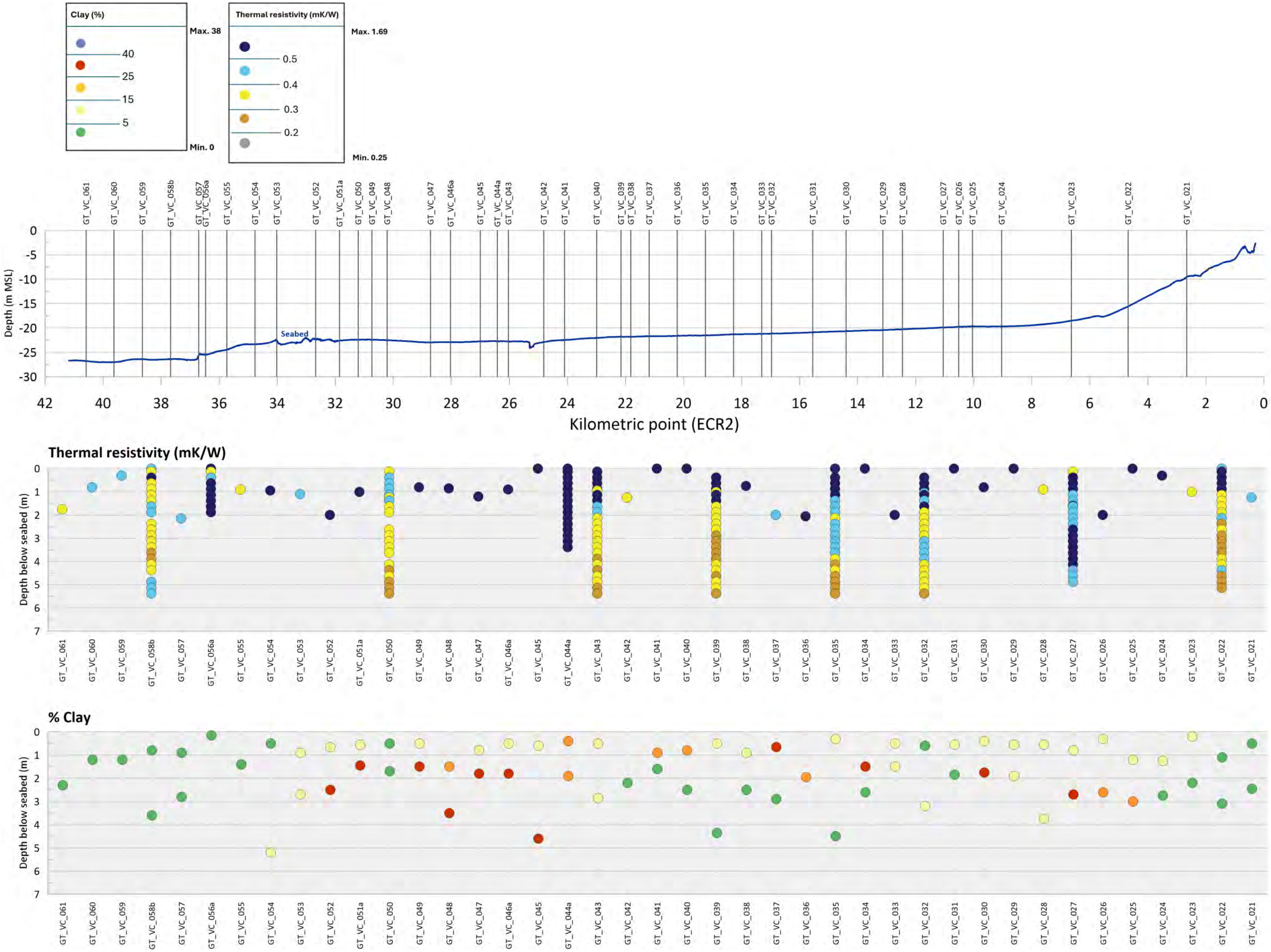


Figure 127: Sample analysis presenting clay (%) and thermal resistivity

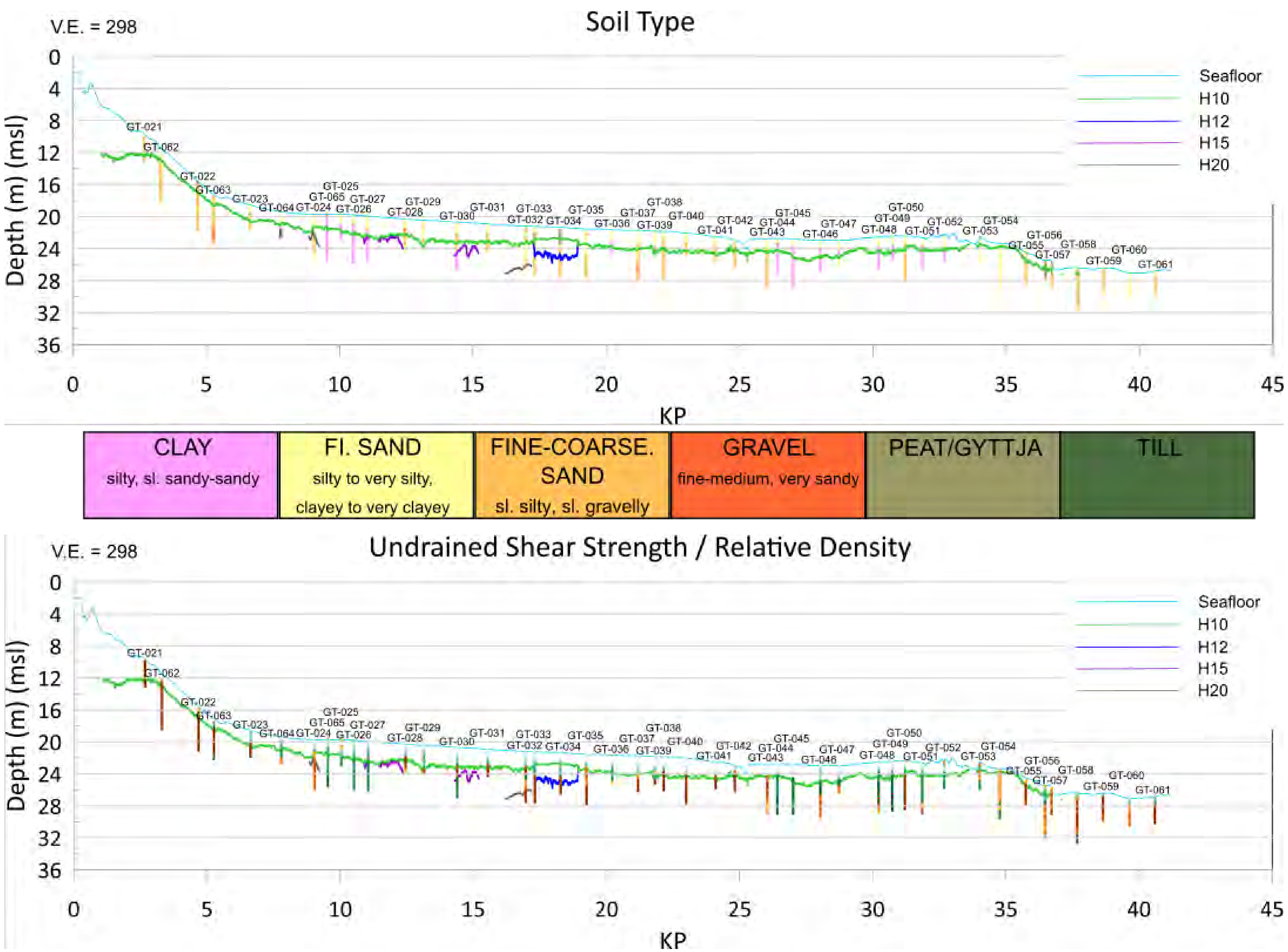


Figure 128: Soil types derived from VC and CPT data (top) and CPT parameters (bottom) compared with key horizons from SBP interpretation

8.7 SUB-SURFACE GEOLOGY

8.7.1 Regional geological history

The geological interpretation along the proposed ECR is based upon the geophysical and geotechnical datasets acquired with reference to the supplied GEUS desk study. This desk study applies a stratigraphic model developed by Jensen et al (2002) in conjunction with archive seismic data and limited ground truth information. There is generally a good correspondence between shallow geology imaged in this project's sub-seabed data and the desk study. This project's unit names are equivalent with those in the desk study (for example Glacial deposits, GL, in this report are equivalent to glacial deposits, GL, within the desk study).

In addition, reports for the OWF have been referenced (Fugro 2024, Ocean Infinity 2024), though horizon and unit naming are not in complete agreement.

In overview the area has a glacial to post-glacial sequence of relatively recent post glacial sediments over much older bedrock. Only the upper post glacial and glacial deposits are discussed along the ECR as the bedrock is deeper than the installation zone of interest and not imaged on the SBP data. Further detail of the regional geological history can be found in section 6.7.1.

8.7.2 Shallow geological overview

Depths quoted below seabed have been converted from time using an assumed seismic velocity of 1650 m/s which is considered suitable for the sediments present along the route.

The interpretation has been carried out based on the seismic acoustic nature of the SBP data, the adjoining Offshore windfarm survey results and report and the GEUS desk study. Geotechnical data, acquired by Geo DK were later available and confirmed the age and depositional environments of the sediments. Table 78 summarises the interpretation, geological units and depositional environments.

Table 78: Shallow geological units

Unit	Upper surface	Lower surface	Main Soil Description	Depositional Environment
I, Post Glacial (PG)	Seabed	H10	SAND with occasional GRAVEL, CLAY and GYTTJA/PEAT layers	Post-glacial marine
IIa, Late Glacial (LG)	Seabed/H10	H12	Variable, includes intervals of laminated CLAY and SAND-prone packages	Periglacial, glaciomarine
IIb, Late Glacial (LG)	Seabed/H10/H12	H15	Variable, includes intervals of laminated CLAY, SAND-prone packages	Periglacial, glaciomarine
IIc, Late Glacial (LG)	Seabed/H10/H12/ H15	H20	Variable, includes intervals of laminated CLAY, SAND-prone packages	Periglacial, glaciomarine
III, Glacial (GL)	Seabed/H10/H12/ H15/H20		Variable, SAND-prone, with CLAY and TILL locally overconsolidated	Glacial with localized direct ice contact

8.7.3 Stratigraphy and general arrangement of units

The model below (Figure 129) shows the arrangement of units along the proposed North Sea ECR2. Table 78 shows the basic characteristics of the stratigraphic units. Key surfaces are the top of Unit III (H20/H15/H12/H10/seabed) which is the top of potentially overconsolidated deposits. Sediments within Units I and II are less well consolidated, with fewer cobbles and boulders present than found in Unit III.

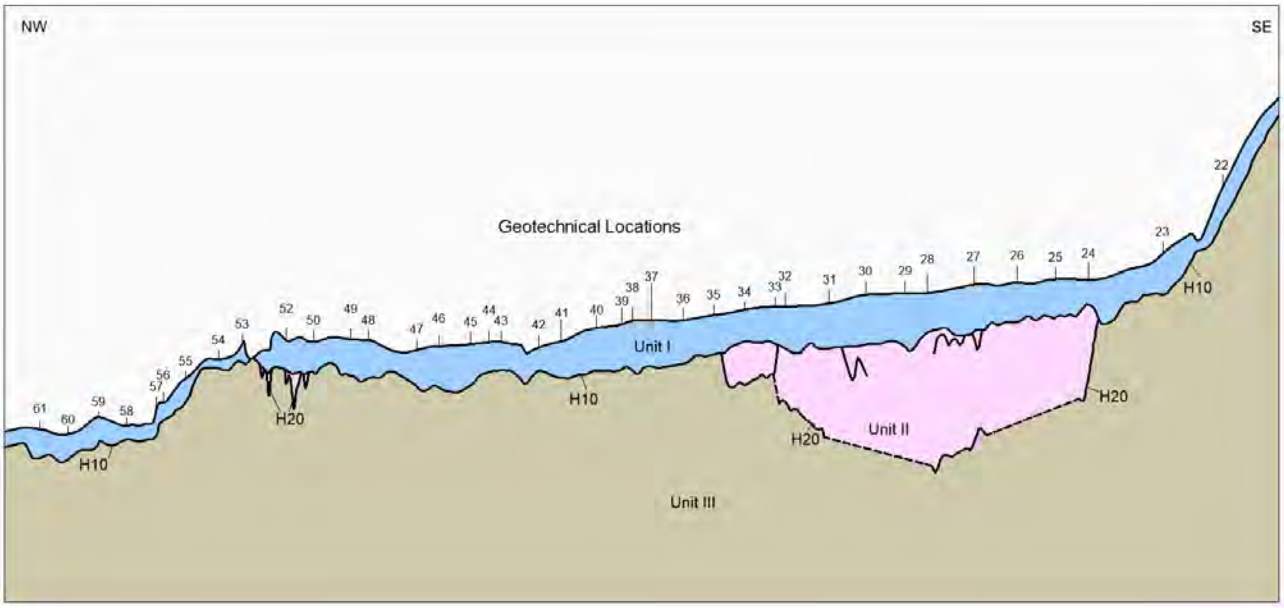


Figure 129: Geological schematic, general arrangement of units with approximate geotechnical locations

8.7.4 Quaternary deglaciation history / stratigraphic units

These bullet points are largely derived from information in the GEUS desk study. Here the stratigraphic units have been linked to the changing paleoenvironments.

- In Denmark the Scandinavian Ice Sheet reached its maximum extent about 22,000 years BP followed by retreat with evidence for short-lived advances over the following 4,000 years. **Unit III was laid down in association with this ice sheet.**
- Marine transgression began around 18,000 years BP leading to rapid deglaciation and establishment of glaciomarine conditions. An isostatic regression occurred shortly after 18,000 years BP. This was followed by renewed marine transgression related to the wasting of the Baltic Ice Stream. **Unit II was laid down over this complex period.**
- After deglaciation the area generally experienced high-stand conditions, though glacio-isostatic rebound outstripped background sea level rise around 11,000 years ago, driving a local regression. **Unit I was deposited in this marine environment.**

a Post Glacial geology

Unit I is a package predominantly of post-glacial SAND with occasional layers of GRAVEL, CLAY and GYTTJA/PEAT which is less than 3 m thick over most of the route. The post-glacial sediments are widely distributed over the cable route corridor (Figure 131) varying from absent to less than 3 m over the majority of the route. It increases in thickness at the nearshore end, reaching a maximum observed thickness of approximately 6 m near KP 1.000. It may be thicker even further inshore, but the horizon is obscured by the seabed multiple.

The geotechnical interpretation from the vibrocores is shown on the data examples and panels. These indicate that there is a lot of lateral variation in the lithology within all of the units. Despite the seismic character being very similar, VC034 shows a veneer of fine to medium sand over a 2 m thick package of gyttja, while VC035 has fine sand with a thin gravel layer over more sand, and VC036 has sandy clay to 1.2 m over a thin sand layer, over further clay (Figure 132). The boundary marking the base of Unit I does not correlate with lithological changes seen on the geotechnical data.

Likewise, further to the north within the ECR (Figure 133), VC0 44a and VC 047 have clay at seabed, and for most of Unit I, while VCs 043, 045 and 046a all have sand at seabed. Though the high amplitude package at the base of Unit I does correlate over this section (KP 26.2 to 32.0) with a layer of clay in the geo technical data. However, a similar layer of high amplitude between KP 11.500 to 17.000 and KP 19.000 to 24.500 corresponds to sand in the geotechnical logs.

Occasional pockets of peat and gyttja are observed in the geotechnical logs, but no seismic expression is noted in the SBP data.

In general the post-glacial package consists of sand with occasional gravel and gyttja in the nearshore end of ECR02, with the first clay observed in VC 036 at KP 20.200.

The location of seismic profiles, which are presented throughout the report, are displayed in Figure 130 below.

Figure 130: Location of the seismic profiles along NS ECR2 presented throughout the report

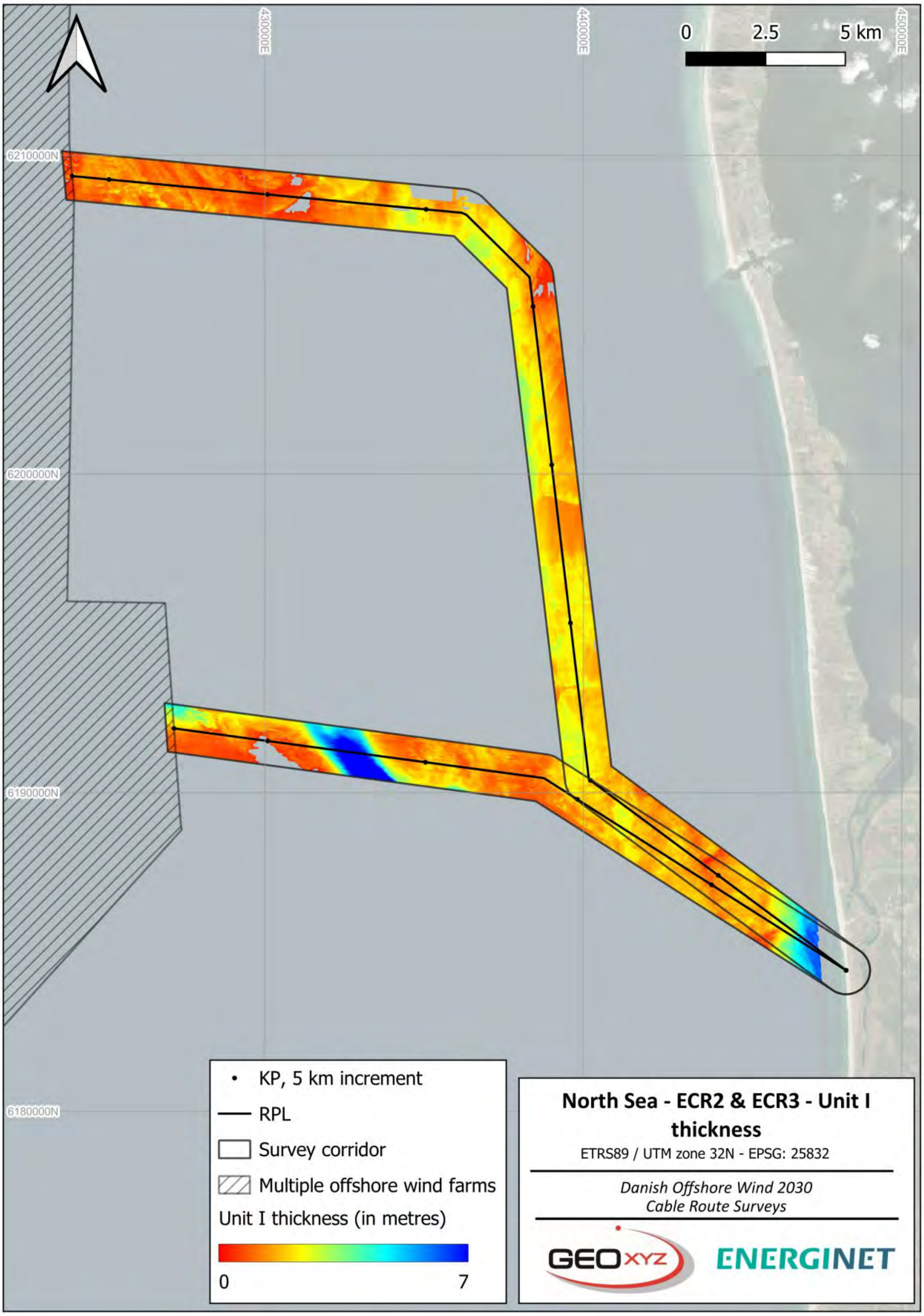


Figure 131: Distribution and thickness of Unit I

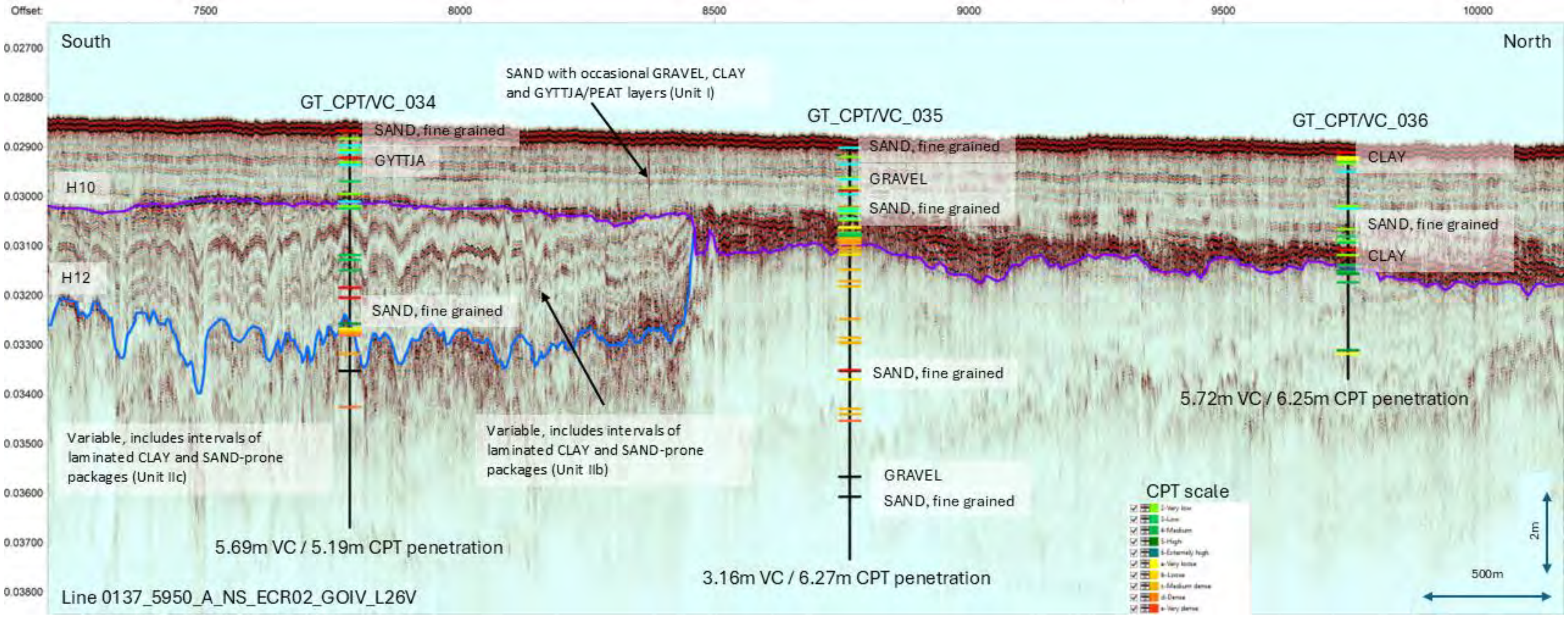


Figure 132: Seismic example showing Unit I – VCs 034 - 036

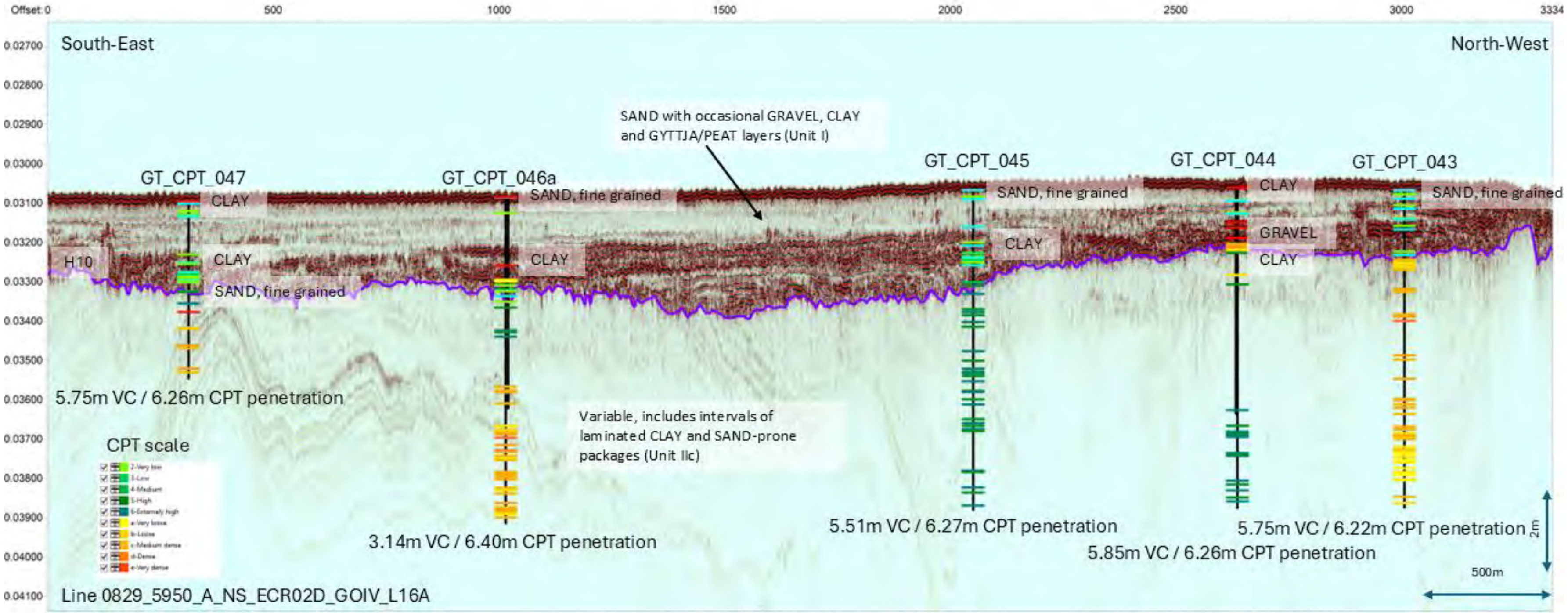


Figure 133: Seismic example showing variation in VC lithology

The base post-glacial deposits are mapped as H10 and the deposits are thickest in the nearshore area, reaching a maximum of approximately 6 m near KP 1.000, then reducing to 2.0 m at KP 2.000, and to 0.5 m at KP 5.500. It increases again to 2.3 m at KP 8.700, from where it undulates gently between 2.7 m and 1.5 m until KP 17.800. It shallows to less than 1.5 m until KP 18.900, where it again deepens to between 1.5 m and 2.5 m until KP 24.500. Between KP 24.500 and KP 26.500 it is less than 1.5 m, reducing to 0.6 m at KP 25.300. From KP 26.500 Unit I thickens to between 1.5 m and 2.7 m until KP 33.100, with a couple of short sections thinner than 1.5 m. From KP 33.100 to the end of the route at KP 41.160, the unit is less than 1.5 m thick, being absent, or very thin, between KP 33.600 and KP 33.900.

Acoustically the interval is almost featureless, with very low amplitude in its upper part, changing to high amplitude discordant internal reflections at the base. Locally there are very subtle unconformities. There are very occasional bright spots which may possibly be organic material.

b Quaternary geology

Unit II, Late Glacial deposits

This interval is very complex due to the area's range of environmental conditions during the Late Weichselian and earliest Holocene. Some intervals show laminations indicative of clays and silts, others may represent sandy beach-type deposits. The unit is mapped with either H12, H15 or H20 at its base (H12 is interpreted as an intermittent internal subunit (IIa)), and has been sub divided into Units IIa, IIb and IIc where the seismic character has distinguishable differences. This is generally at the top of deposits which show clear signs of ice contact, true glacial deposits, or the base of clear channelling.

Along the route corridor Unit II, glaciomarine sediments which infill steep sided channels eroded into the underlying Unit III tills. The extents of Unit II are shown in Figure 134 below. Geotechnical sample locations VC27, 30, and 34, are examples of locations where Unit II has been sampled. From these samples, the geotechnical properties of Unit II are expected to predominantly be silty clay and clayey silt.

A significant channel is present between KP 8.9 and KP 17.2. It is acoustically quiet in character and reaches a maximum depth of approximately 17 m below seabed at KP 13.2 (Unit II ~14 m thick). The edge of the channel is shown on Figure 141.

Within this channel an internal reflector (H15) is present (Figure 141), which corresponds to the top of a clay layer identified in the geotechnical data.

Another channel is observed between KP 17 and KP 19. The channel has a highly erosive base and the sediments are well bedded with the bedding parallel to the irregular basal reflector (Figure 142). The Unit reaches a maximum depth of approximately 5 m below seabed (Unit II ~3.5 m thick). Geotechnical data shows the sediments to be predominantly sand.

Further channels are seen to the north of the ECR between KP 32 and KP 36; and away from the centreline at KP 2.5 to KP 3 and KP 5 to KP 5. They reach a maximum depth of 9 m below seabed, but more usually reach 4 to 5 m below seabed. These channels have a high amplitude chaotic acoustic character. They were sampled in VC 052 and consist of clay.

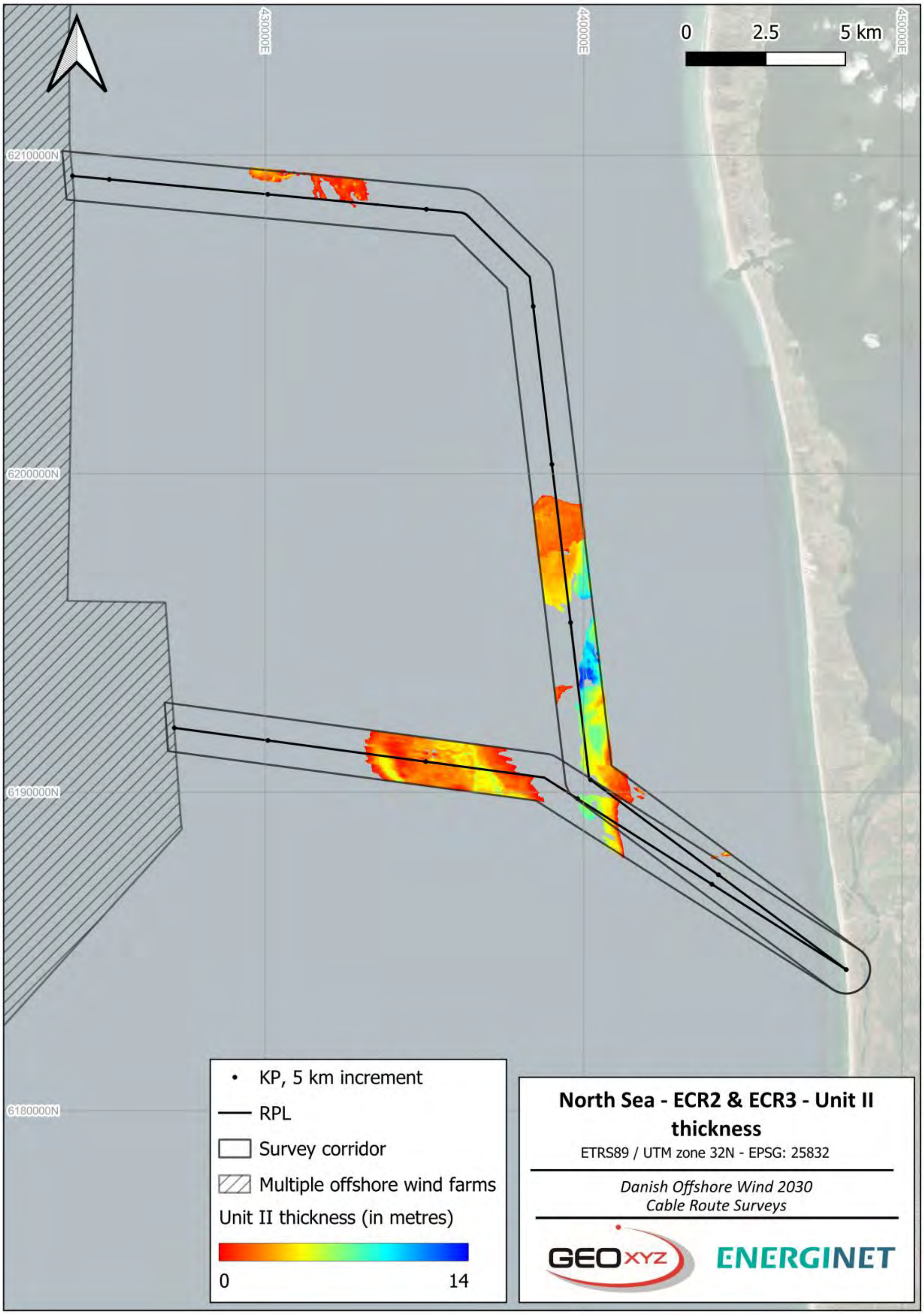


Figure 134: Distribution and thickness of Unit II

8.7.5 C14 Analysis

Carbon 14 analysis to determine soil age has been undertaken on six locations along the NS ECR02 route. Figure 135 shows the C14 sample locations along the route corridor.

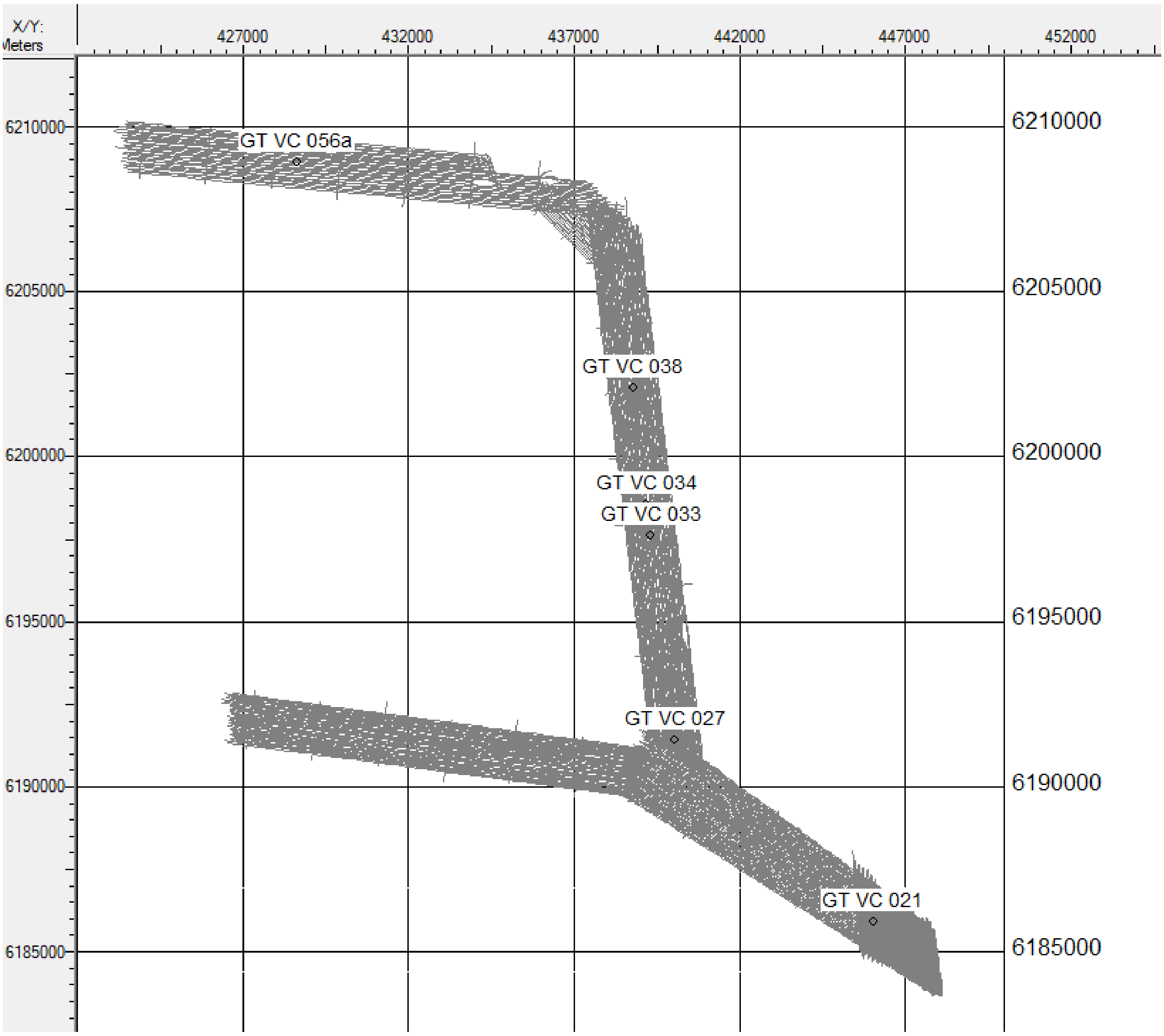


Figure 135: Locations of C14 sampling on ECR02

Figure 136 shows the C14 result at VC_021 plotted on the SBP data. The sample has been taken above the interpreted post glacial interface (H05). The derived age of 3,370 ± 30 BP matches with the expectation of post glacial soils at this location.

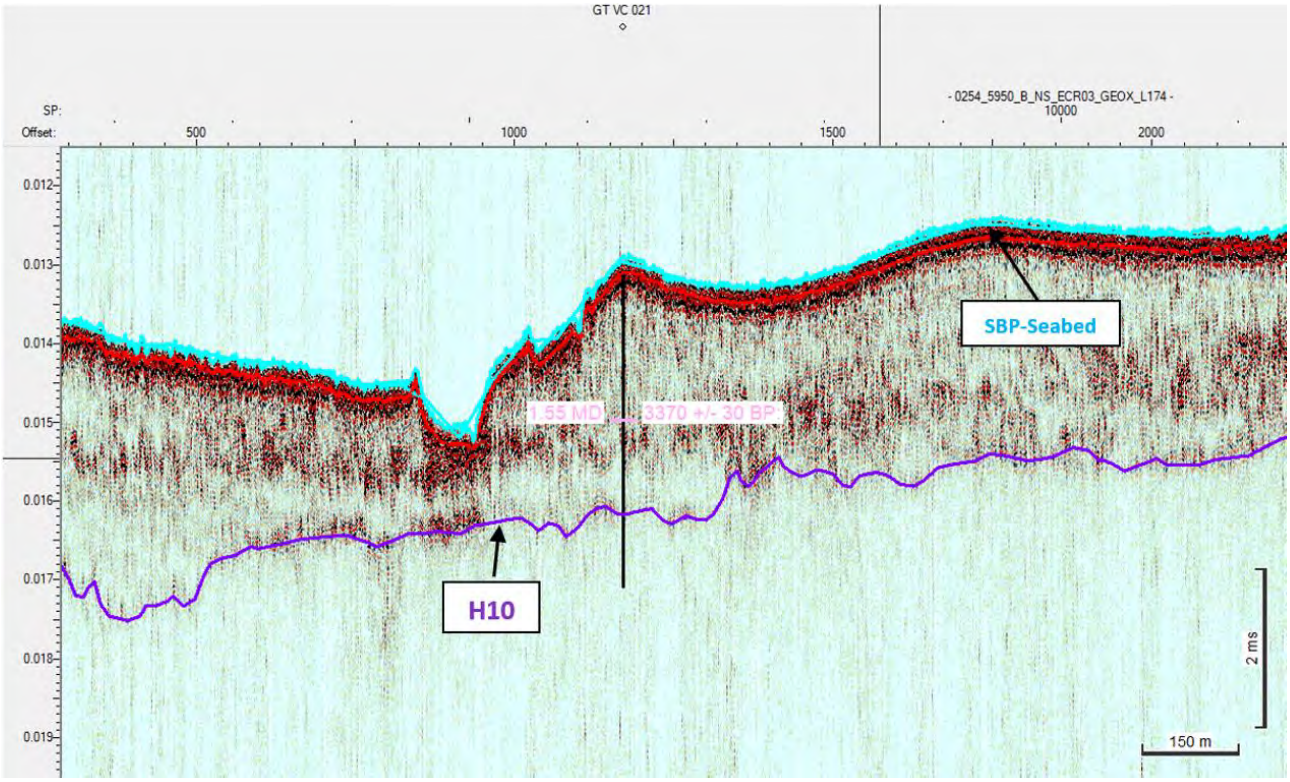


Figure 136: C14 result on SBP profile at VC_021

Figure 137 shows C14 results for VC_027. This sample has returned the maximum age possible with this sampling technique at > 43,500 BP. This sample resides between H10 and H20. It is possible the late glacial unit that the sample is interpreted to reside within from SBP data either has inclusions of reworked glacial material, or it is possible the SBP horizon observed and interpreted as H20 is too deep and that the base of late glacial material should be higher. However, there is no clear reflector above this location where this sample has been taken to interpret a higher horizon. VC_027 has also been interpreted as comprised of late glacial material from 2.1 m below seabed to the sample's maximum depth of 5.7 m.

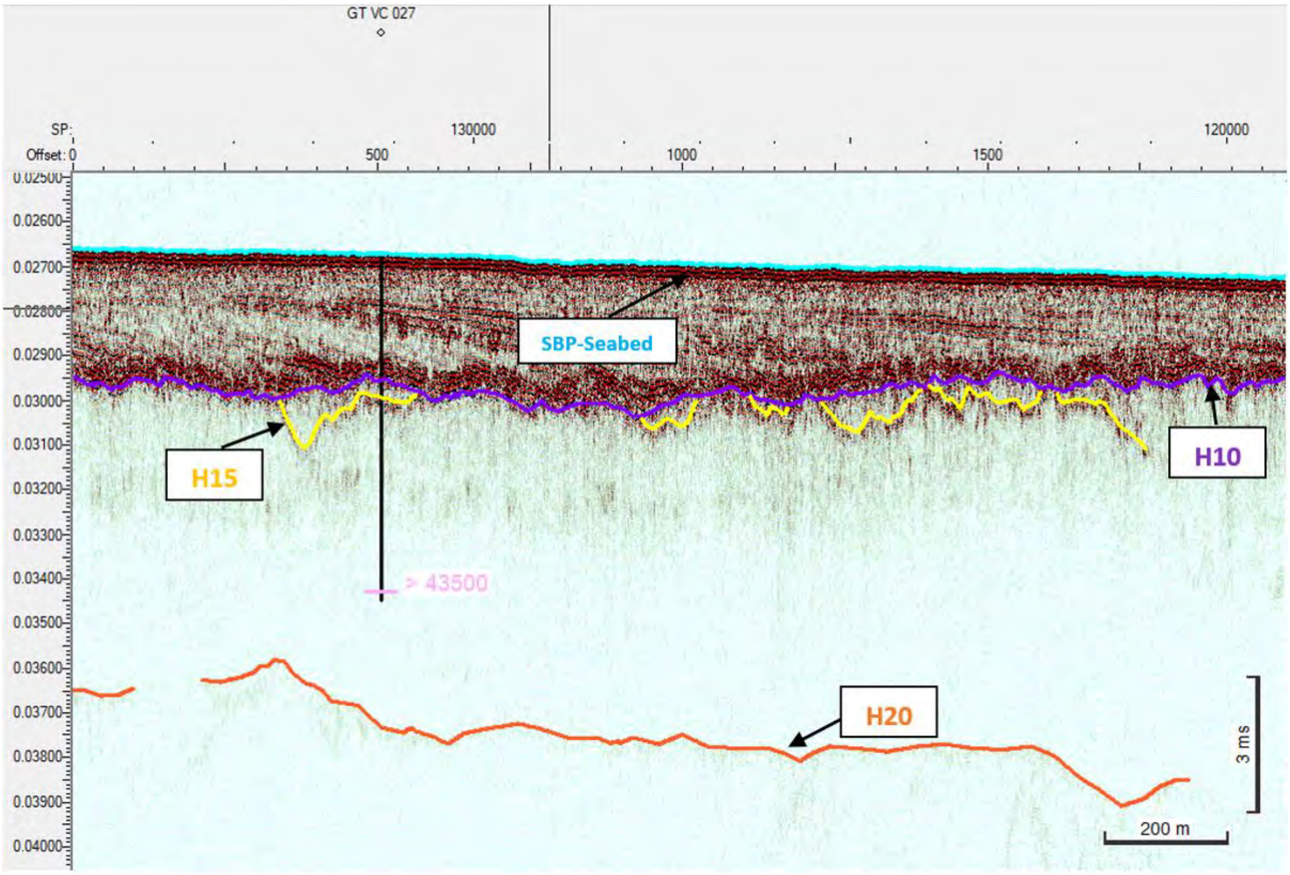


Figure 137: C14 result on SBP profile at VC_027

Figure 138 shows C14 results for VC033 and VC034. Ages of 8,090 ± 30 BP, and 8,900 ± 30 BP, for VC033 and VC034 have been measured respectively. VC034 Is observed above the interpreted base of post glacial sediments (H05) and the age correlates correctly. VC_034 is approximately 0.5m deeper than the interpreted base of post glacial and lies within a shallow channel of interpreted late glacial material. Given that the sample at VC_034 is dated as older, but it clearly within a more recent depositional stage, places doubt on the accuracy of the sample at VC_034. It is possible that the proximity of the post glacial boundary to the sample taken at VC_033 means some material for post glacial sediments may have interfered with the results. Both results are quite close in age and are within <1 m vertically of each other.

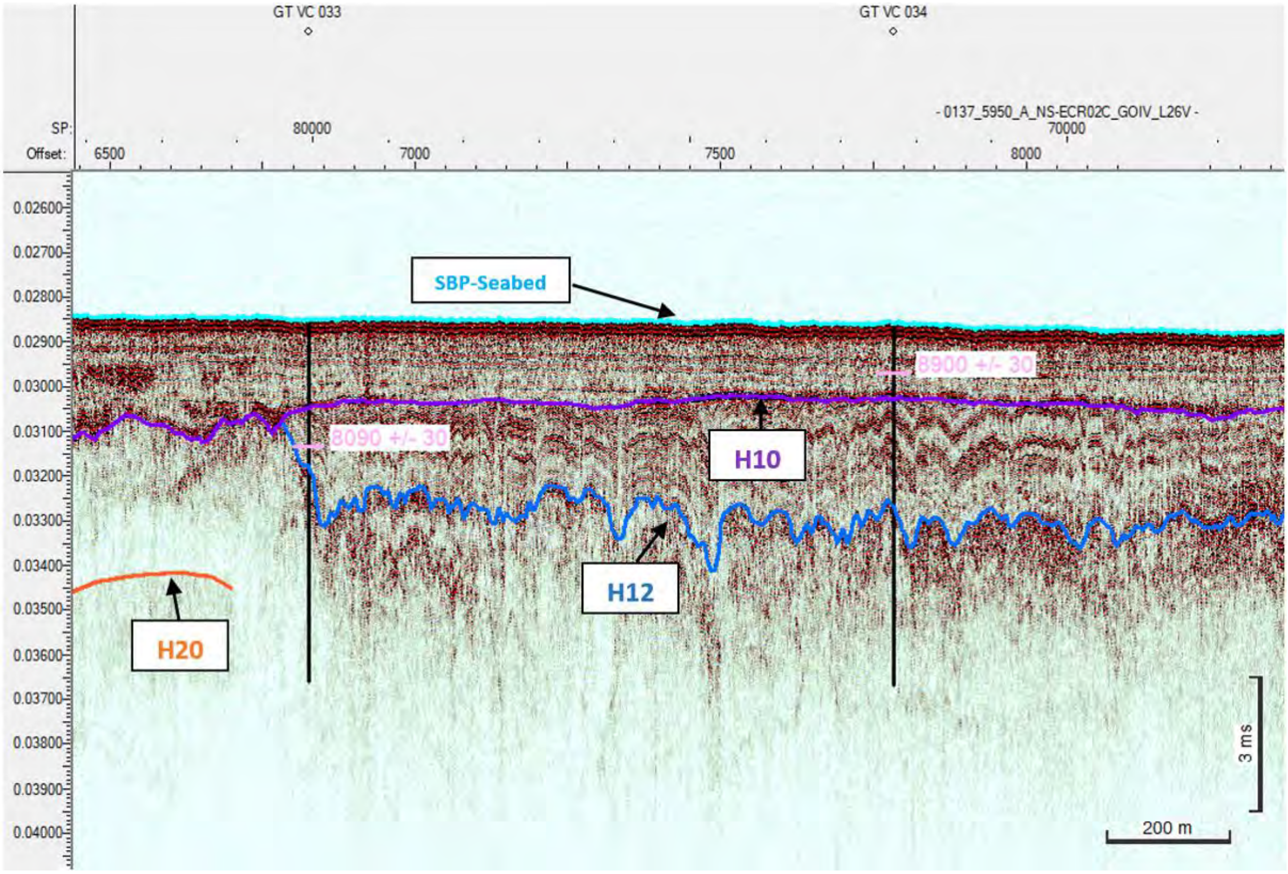


Figure 138: C14 result on SBP profile at VC_033 and VC_034

Figure 139 shows the C14 result for VC_038. The sample lies within 0.5 m of the interface between post glacial and late glacial to glacial. There is uncertainty beneath the interpreted H10 lay and no clear horizons are observed to indicate the presence of late glacial sediments. The VC data has interpreted post glacial sediment to the maximum depth of the core, which conflicts with the SBP interpretation and the C14 result. It appears that the H10 horizon is more to the base of the post glacial, and that some either late glacial or glacial inclusions at the basal interface have led to an older age being derived than expected in the post glacial unit.

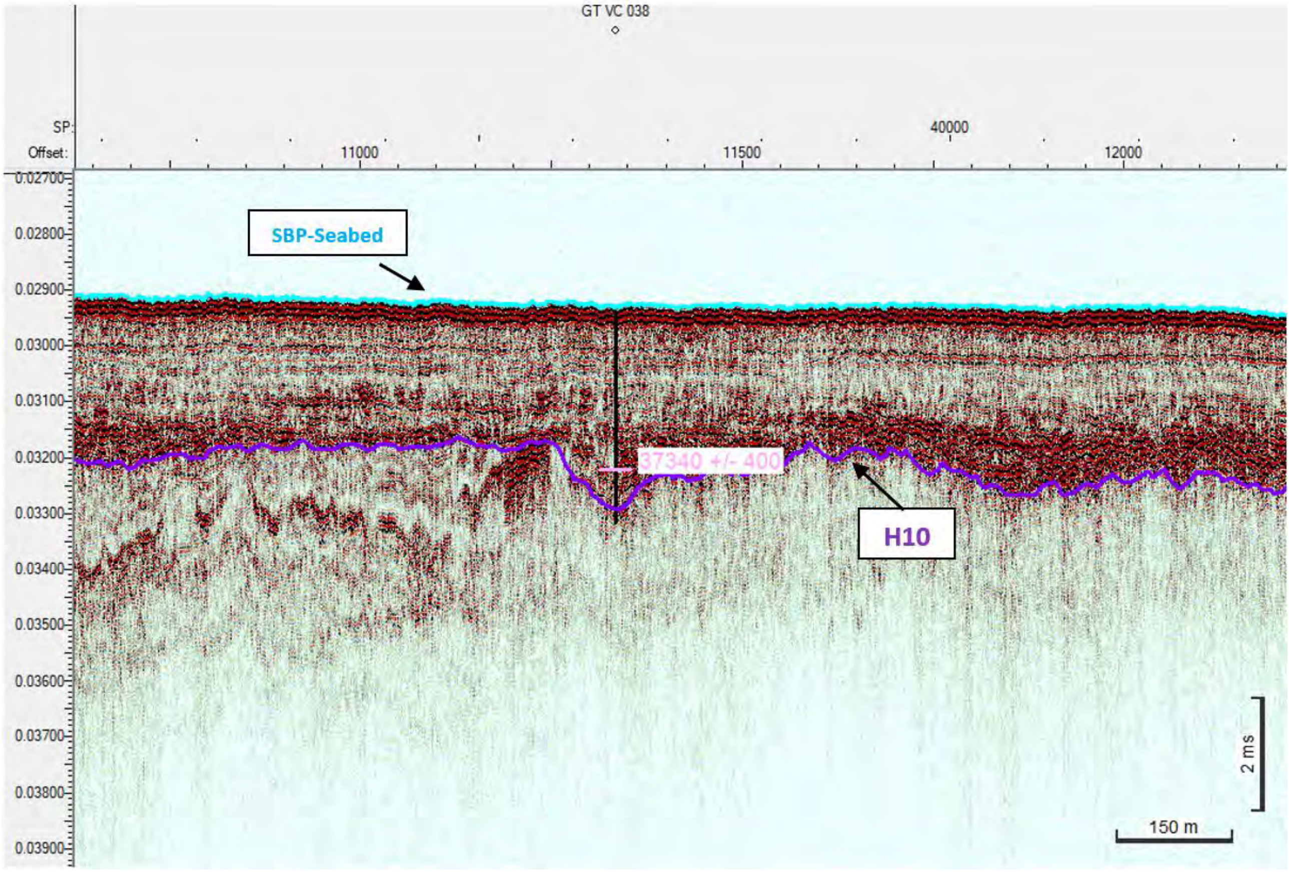


Figure 139: C14 result on SBP profile at VC_038

Figure 139 shows the C14 result for VC_056a. This sample lies at the interface between the interpreted post glacial sediments and the underlying late glacial/glacial. The age is recorded is 8,300 ± 30 BP which lies within the expected post glacial age range. It may be possible that the post glacial unit extends deeper in this area, but it is not clear on SBP data.

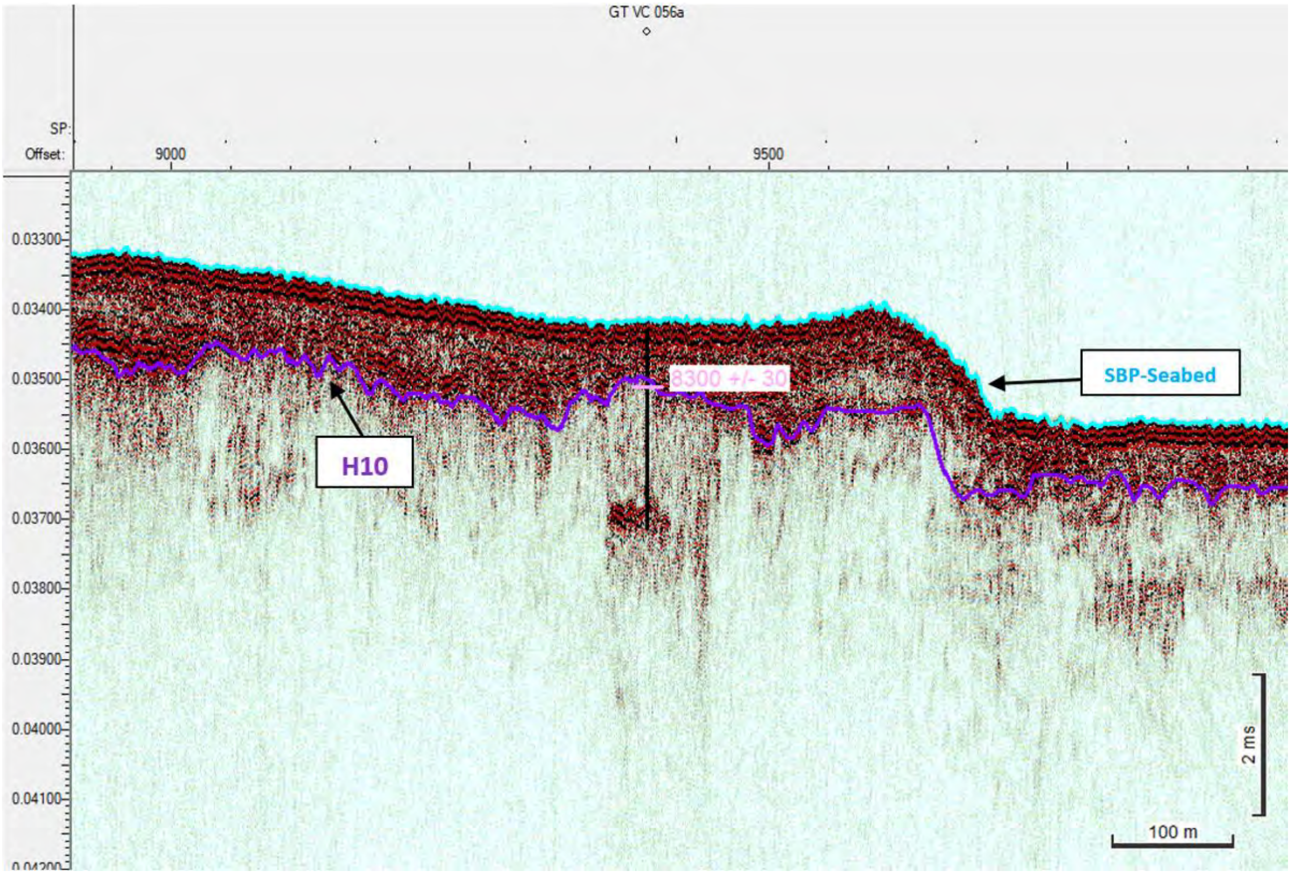


Figure 140: C14 result on SBP profile at VC_056a

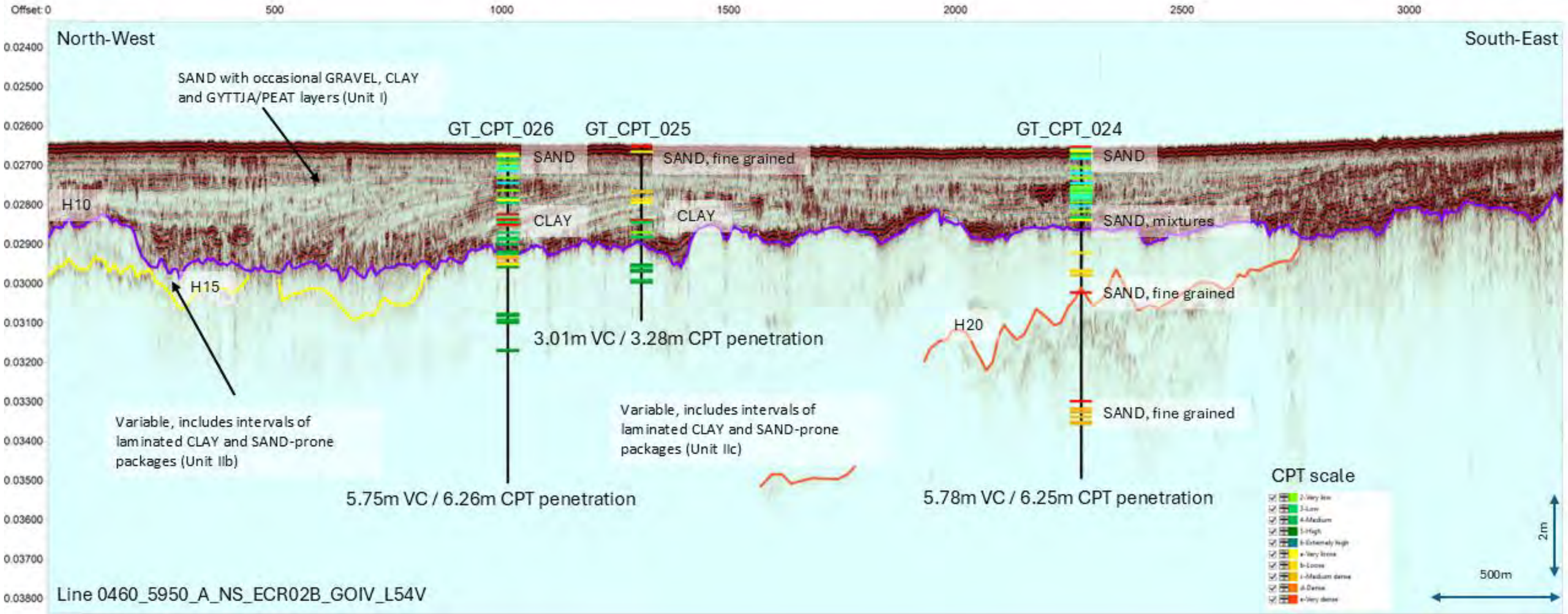


Figure 141: Seismic example displaying Unit II channels

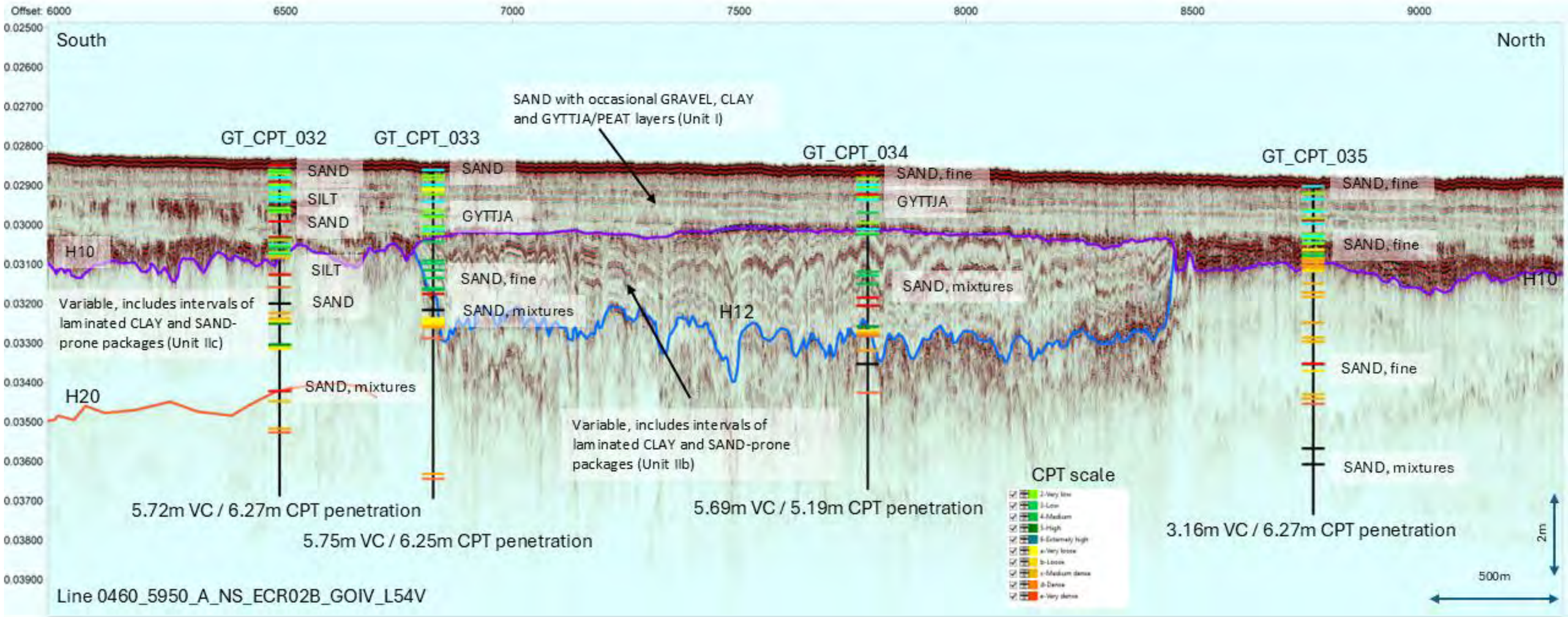


Figure 142: Seismic example showing Unit II channels with clear bedding

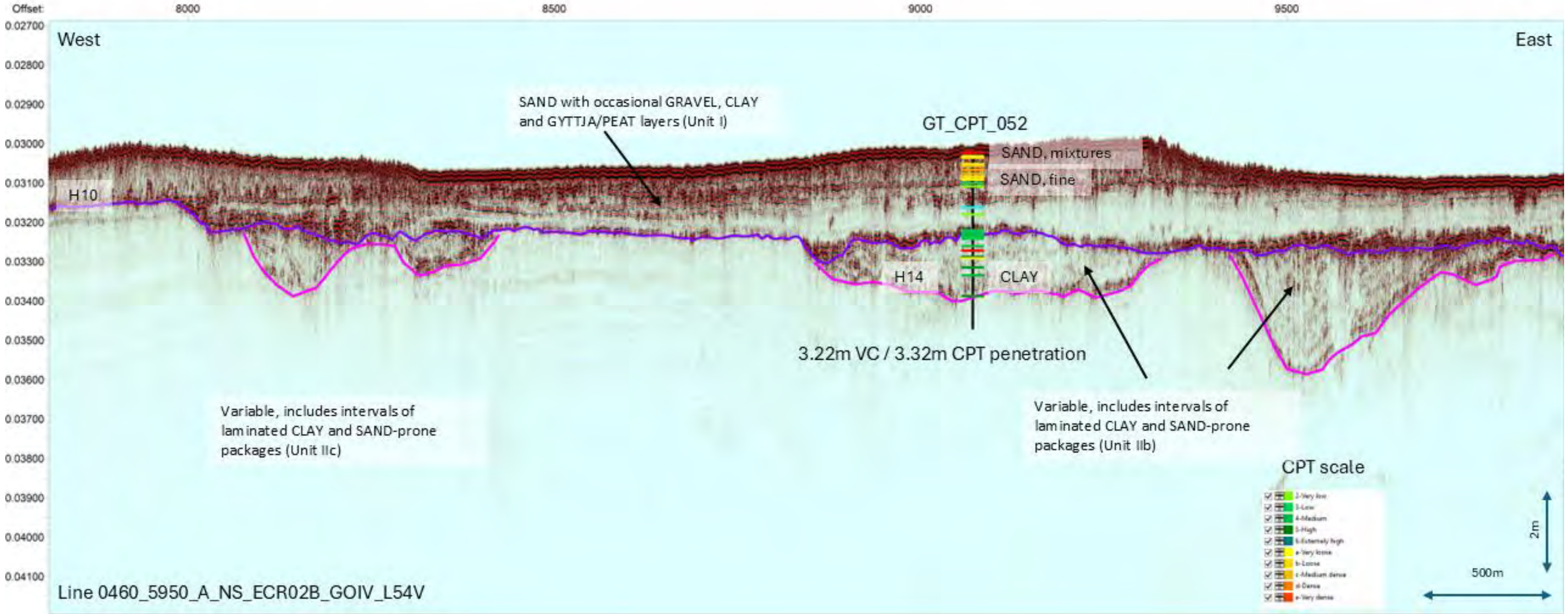


Figure 143: Seismic example showing Unit II channels with chaotic bedding

Unit III, Glacial deposits

Unit III deposits occur along the route corridor, sub-cropping at the seabed where Units I and II are thin to absent (between KP 33.600 and KP 33.900). Unit III is interpreted to be a till laid down in association with the last major ice advance over the area, approximately 22,000 years ago. The till forms a relatively thick blanket, to deeper than the depth of interest for cable burying. The base of the till/ top bedrock is not imaged within the export route corridor.

Unit III is generally a glacial till which has been subjected to direct ice contact, though the unit contains other facies which may have been laid down in ice-marginal environments during oscillations of the ice front. The ice-contact facies may comprise a clay-prone diamicton which is likely to contain subordinate silt, sand, gravel, cobbles and boulders and will be overconsolidated. Consolidation levels may significantly vary over short distances. Seismically, the ice contact facies are generally acoustically structureless.

9 NS_ECR2 ROUTE ANALYSIS

A summarized route analysis along the NS_ECR2 cable route, subdivided in 3 km sections, is displayed in Table 79, below. SBP images with geomodelling, in 3 km sections, are presented in Appendix E. The route analysis is based on correlation between geotechnical and geophysical data.

Table 79: NS_ECR2 Overview per 3 km interval

From KP	To KP	Seabed Geology	Seabed Features	Seabed Topography	Shallow Geology	Environmental and geotechnical	
0	3	Predominantly a mix of SAND and Muddy SAND until KP 1.750, with an isolated area of Gravel and Coarse Sand to the north of the survey corridor near KP 1.250. From KP 1.750 to KP 2.000, the geology is predominantly SAND with an isolated area of Gravel and Coarse SAND around the RPL. From KP 2.000 until KP 3.000, the geology is a mix of Muddy SAND, SAND and Gravel and Coarse Sand.	Ripples and mega ripples dominate the seabed until KP 0.800. From KP 0.800 to KP 1.750, the seabed predominantly consists of sediment waveforms or is featureless. From KP 1.750 to KP 3.000, most of the survey corridor is dominated by large ripples, ripples and areas of mottled seabed.	The nearshore area is characterised by steep slopes. Seabed slope from KP 0.000 to KP 0.500 drops by 4-5 metres. The slope from KP 0.500 to KP 3.000 decreases by 5.5 metres.	H10 present	Geotechnical	None
						Grab samples	NS-3_001_03 NS-3_002_03 NS-3_003_03 NS-3_004_03 NS-3_005_03 NS-3_006_03 NS-ECR-02-01
3	6	Predominantly SAND with larger patches of Gravel and Coarse SAND near the RPL at KP 3.500 and between KP 3.800 and KP 5.000. Between KP 5.400 and KP 5.750, there is an isolated area of Till approximately 40 m NE of the RPL. Further north, adjacent to this Till area, there are additional areas of Gravel and Coarse SAND, as well as Muddy SAND.	The seabed in this KP range is primarily featureless with the exception of boulders. Smaller patches of possible biostructures and mottled seabed are occasionally observed. From KP 5.400 to KP 5.750 a high density boulder field is found approximately 40 m NE of the RPL. Between KP 5.250 to KP 5.750, areas of large ripples, ripples and possible erosional bedform features are also observed to the north of the RPL.	From KP 3.000 to KP 6.000 the seabed slope decreases by 7.5 metres.	H10 present	Geotechnical	VC022 CPT022
						Grab samples	NS-ECR-02-02 NS-ECR-02-03 NS-ECR-02-04

From KP	To KP	Seabed Geology	Seabed Features	Seabed Topography	Shallow Geology	Environmental and geotechnical	
6	9	SAND covers this part of the corridor entirely, with the exception of three smaller patches of Gravel and Coarse SAND away from the RPL from.	From KP 6.000 to KP 6.250, the seabed is featureless, with the exception of boulders. From KP 6.250 to KP 9.000, trawl marks are present throughout the survey corridor.	Seabed slope from KP 6.000 to KP 9.000 slope gradually decreases by 2.2 metres.	H10 and H20 present	Geotechnical	VC023 and CPT023
						Grab samples	NS-ECR-02-05 NS-ECR-02-06 NS-ECR-02-07
9	12	Predominantly SAND with occasional larger patches of Muddy SAND located to either side of the RPL from KP 10.500 to KP 12.000.	From KP 9.000 to KP 10.000, trawl marks are present throughout the survey corridor. Between KP 10.000 and KP 11.400, the seabed is largely featureless, with the exception of boulders and patches of lower reflectivity that are seen on the SSS data. Trawl marks and patches of lower reflectivity are again present from KP 11.400 to KP 12.000.	From KP 9.000 to KP 10.500 the seabed flattens. The seabed slope then gradually decreases by 0.5 metres to from KP 10.500 to KP 12.000.	H10 and H20 present	Geotechnical	VC024 VC025 VC026 VC027 CPT024 CPT025 CPT026 CPT027
						Grab samples	NS-ECR-02-08 NS-ECR-02-09 NS-ECR-02-10
12	15	Predominantly SAND with occasional larger patches of Muddy SAND located to either side of the RPL.	Trawl marks cover the majoirty of the survey corridor. Areas of lower reflectivity as seen in the SSS data are present away from	From KP 12.000 to KP 15.000 the seabed forms a gentle slope. The slope gradually decreases by 0.6 metres.	H10, H12 and H20 present	Geotechnical	VC028 VC029 VC030 CPT028 CPT029 CPT030

From KP	To KP	Seabed Geology	Seabed Features	Seabed Topography	Shallow Geology	Environmental and geotechnical	
			the RPL. The seabed is featureless, with the exception of boulders between KP 12.700 and KP 13.550 on the RPL, and from KP 12.700 to KP 15.000 on the western side of corridor.			Grab samples	NS-ECR-02-11 NS-ECR-02-12 NS-ECR-02-13
15	18	Predominantly SAND with occasional smaller patches of Muddy SAND located to either side of the RPL.	Trawl marks cover the majority of the survey corridor. Areas of lower reflectivity as seen in the SSS data are present away from the RPL. The seabed is featureless, with the exception of boulders between KP 16.400 and KP 17.200 on the RPL, and from KP 15.000 to KP 18.000 on the western side of corridor.	Seadbed slope from KP 15.000 to KP 18.000 gradually decreases by 0.5 metres.	H10, H12 and H15 present	Geotechnical	VC031 VC032 VC033 CPT031 CPT032 CPT033
						Grab samples	NS-ECR-02-14 NS-ECR-02-15 NS-ECR-02-16
18	21	Predominantly SAND with larger patches of Muddy SAND predominantly to the east of the RPL. From KP 19.800 to 20.500, Quaternary CLAY and SILT is present around the RPL.	Trawl marks cover the majority of the survey corridor. Areas of featureless seabed, with the exception of boulders, are also present on the western side of the corridor.	From KP 18.000 to KP 21.000 the seabed slope gradually decreases by 0.4 metres.	H10 and H12 present	Geotechnical	VC034 VC035 VC036 CPT034 CPT035 CPT036
						Grab samples	NS-ECR-02-17 NS-ECR-02-18 NS-ECR-02-19

From KP	To KP	Seabed Geology	Seabed Features	Seabed Topography	Shallow Geology	Environmental and geotechnical	
21	24	Predominantly SAND with larger patches of Muddy SAND. Two patches of Quaternary CLAY and SILT are present between KP 21.000 to KP 22.000. Gravel and Coarse SAND is found in one area to the west of RPL between KP 23.400 and KP 24.000.	Trawl marks cover the majority of the corridor. There are also isolated areas of featureless seabed, with the exception of boulders, patches of lower reflectivity on the SSS data and areas of erosional bedforms between KP 21.400 and KP 22.250 and KP 23.400 and KP 24.000.	From KP 21.000 to KP 24.000 the seabed forms a gentle slope. The slope gradually decreases by 0.6 metres.	H10 present	Geotechnical	VC037 VC038 VC039 VC040 CPT037 CPT038 CPT039 CPT040
						Grab samples	NS-ECR-02-20 NS-ECR-02-21 NS-ECR-02-22
24	27	Predominantly SAND with larger patches of Muddy SAND until KP 25.250. From KP 25.250 to KP 27.000, the eastern side of the corridor is largely dominated by TILL and Gravel and Coarse SAND, whilst the western side of the corridor	Between KP 24.000 and KP 25.200, the seabed is either featureless, with the exception of boulders, or trawl marks are observed. From KP 25.250 to KP 27.000, the eastern side of the corridor is dominated by ripples, erosional bedforms	The seabed slope from KP 24.000 to KP 25.250 gradually decreases by 1.7 metres, followed by elevations (ridges) up to 1 metre high. From KP 25.250 to KP 27.000 the seabed flattens.	H10 present	Geotechnical	VC041 VC042 VC043 VC044a VC045 CPT041 CPT042 CPT043 CPT044 CPT045

From KP	To KP	Seabed Geology	Seabed Features	Seabed Topography	Shallow Geology	Environmental and geotechnical	
		is predominantly SAND. Some patches of Quaternary CLAY and SILT are also present between KP 26.400 and KP 27.000.	and intermediate and high density boulder fields, whilst the western side continues to be predominantly featureless or trawl marks are observed.			Grab samples	NS-ECR-02-23 NS-ECR-02-24 NS-ECR-02-25
27	30	Predominantly SAND with large linear patterned patches of Quaternary CLAY and SILT.	From KP 27.000 to KP 28.200, the seabed contains trawl marks and isolated patches of lower reflectivity from the SSS data. From KP 28.200 to KP 30.000, the seabed is either featureless, with the exception of boulders, or patches of lower reflectivity from the SSS data are observed.	From KP 27.000 to KP 29.000 the seabed forms a gentle slope. The slope gradually decreases by 0.2 metres. The slope from KP 29.000 to KP 30.000 increases up by 0.3 metres.	H10 present	Geotechnical	VC045 VC046a VC047 CPT045 CPT046 CPT047

From KP	To KP	Seabed Geology	Seabed Features	Seabed Topography	Shallow Geology	Environmental and geotechnical	
						Grab samples	NS-ECR-02-26 NS-ECR-02-27 NS-ECR-02-28
30	33	Predominantly SAND with large linear patterned patches of Quaternary CLAY and SILT from KP 30.000 to KP 30.500. From KP 30.500 to KP 31.900, there are additional patches of Muddy SAND as well. From KP 31.900 to KP 33.000, the RPL is largely dominated by Gravel and Coarse SAND, with SAND and patches of Muddy SAND and Quaternary CLAY and SILT throughout the corridor.	From KP 30.000 to KP 31.900, the seabed is either featureless, with the exception of boulders, or patches of lower reflectivity from the SSS data are observed. Between KP 31.900 and KP 33.000, ripples are also additionally present along the RPL and to the north of the RPL.	The slope from KP 30.000 to KP 31.000 increases up by 0.3 metres. From KP 31.000 to 33.000 the slope gradually decreases by 0.4 metres with elevations (ridges) up to 1 metre in height.	H10 present	Geotechnical	VC048 VC049 VC050 VC051a VC052 CPT048 CPT049 CPT050 CPT051 CPT052a
						Grab samples	NS-ECR-02-29 NS-ECR-02-30 NS-ECR-02-31

From KP	To KP	Seabed Geology	Seabed Features	Seabed Topography	Shallow Geology	Environmental and geotechnical	
33	36	From KP 33.000 to KP 34.200, the RPL largely contains Gravel and Coarse SAND. However the rest of the corridor in this section is largely SAND with isolated patches of Muddy SAND. From KP 34.200 to KP 36.000, the RPL is mainly SAND with large patches of Gravel and Coarse SAND and smaller patches of Muddy SAND in the corridor.	The seabed in this region is either featureless, with the exception of boulders, or is covered by ripples. There are also isolated patches of lower reflectivity as seen on the SSS data, mainly away from the RPL. Erosional bedforms are observed just to the south of the RPL between KP 34.800 and KP 35.800.	The seabed slope from KP 33.000 to KP 36.000 gradually decreases by 2 metres with one isolated peak of 0.5 m at KP 34.000.	H10 present	Geotechnical	VC053 VC054 VC055 CPT053 CPT054 CPT055
						Grab samples	NS-ECR-02-32 NS-ECR-02-33 NS-ECR-02-34
36	39	From KP 36.000 to KP 36.800, the RPL largely contains Gravel and Coarse SAND, with some SAND elsewhere in the corridor. From KP 36.800 to 37.4000, the geology is primarily SAND with isolated small patches of Quaternary CLAY and SILT and Muddy SAND, as well as Gravel and Coarse SAND to the south of the corridor. KP 37.400 to KP 39.000 is predominantly SAND the some patches of Muddy SAND and large patches of Gravel and Coarse SAND to the south of the corridor.	Between KP 36.000 and KP 36.800, ripples largely cover the RPL, with areas of featureless seabed additionally present away from the RPL. Between KP 36.800 and KP 38.000, the seabed along the RPL is largely featureless with the exception of boulders and patches of lower reflectivity as seen on the SSS data, with ripples present to the south of the RPL. From KP 38.000 to 39.000, the seabed is largely featureless, with the exception of boulders and ripples are present in the southern half of the corridor.	The seabed slope from KP 36.000 to KP 36.750 gradually decreases by 0.8 metres. At KP 36.750 there is sharp 1 metre decrease in slope. From KP 36.750 to KP 39.000, the seabed flattens.	H10 present	Geotechnical	VC056a VC57 VC058 VC059 CPT056 CPT057 CPT058 CPT059
						Grab samples	NS-ECR-02-35 NS-ECR-02-36 NS-ECR-02-37

<table>
<tr><th>From KP</th><th>To KP</th><th>Seabed Geology</th><th>Seabed Features</th><th>Seabed Topography</th><th>Shallow Geology</th><th colspan="2">Environmental and geotechnical</th></tr>
<tr><td rowspan="2">39</td><td rowspan="2">41.161</td><td rowspan="2">Predominantly Muddy SAND and SAND with isolated small patches of Gravel and Coarse SAND to the south of KP 39.000 and north part of the corridor from KP 41.100 to the end of the route.</td><td rowspan="2">The seabed is primarily featureless, with the exception of boulders and patches of lower reflectivity as seen on the SSS data. Ripples are observed approx. 480 m north of the RPL from KP 41.100 to the end of the route.</td><td rowspan="2">The seabed slope from KP 39.000 to KP 39.500 gradually decreases by 0.5 metres. From KP 39.500 to KP 40.250 the seabed flattens. The slope increases by 0.4 metres from KP 40.250 to KP 41.161.</td><td rowspan="2">H10 present</td><td>Geotechnical</td><td>VC060
VC061 CPT060
CPT061</td></tr>
<tr><td>Grab samples</td><td>NS-ECR-02-38
NS-ECR-02-39
NS-ECR-02-40</td></tr>
</table>

9.1 KP 0.000 – KP 3.000

No VCs or CPTs were acquired along ECR02 in this section. However, CPT021 and VC021 were acquired 132 m southwest of the ECR at approximately KP 2.7. Interpretation is based on geotechnical and geophysical data. Five Grab samples were acquired, all containing silty or clayey SAND.

Post glacial sediments are present which are bounded by H10. They are interpreted to comprise SAND. A 10 cm thick layer of GYTTJA is seen in both geotechnical logs at approximately 1.50 m below seabed. This thin layer has no acoustic response in the geophysical data. Carbon dating aged the Gyttja at 3,370 ± 30 years BP.

Unit I sediments (bounded by H10) are present throughout this section; although inshore of KP 1.000 it is not possible to identify the base of the unit as it is masked by the seabed multiple. Acoustically the unit is of a high amplitude, chaotic character. The unit thins from a maximum thickness of approximately 6 m at KP 1.0 shallowing to around 3 m at KP 2.3, and then undulates around 2 m in thickness towards the end of this section.

Unit III underlies Unit I throughout this section and is acoustically very quiet. Geotechnical logs show the unit to comprise SAND with a 10 cm thick CLAY layer at 2.70 m below seabed in VC/CPT021. This layer has no acoustic response in the geophysical data.

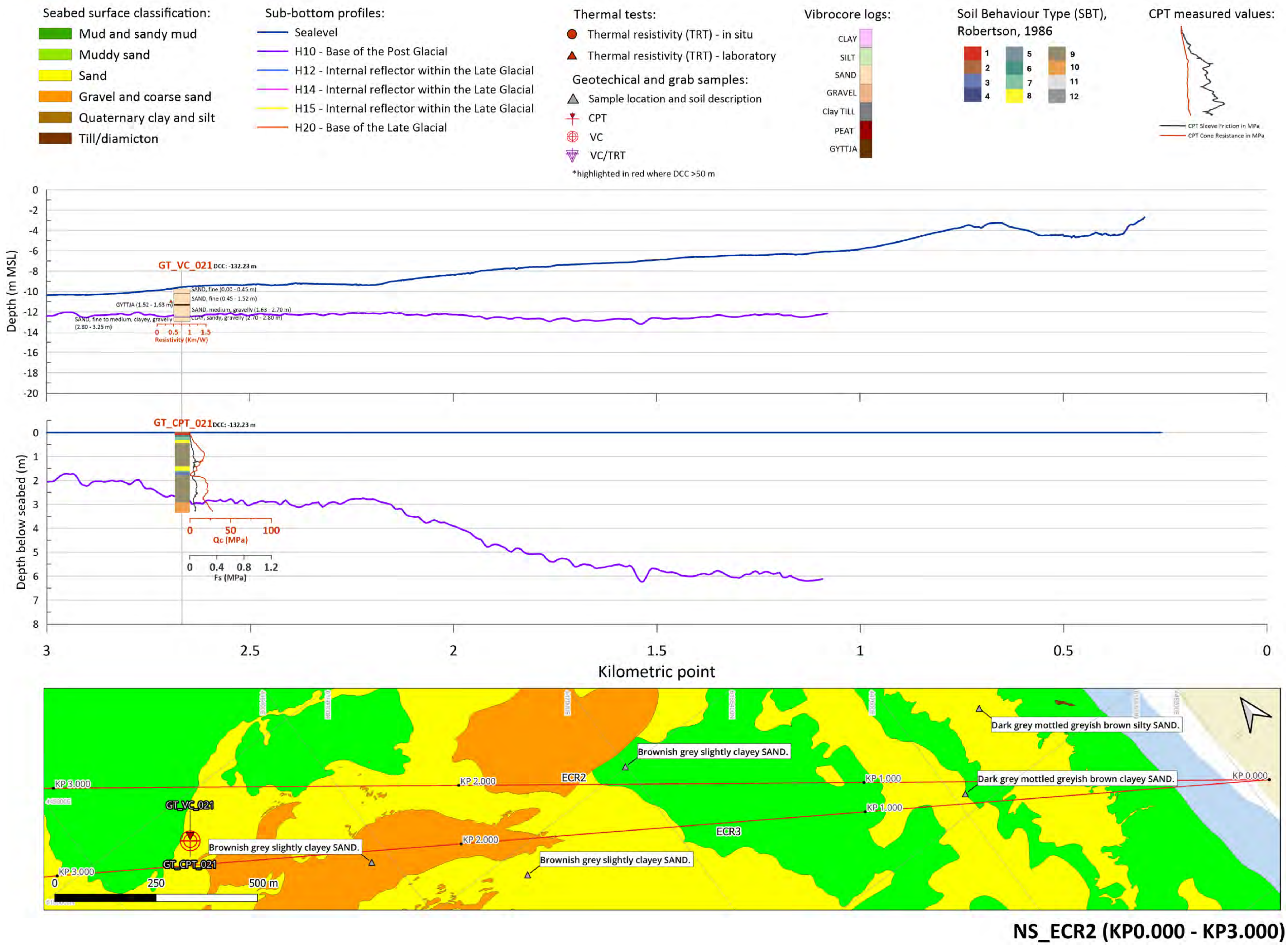


Figure 144: Integrated geotechnical panel KP 0.000 – KP 3.000

9.2 KP 3.000 – KP 6.000

One VC, one CPT and two grab samples were acquired in this section.

Unit I (bounded by H10) is present throughout the section. It varies in thickness between 1 and 2 m, but shoals locally to less than 1 m around KP 5.5. Acoustically it is low to moderate amplitude, with signs of parallel bedding dipping downwards to the northwest.

Geotechnical samples VC022, CPT022 and two grab samples were acquired, showing the sediments to comprise fine to coarse SAND, increasing from loose at seabed to dense at the base of the unit. CPT022 and VC022 show an approx. 60 cm thick layer of GRAVEL at the seabed. Gravel at seabed correlates with the seabed features interpretation at this location.

Unit II (bounded by H20) does not occur within this section.

Unit III underlies Unit I throughout this section and is acoustically very quiet. Geotechnical logs VC022 and CPT022 penetrated this unit and show the unit to comprise medium to coarse SAND with a GRAVEL. This layer has no acoustic response in the geophysical data.

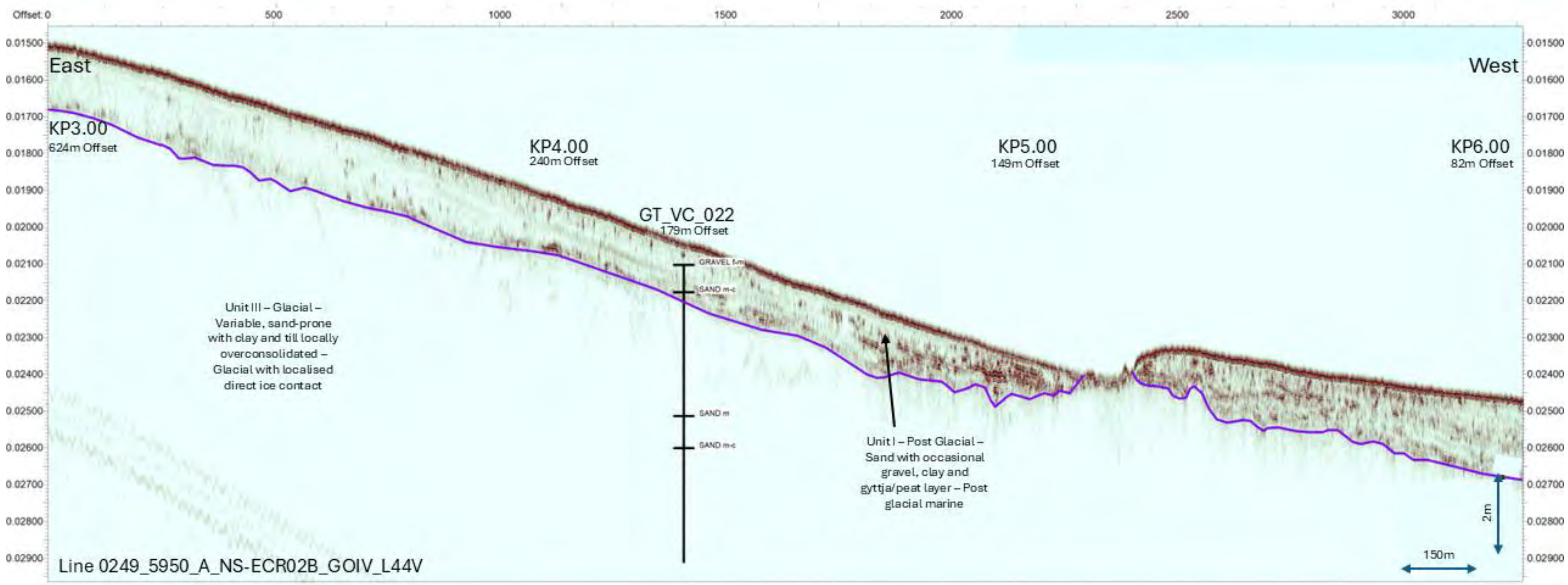


Figure 145: SBP and Geotech, KP 3.000 – KP 6.000

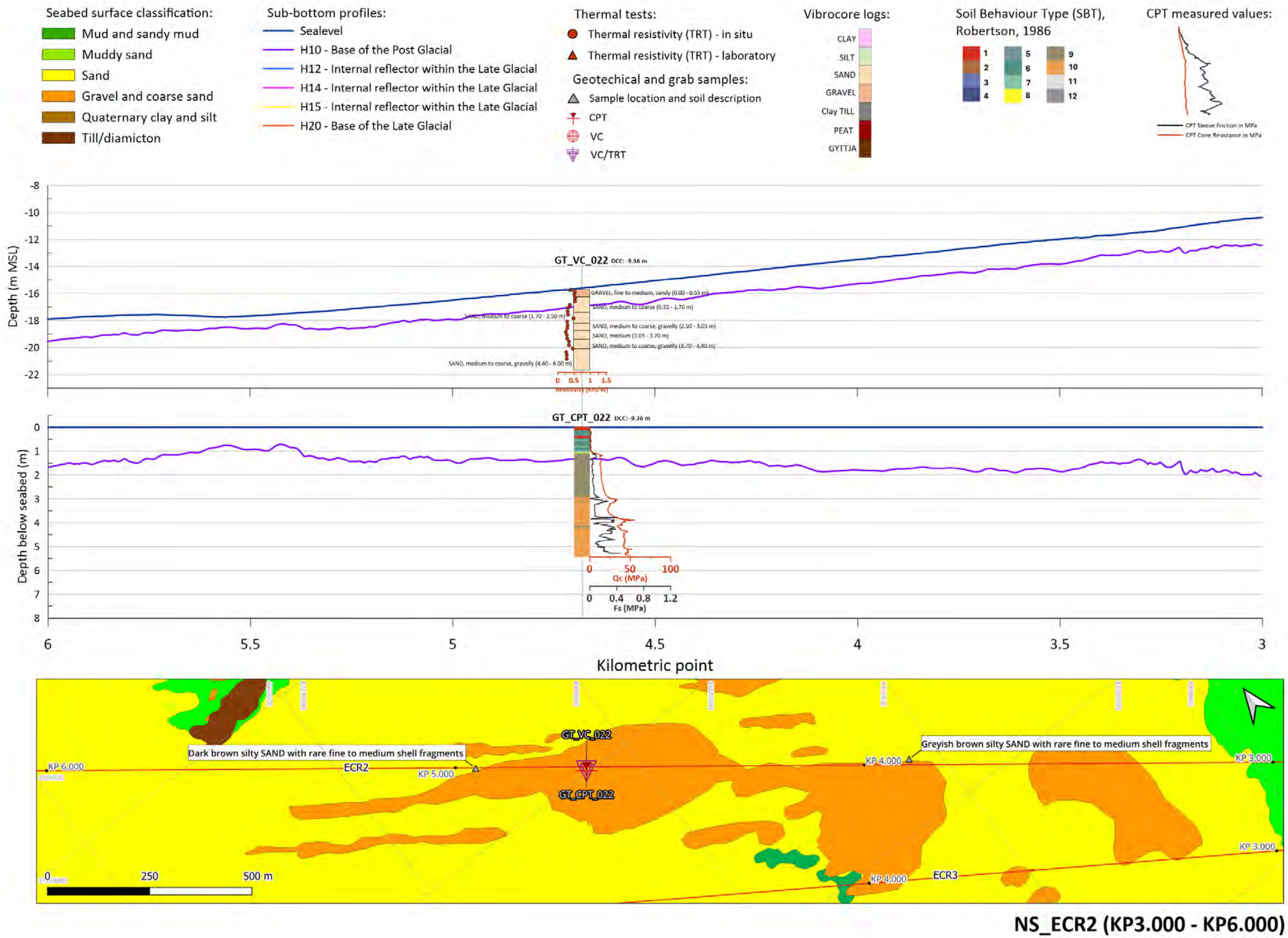


Figure 146: Integrated geotechnical panel KP 3.000 – KP 6.000

9.3 KP 6.000 – KP 9.000

One VC, one CPT and two grab samples were acquired in this section.

Unit I sediments (bounded by H10) are present throughout this section and is generally between 1.5 and 2.0 m thick. Acoustically it is low to moderate amplitude, with signs of parallel bedding.

Geotechnical samples VC023 and CPT023 penetrated this unit, showing the sediments comprise fine to medium silty SAND, increasing from very loose at seabed to loose at the base of the unit. There is a 20 cm layer of GYTTJA recorded at 1.2 m BSB. The CPTs also showed some cohesive sediments of extremely low to medium strength.

Unit II (bounded by H20) occurs as acoustically quiet sediments deposited in erosional channels or depressions. A small area of Unit II occurs from around KP 8.8.

No geotechnical samples penetrated this unit within this section, but samples further along the ECR show them to predominantly comprise high plasticity, medium to high shear strength CLAY.

Unit III underlies Unit I from KP 6.0 to KP 8.8.

Geotechnical samples VC023 and CPT023 penetrated this unit, showing the sediments to comprise a variety of different lithologies. Sediments vary from very dense, fine SAND to gravelly SAND.

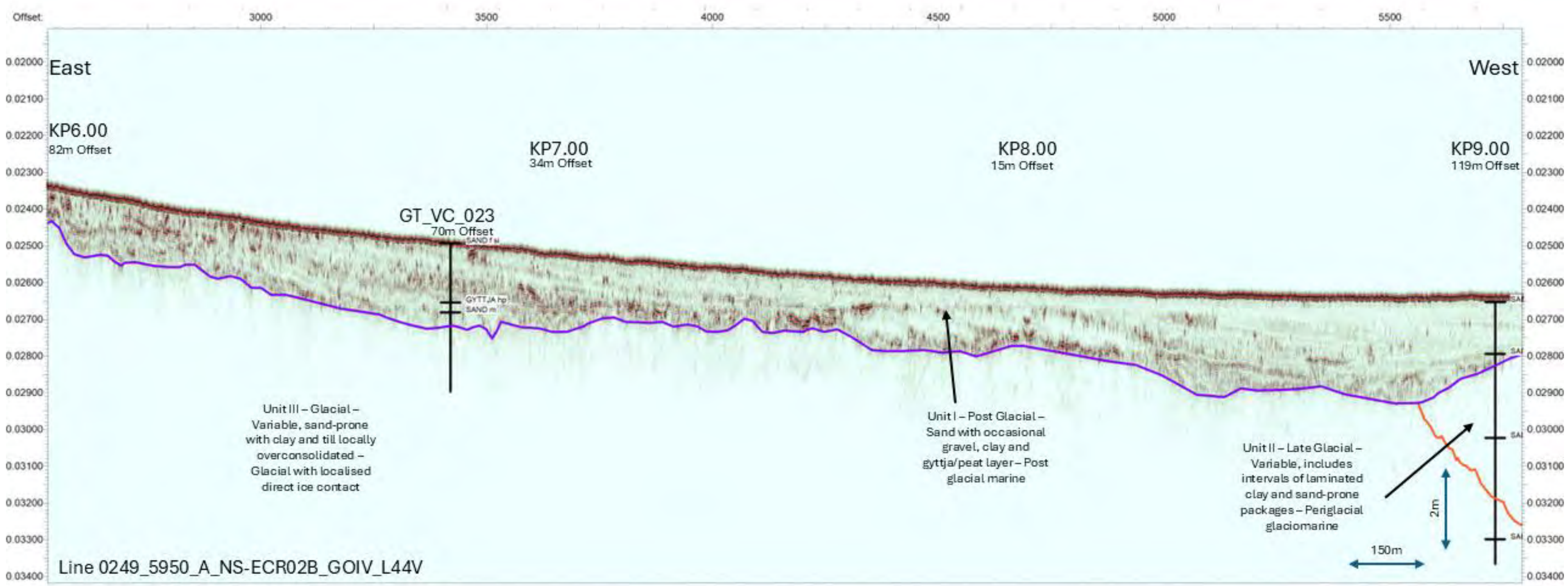


Figure 147: SBP and Geotech, KP 6.000 – KP 9.000

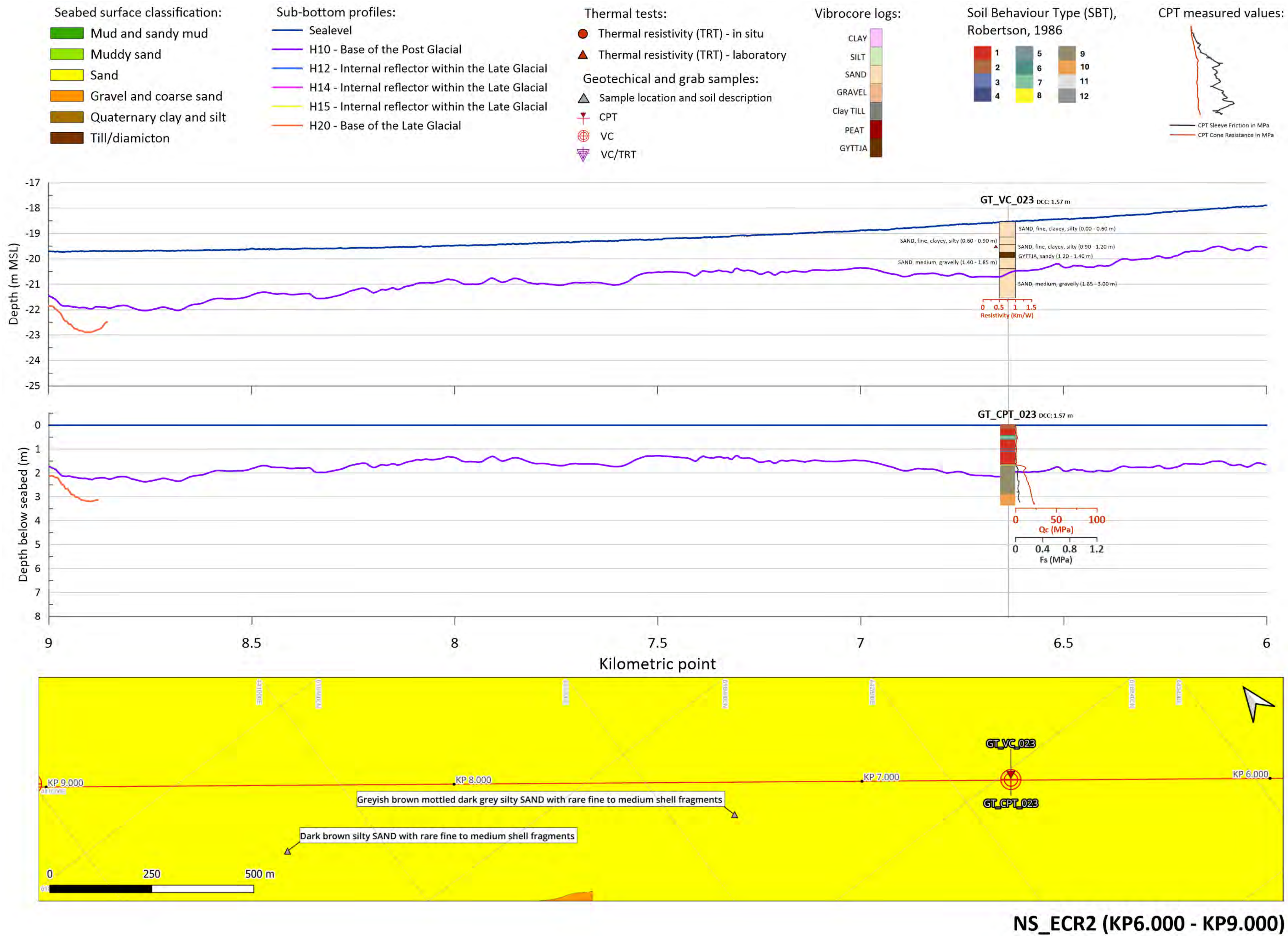


Figure 148: Integrated geotechnical panel KP 6.000 – KP 9.000

9.4 KP 9.000 – KP 12.000

Four VCs, four CPTs and three grab samples were acquired in this section.

Unit I sediments (bounded by H10) are present throughout this section. Acoustically it is low to moderate amplitude presenting a higher amplitude toward the base, with signs of parallel bedding. The unit is generally between 1 and 2 m thick but does reach a maximum of 3.0 m around KP11.

All the geotechnical samples (VC024, VC025, VC026 and VC027, CPT024, CPT025, CPT026 and CPT027 penetrated this unit, showing the sediments to comprise fine to medium clayey, silty SAND. VC06 has a thin layer of GYTTJA at 1.2 m BSB.

VC025 and CPT026 recorded sandy CLAY at the base of Unit I whereas VC027 and CPT027 recorded sandy CLAY at the top of Unit II. VC024 and CPT024 records SAND over its whole length with no distinction between Unita I, II and II. Base of Unit I (H10) does not correlate well with a distinct change in sediment within this section.

Unit II (bounded by H20) occurs as acoustically quiet sediments deposited in erosional channels or depressions. Unit II occurs from KP 8.8 to the end of this section.

Geotechnical samples VC024, VC025, VC026 and VC027, CPT024, CPT025, CPT026 and CPT027 penetrated this unit, showing the sediments comprising mainly CLAY, (other than VC/CPT024 which recorded SAND).

Unit III underlies Unit II over the length of the section and exhibits an acoustically transparent character. GT VC024 and CPT024 penetrate Unit III and recorded fine to medium silty SAND.

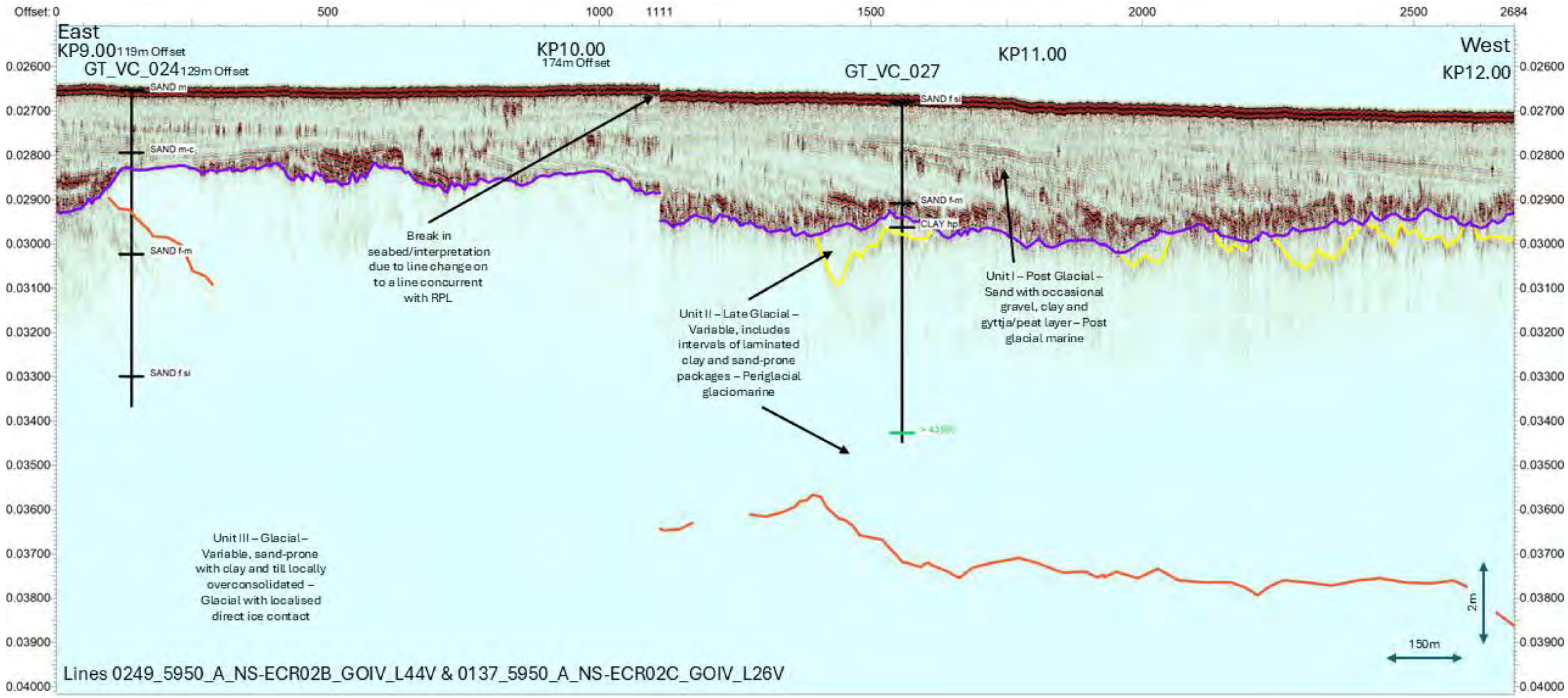


Figure 149: SBP and Geotech, KP 9.000 – KP 12.000

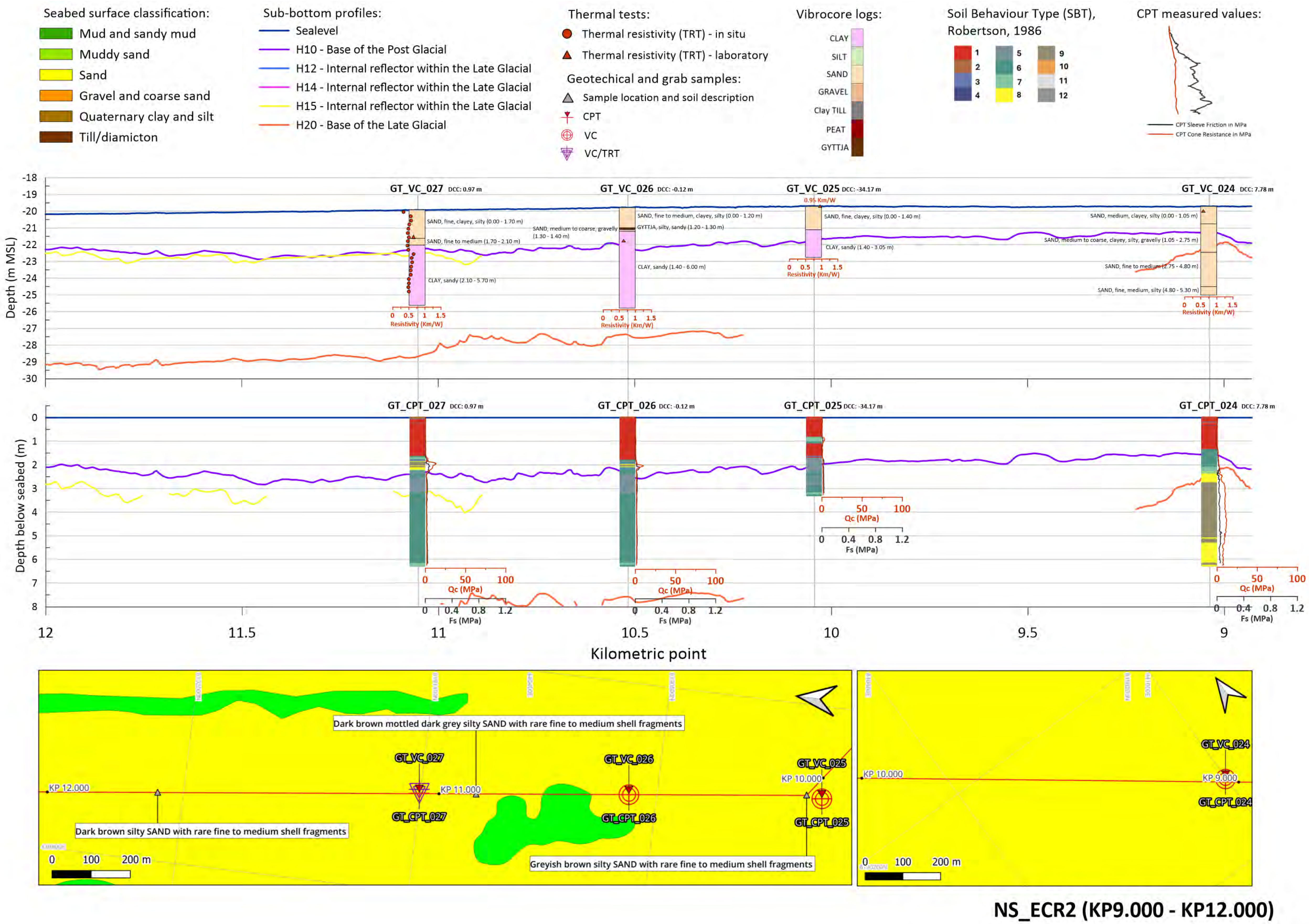


Figure 150: Integrated geotechnical panel KP 9.000 – KP 12.000

9.5 KP 12.000 – KP 15.000

Three VCs, three CPTs and two grab samples were acquired in this section.

Unit I sediments (bounded by H10) are present throughout this section and present as acoustically low to moderate amplitude presenting a higher amplitude toward the base, with signs of parallel bedding, particularly in the top section. The unit is generally around 2m thick but reaches approximately 3m around KP 13.2.

All the geotechnical samples (VC028, VC029, VC030, CPT028, CPT029 and CPT030) penetrated this unit, showing the sediments to comprise fine to medium SAND. A layer of GRAVEL is present at 1.3 m BSB in VC028 and a layer of GYTTJA is present in VC030 at 1.65 m BSB.

Unit IIa (bounded by H12) occurs as well bedded sediments deposited in erosional channels or depressions. It underlies Unit I at the start and end of this section and is not traceable/distinguishable on the geophysical data outside of these areas. Where H12 is present (at VC/CPT030) there is a transition from medium gravelly SAND to sandy CLAY at the boundary, whereas at VC/CPT028 no significant lithological change is recorded. VC/CPT029 only penetrated Unit I.

The boundary between units II and II is indistinct over most of this section and H20 has only been traceable to KP 12.4 along the RPL, however, is present in the eastern part of the survey corridor.

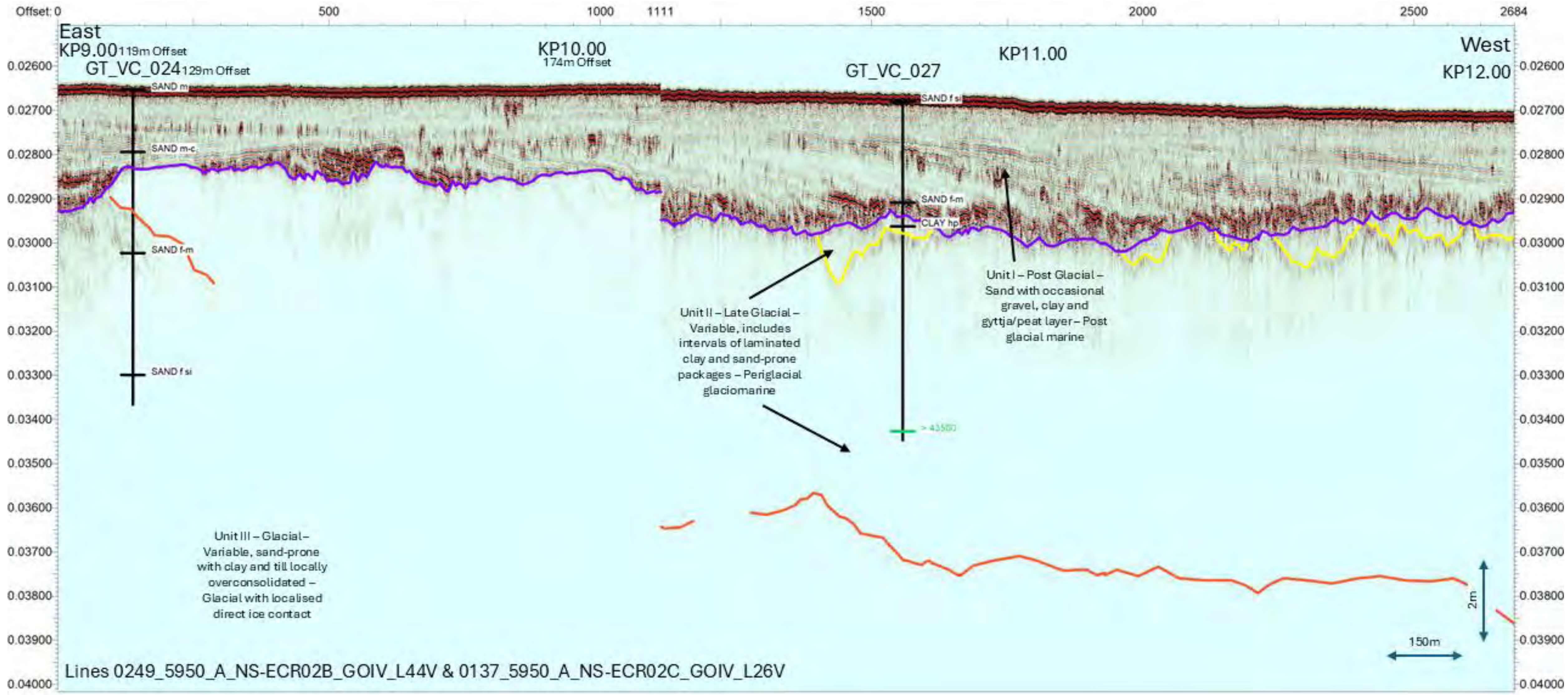


Figure 151: SBP and Geotech, KP 12.000 – KP 15.000

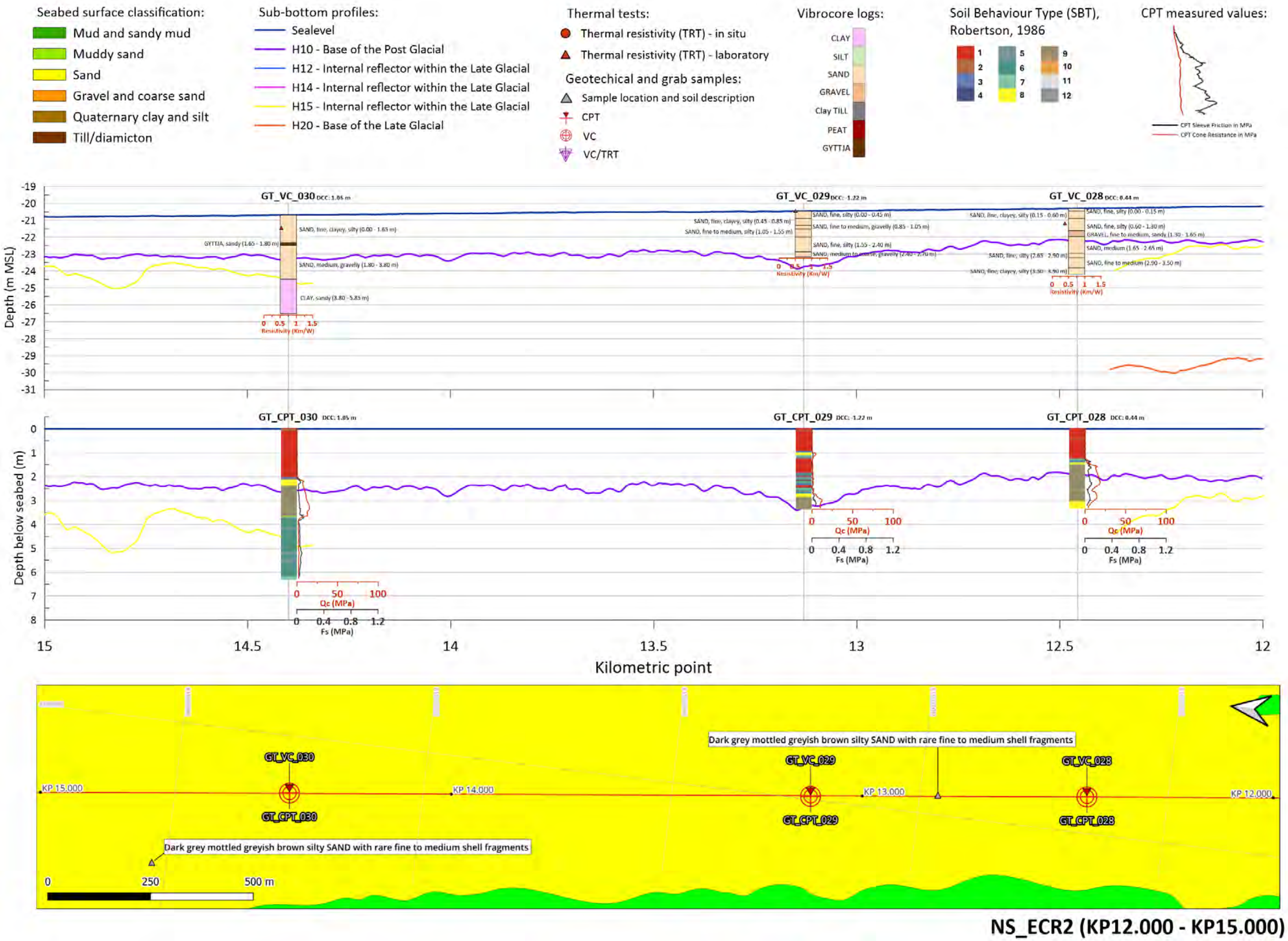


Figure 152: Integrated geotechnical panel KP 12.000 – KP 15.000

9.6 KP 15.000 – KP 18.000

Three VCs, three CPTs and three grab samples were acquired in this section.

Unit I sediments (bounded by H10) are present throughout this section. Acoustically it is low to moderate amplitude presenting a higher amplitude toward the base, with signs of parallel bedding, particularly in the top section. H10 is mostly around 2 m BSB in this section, however, shoals to around 1.5 m from KP 17.27 to KP 18.94.

All the geotechnical samples (VC031, VC032, VC033, CPT031, CPT032 and CPT033) penetrated this unit, showing the unit to comprise variable sediments; predominantly fine to coarse clayey, silty SAND but VC031 and VC033 with layers of GYTTJA (VC033 with a thick layer between 0.9 and 2.25 m BSB). The CPT's consistently record a sensitive fine-grained sediment perhaps highlighting some minor inconsistency between the geotechnical data.

Unit IIa (bounded by H12) occurs generally as well bedded sediments deposited in erosional channels or depressions. It underlies Unit I from around KP 17.27 (where H10 shoals). Unit IIb (bounded by H15) is present around KP 15. Outside of these two areas the subunits of Unit II are not distinguishable from the seismic data.

All the geotechnical samples (VC031, VC032, VC03, CPT031, CPT032 and CPT033) penetrated Unit II recording a predominantly SAND based sediment although in VC/CPT033 the GYTTJA layer extends into Unit II which has a thin layer of PEAT beneath this.

Unit III underlies Units I and II over the length of the section and exhibits an acoustically transparent character. It was sampled in CPT032 and comprises gravelly SAND.

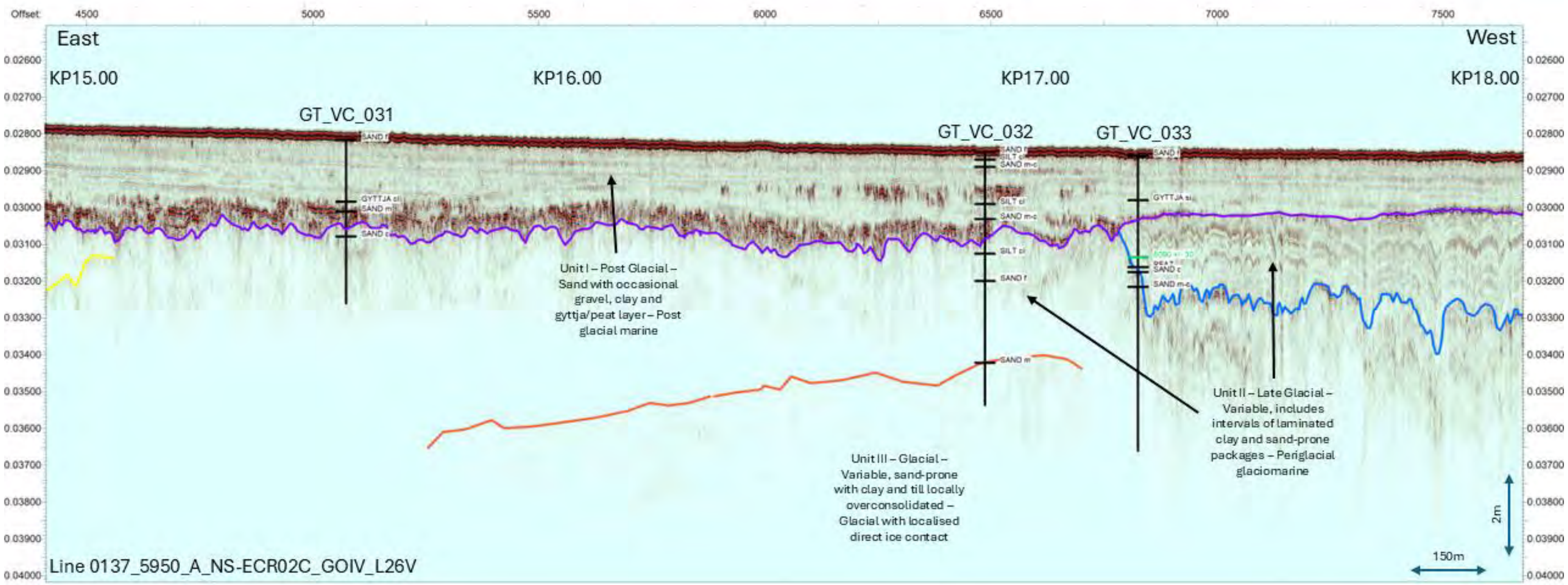


Figure 153: SBP and Geotech, KP 15.000 – KP 18.000

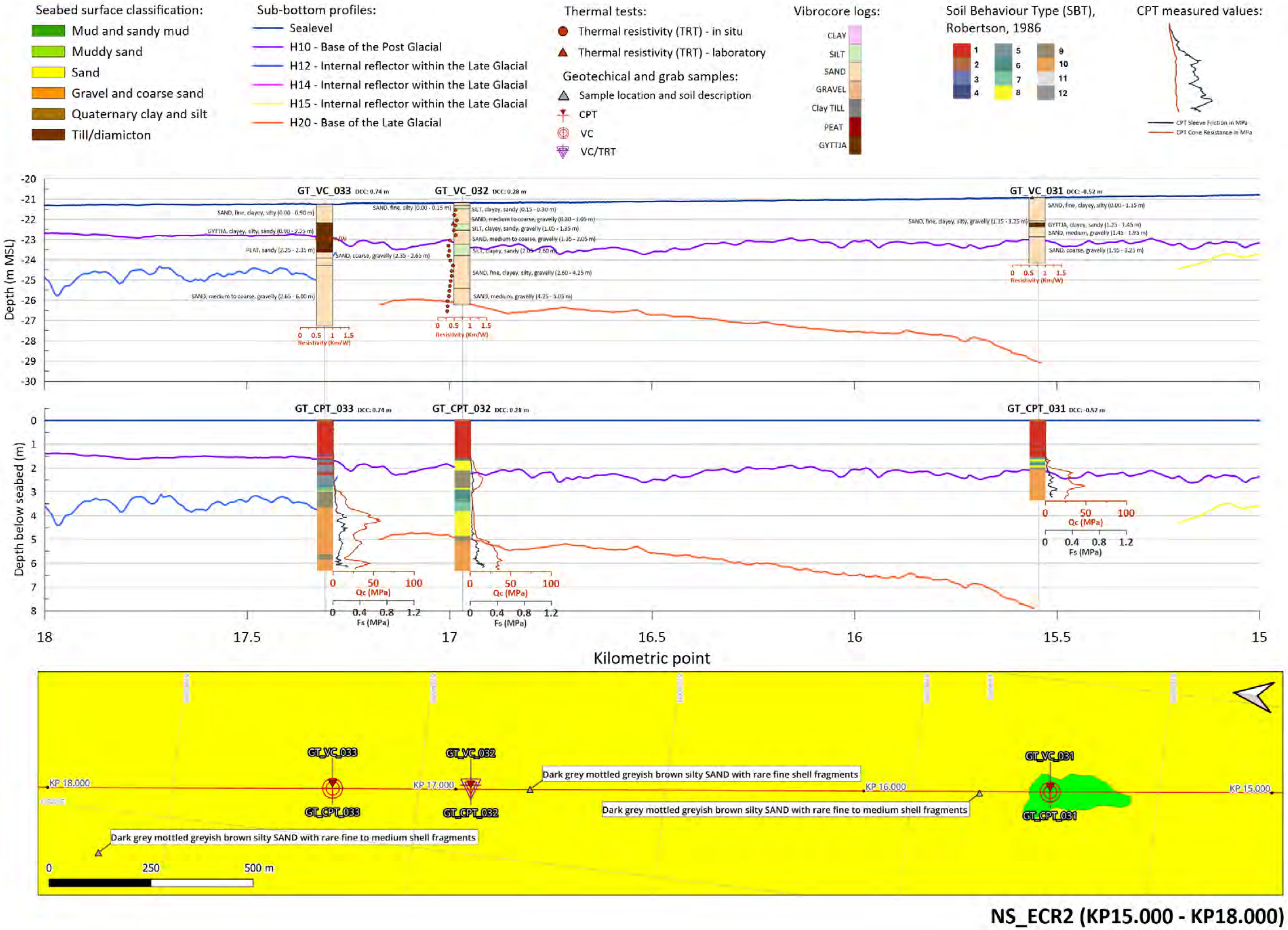


Figure 154: Integrated geotechnical panel KP 15.000 – KP 18.000

9.7 KP 18.000 – KP 21.000

Three VCs, three CPTs and two grab samples were acquired in this section.

Unit I sediments (bounded by H10) are present throughout all this section. Acoustically it is low to moderate amplitude presenting a higher amplitude toward the base, with signs of parallel bedding. Unit I is generally between 2 – 2.5 m thick but is shallower where it overlies Unit IIa from KP17.27 to KP18.96 where Unit IIa pinches out at the base of Unit I.

All the geotechnical samples (VC034, VC035, VC036, CPT034, CPT035 and CPT036) penetrated this unit, presenting various sediment types. VC034 recorded a fine to medium silty SAND overlying GYTTJA, VC035 recorded fine SAND with a layer of GRAVEL at 0.65m and VC036 recorded a predominantly sandy CLAY in Unit I.

Unit IIa (bounded by H12) occurs generally as well bedded sediments deposited in erosional channels or depressions. It underlies Unit I from around KP 18.96

Unit III underlies Unit I over the length of the section (where H12 is not mapped) and exhibits an acoustically transparent character. Some faint parallel bedding is seen on the SBP which possibly could be Unit II, but the data is indistinct and appears to underlie some of the more transparent sediments, so is more likely to be a subunit with Unit III.

Unit III was sampled in VC034, VC035, VC036, CPT034, CPT035 and CPT036 and comprises predominantly fine to coarse SAND and there is a GRAVEL layer present in Unit III in VC035. As per Unit I sediments VC036 presents as predominantly CLAY in Unit III.

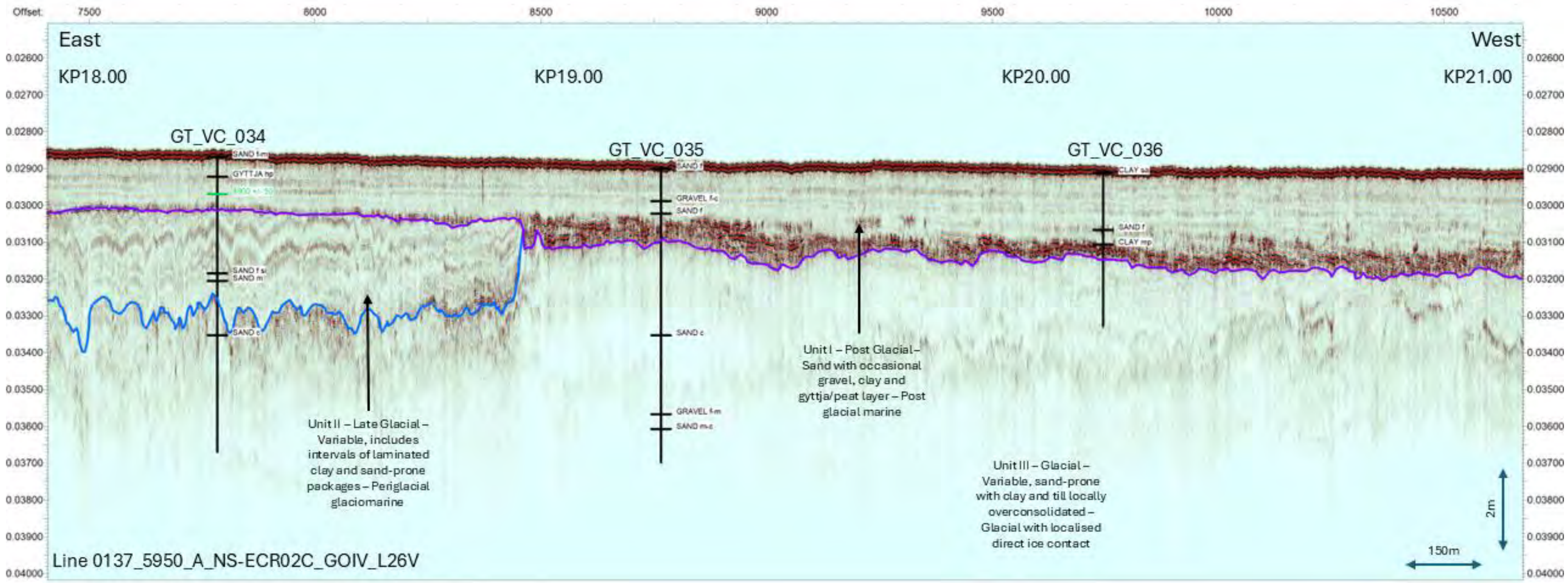


Figure 155: SBP and Geotech, KP 18.000 – KP 21.000

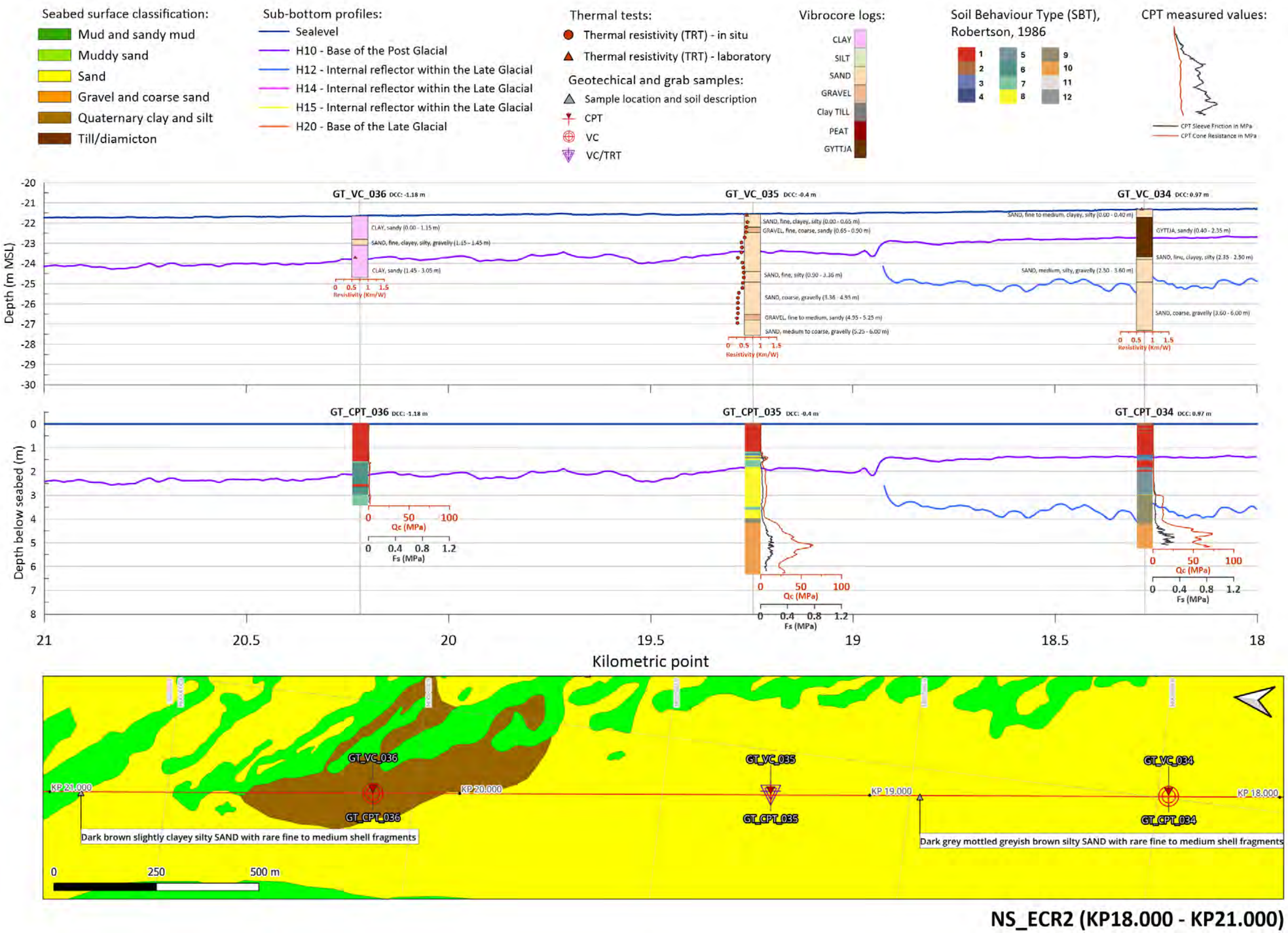


Figure 156: Integrated geotechnical panel KP 18.000 – KP 21.000

9.8 KP 21.000 – KP 24.000

Four VCs, four CPTs and two grab samples were acquired in this section.

Unit I sediments (bounded by H10) are present throughout all this section. Acoustically, it is low to moderate amplitude presenting a higher amplitude toward the base, with signs of parallel bedding mostly in the upper section and is generally between 2 – 3 m in thickness.

All the geotechnical samples (VC037, VC038, VC039, VC040, CPT037, CPT038, CPT039 and CPT040) penetrated Unit I, presenting various sediment types. VC037, VC038 and VC040 recorded a predominantly CLAY soil type with GYTTJA present in samples 037 and 038. VC039 is recorded as being more sand prone (albeit fine grained).

Unit II is not present in this section, as such, Unit III underlies Unit I over the length of the section and exhibits an acoustically transparent character. Some faint parallel bedding is seen on the SBP which possibly could be Unit II (up to approximately KP 21.80), but the data is indistinct and appears to underlie some of the more transparent sediments, so is more likely to be a subunit with Unit III.

Unit III was sampled in VC037, VC039, VC040, CPT037, CPT038, CPT039 and CPT040 and comprises predominantly fine to coarse SAND although it is recorded as more gravelly in VC037.

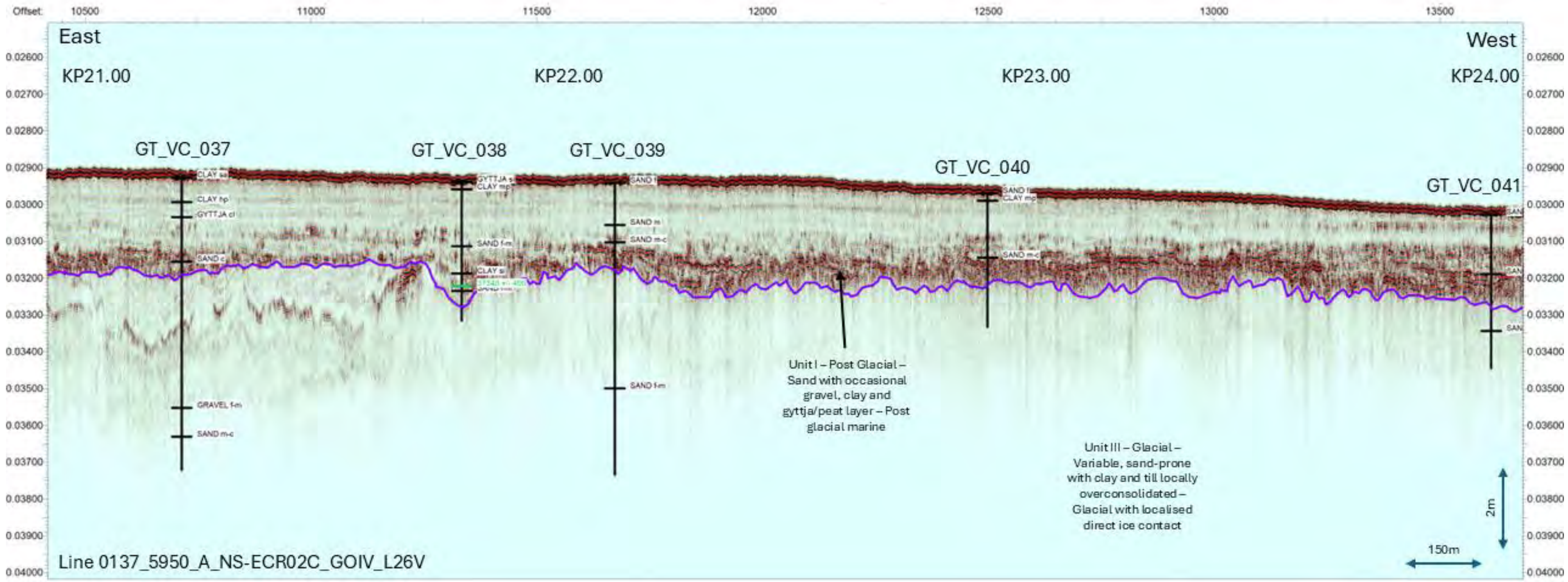


Figure 157: SBP and Geotech, KP 21.000 – KP 24.000

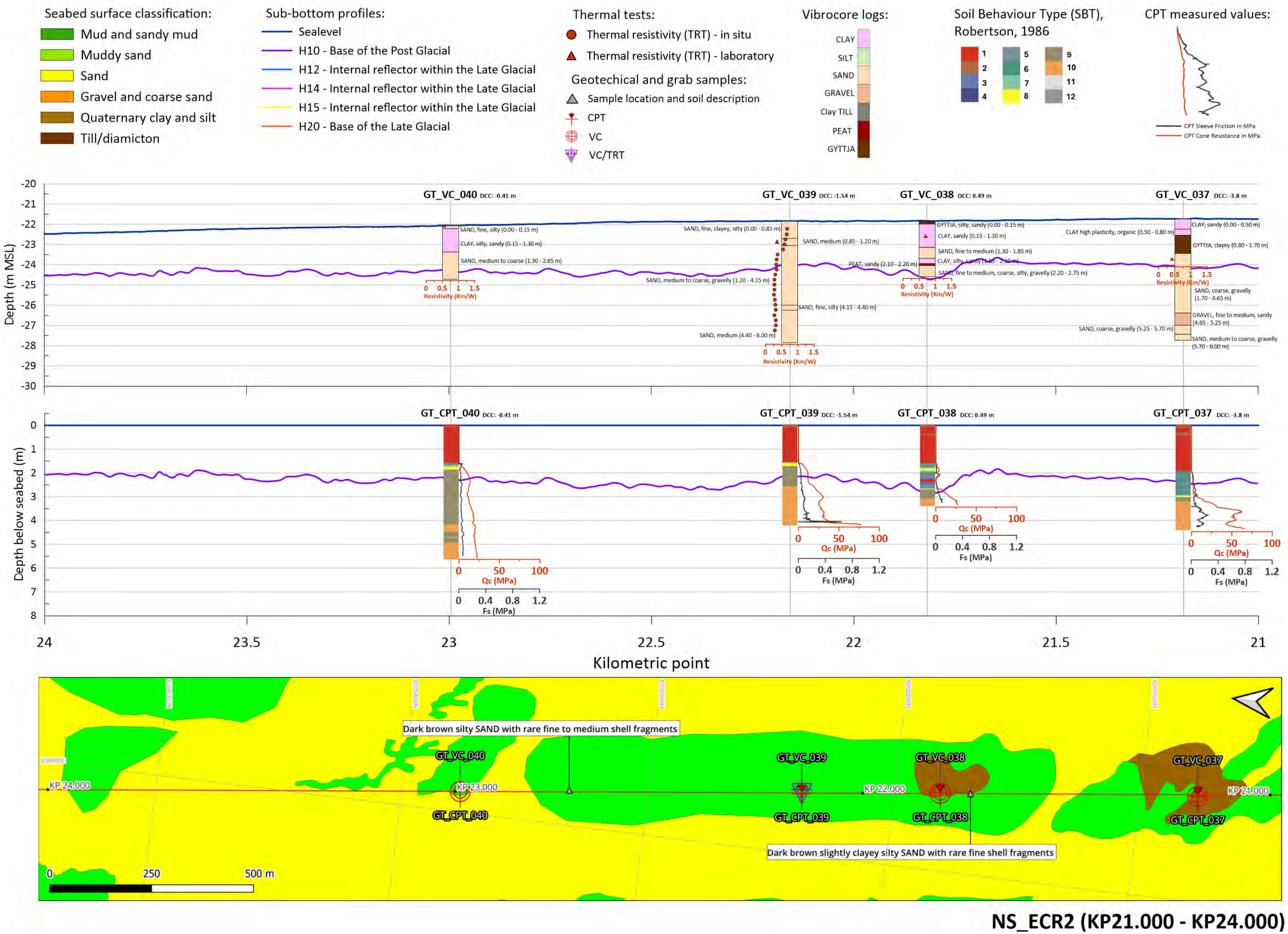


Figure 158: Integrated geotechnical panel KP 21.000 – KP 24.000

9.9 KP 24.000 – KP 27.000

Five VCs, five CPTs and two grab samples were acquired in this section.

Unit I sediments (bounded by H10) are present throughout all this section. Acoustically, it is low to moderate amplitude presenting a higher amplitude toward the base, with signs of parallel bedding mostly in the upper section and is generally between 2 – 3 m in thickness. However: at KP 25.30 it shoals to less than 1 m associated with the seabed depression.

All the geotechnical samples (VC041, VC042, VC043, VC044a, VC045, CPT041, CPT042, CPT043, CPT044 and CPT045) penetrated Unit I, presenting various sediment types. VC041 to VC043 recording a predominantly SAND sequence whereas VC044a And VC045 a more CLAY sequence. VC044a recorded a predominantly CLAY soil type with a layer of GYTTJA overlying a layer of GRAVEL. VC045 recorded a SAND layer to 1 m overlying CLAY.

Unit II is not present in this section, as such, Unit III underlies Unit I over the length of the section and exhibits an acoustically transparent character.

Unit III was sampled in all stations and comprises predominantly fine to coarse SAND although, as per in Unit I, sediments in stations 044a and 045 recorded a more CLAY dominant sediment.

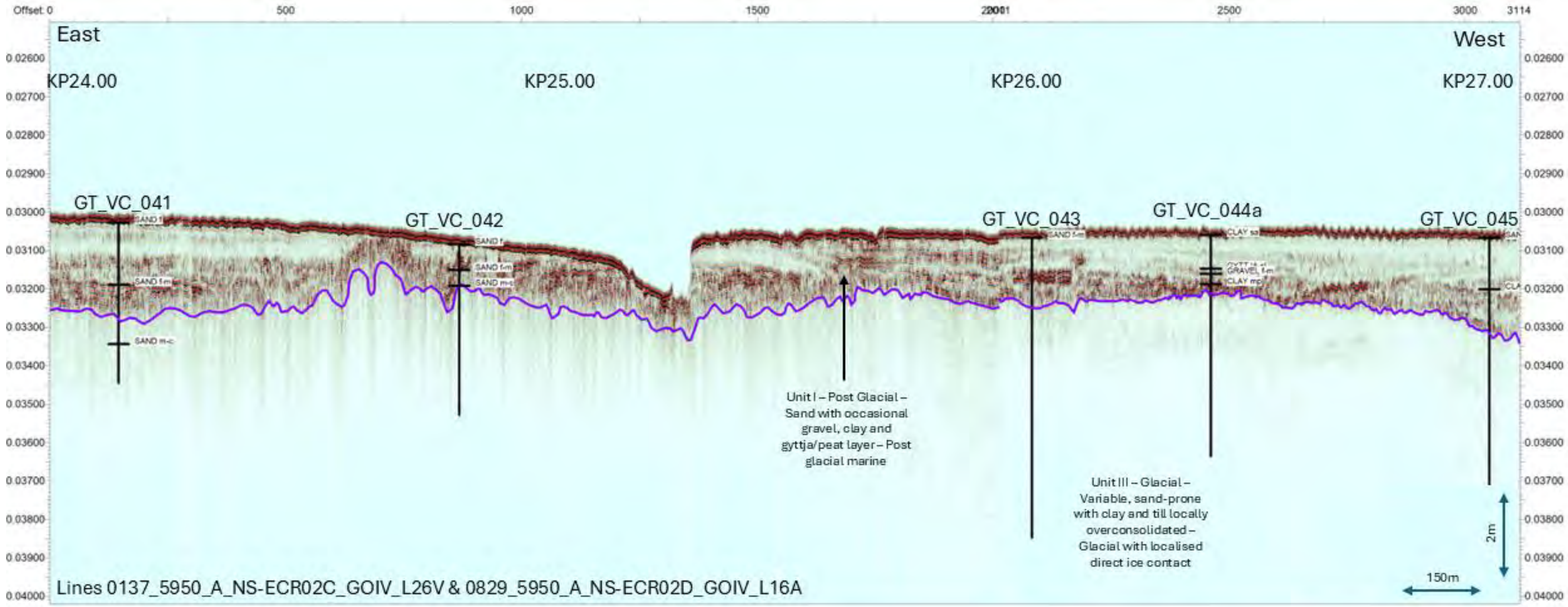


Figure 159: SBP and Geotech, KP 24.000 – KP 27.000

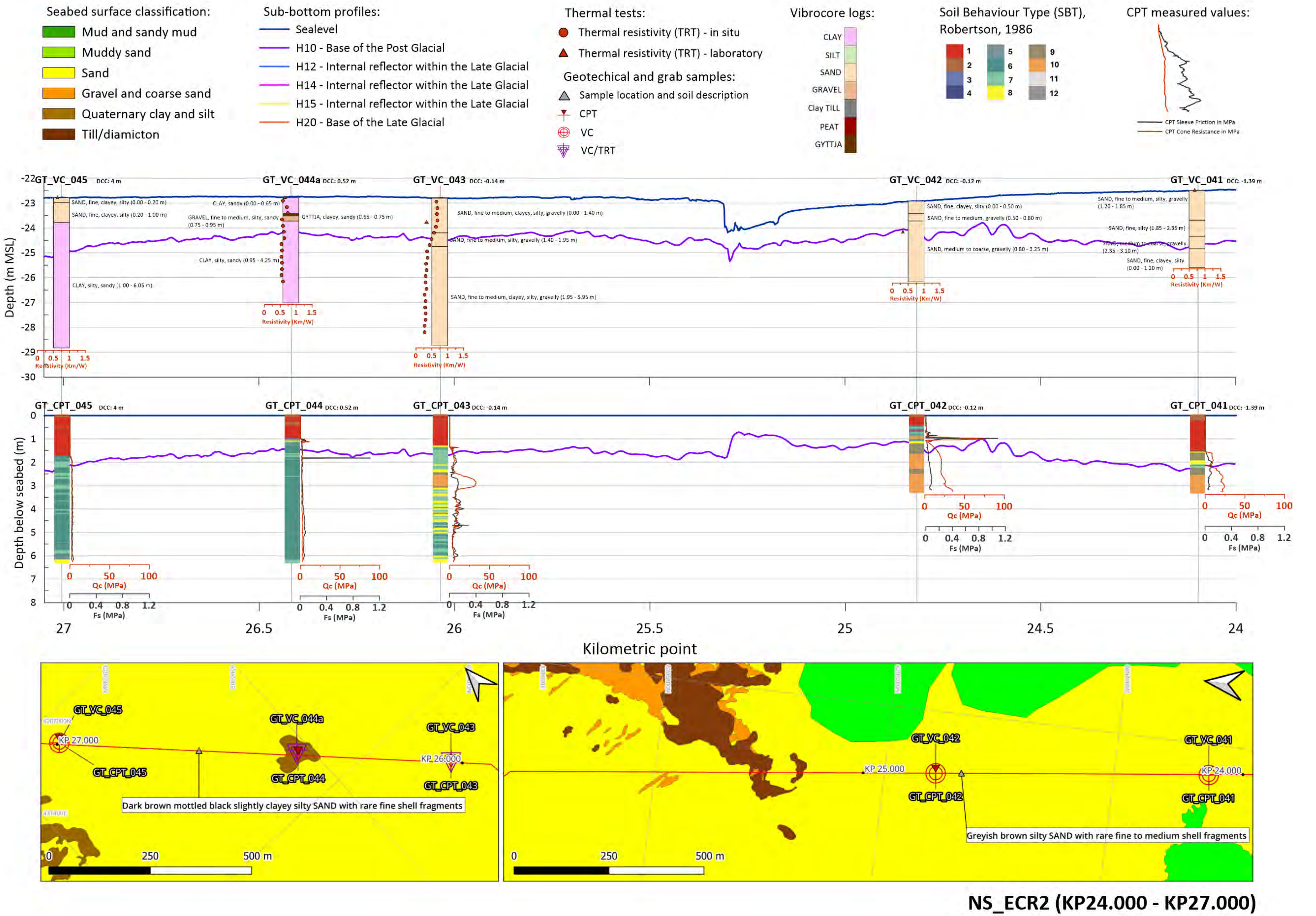


Figure 160: Integrated geotechnical panel KP 24.000 – KP 27.000

9.10 KP 27.000 – KP 30.000

Three VCs, three CPTs and three grab samples were acquired in this section.

Unit I sediments (bounded by H10) are present throughout this section. Acoustically it is low to moderate amplitude presenting a higher amplitude toward the base, with signs of parallel bedding mostly in the upper section and is generally between 1 – 2.5 m in thickness.

All the geotechnical samples (VC045, VC046a, VC047, CPT045, CPT046 and CPT047) penetrated Unit I, presenting predominantly fine clayey SANDS overlying sandy CLAY; however, VC047 is recorded as a sandy CLAY for all of Unit I.

Unit II is not interpreted in this section, as such, Unit III underlies Unit I over the length of the section but exhibits a more variable seismic character. Some faint bedding (possible multiple cut and fill episodes) is present, but the data is indistinct and appears to underlie some of the more transparent sediments, so is more likely to be a subunit with Unit III with some structure apparent.

Unit III was sampled in all stations and comprises silty to sandy CLAY however sediments in Unit III in VC047 are recorded as clayey fine to medium SAND.

Unit III was sampled in all stations and comprises predominantly silty sandy CLAY although sediments in stations 047 are recorded as a more SAND dominant sediment.

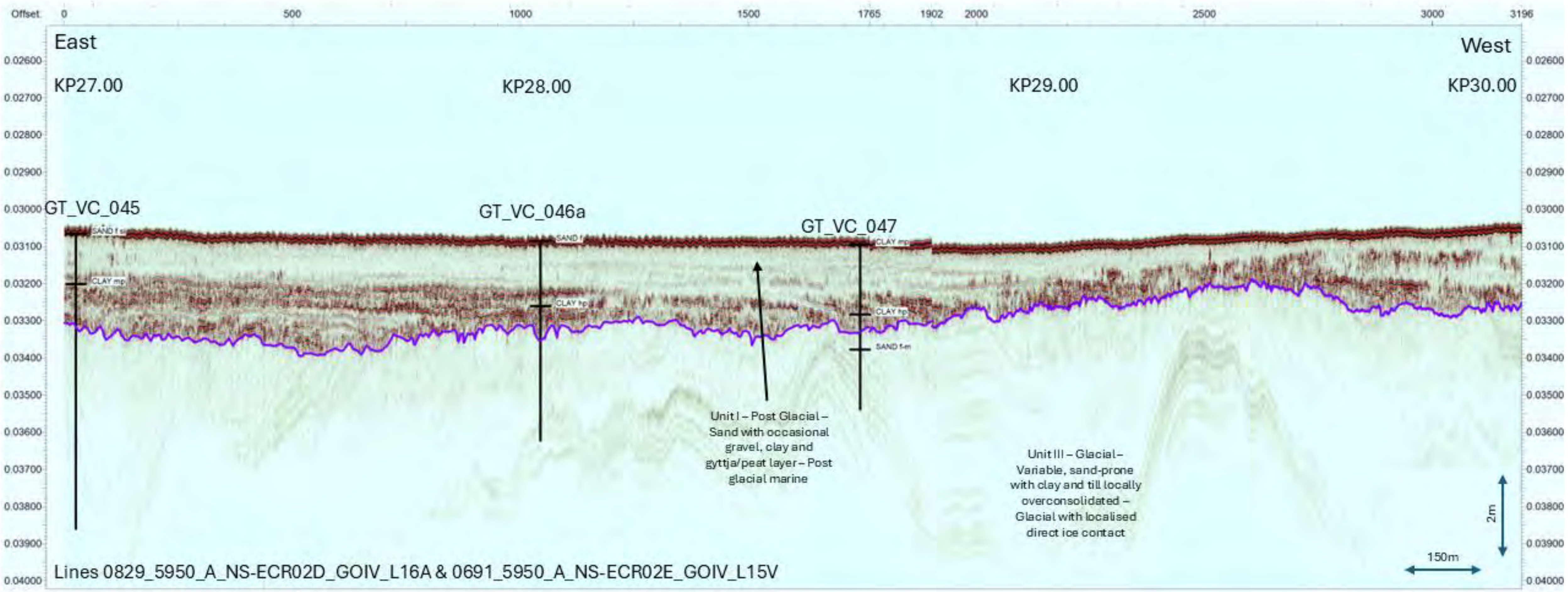


Figure 161: SBP and Geotech, KP 27.000 – KP 30.000

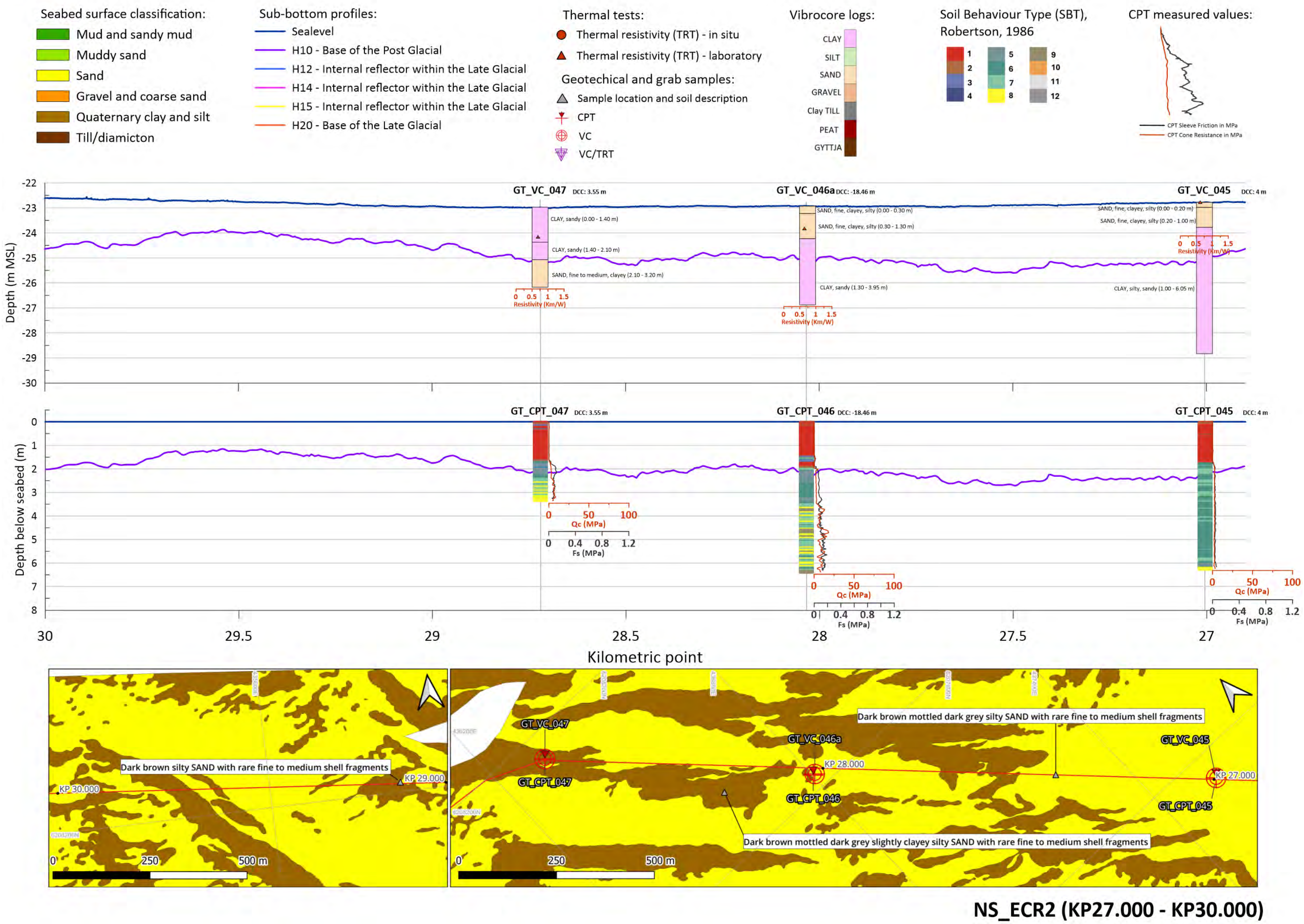


Figure 162: Integrated geotechnical panel KP 27.000 – KP 30.000

9.11 KP 30.000 – KP 33.000

Five VCs, five CPTs and three grab samples were acquired in this section.

Unit I sediments (bounded by H10) are present throughout all this section. Acoustically it is low to moderate amplitude presenting a higher amplitude toward the base, with signs of parallel bedding mostly in the upper section and is generally between 1 – 2 m in thickness.

All the geotechnical samples (VC048, VC049, VC050, VC051a, VC052, CPT048, CPT049, CPT050, CPT051 and CPT052a) penetrated Unit I, presenting predominantly fine clayey SANDS overlying sandy CLAY.

Unit II is not interpreted in this section, as such, Unit III underlies Unit I over the length of the section but exhibits a more variable seismic character. Some faint bedding (possible multiple cut and fill episodes) is present, but the data is indistinct and appears to underlie some of the more transparent sediments, so is more likely to be a subunit with Unit III with some structure apparent.

Unit III was sampled in all stations and comprises sandy CLAY apart from sediments in Unit III in VC050 are recorded as fine to medium silty SAND.

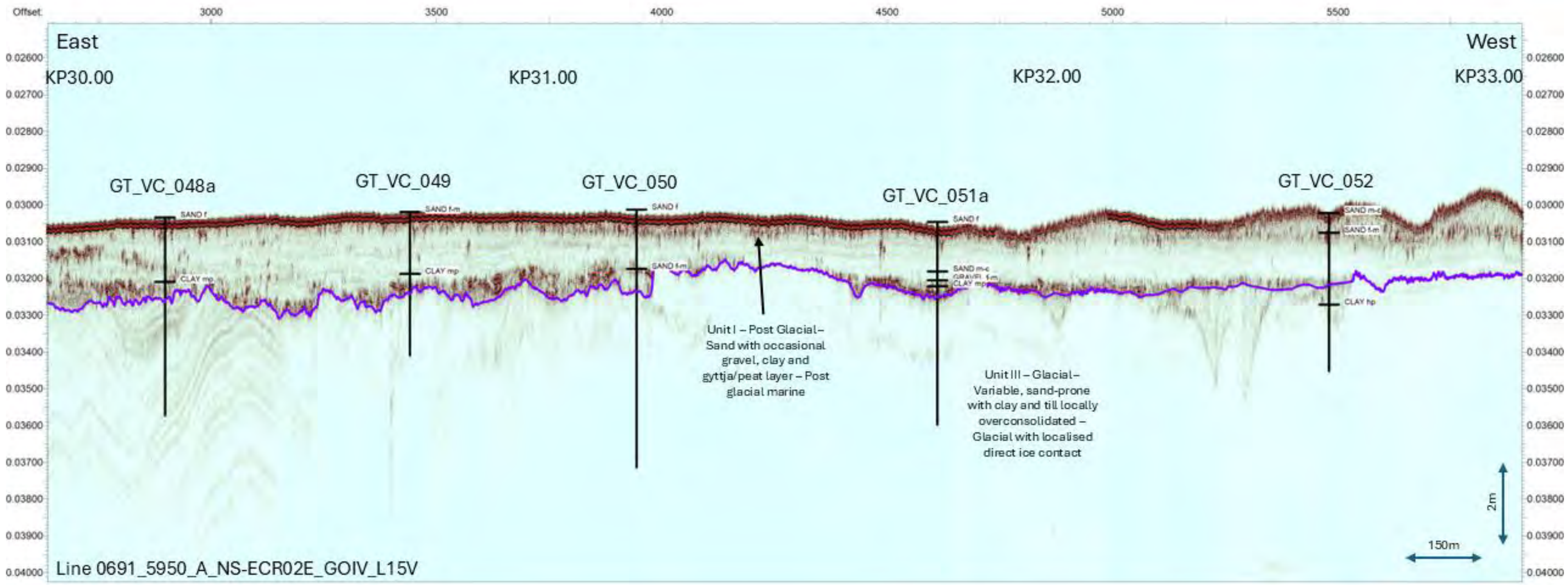


Figure 163: SBP and Geotech, KP 30.000 – KP 33.000

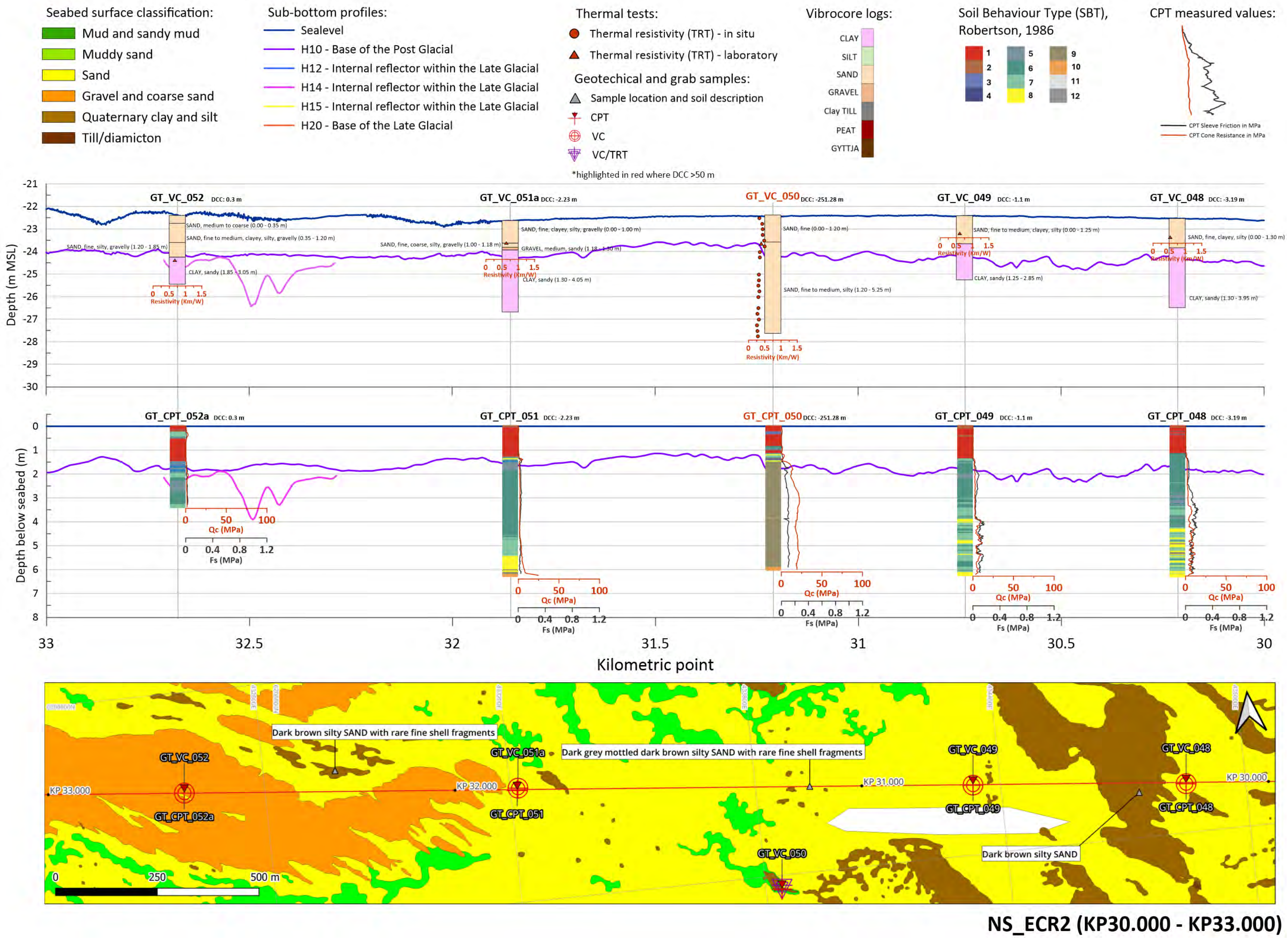


Figure 164: Integrated geotechnical panel KP 30.000 – KP 33.000

9.12 KP 33.000 – KP 36.000

Three VCs, three CPTs and three grab samples were acquired in this section.

Unit I sediments (bounded by H10) are present throughout all this section. Acoustically it is low to moderate amplitude presenting a higher amplitude toward the base, with signs of parallel bedding mostly in the upper section and is generally between 0.5 – 2 m in thickness, however, between KP 33.6 and KP 33.9 H10 is not mapped as it is within the seabed veneer so effectively Unit III subcrops in this part of the route.

All the geotechnical samples (VC053, VC54, VC055, CPT053, CPT054 and CPT055) penetrated Unit I, presenting predominantly fine to medium silty SANDS; however, VC055 also recorded a sandy GYTTJA layer at 0.50 m BSB.

Unit II is not interpreted in this section, as such, Unit III underlies Unit I over the length of the section but exhibits a more variable seismic character. Some faint bedding (possible multiple cut and fill episodes) is present, but the data is indistinct and appears to underlie some of the more transparent sediments, so is more likely to be a subunit with Unit III with some structure apparent.

Unit III was sampled in all stations and comprises a fine to medium silty, clayey SAND but more gravelly in VC055.

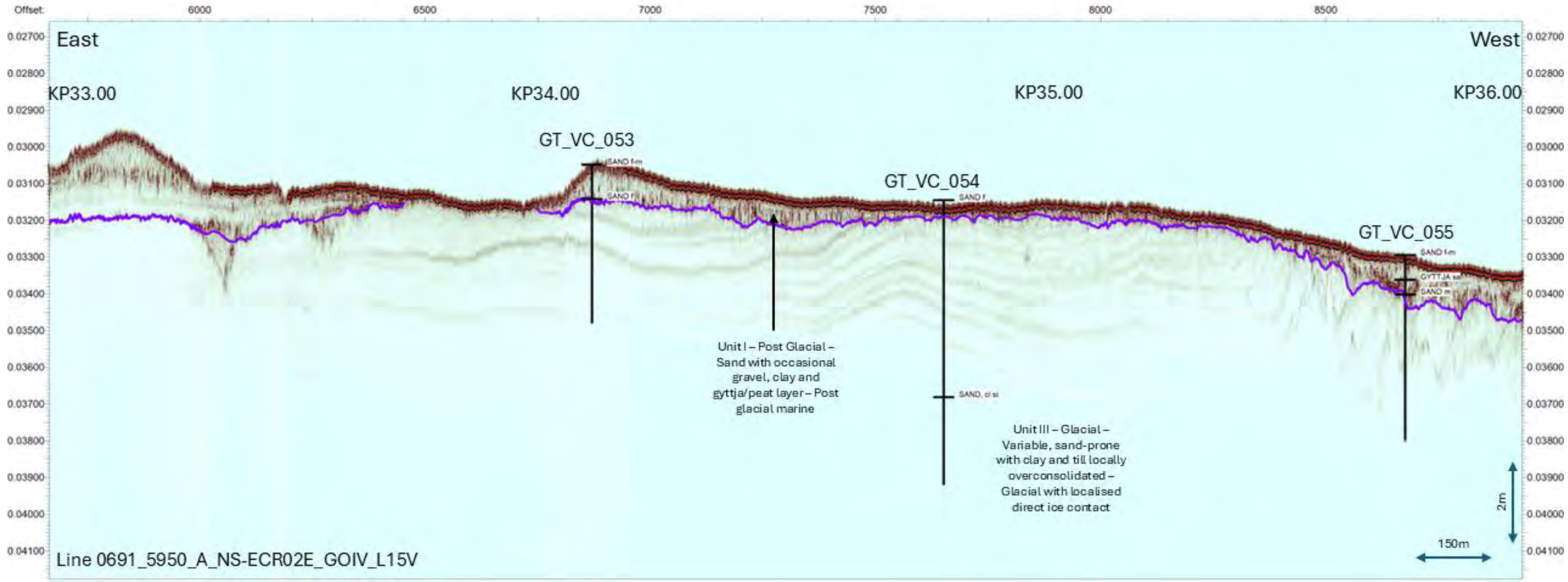


Figure 165: SBP and Geotech, KP 33.000 – KP 36.000

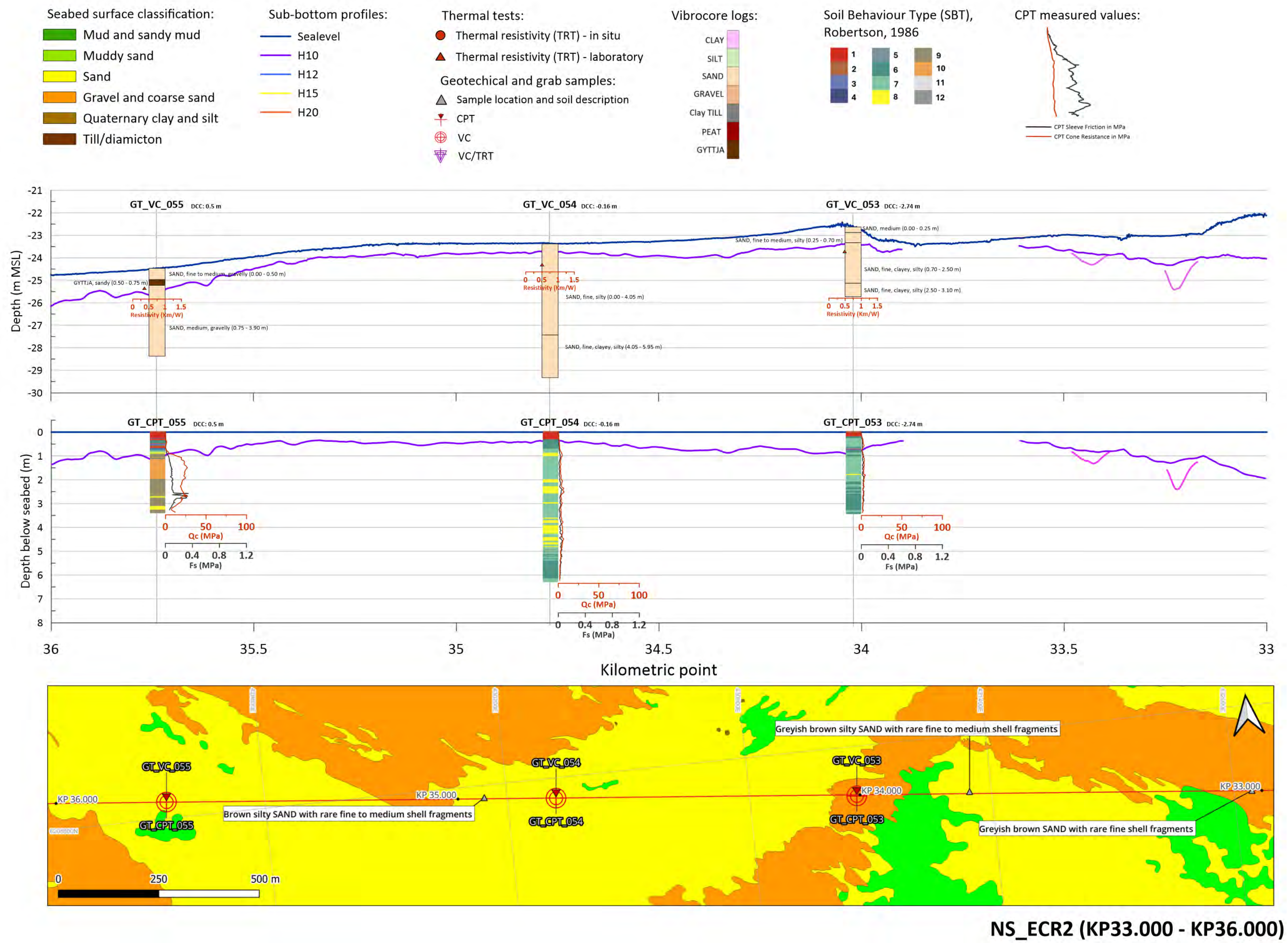


Figure 166: Integrated geotechnical panel KP 33.000 – KP 36.000

9.13 KP 36.000 – KP 39.000

Four VCs, four CPTs and three grab samples were acquired in this section.

Unit I sediments (bounded by H10) are present throughout all this section. Acoustically it is low to moderate amplitude presenting an occasionally higher amplitude toward the base and is generally between 0.5 – 1 m in thickness slightly thickening westwards towards KP 39.

All the geotechnical samples (VC056a, VC57, VC058, VC059, CPT056, CPT057, CPT058 and CPT059) penetrated Unit I, presenting predominantly fine to medium silty SANDS; however, station 56 recorded peat (VC056a) and CLAY (CPT056) towards the base of Unit I and continuing into underlying Unit III.

Unit II is not interpreted in this section, as such, Unit III underlies Unit I over the length of the section. Acoustically Unit III now returns to exhibit a more opaque character.

Unit III was sampled in all stations and comprises a fine to medium silty, clayey SAND apart from at station 056 where PEAT/fine grained sediments are recorded.

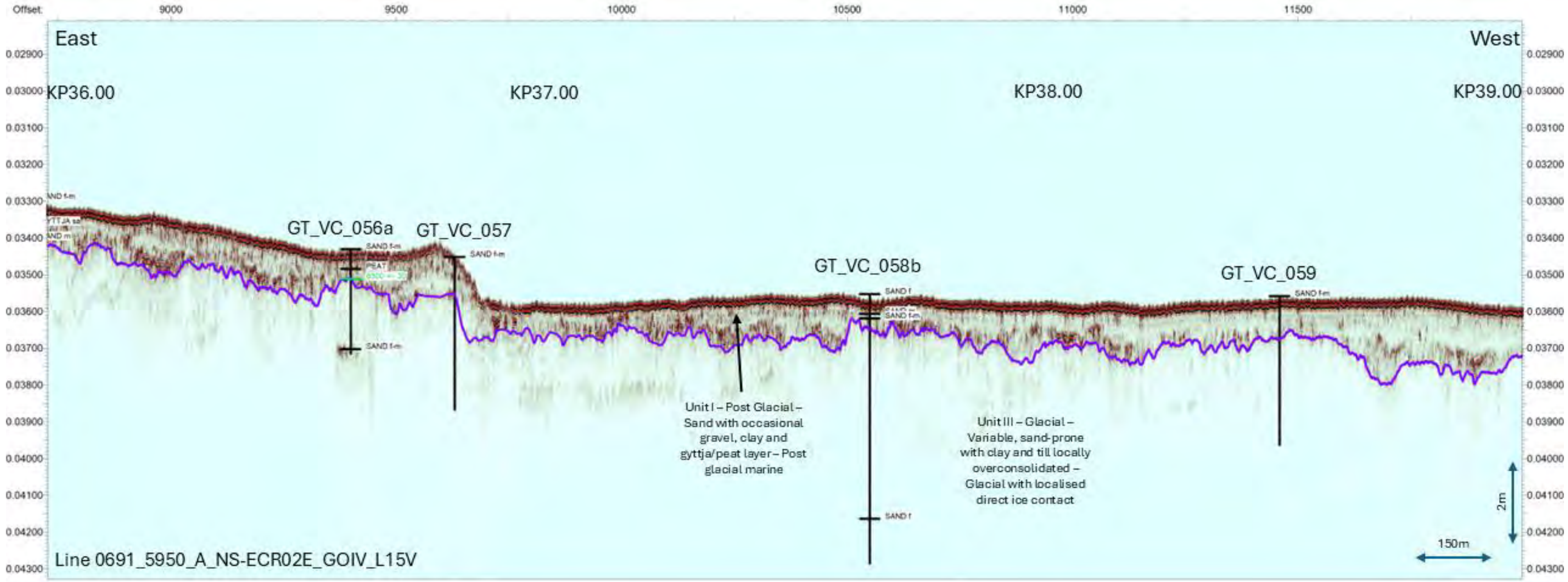


Figure 167: SBP and Geotech, KP 36.000 – KP 39.000

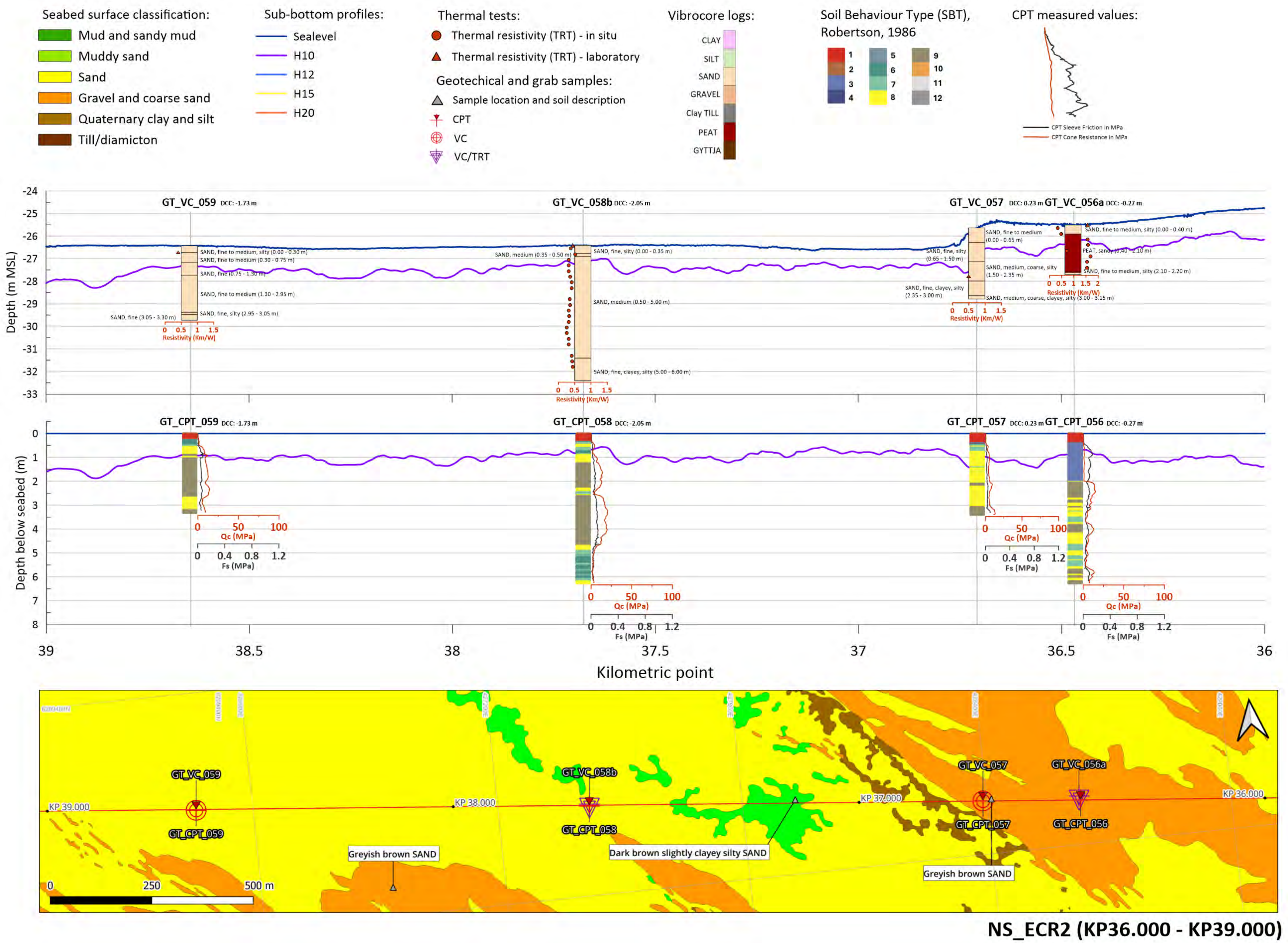


Figure 168: Integrated geotechnical panel KP 36.000 – KP 39.000

9.14 KP 39.000 – KP 41.161

Two VCs, two CPTs and three grab samples were acquired in this section.

Unit I sediments (bounded by H10) are present throughout all this section. Acoustically it is low to moderate amplitude presenting an occasionally slightly higher amplitude toward the base and is generally between 1 - 2 m.

All the geotechnical samples (VC060, VC061, CPT060 and CPT061) penetrated Unit I, presenting predominantly fine, clayey, silty SANDS; however, station 60 recorded a coarser and more gravelly SAND continuing into underlying Unit III.

Unit II is not interpreted in this section, as such, Unit III underlies Unit I over the length of the section. Acoustically, Unit IIII exhibits an opaque character.

Unit III was sampled in all stations and comprises a fine to medium SAND apart from at station 060 which records a coarser more gravelly SAND.

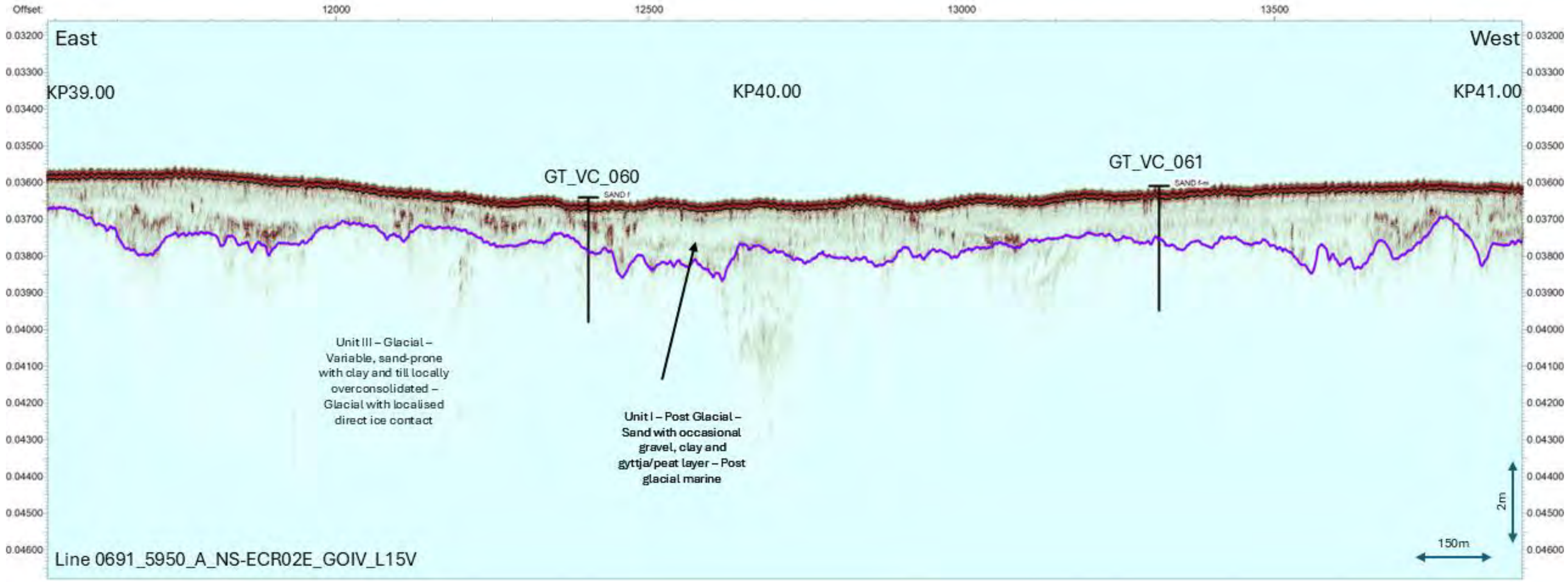


Figure 169: SBP and Geotech, KP 39.000 – KP 41.161

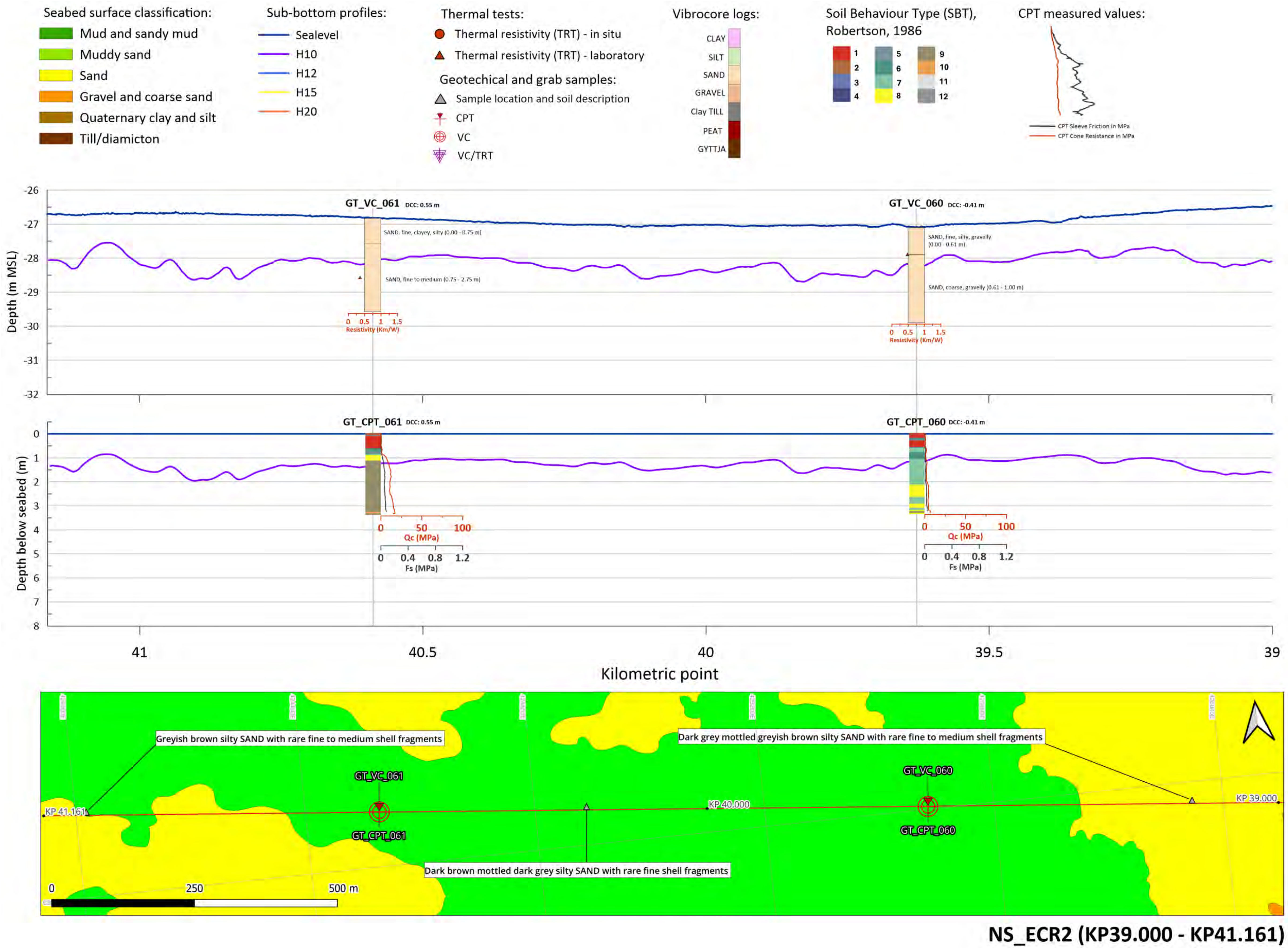


Figure 170: Integrated geotechnical panel KP 39.000 – KP 41.161

9.15 SHALLOW GEOLOGICAL INSTALLATION CONSTRAINTS AND GEOHAZARDS

Unit I sediments are very weak/soft. Their bearing capacity will be negligible and could cause retrieval difficulties related to settlement of seabed frames etc. The sediments in this Unit I may also contain diffuse organic material.

Units II and III contain numerous cobbles and boulders.

Unit III may have variable levels of overconsolidation.

9.15.1 Cobbles and Boulders

There are occasional indications of boulders within the sub-bottom profiler data. These data have been optimized to resolve the shallow stratigraphy and do not readily generate diffraction hyperbola, which are the usual seismic indication of point contacts in the sub-surface. A further complication is that the units most likely to contain boulders, Unit II and III, have been deformed and compressed by ice confusing any returns from individual point contacts.

Due to these circumstances, appearance of clear hyperbolae that could be interpreted as isolated individual point targets relating to buried boulders have not been observed.

9.15.2 Organic Material

GYTTJA and PEAT layers have been observed in geotechnical data within ECR02, which have been presented and described in the route analysis. However, these have not presented as clear or continuous reflectors in SBP data, and hence are not mapped spatially, away from GT locations. These present a possible geohazard relating to heat dissipation as well as trenching considerations for PEAT.

9.15.3 Comparison between seabed and sub-seabed findings

In the later stage of interpretation, surficial geology has been correlated to the SBP results. Where sub-seabed Unit III (i.e. basal unit) identified as a glacial till is at or near the seabed there is an abundance of boulders, these areas are delineated by “intermediate” boulder fields seabed features (Figure 115) and as “Till/ diamicton” in the seabed geology (Figure 114). Inversely there is a strong correlation between the presence of sub-seabed Unit I/II (Figure 131/Figure 134) and the “Gravel and Coarse SAND”, “SAND” and “Mud and Sandy Mud” surficial substrates.

9.16 CONCLUSIONS

The elevation levels across the North Sea ECR2 site range from 19.31 metres above Mean Sea Level (MSL) in the eastern landfall area to -27.34 metres below MSL towards the northwestern area near the end of the RPL.

Starting at the landfall and moving eastwards towards the KP 0.000 of the RPL of NS_ECR2, the gradient rises at approximately 2.7° over 62 metres, resulting in an elevation gain of 3.5 metres at the beginning of the RPL. Continuing landwards, there is an increase in the elevation with the gradient of 4.3° over 70 metres (70 metres is the distance from the KP 0.000 to the closest approximate highest point on land). Further inland the survey area is characterised by gentle mounds / dunes with the highest point of 19.31 metres MSL located northeastern form the KP 0.000. The height of these mounds / dunes decreases when moving further eastward and reach close to 0 m MSL in the vicinity of coastal lake Gammel Gab.

The majority of the offshore NS_ECR2 area is characterised by very gentle to gentle slopes. The highest concentration of steep slopes is located near KP 0.000, towards the inland areas. In the eastern, nearshore part of the route from KP 0.000 towards KP 6.000 there is a sudden deepening of the seabed, ranging from 3.5 m MSL at the landfall to approximately -18 m MSL at KP 6.000. From KP 10.000 to KP 24.000, the seabed depth flattens. Around KP 25.250 there is a ridge approximately 1 meter high which separates the boulder fields area from a predominantly featureless area of seabed. From KP 25.000 to the KP 31.000 there is a slight raise in the seabed depth, measuring 0.5 metres. From KP 31.000 till the end of the RPL survey area, seabed deepens towards the 26.7 metres MSL at the end of the RPL. There is an increase in slope values in this part, from gentle to moderate slopes, correlating with areas of dynamic seabed such as ripples.

The seabed geology of the North Sea ECR2 survey area consists predominantly of sand, along with sediments such as gravel and coarse sand, muddy sand, Quaternary clay and silt and a few isolated areas till/diamicton.

The beginning of the route, from KP 0.000 to approximately KP 6.000, is dominated by a mix of sediments including sand, patches of gravel and coarse sand, and muddy sand areas. From KP 5.400 to KP 5.750 there is an isolated area of till located approximately 40m north-east of the RPL. Between KP 6.000 and KP 10.500, sand covers the full width of the corridor, with the exception of three small patches of gravel and coarse sand. From KP 10.500 to KP 25.250, the seabed geology is primarily sand with some large patches of muddy sand, in correlation with a flatter area of seabed on the bathymetry data. Occasional smaller patches of Quaternary clay and silt were also interpreted along the RPL, in correlation with Vibrocore Top Geology (seabed) results between KP 19.800 and KP 21.900. From KP 25.250 to KP 27.000, the eastern side of the cable corridor is largely dominated by till and gravel and coarse sand, whilst the western side of the corridor is predominantly sand. From KP 27.00 to KP 30.500, sand is present along with an abundance of large linear patterned patches of Quaternary clay and silt. These are orientated in an NW-SE direction. From KP 30.500 to the end of the RPL, the route is dominated by large patches of muddy sandy and gravel and coarse sand, in correlation with the gentle to moderate slopes seen in the bathymetry and consistent with dynamic seabed features, such as ripples.

The seabed morphology at the beginning of the NS_ECR2 route until KP 0.800, is dominated by ripples and megaripples. From KP 0.800 to KP 3.000, the seabed is further dominated by ripples, large ripples and areas of sediment waveforms. This indicates dynamic areas, which are also presented within the bathymetric and slope profile. From KP 3.000 to KP 6.250 the seabed is predominantly featureless, with the exception of boulders. There are also occasional isolated areas of patches of mottled seabed and areas of possible biostructures, off the RPL. From KP 5.400 to KP 5.750 there is an isolated boulder field area located approximately 40m north-east of the RPL, which correlates with an area of till in the seabed geology. An area of ripples, large ripples and erosional bedforms are also present, adjacent to the north-east of the boulder field. Between KP 6.250 to KP 28.200, the seabed is largely dominated by trawl marks, with some isolated large patches of featureless seabed also present. Occasional patches of lower reflectivity are also seen along this section, in correlation with areas of muddy sand. From KP 25.250 to KP 27.000, the eastern side of the cable corridor is largely dominated by boulder fields and ripples, whilst the western side of the corridor remains either featureless, or trawl marks are observed. From KP 27.00 to KP 31.900, the seabed is featureless with the exception of boulders and an abundance of large linear patterned patches of lower reflectivity visible on the SSS data, that correlate to Quaternary clay and silt or muddy sand. These patches are predominantly orientated in an NW-SE direction. Between KP 31.900 and KP 39.400, the route is either featureless, with the exception of boulders, or is dominated by large areas of ripples and erosional bedforms.

From KP 39.400 to the end of the RPL, the seabed is again, either featureless with the exception of boulders, or patches of lower reflectivity as seen on the SSS are again present.

A total of 1,034 point contacts were detected in NS_ECR2, with 121 of these attributed to be man-made (MMO) point targets and 913 point targets interpreted as boulders. A total of 18 MMO linear features were detected. Four of these features were identified as soft ropes, seven of them as other linear objects and an additional seven cable crossings. All seven cable crossings were detected in the background data but only three of them were detectable by magnetometer. There were 31 metallic objects found within the NS_ECR2 survey area. Additional 85 items of the debris point contacts were observed within the site. All of these were interpreted as non-ferrous objects. There were no wrecks, and no pipelines identified within the NS_ECR2 site.

The geological interpretation along the proposed ECR is based upon the geophysical and geotechnical datasets acquired with reference to the supplied GEUS desk study. Details of specific correlations between the geophysical and geotechnical datasets can be found in the 3 km route analysis sections of the report.

Overall, the area has a glacial to post-glacial sequence of relatively recent sediments over much older bedrock. Only the upper post glacial and glacial deposits are discussed along the ECR as the bedrock is deeper than the installation zone of interest and not imaged on the SBP data.

The Post-Glacial unit (Unit I) I is a package predominantly of post-glacial SAND with occasional layers of GRAVEL, CLAY and GYTTJA/PEAT which is less than 2 m thick over large parts of the site. The interval includes a veneer of sandier seabed sediments, though this is interpreted to be very thin and not resolvable in the SBP data. The post glacial sediments are widely distributed over the cable route corridor varying from absent to less than 3 m over the majority of the route. It increases in thickness at the nearshore end, reaching its thickest, at approximately 6 m, near KP 1.000. It may be thicker even further inshore, but the horizon is obscured by the seabed multiple. Occasional pockets of peat and gyttja are observed in the geotechnical logs, but no seismic expression is noted in the SBP data. In general, the post glacial package consists of sand with occasional gravel and gyttja in the nearshore end of ECR2.

The late glacial deposits (Unit II) are very complex due to the area's range of environmental conditions during the Late Weichselian and earliest Holocene. Some intervals show laminations indicative of clays and silts, others may represent sandy beach-type deposits. Along the route corridor Unit II, glaciomarine sediments infill steep sided channels eroded into the underlying Unit III tills.

A significant channel is present between KP 8.900 and KP 17.200. It is acoustically quiet in character and reaches a maximum depth of approximately 17 m below seabed at KP 13.200. Within this channel an internal reflector (H15) is present, which corresponds to the top of a clay layer identified in the geotechnical data.

Another channel is observed between KP 17.000 and KP 19.000. The channel has a highly erosive base, and the sediments are well bedded with the bedding parallel to the irregular basal reflector. The Unit reaches a maximum depth of approximately 5 m below seabed (Unit II ~3.5 m thick). Geotechnical data shows the sediments to be predominantly sand.

Further channels are seen to the north of the NS_ECR2 between KP 32.000 and KP 36.000; and away from the centreline at KP 2.500 to KP 3.000 and KP 5.000 to KP 5.600. They reach a maximum depth of 9 m below seabed, but more usually reach 4 to 5 m below seabed. They samples indicate clay.

The glacial deposits (Unit III) occur along the route corridor, sub-cropping at the seabed where Units I and II are thin to absent (between KP 33.600 and KP 33.900). Unit III is interpreted to be a till laid down in association with the last major ice advance over the area, approximately 22,000 years ago. The till forms a relatively thick blanket, to deeper than the depth of interest for cable burying. The base of the till/ top bedrock is not imaged within the export route corridor.

Unit III is generally a glacial till which has been subjected to direct ice contact, though the unit contains other facies which may have been laid down in ice-marginal environments during oscillations of the ice front. The ice-contact facies may comprise a clay-prone diamicton which is likely to contain subordinate silt, sand, gravel, cobbles and boulders and will be overconsolidated. Consolidation levels may significantly vary over short distances. Seismically, the ice contact facies are generally acoustically structureless.

Unit I sediments are very weak and soft, with negligible bearing capacity, potentially causing retrieval difficulties related to the settlement of seabed frames. Unit II contains numerous cobbles and boulders. Unit III may exhibit variable levels of over-consolidation and also contains numerous cobbles and boulders. Some isolated patches of Gyttja and Peat have also been observed in the geotechnical data, though these have not presented as clear or continuous reflectors in the SBP data and hence are not mapped spatially away from the geotechnical locations. These present a possible geohazard relating to heat dissipation, as well as trenching considerations for Peat.

10 NS_ECR3 ROUTE OVERVIEW

10.1 RESULTS

This report section provides a detailed analysis of the findings within the NS_ECR3 site from topographic data, bathymetric data, side scan sonar data, sub-bottom profiling, and magnetometer surveys conducted within the survey area.

Datasets were reduced to MSL, which involved applying the DTU21MSL geoid separation model during post-processing.

Listings for all sonar, magnetometer and sub-bottom contacts and linear targets across the site are presented within each relevant section of the text. A confidence level is assigned to sonar contacts as presented previously in Section 5.8.

10.2 BATHYMETRY AND TOPOGRAPHY

The elevation levels across the NS_ECR3 site range from a highest point of 19.31 metres above MSL near 448361 mE, 6184519 mN in the eastern landfall area, to a deepest point of 24.80 metres below mean sea level (MSL) near coordinates 428343 mE, 6192577 mN towards the northwestern boundary of the survey area. Figure 171 presents a comprehensive overview of the NS_ECR3 survey area, merging both topographic and bathymetric data to illustrate general morphology.

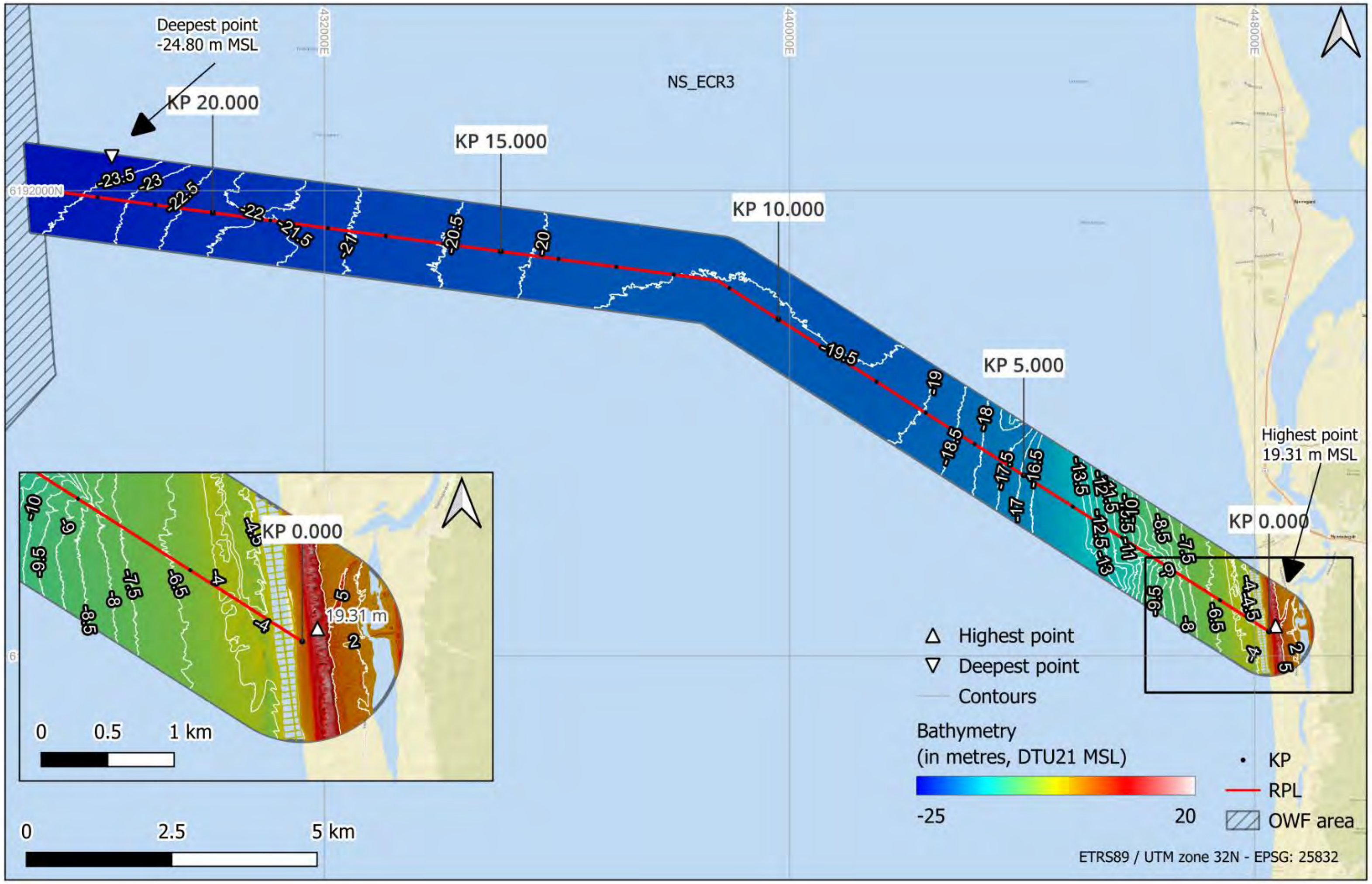


Figure 171: Bathymetry and topographic combined overview – NS_ECR3

10.2.1 Landfall and topography

Starting at the landfall and moving eastwards the KP 0.000 of the RPL, the gradient rises at approximately 2.8° over 59 metres, resulting in an elevation gain of 3.5 metres at the beginning of the RPL. Rising is gradual, without sudden or dynamic changes in elevation. Continuing landwards, there is an increase in the elevation with the gradient of 4.3° over 70 metres (70 metres is the distance from the KP 0.000 to the closest approximate highest point on land). Further inland, the survey area is characterised by gentle mounds / dunes with the highest point of 19.31 metres MSL located northeastern from the KP 0.000. The height of these mounds / dunes decreases when moving further eastward and reach close to 0 MSL in the vicinity of coastal lake Gammel Gab. The topographic overview is provided in Figure 172, and a detailed landfall overview is presented in Figure 173.

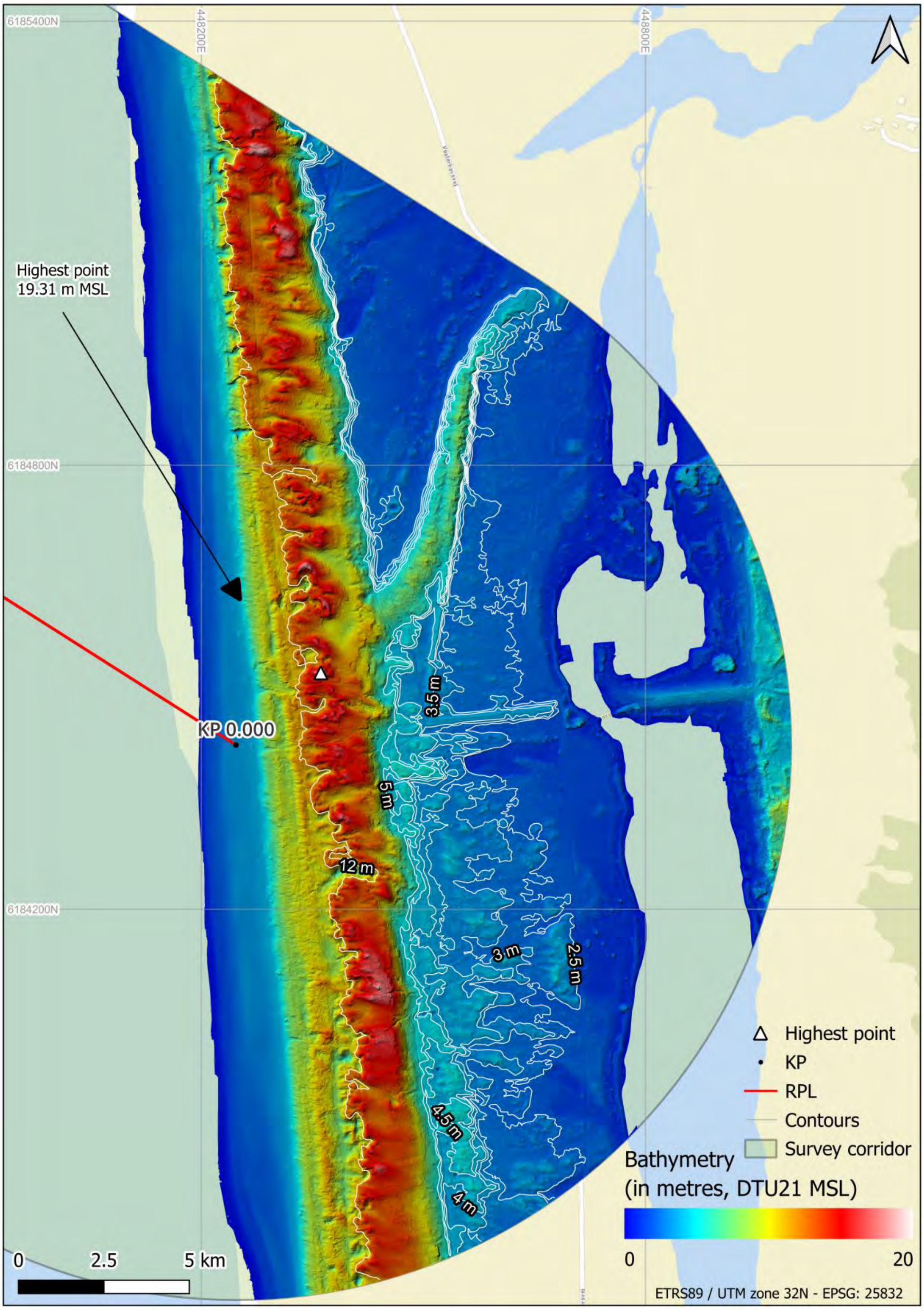


Figure 172: Topographic overview – NS_ECR3

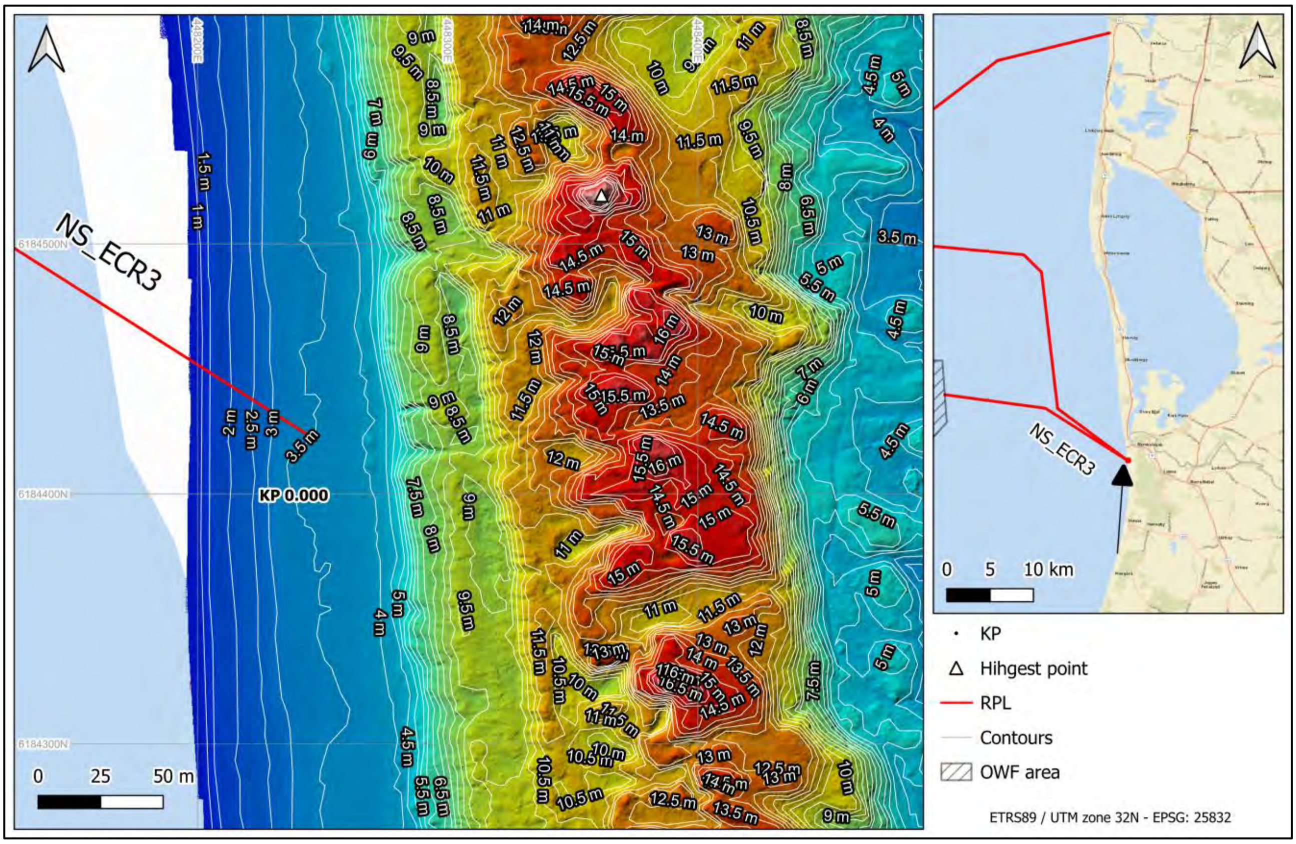


Figure 173: NS_ECR3, landfall, detailed overview

10.2.2 Bathymetry overview

A comprehensive overview of the bathymetry within the NS_ECR3 survey area is presented in Figure 174, while a detailed bathymetry profile along the Route Position List (RPL) is depicted in Figure 175.

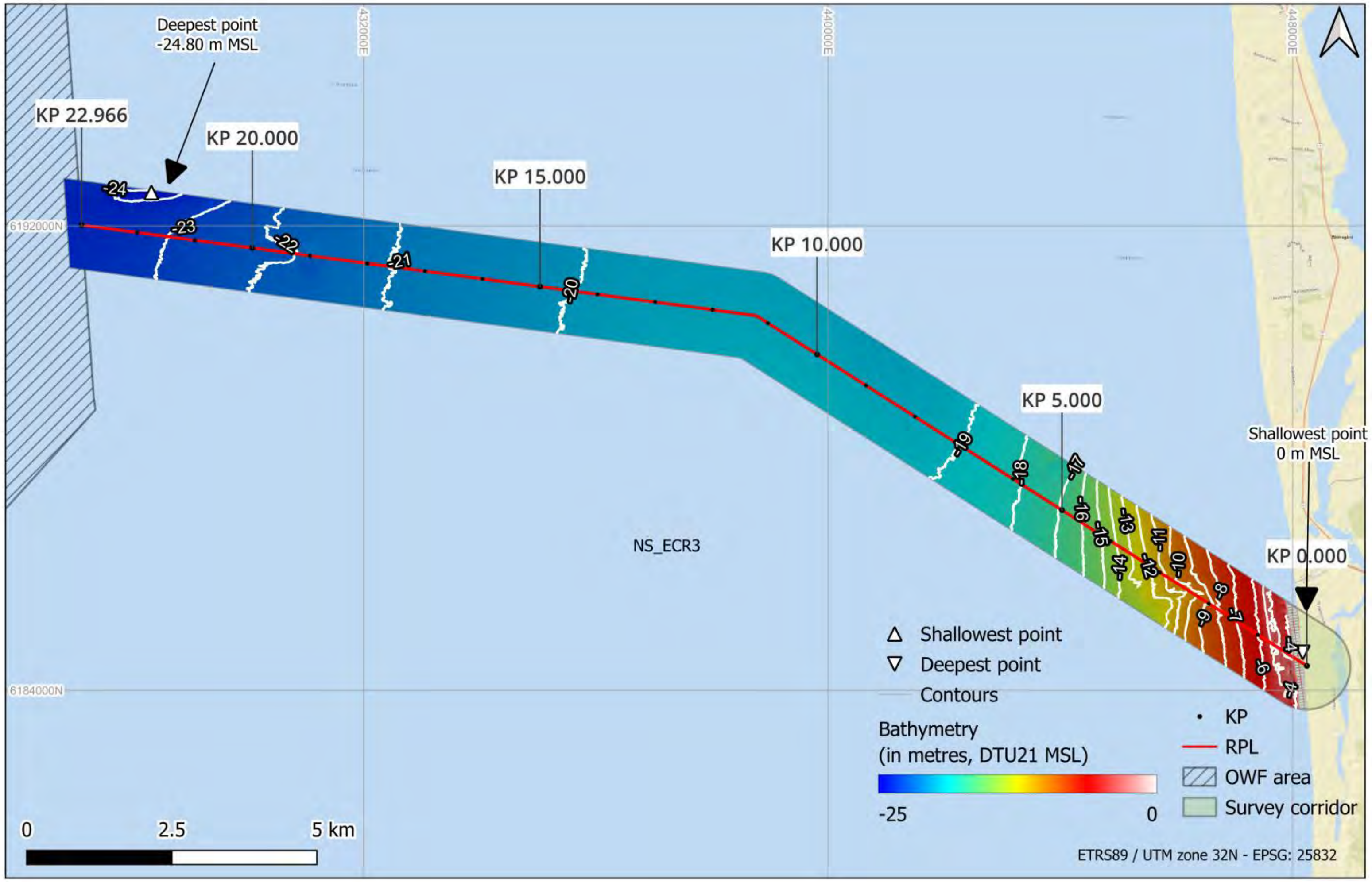


Figure 174: Bathymetry overview up the landfall – NS_ECR3

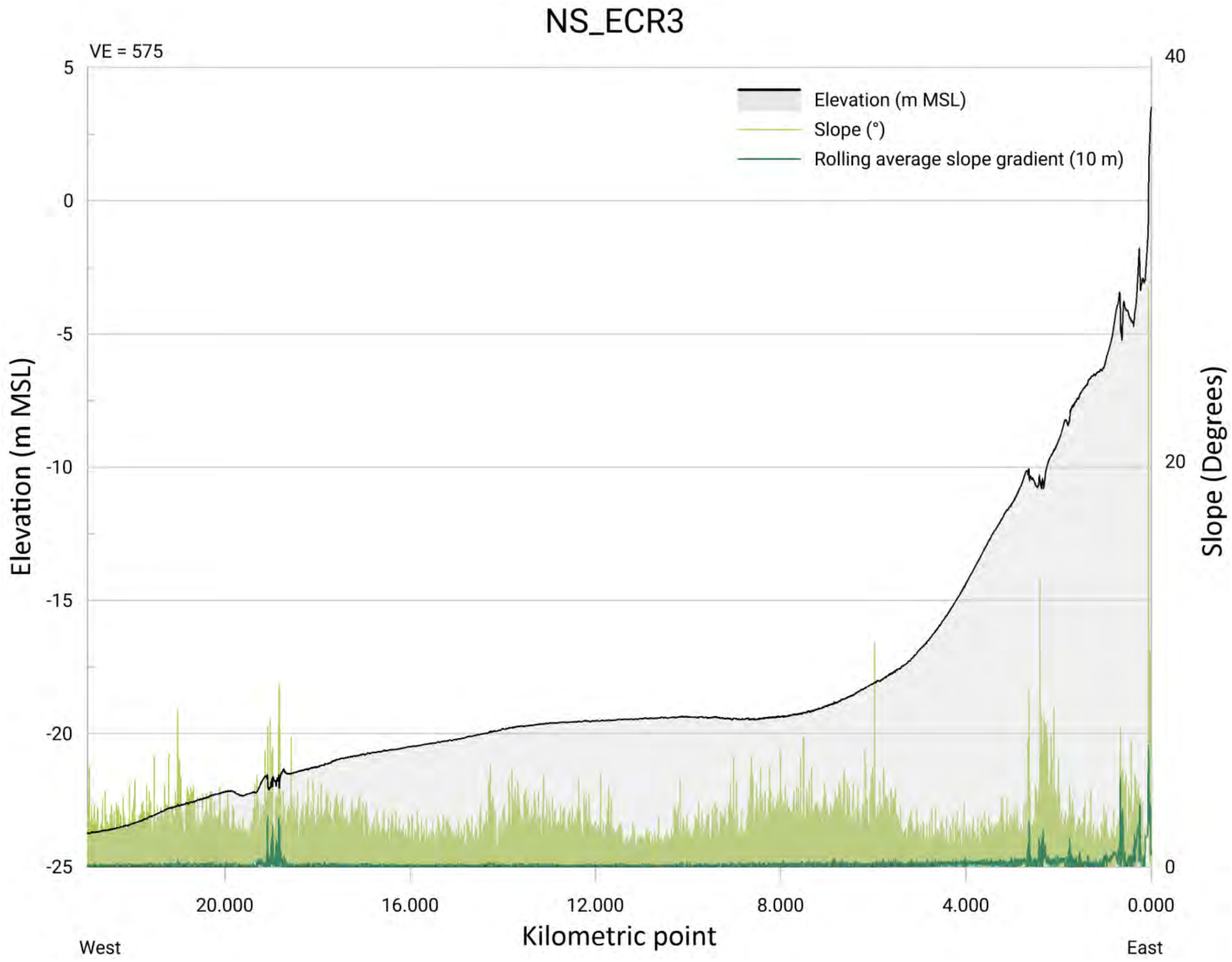


Figure 175: Depth and slope profile along the NS_ECR3 route RPL (created form 0.25 m grid)

Overall, the majority of the NS_ECR3 area is characterised by very gentle slopes on most of the cable survey area. The highest concentration of steep slopes located to the east of the KP 0.000, towards the inland areas.

Nearshore part of the route, from KP 0.000 to KP 8.000 exhibits a significant deepening of the seabed, with steep slopes.

Between KP 2.000 and KP 3.000 there is a channel-type structure, corresponding to ripples, after which the seafloor continues to deepen towards the KP 8.000, Figure 176.

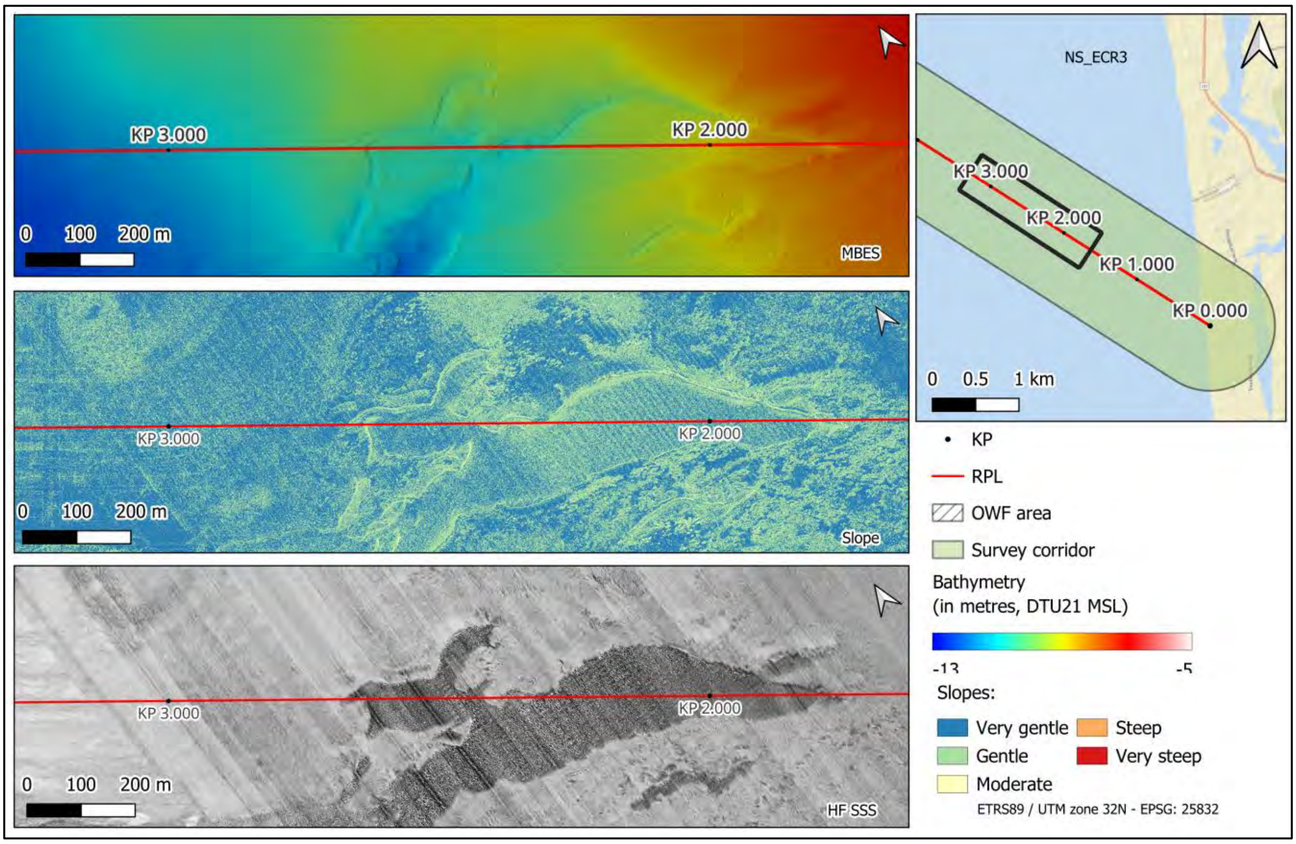


Figure 176: NS_ECR3, MBES, slope and HF SSS, KP 2.000 – KP 3.000

The area between KP 8.000 and KP 12.000 is characterised by almost flat seabed, without any changes in the depth. Following the KP 14.500 the seabed continues to deepen with some sudden changes in elevation with differences reaching up to 2 m between around KP 19.000. This dynamic area corresponds to ripples and large ripples (Figure 177).

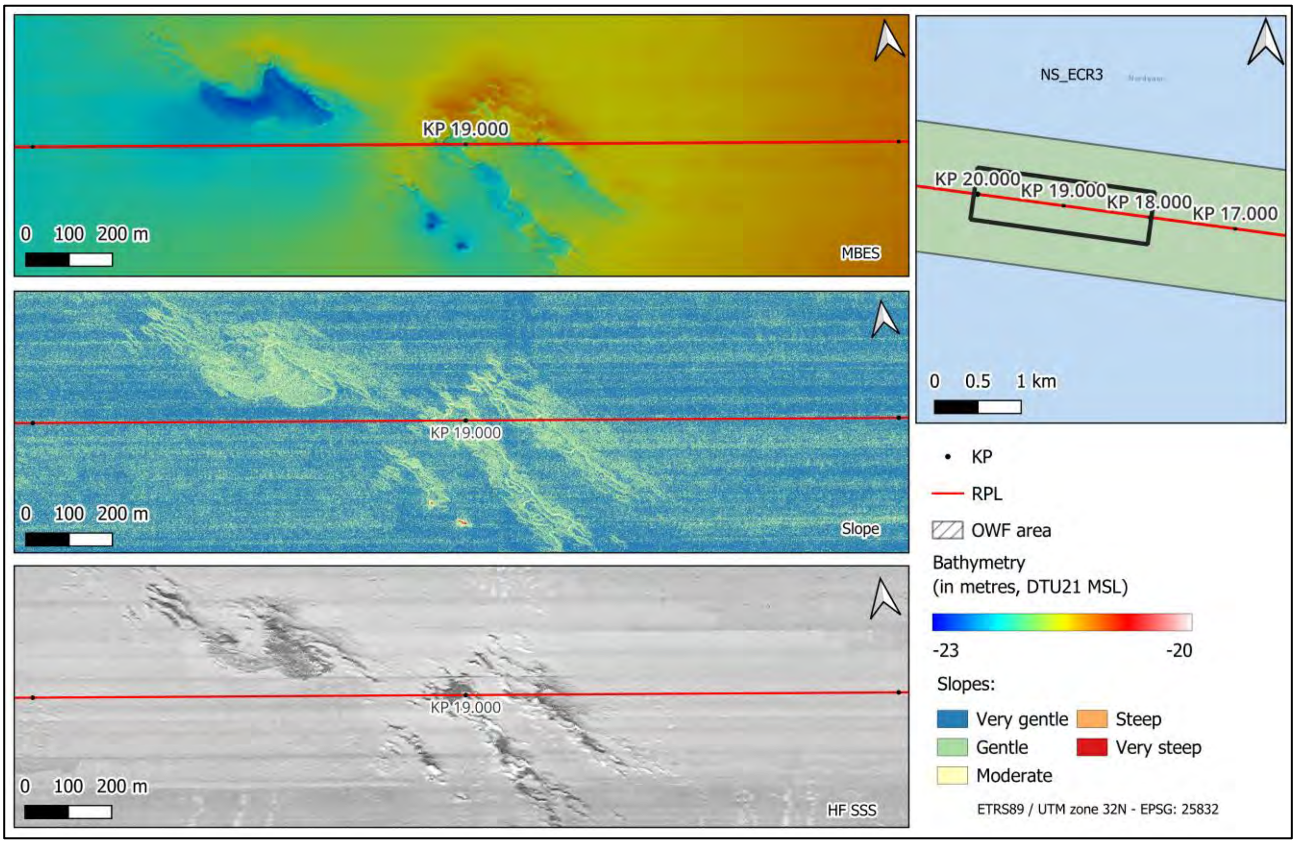


Figure 177: NS_ECR3, MBES, slope, HF SSS near KP 19.000

Figure 178 displays overall slope overview with inset maps:

A – changes in slope corresponding to ripple and large ripple areas

B – changes in slope corresponding to ripple and large ripple areas

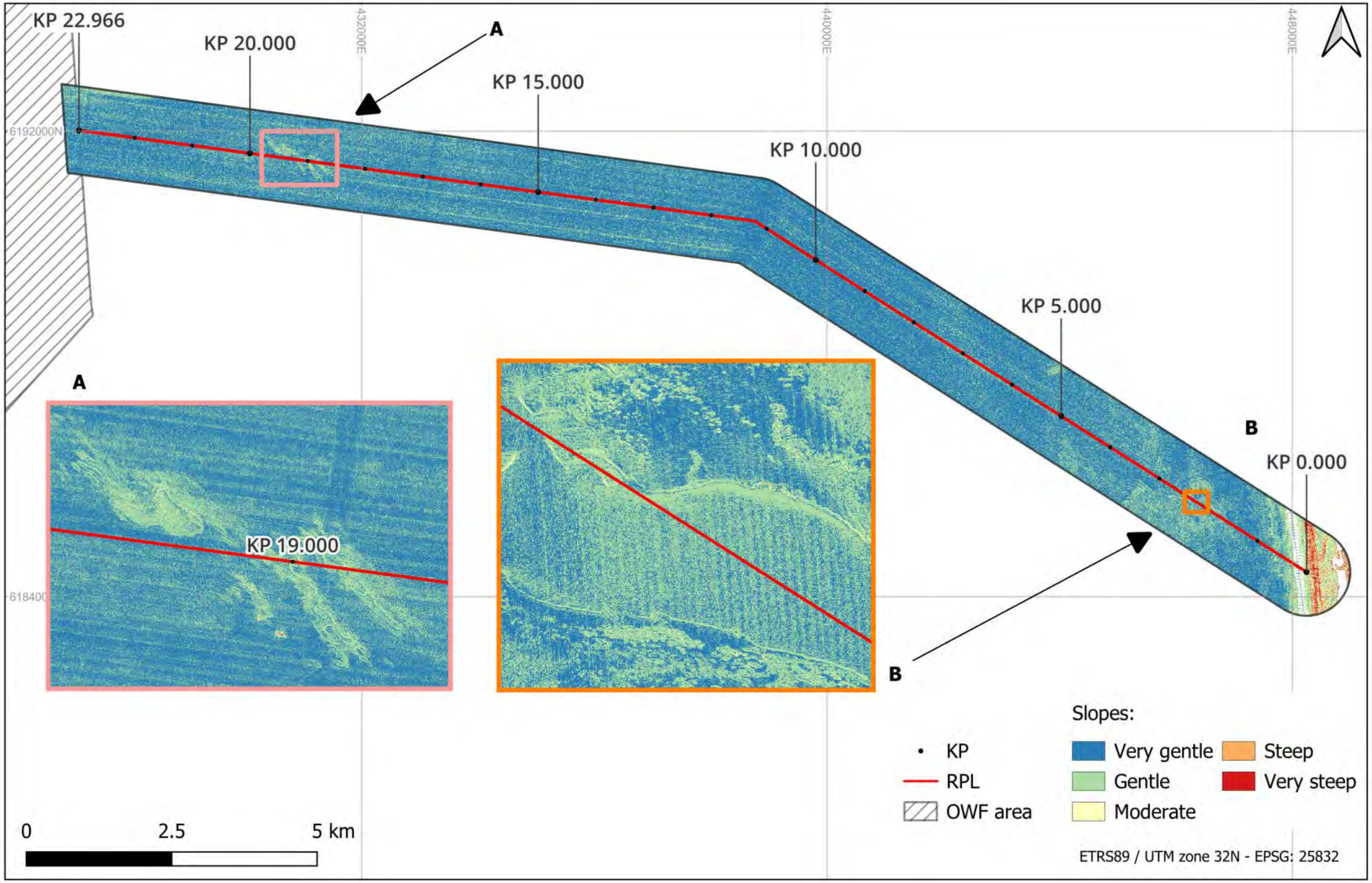


Figure 178: Slope overview of the NS_ECR3 route

10.3 SEABED SURFACE GEOLOGY

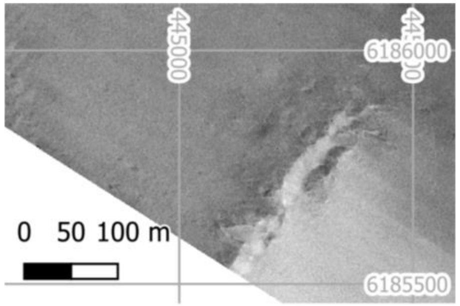
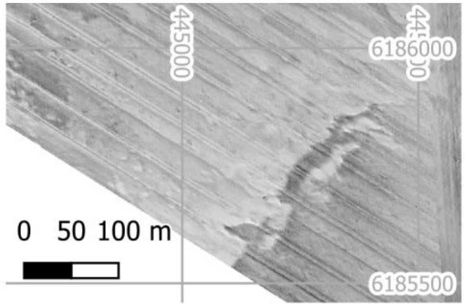
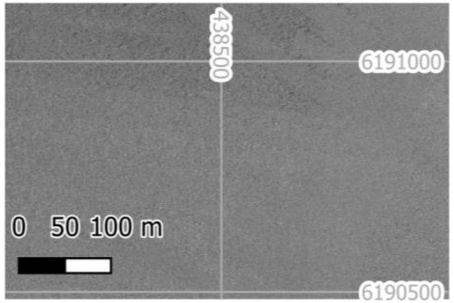
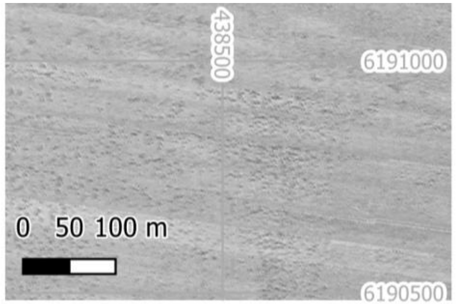
The seabed geology for NS_ECR3 site was evaluated from the interpretation of the low and high frequency SSS data, the backscatter imagery and the MBES dataset. Data analysis and classification was performed using the seabed acoustic characteristics, such as reflectivity and backscatter strength, as well as the seafloor relief and the overall pattern. During the interpretation of the SSS data, higher reflectivity areas – higher intensity sonar returns (darker grey to black colours) have been related to relatively coarse-grained sediments and lower reflectivity areas – lower intensity sonar returns have been related to relatively fine-grained sediments (Table 80). Bathymetric data aided the interpretation mainly in outlining of possible outcrops and the boulder field delineation. GEUS terminology was used to define the identified seafloor sediment in the survey area. As detailed in section 5.8.5, GEUS terminology was used to define the identified seafloor sediment in the survey area.

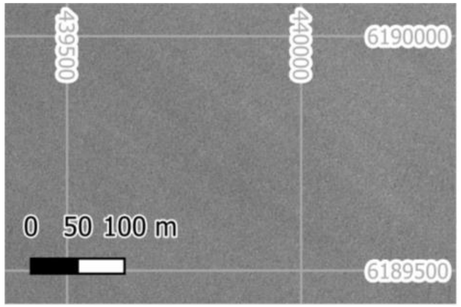
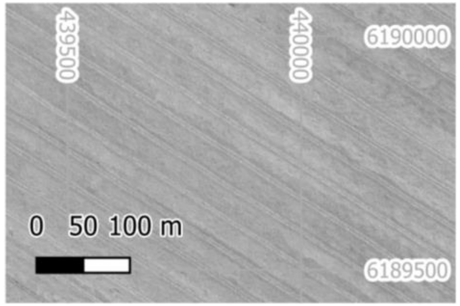
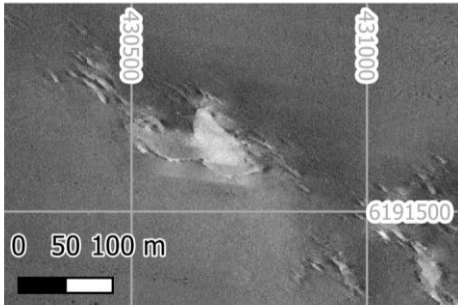
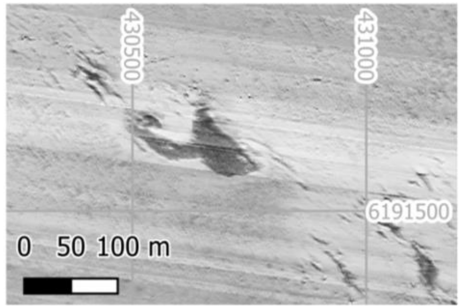
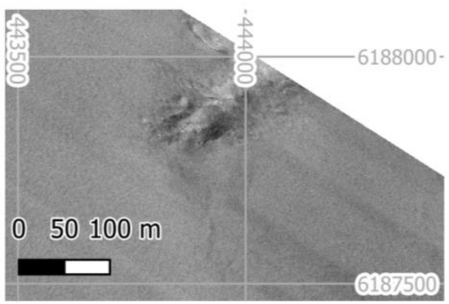
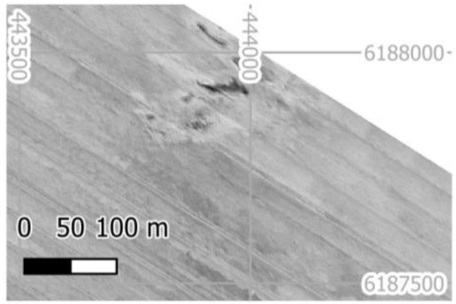
The resultant seabed surface geology has been correlated to the soil description of the surficial grab samples and the onshore laboratory results. Field descriptions of the grab results were in accordance to DGF however the laboratory analysis, the definition of the particle sizes followed the Wentworth scale (Figure 55) in accordance to BS EN ISO 17892-4. Seabed geology was also correlated to Vibrocore Top Geology (seabed) results.

It should be noted that not only the grab samples (that might not be representative of the entire area outlined), but also SSS reflectivity, MBES relief, backscatter data, sub-surficial geology and the EMODnet classification have been considered for the Geology polygons.

Finally, seafloor sediment classification has been integrated to the sub-seabed geology data.

Table 80: Acoustic characteristics of the sediment types within NS_ECR3

Geological interpretation	Colour and code	Sediment interpretation	Acoustic description	Backscatter image	LF SSS image
Mud and sandy mud	21	Predominately mud with minor to significant fractions of sand. May contain minor fractions of gravel	Low reflectivity		
Muddy sand	13	Predominately sand with significant fractions of mud and muddy sand. May contain minor fractions of gravel	Low to medium reflectivity		

Geological interpretation	Colour and code	Sediment interpretation	Acoustic description	Backscatter image	LF SSS image
Sand	12	Predominately sand. May contain minor fractions of mud and/or gravel	Medium reflectivity		
Gravel and coarse sand	11	Mixed sediment. Predominately gravel and sand. May contain mud.	Medium to High reflectivity. Patches of high reflectivity interspersed in areas of low to medium reflectivity		
Till/diamicton	41	Mixed sediment. Constituents range between mud and boulders.	Low to High reflectivity. Patches of high reflectivity interspersed in areas of low to medium reflectivity. Usually, positive relief in MBES data		

The seabed geology of the North Sea ECR3 survey area consists predominantly of sand, along with sediments such as gravel and coarse sand, muddy sand and one isolated area of till/diamicton.

The beginning of the route, from KP 0.000 to approximately KP 6.000, is dominated by a mix of sediments including sand, patches of gravel and coarse sand, muddy sand and mud and sandy mud areas. From KP 5.400 to KP 5.750 there is an isolated area of till located approximately 440m north-east of the RPL, which correlates to a boulder field area in the seabed morphology.

Between KP 6.000 and KP 10.900, sand covers the full width of the corridor, with the exception of one small patch of gravel and coarse sand just north of the RPL near KP 8.000. From KP 10.900 to the end of the RPL, the seabed geology is dominated by muddy sand and sand. The exception to this is between KP 18.750 and KP 19.850, where there are isolated patches of gravel and coarse sand near the RPL, and similarly between KP 21.600 and then the end of the route, along the northern edge of the corridor. These areas correlate with areas of large ripples and ripples.

Figure 179 displays seabed surface geology overview with inset maps showing:

A – Area of sand and muddy sand with patches of gravel and coarse sand.

B – Mix of sediments including sand, gravel and coarse sand, and muddy sand.

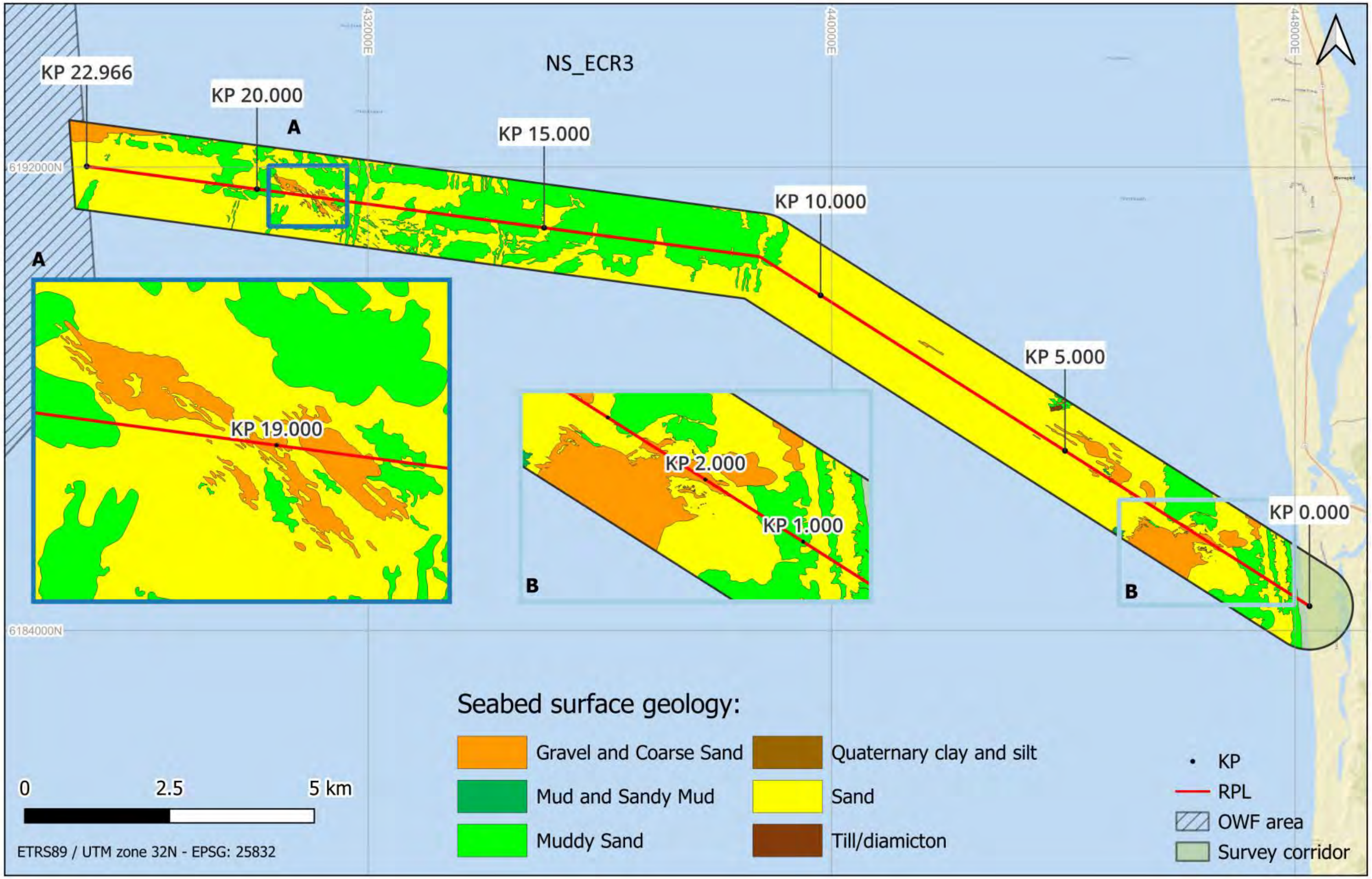


Figure 179: Seabed surface geology classification

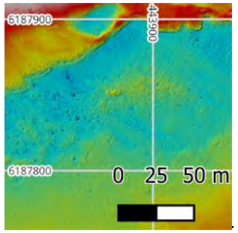
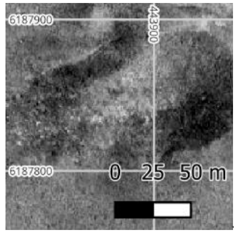
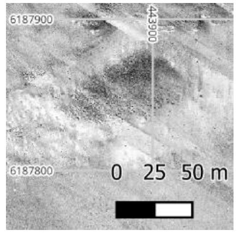
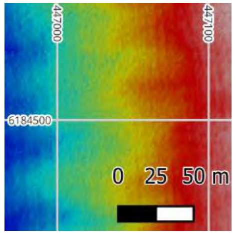
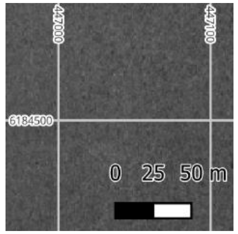
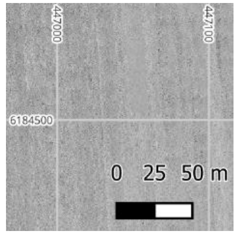
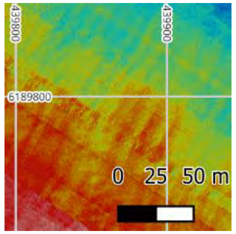
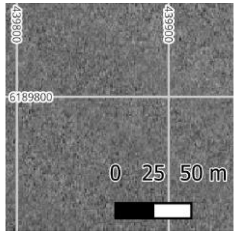
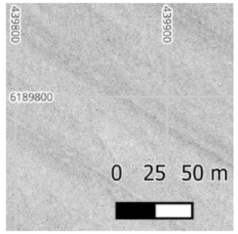
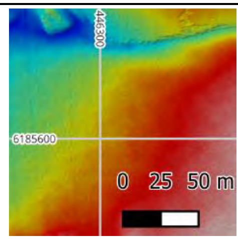
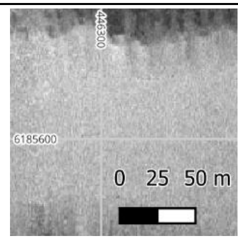
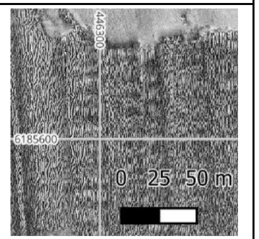
10.4 SEABED SURFACE MORPHOLOGY

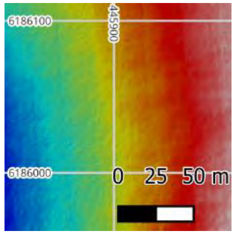
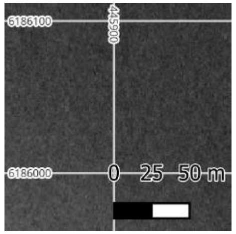
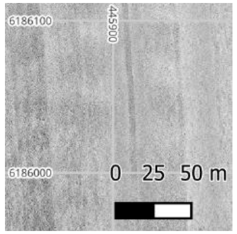
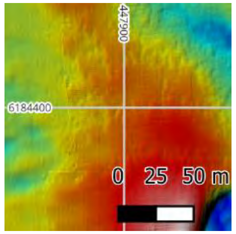
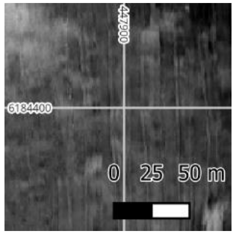
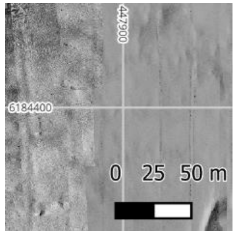
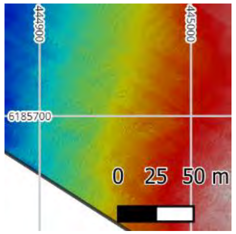
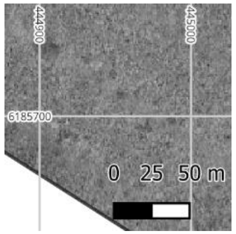
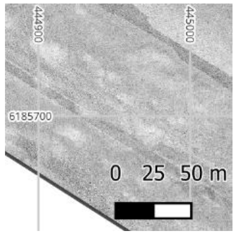
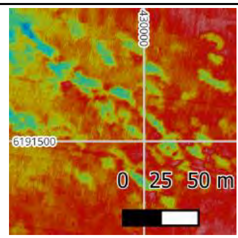
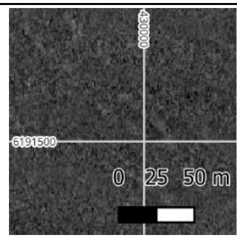
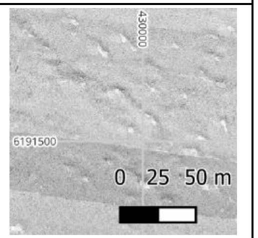
The seafloor morphology and seabed features were analysed using SSS (Side Scan Sonar), BS (Backscatter), and MBES (Multibeam Echo Sounder) datasets, with additional insights derived from SBP (Sub-Bottom Profiler) data. The acoustic characteristics of the interpreted seabed features at the NS_ECR3 site are depicted in

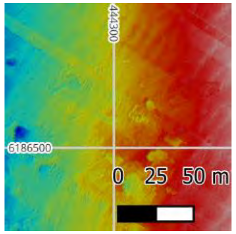
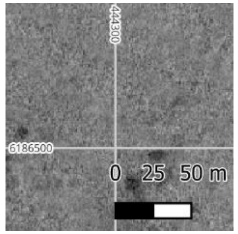
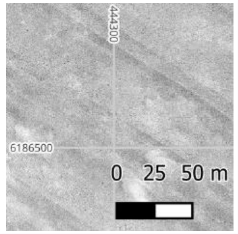
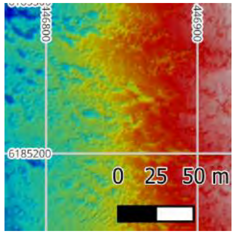
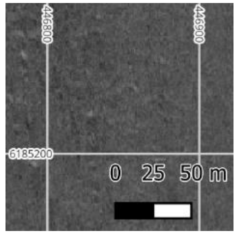
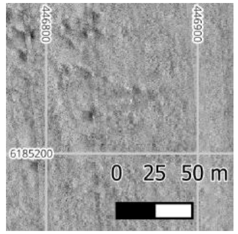
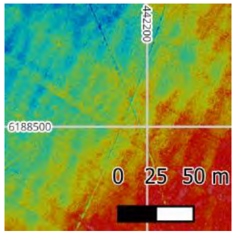
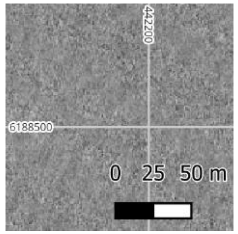
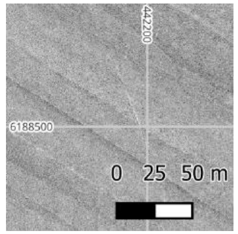
Table 81.

A variety of morphological seabed features of differing dimensions were identified. These features reflect a diverse geological environment influenced by both historical and current hydrodynamic conditions associated with sea level fluctuations (e.g., areas of boulders, ripples). Ripples were classified based on whichever of the two, height or wavelength, fall into the larger category, e.g. for example, if wavelength of the ripple was 3 m but height was 0.3 m then it was classified as a large ripple. Additionally, some features have anthropogenic origins, such as trawl marks.

Table 81: Morphological interpretation – NS_ECR3

Seabed Feature	Symbology	Description	MBES image	Backscatter image	HF SSS image
Boulder field - High density (Class 2)		High reflectivity contacts of high density (more than 20 boulders in a 50 x 50 m box), visible in MBES			
Other – Bedforms. Sediment waveforms		Low to medium reflectivity, appear as elongated area, visible in MBES. Related to sediment transport and deposition			
Other – Featureless seabed		Areas of no significant seabed features (exception of boulders)			
Ripples		Low to high reflectivity alternating areas. Clear in MBES. Wavelength (<5 m) and height <0.01m -0.1m) are the primary classifiers			

Seabed Feature	Symbology	Description	MBES image	Backscatter image	HF SSS image
Large Ripples		Low to high reflectivity alternating areas. Visible in MBES. Wavelength, 5m - 15 m, height 0.1 m - 1 m.			
Mega ripples		Low to high reflectivity alternating areas. Visible in MBES. Wavelength, 15 m - 50 m, height 1 m - 3 m.			
Unknown – Patches of lower reflectivity		Low reflectivity irregular patches, distinguishable in SSS.			
Unknown – Possible erosional bedform features		Low to medium reflectivity features formed from sediment removal. Possibly early-stage ripple formation			

Seabed Feature	Symbology	Description	MBES image	Backscatter image	HF SSS image
Unknown – Possible biostructures		Low to medium reflectivity patches, visible in MBES			
Unknown – Mottled seabed (erosional)		Low reflective, circular, raised patches of seabed, surrounded by medium reflective seabed.			
Trawl mark area		Area of linear scours caused by trawling related fishing activity			

The resulting seabed surface morphology interpretation for North Sea ECR3 is presented in Figure 180. The route does not exhibit any significant seabed features of concern, aside from the presence of one boulder field. The morphology and distribution of these features are detailed below.

At the beginning of the route until KP 0.800, the seabed is dominated by ripples and megaripples. From KP 0.800 to KP 3.000, the seabed is further dominated by ripples, large ripples and areas of sediment waveforms. This indicates dynamic areas, which are also presented within the bathymetric and slope profile in Figure 175.

From KP 3.000 to KP 6.250 the seabed is predominantly featureless, with the exception of boulders. There are also occasional isolated areas of patches of mottled seabed and areas of possible biostructures, off the RPL. From KP 5.400 to KP 5.750 there is an isolated boulder field area located approximately 440m north-east of the RPL, which correlates with an area of till in the seabed geology. An area of ripples, large ripples and erosional bedforms are also present, adjacent to the north-east of the boulder field.

Between KP 6.250 to KP 9.400, the seabed is dominated by trawl marks before becoming featureless, with the exception of boulders, from KP 9.400 to KP 10.900. The end half of the route, from KP 10.900 to KP 22.966 is dominated by a mix of featureless seabed with the exception of boulders, linear seabed scars and patches of lower reflectivity as seen on the SSS data. Between KP 18.750 and KP 19.850, there are also isolated patches of ripples and large ripples near the RPL, and similarly between KP 21.600 and then the end of the route, along the northern edge of the corridor. These areas correlate with areas of gravel and coarse sand in the seabed geology.

Figure 180 displays NS_ECR3 seabed surface morphology overview with detail views of the:

A – Areas of ripples and large ripples.

B – Areas of ripples, large ripples and mottled seabed.

Figure 181 presents the overview of the linear seabed features within the NS_ECR3 cable survey area.

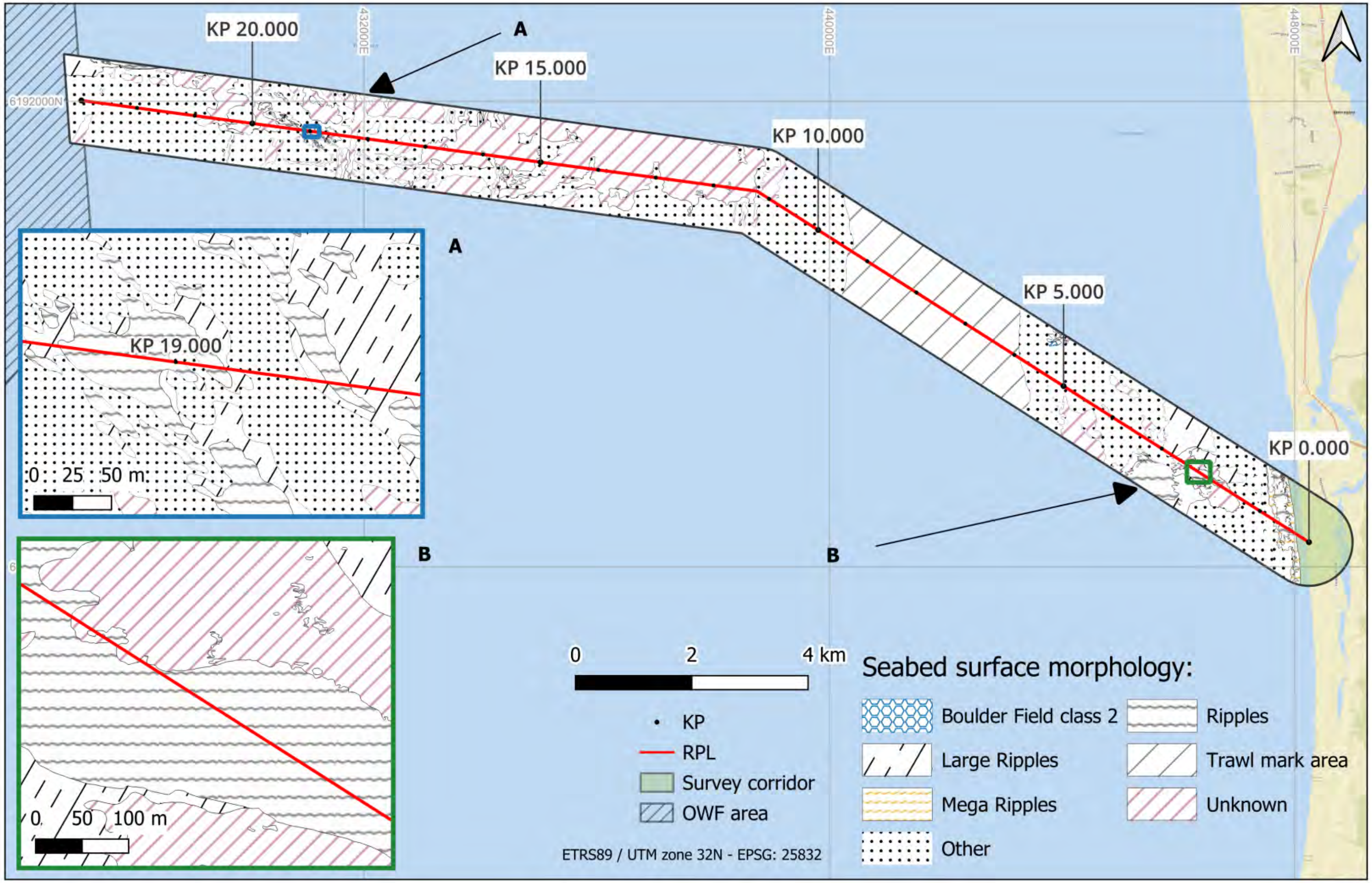


Figure 180: Seabed surface morphology overview, NS_ECR3

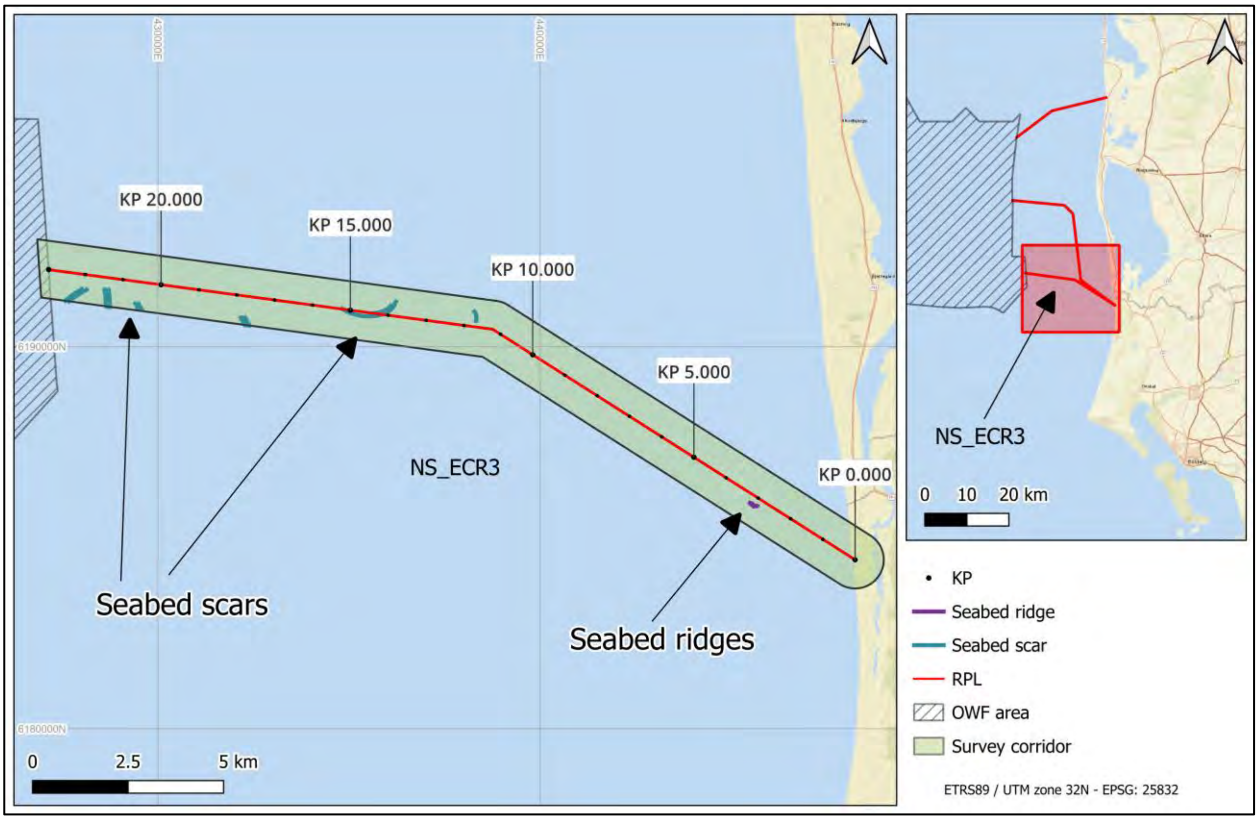


Figure 181: Seabed surface morphology overview - linear features, NS_ECR3

10.5 SEABED SURFACE FEATURES

Seabed surface objects within NS_ECR3 which are determined to be man-made objects (MMO) are outlined in Table 82 and Table 83. Table 84 outlines two debris fields which were detected within the site.

Linear features have been determined from MBES and SSS data. Point seabed features have been determined as a Master target list without the man – made object point features. Polygon features have been detected from SSS and MBES data.

A total of 23 linear man-made objects were identified through the interpretation of the MBES, SSS, and MAG datasets. There are an additional 17 linear seabed features detected as seabed scars or seabed ridges.

A total of 447 point contacts were detected through the interpretation of the MBES, SSS, and MAG datasets within the survey area. 53 are identified within the MMO point file and 394 are identified within the seabed features point file and interpreted as boulders. It should be noted that some MMOs could be classified into more than one feature type (e.g., two objects have been classified as both linear and point contacts). Therefore, the sum of the amounts found in Table 82 and Table 83 does not amount to the total number of objects.

Table 82: Summary of linear contact man-made objects within NS_ECR3

Feature type	Total amount	Comment
Wrecks	0	No shipwrecks were detected as linear contacts.
Metallic	0	No linear objects were detected to be within a 5m radius of a magnetic anomaly.
Soft rope	18	17 free span ropes and 1 possible rope fragment were detected.

Feature type	Total amount	Comment
Other contacts	3	1 debris and 2 linear objects were detected.
Cable/pipeline	2	2 cable crossings were identified.

Table 83: Summary of point contact man-made objects within NS_ECR3

Feature type	Total amount	Comment
Wrecks	1	One wreck was identified on site.
Metallic	10	10 sonar contacts were found within a 5 m radius of a magnetic anomaly, with one of these possibly associated with the wreck.
Anchor	0	No anchors were identified on site.
Soft rope	18	17 free span ropes and 1 possible rope fragment were detected.
Other contacts	24	24 sonar contacts are identified to be debris.
Cable/pipeline	0	No cable or pipeline point contacts were identified on site.

Table 84: Summary of polygonal contact man-made objects

Feature type	Total amount	Comment
Other	1	1 debris field was identified on site.
Wrecks	1	The outline of 1 wreck was identified on the site.

10.5.1 Wrecks

One wreck was found south of the KP 19.013. Wreck location and dimensions are displayed in Table 85. Wreck overview on MBES, HF SSS and MAG is presented in Figure 182.

Table 85: Wreck dimensions and coordinates

TargetID	Easting (m)	Northing (m)	Length (m)	Width (m)	Height (m)	KP
NS_ECR3_MMO_PTS_0031	431034	6191255	23.01	8.59	1.03	19.013

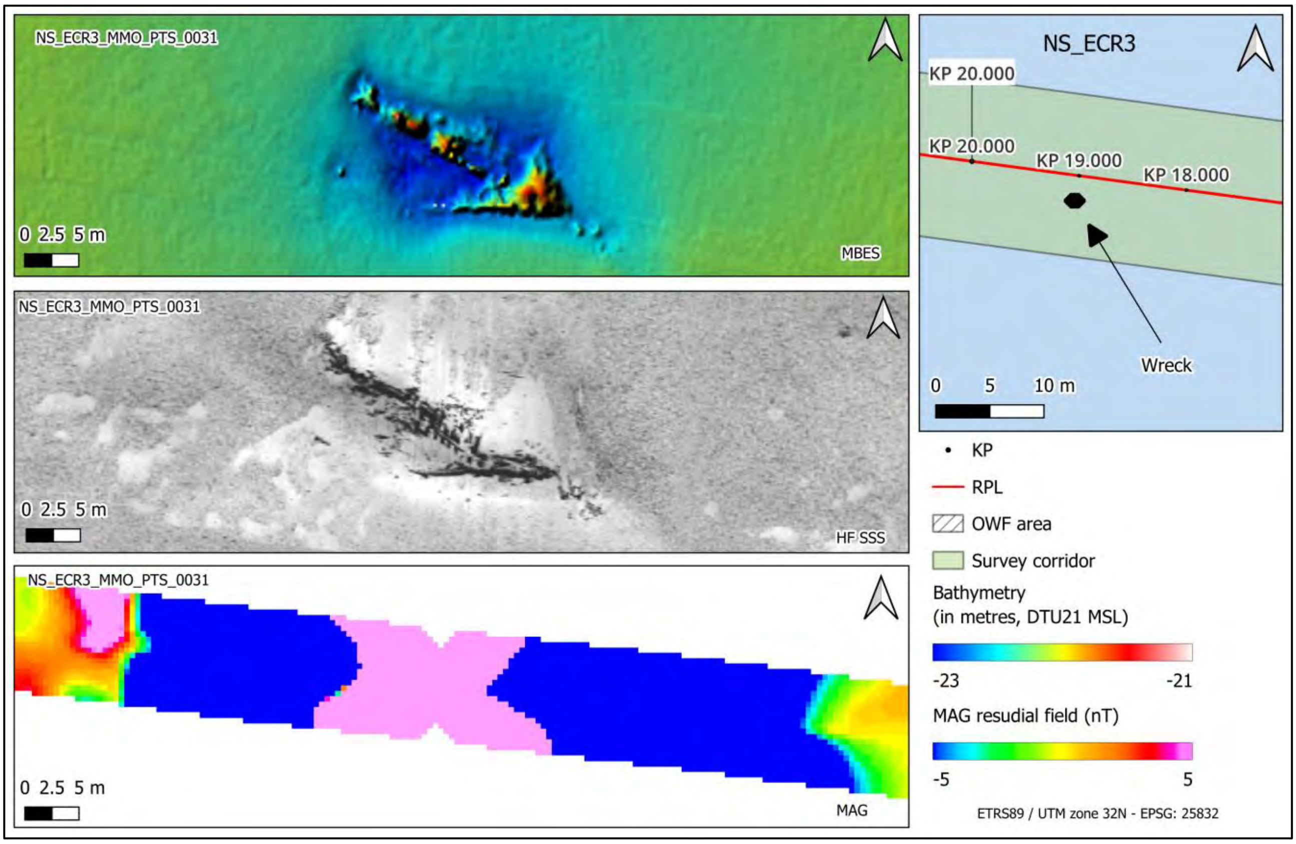


Figure 182: Wreck found within the NS_ECR3 survey area

10.5.2 Cables, wires, and ropes

There were 23 linear objects detected within the NS_ECR3 area. 18 of them are classified as soft rope, two of them are classified as cables crossing the survey area, and 3 are “other” linear objects. Cable crossings were detected in the background data, cable databases, and nautical charts. Distribution of these linear man-made objects is presented in Figure 183.

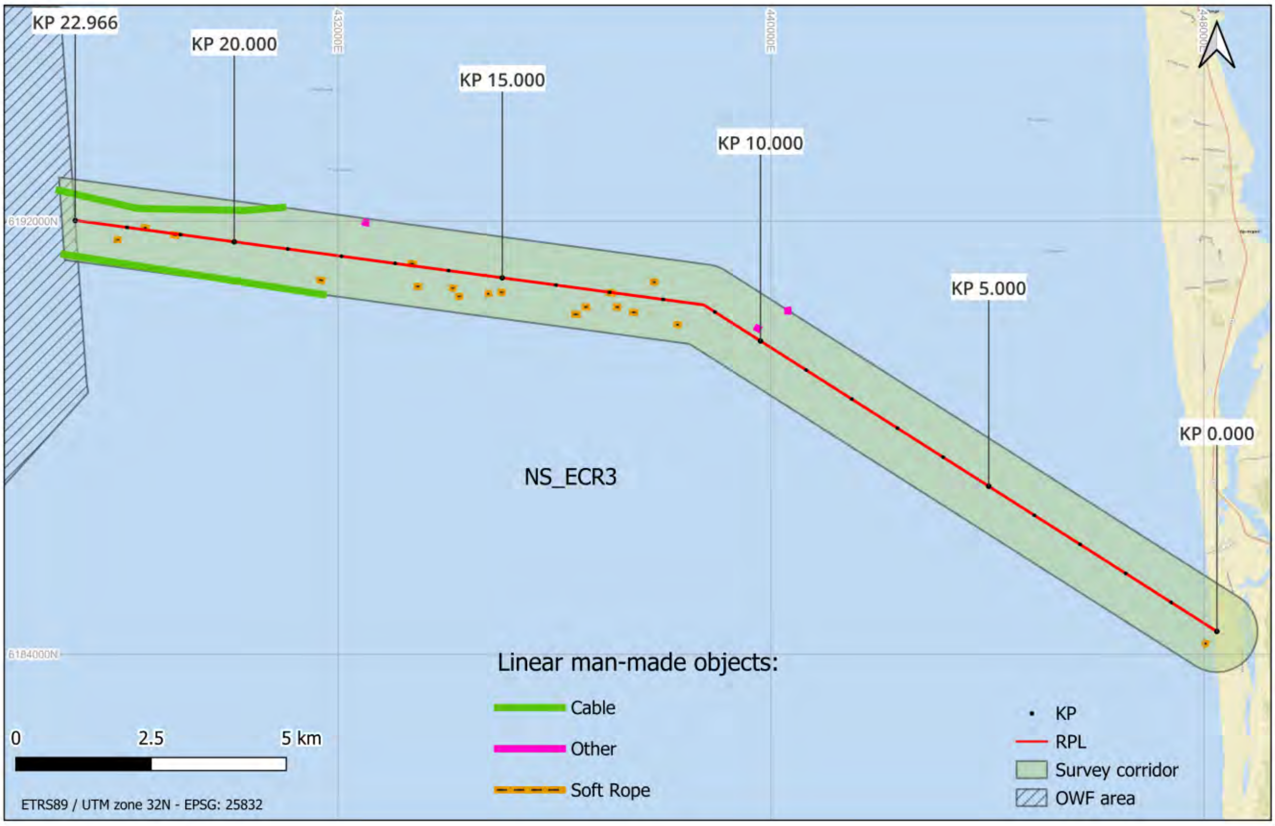


Figure 183: Overview of linear MMO found within the NS_ECR3 survey site

10.5.3 Pipelines

No pipelines were identified within or crossing the within the NS_ECR3 area.

10.5.4 Debris

An object identified from SSS and MBES, confirmed to be within a 5-metre radius of a magnetic anomaly, is classified as a metallic object. There were ten metallic objects found within the NS_ECR3 survey area, all of these had associated SSS anomalies. The distribution of the metallic objects is presented in the Figure 184.

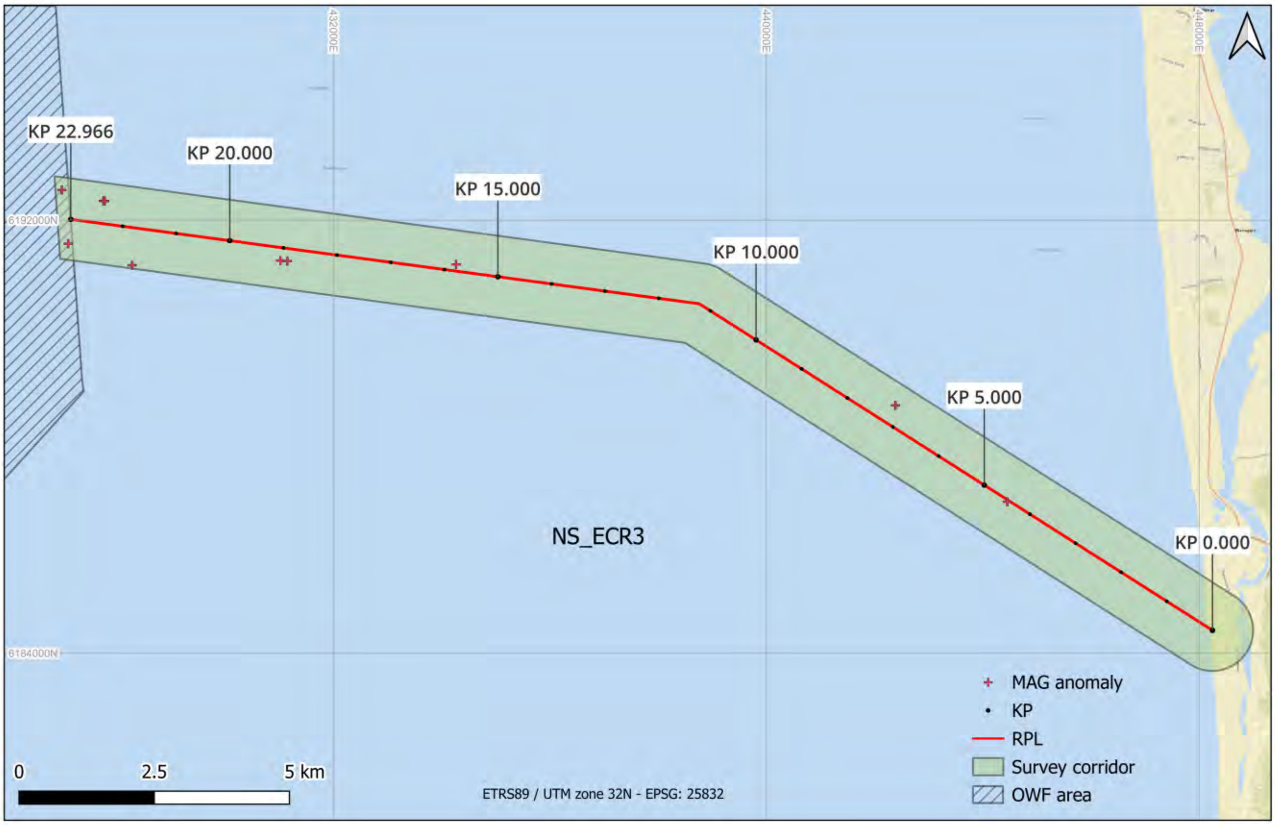


Figure 184: Overview of debris items within the NS_ECR3 survey site

An additional 24 items of the debris point contacts were observed within the site. All of these were interpreted as non-ferrous objects and detected only in the SSS data or MBES. There were also 18 soft ropes discovered. Figure 185 presents MBES, HF SSS and MAG overviews of NS_ECR3_MMO_PTS_0037 which was classified as debris and NS_ECR3_MMO_PTS_0017 classified as free span rope.

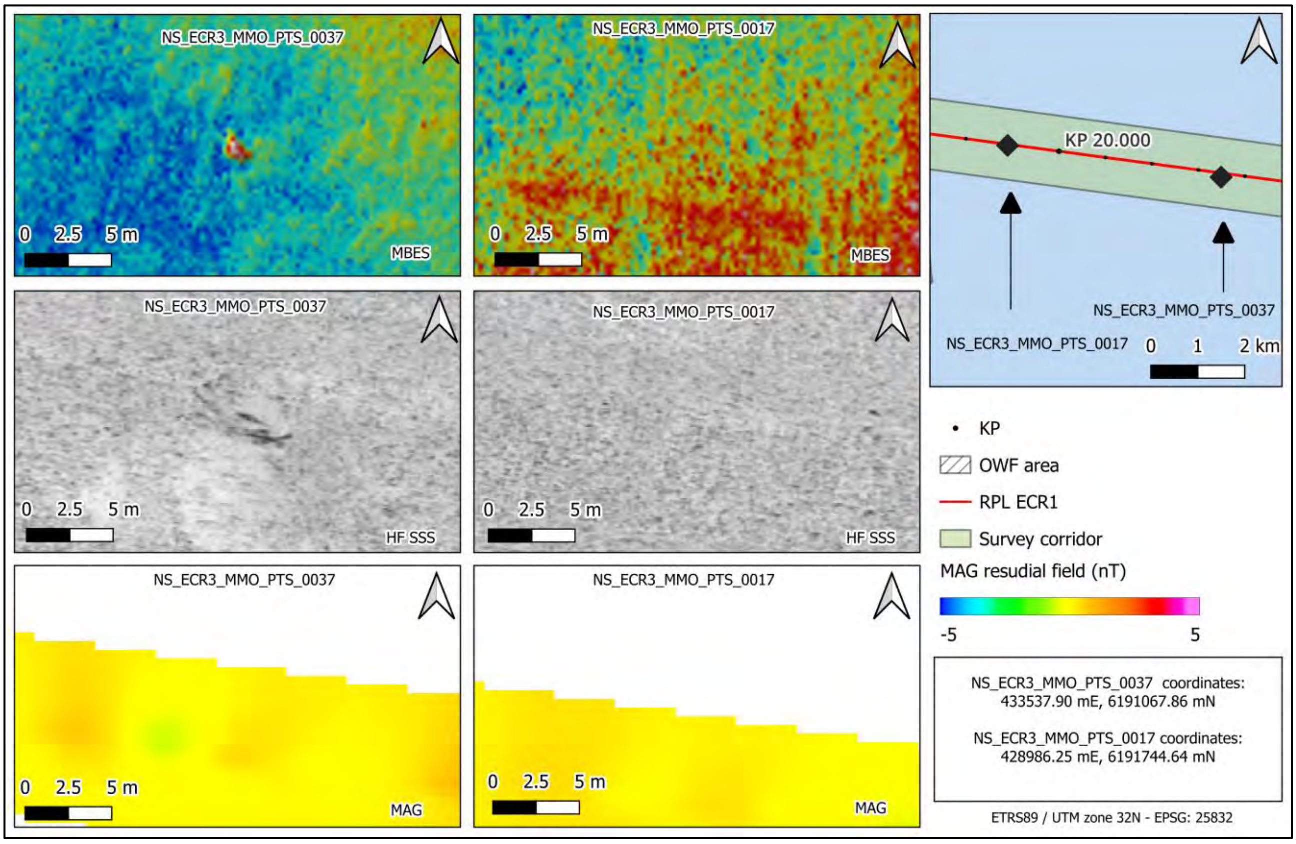


Figure 185: NS_ECR3_MMO_PTS_0037 – Debris and NS_ECR3_MMO_PTS_0017 - Free span rope

10.5.5 Items related to fishing activities, and seabed disturbances

Trawl marks, seabed scars, and ropes identified within the NS_ECR3 cable survey area are highly likely related to fishing activities.

10.5.6 Archaeological findings

No anthropogenic contacts identified have been associated with archaeological significance within the NS_ERC3 site.

GEOxyz is not specialised in providing archaeological services. As such, the findings in this report are based on an interpretation of the data, which is a matter of opinion on which professionals may differ.

10.6 GEOTECHNICAL RESULTS

The following section presents a summary of the selected results from the geotechnical investigation conducted along the route.

Figure 186 and Figure 187 illustrate the locations of VC and CPT measurements, along with the achieved penetration depth.

Figure 188 to Figure 190 display the sample analysis results for each vibrocore, including:

- Description of the soil type
- D50 percentile value

- D90 percentile value
- Bulk density
- Water content

Figure 191 presents the cone resistance and friction resistance measurements for each CPT location along the route.

In Figure 192, the percentage of clay and the thermal resistivity values along the route are presented.

A detailed account of the geotechnical dataset can be found in the geotechnical report. For full access to the results from the geotechnical investigation, please refer to the external document provided in Appendix C.

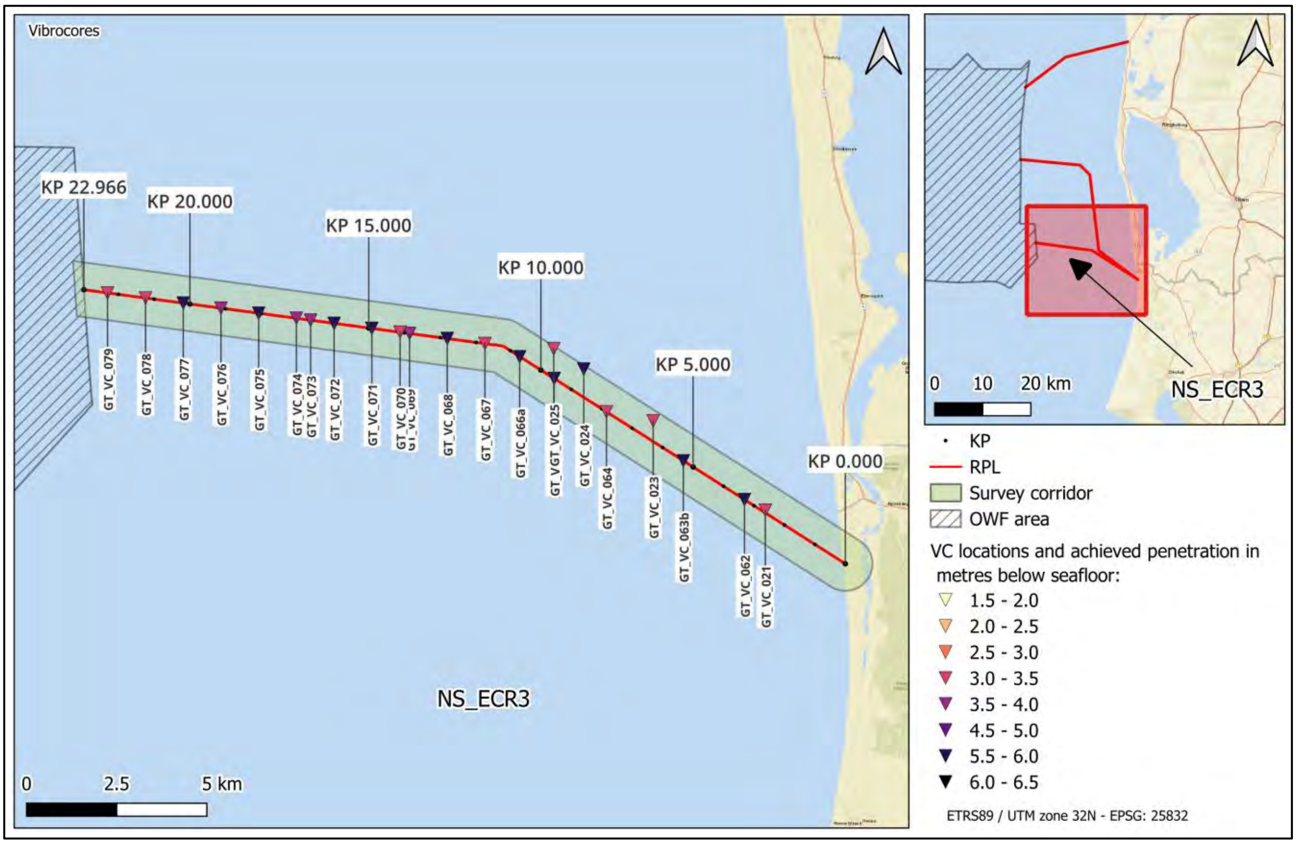


Figure 186: VC locations overview with achieved depths below seabed

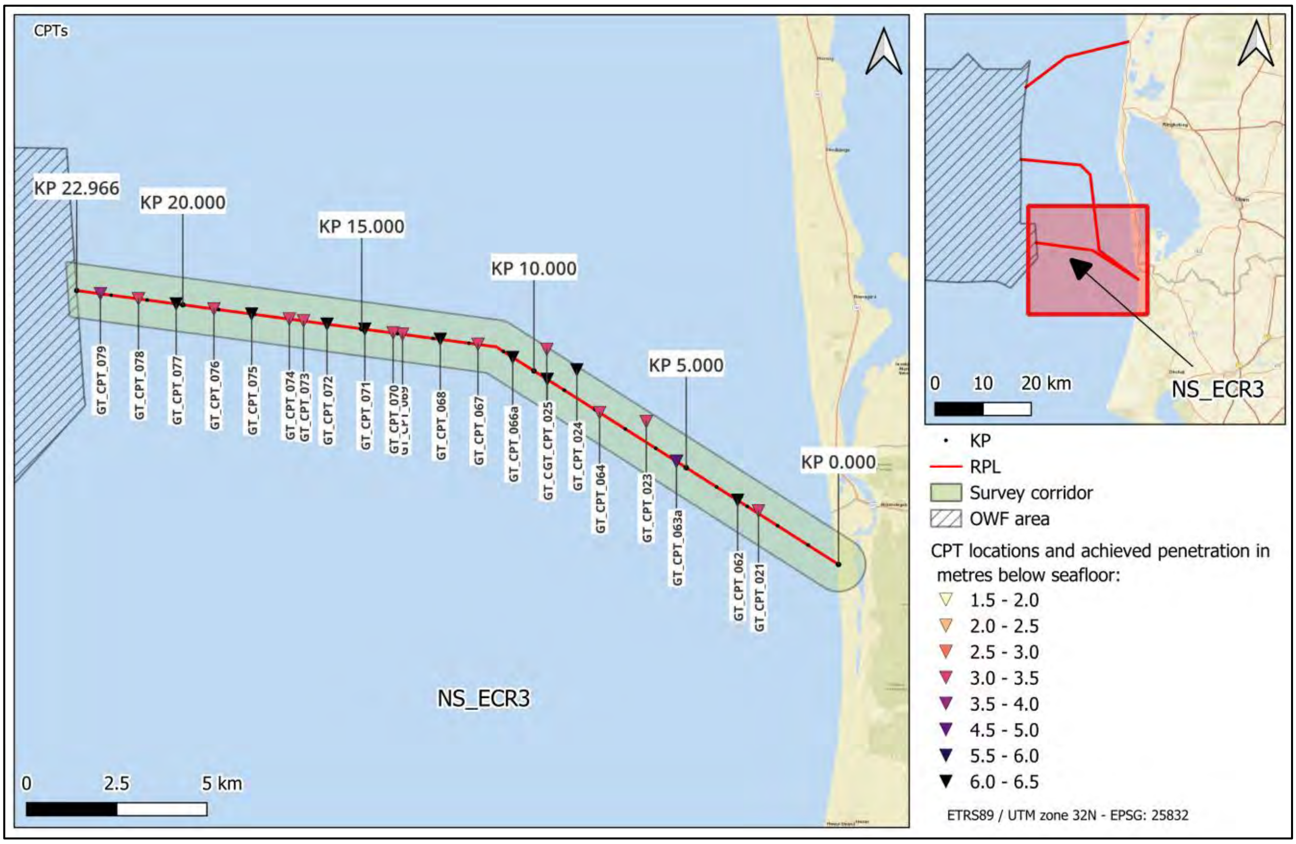


Figure 187: CPT locations overview with achieved depths below seabed

10.6.1 Particle size distribution and soil type analysis

Visual and PSD analyses of VC samples (Figure 189) reveal sand as the dominant soil type across the NS_ECR3 route. Clay was recovered between GT-065 and GT-068, where it is capped by a medium bed of silty fine sand. Thin to medium beds of gravel were identified from GT-021 to GT-063, and a medium bed of till was recovered below 2 mbsb at GT-064.

Similar to the previously described route, two distinct sand types—clean fine to medium sand and silty fine sand—were identified along NS_ECR3, based on PSD results. Clean sand is predominantly present on the eastern side of the route (from GT-021 to GT-064) and at GT-071, where comparison between D50 and D90 highlight presence of gravel higher than 10%.

10.6.2 Moisture content, bulk density and dry density

Compared to the previously described NS_ECR1 and NS_ECR2 routes, moisture content is less variable along the NS_ECR3 route, generally ranging between 15 % and 25 %. This reduced variability reflects the lower diversity of soil types encountered in the VCs, which are generally sand dominated (Figure 190).

Lower moisture content values (below 15 %) were measured at GT-061, corresponding to fine to coarse clean sand with a considerable presence of gravel. This geotechnical station also recorded the lowest bulk density, at less than 1.8 g/cm³ (Figure 190).

The highest moisture content values were detected within the clay layer between VC-064 and VC-067, with an average moisture content exceeding 35 % and one measurement surpassing 75 %.

10.6.3 Thermal resistivity from TRT measurements

Thermal resistivity measurements from TRT conducted at six geotechnical stations (GT_022, GT_063b, GT_066a, GT_072, GT_075, and GT_077) illustrate the thermal response of different soil types encountered along the RPL, with values ranging from 0.27 to 1.1 mK/W. Additional resistivity values were taken as discrete samples from selected vibrocore core samples. The lowest thermal resistivity values (<0.3 mK/W) were recorded on GT_066a and GT_072, correlating where soil types were fine to medium gravelly SAND. The highest thermal resistivity values (>1 mK/W) were recorded by a discrete lab test on GT_078 where organic peaty sands were observed in the vibrocore sample.

Generally, the near surface (<1 m below seabed) TRT and lab resistivity showed low resistivity (<0.5 mK/W) in the near surface due to the sandy and loose nature of the upper post glacial sediments, with rare deviations up to 0.7 mK/W apart from the one instance on GT_078 discussed above, where a lab test sampled thermal resistivity at the seabed at 1.1 mK/W. Increases in resistivity then occurred at depths >1 m or where post glacial sediments were thin, where clays and more compacted soils were present in the subsurface.

All in-situ and lab thermal testing have been plotted on the 3 km profile panels presented in the route analysis section.

10.6.4 Correlation between derived CPT parameters, soil types and geophysical units

Undrained shear strength and relative density data derived from CPT measurements were correlated with soil type information from VC samples, enabling further characterization of the subsurface and validation of SBP-interpreted units (Figure 193).

As with the NS_ECR1 and NS_ECR2 routes, cone resistance (Qc) is generally below 15 MPa across most geotechnical stations. However, localized areas at GT-062, GT-063, GT-071, and GT-072 show Qc values reaching 40–50 MPa. These elevated readings correspond to zones of clean, fine to coarse sand with a significant presence of gravel (Figure 189 and Figure 193). Relative density plots (Figure 193) indicate very dense sand at these locations, consistent with the observed material.

Conversely, geotechnical stations encountering silty fine sand exhibit lower relative density (medium dense to dense). In some cases, such as between GT-073 and GT-076, CPT data suggest a high silt content, which could impact drainage properties. This soil type is interpreted as alternating between relative density and undrained shear strength in CPT-derived parameters. Finally, the clay unit encountered between GT-065 and GT-068 is characterized by high to very high undrained shear strength (Figure 193).

Horizon H10, derived from SBP interpretation, separates Holocene post-glacial sediments (Unit I) from periglacial sediments (Unit II) (see Section 010.7). This boundary is clearly identifiable from GT-023 onward, where H10 divides loose to medium-dense silty sand from more consolidated clean sand or clay. However, between GT-021 and GT-063, this limit is less distinct, as H10 intersects very dense, clean sand with no clear boundaries (Figure 193).

As noted for the NS_ECR2 route, Horizon H15 within Unit II marks the top of the clay unit encountered between GT-065 and GT-068. Lastly, Horizon H12, which does not correspond to substantial differences in soil type, strength, or density parameters, aligns with a thin (5 cm) layer of peat described in VCs at GT-071 and GT-072. In other locations, such as GT-067 and GT-068, the depths of H12 coincide with organic-rich intervals or plant material traces. This highly organic, low-density layer likely explains the presence of the horizon (Figure 193) (for more detail about the highly organic layer corresponding to H12, refer to the Geotechnical Report).

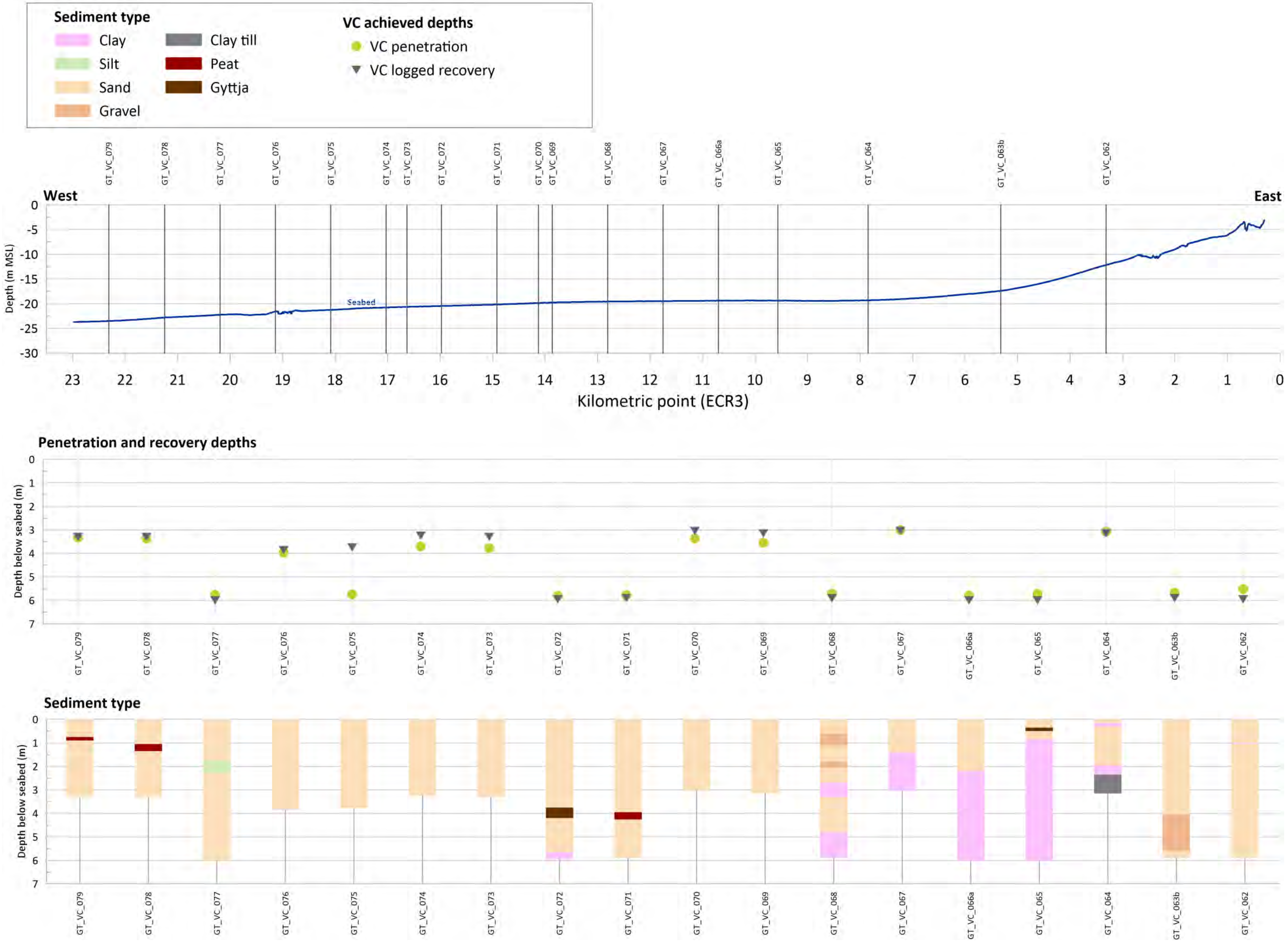


Figure 188: Sample analysis showing achieved depths and soil type distribution

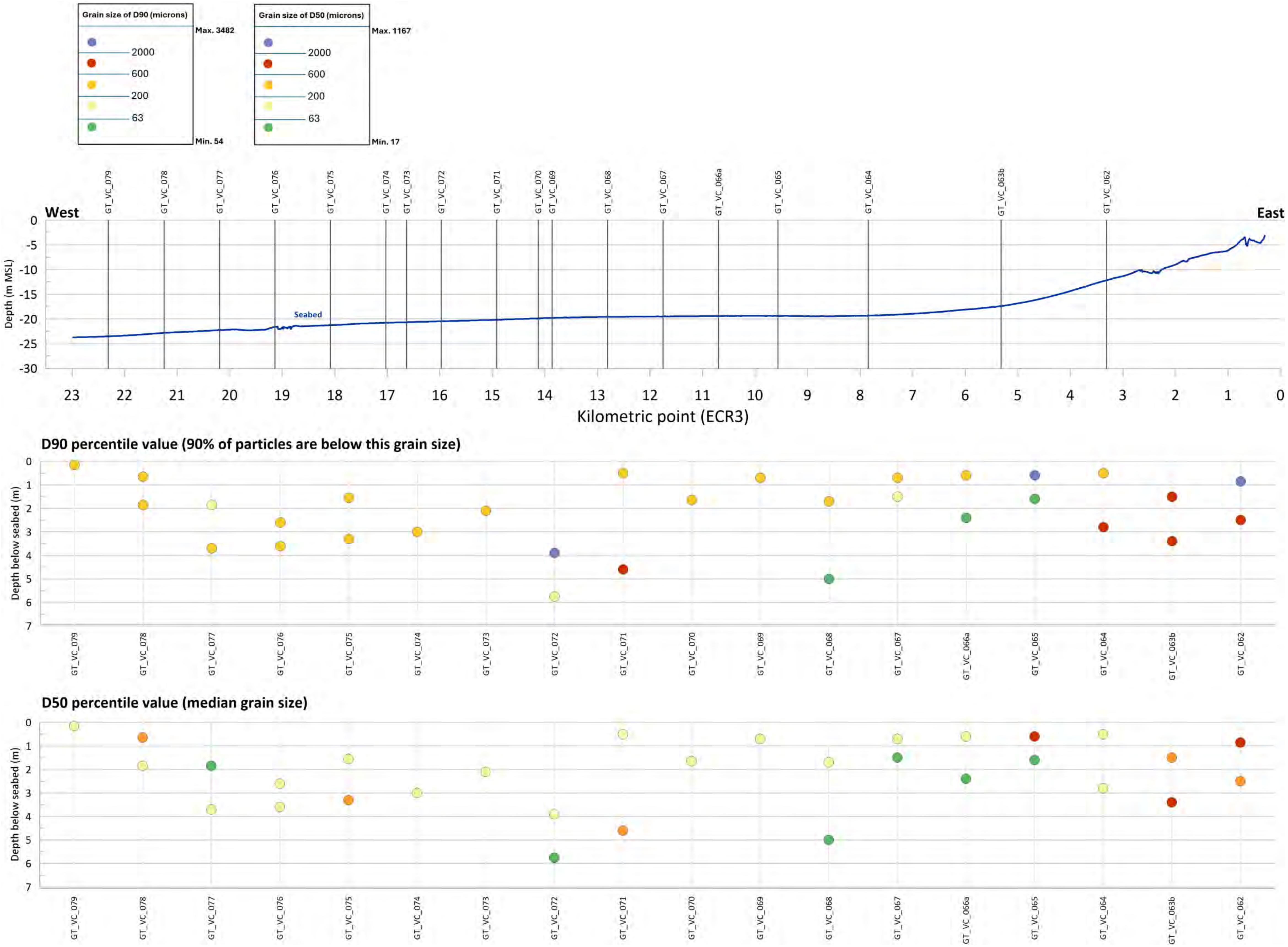


Figure 189: Sample analysis showing D50 and D90 grain size diameters

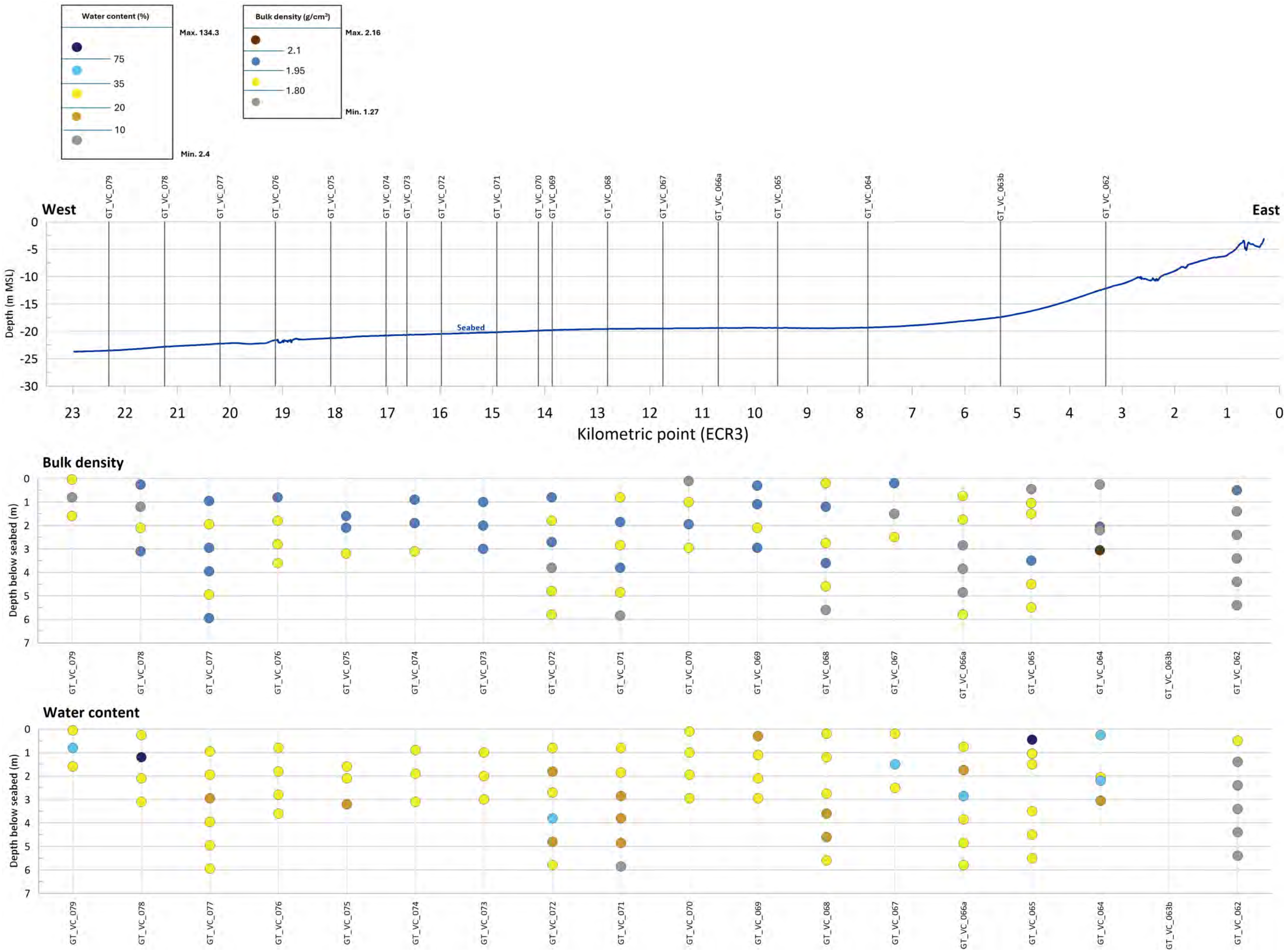


Figure 190: Sample analysis presenting bulk density (g/cm³) and water content (%)

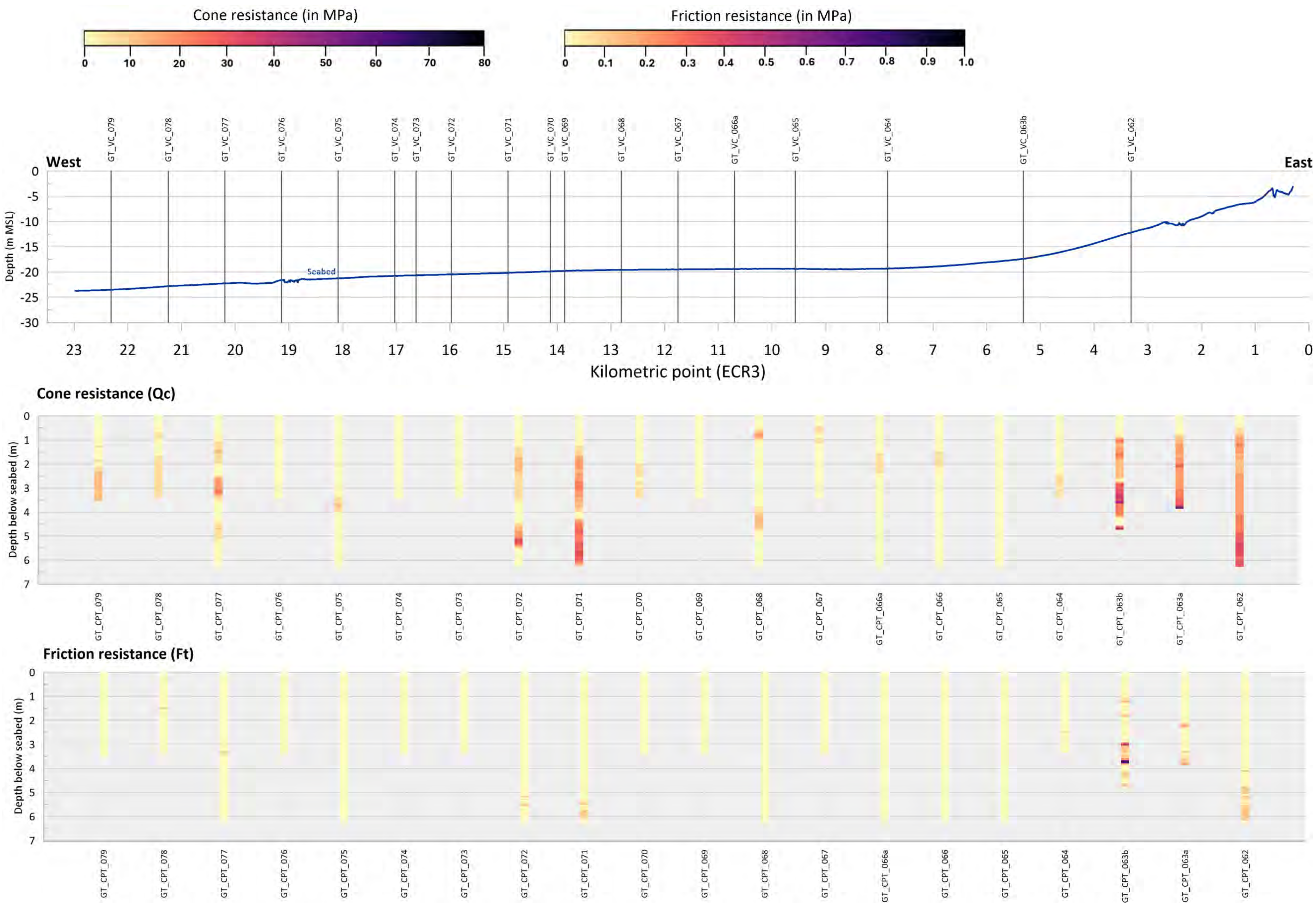


Figure 191: Sample analysis showing cone resistance and friction resistance in MPa

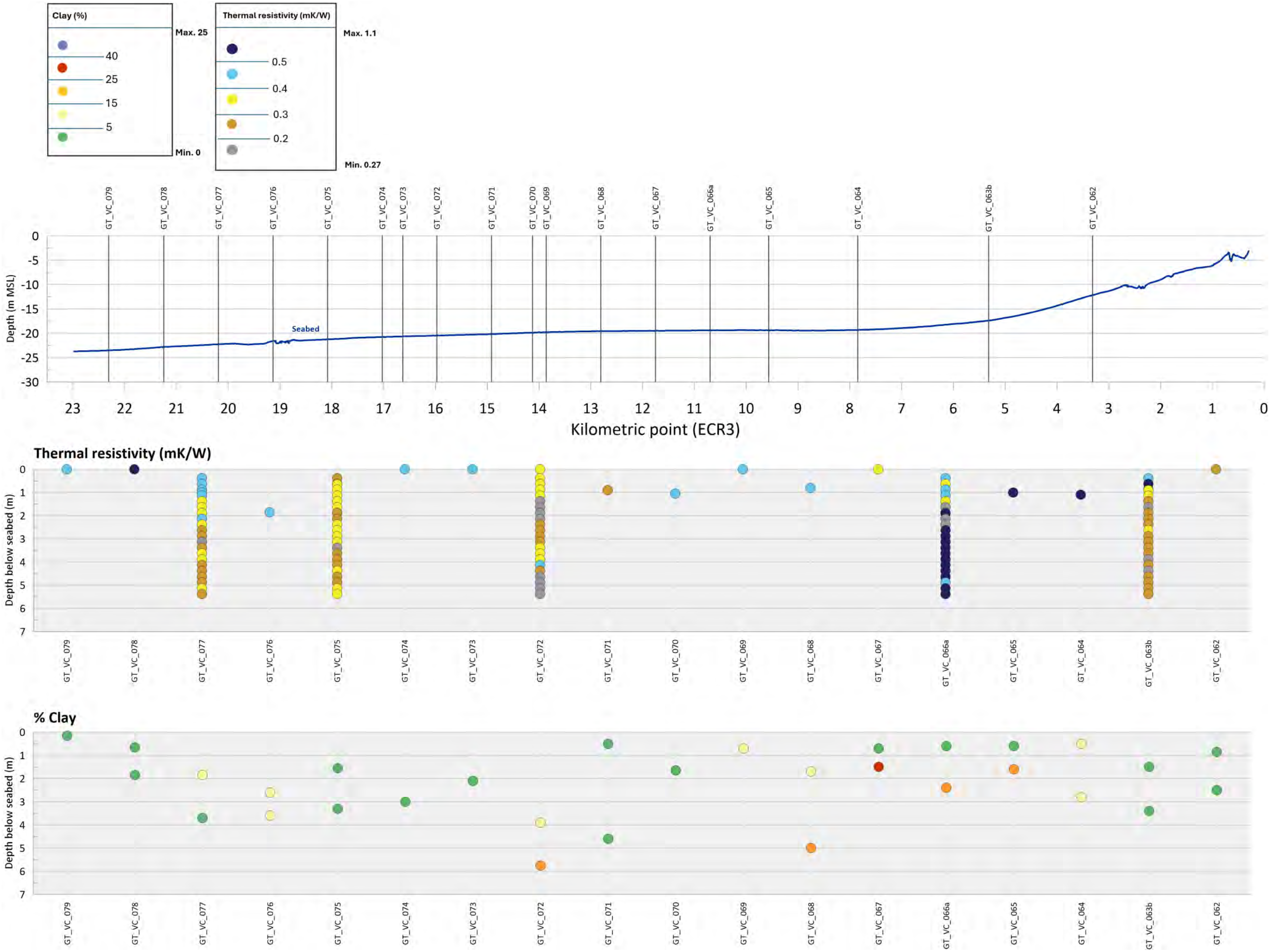


Figure 192: Sample analysis presenting clay (%) and thermal resistivity

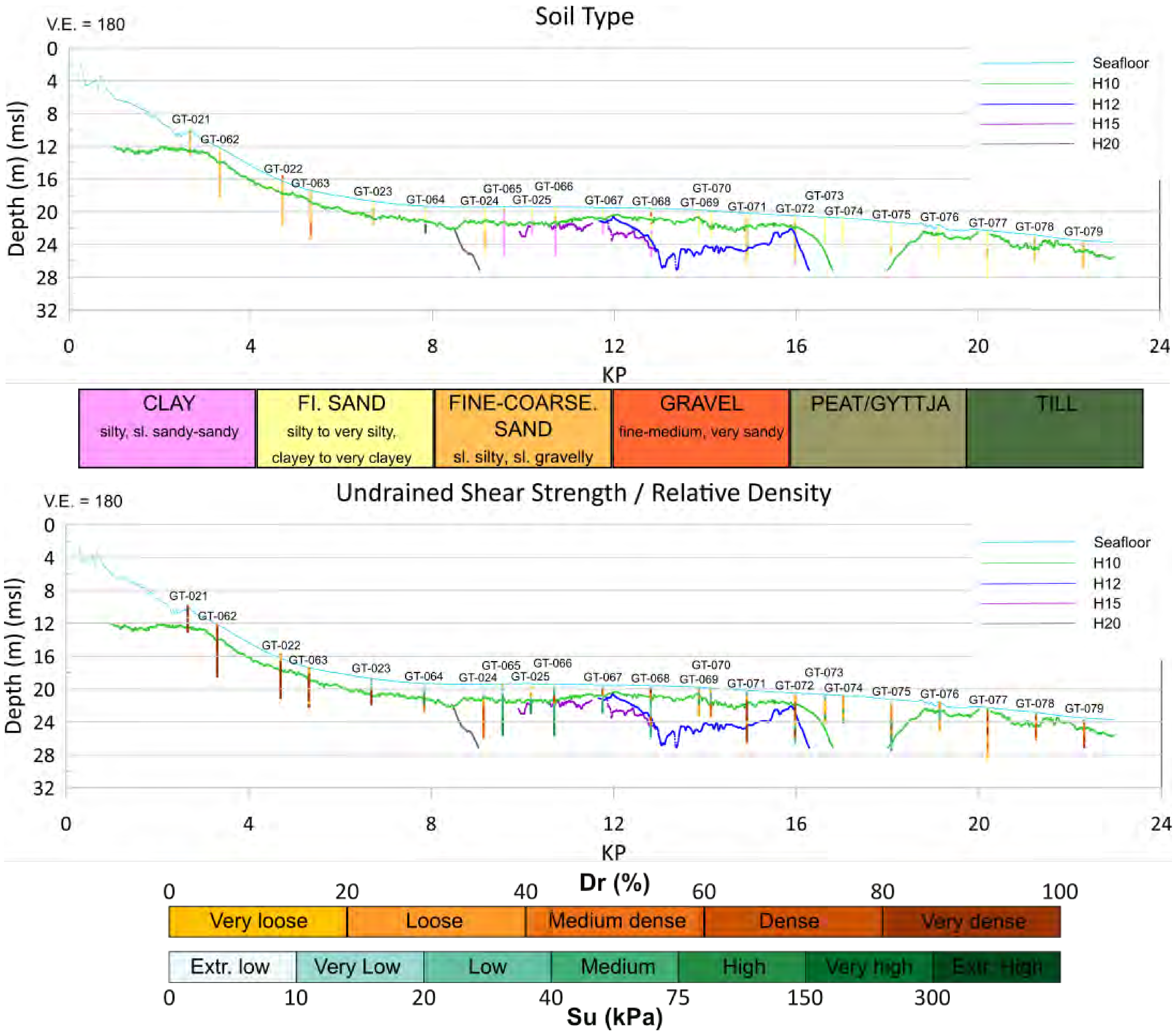


Figure 193: Soil types derived from VC and CPT data (top) and CPT parameters (bottom) compared with key horizons from SBP interpretation

10.7 SUB-SURFACE GEOLOGY

10.7.1 Regional geological history

The geological interpretation along the proposed ECR is based upon the geophysical and geotechnical datasets acquired with reference to the supplied GEUS desk study. This desk study applies a stratigraphic model developed by Jensen et al. (2002) in conjunction with archive seismic data and limited ground truth information. There is generally a good correspondence between shallow geology imaged in this project's sub-seabed data and the desk study. This project's unit names are equivalent with those in the desk study (for example Glacial deposits, GL, in this report are equivalent to glacial deposits, GL, within the desk study).

In addition, reports for the OWF have been referenced (Fugro 2024, Ocean Infinity 2024), though horizon and unit naming are not in complete agreement.

In overview, the area has a glacial to post-glacial sequence of relatively recent post glacial sediments over much older bedrock. Only the upper post glacial and glacial deposits are discussed along the ECR as the bedrock is deeper than the installation zone of interest and not imaged on the SBP data.

10.7.2 Shallow geological overview

Depths quoted below seabed have been converted from time using an assumed seismic velocity of 1650 m/s which is considered suitable for the sediments present along the route.

The interpretation has been carried out based on the seismic acoustic nature of the SBP data, the adjoining Offshore windfarm survey results and report and the GEUS desk study. Geotechnical data, acquired by Geo DK were later available and confirmed the age and depositional environments of the sediments. Table 86 summarises the interpretation, geological units and depositional environments.

Table 86: Shallow geological units

Unit	Upper surface	Lower surface	Main Soil Description	Depositional Environment
I, Post Glacial (PG)	Seabed	H10	SAND with occasional GRAVEL, CLAY and GYTTJA/PEAT layers	Post-glacial marine
IIa, Late Glacial (LG)	Seabed/H10	H12	Variable, includes intervals of laminated CLAY and SAND-prone packages	Periglacial, glaciomarine
IIb, Late Glacial (LG)	Seabed/H10/H12	H15		
IIc, Late Glacial (LG)	Seabed/H10/H12/H15	H20		
III, Glacial (GL)	Seabed/H10/H12/H15/H20		Variable, SAND-prone, with CLAY and TILL locally overconsolidated	Glacial with localized direct ice contact

10.7.3 Stratigraphy and general arrangement of units

Figure 194 displays the arrangement of units along the proposed North Sea ECR3. Table 86 shows the basic characteristics of the stratigraphic units. Key surfaces are the top of Unit III (H20/H15/H12/H10/seabed) which is the top of potentially overconsolidated deposits. Sediments within Units I and II are less well consolidated, with fewer cobbles and boulders present than found in Unit III.

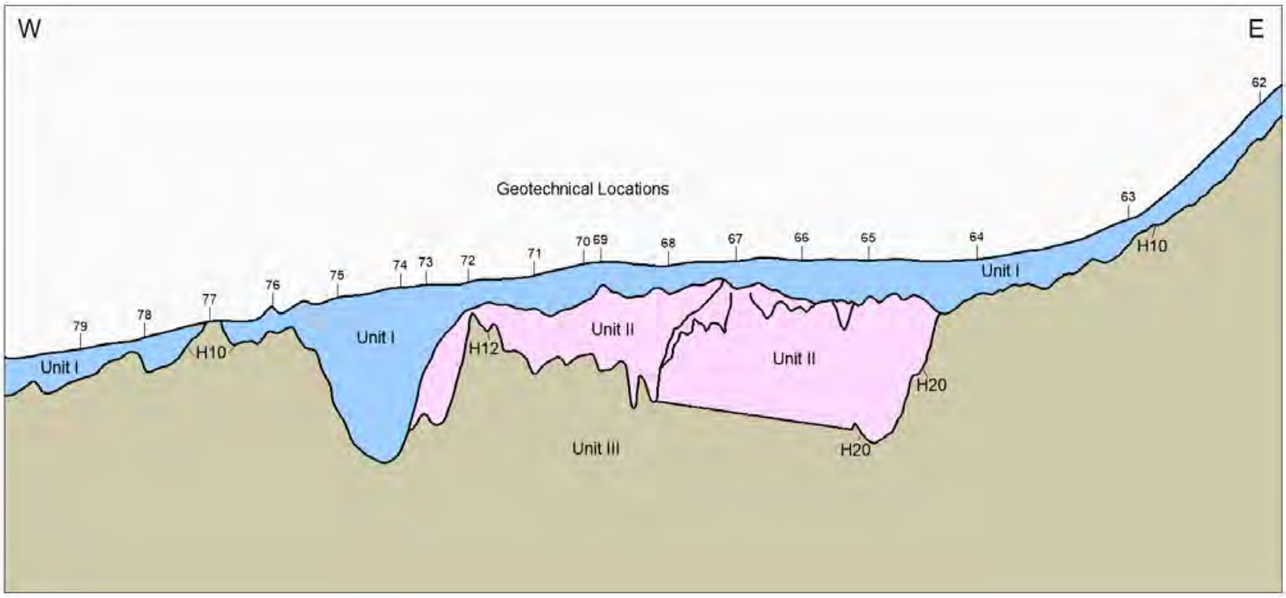


Figure 194: Geological schematic, general arrangement of units with the approximate geotechnical locations

10.7.4 Quaternary deglaciation history / stratigraphic units

These bullet points are largely derived from information in the GEUS desk study. Here the stratigraphic units have been linked to the changing paleoenvironments.

- In Denmark the Scandinavian Ice Sheet reached its maximum extent about 22,000 years BP followed by retreat with evidence for short-lived advances over the following 4,000 years. **Unit III was laid down in association with this ice sheet.**
- Marine transgression began around 18,000 years BP leading to rapid deglaciation and establishment of glaciomarine conditions. An isostatic regression occurred shortly after 18,000 years BP. This was followed by renewed marine transgression related to the wasting of the Baltic Ice Stream. **Unit II was laid down over this complex period.**
- After deglaciation the area generally experienced high-stand conditions, though glacio-isostatic rebound outstripped background sealevel rise around 11,000 years ago, driving a local regression. **Unit I was deposited in this marine environment.**

a Post Glacial geology

Unit I is a package predominantly of post-glacial SAND with occasional layers of GRAVEL, CLAY and GYTTJA/PEAT, which is less than 2 m thick over most of the route. The Post Glacial sediments are widely distributed over the cable route corridor (Figure 196), varying from absent to maximum observed thickness of 10.7m on the southern edge of the survey corridor near KP 16.5 in a northwest to southeast trending channel. It also increases in the nearshore section to approximately 6 m, and may be even thicker further inshore, but the horizon is obscured by the seabed multiple.

The geotechnical interpretation from the vibrocores is shown on the data examples and panels. These indicate a lot of lateral variation in the lithology within all of the units. Despite the seismic character being very similar, VC064 and VC066 show a 2-metre-thick package of sand, while VC065 has fine sand with a thin gyttja layer over more sand and then clay towards the base of the unit (Figure 197). The boundary marking the base of Unit I does not generally correlate with lithological changes seen on the geotechnical data, however it is predominantly sand in most of the geotechnical logs.

Likewise, further to the west of the ECR (Figure 198), VC0 72 to VC 076 all encountered sand in the geotechnical samples for all of Unit I.

Occasional pockets of peat and gyttja are observed in the geotechnical logs, but no seismic expression is noted in the SBP data.

In general, the post-glacial package consists of sand with occasional gravel and gyttja in the nearshore end of the ECR.

The base post-glacial deposits is mapped as H10. The post glacial deposits are approximately 6 m near KP 1.000, then shallow to 2.0 m at KP 2.000. It then undulates gently between 0.8 m (at KP 12.100) and 2.7 m (at KP 8.400) until KP 16.400. Unit I then thickens in a NW to SE trending channel, reaching a thickness of 8.8 m at KP 17.400 (though it deepens to 10.7 m at the southern edge of the survey corridor). The channel is approximately 1500 m wide. Beyond the channel, the unit thins to less than 1.0 m and is absent between KP 20.000 and KP 20.300, and remains less than 2 m thick until the end of the route.

Acoustically the unit displays a moderate to high amplitude with parallel bedding in places, most noticeably in the channel (Figure 198), but elsewhere, and predominantly towards the base of the unit, there is a high amplitude chaotic character.

There are very occasional bright spots which may possibly be organic material.

The location of the seismic profiles, which are presented throughout the report, are displayed in Figure 195 below.

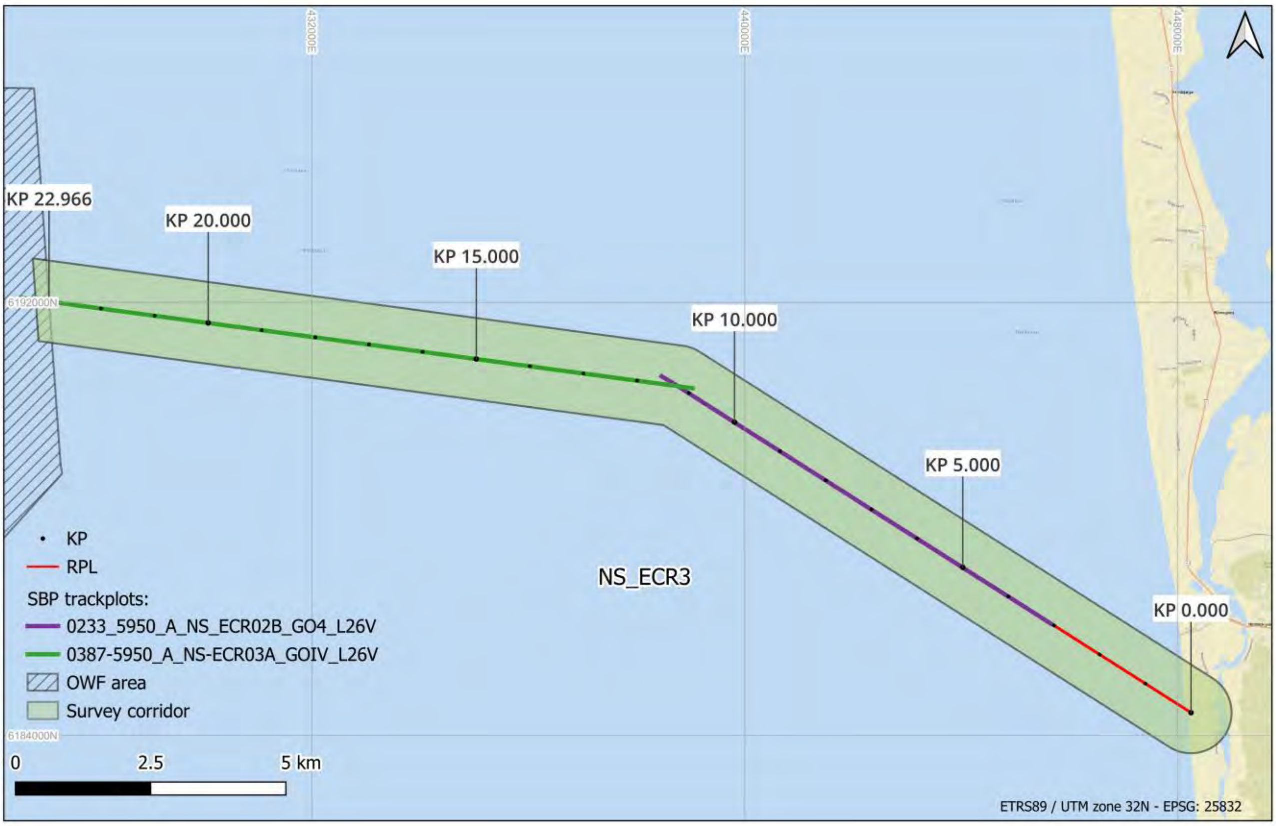


Figure 195: Location of the seismic profiles along NS_ECR3 displayed throughout the report

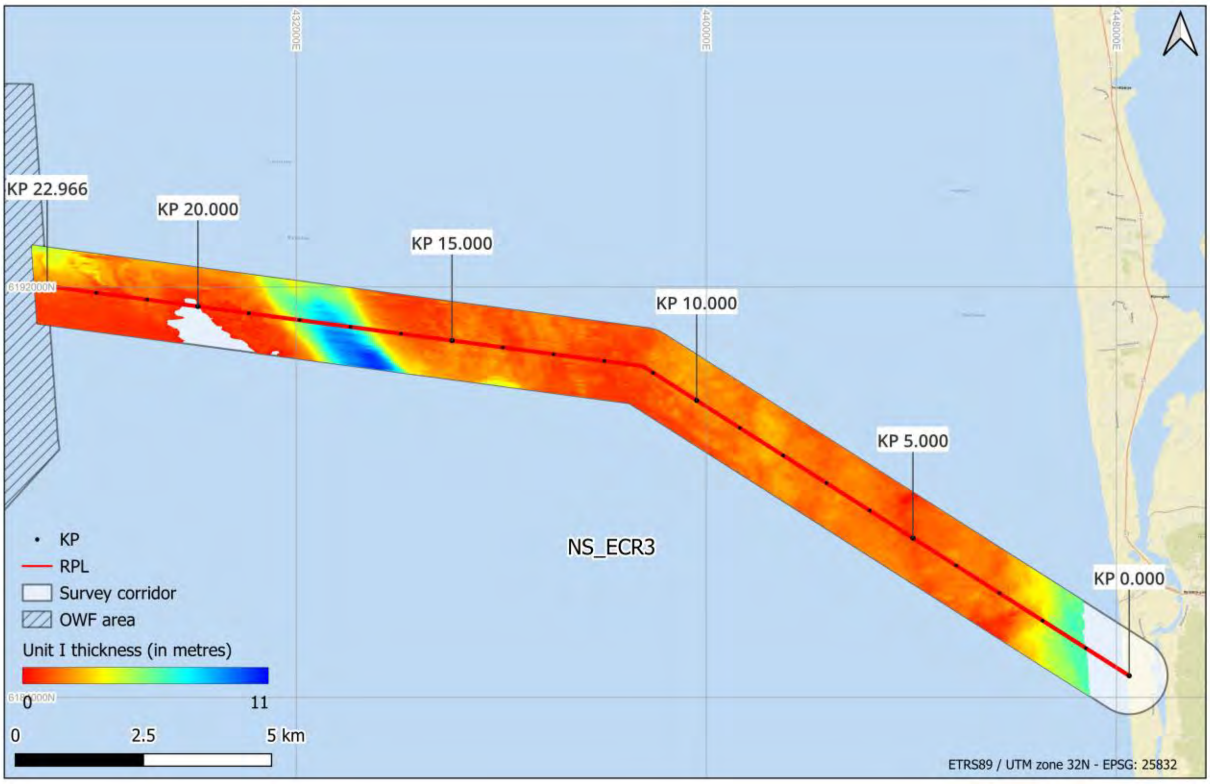


Figure 196: Distribution and thickness of Unit I

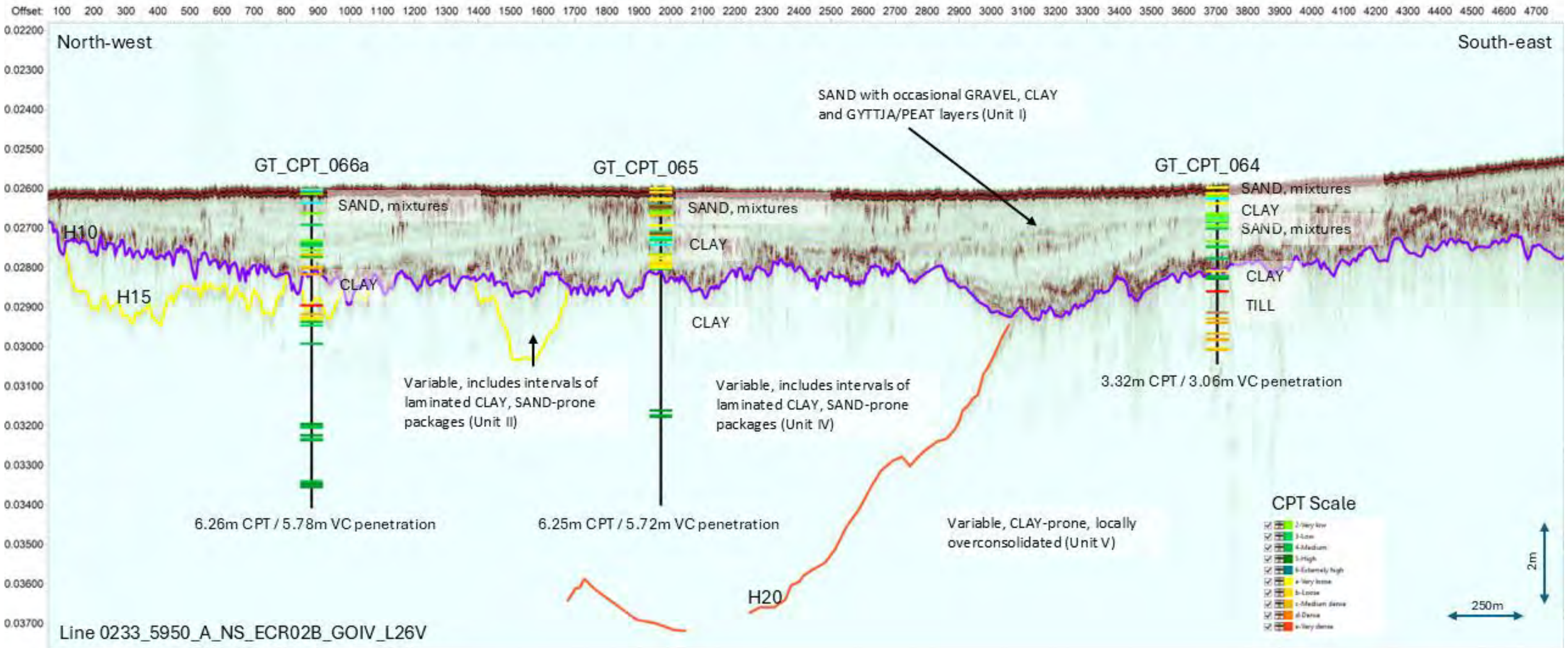


Figure 197: Seismic example displaying Unit I – VCs 064 – 066a

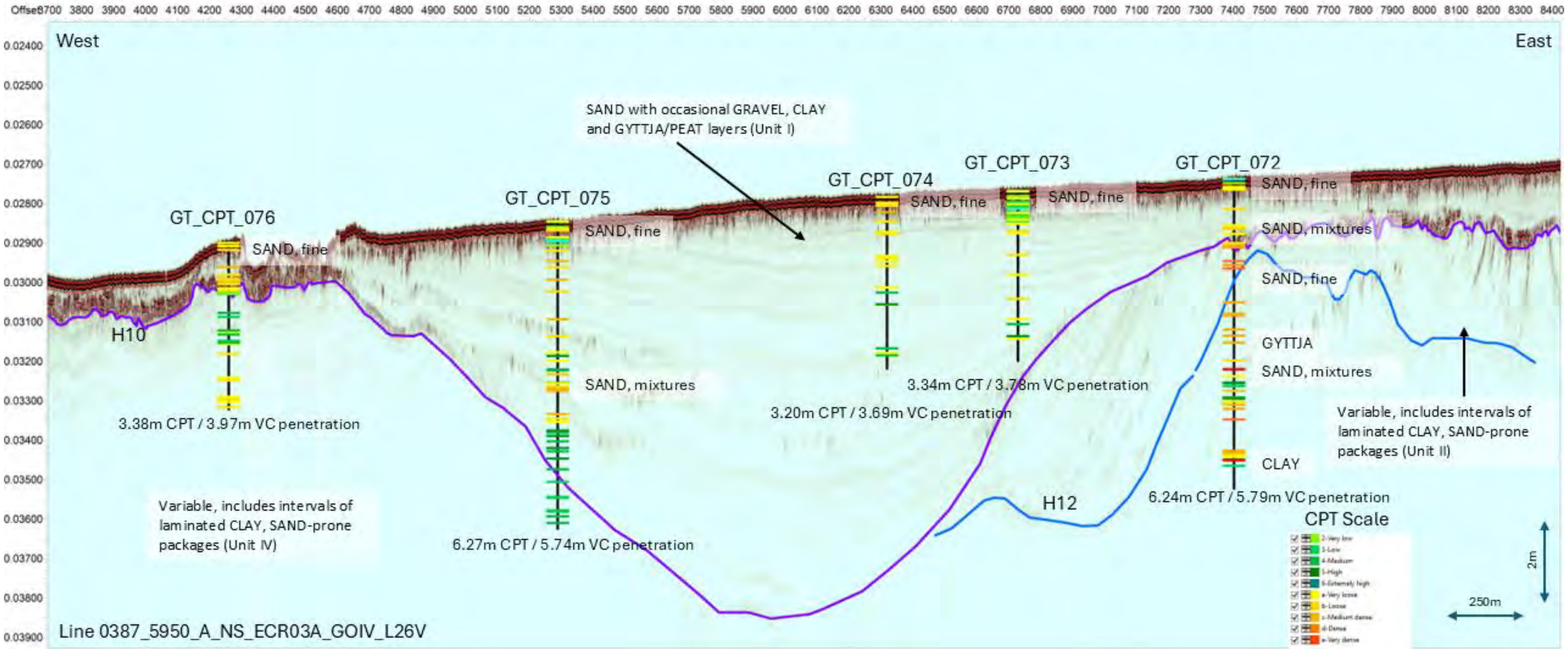


Figure 198: Seismic example displaying deep Post Glacial channel

b Quaternary geology

Unit II, Late Glacial deposits

This interval is very complex due to the area's range of environmental conditions during the Late Weichselian and earliest Holocene. Some intervals show laminations indicative of clays and silts, others may represent sandy beach-type deposits. The unit is mapped with either H12, H15 or H20 at its base, and has been sub divided into Units IIa, IIb and IIc where the seismic character has distinguishable differences. This is generally at the top of deposits which show clear signs of ice contact, true glacial deposits, or the base of clear channelling.

Along the route corridor, Unit II comprises glaciomarine sediments which infill steep sided channels eroded into the underlying Unit III tills. The extents of Unit II are shown in Figure 199 below. Geotechnical sample locations VC-065 and VC-066a are examples of locations where Unit II has been sampled. From these samples, the geotechnical properties of Unit II are expected to predominantly be silty clay.

A significant channel is present between KP 8.900 and KP 17.200. It is acoustically transparent in character and reaches a maximum depth of approximately 17 m below seabed at KP 13.200 (Unit II ~14 m thick). The edge of the channel is shown on Figure 198. Within this channel an internal reflector (H15) is present (Figure 198 and Figure 200), which corresponds to the top of a clay layer identified in the geotechnical data.

Another channel is observed between KP 12.000 and KP 17.000. The channel has a highly erosive base and the sediments are well bedded with the bedding parallel to the irregular basal reflector (Figure 200). The Unit reaches a maximum depth of approximately 7.5 m below seabed at KP 13.400 (Unit II ~6.0 m thick). Geotechnical data shows the sediments to be predominantly sand.

Further channels are seen away from the centreline at KP 2.500 to KP 3.000 and KP 5.000 to KP 5.600. They reach a maximum depth of 9 m below seabed, but more usually reach 4 to 5 m below seabed. These channels have a high amplitude chaotic acoustic character. They were sampled in VC 052 and consist of clay.

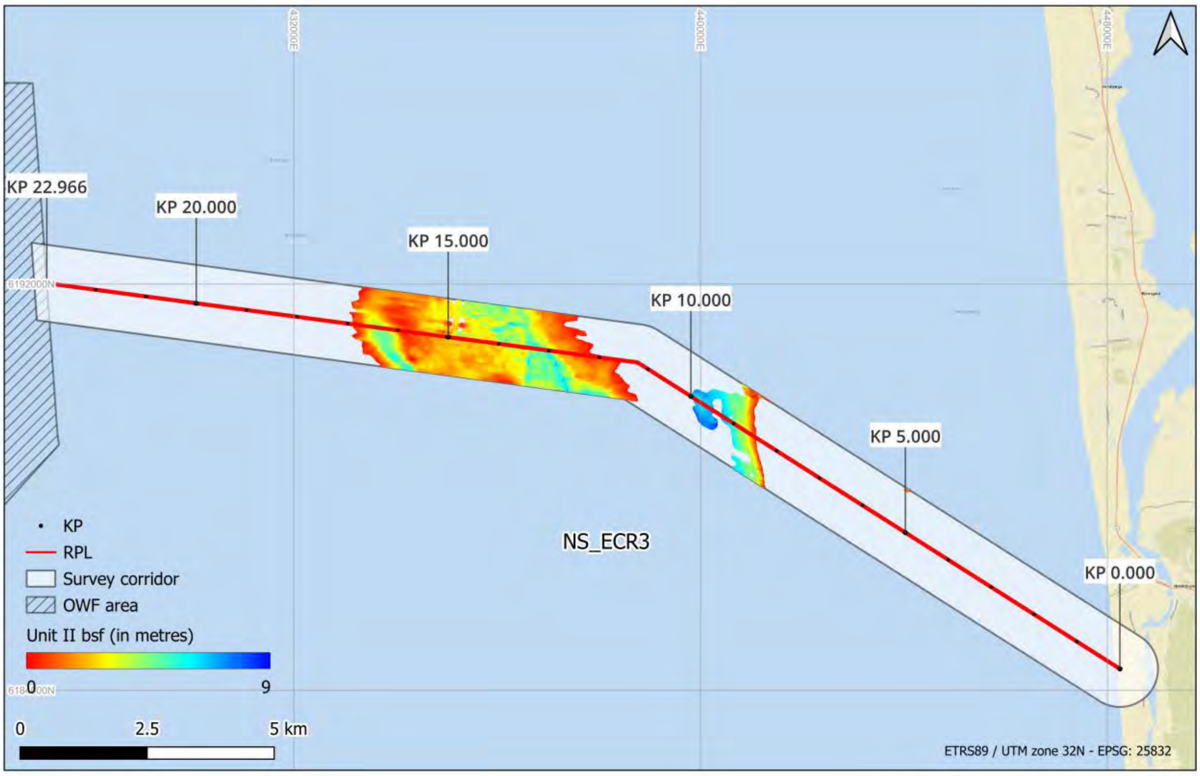


Figure 199: Distribution and thickness of Unit II

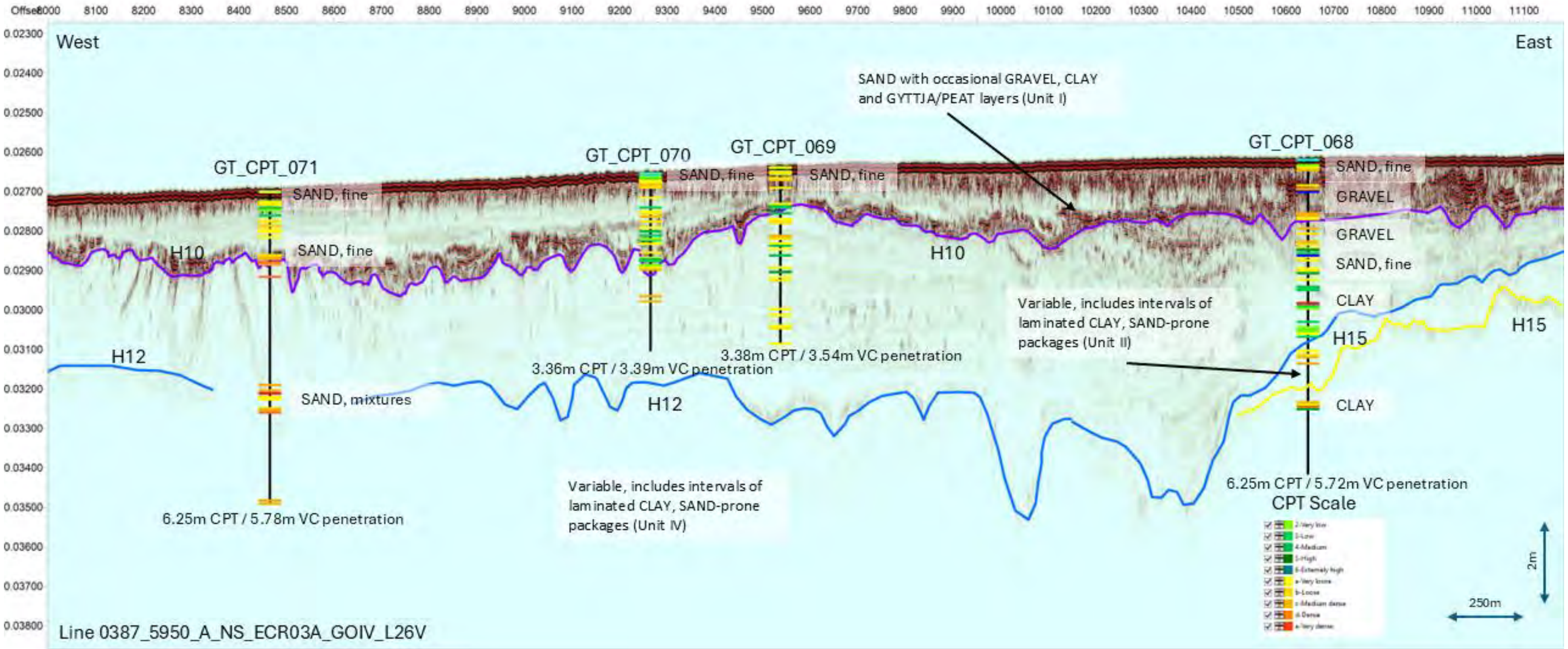


Figure 200: Seismic example showing Unit II channels

Unit III, Glacial deposits

Unit III deposits occur along the route corridor, sub-cropping at seabed where Units I and II are thin to absent (between KP 20.000 and KP 20.300). Unit III is interpreted to be a till laid down in association with the last major ice advance over the area, approximately 22,000 years ago. The till forms a relatively thick blanket, mostly to deeper than the depth of interest for cable burying. The base of the till/ top bedrock is not imaged within the export route corridor.

Unit III is generally a glacial till which has been subjected to direct ice contact, though the unit contains other facies which may have been laid down in ice-marginal environments during oscillations of the ice front. The ice-contact facies may comprise a clay-prone diamicton which is likely to contain subordinate silt, sand, gravel, cobbles and boulders and will be overconsolidated. Consolidation levels may significantly vary over short distances. Seismically, the ice contact facies are generally acoustically structureless.

10.7.5 C14 Analysis

Carbon 14 analysis to determine soil age has been undertaken on six locations along the NS ECR03 route. Figure 135 shows the C14 sample locations along the route corridor.

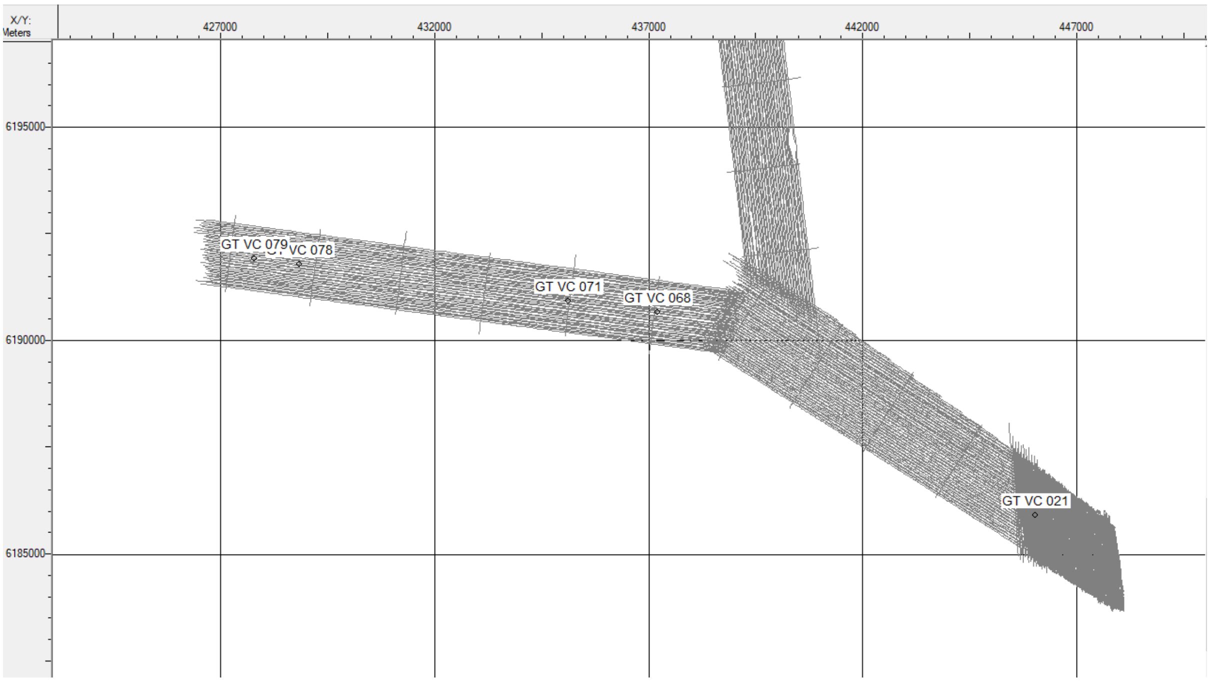


Figure 201: Locations of C14 sampling on ECR03

The sample taken at VC_021 is already reported in the C14 Analysis Section 8.7.5.

Figure 136 shows the C14 results at VC_068 and VC_071 plotted on the SBP data. The C14 sample on VC_068 has a derived age of 8060 ±30 BP and the sample at VC_071 has a derived age of 6930 ±30 BP. These sample lie between internal reflector H12 and H10, which conflicts with the measured C14 ages, as the unit is interpreted to be last glacial. The H10 reflector follows the major unconformity surface that was interpreted as the base of post glacial sediments. It is possible that the H12 layer in this area represents a different phase of post glacial deposition but the constitution is very similar to other late glacial deposits.

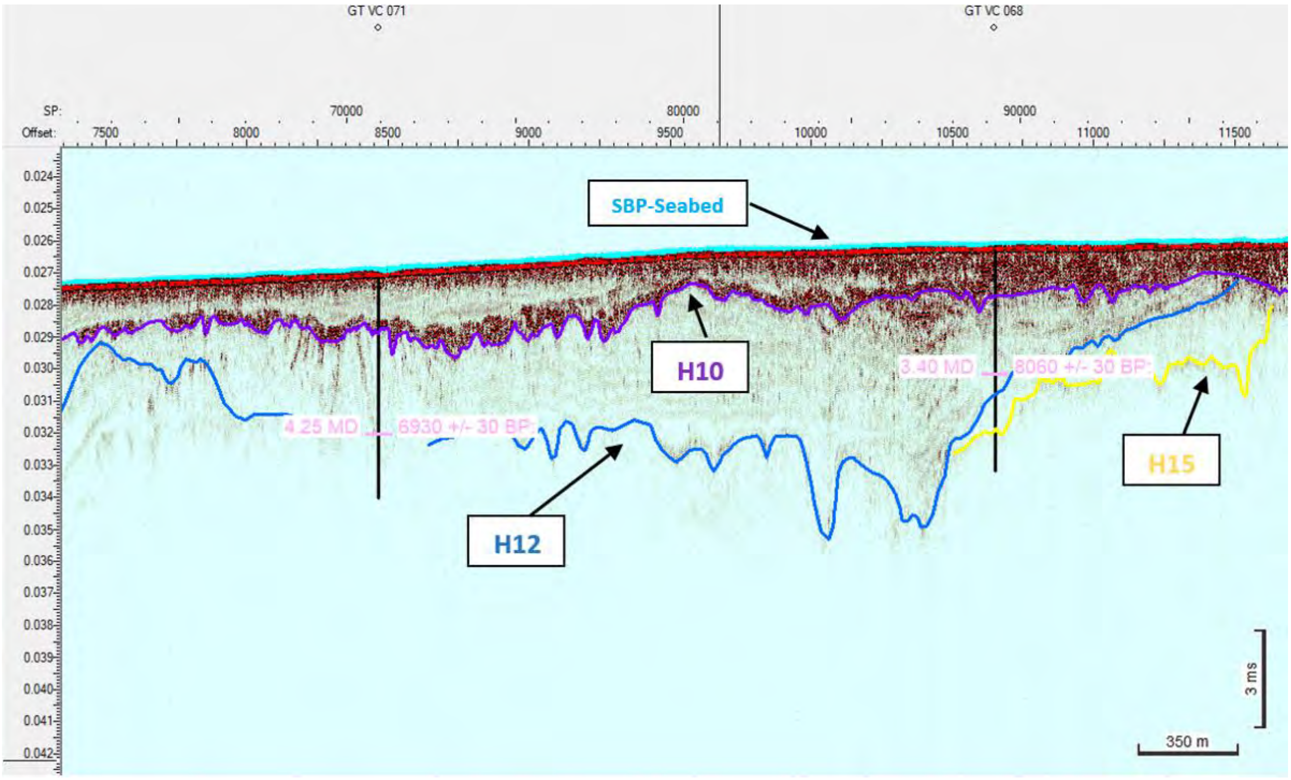


Figure 202: C14 result on SBP profile at VC_068 and VC_071

Figure 137 shows C14 results for VC_078 and VC79. Both samples are spatially close, vertically (<1 m) and horizontally (<1.5 km). VC_078 has a derived age of 10,830 ± 30 BP and VC_079 has a derived age of 10,930 ± 30 BP. The figure below shows they reside in a similar sediment layer above H10, which agrees with the inferred post glacial age range, if not right on the edge leading into late glacial. These are the oldest post glacial deposits measured on the ECR02/ECR03 area.

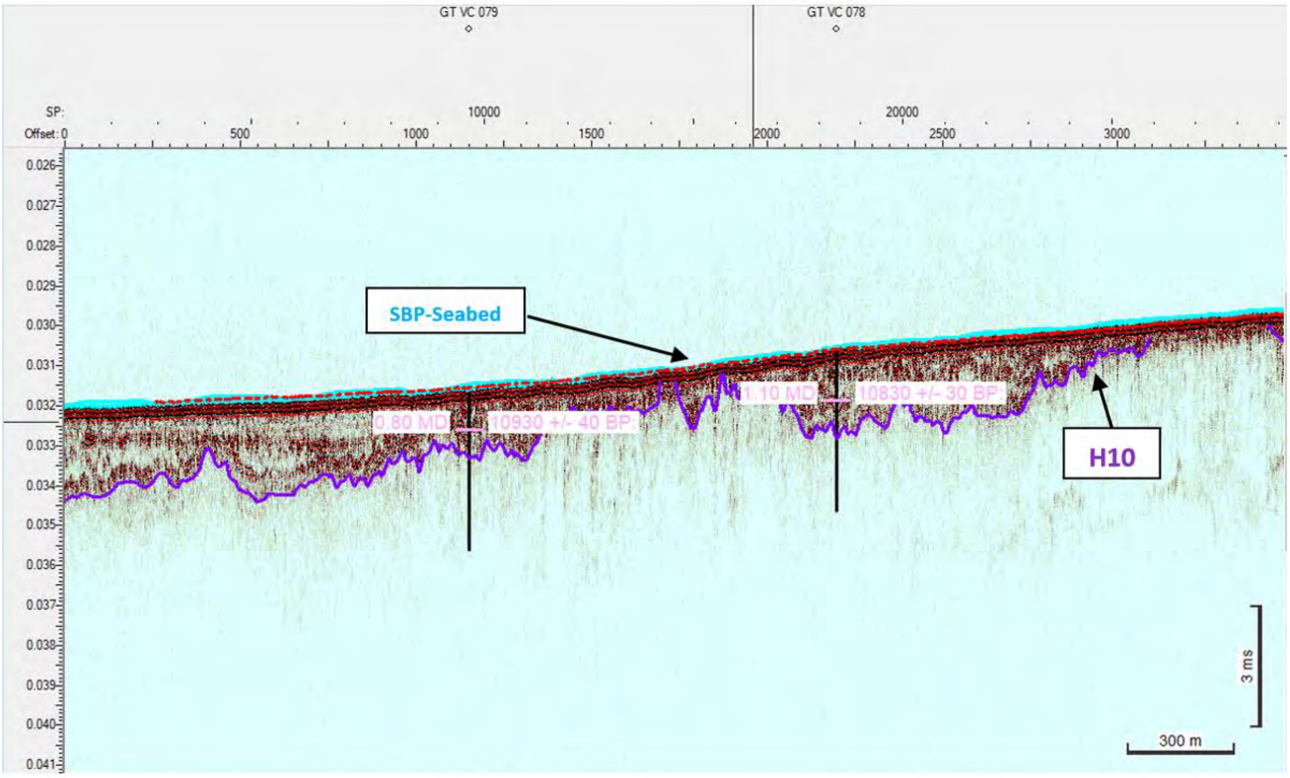


Figure 203: C14 result on SBP profile at VC_078 and VC_079

11 NS_ECR3 ROUTE ANALYSIS

A summarized route analysis along the NS_ECR3 cable route, subdivided in 3 km sections, is displayed in Table 87 below. SBP images with geomodelling, in 3 km sections, are presented in Appendix E. The route analysis is based on correlation between geotechnical and geophysical data.

Table 87: NS_ECR3 Overview per 3 km interval

From KP	To KP	Seabed Geology	Seabed Features	Seabed Topography	Shallow Geology	Environmental and geotechnical	
0	3	Predominantly a mix of SAND and Muddy SAND until KP 1.800, with patches of Gravel and Coarse Sand to the north of the survey corridor near KP 1.250 and between KP 1.500 and KP 1.800. From KP 1.800 to KP 2.700, the geology is predominantly Gravel and Coarse SAND along the RPL and to the south of it, with Muddy SAND to the north. From KP 2.700 until KP 3.000, the geology is a mix of Muddy SAND, SAND and Gravel and Coarse Sand.	Ripples and mega ripples dominate the seabed until KP 0.800. From KP 0.800 to KP 1.750, the seabed predominantly consists of sediment waveforms or is featureless. From KP 1.750 to KP 3.000, most of the survey corridor is dominated by large ripples, ripples and areas of mottled seabed.	Seabed slope from KP 0.000 to KP 0.500 drops by 4-5 metres. The slope from KP 0.500 to KP 3.000 gradually decreases by 5.5 metres.	H10 and H15 present	Geotechnical	None
						Grab samples	NS-3_001_03 NS-3_002_03 NS-3_003_03 NS-3_004_03 NS-3_005_03 NS-3_006_03 NS-ECR-02-01
3	6	Predominantly SAND with larger patches of Gravel and Coarse SAND in the north of the corridor. Between KP 5.400 and KP 5.750, there is an isolated area of Till approximately 440 m north-	The seabed in this KP range is primarily featureless with the exception of boulders. Smaller patches of mottled seabed are occasionally observed, with a large area of possible biostructures observed to the	From KP 3.000 to KP 6.000 the seabed slope gradually decreases by 7.5 metres.	H10 and H20 present	Geotechnical	VC062 VC022 VC063b CPT062 CPT022 CPT063b

From KP	To KP	Seabed Geology	Seabed Features	Seabed Topography	Shallow Geology	Environmental and geotechnical	
		east of the RPL. Further north, adjacent to this Till area, there are additional areas of Gravel and Coarse SAND, as well as Muddy SAND.	south of the RPL between KP 3.700 and KP 4.900. From KP 5.400 to KP 5.700 a high density boulder field is found approx. 440 m north-east of the RPL. Between KP 5.250 to KP 5.750, areas of large ripples, ripples and possible erosional bedform features are also observed to the north of the RPL.			Grab samples	NS-ECR-02-02 NS-ECR-02-03
6	9	SAND covers this part of the corridor entirely, with the exception of one smaller patch of Gravel and Coarse SAND to the north of the RPL.	Throughout this section, trawl marks are the dominant seabed feature, as well as isolated boulders.	Seabed slope from KP 6.000 to KP 9.000 slope gradually decreases by 2.2 metres.	H10 and H20 present	Geotechnical	VC023 VC064 CPT023 CPT064
						Grab samples	NS-ECR-02-04 NS-ECR-02-05 NS-ECR-02-06
9	12	Predominantly SAND with occasional larger patches of Muddy SAND located to either side of the RPL from KP 10.900 to KP 12.000.	From KP 9.000 to KP 9.400, trawl marks are present throughout the survey corridor. Between KP 9.400 and KP 10.900, the seabed is largely featureless, with the	From KP 9.000 too KP 12.000 the seabed flattens.	H10, H12, H15 and H20 present	Geotechnical	VC065 VC066a VC067 CPT065 CPT066a CPT067

From KP	To KP	Seabed Geology	Seabed Features	Seabed Topography	Shallow Geology	Environmental and geotechnical	
			exception of boulders. Between KP 10.900 to KP 12.000, the seabed is predominantly covered by patches of lower reflectivity as seen on the SSS data, with some areas of featureless seabed observed mainly to the south of the corridor.			Grab samples	NS-ECR-02-07 NS-ECR-02-08 NS-ECR-03-01 NS-ECR-03-02
12	15	Predominantly Muddy SAND with some areas of SAND generally more present in the south of the corridor.	The seabed in this section is covered by patches of lower reflectivity as seen on the SSS data, or is featureless, with the exception of boulders.	Seabed slope from KP 12.000 to KP 15.000 gradually decreases by 1 metre.	H10, H12 and H20 present	Geotechnical	VC068 VC069 VC070 VC071 CPT068 CPT069 CPT070 CPT071
						Grab samples	NS-ECR-03-03 NS-ECR-03-04 NS-ECR-03-05
15	18	Predominantly Muddy SAND and SAND are present in this section.	The seabed in this section is covered by patches of lower reflectivity as seen on the SSS	Seabed slope from KP 15.000 to KP 18.000 gradually decreases by 1.2 metres.	H10 and H12 present	Geotechnical	VC072 VC073 VC074 CPT072

From KP	To KP	Seabed Geology	Seabed Features	Seabed Topography	Shallow Geology	Environmental and geotechnical	
			data, or is featureless, with the exception of boulders.				CPT073 CPT074
						Grab samples	NS-ECR-03-06 NS-ECR-03-07
18	21	Predominantly Muddy SAND and SAND are present in this section. However, between KP 18.750 and KP 19.850, there are additionally isolated areas of Gravel and Coarse SAND near the RPL.	The seabed in this section is primarily covered by patches of lower reflectivity as seen on the SSS data, possible erosional bedforms or is featureless, with the exception of boulders. However, between KP 18.750 and KP 19.850, there are additionally isolated areas of ripples and large ripples near the RPL.	Seabed slope from KP 18.000 to KP 21.000 gradually decreases by 1.8 metres with isolated depressed regions up to 0.8 metres deep between KP 18.750 to KP 19.750.	H10 present	Geotechnical	VC075 VC076 VC077 CPT075 CPT076 CPT077
						Grab samples	NS-ECR-03-08 NS-ECR-03-09 NS-ECR-03-10 NS-ECR-03-11

From KP	To KP	Seabed Geology	Seabed Features	Seabed Topography	Shallow Geology	Environmental and geotechnical	
21	22.966	Predominantly SAND with large patches of Muddy SAND are present in this section. Between KP 21.600 and the end of the route, Gravel and Coarse SAND is also present along the northern edge of the corridor.	The seabed is predominantly featureless, with the exception of boulders. There are also patches of lower reflectivity as seen on the SSS data and possible erosional bedforms, mainly in the northern half of the corridor. Between KP 21.600 and the end of the route, ripples and large ripples are also present along the northern edge of the corridor.	From KP 21.000 to KP 22.966 the seabed slope gradually decreases by 1.3 metres.	H10 present	Geotechnical	VC078 VC079 CPT078 CPT079
						Grab samples	NS-ECR-03-12 NS-ECR-03-13

11.1 KP 0.000 – KP 3.000

No VCs or CPTs were acquired along ECR03 in this section. However, CPT021 and VC021 were acquired 60 m to the northeast of the ECR at KP 2.670. Interpretation is based on the geotechnical and geophysical data. Five grab samples were acquired, all containing silty or clayey SAND.

Post glacial sediments are seen, bounded by H10. They are interpreted to comprise SAND. A 10-cm-thick layer of GYTTJA is seen in both geotechnical logs at approximately 1.50 m below seabed. This thin layer has no acoustic response in the geophysical data. Carbon dating aged the Gyttja at 3,370 ± 30 years BP.

Unit I sediments (bounded by H10) are seen throughout this section, though inshore of KP 1.000 it is not possible to identify the base of the unit, since it is masked by the seabed multiple. Acoustically the unit is of a high amplitude, chaotic character. The unit thins from a maximum thickness of approximately 6 m at KP 1.000 to 2 m at KP 2.300, and then undulates around 2 m thick.

Unit II (bounded by H15) occurs as acoustically quiet sediments deposited in erosional depressions towards the southwest edge of the survey area. The sediments occur between KP 2.500 and KP 3.000, and at their closest approach lie approximately 300 m from the ECR.

Unit III underlies Units I and II throughout this section and is acoustically very quiet. Geotechnical logs show the unit to comprise SAND with a 10 cm thick CLAY layer at 2.70 m below seabed in VC/CPT021. This layer has no acoustic response in the geophysical data.

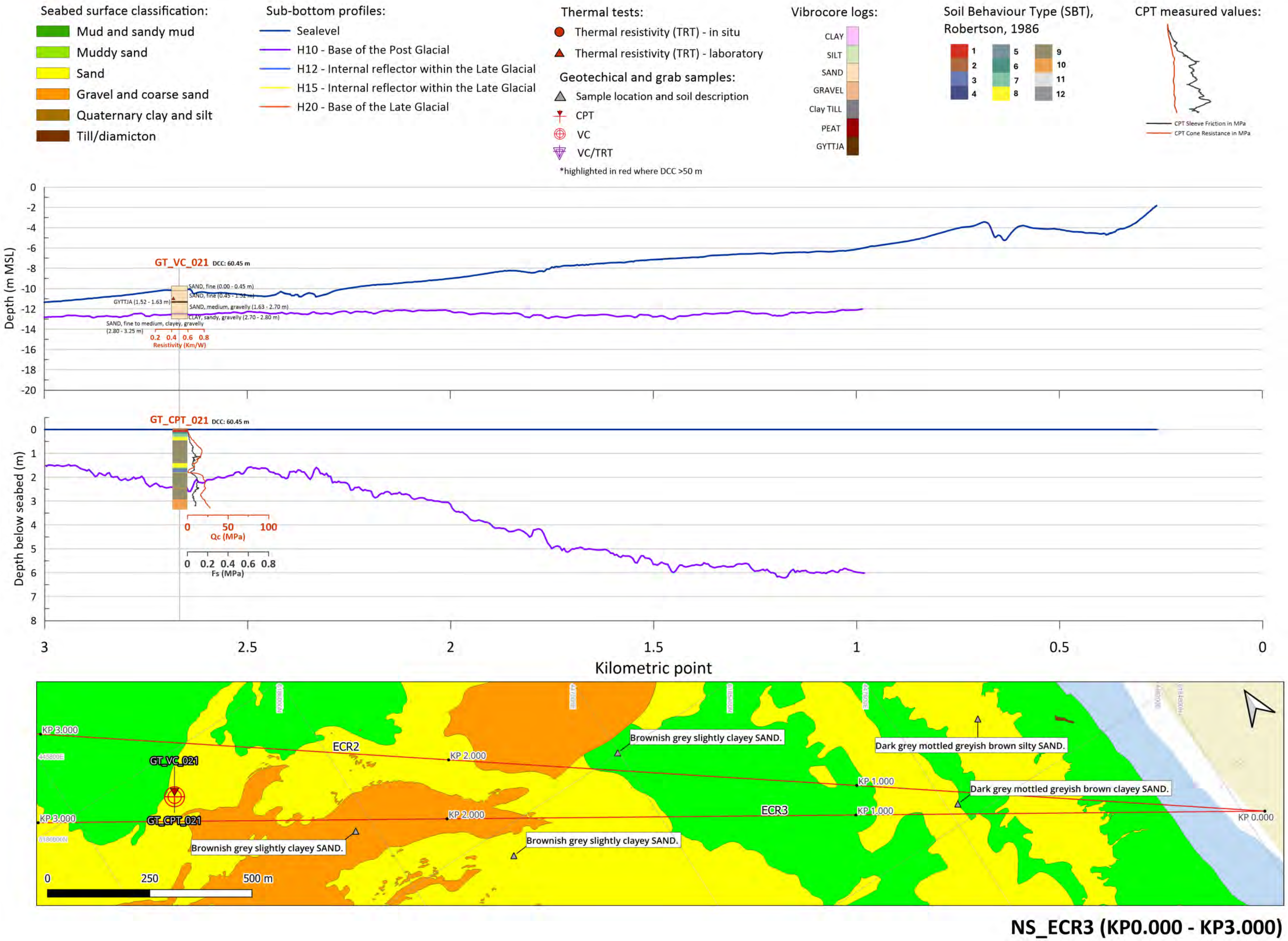


Figure 204: Integrated geotechnical panel KP 0.000 – KP 3.000

11.2 KP 3.000 – KP 6.000

Three VCs, three CPTs and one grab sample were acquired in this section. One of the VC/CPT pairs (022) was acquired approximately 330 m to the northeast of the ECR.

Unit I (bounded by H10) occurs throughout the section. It varies in thickness between 0.2 and 2.6 m but is generally between 1 and 2 m thick. Acoustically it is high amplitude, with signs of parallel bedding dipping downwards to the northwest.

Geotechnical samples VC062, VC022, VC063b, CPT062, CPT022 and CPT063b and a grab sample were acquired, showing the sediments to comprise fine to coarse SAND, increasing from loose at seabed to dense at the base of the unit. CPT022 and VC022 show an approximately 60 cm thick layer of GRAVEL at the seabed, but this sample is 330 m away from the ECR centreline. Gravel at seabed correlates with the seabed features interpretation at this location.

Unit II (bounded by H20) does not occur within this section.

Unit III underlies Unit I throughout this section and is acoustically very quiet. Geotechnical logs VC062, VC022, VC063b, CPT062, CPT022 and CPT063b penetrated this unit and show the unit to comprise SAND with a GRAVEL layer seen in VC/CPT063b. This layer has no acoustic response in the geophysical data.

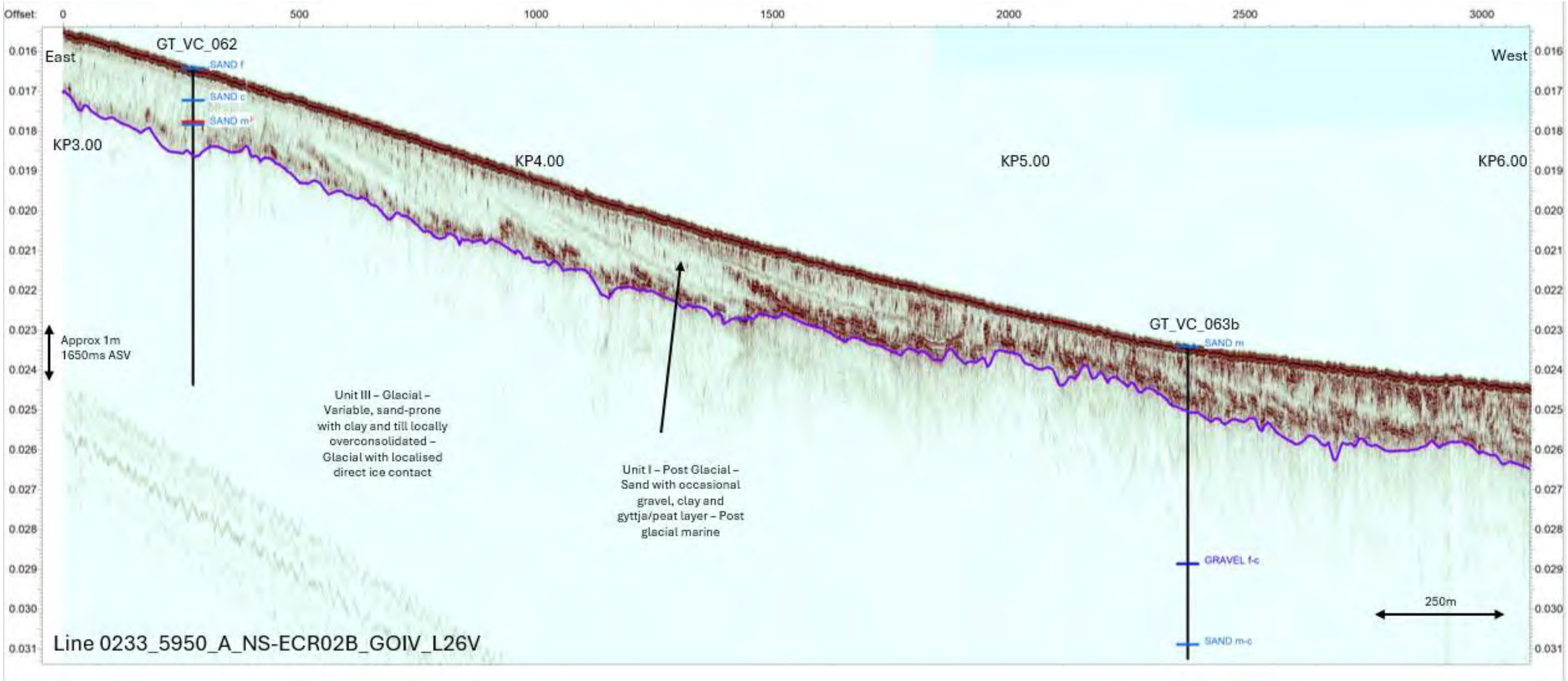
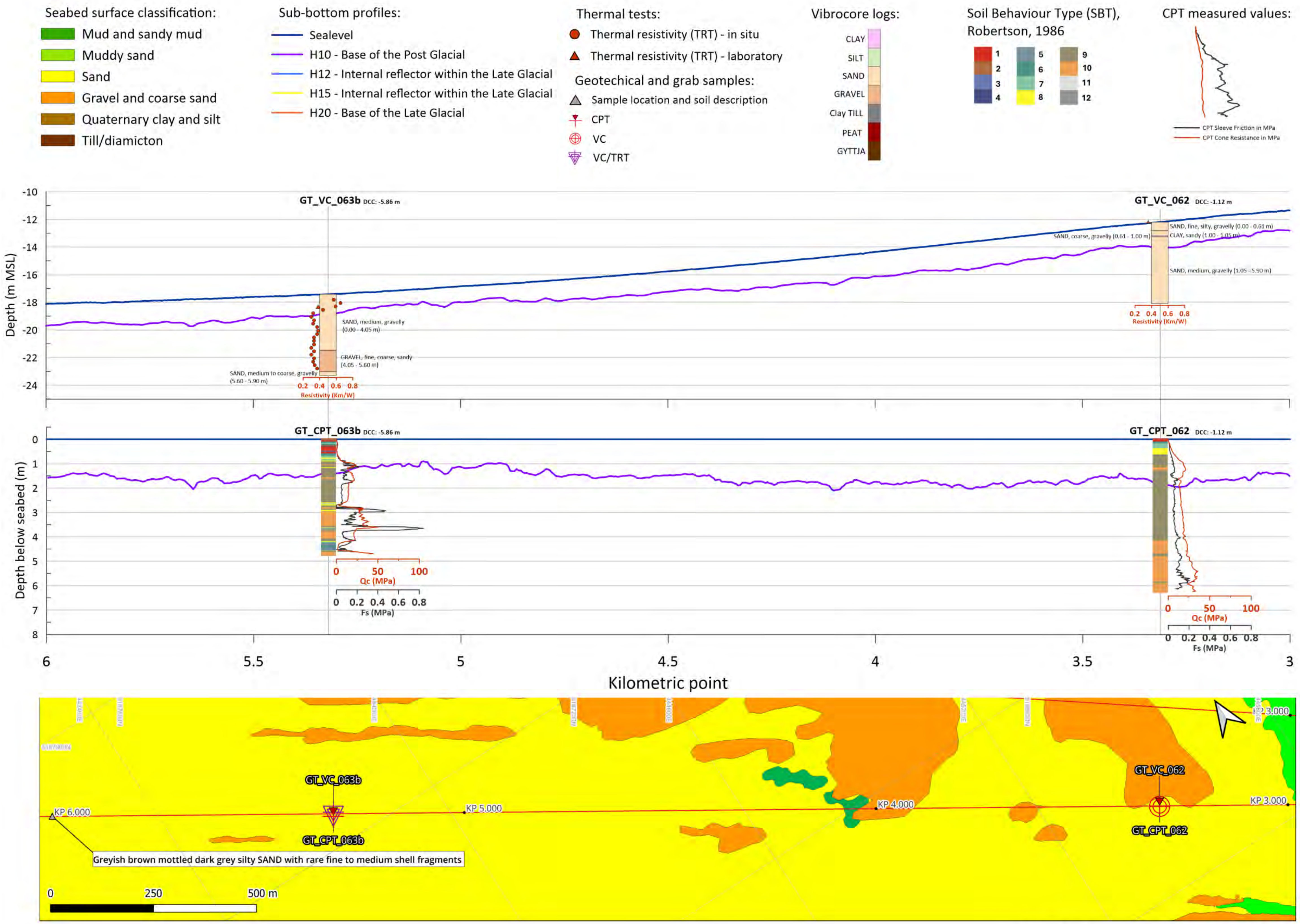


Figure 205: SBP and Geotech, KP 3.000 – KP 6.000



NS_ECR3 (KP3.000 - KP6.000)

Figure 206: Integrated geotechnical panel KP 3.000 – KP 6.000

11.3 KP 6.000 – KP 9.000

Two VCs and two CPTs were acquired in this section. One of the VC/CPT pairs was acquired approximately 480 m to the northeast of the ECR.

Unit I sediments (bounded by H10) are seen throughout this section. It varies in thickness between 1.0 and 3.0 m but is generally between 1.5 and 2.0 m thick. Acoustically it is high amplitude, with signs of parallel bedding.

Geotechnical samples VC023, VC064, CPT023 and CPT064 penetrated this unit, showing the sediments to comprise fine to medium silty SAND, increasing from very loose at seabed to loose at the base of the unit. The CPTs also showed some cohesive sediments of extremely low to medium strength.

Unit IIc (bounded by H20) occurs as acoustically quiet sediments deposited in erosional channels or depressions. An area of Unit II occurs beyond KP 8.500. The channel extends to beyond the limit of penetration.

No geotechnical samples penetrated this unit within this section, but samples further along the ECR show them to predominantly comprise high plasticity, medium to high shear strength CLAY.

Unit III underlies Unit I from KP 6.000 to KP 8.500.

Geotechnical samples VC023, VC064, CPT023, and CPT064 penetrated this unit, showing the sediments to comprise a variety of different lithologies. Sediments vary from very dense, fine SAND to very sandy CLAY TILL to CLAY.

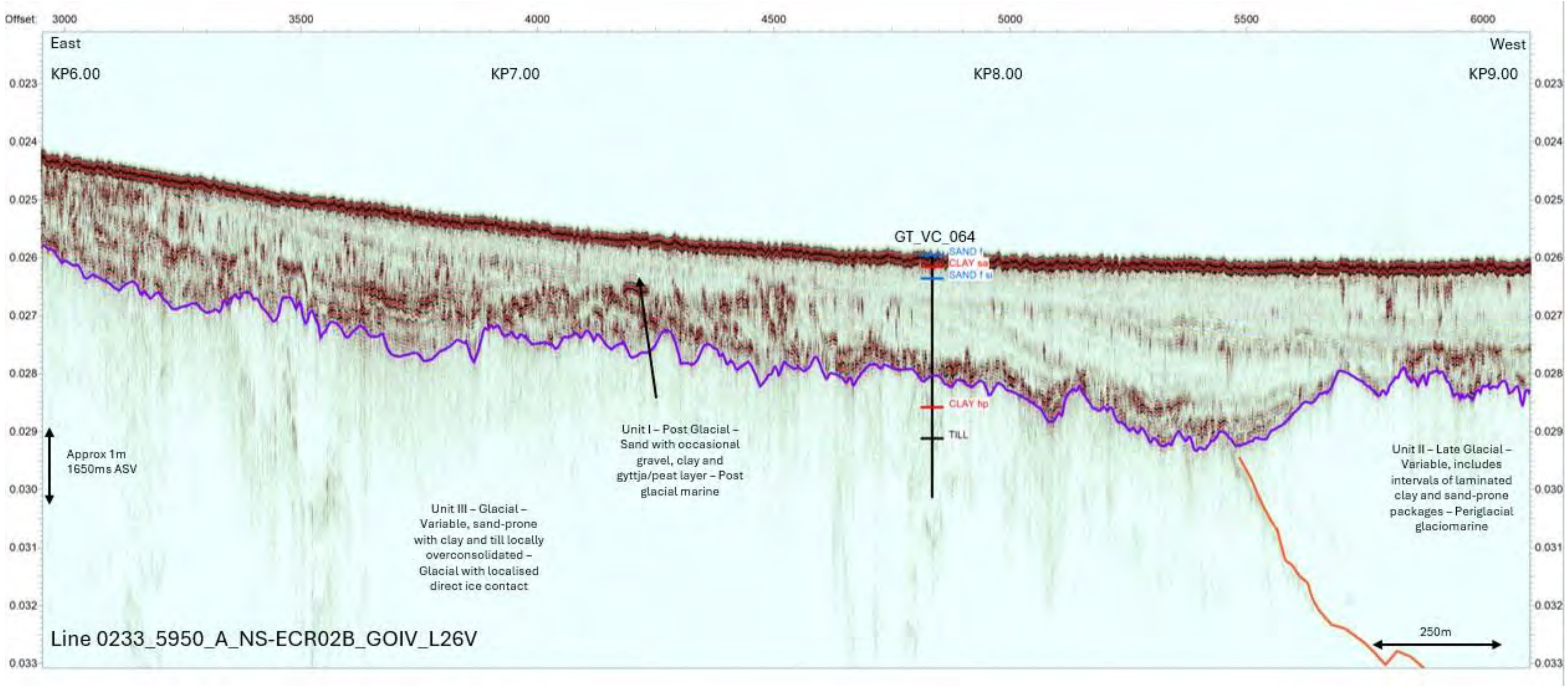
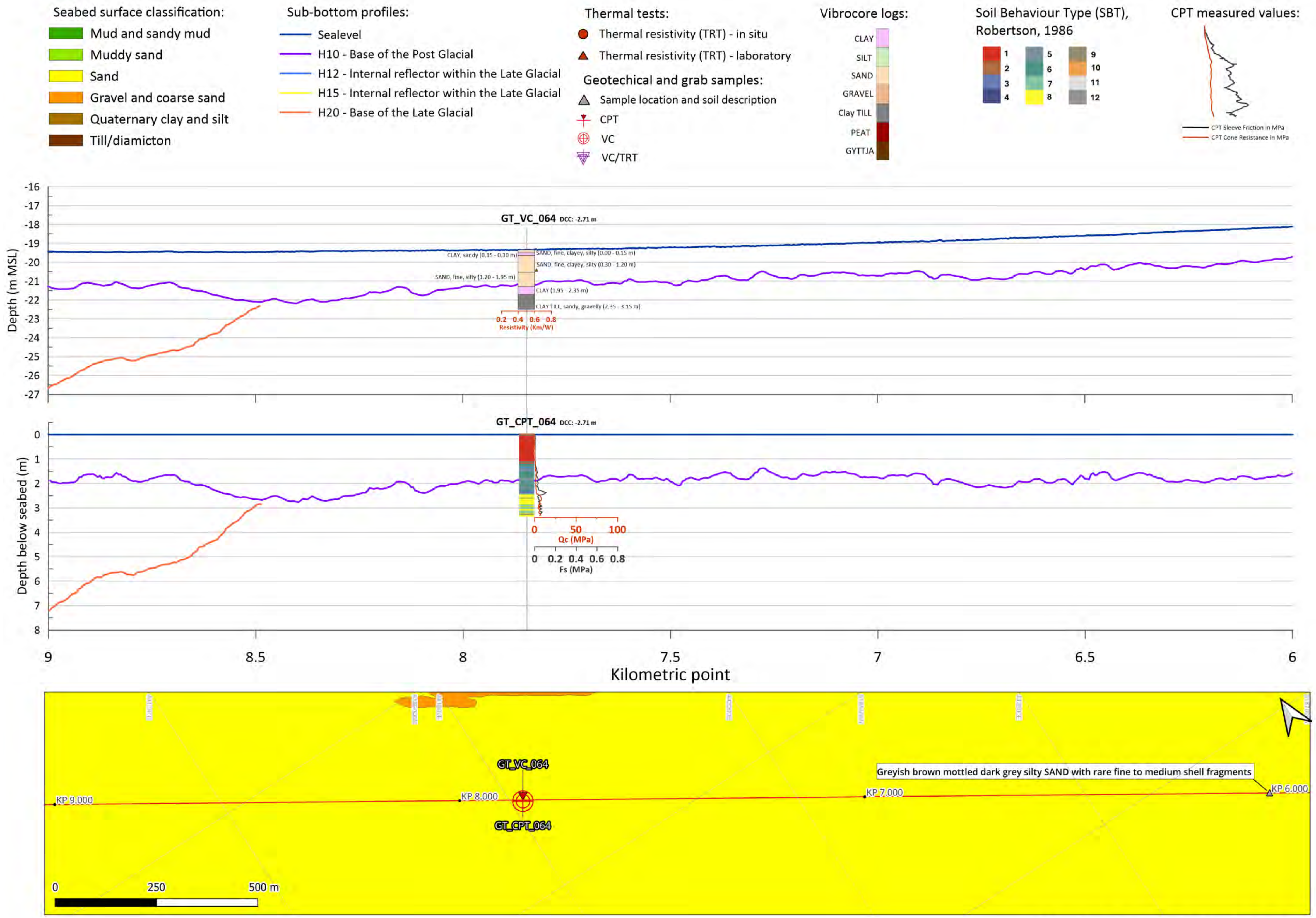


Figure 207: SBP and Geotech, KP 6.000 – KP 9.000



NS_ECR3 (KP6.000 - KP9.000)

Figure 208: Integrated geotechnical panel KP 6.000 – KP 9.000

11.4 KP 9.000 – KP 12.000

Three VCs, three CPTs and three grab samples were acquired in this section. Two further VC/CPT pairs were acquired along this section but are 660 m and 690 m offset from the ECR. The ECR changes direction from a bearing of 302° to 278° at KP 11.242.

Unit I sediments (bounded by H10) are seen throughout this section. Acoustically it is high amplitude, with signs of parallel bedding. They are generally between 1 and 2 m thick but do reach a maximum of 3.0 m in a minor broad channel, to the north of the ECR at KP 10.200.

All the geotechnical samples (VC065, VC066a, VC067, CPT065, CPT066a and CPT067) penetrated this unit, showing the sediments to comprise fine to coarse SAND.

VC065 and CPT065 observed SAND to 0.85 m BSB, underlain by very silty CLAY to the base of Unit I. The seismic data does show a reflector at the top of the clay, and this reflector extends to VC/CPT64, where Clay is not present. The seismic character of the sand and underlying clay is also very similar, and very dissimilar from the underlying Unit II.

Minor inconsistencies are seen between the geotechnics. At VC/CPT 24 (offset 660 m from the ECR), the VC showed sand throughout the core, while the CPT showed cohesive sediments with extremely low to medium shear strengths.

Unit II (bounded by H20) occurs as acoustically quiet sediments deposited in erosional channels or depressions. Unit II occurs from KP 8.500 to KP 17.000. The channel extends to beyond the limit of penetration, and shows several internal reflectors, H12 and H15, of Unit IIa and IIb respectively.

Geotechnical samples VC065, VC066a, VC067, CPT065, CPT066a and CPT067 penetrated this unit, showing the sediments to be highly variable, but comprising mainly CLAY, with some SAND towards the top of the unit. The CPTs showed the CLAY to be medium to high shear strength.

Minor inconsistencies are seen between the geotechnics and geophysics. At VC/CPT 24 (offset 660 m from the ECR), the VC and CPT both showed sand within Unit II, while the geophysics correlates with other VC/CPTs where a more clay prone sediment is expected.

Unit III underlies Unit II over the length of the section and exhibits an acoustically transparent character. It is not sampled by any of the geotechnics.

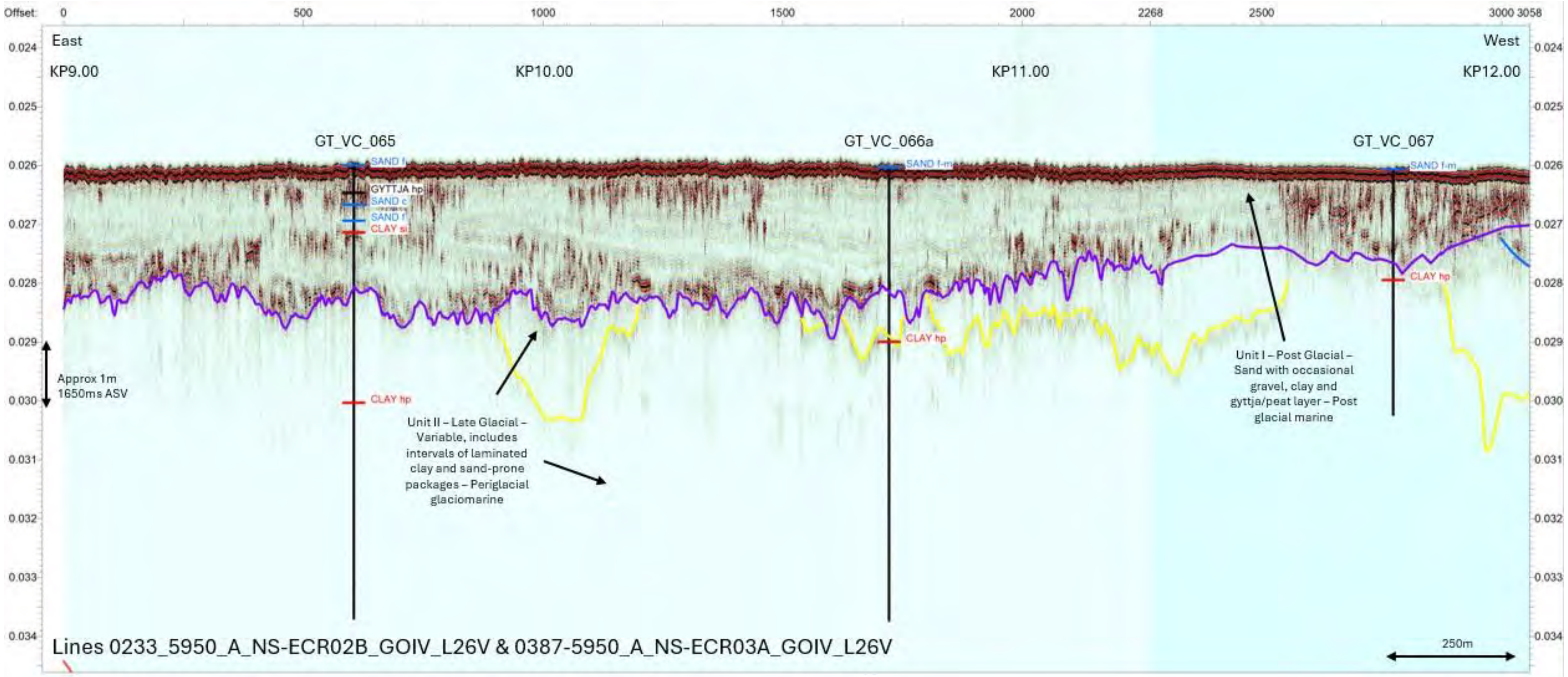


Figure 209: SBP and Geotech, KP 9.000 – KP 12.000

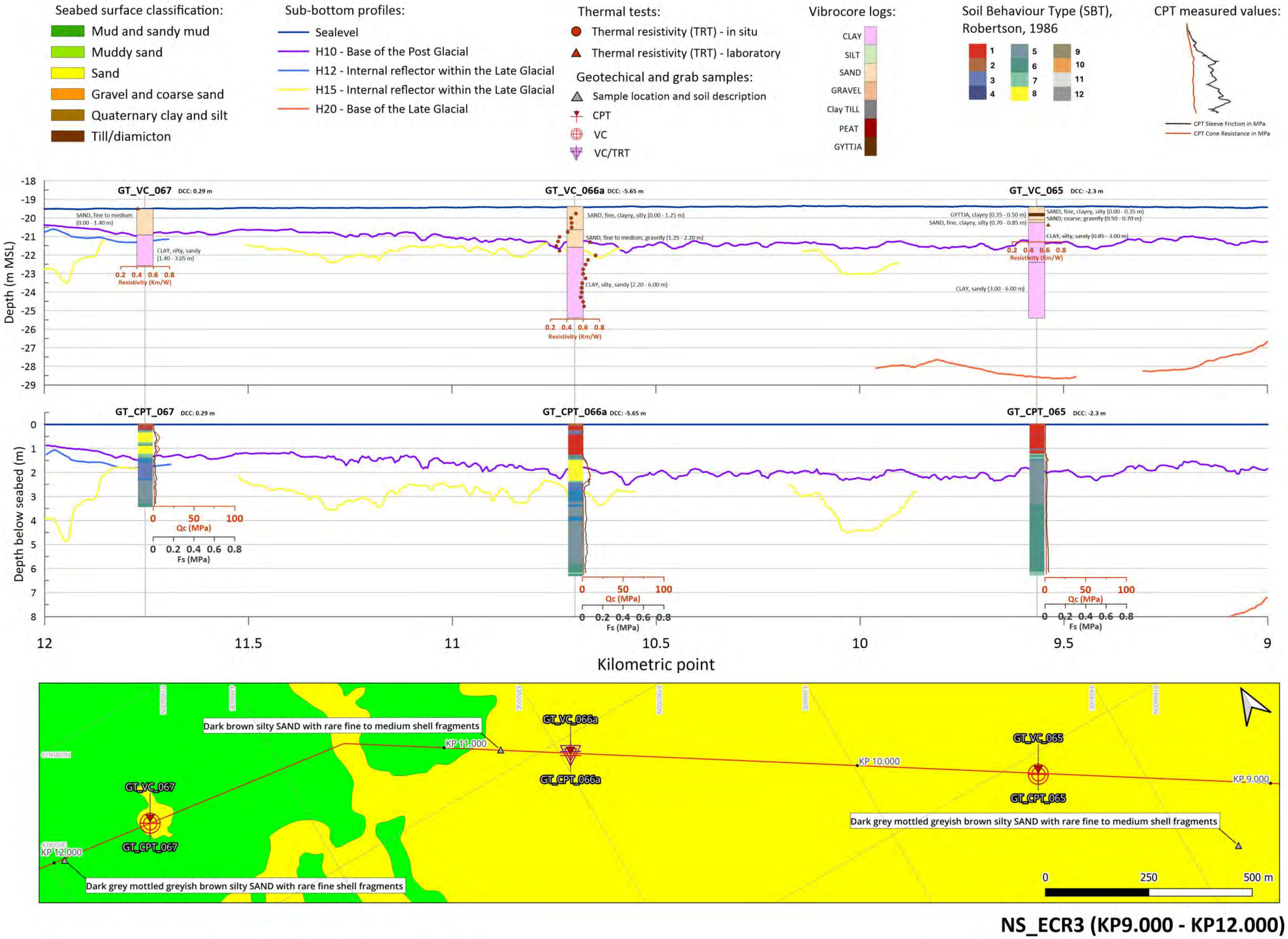


Figure 210: Integrated geotechnical panel KP 9.000 – KP 12.000

11.5 KP 12.000 – KP 15.000

Four VCs, four CPTs and four grab samples were acquired in this section.

Unit I sediments (bounded by H10) are seen throughout this section. Acoustically it is high amplitude, with signs of parallel bedding. They are generally between 1 and 2 m thick but do reach a maximum of 4.7 m in a depression, to the south of the ECR at KP 14.225.

All the geotechnical samples (VC068, VC069, VC070, VC071, CPT068, CPT069, CPT070 and CPT071) penetrated this unit, showing the sediments to comprise fine to medium SAND. A layer of GRAVEL is seen at the base of the unit in VC/CPT068.

Unit IIa (bounded by H12) occurs as well bedded sediments deposited in erosional channels or depressions. It underlies Unit I throughout, reaching a maximum depth of approximately 8 m BSB in a northwest to southeast trending channel, crossing the ECR at approximately KP 13.250.

All the geotechnical samples penetrated this unit, showing the sediments to be predominantly SAND. A thin PEAT layer is seen at the base of the unit in VC/CPT071. At VC/CPT068, the unit is more variable, containing GRAVEL and CLAY layers, though no major changes are seen within the geophysical data. Carbon dating was performed on samples from the base of Unit IIa in VC068 and VC071, and yielded ages of 8,060 ± 30 years and 6,930 ± 30 years BP respectively.

Unit IIb is seen at the east of this section with an acoustically transparent character. It was sampled in VC068 and CPT068 and comprises medium to coarse SAND.

Unit IIc (bounded by H20) is anticipated to pinch out at approximately KP 13.000, although no definitive reflector is seen. It is sampled in VC/CPT068 and comprises CLAY.

Unit III underlies Unit II over the length of the section and exhibits an acoustically transparent character. It was sampled in VC/CPT071 and comprises gravelly SAND.

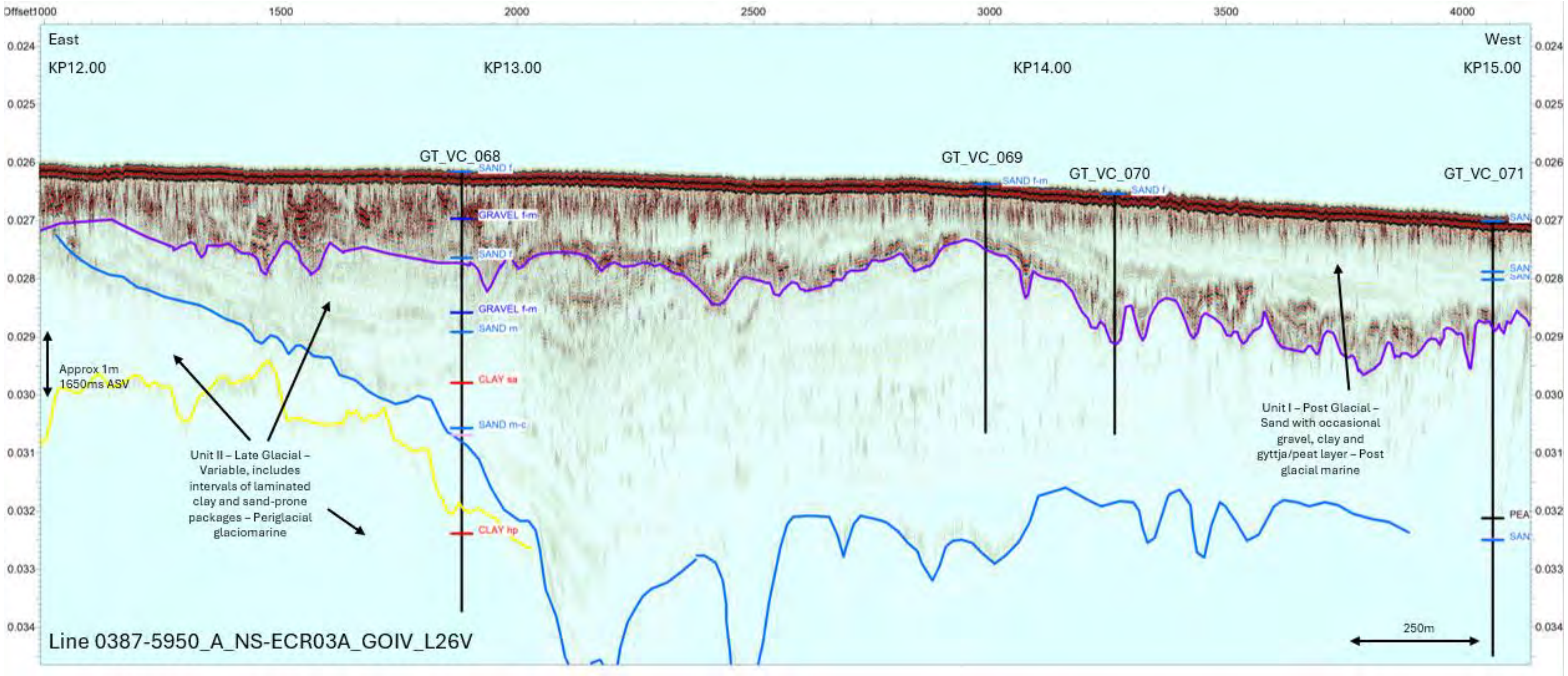


Figure 211: SBP and Geotech, KP 12.000 – KP 15.000

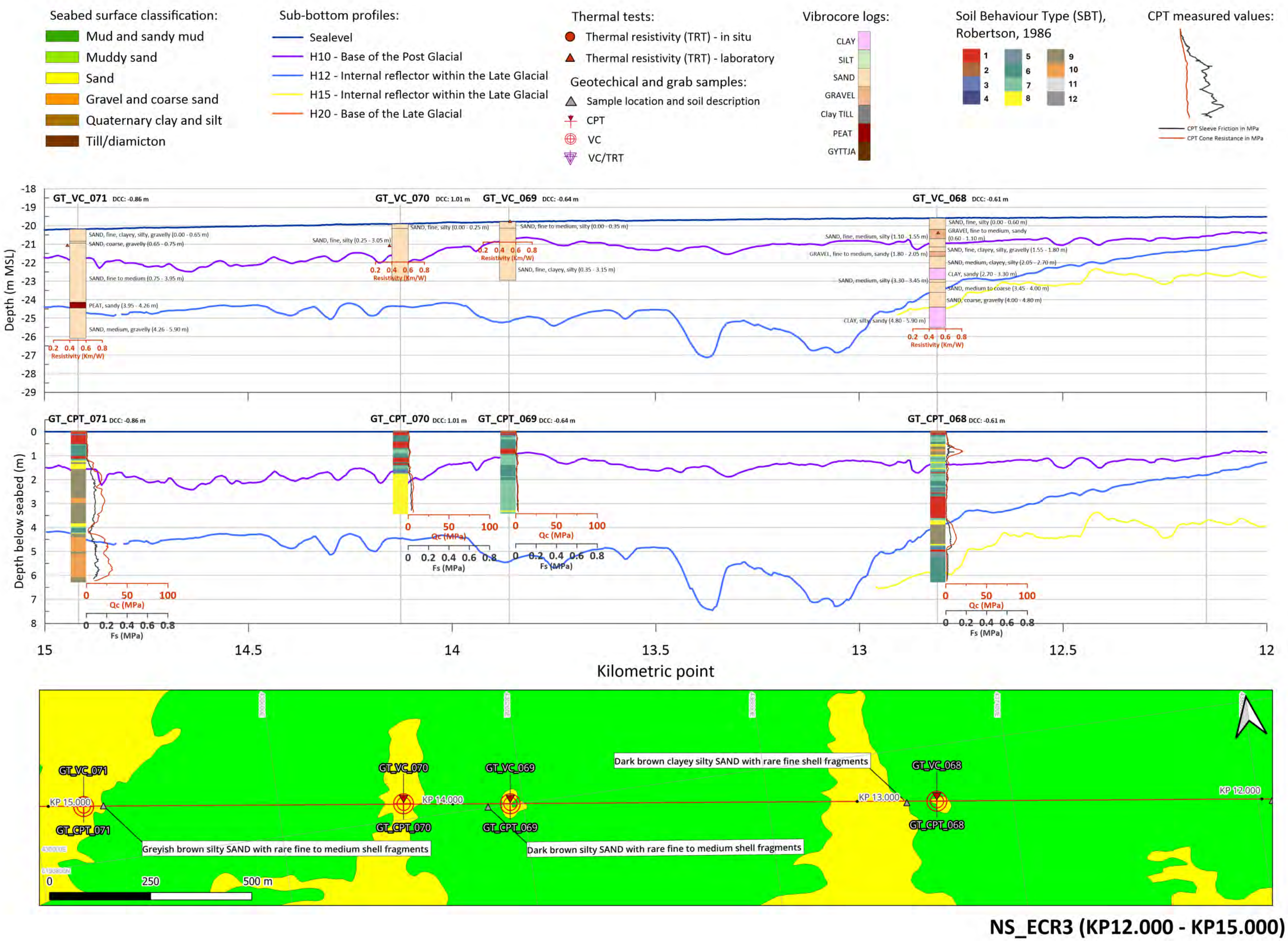


Figure 212: Integrated geotechnical panel KP 12.000 – KP 15.000

11.6 KP 15.000 – KP 18.000

Three VCs, three CPTs and two grab samples were acquired in this section.

Unit I sediments (bounded by H10) are seen throughout this section. Acoustically it is high amplitude, with signs of parallel bedding. A large channel crosses the route corridor, reaching a maximum depth of approximately 10.7 m BSB on the southern edge of the corridor. The channel is approximately 1500 m wide, crossing the ECR from northwest to southeast. The channel axis crosses the route at approximately KP 17.320.

All the geotechnical samples (VC072, VC073, VC074, CPT072, CPT073 and CPT074) penetrated this unit, showing the sediments to comprise fine SAND.

Unit IIa (bounded by H12) occurs generally as well bedded sediments deposited in erosional channels or depressions. It underlies Unit I to the east of the deep Unit I channel, reaching a maximum depth of approximately 11 m BSB.

VC/CPT072 penetrated this unit, showing the sediments to comprise medium to coarse SAND.

Unit III underlies Units I and II over the length of the section and exhibits an acoustically transparent character. It was sampled in VC/CPT072 and comprises fine to coarse SAND. A 0.45 m thick GYTTJA layer was observed in the vibrocore, and CLAY was observed beyond a depth of 5.65 m BSB.

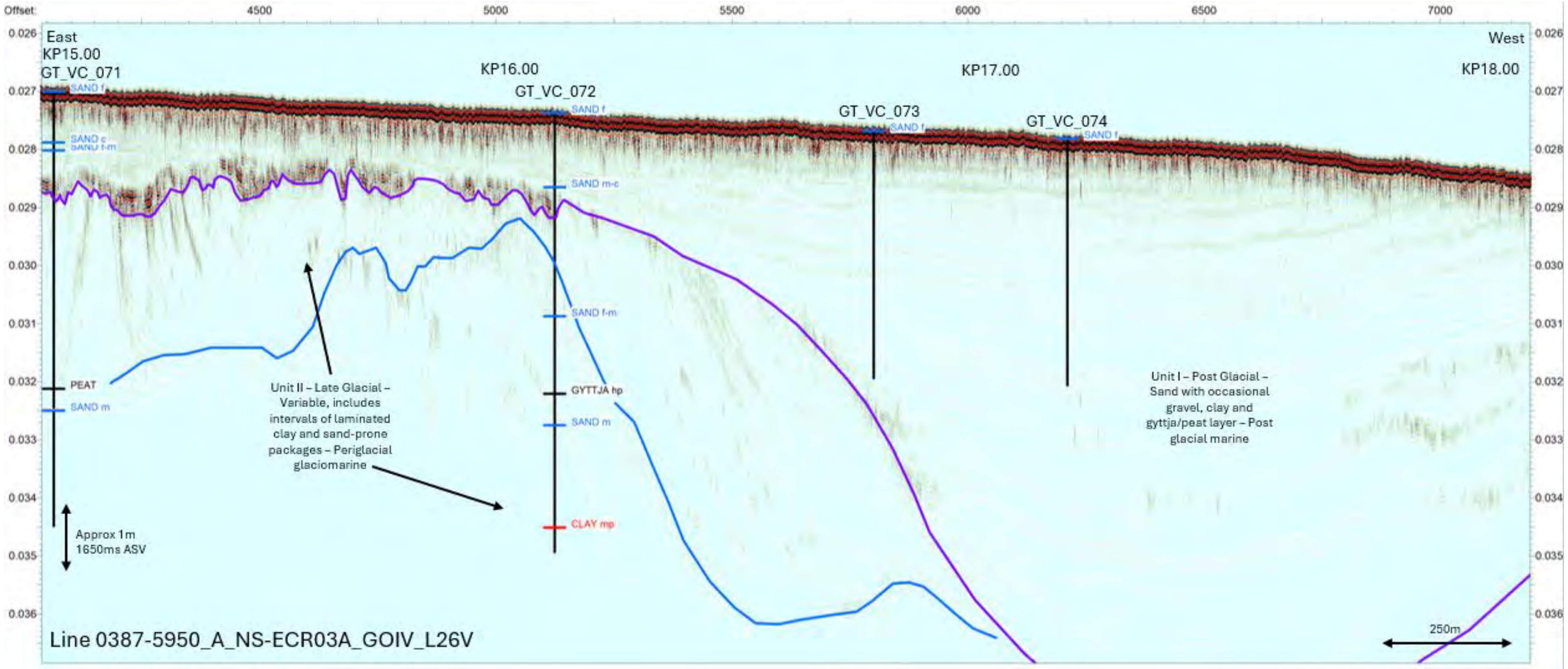
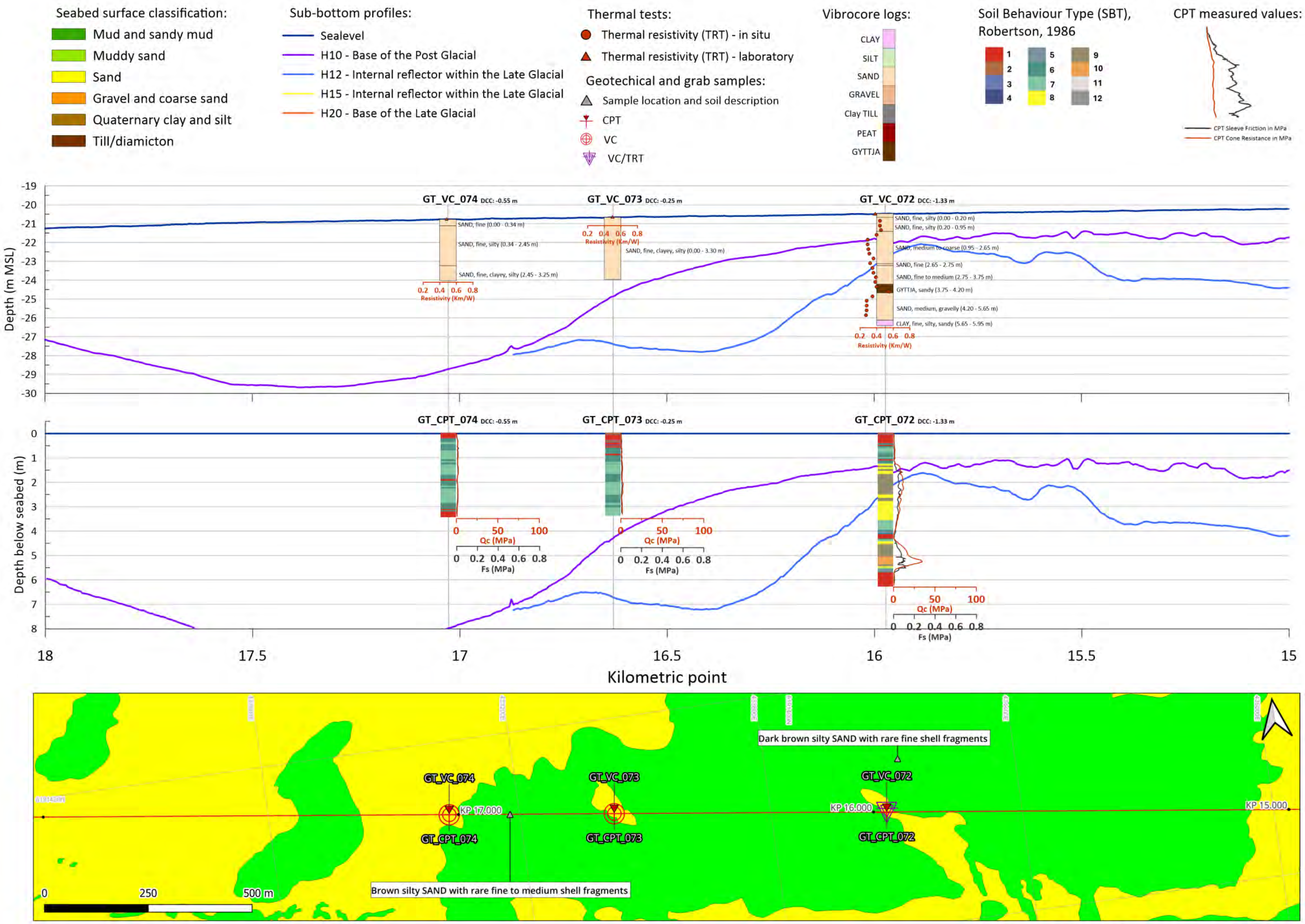


Figure 213: SBP and Geotech, KP 15.000 – KP 18.000



NS_ECR3 (KP15.000- KP18.000)

Figure 214: Integrated geotechnical panel KP 15.000 – KP 18.000

11.7 KP 18.000 – KP 21.000

Three VCs, three CPTs and four grab samples were acquired in this section.

Unit I sediments (bounded by H10) are seen throughout most of this section. Acoustically it is high amplitude, with signs of parallel bedding. They are generally between 1 and 2 m thick but do reach a maximum of approximately 6.5 m in a depression, to the north of the in the continuation of the deep channel crossing the route to the east of this section.

All the geotechnical samples (VC075, VC076, VC077, CPT075, CPT076 and CPT077) penetrated this unit, showing the sediments to comprise fine to medium SAND; although Unit 1 is thin/absent at VC077 location.

Gravel is seen in two of the grab samples, which correlates with the seabed features interpretation, but in areas where VCs or CPTs were not acquired.

Unit II (bounded by H12/H15/H20) is not interpreted to occur within this section.

Unit III underlies Unit I over the length of the section and exhibits an acoustically transparent character. Some faint parallel bedding is seen on the SBP data just to the west of the deep Unit I channel, which possibly could be Unit II, but the data is indistinct and appears to underlie some of the more transparent sediments, so is more likely to be a subunit with Unit III.

Unit III was sampled in VC076, VC077, CPT075, CPT076 and CPT077 and comprises fine to medium SAND. A thin SILT layer is seen in VC077. CPT075 and 076 showed that the sediments were cohesive with low to medium shear strengths. The sands were predominantly very loose to loose in CPT076 (in the bedded sub-unit), but medium to very dense in CPT077.

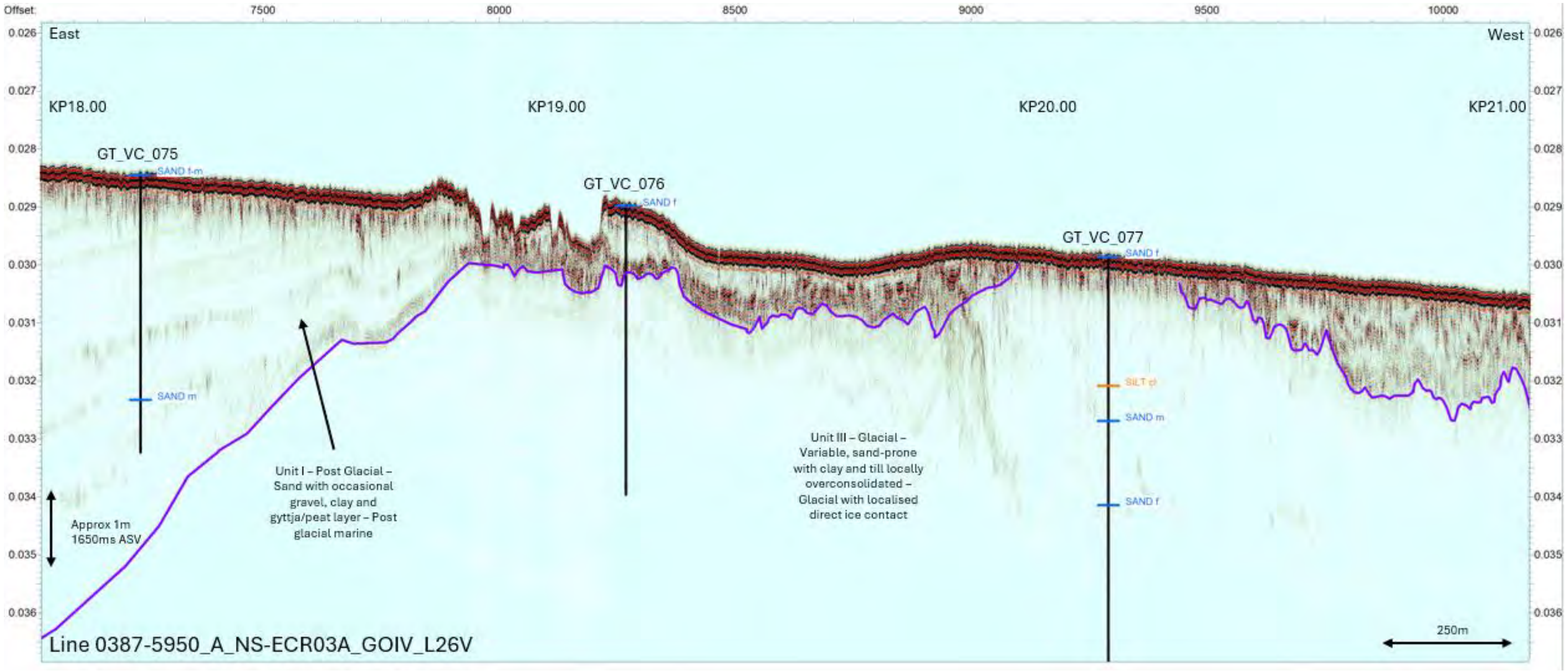


Figure 215: SBP and Geotech, KP 18.000 – KP 21.000

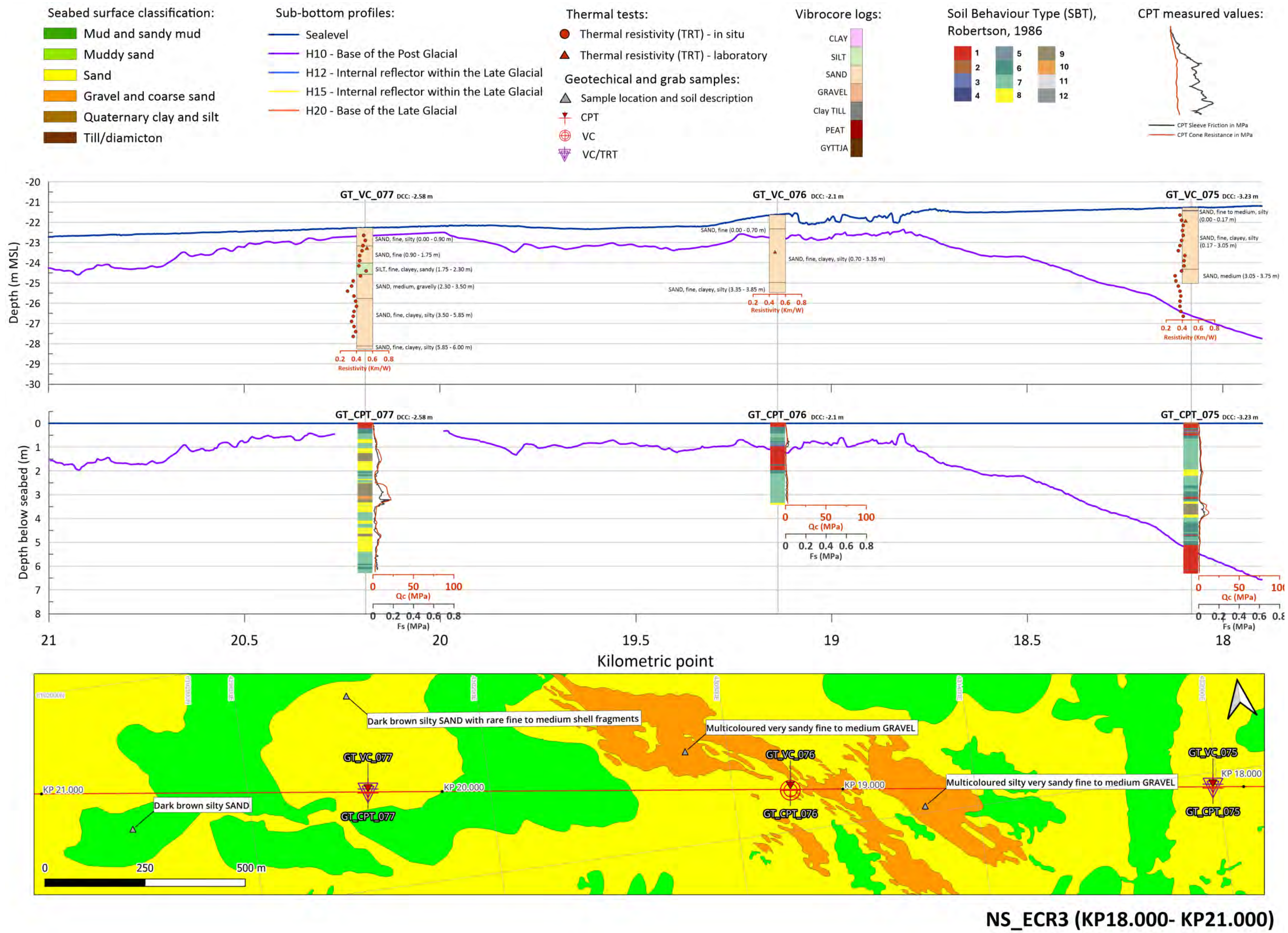


Figure 216: Integrated geotechnical panel KP 18.000 – KP 21.000

11.8 KP 21.000 – KP 22.966

Two VCs and two CPTs were acquired in this section.

Unit I sediments (bounded by H10) are seen throughout this section. Acoustically it is high amplitude, with signs of parallel bedding. Unit I is generally between 0.5 and 2 m thick but thickens to the north, reaching a maximum of 4.7 m.

All the geotechnical samples (VC078, VC079, CPT078 and CPT079) penetrated this unit, showing the sediments to comprise fine to coarse SAND. A layer of PEAT/GYTTJA is seen near the base of the unit in all the geotechnical samples. Carbon dating has been performed and gave consistent results of 10,830 ± 30 years and 10,930 ± 40 years BP.

Unit II (bounded by H12/H15/H20) is not interpreted to occur within this section.

Unit III underlies Unit I over the length of the section and exhibits an acoustically transparent character.

Unit III was sampled in VC078, VC079, CPT078 and CPT079 and comprises fine to medium SAND. The sands are predominantly medium to very dense.

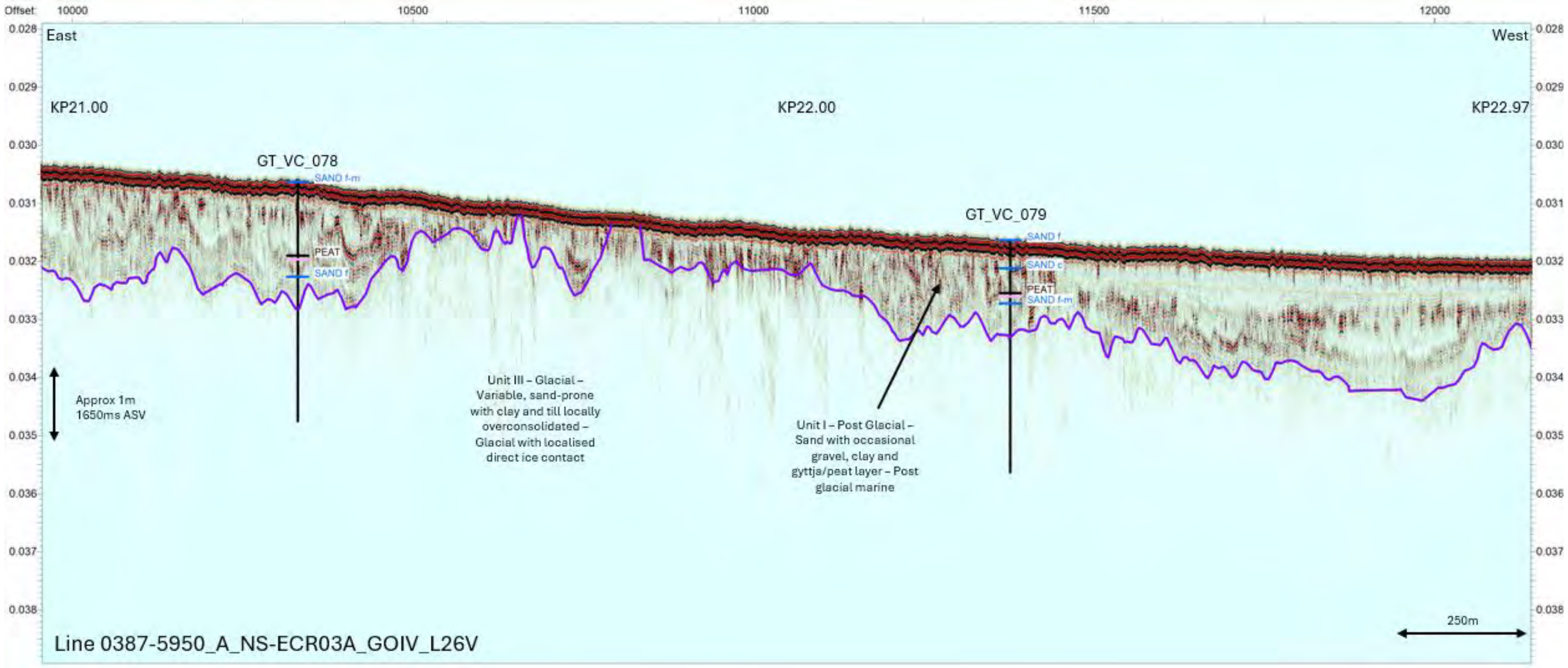


Figure 217: SBP and Geotech, KP 21.000 – KP 22.966

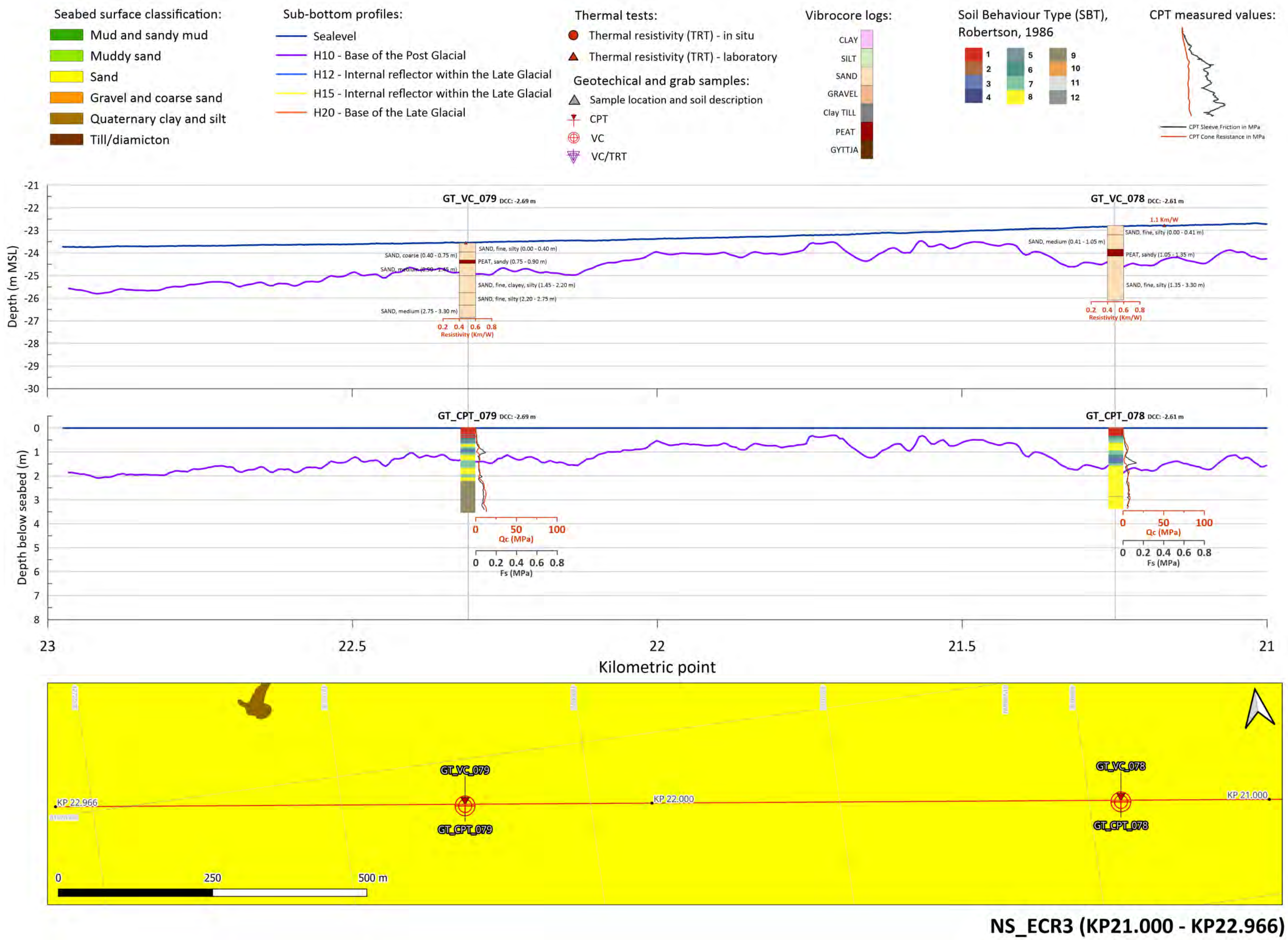


Figure 218: Integrated geotechnical panel KP 21.000 – KP 22.966

11.9 SHALLOW GEOLOGICAL INSTALLATION CONSTRAINTS AND GEOHAZARDS

Unit I sediments are very weak/soft. Their bearing capacity will be negligible and could cause retrieval difficulties related to settlement of seabed frames etc. The sediments in Unit I may also contain diffuse organic material.

Units II and III contain numerous cobbles and boulders.

Unit III may have variable levels of overconsolidation.

11.9.1 Cobbles and Boulders

There are occasional indications of boulders within the sub-bottom profiler data. These data have been optimized to resolve the shallow stratigraphy and do not readily generate diffraction hyperbola, which are the usual seismic indication of point contacts in the sub-surface. A further complication is that the units most likely to contain boulders, Units II and III, have been deformed and compressed by ice confusing any returns from individual point contacts.

Due to these circumstances, appearance of clear hyperbolae that could be interpreted as isolated individual point targets relating to buried boulders have not been observed.

11.9.2 Organic Material

GYTTJA and PEAT layers have been observed in geotechnical data within ECR03, which have been presented and described in the route analysis. However, these have not presented as clear or continuous reflectors in SBP data, and hence are not mapped spatially, away from GT locations. These present a possible geohazard relating to heat dissipation as well as trenching considerations for PEAT.

11.10 COMPARISON BETWEEN SEABED AND SUB-SEABED FINDINGS

In the later stage of interpretation, surficial geology has been correlated to the SBP results. Where sub-seabed Unit III (i.e. base of H10/H12/H15/H20)(Figure 196/ Figure 199) identified as a glacial till is at or near the seabed there is an abundance of boulders, some of these areas are delineated by “intermediate” boulder fields seabed features (Figure 180) and as “Till/diamicton” in the seabed geology (Figure 179).

11.11 CONCLUSIONS

The elevation levels across the NS_ECR3 site range from a highest point of 19.31 metres above MSL in the eastern landfall area, to a deepest point of 24.80 metres below mean sea level (MSL) towards the northwestern boundary of the survey area.

Starting at the landfall and moving eastwards, the elevation increases gradually by 3.5 m, with a gradient of approximately 2.8°, over 59 metres. Continuing landwards, there is a further increase in elevation with the gradient of 4.3° over 70 metres. Further inland, the survey area is characterised by gentle mounds / dunes with the highest point of 19.31 metres MSL located northeastern from the KP 0.000. The height of these mounds / dunes decreases when moving further eastward and reach close to 0 MSL in the vicinity of coastal lake Gammel Gab.

The offshore area of the NS_ECR3 site is characterised by very gentle slopes on most of the cable survey area. The highest concentration of steep slopes located to the east of the KP 0.000, towards the inland areas. In this nearshore part of the route, from KP 0.000 to KP 8.000, a significant deepening of the seabed, with steep slopes is observed. Between KP 2.000 and KP 3.000 there is a channel-type structure, corresponding to ripples, after which the seafloor continues to deepen towards the KP 8.000. The area between KP 8.000 and KP 12.000 is characterised by almost flat seabed floor, without any changes in the depth. Following the KP 14.500 the seabed continues to deepen till the end of the RPL. There are sudden changes in elevation with differences reaching up to 2 m between around KP 19.000. This dynamic area corresponds to ripples and large ripples.

The seabed geology of the North Sea ECR3 survey area consists predominantly of sand, along with sediments such as gravel and coarse sand, muddy sand and one isolated area of till/diamicton.

The beginning of the NS_ECR3 route, from KP 0.000 to approximately KP 6.000, is dominated by a mix of sediments including sand, patches of gravel and coarse sand, muddy sand and mud and sandy mud areas. From KP 5.400 to KP 5.750 there is an isolated area of till located approximately 440m north-east of the RPL, which correlates to a boulder field area in the seabed morphology. Between KP 6.000 and KP 10.900, sand covers the full width of the corridor, with the exception of one small patch of gravel and coarse sand just north of the RPL near KP 8.000. From KP 10.900 to the end of the RPL, the seabed geology is dominated by muddy sand and sand. The exception to this is between KP 18.750 and KP 19.850, where there are isolated patches of gravel and coarse sand near the RPL, and similarly between KP 21.600 and then the end of the route, along the northern edge of the corridor. These areas correlate with areas of large ripples and ripples.

The seabed morphology at the beginning of the NS_ECR3 route until KP 0.800, the seabed is dominated by ripples and megaripples. From KP 0.800 to KP 3.000, the seabed is further dominated by ripples, large ripples and areas of sediment waveforms. This indicates dynamic areas, which are also shown within the bathymetric and slope data. From KP 3.000 to KP 6.250 the seabed is predominantly featureless, with the exception of boulders. There are also occasional isolated areas of patches of mottled seabed and areas of possible biostructures, off the RPL. From KP 5.400 to KP 5.750 there is an isolated boulder field area located approximately 440m north-east of the RPL, which correlates with an area of till in the seabed geology. An area of ripples, large ripples and erosional bedforms are also present, adjacent to the north-east of the boulder field. Between KP 6.250 to KP 9.400, the seabed is dominated by trawl marks before becoming featureless, with the exception of boulders, from KP 9.400 to KP 10.900. The end half of the route, from KP 10.900 to KP 22.966 is dominated by a mix of featureless seabed with the exception of boulders, linear seabed scars and patches of lower reflectivity as seen on the SSS data. Between KP 18.750 and KP 19.850, there are also isolated patches of ripples and large ripples near the RPL, and similarly between KP 21.600 and then the end of the route, along the northern edge of the corridor. These areas correlate with areas of gravel and coarse sand in the seabed geology.

A total of 447 point contacts were detected in NS_ECR3, with 53 of these attributed to be man-made (MMO) point targets and 394 point targets interpreted as boulders. A total of 23 MMO linear features were detected. 17 of these features were associated with soft ropes, 1 as debris, 2 of them as other linear objects and an additional 2 cable crossings. The cable crossings were detected in the background data and by the magnetometer. There were 10 metallic objects found within the NS_ECR2 survey area. Additional 24 items of debris point contacts were observed within the site. All of these were interpreted as non-ferrous objects. One wreck was also identified on the site, just south of KP 19.013 at the coordinates 431034 mE 6191255 mN. The wreck is approximately 23 m long, 8.5 m wide and 1 m in height. There were no pipelines identified within the NS_ECR3 site.

The geological interpretation along the proposed ECR is based upon the geophysical and geotechnical datasets acquired with reference to the supplied GEUS desk study. Details of specific correlations between the geophysical and geotechnical datasets can be found in the 3 km route analysis sections of the report.

In general, the area has a glacial to post-glacial sequence of relatively recent sediments over much older bedrock. Only the upper post glacial and glacial deposits are discussed along the ECR. The bedrock is deeper than the installation zone of interest and not imaged on the SBP data.

The post glacial unit (Unit I) predominantly of SAND with occasional GRAVEL, CLAY and GYTTJA/PEAT layers which is less than 2 m thick over large parts of the site. The interval includes a veneer of sandier seabed sediments, though this is interpreted to be very thin and not resolvable in the SBP data. The post glacial sediments are widely distributed over the cable route corridor, varying from absent to less than 2 m over most of the route. It reaches a maximum observed thickness of 10.7 m on the southern edge of the survey corridor near KP 16.500 in a northwest to southeast trending channel. It also increases in the nearshore section to approximately 6 m, and may be even thicker further inshore, but the horizon is obscured by the seabed multiple. Occasional pockets of peat and gyttja are observed in the geotechnical logs, but no seismic expression is noted in the SBP data. In general, the post glacial package consists of sand with occasional gravel and gyttja in the nearshore end of the ECR.

The late glacial deposits (Unit II) are very complex due to the area's range of environmental conditions during the Late Weichselian and earliest Holocene. Some intervals show laminations indicative of clays and silts, others may represent sandy beach-type deposits. Along the route corridor Unit II, glaciomarine sediments infill steep sided channels eroded into the underlying Unit III tills.

A significant channel is present between KP 8.900 and KP 17.200. It is acoustically transparent in character and reaches a maximum depth of approximately 17 m below seabed at KP 13.200. Another channel is observed between KP 12.000 and KP 17.000. The channel has a highly erosive base, and the sediments are well bedded with the bedding parallel to the irregular basal reflector. The Unit reaches a maximum depth of approximately 7.5 m below seabed at KP 13.400 (Unit II ~6.0 m thick). Geotechnical data shows the sediments to be predominantly sand. Further channels are seen away from the centreline at KP 2.500 to KP 3.000 and KP 5.000 to KP 5.600. They reach a maximum depth of 9 m below seabed, but more usually reach 4 to 5 m below seabed.

The glacial deposits (Unit III) occur along the route corridor, sub-cropping at seabed where Units I and II are thin to absent (between KP 20.000 and KP 20.300). Unit III is interpreted to be a till laid down in association with the last major ice advance over the area, approximately 22,000 years ago. The till forms a relatively thick blanket, to deeper than the depth of interest for cable burying. The base of the till/ top bedrock is not imaged within the export route corridor. Unit III is generally a glacial till which has been subjected to direct ice contact, though the unit contains other facies which may have been laid down in ice-marginal environments during oscillations of the ice front. The ice-contact facies may comprise a clay-prone diamicton which is likely to contain subordinate silt, sand, gravel, cobbles and boulders and will be overconsolidated. Consolidation levels may significantly vary over short distances. Seismically, the ice contact facies are generally acoustically structureless.

Unit I sediments are very weak and soft, with negligible bearing capacity, potentially causing retrieval difficulties related to the settlement of seabed frames. Unit II contains numerous cobbles and boulders. Unit III may exhibit variable levels of over-consolidation and also contains numerous cobbles and boulders. Some isolated patches of Gyttja and Peat have also been observed in the geotechnical data, though these have not presented as clear or continuous reflectors in the SBP data and hence are not mapped spatially away from the geotechnical locations. These present a possible geohazard relating to heat dissipation, as well as trenching considerations for Peat.

12 DIGITAL DATA DELIVERABLES OVERVIEW

12.1 DIGITAL DELIVERABLES SUMMARY

Table 88: Digital deliverables, overview

Deliverable	Format
All sensors	
All sensors trackplots (line)	Shapefile
Man-made objects (point)	Shapefile
Man-made objects (line)	Shapefile
Man-made objects (polygon)	Shapefile
Seabed features (point)	Shapefile
Seabed features (line)	Shapefile
Seabed features (polygon)	Shapefile
Seabed geology (polygon)	Shapefile
Seabed substrate (polygon)	Shapefile
Catalogue of seabed objects	PDF
MBES	
Despiked, motion and tidal corrected point clouds	ASCII
Bathymetric average values gridded surface 0.25 m, 1 m and 5 m	ASCII
	Encoded TIF
Bathymetry Total Vertical Uncertainty values gridded surface 1 m	ASCII
	Encoded TIF
Bathymetric Total Horizontal Uncertainty values gridded surface	ASCII
	Encoded TIF
Hit count	Encoded TIF
Bathymetry contours 0.5 m	Shapefile
MBES targetlist (>1 m)	Shapefile
Vessel tracks	Shapefile
SVP	
SVP logfiles	Native system format
Backscatter	
Gridded 1 m	Encoded TIF
SSS	
Processed SSS data	HF XTF
	LF XTF
SSS track	Shapefile
SSS mosaic HF, 0.1 m	RGB TIF
SSS mosaic LF, 1 m	RGB TIF
Navigation files	ASCII

Deliverable	Format
SonarWiz project	SonarWiz Project Files
SSS targetlist (>1 m)	Shapefile
Magnetometer	
Processed magnetometric data	ASCII
MAG track (1 track per MAG)	Shapefile
MAG targetlist (Magnetic linear anomalies - ferrous mass >50 kg buried up to 2 m below the seabed surface)	Shapefile
Total field grid, 0.5 m	Encoded TIF
Residual signal grid, 0.5 m	Encoded TIF
Oasis Montaj project	Oasis Montaj Project
SBP	
Processed SBP data	SEG-Y
Processed SBP data images	TIFF or PNG
SBP instrument tracks	Shapefile
Interpretation of post processed seismic data	ASCII
Processing project	N/A
SBP targetlist	Shapefile
Depth SEG-Y format	SEG-Y
SBP TWT SEG-Y	SEG-Y
Horizon interpretation depth MSL gridded surface	ASCII
	Encoded TIF
Horizon interpretation depth below seabed gridded surface	ASCII
	Encoded TIF
Isochore gridded surface	ASCII
	Encoded TIF
Processing project	Kingdom Project Files
Grab Sampling	
Grab sample positions	Shapefile
Grab sample classifications	Excel Doc
Grab sample lab analysis	Excel Doc
Interim deliverables	
Trackplots (for CoG, MBES, SSS, SBP, MAG)	Shapefile
MBES hit count	Encoded TIF
MBES DTM	Encoded TIF
SSS coverage	RGB TIF
SSS mosaic	RGB TIF
SBP infills	Shapefile
SBP SEG-Y	SEG-Y

Deliverable	Format
SBP profile images	JPGE
Residual grid	Encoded TIF
Reports	
Mob and Cal report	PDF
Operations report	PDF
Geotechnical report	PDF
Lidar report	PDF
Cable crossing report	PDF
Cable route integrated report	PDF
GIS	
Trackplots (all sensors)	Shapefile
MBES contours	Shapefile
MBES anomalies	Shapefile
MBES grid 0.25 m, 1.0 m and 5.0 m	Encoded TIF
MBES THU Grid 1.0 m	Encoded TIF
MBES TVU Grid 1.0 m	Encoded TIF
Backscatter Grid 1.0 m	Encoded TIF
SSS anomalies	Encoded TIF
Magnetic anomalies	Encoded TIF
SBP anomalies	Encoded TIF
SBP horizon MSL grids H05	Encoded TIF
SBP horizon MSL grids H10	Encoded TIF
SBP horizon MSL grids H20	Encoded TIF
SBP horizon DBS grids H05	Encoded TIF
SBP horizon DBS grids H10	Encoded TIF
SBP horizon DBS grids H20	Encoded TIF
SBP isopach grids	Encoded TIF
Grab sample positions	Shapefile
Seabed surface geology (polygon)	Shapefile
Seabed surface type (polygon)	Shapefile
Seabed surface features (points)	Shapefile
Seabed surface features (line)	Shapefile
Seabed surface features (polygon)	Shapefile
Man-made objects (points)	Shapefile
Man-made objects (line)	Shapefile
Man-made objects (polygon)	Shapefile
Charting	
Trackplots and sampling locations	PDF
Bathymetry	PDF

Deliverable	Format
Backscatter	PDF
Seabed surface classification	PDF
Seabed objects	PDF
Seabed features	PDF
Sub-seabed geology	PDF
Lidar	
Trackplot	Shapefile
Integrated despiked and motion and vertical corrected point clouds	ASCII
Integrated LIDAR average values gridded surface 0.25 m	ASCII
	Encoded TIF
Integrated LIDAR average values gridded surface 1 m	ASCII
	Encoded TIF
Integrated LIDAR average values gridded surface 5 m	ASCII
	Encoded TIF
Topobathymetric contours 0.5 m	Shapefile

12.2 INTERPRETATION DELIVERABLES

Table 89: Interpretation deliverables, overview

Deliverable	Format
Seabed surface geology (polygon)	Shapefile
Seabed substrate type (polygon)	Shapefile
Seabed surface features (point)	Shapefile
Seabed surface features (line)	Shapefile
Seabed surface features (polygon)	Shapefile
Man-made objects (point)	Shapefile
Man-made objects (line)	Shapefile
Man-made objects (polygon)	Shapefile

APPENDIX A. GRAB SAMPLE CLASSIFICATION

ECR01

Point ID	Attempt	Easting	Northing	Elevation (m)	Lithology description	Carbonate content	Depositional Age	Depositional Environment	KP	Offset from RPL	KP reference
Nearshore											
NS-1_001_03	3	445135.42	6233542.35	8.80	Cream mottled light brown slightly clayey sandy fine to coarse GRAVEL	Slightly calcareous	Post Glacial	Post-glacial marine	1.043	-17.52	SN2023_027_KP_ROUTE_LIN_UTM 32N / Part 1
NS-1_002_03	3	444764.04	6233119.07	10.80	Multicoloured slightly clayey very sandy fine to medium GRAVEL and rare fine shell fragments	Slightly calcareous	Post Glacial	Post-glacial marine	1.505	-339.89	SN2023_027_KP_ROUTE_LIN_UTM 32N / Part 1
NS-1_003_03	3	444675.19	6233662.87	12.60	Dark grey mottled greyish brown slightly clayey SAND with rare fine to medium shell fragments.	Slightly calcareous	Post Glacial	Post-glacial marine	1.461	209.59	SN2023_027_KP_ROUTE_LIN_UTM 32N / Part 1
NS-1_004_03	3	445365.89	6233980.24	7.60	Brownish grey slightly clayey SAND.	Slightly calcareous	Post Glacial	Post-glacial marine	0.714	352.73	SN2023_027_KP_ROUTE_LIN_UTM 32N / Part 1
NS-1_005_03	3	444711.66	6233947.28	12.10	Brownish grey slightly clayey SAND.	Slightly calcareous	Post Glacial	Post-glacial marine	1.358	477.13	SN2023_027_KP_ROUTE_LIN_UTM 32N / Part 1
Offshore											
NS-ECR-01-01	1	444634.42	6233439.56	9.87	Greyish brown silty SAND	Slightly calcareous	Post Glacial	Post-glacial marine	1.554	2.42	SN2023_027_KP_ROUTE_LIN_UTM 32N / Part 1
NS-ECR-01-02	1	443723.61	6233213.37	14.02	Greyish brown mottled dark grey silty SAND with rare fine to medium shell fragments	Non-calcareous	Post Glacial	Post-glacial marine	2.493	0.47	SN2023_027_KP_ROUTE_LIN_UTM 32N / Part 1
NS-ECR-01-03	1	442927.91	6233019.77	16.93	Greyish brown mottled dark grey silty SAND with rare fine to medium shell fragments	Slightly calcareous	Post Glacial	Post-glacial marine	3.312	2.65	SN2023_027_KP_ROUTE_LIN_UTM 32N / Part 1
NS-ECR-01-04	1	441776.51	6232734.12	16.65	Greyish brown mottled dark grey silty SAND with rare fine to medium shell fragments	Slightly calcareous	Post Glacial	Post-glacial marine	4.499	0.46	SN2023_027_KP_ROUTE_LIN_UTM 32N / Part 1
NS-ECR-01-05	1	440755.98	6232482.68	15.79	Greyish brown mottled dark grey silty SAND with rare fine to medium shell fragments	Slightly calcareous	Post Glacial	Post-glacial marine	5.55	0.22	SN2023_027_KP_ROUTE_LIN_UTM 32N / Part 1
NS-ECR-01-06	1	439759.51	6232236.34	15.01	Dark grey mottled brownish grey silty SAND with rare fine to medium shell fragments	Slightly calcareous	Post Glacial	Post-glacial marine	6.577	-0.83	SN2023_027_KP_ROUTE_LIN_UTM 32N / Part 1
NS-ECR-01-07	1	438820.10	6232007.01	15.17	Greyish brown and dark grey mottled silty SAND with rare fine to medium shell fragments	Slightly calcareous	Post Glacial	Post-glacial marine	7.544	1.01	SN2023_027_KP_ROUTE_LIN_UTM 32N / Part 1
NS-ECR-01-08	1	437826.78	6231761.67	16.37	Greyish brown mottled dark grey silty SAND with rare fine to medium shell fragments	Slightly calcareous	Post Glacial	Post-glacial marine	8.568	0.19	SN2023_027_KP_ROUTE_LIN_UTM 32N / Part 1
NS-ECR-01-09	1	436869.24	6231528.38	16.24	Greyish brown mottled dark grey silty SAND	Slightly calcareous	Post Glacial	Post-glacial marine	9.554	2.51	SN2023_027_KP_ROUTE_LIN_UTM 32N / Part 1
NS-ECR-01-10	1	435868.82	6231280.56	17.36	Brown SAND	Slightly calcareous	Post Glacial	Post-glacial marine	10.585	0.97	SN2023_027_KP_ROUTE_LIN_UTM 32N / Part 1
NS-ECR-01-11	1	434934.11	6231046.67	18.98	Dark grey mottled greyish brown silty SAND with rare fine shell fragments	Slightly calcareous	Post Glacial	Post-glacial marine	11.549	-2.74	SN2023_027_KP_ROUTE_LIN_UTM 32N / Part 1
NS-ECR-01-12	1	433906.32	6230793.51	18.37	Brown silty SAND	Slightly calcareous	Post Glacial	Post-glacial marine	12.607	-2.92	SN2023_027_KP_ROUTE_LIN_UTM 32N / Part 1
NS-ECR-01-13	1	432912.47	6230379.57	17.68	Multicoloured silty SAND with rare fine shell fragments	Slightly calcareous	Post Glacial	Post-glacial marine	13.706	-0.02	SN2023_027_KP_ROUTE_LIN_UTM 32N / Part 1
NS-ECR-01-14	1	432337.17	6229942.26	18.80	Light brown SAND	Slightly calcareous	Post Glacial	Post-glacial marine	14.429	-1.97	SN2023_027_KP_ROUTE_LIN_UTM 32N / Part 1

Point ID	Attempt	Easting	Northing	Elevation (m)	Lithology description	Carbonate content	Depositional Age	Depositional Environment	KP	Offset from RPL	KP reference
NS-ECR-01-15	1	431693.96	6229455.66	20.29	Dark brown clayey silty SAND	Slightly calcareous	Post Glacial	Post-glacial marine	15.236	-2.28	SN2023_027_KP_ROUTE_LIN_UTM 32N / Part 1
NS-ECR-01-16	1	430858.79	6228825.46	20.37	Light brown SAND with rare fine gravel	Slightly calcareous	Post Glacial	Post-glacial marine	16.283	-1.39	SN2023_027_KP_ROUTE_LIN_UTM 32N / Part 1
NS-ECR-01-17	1	430100.49	6228249.73	21.27	Light brown silty SAND	Slightly calcareous	Post Glacial	Post-glacial marine	17.235	-3.4	SN2023_027_KP_ROUTE_LIN_UTM 32N / Part 1
NS-ECR-01-18	1	429313.07	6227652.39	21.79	Light brown silty SAND	Slightly calcareous	Post Glacial	Post-glacial marine	18.224	-5.09	SN2023_027_KP_ROUTE_LIN_UTM 32N / Part 1
NS-ECR-01-19	1	428551.69	6227077.03	24.14	Brownish grey mottled dark grey silty SAND	Slightly calcareous	Post Glacial	Post-glacial marine	19.178	-4.95	SN2023_027_KP_ROUTE_LIN_UTM 32N / Part 1
NS-ECR-01-20	1	427578.38	6226349.20	23.13	Light brown silty SAND with rare fine shell fragments	Slightly calcareous	Post Glacial	Post-glacial marine	20.394	1.36	SN2023_027_KP_ROUTE_LIN_UTM 32N / Part 1
NS-ECR-01-21	1	426905.75	6225844.86	24.61	Greyish brown SAND with rare fine shell fragments	Slightly calcareous	Post Glacial	Post-glacial marine	21.235	4.64	SN2023_027_KP_ROUTE_LIN_UTM 32N / Part 1
NS-ECR-01-22	1	426118.77	6225247.29	21.90	Light brown SAND with rare fine shell fragments	Slightly calcareous	Post Glacial	Post-glacial marine	22.224	2.5	SN2023_027_KP_ROUTE_LIN_UTM 32N / Part 1
NS-ECR-01-23	1	425314.70	6224637.39	24.47	Greyish brown silty SAND with rare fine shell fragments	Slightly calcareous	Post Glacial	Post-glacial marine	23.233	0.83	SN2023_027_KP_ROUTE_LIN_UTM 32N / Part 1

ECR02

Point ID	Attempt	Easting	Northing	Elevation (m)	Lithology description	Carbonate content	Depositional Age	Depositional Environment	KP	Offset from RPL	KP reference
Nearshore											
NS-3_001_03	1	446355.52	6185591.53	9.90	Brownish grey slightly clayey SAND.	Slightly calcareous	Post Glacial	Post-glacial marine	2.217	-188.54	SN2023_027_KP_ROUTE_LIN_UTM 32N / Part 2
NS-3_002_03	1	446644.01	6185335.36	8.30	Brownish grey slightly clayey SAND.	Slightly calcareous	Post Glacial	Post-glacial marine	1.832	-222.24	SN2023_027_KP_ROUTE_LIN_UTM 32N / Part 2
NS-3_003_03	3	446306.50	6186309.70	8.80	Brownish grey mottled dark grey clayey SAND.	Slightly calcareous	Post Glacial	Post-glacial marine	2.684	359.02	SN2023_027_KP_ROUTE_LIN_UTM 32N / Part 2
NS-3_004_03	2	446997.10	6185403.50	7.10	Brownish grey slightly clayey SAND.	Slightly calcareous	Post Glacial	Post-glacial marine	1.589	43.07	SN2023_027_KP_ROUTE_LIN_UTM 32N / Part 2
NS-3_005_03	3	447626.80	6184845.40	3.90	Dark grey mottled greyish brown clayey SAND.	Slightly calcareous	Post Glacial	Post-glacial marine	0.751	-29.63	SN2023_027_KP_ROUTE_LIN_UTM 32N / Part 2
NS-3_006_03	3	447781.10	6184993.30	4.40	Dark grey mottled greyish brown silty SAND.	Slightly calcareous	Post Glacial	Post-glacial marine	0.715	181.18	SN2023_027_KP_ROUTE_LIN_UTM 32N / Part 2
Offshore											
NS-ECR-02-01	1	445504.71	6185591.95	11.34	Brownish grey silty SAND with rare fine to medium shell fragments	Slightly calcareous	Post Glacial	Post-glacial marine	2.9	-695.62	SN2023_027_KP_ROUTE_LIN_UTM 32N / Part 2
NS-ECR-02-02	2	445131.64	6186751.89	12.10	Greyish brown silty SAND with rare fine to medium shell fragments	Slightly calcareous	Post Glacial	Post-glacial marine	3.892	13.5	SN2023_027_KP_ROUTE_LIN_UTM 32N / Part 2
NS-ECR-02-03	1	444271.64	6187371.86	15.14	Dark brown silty SAND with rare fine to medium shell fragments	Slightly calcareous	Post Glacial	Post-glacial marine	4.952	-1.47	SN2023_027_KP_ROUTE_LIN_UTM 32N / Part 2
NS-ECR-02-04	1	443183.84	6187642.44	16.78	Greyish brown mottled dark grey silty SAND with rare fine to medium shell fragments	Slightly calcareous	Post Glacial	Post-glacial marine	5.987	-432.9	SN2023_027_KP_ROUTE_LIN_UTM 32N / Part 2
NS-ECR-02-05	1	442328.13	6188717.65	18.19	Greyish brown mottled dark grey silty SAND with rare fine to medium shell fragments	Slightly calcareous	Post Glacial	Post-glacial marine	7.316	-79.67	SN2023_027_KP_ROUTE_LIN_UTM 32N / Part 2

Point ID	Attempt	Easting	Northing	Elevation (m)	Lithology description	Carbonate content	Depositional Age	Depositional Environment	KP	Offset from RPL	KP reference
NS-ECR-02-06	1	441399.37	6189305.86	17.95	Dark brown silty SAND with rare fine to medium shell fragments	Slightly calcareous	Post Glacial	Post-glacial marine	8.412	-161.15	SN2023_027_KP_ROUTE_LIN_UTM 32N / Part 2
NS-ECR-02-07	1	440510.35	6189160.45	17.32	Dark grey mottled greyish brown silty SAND with rare fine to medium shell fragments	Slightly calcareous	Post Glacial	Post-glacial marine	9.074	-153.46	SN2023_027_KP_ROUTE_LIN_UTM 32N / Part 3
NS-ECR-02-08	1	440170.10	6190420.20	18.08	Greyish brown silty SAND with rare fine to medium shell fragments	Slightly calcareous	Post Glacial	Post-glacial marine	10.064	0.71	SN2023_027_KP_ROUTE_LIN_UTM 32N / Part 2
NS-ECR-02-09	1	440069.74	6191258.32	18.80	Dark brown mottled dark grey silty SAND with rare fine to medium shell fragments	Slightly calcareous	Post Glacial	Post-glacial marine	10.909	-0.14	SN2023_027_KP_ROUTE_LIN_UTM 32N / Part 2
NS-ECR-02-10	1	439975.11	6192065.82	19.00	Dark brown silty SAND with rare fine to medium shell fragments	Slightly calcareous	Post Glacial	Post-glacial marine	11.723	0.71	SN2023_027_KP_ROUTE_LIN_UTM 32N / Part 2
NS-ECR-02-11	1	439847.92	6193155.97	18.70	Dark grey mottled greyish brown silty SAND with rare fine to medium shell fragments	Slightly calcareous	Post Glacial	Post-glacial marine	12.821	2.42	SN2023_027_KP_ROUTE_LIN_UTM 32N / Part 2
NS-ECR-02-12	1	440101.54	6194080.21	19.10	Dark grey mottled greyish brown silty SAND with rare fine to medium shell fragments	Slightly calcareous	Post Glacial	Post-glacial marine	13.709	362.94	SN2023_027_KP_ROUTE_LIN_UTM 32N / Part 2
NS-ECR-02-13	1	439452.93	6195034.98	19.02	Dark grey mottled greyish brown silty SAND with rare fine to medium shell fragments	Slightly calcareous	Post Glacial	Post-glacial marine	14.734	-169.25	SN2023_027_KP_ROUTE_LIN_UTM 32N / Part 2
NS-ECR-02-14	1	439501.36	6196035.55	18.89	Dark grey mottled greyish brown silty SAND with rare fine to medium shell fragments	Slightly calcareous	Post Glacial	Post-glacial marine	15.722	-3.6	SN2023_027_KP_ROUTE_LIN_UTM 32N / Part 2
NS-ECR-02-15	1	439375.71	6197129.64	19.62	Dark grey mottled greyish brown silty SAND with rare fine shell fragments	Slightly calcareous	Post Glacial	Post-glacial marine	16.824	0.1	SN2023_027_KP_ROUTE_LIN_UTM 32N / Part 2
NS-ECR-02-16	1	439093.15	6198160.70	19.43	Dark grey mottled greyish brown silty SAND with rare fine to medium shell fragments	Slightly calcareous	Post Glacial	Post-glacial marine	17.881	-159.49	SN2023_027_KP_ROUTE_LIN_UTM 32N / Part 2
NS-ECR-02-17	1	439130.09	6199174.87	18.49	Dark grey mottled greyish brown silty SAND with rare fine to medium shell fragments	Slightly calcareous	Post Glacial	Post-glacial marine	18.884	-3.66	SN2023_027_KP_ROUTE_LIN_UTM 32N / Part 2
NS-ECR-02-18	1	439328.98	6200015.86	18.11	Dark grey mottled greyish brown slightly clayey silty SAND with rare fine to medium shell fragments	Slightly calcareous	Post Glacial	Post-glacial marine	19.696	292.72	SN2023_027_KP_ROUTE_LIN_UTM 32N / Part 2
NS-ECR-02-19	1	438891.08	6201206.81	18.40	Dark brown slightly clayey silty SAND with rare fine to medium shell fragments	Slightly calcareous	Post Glacial	Post-glacial marine	20.931	-2.4	SN2023_027_KP_ROUTE_LIN_UTM 32N / Part 2
NS-ECR-02-20	1	438798.20	6202013.71	19.29	Dark brown slightly clayey silty SAND with rare fine shell fragments	Slightly calcareous	Post Glacial	Post-glacial marine	21.744	0.12	SN2023_027_KP_ROUTE_LIN_UTM 32N / Part 2
NS-ECR-02-21	1	438686.62	6202992.06	18.90	Dark brown silty SAND with rare fine to medium shell fragments	Slightly calcareous	Post Glacial	Post-glacial marine	22.729	4.2	SN2023_027_KP_ROUTE_LIN_UTM 32N / Part 2
NS-ECR-02-22	1	438096.11	6204099.24	18.87	Brown silty SAND with rare fine to medium shell fragments	Slightly calcareous	Post Glacial	Post-glacial marine	23.898	-452.38	SN2023_027_KP_ROUTE_LIN_UTM 32N / Part 2
NS-ECR-02-23	2	438445.68	6204998.49	19.08	Greyish brown silty SAND with rare fine to medium shell fragments	Slightly calcareous	Post Glacial	Post-glacial marine	24.75	0.53	SN2023_027_KP_ROUTE_LIN_UTM 32N / Part 2
NS-ECR-02-24	1	438778.23	6205993.91	19.62	Greyish brown silty SAND with rare fine to medium shell fragments	Slightly calcareous	Post Glacial	Post-glacial marine	25.7	447.83	SN2023_027_KP_ROUTE_LIN_UTM 32N / Part 2
NS-ECR-02-25	1	437792.87	6206684.99	21.37	Dark brown mottled black slightly clayey silty SAND with rare fine shell fragments	Slightly calcareous	Post Glacial	Post-glacial marine	26.66	0.75	SN2023_027_KP_ROUTE_LIN_UTM 32N / Part 2
NS-ECR-02-26	1	437255.55	6207214.91	20.72	Dark brown mottled dark grey silty SAND with rare fine to medium shell fragments	Slightly calcareous	Post Glacial	Post-glacial marine	27.415	0.43	SN2023_027_KP_ROUTE_LIN_UTM 32N / Part 2
NS-ECR-02-27	1	436605.84	6207759.57	21.03	Dark brown mottled dark grey slightly clayey silty SAND with rare fine to medium shell fragments	Slightly calcareous	Post Glacial	Post-glacial marine	28.26	-68.38	SN2023_027_KP_ROUTE_LIN_UTM 32N / Part 2
NS-ECR-02-28	1	435935.33	6208224.59	20.77	Dark brown silty SAND with rare fine to medium shell fragments	Slightly calcareous	Post Glacial	Post-glacial marine	29.128	3.85	SN2023_027_KP_ROUTE_LIN_UTM 32N / Part 2
NS-ECR-02-29	1	434737.12	6208310.09	21.78	Dark brown silty SAND	Slightly calcareous	Post Glacial	Post-glacial marine	30.329	-23.42	SN2023_027_KP_ROUTE_LIN_UTM 32N / Part 2
NS-ECR-02-30	1	433933.09	6208409.55	20.28	Dark grey mottled dark brown silty SAND with rare fine shell fragments	Slightly calcareous	Post Glacial	Post-glacial marine	31.139	0.21	SN2023_027_KP_ROUTE_LIN_UTM 32N / Part 2
NS-ECR-02-31	1	432776.53	6208569.67	19.84	Dark brown silty SAND with rare fine shell fragments	Slightly calcareous	Post Glacial	Post-glacial marine	32.306	51.17	SN2023_027_KP_ROUTE_LIN_UTM 32N / Part 2

Point ID	Attempt	Easting	Northing	Elevation (m)	Lithology description	Carbonate content	Depositional Age	Depositional Environment	KP	Offset from RPL	KP reference
NS-ECR-02-32	1	432044.72	6208587.56	20.64	Greyish brown SAND with rare fine shell fragments	Slightly calcareous	Post Glacial	Post-glacial marine	33.036	0.33	SN2023_027_KP_ROUTE_LIN_UTM 32N / Part 2
NS-ECR-02-33	1	431345.87	6208658.18	21.26	Greyish brown silty SAND with rare fine to medium shell fragments	Slightly calcareous	Post Glacial	Post-glacial marine	33.739	5.1	SN2023_027_KP_ROUTE_LIN_UTM 32N / Part 2
NS-ECR-02-34	1	430143.64	6208769.39	21.64	Brown silty SAND with rare fine to medium shell fragments	Slightly calcareous	Post Glacial	Post-glacial marine	34.947	3.06	SN2023_027_KP_ROUTE_LIN_UTM 32N / Part 2
NS-ECR-02-35	1	428411.72	6208934.50	23.88	Greyish brown SAND	Slightly calcareous	Post Glacial	Post-glacial marine	36.687	5.01	SN2023_027_KP_ROUTE_LIN_UTM 32N / Part 2
NS-ECR-02-36	1	427931.10	6208982.96	24.95	Dark brown slightly clayey silty SAND	Slightly calcareous	Post Glacial	Post-glacial marine	37.17	8.18	SN2023_027_KP_ROUTE_LIN_UTM 32N / Part 2
NS-ECR-02-37	2	426923.37	6208871.79	24.72	Greyish brown SAND	Slightly calcareous	Post Glacial	Post-glacial marine	38.164	-197.08	SN2023_027_KP_ROUTE_LIN_UTM 32N / Part 2
NS-ECR-02-38	1	425945.62	6209167.55	25.18	Dark grey mottled greyish brown silty SAND with rare fine to medium shell fragments	Slightly calcareous	Post Glacial	Post-glacial marine	39.165	5.75	SN2023_027_KP_ROUTE_LIN_UTM 32N / Part 2
NS-ECR-02-39	1	424890.41	6209266.97	26.36	Dark brown mottled dark grey silty SAND with rare fine shell fragments	Slightly calcareous	Post Glacial	Post-glacial marine	40.225	5.77	SN2023_027_KP_ROUTE_LIN_UTM 32N / Part 2
NS-ECR-02-40	1	424018.65	6209348.86	24.86	Greyish brown silty SAND with rare fine to medium shell fragments	Non-calcareous	Post Glacial	Post-glacial marine	41.101	5.54	SN2023_027_KP_ROUTE_LIN_UTM 32N / Part 2

ECR03

Point ID	Attempt	Easting	Northing	Elevation (m)	Lithology description	Carbonate content	Depositional Age	Depositional Environment	KP	Offset from RPL	KP reference
Nearshore											
NS-3_001_03	3	446355.60	6185591.60	9.90	Brownish grey slightly clayey SAND.	Slightly calcareous	Post Glacial	Post-glacial marine	2.224	-27.93	SN2023_027_KP_ROUTE_LIN_UTM32N / Part 3
NS-3_002_03	3	446647.30	6185330.60	8.30	Brownish grey slightly clayey SAND.	Slightly calcareous	Post Glacial	Post-glacial marine	1.838	-91.64	SN2023_027_KP_ROUTE_LIN_UTM32N / Part 3
NS-3_003_03	3	446306.50	6186309.70	8.80	Brownish grey mottled dark grey clayey SAND.	Slightly calcareous	Post Glacial	Post-glacial marine	2.651	551.86	SN2023_027_KP_ROUTE_LIN_UTM32N / Part 3
NS-3_004_03	2	446997.10	6185403.50	7.10	Brownish grey slightly clayey SAND.	Slightly calcareous	Post Glacial	Post-glacial marine	1.589	43.07	SN2023_027_KP_ROUTE_LIN_UTM32N / Part 2
NS-3_005_03	3	447626.80	6184845.40	3.90	Dark grey mottled greyish brown clayey SAND.	Slightly calcareous	Post Glacial	Post-glacial marine	0.751	24.64	SN2023_027_KP_ROUTE_LIN_UTM32N / Part 3
NS-3_006_03	3	447781.10	6184993.30	4.40	Dark grey mottled greyish brown silty SAND.	Slightly calcareous	Post Glacial	Post-glacial marine	0.7	232.32	SN2023_027_KP_ROUTE_LIN_UTM32N / Part 3
Offshore											
NS-ECR-02-01	1	445504.71	6185591.95	11.34	Brownish grey silty SAND with rare fine to medium shell fragments	Slightly calcareous	Post Glacial	Post-glacial marine	2.943	-484.44	SN2023_027_KP_ROUTE_LIN_UTM32N / Part 3
NS-ECR-02-02	2	445131.64	6186751.89	12.10	Greyish brown silty SAND with rare fine to medium shell fragments	Slightly calcareous	Post Glacial	Post-glacial marine	3.881	294.39	SN2023_027_KP_ROUTE_LIN_UTM32N / Part 3
NS-ECR-02-03	1	444271.64	6187371.86	15.14	Dark brown silty SAND with rare fine to medium shell fragments	Slightly calcareous	Post Glacial	Post-glacial marine	4.939	356.02	SN2023_027_KP_ROUTE_LIN_UTM32N / Part 3
NS-ECR-02-04	1	443183.84	6187642.44	16.78	Greyish brown mottled dark grey silty SAND with rare fine to medium shell fragments	Slightly calcareous	Post Glacial	Post-glacial marine	6.003	0.44	SN2023_027_KP_ROUTE_LIN_UTM32N / Part 3
NS-ECR-02-05	1	442328.13	6188717.65	18.19	Greyish brown mottled dark grey silty SAND with rare fine to medium shell fragments	Slightly calcareous	Post Glacial	Post-glacial marine	7.302	448.64	SN2023_027_KP_ROUTE_LIN_UTM32N / Part 3
NS-ECR-02-06	1	441399.37	6189305.86	17.95	Dark brown silty SAND with rare fine to medium shell fragments	Slightly calcareous	Post Glacial	Post-glacial marine	8.402	446.55	SN2023_027_KP_ROUTE_LIN_UTM32N / Part 3
NS-ECR-02-07	1	440510.35	6189160.45	17.32	Dark grey mottled greyish brown silty SAND with rare fine to medium shell fragments	Slightly calcareous	Post Glacial	Post-glacial marine	9.074	-153.46	SN2023_027_KP_ROUTE_LIN_UTM32N / Part 3

Point ID	Attempt	Easting	Northing	Elevation (m)	Lithology description	Carbonate content	Depositional Age	Depositional Environment	KP	Offset from RPL	KP reference
NS-ECR-02-08	1	440170.10	6190420.20	18.08	Greyish brown silty SAND with rare fine to medium shell fragments	Slightly calcareous	Post Glacial	Post-glacial marine	10.038	727.23	SN2023_027_KP_ROUTE_LIN_UTM32N / Part 3
NS-ECR-03-01	1	439080.90	6190252.28	17.07	Dark brown silty SAND with rare fine to medium shell fragments	Slightly calcareous	Post Glacial	Post-glacial marine	10.867	0.76	SN2023_027_KP_ROUTE_LIN_UTM32N / Part 3
NS-ECR-03-02	1	438034.83	6190548.56	18.42	Dark grey mottled greyish brown silty SAND with rare fine shell fragments	Slightly calcareous	Post Glacial	Post-glacial marine	11.978	-3.82	SN2023_027_KP_ROUTE_LIN_UTM32N / Part 3
NS-ECR-03-03	1	437139.51	6190668.79	17.44	Dark brown clayey silty SAND with rare fine shell fragments	Calcareous	Post Glacial	Post-glacial marine	12.882	-3.84	SN2023_027_KP_ROUTE_LIN_UTM32N / Part 3
NS-ECR-03-04	1	436112.79	6190802.16	17.33	Dark brown silty SAND with rare fine to medium shell fragments	Slightly calcareous	Post Glacial	Post-glacial marine	13.918	-8.32	SN2023_027_KP_ROUTE_LIN_UTM32N / Part 3
NS-ECR-03-05	1	435171.50	6190937.65	16.14	Greyish brown silty SAND with rare fine to medium shell fragments	Slightly calcareous	Post Glacial	Post-glacial marine	14.869	0.67	SN2023_027_KP_ROUTE_LIN_UTM32N / Part 3
NS-ECR-03-06	1	434120.30	6191207.35	18.38	Dark brown silty SAND with rare fine shell fragments	Slightly calcareous	Post Glacial	Post-glacial marine	15.947	128.08	SN2023_027_KP_ROUTE_LIN_UTM32N / Part 3
NS-ECR-03-07	1	433177.43	6191204.50	19.51	Brown silty SAND with rare fine to medium shell fragments	Slightly calcareous	Post Glacial	Post-glacial marine	16.882	-0.29	SN2023_027_KP_ROUTE_LIN_UTM32N / Part 3
NS-ECR-03-08	2	431269.70	6191416.85	19.88	Multicoloured silty very sandy fine to medium GRAVEL	Calcareous	Post Glacial	Post-glacial marine	18.801	-43.79	SN2023_027_KP_ROUTE_LIN_UTM32N / Part 3
NS-ECR-03-09	2	430694.91	6191634.33	22.06	Multicoloured very sandy fine to medium GRAVEL	Slightly calcareous	Post Glacial	Post-glacial marine	19.4	95.29	SN2023_027_KP_ROUTE_LIN_UTM32N / Part 3
NS-ECR-03-10	1	429876.95	6191889.63	20.82	Dark brown silty SAND with rare fine to medium shell fragments	Slightly calcareous	Glacial	Glacial	20.245	239.49	SN2023_027_KP_ROUTE_LIN_UTM32N / Part 3
NS-ECR-03-11	1	429303.24	6191635.02	19.71	Dark brown silty SAND	Slightly calcareous	Post Glacial	Post-glacial marine	20.78	-89.34	SN2023_027_KP_ROUTE_LIN_UTM32N / Part 3
NS-ECR-03-12	1	428092.54	6191891.14	20.69	Dark brown silty SAND with rare fine to medium shell fragments	Slightly calcareous	Post Glacial	Post-glacial marine	22.014	3.38	SN2023_027_KP_ROUTE_LIN_UTM32N / Part 3
NS-ECR-03-13	1	427260.15	6191681.54	23.26	Dark brown silty SAND with rare fine to medium shell fragments	Slightly calcareous	Post Glacial	Post-glacial marine	22.812	-315.27	SN2023_027_KP_ROUTE_LIN_UTM32N / Part 3

APPENDIX B. GEOTECHNICAL RESULTS OVERVIEW TABLES

All tests were completed, and target depths have been reached.

POINTID	TRT analysis	EASTING	NORTHING	ELEV_SURFA	ELEV_TOP	ELEV_BOT	KP	OFFSET	PENETRATIO	RECOVERY
Vibrocore NS_ECR1										
GT_VC_001	No	444924.13	6233508.50	10.01	0	3	1.255	4.32	1.19	1.00
GT_VC_002	No	443817.56	6233236.00	15.70	0	3	2.395	-0.40	1.89	1.70
GT_VC_002a	No	443817.56	6233236.00	15.70	0	3	2.394	4.31	1.49	1.50
GT_VC_003	No	442850.19	6232998.00	18.52	0	3	3.392	-0.92	1.00	1.00
GT_VC_004	No	441604.47	6232691.50	19.14	0	3	4.676	0.16	2.90	2.80
GT_VC_005	No	440498.03	6232418.00	18.93	0	6	5.817	-1.35	1.89	1.90
GT_VC_005a	Yes	440498.03	6232418.00	18.93	0	6	5.811	-1.34	1.94	1.95
GT_VC_006	No	439678.41	6232218.00	18.80	0	3	6.660	0.90	3.39	3.00
GT_VC_007	Yes	438292.66	6231874.00	18.73	0	6	8.089	-1.81	4.50	5.15
GT_VC_008	No	437178.16	6231602.00	18.76	0	6	9.236	-0.69	5.07	5.85
GT_VC_009	No	436071.78	6231328.50	18.88	0	3	10.376	-0.77	3.42	3.85
GT_VC_010	No	435392.78	6231162.50	19.90	0	3	11.075	0.52	3.24	4.05
GT_VC_011	Yes	433858.78	6230783.50	20.53	0	6	12.655	-2.17	4.49	4.75
GT_VC_011a	No	433858.78	6230783.50	20.53	0	6	12.655	2.97	5.07	5.30
GT_VC_012	No	432731.00	6230242.50	21.12	0	3	13.931	3.41	3.17	2.85
GT_VC_013	No	431821.91	6229555.00	21.78	0	3	15.073	-0.56	4.58	4.20
GT_VC_014	No	430586.72	6228622.00	22.52	0	6	16.623	-0.93	5.74	6.00
GT_VC_015	Yes	430112.59	6228263.00	22.58	0	6	17.220	-1.04	5.79	5.65
GT_VC_016	No	429095.09	6227493.50	24.14	0	3	18.495	0.65	3.38	3.25
GT_VC_017	No	428185.47	6226806.50	25.32	0	6	19.636	-0.86	5.80	5.90
GT_VC_018	No	427276.38	6226119.00	24.57	0	3	20.773	0.93	3.36	3.10
GT_VC_019	Yes	426092.63	6225226.00	25.42	0	6	22.257	2.62	5.51	4.95
GT_VC_020	No	425436.63	6224726.00	26.01	0	6	23.084	-2.05	5.80	5.85

All tests were completed, and target depths have been reached.

POINTID	TRT analysis	EASTING	NORTHING	ELEV_SURFA	ELEV_TOP	ELEV_BOT	KP	OFFSET	PENETRATIO	RECOVERY
Vibrocore NS_ECR2										
GT_VC_021	No	446030.00	6185904.00	9.74	0	3	2.664	-132.23	3.07	3.25
GT_VC_022	Yes	444484.75	6187204.50	15.69	0	6	4.681	-9.36	5.49	6.00
GT_VC_023	No	442920.31	6188379.00	18.54	0	3	6.638	1.57	3.12	3.00
GT_VC_024	No	440997.00	6189814.00	19.71	0	6	9.039	7.78	5.78	5.30
GT_VC_025	No	440165.00	6190380.00	19.71	0	3	10.045	-34.17	3.02	3.05
GT_VC_026	No	440116.16	6190870.50	19.79	0	6	10.519	-0.12	5.75	6.00
GT_VC_027	Yes	440053.63	6191403.00	19.92	0	6	11.054	0.97	5.11	5.70
GT_VC_028	No	439888.09	6192795.50	20.31	0	3	12.458	0.44	3.67	3.90

POINTID	TRT analysis	EASTING	NORTHING	ELEV_SURFA	ELEV_TOP	ELEV_BOT	KP	OFFSET	PENETRATIO	RECOVERY
GT_VC_029	No	439807.59	6193463.00	20.46	0	3	13.131	-1.22	3.03	2.70
GT_VC_030	No	439660.69	6194721.50	20.68	0	6	14.399	1.05	5.52	5.85
GT_VC_031	No	439524.81	6195864.00	20.92	0	3	15.549	-0.52	3.16	3.25
GT_VC_032	Yes	439358.53	6197274.00	21.18	0	6	16.969	0.28	5.72	5.05
GT_VC_033	No	439319.56	6197610.50	21.26	0	6	17.308	0.74	5.75	6.00
GT_VC_034	No	439204.88	6198573.50	21.32	0	6	18.278	0.97	5.70	6.00
GT_VC_035	Yes	439090.34	6199536.00	21.56	0	6	19.248	-0.40	5.74	5.95
GT_VC_036	No	438976.19	6200499.00	21.65	0	3	20.219	-1.18	3.26	3.05
GT_VC_037	No	438860.31	6201458.50	21.74	0	6	21.186	-3.80	5.79	6.00
GT_VC_038	No	438790.91	6202087.00	21.84	0	3	21.818	0.49	3.07	2.75
GT_VC_039	Yes	438748.13	6202424.50	21.85	0	6	22.158	-1.54	5.73	6.00
GT_VC_040	No	438651.06	6203257.00	22.07	0	3	22.996	-0.41	3.07	2.65
GT_VC_041	No	438520.88	6204351.00	22.49	0	3	24.099	-1.39	3.26	3.10
GT_VC_042	No	438436.81	6205065.00	22.92	0	3	24.818	-0.12	3.31	3.25
GT_VC_043	Yes	438235.88	6206247.00	22.80	0	6	26.037	-0.14	5.75	5.95
GT_VC_044	No	437966.84	6206512.00	22.77	0	6	26.415	0.52	1.00	1.55
GT_VC_044a	Yes	437966.84	6206512.00	22.77	0	6	26.418	3.69	3.86	4.25
GT_VC_044b	No	437966.84	6206512.00	22.77	0	6	26.411	-3.23	3.14	3.45
GT_VC_045	No	437550.03	6206929.50	22.78	0	6	27.005	4.00	5.51	6.05
GT_VC_046	No	436802.56	6207636.00	22.93	0	6	28.034	-18.46	2.98	2.65
GT_VC_046a	No	436802.56	6207636.00	22.93	0	6	28.030	-15.25	3.15	2.95
GT_VC_047	No	436327.97	6208133.50	22.97	0	3	28.721	3.55	3.33	3.20
GT_VC_048	No	434853.47	6208319.50	22.54	0	6	30.214	-3.19	3.48	3.95
GT_VC_048a	No	434853.47	6208319.50	22.54	0	6	30.210	-2.75	4.14	3.50
GT_VC_049	No	434332.53	6208370.50	22.41	0	6	30.738	-1.10	2.77	2.85
GT_VC_049a	No	434332.53	6208370.50	22.41	0	6	30.734	3.60	2.59	2.50
GT_VC_050	Yes	433838.28	6208165.50	22.38	0	6	31.210	-251.28	5.73	5.25
GT_VC_051	No	433217.50	6208475.50	22.63	0	6	31.858	-2.23	3.55	3.85
GT_VC_051a	No	433217.50	6208475.50	22.63	0	6	31.857	3.53	3.74	4.05
GT_VC_052	No	432406.09	6208552.50	22.40	0	3	32.677	0.30	3.23	3.05
GT_VC_053	No	431064.13	6208678.00	22.63	0	3	34.020	-2.74	3.20	3.10
GT_VC_054	No	430321.44	6208749.00	23.38	0	6	34.768	-0.16	5.69	5.95
GT_VC_055	No	429355.97	6208840.50	24.47	0	3	35.738	0.50	3.46	3.90
GT_VC_056	No	428630.63	6208909.00	25.51	0	6	36.467	-0.27	1.96	2.00
GT_VC_056a	Yes	428630.63	6208909.00	25.51	0	6	36.471	-0.12	2.15	2.20
GT_VC_057	No	428390.47	6208931.50	25.64	0	3	36.708	0.23	3.33	3.15
GT_VC_058	Yes	427425.09	6209020.50	26.41	0	6	37.678	-2.05	5.78	5.95
GT_VC_058a	No	427425.09	6209020.50	26.41	0	6	37.679	3.18	3.55	3.40
GT_VC_058b	Yes	427425.09	6209020.50	26.41	0	6	37.678	-6.83	5.72	6.00

POINTID	TRT analysis	EASTING	NORTHING	ELEV_SURFA	ELEV_TOP	ELEV_BOT	KP	OFFSET	PENETRATIO	RECOVERY
GT_VC_059	No	426459.66	6209111.50	26.43	0	3	38.647	-1.73	3.52	3.30
GT_VC_060	No	425484.00	6209205.00	27.10	0	3	39.628	-0.41	3.21	2.80
GT_VC_061	No	424528.66	6209295.50	26.83	0	3	40.588	0.55	3.09	2.75
GT_VC_062	No	445451.38	6186198.00	12.20	0	6	3.304	-240.27	5.52	5.95
GT_VC_063b	Yes	443759.00	6187275.00	17.42	0	6	5.255	-389.75	5.67	5.90
GT_VC_064	No	441628.00	6188630.00	19.34	0	3	7.794	-570.44	3.07	3.15
GT_VC_065	No	440177.88	6189551.50	19.40	0	6	9.537	-692.59	5.72	6.00

All tests were completed, and target depths have been reached.

POINTID	TRT analysis	EASTING	NORTHING	ELEV_SURFA	ELEV_TOP	ELEV_BOT	KP	OFFSET	PENETRATIO	RECOVERY
Vibrocore NS_ECR3										
GT_VC_021	No	446030.00	6185904.00	9.74	0	3	2.667	60.45	3.07	3.25
GT_VC_022	Yes	444484.75	6187204.50	15.69	0	6	4.701	328.51	5.49	6.00
GT_VC_023	No	442920.31	6188379.00	18.54	0	3	6.687	480.59	3.12	3.00
GT_VC_024	No	440997.00	6189814.00	19.71	0	6	9.150	660.90	5.78	5.30
GT_VC_025	No	440165.00	6190380.00	19.71	0	3	10.186	690.77	3.02	3.05
GT_VC_062	No	445451.38	6186198.00	12.20	0	6	3.313	-1.12	5.52	5.95
GT_VC_063b	Yes	443759.00	6187275.00	17.42	0	6	5.320	-5.86	5.67	5.90
GT_VC_064	No	441628.00	6188630.00	19.34	0	3	7.847	-2.71	3.07	3.15
GT_VC_065	No	440177.88	6189551.50	19.40	0	6	9.566	-2.30	5.72	6.00
GT_VC_066a	Yes	439222.34	6190160.00	19.39	0	6	10.698	-5.65	5.79	6.00
GT_VC_067	No	438258.63	6190523.00	19.52	0	3	11.753	0.29	3.02	3.05
GT_VC_068	No	437213.28	6190662.50	19.60	0	6	12.808	-0.61	5.72	5.90
GT_VC_069	No	436167.81	6190802.50	19.79	0	3	13.863	-0.64	3.55	3.15
GT_VC_070	No	435907.28	6190839.00	19.91	0	3	14.127	1.01	3.36	3.05
GT_VC_071	No	435122.56	6190943.50	20.19	0	6	14.918	-0.86	5.78	5.90
GT_VC_072	Yes	434076.84	6191083.50	20.47	0	6	15.974	-1.33	5.80	5.95
GT_VC_073	No	433425.56	6191171.50	20.67	0	3	16.631	-0.25	3.78	3.30
GT_VC_074	No	433032.06	6191223.50	20.78	0	3	17.028	-0.55	3.70	3.25
GT_VC_075	Yes	431986.63	6191362.00	21.27	0	6	18.083	-3.23	5.74	3.75
GT_VC_076	No	430941.31	6191503.00	21.63	0	3	19.138	-2.10	3.97	3.86
GT_VC_077	Yes	429896.03	6191643.50	22.27	0	6	20.192	-2.58	5.76	6.00
GT_VC_078	No	428850.63	6191783.00	22.79	0	3	21.248	-2.61	3.37	3.30
GT_VC_079	No	427797.56	6191925.00	23.56	0	3	22.311	-2.69	3.32	3.30

POINTID	COMMENT	EASTING	NORTHING	ELEV_SURFA	ELEV_TOP	ELEV_BOT	KP	OFFSET	Est_sett	PENETRATIO
Cone penetration test NS ECR1										
GT_CPT_001	Cone ID: GG60451. Cone size: 10	444924.13	6233508.50	10.01	0	3	1.255	4.32	0.00	3.30

POINTID	COMMENT	EASTING	NORTHING	ELEV_SURFA	ELEV_TOP	ELEV_BOT	KP	OFFSET	Est_sett	PENETRATIO
GT_CPT_002	Cone ID: GG60451. Cone size: 10	443817.56	6233236.00	15.70	0	3	2.395	-0.40	0.07	3.34
GT_CPT_003	Cone ID: GG60451. Cone size: 10	442850.19	6232998.00	18.52	0	3	3.392	-0.92	0.07	3.29
GT_CPT_004	Cone ID: GG60484. Cone size: 10	441604.47	6232691.50	19.14	0	3	4.676	0.16	0.07	3.39
GT_CPT_005	Cone ID: GG60484. Cone size: 10	440498.03	6232418.00	18.93	0	6	5.817	-1.35	0.06	6.21
GT_CPT_006	Cone ID: GG60484. Cone size: 10	439678.41	6232218.00	18.80	0	3	6.660	0.90	0.05	3.38
GT_CPT_007	Cone ID: GG60484. Cone size: 10	438292.66	6231874.00	18.73	0	6	8.089	-1.81	0.06	4.59
GT_CPT_007a	Cone ID: GG60484. Cone size: 10	438292.66	6231874.00	18.73	0	6	8.089	2.25	0.07	4.38
GT_CPT_008	Cone ID: GG60484. Cone size: 10	437178.16	6231602.00	18.76	0	6	9.236	-0.69	0.07	6.22
GT_CPT_009	Cone ID: GG60484. Cone size: 10	436071.78	6231328.50	18.88	0	3	10.376	-0.77	0.02	3.28
GT_CPT_010	Cone ID: GG60484. Cone size: 10	435392.78	6231162.50	19.90	0	3	11.075	0.52	0.00	3.23
GT_CPT_011	Cone ID: GG60484. Cone size: 10	433858.78	6230783.50	20.53	0	6	12.655	-2.17	0.02	3.51
GT_CPT_011a	Cone ID: GG60484. Cone size: 10	433858.78	6230783.50	20.53	0	6	12.655	2.97	0.03	6.17
GT_CPT_012	Cone ID: GG60482. Cone size: 10	432731.00	6230242.50	21.12	0	3	13.931	3.41	0.06	3.36
GT_CPT_013	Cone ID: GG60482. Cone size: 10	431821.91	6229555.00	21.78	0	3	15.073	-0.56	0.03	4.33
GT_CPT_014	Cone ID: GG60482. Cone size: 10	430586.72	6228622.00	22.52	0	6	16.623	-0.93	0.08	6.21
GT_CPT_015	Cone ID: GG60482. Cone size: 10	430112.59	6228263.00	22.58	0	6	17.220	-1.04	0.00	5.62
GT_CPT_016	Cone ID: GG60482. Cone size: 10	429095.09	6227493.50	24.14	0	3	18.495	0.65	0.09	3.39
GT_CPT_017	Cone ID: GG60484. Cone size: 10	428185.47	6226806.50	25.32	0	6	19.636	-0.86	0.06	6.21
GT_CPT_018	Cone ID: GG60484. Cone size: 10	427276.38	6226119.00	24.57	0	3	20.773	0.93	0.04	3.36
GT_CPT_019	Cone ID: GG60484. Cone size: 10	426092.63	6225226.00	25.42	0	6	22.257	2.62	0.06	6.23
GT_CPT_020	Cone ID: GG60484. Cone size: 10	425436.63	6224726.00	26.01	0	6	23.084	-2.05	0.08	5.30

POINTID	COMMENT	EASTING	NORTHING	ELEV_SURFA	ELEV_TOP	ELEV_BOT	KP	OFFSET	Est_sett	PENETRATIO
Cone penetration test NS_ECR2										
GT_CPT_021	Cone ID: GG60484. Cone size: 10	446030.00	6185904.00	9.74	0	3	2.664	-132.23	0.05	3.31
GT_CPT_022	Cone ID: GG60484. Cone size: 10	444484.75	6187204.50	15.69	0	6	4.681	-9.36	0.08	5.39
GT_CPT_023	Cone ID: GG60463. Cone size: 10	442920.31	6188379.00	18.54	0	3	6.638	1.57	0.10	3.32
GT_CPT_024	Cone ID: GG60463. Cone size: 10	440997.00	6189814.00	19.71	0	6	9.039	7.78	0.08	6.25
GT_CPT_025	Cone ID: GG60484. Cone size: 10	440165.00	6190380.00	19.71	0	3	10.045	-34.17	0.09	3.29
GT_CPT_026	Cone ID: GG60484. Cone size: 10	440116.16	6190870.50	19.79	0	6	10.519	-0.12	0.09	6.26
GT_CPT_027	Cone ID: GG60484. Cone size: 10	440053.63	6191403.00	19.92	0	6	11.054	0.97	0.10	6.27
GT_CPT_028	Cone ID: GG60484. Cone size: 10	439888.09	6192795.50	20.31	0	3	12.458	0.44	0.10	3.31
GT_CPT_029	Cone ID: GG60484. Cone size: 10	439807.59	6193463.00	20.46	0	3	13.131	-1.22	0.11	3.32
GT_CPT_030	Cone ID: GG60463. Cone size: 10	439660.69	6194721.50	20.68	0	6	14.399	1.05	0.11	6.28
GT_CPT_031	Cone ID: GG60463. Cone size: 10	439524.81	6195864.00	20.92	0	3	15.549	-0.52	0.10	3.31
GT_CPT_032	Cone ID: GG60463. Cone size: 10	439358.53	6197274.00	21.18	0	6	16.969	0.28	0.10	6.28
GT_CPT_033	Cone ID: GG60463. Cone size: 10	439319.56	6197610.50	21.26	0	6	17.308	0.74	0.10	6.26
GT_CPT_034	Cone ID: GG60482. Cone size: 10	439204.88	6198573.50	21.32	0	6	18.278	0.97	0.12	5.19
GT_CPT_035	Cone ID: GG60482. Cone size: 10	439090.34	6199536.00	21.56	0	6	19.248	-0.40	0.12	6.29

POINTID	COMMENT	EASTING	NORTHING	ELEV_SURFA	ELEV_TOP	ELEV_BOT	KP	OFFSET	Est_sett	PENETRATIO
GT_CPT_036	Cone ID: GG60482. Cone size: 10	438976.19	6200499.00	21.65	0	3	20.219	-1.18	0.10	3.40
GT_CPT_037	Cone ID: GG60482. Cone size: 10	438860.31	6201458.50	21.74	0	6	21.186	-3.80	0.11	4.36
GT_CPT_038	Cone ID: GG60482. Cone size: 10	438790.91	6202087.00	21.84	0	3	21.818	0.49	0.11	3.34
GT_CPT_039	Cone ID: GG60482. Cone size: 10	438748.13	6202424.50	21.85	0	6	22.158	-1.54	0.11	4.16
GT_CPT_040	Cone ID: GG60450. Cone size: 10	438651.06	6203257.00	22.07	0	3	22.996	-0.41	0.11	5.59
GT_CPT_041	Cone ID: GG60450. Cone size: 10	438520.88	6204351.00	22.49	0	3	24.099	-1.39	0.13	3.30
GT_CPT_042	Cone ID: GG60450. Cone size: 10	438436.81	6205065.00	22.92	0	3	24.818	-0.12	0.10	3.27
GT_CPT_043	Cone ID: GG60450. Cone size: 10	438235.88	6206247.00	22.80	0	6	26.037	-0.14	0.10	6.22
GT_CPT_044	Cone ID: GG60450. Cone size: 10	437966.84	6206512.00	22.77	0	6	26.415	0.52	0.12	6.27
GT_CPT_045	Cone ID: GG60484. Cone size: 10	437550.03	6206929.50	22.78	0	6	27.005	4.00	0.12	6.27
GT_CPT_046	Cone ID: GG60484. Cone size: 10	436802.56	6207636.00	22.93	0	6	28.034	-18.46	0.27	6.41
GT_CPT_047	Cone ID: GG60451. Cone size: 10	436327.97	6208133.50	22.97	0	3	28.721	3.55	0.13	3.35
GT_CPT_048	Cone ID: GG60451. Cone size: 10	434853.47	6208319.50	22.54	0	6	30.214	-3.19	0.11	6.28
GT_CPT_049	Cone ID: GG60451. Cone size: 10	434332.53	6208370.50	22.41	0	6	30.738	-1.10	0.10	6.22
GT_CPT_050	Cone ID: GG60482. Cone size: 10	433838.28	6208165.50	22.38	0	6	31.210	-251.28	0.09	6.00
GT_CPT_051	Cone ID: GG60482. Cone size: 10	433217.50	6208475.50	22.63	0	6	31.858	-2.23	0.10	6.27
GT_CPT_052a	Cone ID: GG60484. Cone size: 10	432406.09	6208552.50	22.40	0	3	32.677	0.30	0.00	3.32
GT_CPT_053	Cone ID: GG60507. Cone size: 10	431064.13	6208678.00	22.63	0	3	34.020	-2.74	0.08	3.36
GT_CPT_054	Cone ID: GG60507. Cone size: 10	430321.44	6208749.00	23.38	0	6	34.768	-0.16	0.08	6.25
GT_CPT_055	Cone ID: GG60507. Cone size: 10	429355.97	6208840.50	24.47	0	3	35.738	0.50	0.10	3.37
GT_CPT_056	Cone ID: GG60507. Cone size: 10	428630.63	6208909.00	25.51	0	6	36.467	-0.27	0.09	6.27
GT_CPT_057	Cone ID: GG60507. Cone size: 10	428390.47	6208931.50	25.64	0	3	36.708	0.23	0.09	3.40
GT_CPT_058	Cone ID: GG60482. Cone size: 10	427425.09	6209020.50	26.41	0	6	37.678	-2.05	0.10	6.26
GT_CPT_059	Cone ID: GG60482. Cone size: 10	426459.66	6209111.50	26.43	0	3	38.647	-1.73	0.10	3.32
GT_CPT_060	Cone ID: GG60482. Cone size: 10	425484.00	6209205.00	27.10	0	3	39.628	-0.41	0.09	3.32
GT_CPT_061	Cone ID: GG60482. Cone size: 10	424528.66	6209295.50	26.83	0	3	40.588	0.55	0.11	3.34
GT_CPT_062	Cone ID: GG60484. Cone size: 10	445451.38	6186198.00	12.20	0	6	3.304	-240.27	0.08	6.25
GT_CPT_063a	Cone ID: GG60463. Cone size: 10	443759.00	6187275.00	17.42	0	6	5.258	-381.30	0.09	3.83
GT_CPT_063b	Cone ID: GG60463. Cone size: 10	443759.00	6187275.00	17.42	0	6	5.255	-389.75	0.08	4.71
GT_CPT_064	Cone ID: GG60463. Cone size: 10	441628.00	6188630.00	19.34	0	3	7.794	-570.44	0.10	3.33
GT_CPT_065	Cone ID: GG60484. Cone size: 10	440177.88	6189551.50	19.40	0	6	9.537	-692.59	0.08	6.25

POINTID	STOPCRITER	COMMENT	EASTING	NORTHING	ELEV_SURFA	ELEV_TOP	ELEV_BOT	KP	OFFSET	Est_sett	PENETRATIO
Cone penetration test NS_ECR3											
GT_CPT_021	DEPTH	Cone ID: GG60484. Cone size: 10	446030.00	6185904.00	9.74	0	3	2.667	60.45	0.05	3.31
GT_CPT_022	THRUST	Cone ID: GG60484. Cone size: 10	444484.75	6187204.50	15.69	0	6	4.701	328.51	0.08	5.39
GT_CPT_023	DEPTH	Cone ID: GG60463. Cone size: 10	442920.31	6188379.00	18.54	0	3	6.687	480.59	0.10	3.32
GT_CPT_024	DEPTH	Cone ID: GG60463. Cone size: 10	440997.00	6189814.00	19.71	0	6	9.150	660.90	0.08	6.25
GT_CPT_025	DEPTH	Cone ID: GG60484. Cone size: 10	440165.00	6190380.00	19.71	0	3	10.186	690.77	0.09	3.29

POINTID	STOPCRITER	COMMENT	EASTING	NORTHING	ELEV_SURFA	ELEV_TOP	ELEV_BOT	KP	OFFSET	Est_sett	PENETRATIO
GT_CPT_062	DEPTH	Cone ID: GG60484. Cone size: 10	445451.38	6186198.00	12.20	0	6	3.313	-1.12	0.08	6.25
GT_CPT_063a	THRUST	Cone ID: GG60463. Cone size: 10	443759.00	6187275.00	17.42	0	6	5.321	2.86	0.09	3.83
GT_CPT_063b	THRUST	Cone ID: GG60463. Cone size: 10	443759.00	6187275.00	17.42	0	6	5.320	-5.86	0.08	4.71
GT_CPT_064	DEPTH	Cone ID: GG60463. Cone size: 10	441628.00	6188630.00	19.34	0	3	7.847	-2.71	0.10	3.33
GT_CPT_065	DEPTH	Cone ID: GG60484. Cone size: 10	440177.88	6189551.50	19.40	0	6	9.566	-2.30	0.08	6.25
GT_CPT_066a	THRUST	Cone ID: GG60551. Cone size: 10	439222.34	6190160.00	19.39	0	6	10.698	-5.65	0.11	6.27
GT_CPT_067	DEPTH	Cone ID: GG60463. Cone size: 10	438258.63	6190523.00	19.52	0	3	11.753	0.29	0.07	3.39
GT_CPT_068	DEPTH	Cone ID: GG60463. Cone size: 10	437213.28	6190662.50	19.60	0	6	12.808	-0.61	0.08	6.25
GT_CPT_069	DEPTH	Cone ID: GG60463. Cone size: 10	436167.81	6190802.50	19.79	0	3	13.863	-0.64	0.06	3.38
GT_CPT_070	DEPTH	Cone ID: GG60463. Cone size: 10	435907.28	6190839.00	19.91	0	3	14.127	1.01	0.05	3.39
GT_CPT_071	DEPTH	Cone ID: GG60463. Cone size: 10	435122.56	6190943.50	20.19	0	6	14.918	-0.86	0.08	6.25
GT_CPT_072	DEPTH	Cone ID: GG60463. Cone size: 10	434076.84	6191083.50	20.47	0	6	15.974	-1.33	0.07	6.24
GT_CPT_073	DEPTH	Cone ID: GG60463. Cone size: 10	433425.56	6191171.50	20.67	0	3	16.631	-0.25	0.08	3.34
GT_CPT_074	DEPTH	Cone ID: GG60482. Cone size: 10	433032.06	6191223.50	20.78	0	3	17.028	-0.55	0.09	3.40
GT_CPT_075	DEPTH	Cone ID: GG60482. Cone size: 10	431986.63	6191362.00	21.27	0	6	18.083	-3.23	0.08	6.28
GT_CPT_076	DEPTH	Cone ID: GG60482. Cone size: 10	430941.31	6191503.00	21.63	0	3	19.138	-2.10	0.07	3.38
GT_CPT_077	DEPTH	Cone ID: GG60482. Cone size: 10	429896.03	6191643.50	22.27	0	6	20.192	-2.58	0.08	6.25
GT_CPT_078	DEPTH	Cone ID: GG60482. Cone size: 10	428850.63	6191783.00	22.79	0	3	21.248	-2.61	0.10	3.35
GT_CPT_079	DEPTH	Cone ID: GG60482. Cone size: 10	427797.56	6191925.00	23.56	0	3	22.311	-2.69	0.10	3.51