ENGINEERING INFRASTRUCTURE DEVELOPMENT PLAN OF THE PROJECT OF EXCLUSIVE STATE IMPORTANCE „DEVELOPMENT OF THE TERRITORIES REQUIRED TO CONNECT POWER PLANTS USING RENEWABLE ENERGY RESOURCES IN THE BALTIC SEA PART(S) OF THE REPUBLIC OF LITHUANIA AND (OR) THE EXCLUSIVE ECONOMIC ZONE OF THE REPUBLIC OF LITHUANIA TO THE ELECTRICITY TRANSMISSION NETWORKS, PREPARATION FOR ENGINEERING INFRASTRUCTURE DEVELOPMENT"

REPORT OF THE SEA BOTTOM SURVEY

Klaipėda 2023-07-19

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Content

Aim

To collect the data on the bathymetry of the seabed, identify objects that may affect the installation of infrastructure, determine the features of the seabed relief. Seabed surveys are being carried out in the corridors identified in the siting study for connections and associated infrastructure that can be used to connect two renewable energy power parks (Fig. 1).

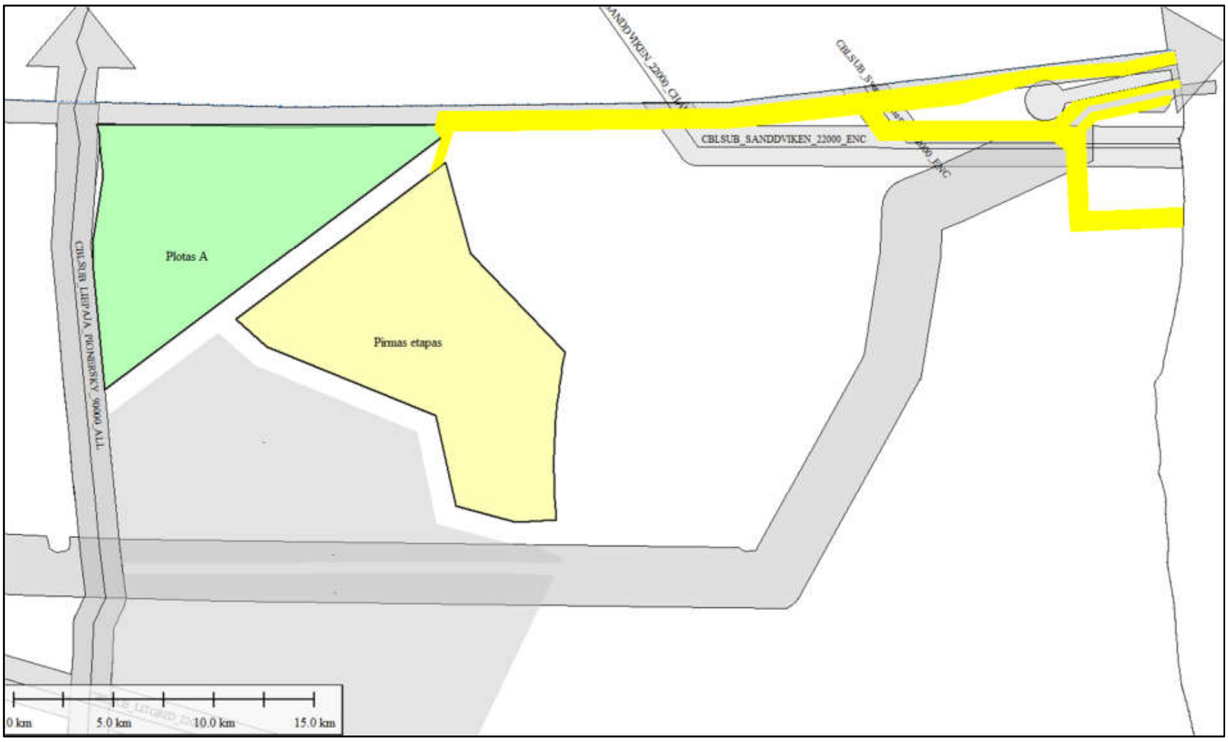


Fig. 1. Corridors under the survey

Methods and equipment

Hydrographic-geophysical surveys of the seabed in the sea and at the nearshore were organized in 2 stages along the pre-planned survey tracks (Fig. 2)

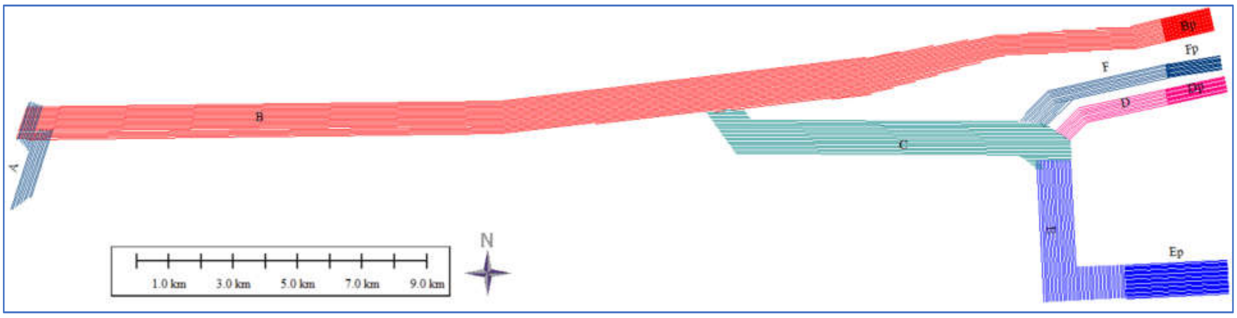


Fig. 2. Survey tracks

The offshore survey was planned in such a way as to obtain the main parameters corresponding to the technical task:

- - 200 percent side scan sonar coverage (i.e. ensuring that all objects are scanned while sailing along a defined profile from both sides);
- - 100 percent coverage and 10 percent overlap of multibeam echo-sounder survey.

Due to the different sea depths in different parts of the planned corridor, the distance between the parallel profiles also varies - in deeper areas, the distance between the profiles is usually greater than in shallow areas. Therefore, in the open sea, the distance between parallel profiles was 50 and 60 m, and at the nearshore (in sea depths from 15 m and shallower), the research profiles were placed twice as densely, i.e. every 25 and 30 m.

Due to the complex geometry of the planned corridor, the research area was divided into separate zones:

- - Offshore: A, B, C, D, E, and F;
- - Nearshore: Bp; Dp; Ep and Fp.

Main parameters of research areas:

- Zone A (Fig. 3): the tracks start from the north-eastern border of wind power development territories planned by the resolutions[1] of the Government of the Republic of Lithuania and extend to the infrastructure corridor on the border with Latvia provided for in the decisions of the Comprehensive Plan of Lithuania[2] (hereinafter - CP). The central track is A, the others are placed in parallel at 60 m spacing. All tracks to the west of the central track ("Plotas A" offshore wind park (hereinafter - OWP) connection corridor to the transmission network) are numbered with a "-" sign, to the east ("Pirmas etapas" OWP connection corridor) - with a "+". A total of 17 tracks were investigated in zone A. The width of the investigated corridor is about 500 m for each OWP connection.

[1] Lietuvos Respublikos Vyriausybės 2020 m. birželio 22 d. nutarimas Nr. 697 „Dėl Lietuvos Respublikos teritorinės jūros ir (ar) Lietuvos Respublikos išskirtinės ekonominės zonos Baltijos jūroje dalių, kuriose tikslinga organizuoti konkursą (konkursus) atsinaujinančius energijos išteklius naudojančių elektrinių plėtrai ir eksploatacijai, ir šių elektrinių didžiausios leistinos generuoti galios ir mažiausios įrengtosios galios nustatymo“ ir Lietuvos Respublikos Vyriausybės 2023 m. kovo 15 d. nutarimas Nr. 171 „Dėl Lietuvos Respublikos teritorinės jūros ir (ar) Lietuvos Respublikos išskirtinės ekonominės zonos Baltijos jūroje dalių, kuriose tikslinga organizuoti konkursą (konkursus) netaikant skatinimo priemonių atsinaujinančius energijos išteklius naudojančių elektrinių plėtrai ir eksploatacijai, ir šių elektrinių didžiausios leistinos generuoti galios ir mažiausios įrengtosios galios nustatymo“

[2] Patvirtintas Lietuvos Respublikos Vyriausybės 2021 m. rugsėjo 29 d. nutarimu Nr. 789 „Dėl Lietuvos Respublikos teritorijos bendrojo plano patvirtinimo“

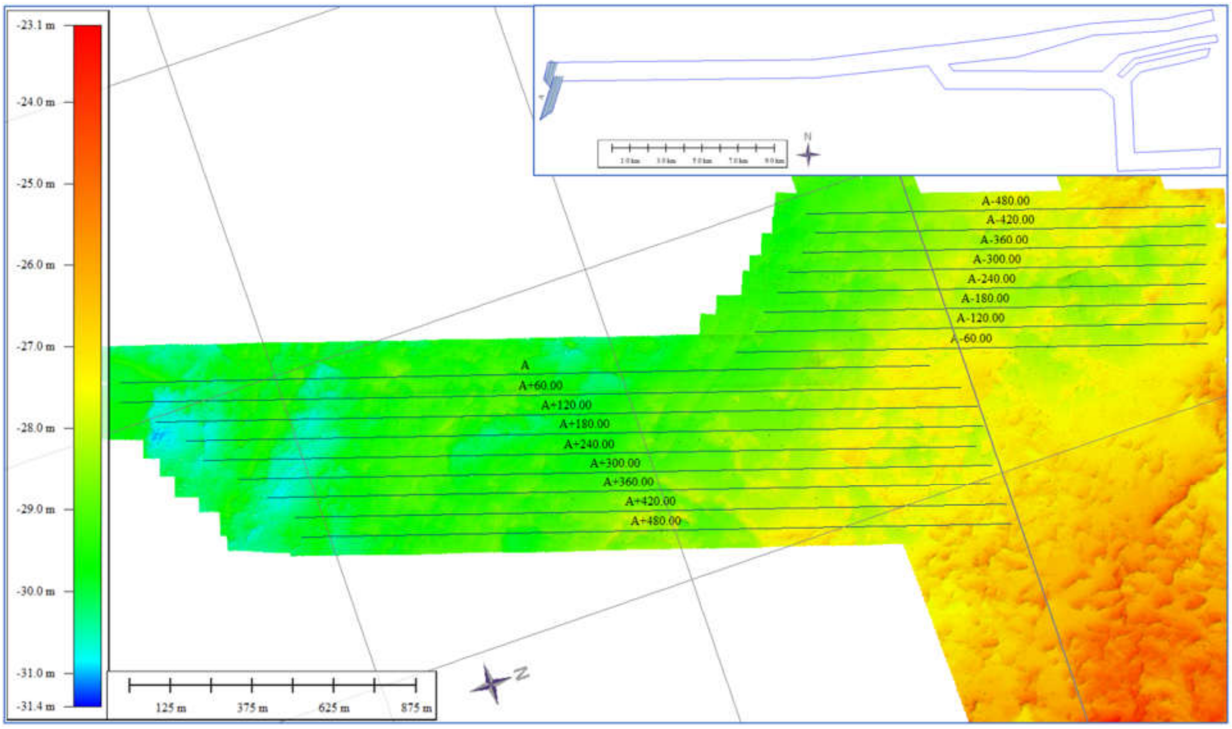


Fig. 3. Layout and nomenclature of survey tracks in zone A

- Zone B (Fig. 4): all tracks of this zone are located along the infrastructure corridor at the border with Latvia (as per spatial solution of CP). The central track is B, the others are placed in parallel at 50 m spacing. All tracks to the north of the central line are numbered with a "-" sign, to the south - with a "+". A total of 29 tracks were surveyed in zone B, and the total width of the studied corridor (for the connection of both OWPs) varies from 650 m in the shallowest part (nearshore) to more than 1100 m in the widest part of the corridor.

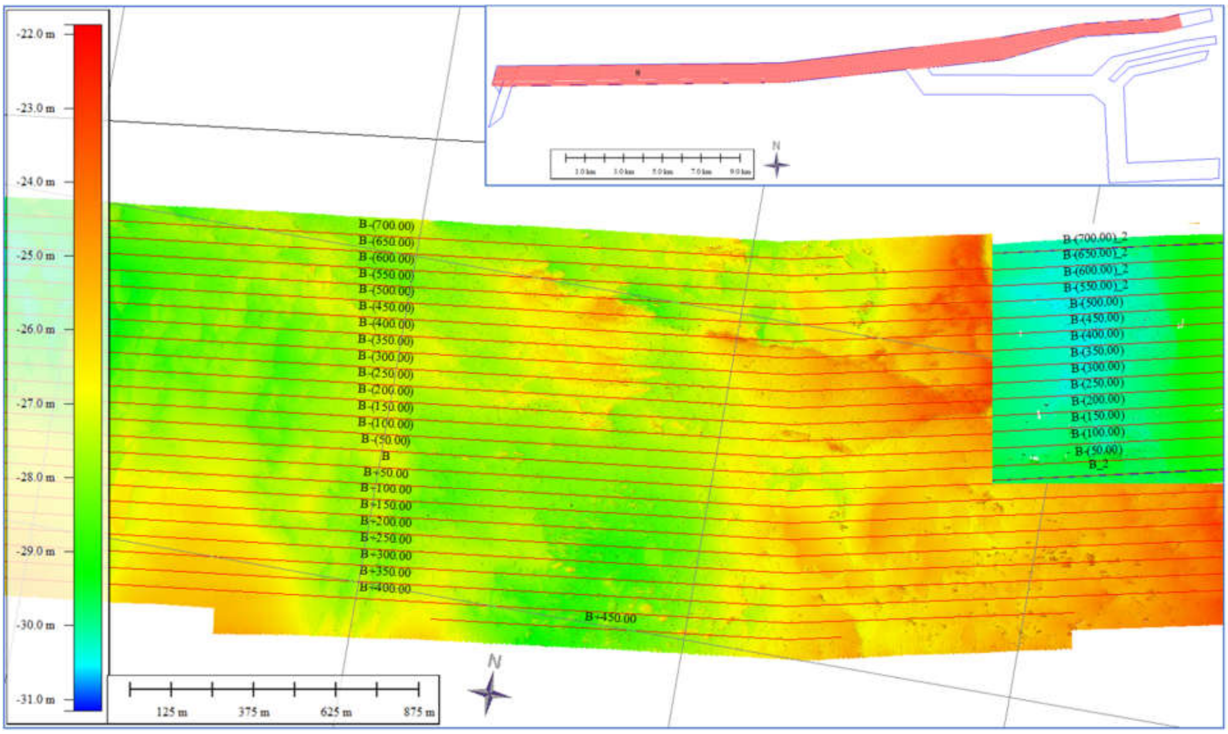


Fig. 4. Layout and nomenclature of survey tracks in zone B

- Zone C (Fig. 5): the tracks of this zone are located further south - almost parallel to the tracks of zone B starting from the intersection of other (telecommunication) cables. The zone C corridor is intended to bypass the marine infrastructure of the Būtingė oil terminal from the southern side by directing the possible electric cable lines towards the planned Harmony Link corridor of the HVDC power transmission line. The first track is C, the others are placed in parallel with 60 m spacing. All tracks to the north of the central track are numbered with a "-" sign, to the south - with a "+". In total, 30 tracks were studied in zone C, and the total width of the studied corridor (for connection of both OWP) varies from 1000 m in the shallowest part to about 1200 m in the widest part of the corridor.

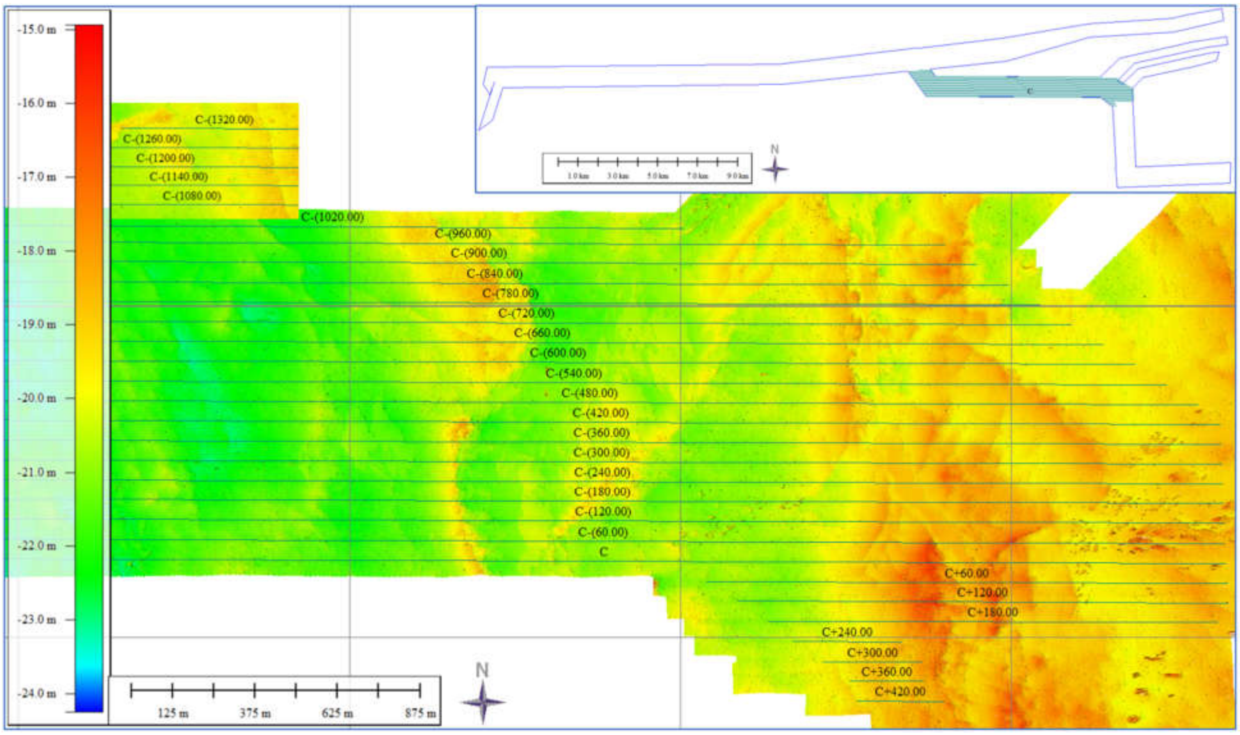


Fig. 5. Layout and nomenclature of survey tracks in zone C

- Zone D (Fig. 6): The tracks of this zone are located in the southern part of the planned Harmony Link corridor. The Zone D corridor is planned for the possible connection of one OWP, possibly placing it within the southern part of planned Harmony Link corridor. The first track is D, the others are located in the north – in parallel with 60 m spacing. 9 tracks were surveyed in the entire zone D, and the total width of the studied corridor (planned for the connection of one OWP) is about 500 m.

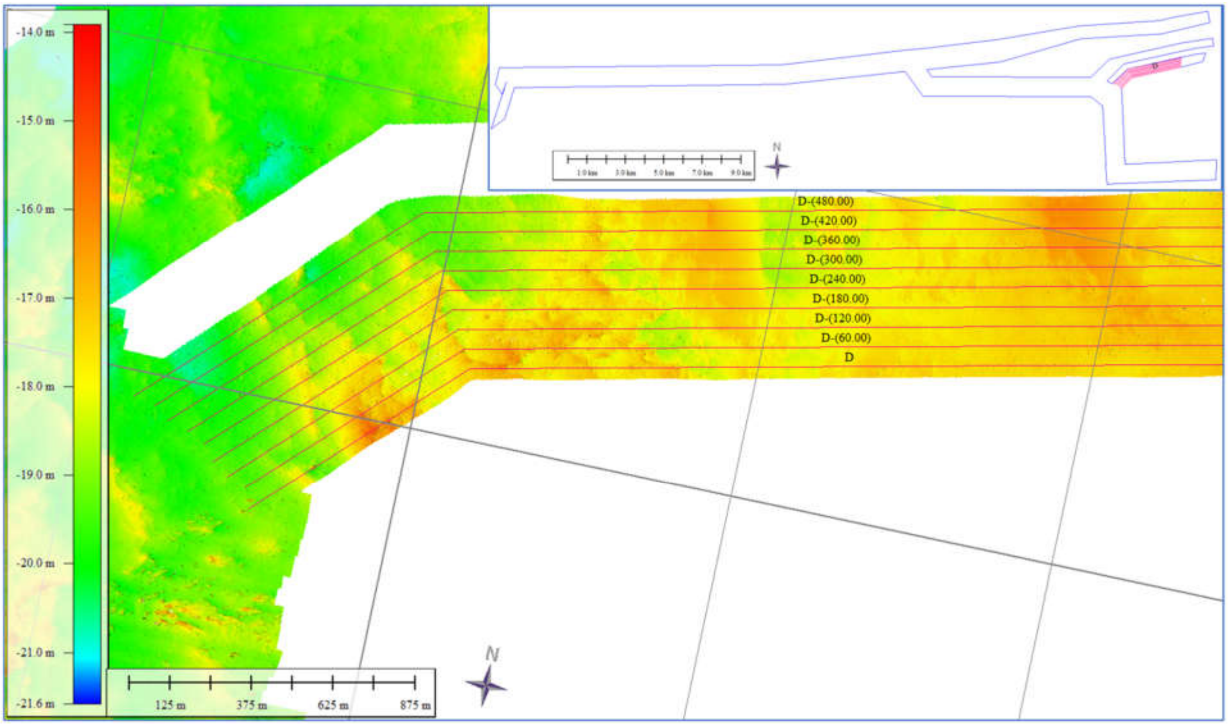


Fig. 6. Layout and nomenclature of survey tracks in zone D

- Zone F (Fig. 7): The tracks of this zone are located in the northern part of the planned Harmony Link corridor. The zone F corridor is planned for the possible connection of one OWP, possibly placing it within the northern part of planned Harmony Link corridor. The first track is F, the others are located further south – in parallel with 60 m spacing. 13 tracks were investigated in the entire F zone, and the total width of the investigated corridor (planned for the connection of one OWP) is from 700 m to 420 m (closer to the shore).

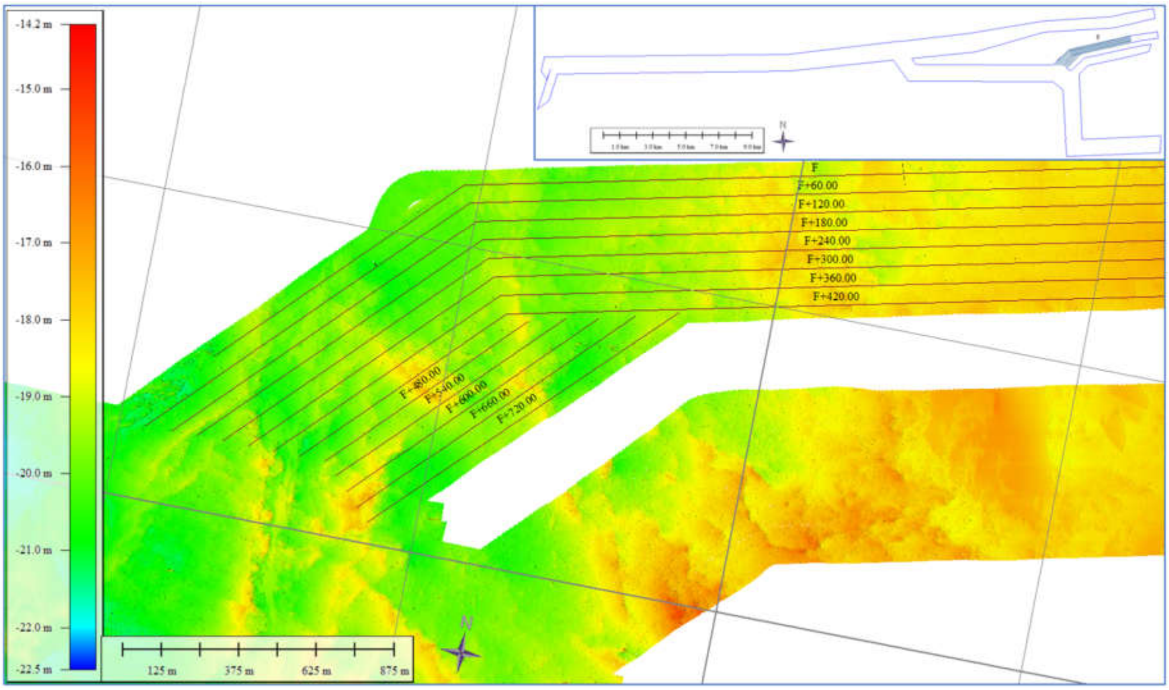


Fig. 7. Layout and nomenclature of survey tracks in zone F

- Zone E (Fig. 8): this zone is planned to bypass the roadstead of port of Šventoji from the south. The tracks run in the north-south direction. The corridor at zone F is planned for the possible connection of both OWPs. The first track is E, the others are located to the east – in parallel with 60 m spacing. A total of 43 tracks were studied in the zone E, and the total width of the studied corridor is about 1000 m.

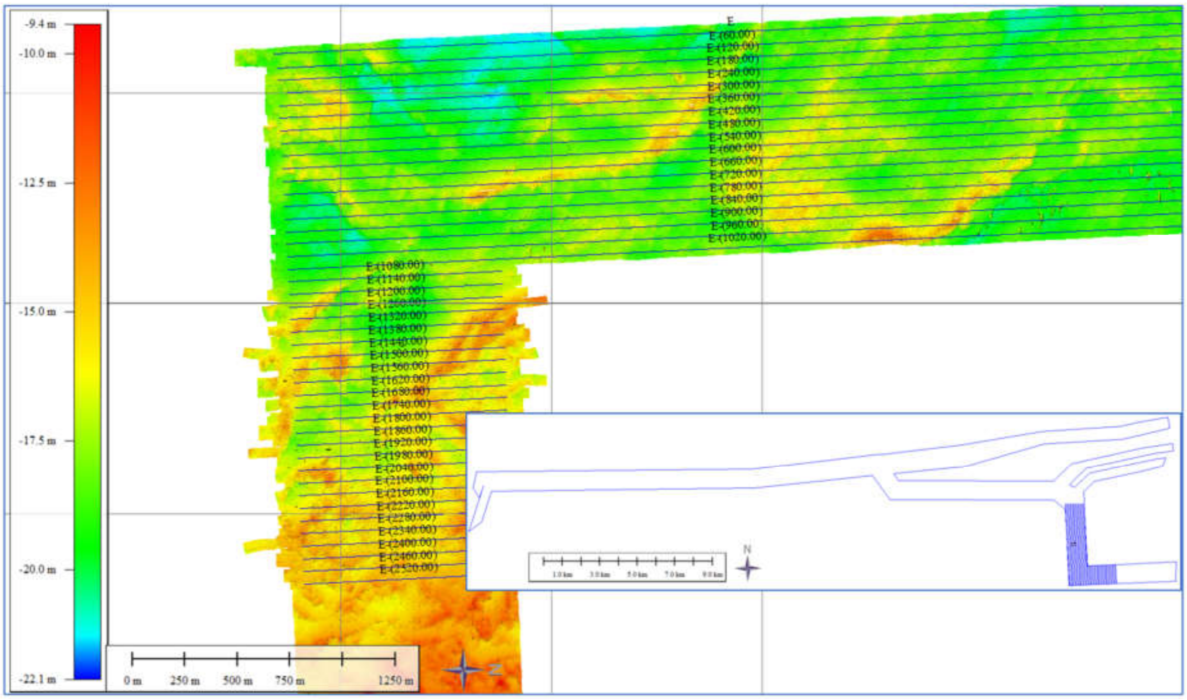


Fig. 8. Layout and nomenclature of survey tracks in zone E

- Bp zone (Fig. 9): all tracks of this zone are located at the nearshore along the infrastructure corridor at the border with Latvia (as per CP spatial solution). The first track is Bp, the others are located to the north of it, in parallel with 25 m spacing. 27 tracks were surveyed in the entire zone Bp, and the total width of the studied corridor (planned for the possible connection of both OWPs) is about 600 m.

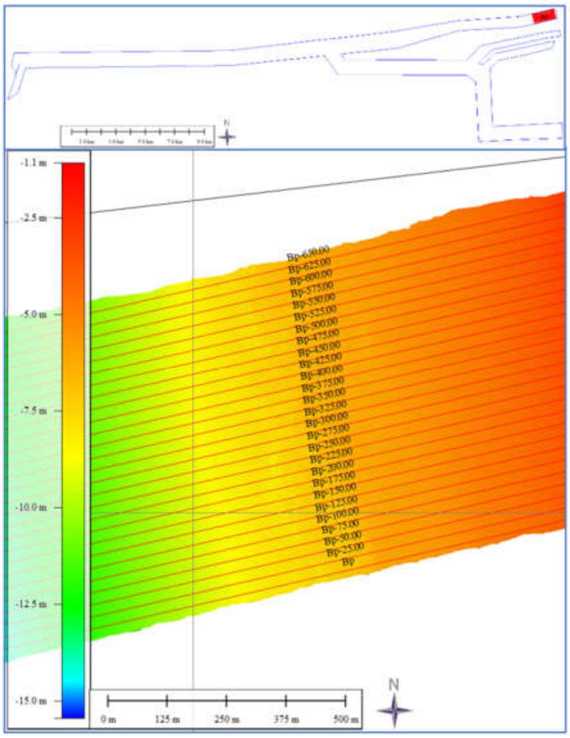


Fig. 8. Layout and nomenclature of survey tracks in zone Bp

- Dp zone (Fig. 9): tracks of this zone are located in the nearshore at the southern part of the planned Harmony Link corridor. The zone Dp corridor is planned for the possible connection of one OWP, possibly placing it within the southern part of planned Harmony Link corridor. The first track is Dp, the others are located to the north – in parallel with 30 m spacing. 17 tracks were investigated in the entire zone Dp, and the total width of the investigated corridor (planned for the possible connection of one OWP) is about 500 m.

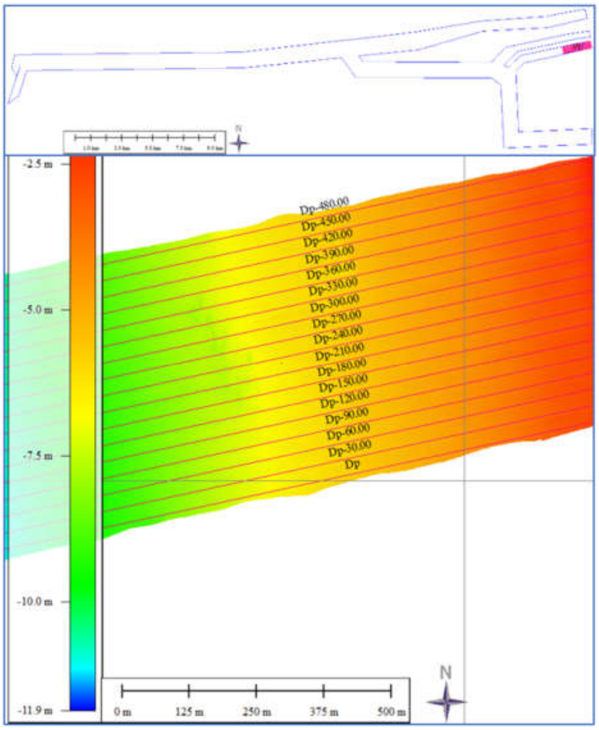


Fig. 9. Layout and nomenclature of survey tracks in zone Dp

- Fp zone (Fig. 10): the tracks of this zone are located at the nearshore, in the northern part of the planned Harmony Link corridor. The corridor of the zone Fp is planned for the possible connection of one OWP, possibly placing it within the northern part of planned Harmony Link corridor. The first track is Fp, the others are located further south – in parallel with 30 m spacing. 15 tracks were investigated in the entire zone Fp, and the total width of the investigated corridor (planned for the possible connection of one OWP) is about 420 m.

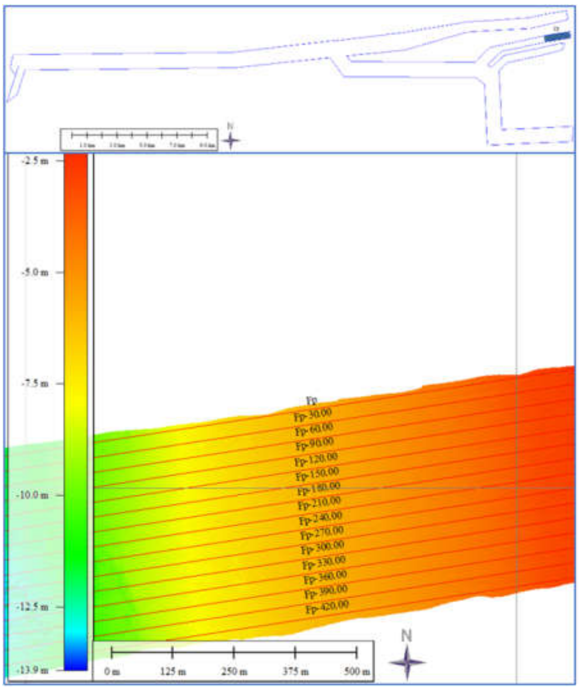


Fig. 10. Layout and nomenclature of survey tracks in zone Fp

- Ep zona (11 pav.): ši priekrantės zona skirta galimų VE parkų prijungimo koridorių apėjimui piečiau Šventosios uosto reido. Profiliai išdėstyti vakarų-rytų kryptimi. Fp zonos koridorius skirtas galimai abiejų VE parkų kabelių klojimui. Pirmoji linija – Ep, kitos išdėstytos į pietus - lygiagrečiai kas 30 m atstumu. Viso Ep zonoje ištirti 35 profiliai, o bendras ištirto koridoriaus plotis – apie 1000 m.
- Ep zone (Fig. 11): this nearshore zone is planned to bypass the roadstead of port of Šventoji from the south. The tracks are arranged in the west-east direction. The zone Fp corridor is planned for the possible connection of both OWPs. The first track is Ep, the others are located to the south – in parallel with 30 m spacing. 35 tracks were studied in the entire zone Ep, and the total width of the studied corridor is about 1000 m.

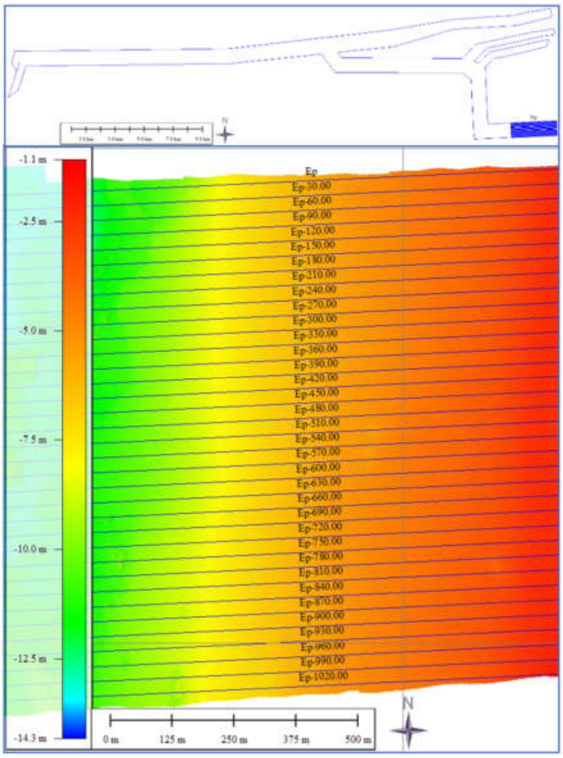


Fig. 11. Layout and nomenclature of survey tracks in zone Ep

Vessels

Two vessels were used for the seabed research: "Mintis", an offshore multipurpose research vessel, which carried out the main part of the research, and a small inland motorboat, "EGO", which was designed to take measurements in the shallowest part of the research area, the nearshore.

"MINTIS"

- Type: Catamaran
- Registration (IMO) number: 9713636
- Flag: LT
- Built: 2014
- Length: 39,25 m.
- Breadth: 12 m.
- Draft: 3,6 m
- Gross tonnage: 499 t

"EGO"

- Type: motorboat
- Registration number: LT -9270
- Flag: LT
- Built: 2009
- Length: 5,36 m.
- Breadth: 2,10 m.
- Draft: 0,70 m.

In the 1st stage of the research, multi-beam echo sounding (bottom morphology and depth survey), side scan (search for objects on the bottom and distribution of surface sediments) equipment was installed and ready for operation on the ships, which simultaneously collected information on the morphology of the bottom and objects on the bottom along the assigned survey tracks;
During the 2nd phase, the vessels were equipped with seismoacoustic (study of the surface structure of the seabed) and magnetometric (study of magnetic anomalies) equipment, which collected data on the deep structure of the bottom and magnetic anomalies while navigating the same tracks as during the 1st phase.

Multibeam echo-sounding

The multibeam echo sounder and the motion sensor were mounted on a single frame, which was placed in a special 0.5x0.5 m moon-pool of the Mintis. During operation, the multibeam echo sounder is placed in the working position so that the sonar sensors are out of the ship's hull. Using the ship's positioning system and real-time corrections (RTK), the exact coordinate of each measurement reflection is obtained, and the distortions obtained due to the movements of the ship are compensated through the activation of the stationary gyrocompass and motion sensor. The depth discrepancy due to the different speed of sound propagation in water (caused by changing temperature and salinity) is eliminated by adapting the results of the sound speed profile measurements.

Equipment	Technical parameters
Multibeam echosounder Teledyne Reson Seabat 7125 SV2; used on MINTIS	Operational frequency: 400 kHz; Number of beams – 512; Depth resolution – 6 mm;
Stationary gyrocompass and motion sensor Ixblue Octans 3000 Rovins;	Heading accuracy: 0.1° secant latitude, resolution: 0.01°, full accuracy setting time: < 5 min;

	Heave accuracy: 2.5 cm or 2.5% (whichever is greater); Roll/Pitch dynamic accuracy: 0.01°, resolution: 0.001°
Sound velocity probe Reson SVP70 and sound velocity profiler Sea&Sun CTM48M CTD	Resolution: 0,1 m/s; Accuracy: ± 0,15 m/s Range: 1350–1600 m/s
Multibeam echo-sounder Norbit iWBMSe with integrated motions sensor and positioning system, used on EGO	Operational frequency: 400 kHz; Number of beams – 256-512; Depth resolution – <10 mm;
Data acquisition and processing software QPS QINSy/Qimera	Standard procedures were used to process the depth measurement data: • Positioning correction; • Evaluation of the correction of changes due to sound propagation in water; • Automatic and, if necessary, manual elimination of acoustic noise; • Export to custom size grid.
Minimal parameters of the provided results:	Coverage: 100%; Overlapping: 10%; Spatial resolution: 50x50 cm; Vertical accuracy: 10 cm;

Side scan sonar

When performing a bottom surface survey with a side scan sonar device, in addition to the sonar itself, an underwater positioning system and a hydrographic winch are used to tow the sonar and transfer data to the ship. The integrated system ensures that the position of the device towed overboard by a special cable is precisely fixed by applying the ship's positioning system and the corresponding position correction is obtained from the underwater positioning system (USBL).

Equipment	**Technical parameters**
Side scan sonar L-3 Klein 3900	Dual frequency: low ~ 445 kHz; Beams: horizontal: 0.2° @ @ 445 kHz; vertical: 40°
Underwater Positioning System Sonardyne Ranger Mini	Frequency range:19-34 kHz; Position update frequency: 3 Hz; Acoustic beacons: 2 pcs; Position accuracy: 1,3 % of direct distance;
Hydrographic winch for sonar towing and data transfer emma DT3025-EHLWR (emma technologies GmbH)	Power supply: 400V/ 50 Hz; Drum capacity: 500 m of coaxial Ø10,4mm cable, Break strength: 58kN Load: 12 kN
Data processing: object identification was performed with the original SonarWiz 7 software;	Standard image processing procedures were performed when processing the side scan data: • signal amplification, • geometric correction of the data was performed; • by adjusting the signal strength - the image is smoothed; • "blind" zone is removed.
Minimal parameters of the provided results:	Coverage: 200%, each point is scanned from both sides Overlappig: 100%; Spatial resolution <0,5 m The smallest identified object:>0,5 m..

Sub bottom profiler survey

Seismoacoustic profiling usually is applied when studying the upper part of sediments beneath the seafloor. This method is single-channel, i.e. a transmitter and a receiver generating a seismic pulse are installed in the same device, and the research method is based on the vertical reflection of the seismic wave from geological boundaries with different physical properties. The device is installed on a ship on a side pole, and uses the ship's navigation system and motion sensors for reflection positioning and signal movement compensation.

Equipment	Technical parameters
Sub bottom profiler Innomar SES-2000 compact	Penetration depth: up to 10 m, (in perfect geological conditions up to 15-20 m. Vertical resolution: ~ 0,25 m; Working frequency: -Low: 5-15 kHz; -High: ~ 100 kHz; Pulse length: 66 to 800µs; Pulse rate: more than 30 per second.
Data processing: data acquisition performed with SESWIN software provided by equipment manufacturer. Data interpretation: Gverse Geographix (LMKR) software.	The processing workflow consisted of: • Data import • Positioning correction – elimination of geometry jumps and interpolation of gaps • Combining of data to cross sections • Band pass filter • Stacking of neighboring traces • 2D data export (SEG-Y)

Magnetic survey

Equipment	Technical parameters
Geometrics G-882 Cesium magnetometer and transverse gradiometer TVG (2x G-882);	Noise: <0,004 nT/Hz rms Heading error: <2 nT Operating range: 20 000–100 000 nT
Data processing	The processing workflow consisted of: • Position correction – coordinates cleared of unevenness and jumps; linear interpolation of coordinates by time was used to fill the gaps; • Geomagnetic corrections were made using data of the observatory closest to the research object (HLP(Hel) Poland http://www.wdc.bgs.ac.uk/obsinfo/hlp.html); i.e. recalculated values of the IGRF13 Earth magnetic model and subtracted from the total measured magnetic field; • Calculated residual magnetic field
Minimal parameters of the provided results:	Accuracy: <3 nT; Frequency: ≥10Hz; Positioning error: ≤ ± 2 m

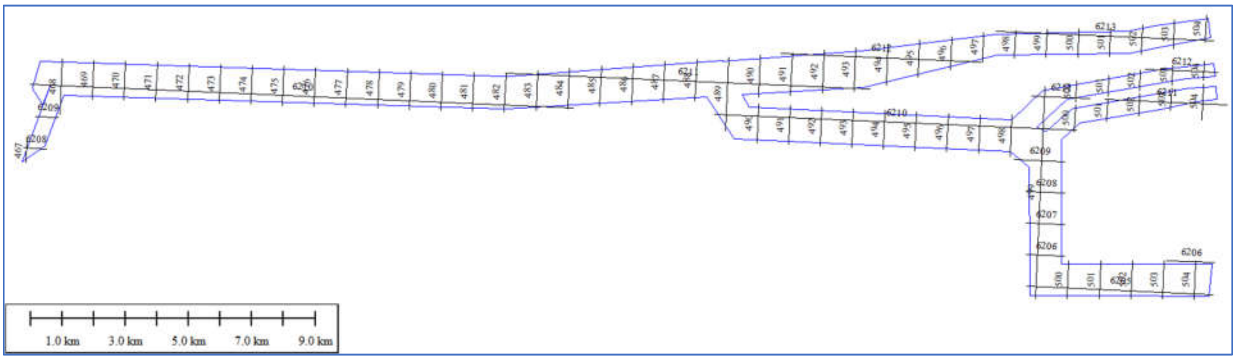
Survey results

Sea depth and bottom morphology

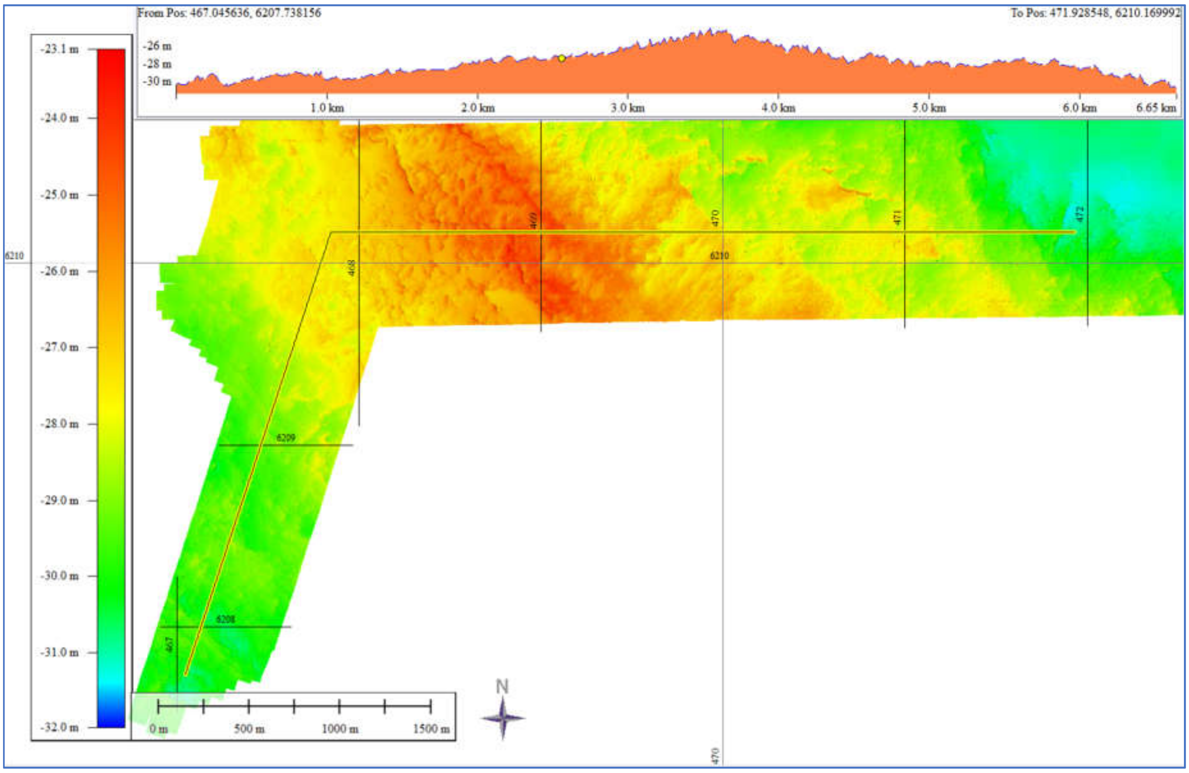
According to the studies using a multibeam echo sounder, a diagram of sea depths (bathymetry) was drawn up (Fig. 12). In the study area, the sea depth ranges from 0 (in contact with the shoreline) to ~39 m in the deepest (central) part of zone B.

Fig. 12. Sea depth and slope profile along the route

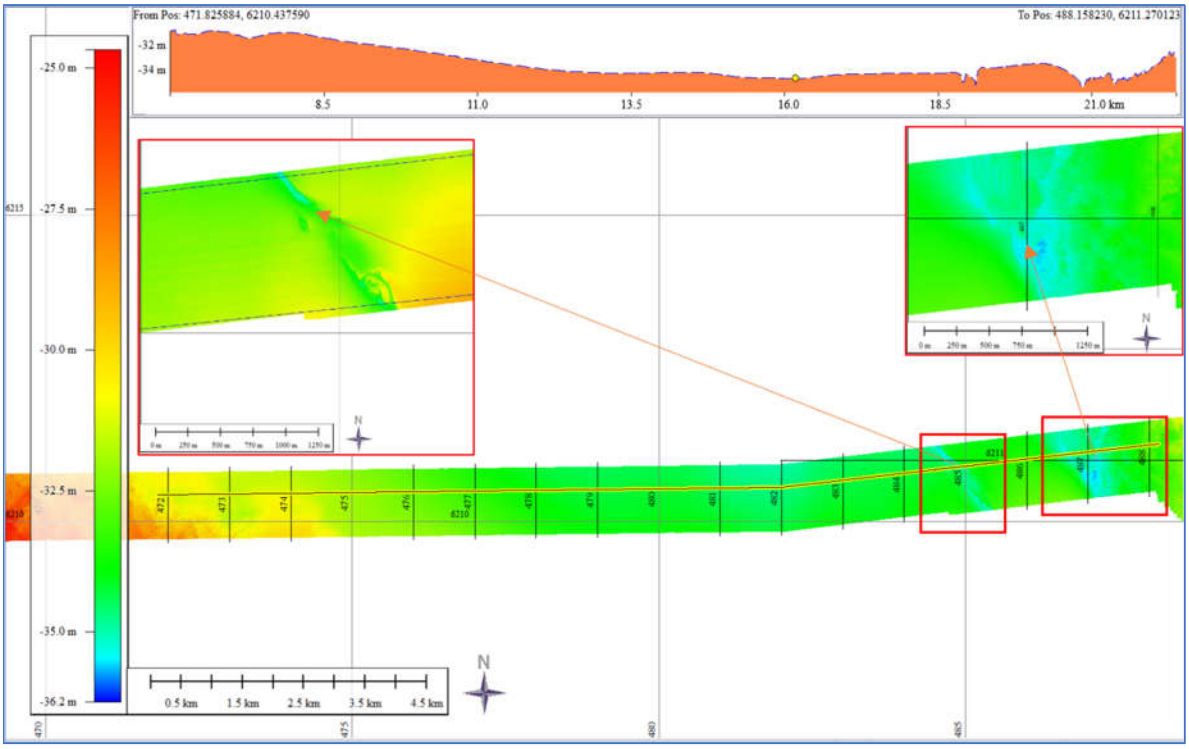
Morphologically, the bottom can be divided into four characteristic parts. Due to the multiple trajectory of the route, the mileage reference is indicated according to the UTM 34 N grid X (467-504 km) and Y (6205-6210 km) references:



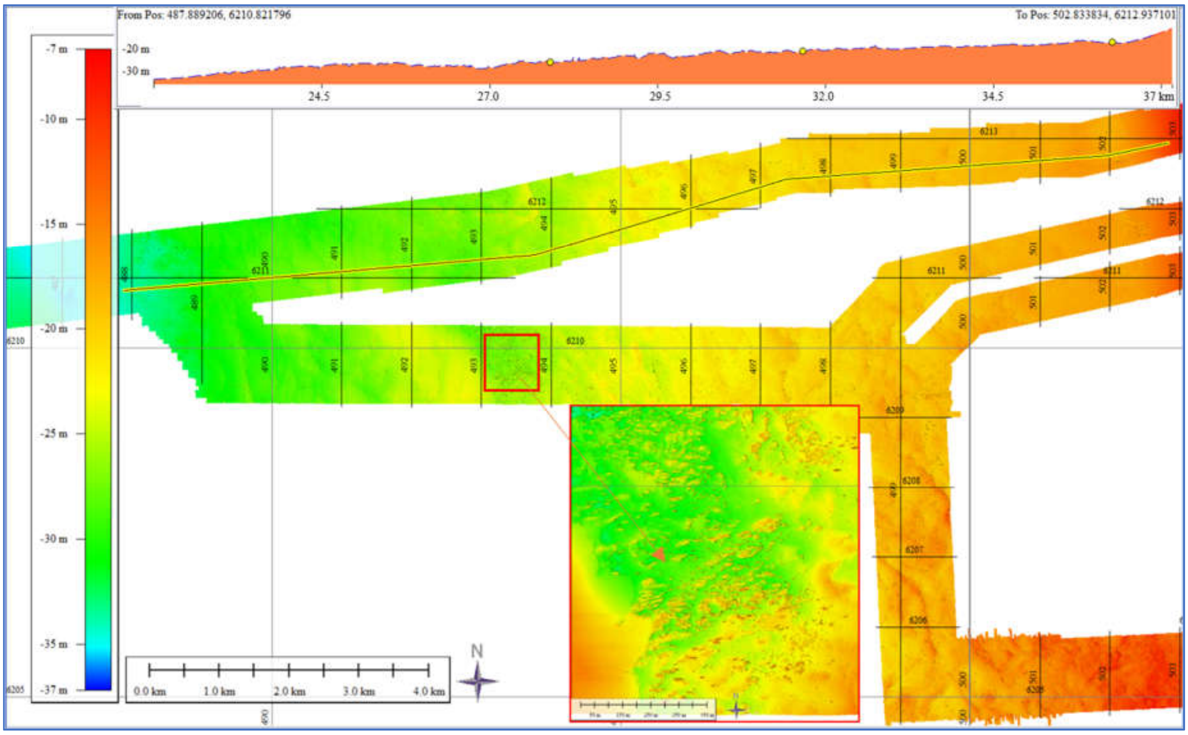
- Western (from X467 to ~ X472 kilometre mark) – the relief of Klaipėda-Ventspils moraine plateau and its slopes with a characteristic - roughened surface of worn-out moraine;



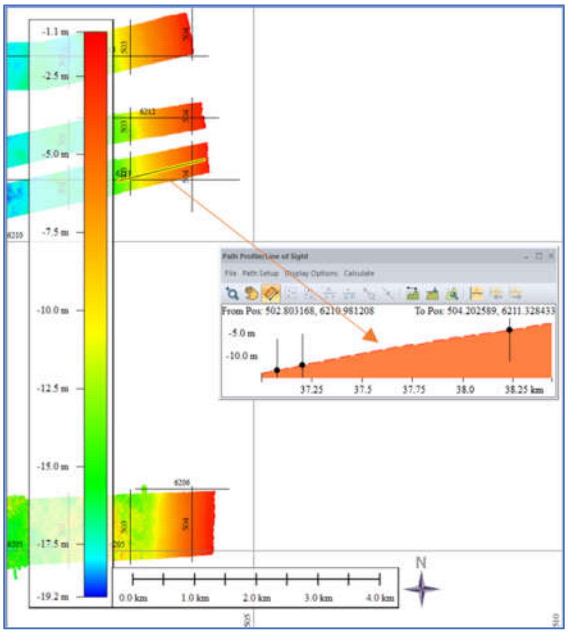
- - Central (~X472 - X488 kilometre mark) – relatively homogeneous, even flat terrain with little fragmentation and slight slope inclination. Characteristically smooth surface - characteristic for morainic plains, single stones and distinct erosion ridges (at ~X485 km and ~X487 km markings) are observed in the eastern part of the section.



- Eastern (~X488 - X503 km mark) – a zone of complex morphology, with traces of outwashes of the morainic base, fields of sand and gravel fields and expressive areas of relict moraine ridges (drumlins) (single and drumlin fields);



- Nearshore (~X503 – X505 km mark) – evenly shallowing towards the shore, fairly even sandy plain with a dynamic zone of low (0.5-1 m high) sandbars formed at the nearshore.



Seafloor and obstacles

In the generated acoustic mosaic of the side scan sonar imagery (Fig. 13), several characteristic features of the bottom emerged. The research area was divided into several characteristic areas, which (after geological studies) can be assigned to different lithological types.

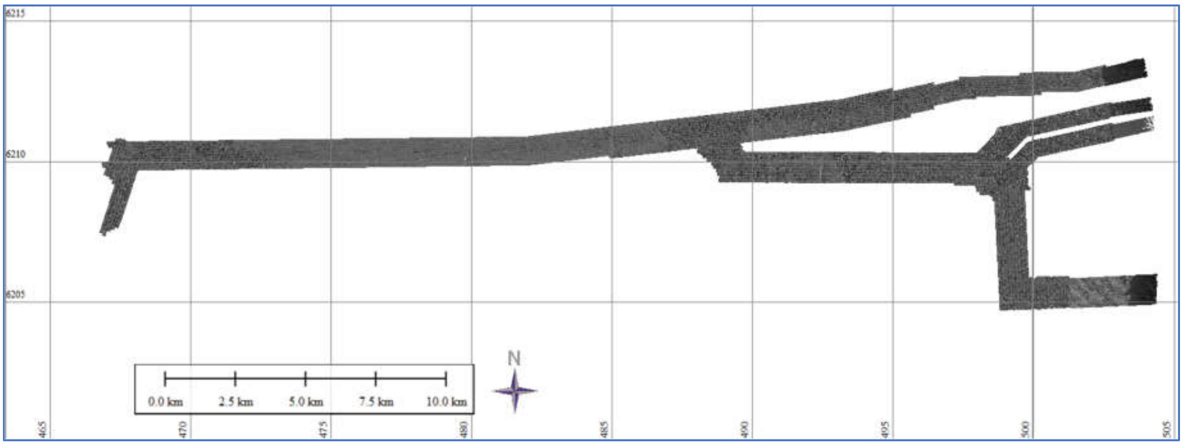
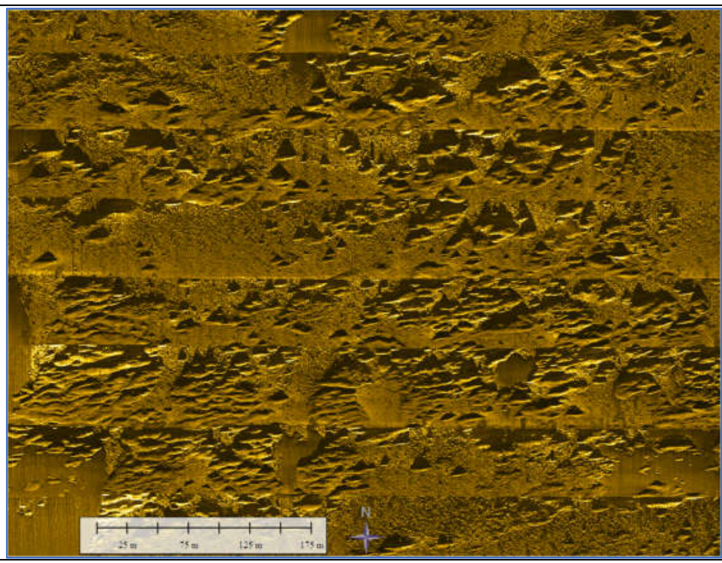
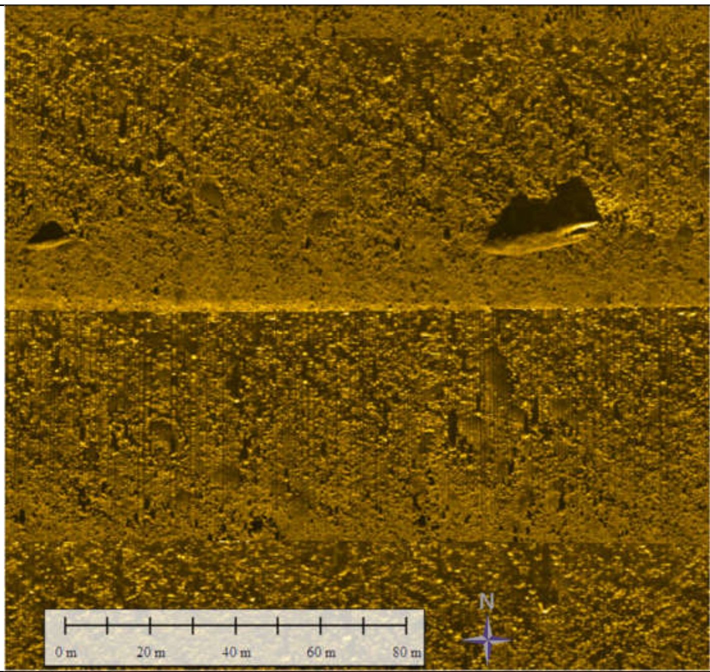
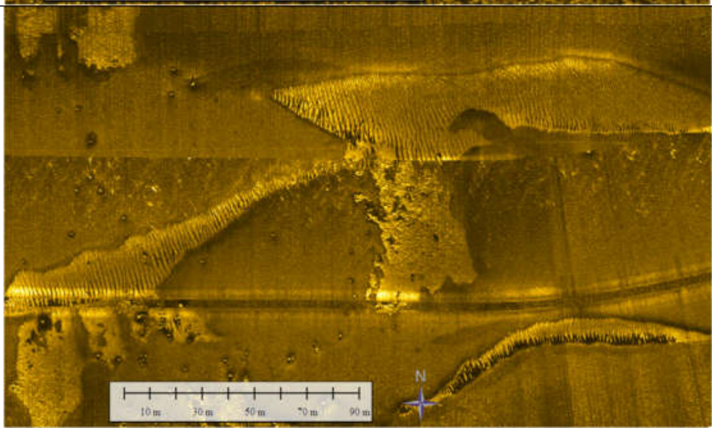
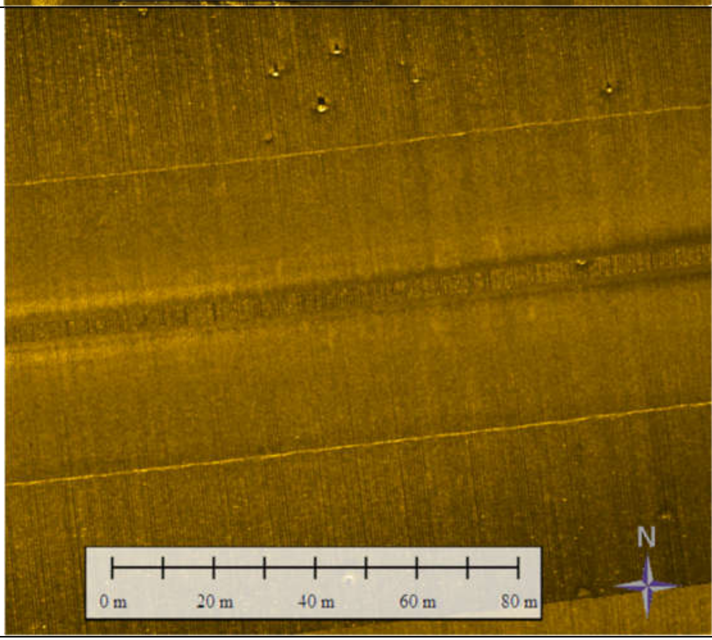


Fig. 13. Seafloor acoustic imagery mosaic

The seabed reflects (or absorbs) the acoustic signal differently depending on the morphology of the bottom, the composition of the sediments and the properties of the sunken objects. As a result, characteristic reflections (acoustic shadow images) were obtained, which were preliminarily divided and characterized (Table 1), and based on them, a preliminary scheme of the distribution of bottom sediments was made (Fig. 14).

Table 1. Catalogue of the acoustic images

Moraine ridges or drumlin fields. Characteristic relic bottom relief forms of glacial exertion origin - ridges consist of hard glacial deposits (moraine loam), the size of which varies from a few to a dozen meters, and the height can reach from one to 2-3 meters, and in exceptional cases, up to 5-6 meters in height from the bottom of the sea. Moraine ridges have an elongated shape, the direction of which reflects the direction of the advancing glacier.	

Single moraine ridges. They are observed less often, but they are quite clearly visible on the terrain - large, tens of meters long and several meters high hills. Their spatial orientation, as well as in the case of cloud fields, reflects the direction of glacier movement.	
In places of intensive morainic bed washout, clearly visible sand/gravel ridges have formed, which testify to active dynamic conditions - the influence of underwater currents on the formation of bottom sediments. Ripples are formed only in conditions of flowing water and during the laying of sand and gravel deposits (sand ripples are smaller, respectively, gravel forms coarser ones).	
A smooth and low-impacted bottom indicates stable sedimentary/hydrodynamic conditions and/or the presence of a hard, hard-eroding surface. This type of acoustic photo is likely to be typical for glacial plains where the bottom is covered by a hard clay moraine. The glacial origin of these deposits is also evidenced by single boulders observed on the bottom moraine surface.	

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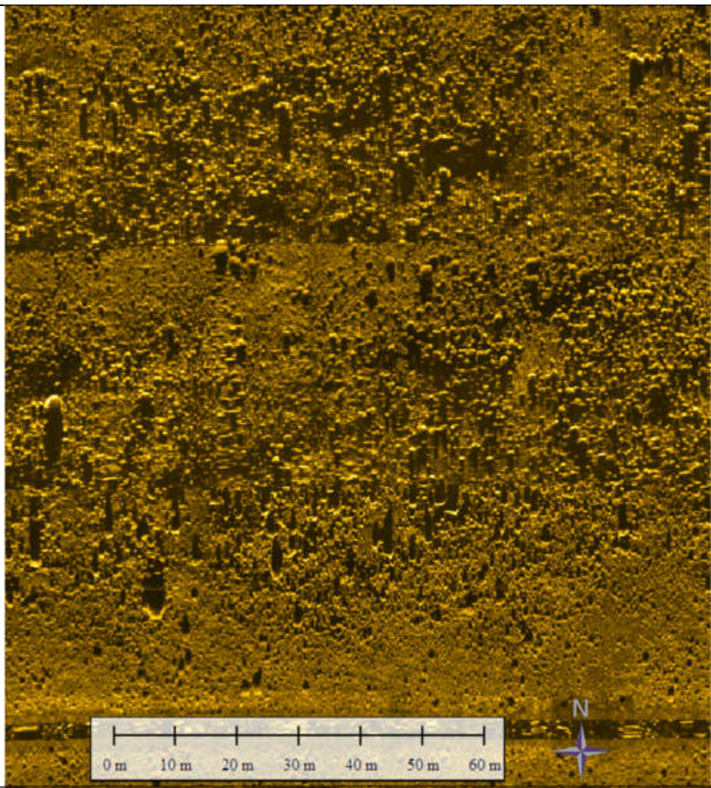
<tr>
<td>A large part of the research area is covered with decaying moraine deposits, - fields of boulders and sand-gravel of various coarseness are observed, which lie on a solid moraine base.</td>
<td>
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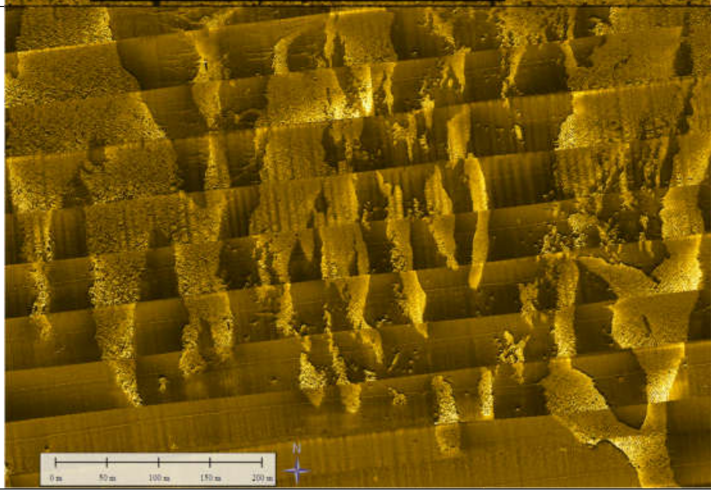
<td>Part of the territory has experienced very well-observed erosion - characteristic erosion gullies have formed, where sand and gravel ridges have often formed, testifying to the activity of flowing water. The depth of the created ravines reaches 1-3 meters, the width varies, from several tens to several hundreds of meters</td>
<td></td>
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Based on the preliminary classification of the acoustic images presented above (which needs to be refined after geological research of the bottom samples), a preliminary lithological scheme was drawn up (Fig. 14). Three main groups of sediments can be distinguished (preliminarily, it can be clarified after carrying out geological studies): nearshore, a layer of fine and medium coarse sand extends to a depth of about 14-16 m (yellow colour); the entire eastern zone of the research area is filled with moraines of glacial origin (clayey and sandy loam, orange colour) and fields of sand, gravel, gravel and boulders of varying coarseness (green colour), which were formed by the erosion of the moraine and the action of glacial meltwater.

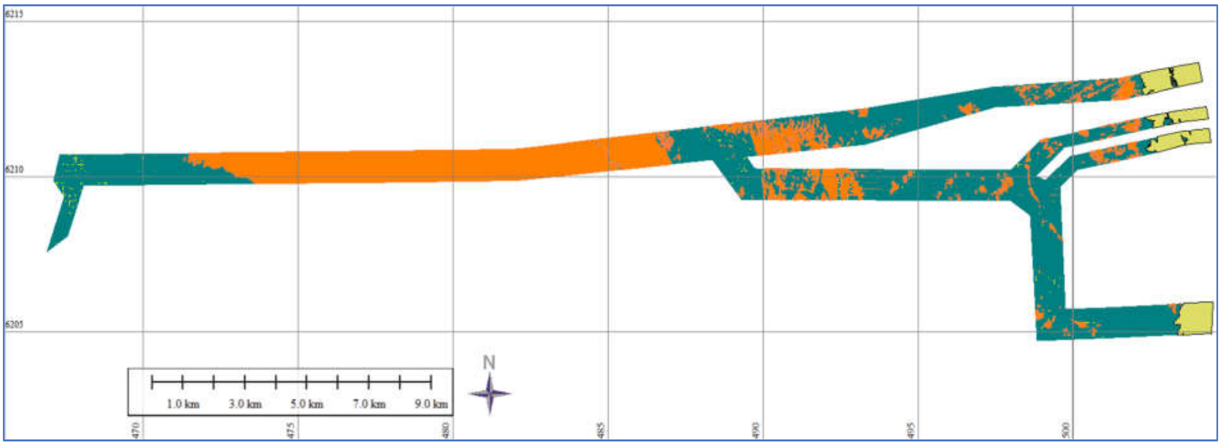


Fig. 14. Preliminary lithological scheme

Due to widespread glaciofluvial and moraine deposits, the main objects on the bottom (Fig. 15) are single boulders (and fields) of natural origin and moraine ridges (marked in the lithological scheme). Boulder fields reproduce the erosive boundaries of the zones of glacial erosion and the most intense glacial meltwater action, concentrated in the western and eastern zones of the studied area, the rest of the area is dominated by individual larger boulders. In total, more than 4.5 thousand natural objects (boulders) were identified, not counting moraine ridges, of which we would count several hundred more in the study area. In addition, three possibly anthropogenic objects were identified, two linear objects that more or less coincide with the telecommunication cables marked on the navigation maps and are quite clearly visible in some sonarograms, and one possibly unnatural object of unknown origin closer to the coast (Table 2).

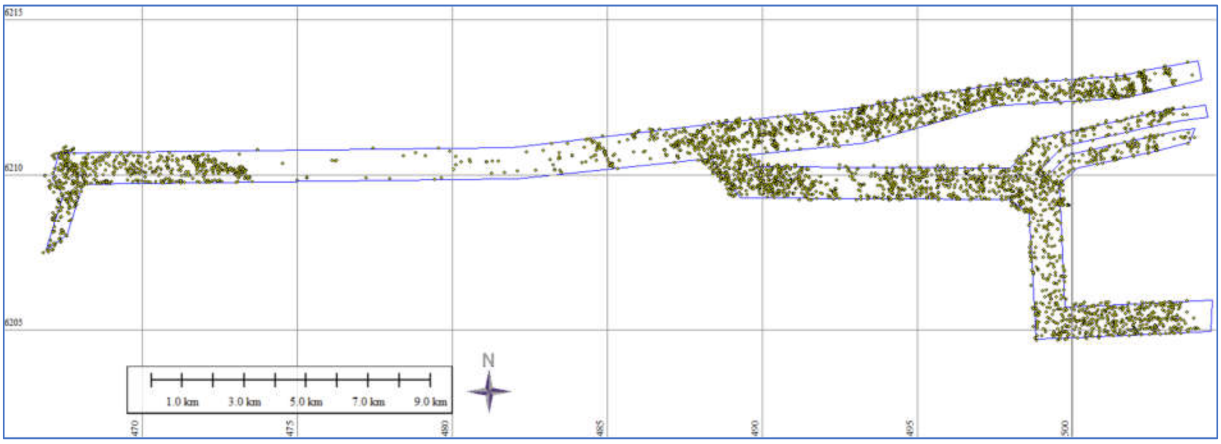
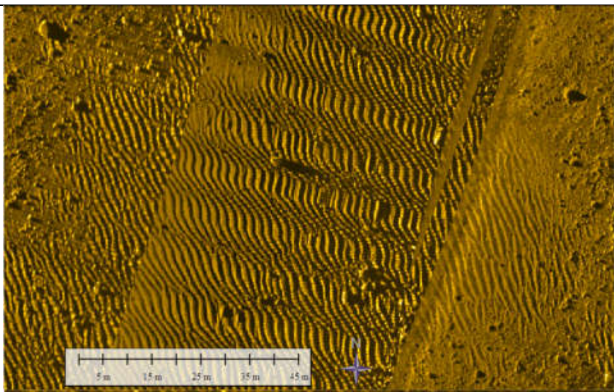
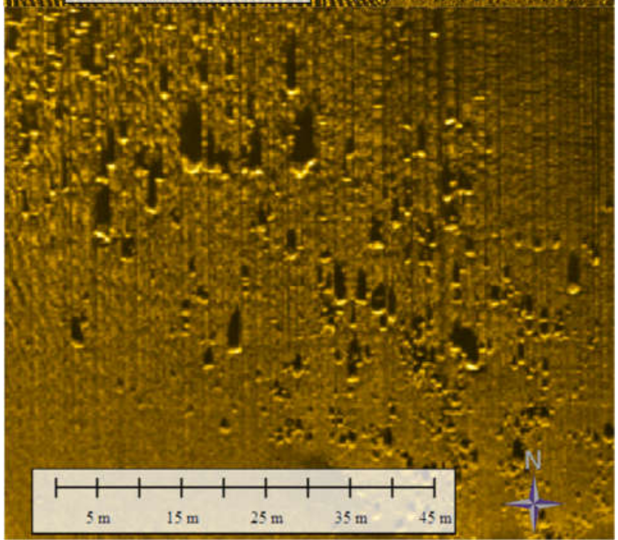
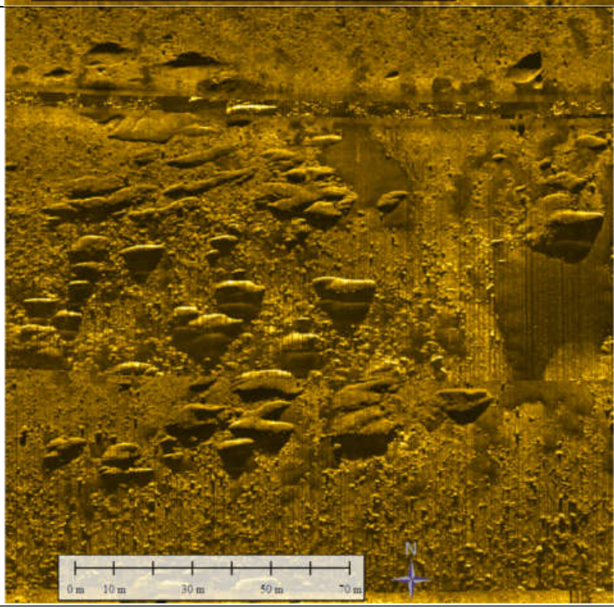
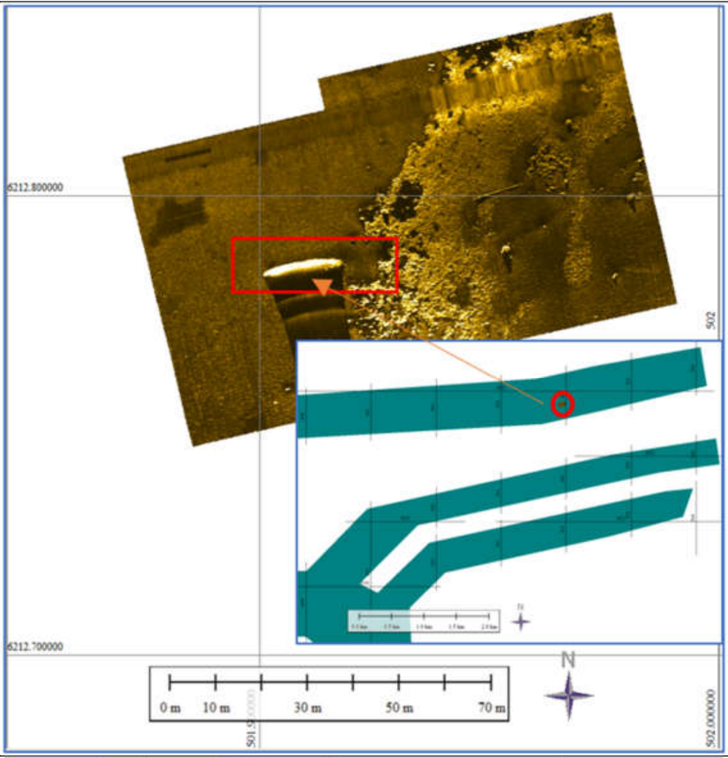
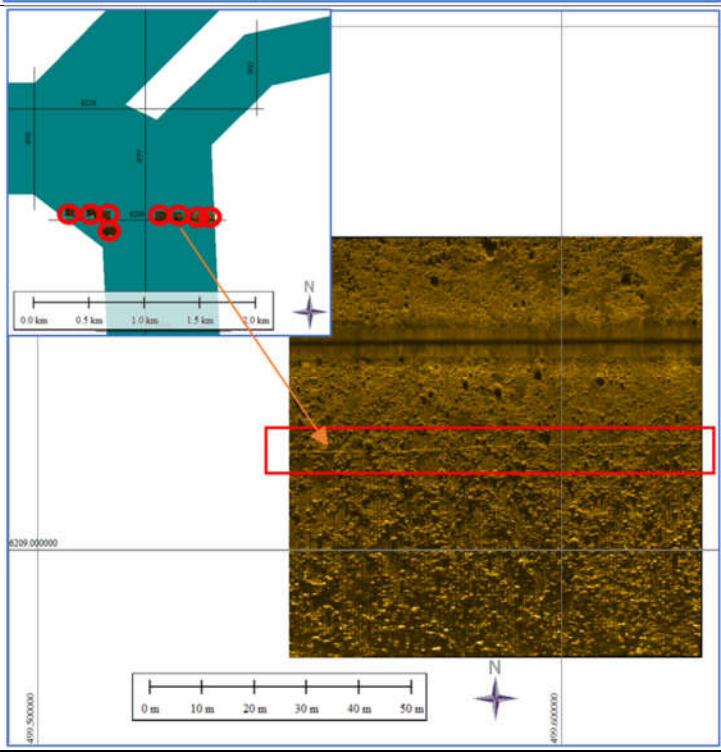


Fig. 15. Obstacles on the seafloor

Table 2. Obstacles on the seafloor

Single boulders and their accumulations. In total - over 4.5 thousand objects	 
Individual moraine ridges and their fields. In total - more than several hundred objects.	

An object of possible anthropogenic origin. The length of the object is 16.5 m, and the width is about 3.5 m. Object position (WGS‘84): 21° 1.840' E 56° 3.614' N	
Two linear structures are observed - telecommunication cables laid next to each other. It is noteworthy that the southern cable is about 4 meters south of the cable marked on the navigation maps, while the northern one is visible ~ 80 m south of the indicated cable line.	

Recommendations for geological investigations

In order to clarify the preliminary lithological scheme and evaluate the geomechanical properties of the soil, it is recommended to carry out:

- Lithological analysis of bottom surface samples. Sampling density should not be less than 1 sample per 1 km^2 area or - every ~0.5 km along the planned cable laying corridor/s. It is recommended to ensure that the sampling by grab area is at least 0.1 m^2, and the depth of penetration is at least 5-10 cm. It is necessary to determine the lithological type of the samples.
- In order to determine the deeper composition of surface sediments, it is necessary to perform vibro-coring at proposed stations, so as to ensure the representativeness of different sedimentary conditions (identified different types of lithological zones) - i.e. so that at least 4-5 shallow (up to 3 m long) boreholes and the same number of shallow (up to 3 m deep penetration) static probing (CPT) points would be required for each type of bottom determined during the lateral survey scan (Fig. 14). In areas with more complex morphology or geology, additional drilling and CPT are recommended. Recommended drilling and CPT locations are shown in Table 3 and Fig. 16.

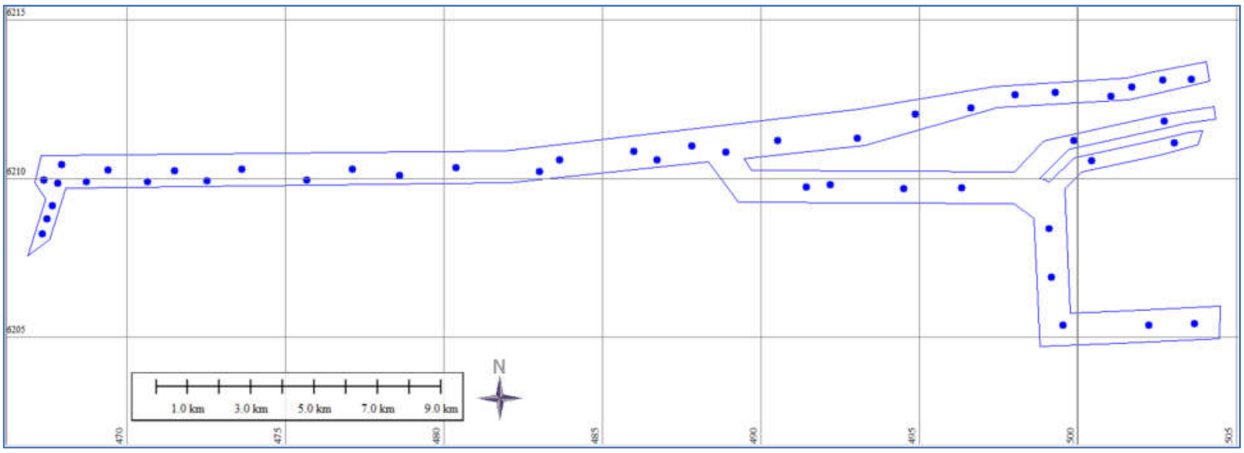


Fig. 16. Recommended positions for vibro-coring and CPT

Table 3. Recommended positions for vibro-coring and CPT.

ID	X_LKS'94	Y_LKS'94	X_WGS	Y_WGS
1	315907,4	6218265,6	21° 2.614' E	56° 3.774' N
2	315896,9	6216988,7	21° 2.657' E	56° 3.087' N
3	316191,0	6216277,7	21° 2.969' E	56° 2.711' N
4	316569,9	6210559,9	21° 3.567' E	55° 59.642' N
5	286728,6	6216732,6	20° 34.624' E	56° 2.223' N
6	290229,9	6216580,4	20° 37.996' E	56° 2.234' N
7	293483,7	6216482,3	20° 41.128' E	56° 2.266' N
8	296768,0	6216589,3	20° 44.280' E	56° 2.408' N
9	299121,6	6216769,4	20° 46.535' E	56° 2.564' N
10	280344,0	6214961,1	20° 28.576' E	56° 1.097' N
11	280701,6	6215857,8	20° 28.875' E	56° 1.590' N
12	281051,0	6217121,8	20° 29.149' E	56° 2.279' N
13	280485,8	6216668,5	20° 28.628' E	56° 2.020' N
14	284598,1	6216774,5	20° 32.575' E	56° 2.189' N
15	282503,6	6216894,5	20° 30.556' E	56° 2.197' N
16	302030,6	6216595,6	20° 49.339' E	56° 2.543' N

17	308050,4	6217540,8	20° 55.087' E	56° 3.199' N
18	311221,0	6218007,4	20° 58.116' E	56° 3.526' N
19	309424,5	6215163,8	20° 56.510' E	56° 1.953' N
20	312123,9	6212212,8	20° 59.228' E	56° 0.428' N
21	303679,3	6216894,1	20° 50.911' E	56° 2.745' N
22	305266,9	6215442,3	20° 52.501' E	56° 2.002' N
23	314907,8	6218100,8	21° 1.659' E	56° 3.662' N
24	315134,3	6210555,4	21° 2.189' E	55° 59.606' N
25	313540,8	6215830,5	21° 0.439' E	56° 2.409' N
26	280523,0	6215430,1	20° 28.725' E	56° 1.355' N
27	280905,1	6216557,5	20° 29.037' E	56° 1.972' N
28	283729,5	6216485,9	20° 31.754' E	56° 2.010' N
29	285630,8	6216417,7	20° 33.584' E	56° 2.025' N
30	288761,2	6216310,6	20° 36.598' E	56° 2.050' N
31	281814,1	6216561,9	20° 29.910' E	56° 1.999' N
32	296121,8	6216251,3	20° 43.675' E	56° 2.210' N
33	291689,5	6216335,2	20° 39.411' E	56° 2.140' N
34	299830,1	6216452,1	20° 47.230' E	56° 2.411' N
35	300969,6	6216851,4	20° 48.308' E	56° 2.655' N
36	306190,1	6216867,0	20° 53.327' E	56° 2.791' N
37	309808,0	6217654,5	20° 56.772' E	56° 3.302' N
38	312495,5	6218026,3	20° 59.342' E	56° 3.566' N
39	314232,6	6217840,8	21° 1.020' E	56° 3.507' N
40	316792,2	6218256,9	21° 3.466' E	56° 3.790' N
41	313018,1	6216485,4	20° 59.909' E	56° 2.749' N
42	312124,7	6213761,3	20° 59.164' E	56° 1.262' N
43	312408,0	6210691,4	20° 59.565' E	55° 59.616' N
44	307576,6	6215212,5	20° 54.731' E	56° 1.935' N
45	304500,7	6215400,4	20° 51.766' E	56° 1.961' N

Magnetic anomalies

Survey of magnetic anomalies was carried out along the main hydrographic survey tracks (Fig. 2) – i.e. every 50-60 m. Such a resolution does not allow to expect a complete survey of the area, but it provides valuable information about the general characteristics of the magnetic field and - records larger magnetic anomalies (located along the survey track), which must be taken into account before starting detailed geological surveys of the electric cable construction lines. The total magnetic field (Fig. 17) varies from 50.791 to 52.616 nT and reflects the total geomagnetic field in the study area.

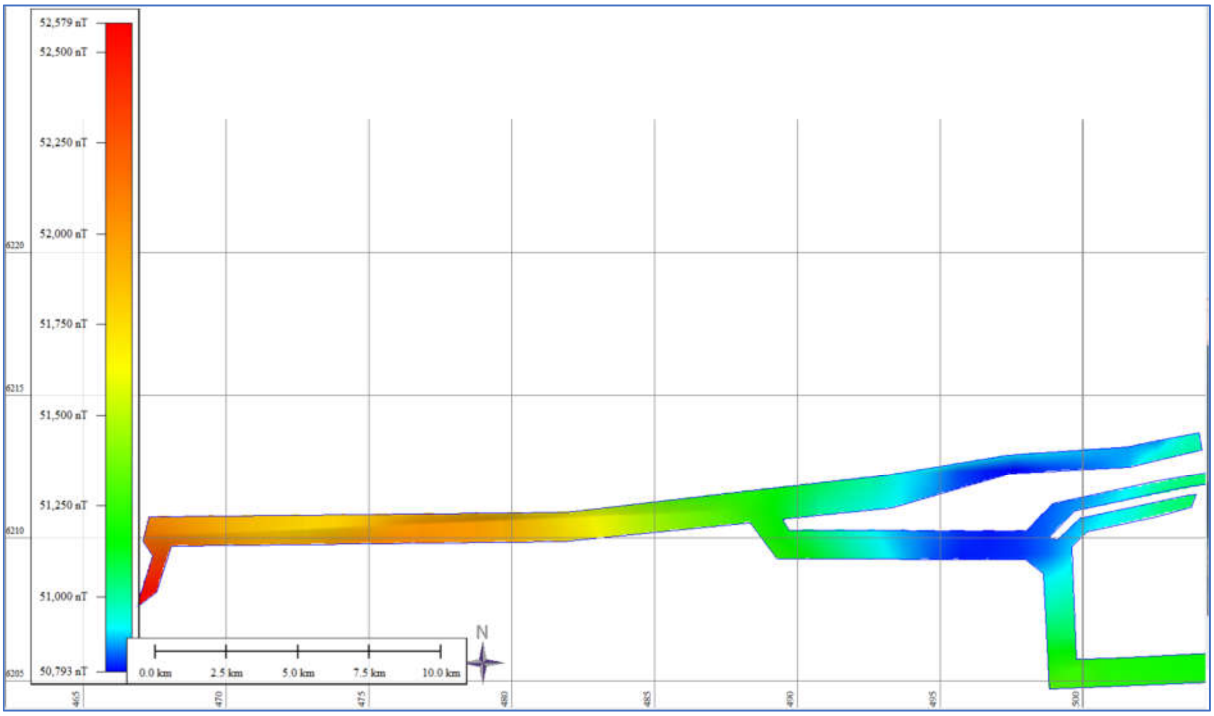


Fig. 17. Total magnetic field

After performing geomagnetic corrections, the residual magnetic field reflecting the geological conditions characteristic of the area was obtained. In order to identify areas where additional caution is necessary while planning engineering works, the general magnetic field was compared with the magnetic values determined in a specific profile, i.e. a magnetic field gradient or magnetic anomalies have been identified, reflecting possibly anthropogenic metallic objects on the seabed and highlighting magnetic anomalies (Fig. 18). 398 magnetic anomalies have been identified, most of which are associated with natural geological conditions and accumulations of large ferromagnetic mineral-rich boulders, but 41 magnetic anomalies have been identified that reflect intersections with subsea telecommunications cables.

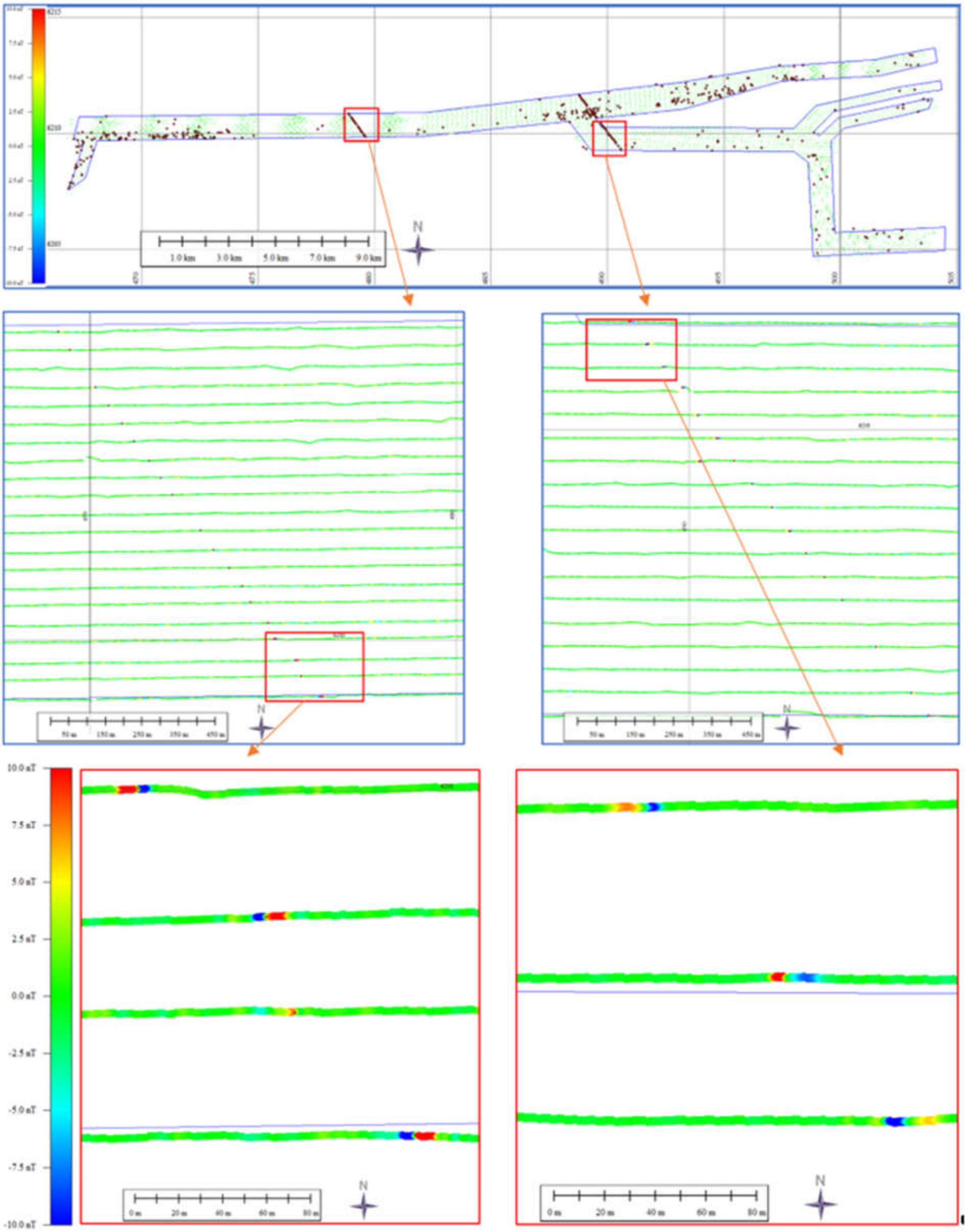


Fig. 18. Residual magnetic field and anomalies

Alternatives of the cabling routes

Technical properties of the planned corridor

It is planned that 220 kV alternating current supply power cables will be laid from planed OWPs. In order to connect each OWP to the Lithuanian electricity transmission networks, an infrastructure corridor of the necessary width will be formed. It is planned that it should accommodate three power cables of 350 MW or more. Minimum distance between cables ~70 m (or at least 2x sea depth). It is also planned that a 100 m protection zone will be established (Fig. 19).

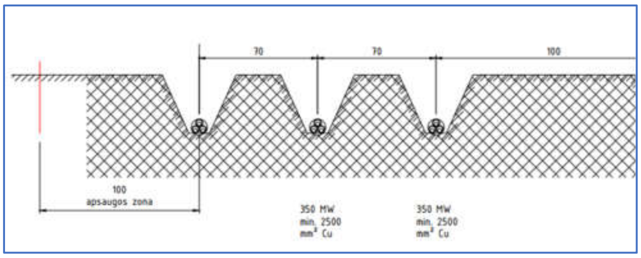


Fig. 19. Scheme of cable corridor for single OWP connection

Nomenclature of cabling corridors alternatives

Since no obvious critical obstacles have been identified in the study area, all tentatively proposed alternatives are suitable for the construction of marine cables. However, due to the planning uncertainties, due to the incomplete survey/design of the planned Harmony Link HVDC cable corridor and the difficult passage through the Holy Ancient Settlement cultural heritage site, the main (Fig. 20) and additional (Fig. 21) (partially aligned with the Harmony Link corridor and to the south of roadstead of Šventoji port) cable route alternatives.

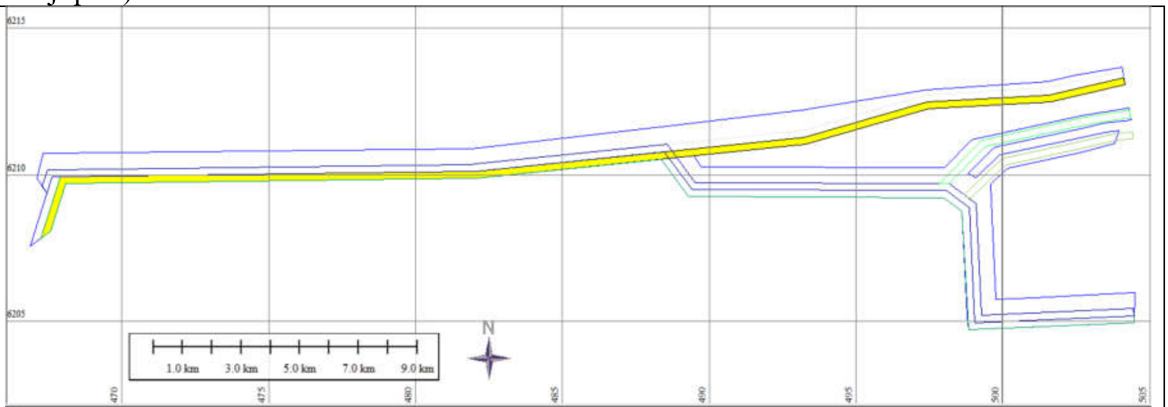
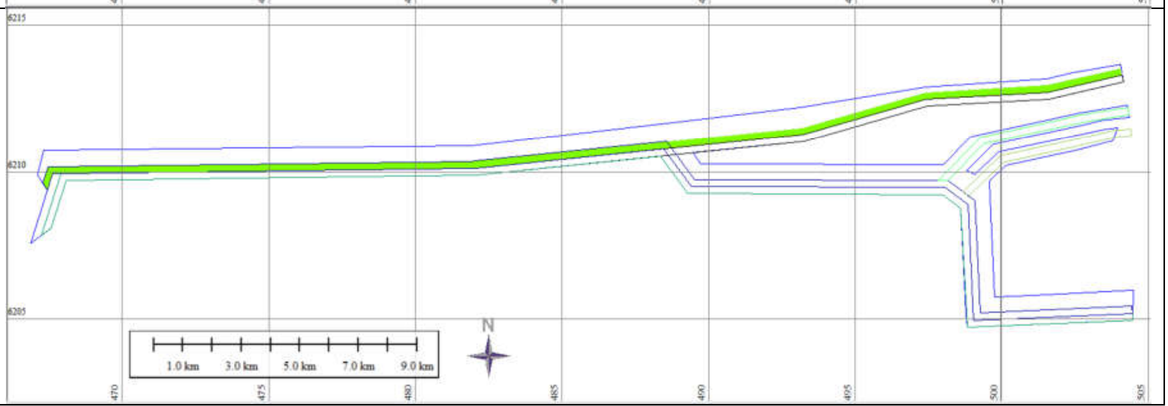
A1	
B1	

Fig. 20. Proposed main cabling corridor alternative

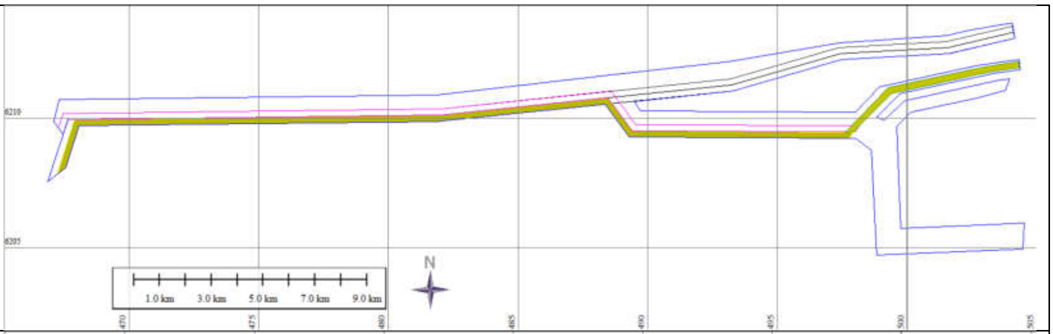
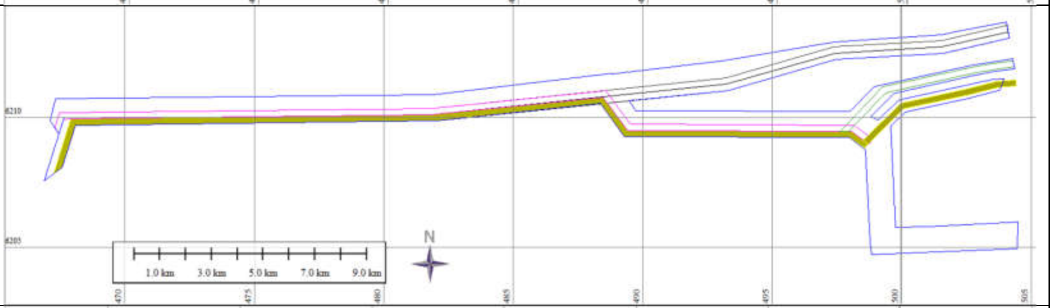
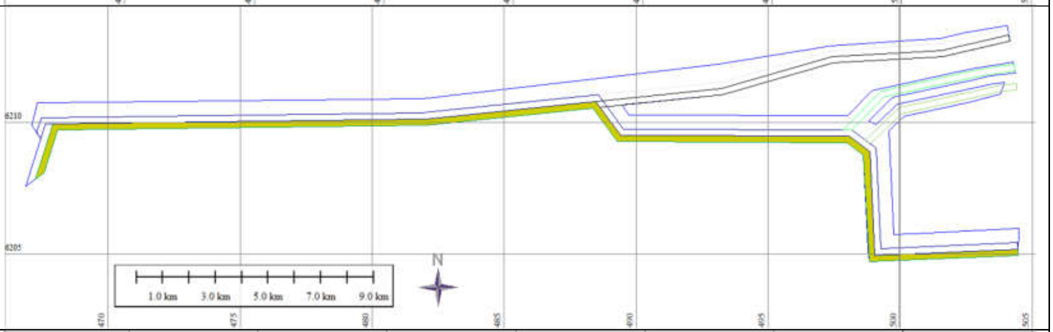
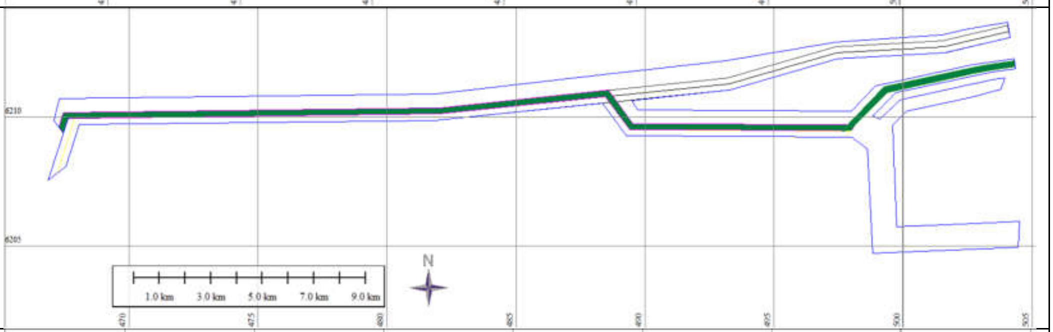
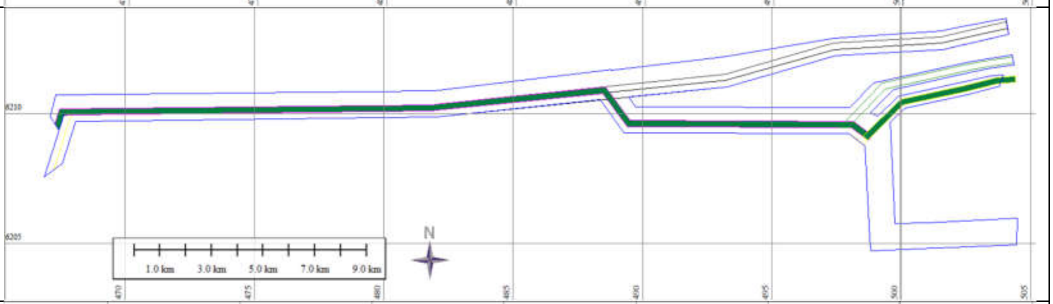
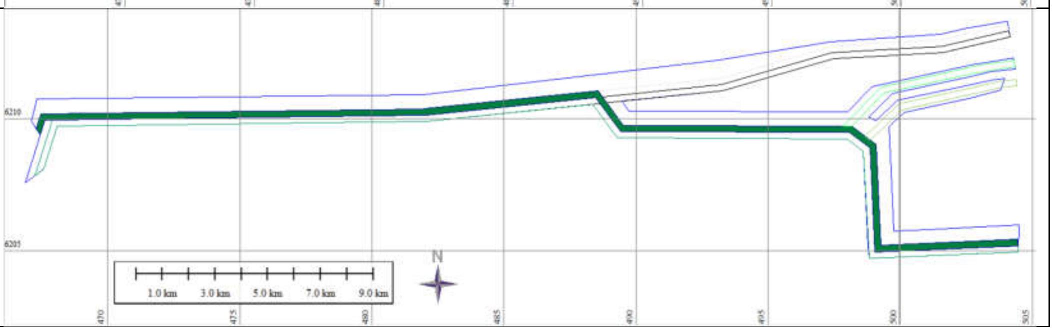
A2	
A3	
A4	
B2	
B3	
B4	

Fig. 21. Proposed additional cabling corridor alternatives

Main cabling route alternative

A1 (connecting „Pirmas etapas“ OWP) and B1 (connecting “A plotas“ OWP) cabling alternatives are proposed along the southern part of the established (as per valid CP spatial solution) northern (along Lithuania-Latvia marine boarder) infrastructure corridor(Fig. 22.).

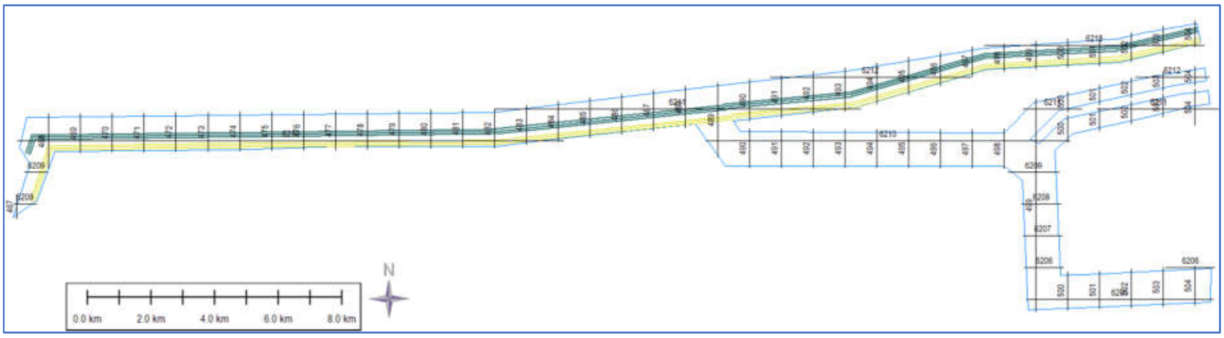
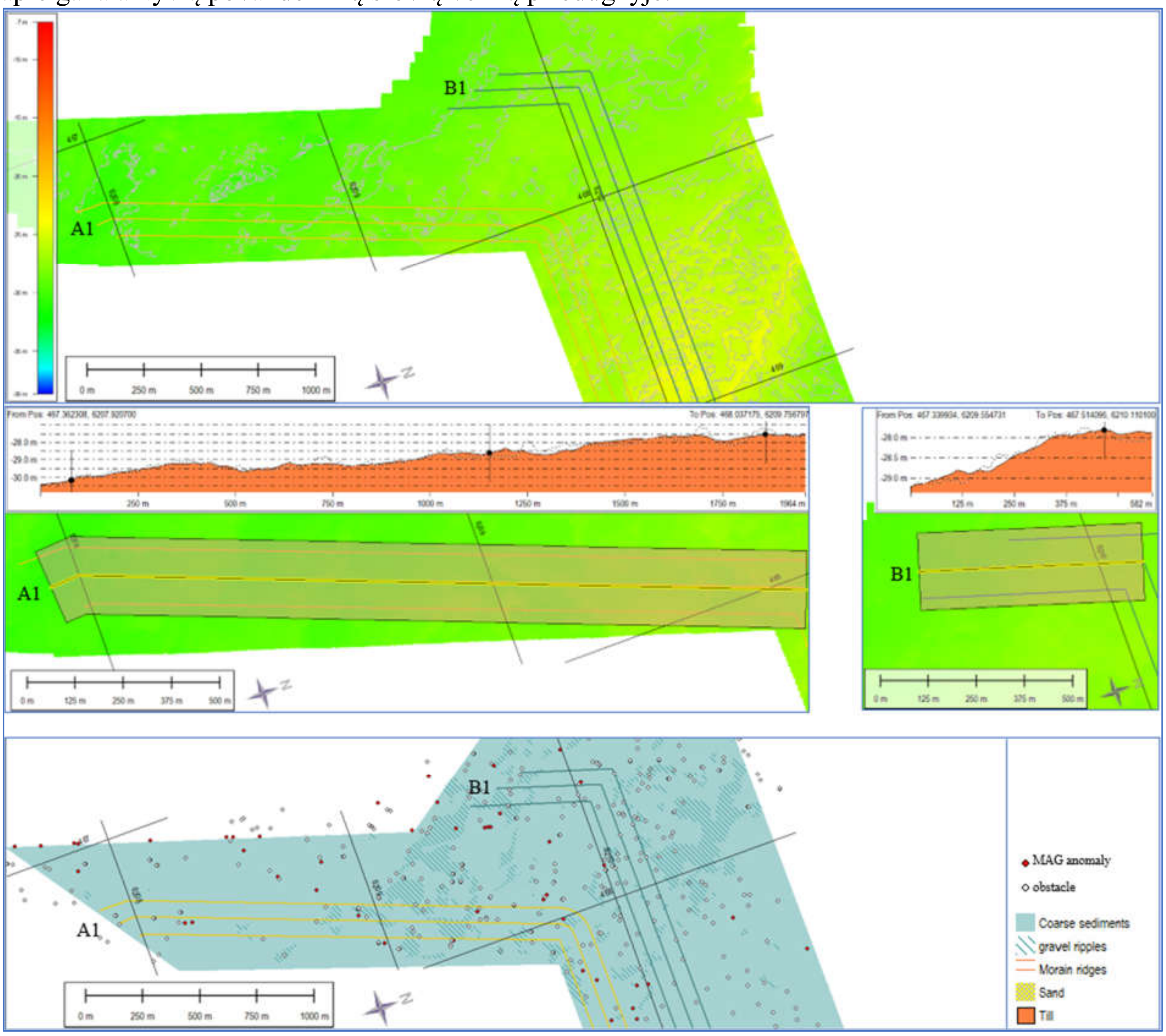
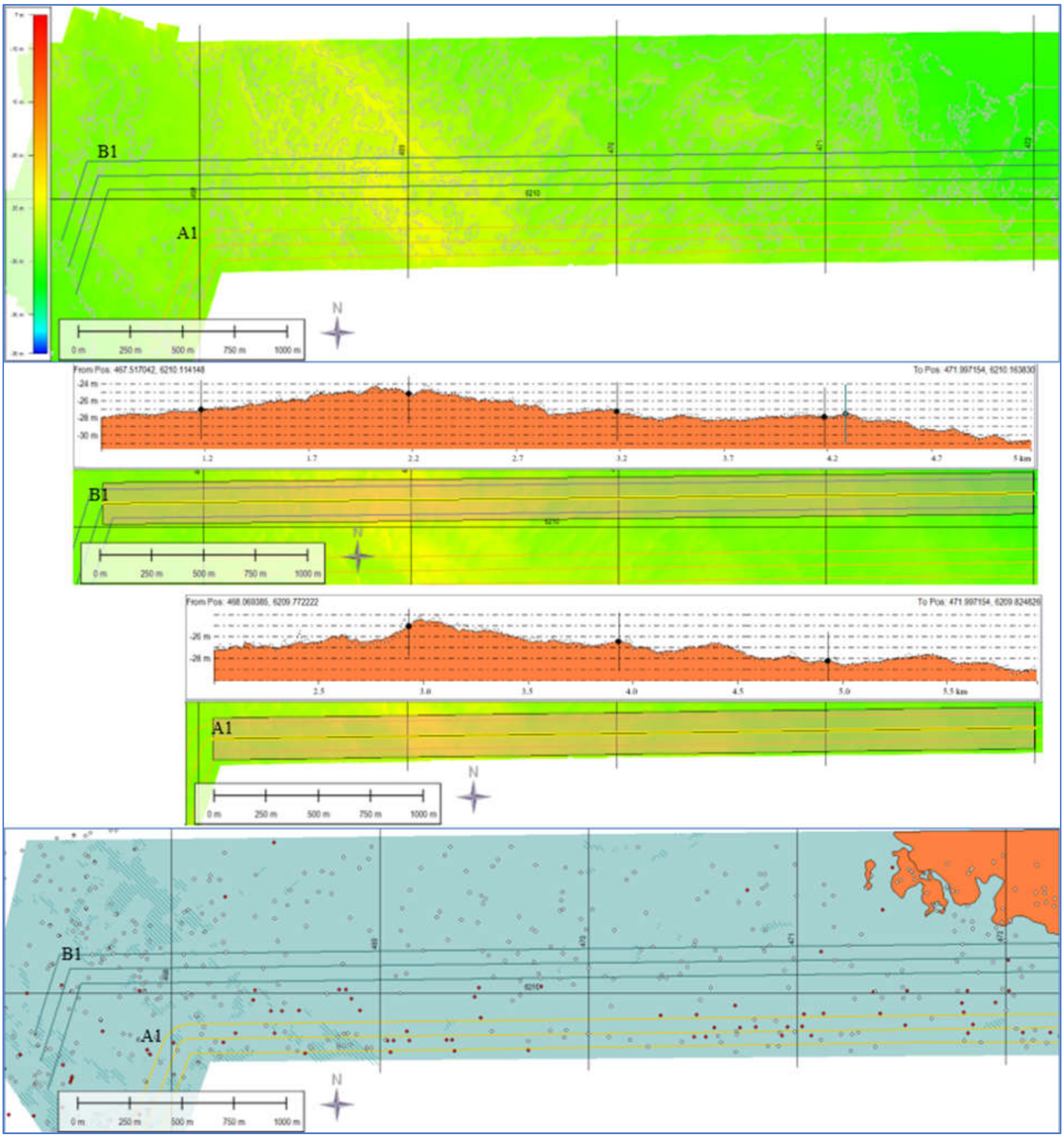


Fig. 22. Proposed main alternatives of the cabling routes

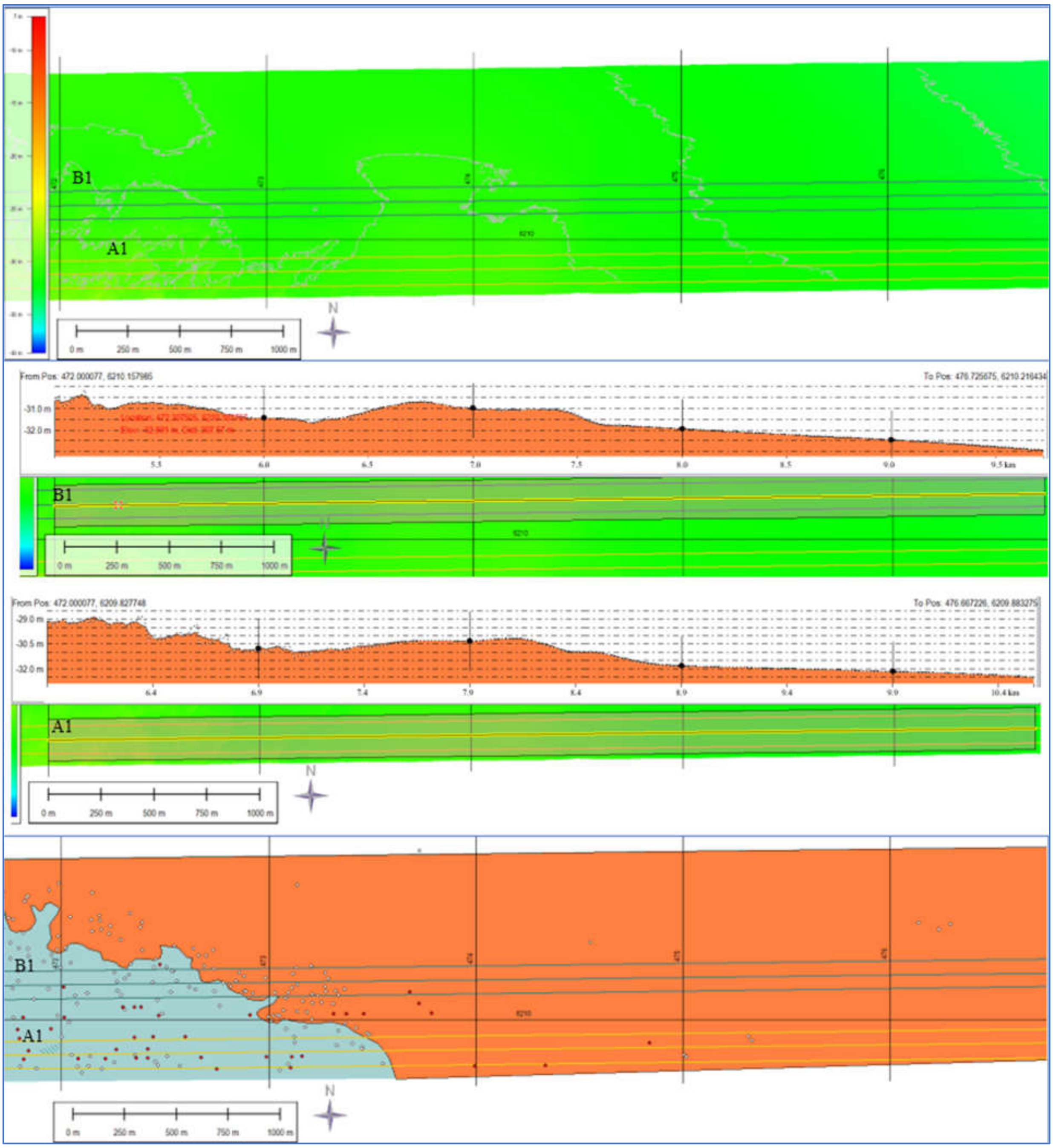
Atkarpa Y6208-Y6210,5 km: kabeliai praeina per tolygiai aukštėjantį reljefą, kurio peraukštėjimas vietomis siekia iki pusės metro, o bendras reljefo pokytis apie 2 metrai. Kabelių trasa praeina per kieto grunto lauką, kuriame sutinkami ir biogeniniai rifai, sutinkama daug riedulių ir (tikėtina) su jais susijusių magnetinių anomalijų. Atkarpoje taip pat stebimi smėlio ir gargždo ruzgų laukai, kas liudija apie gana aktyvią povandeninių srovių veiklą priedugnyje.



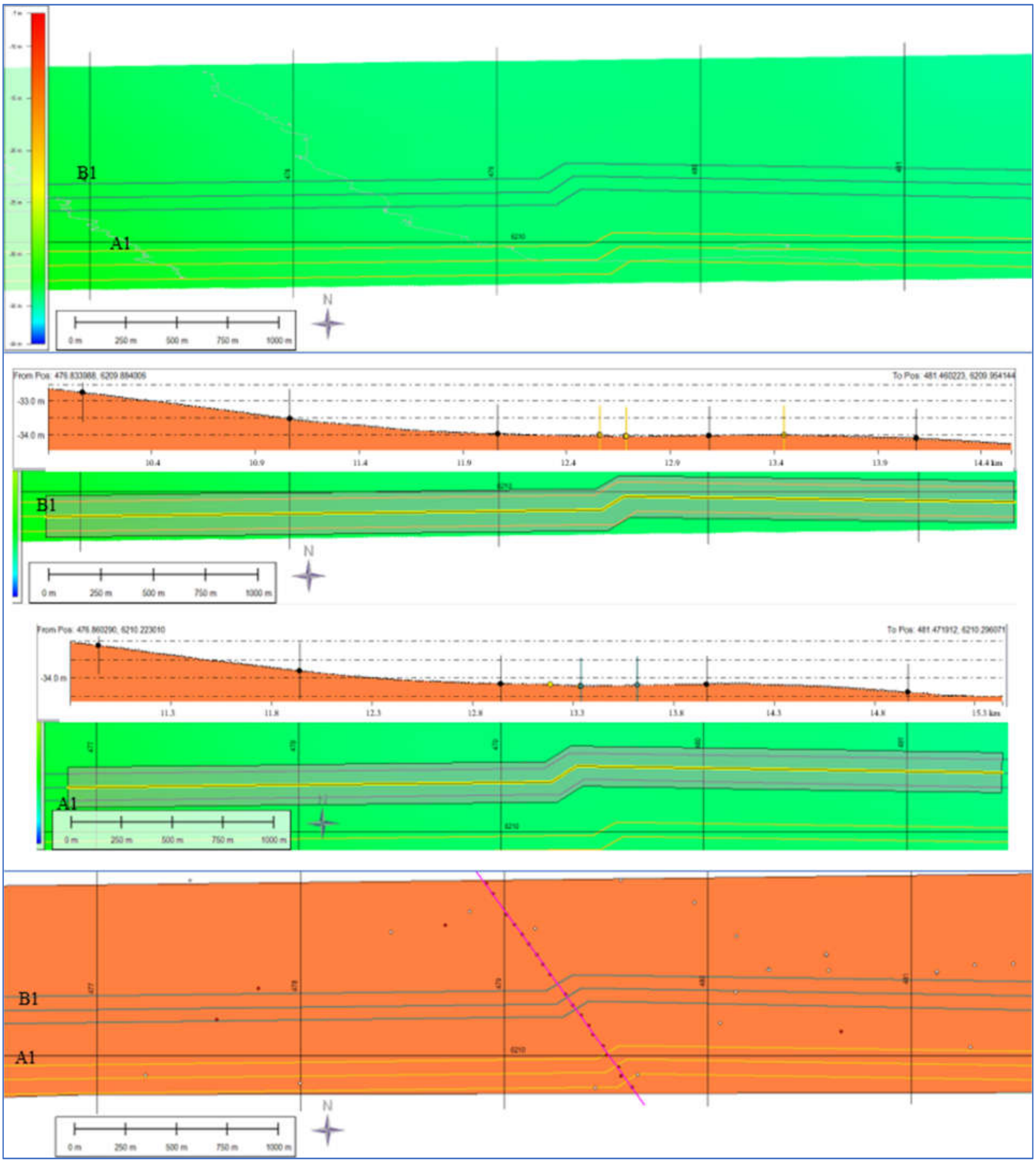
Section Y6208-Y6210.5 km: the cables pass through a steadily descending terrain, with a rise in elevation of up to half a meter, and a total change in terrain of about 2 meters. The cable route passes through a field of hard ground, where biogenic reefs are also encountered, and many boulders and (probably) associated magnetic anomalies are encountered. In the section, there are also fields of sand and gravel, which testify to the rather active activity of underwater currents in the seabed.



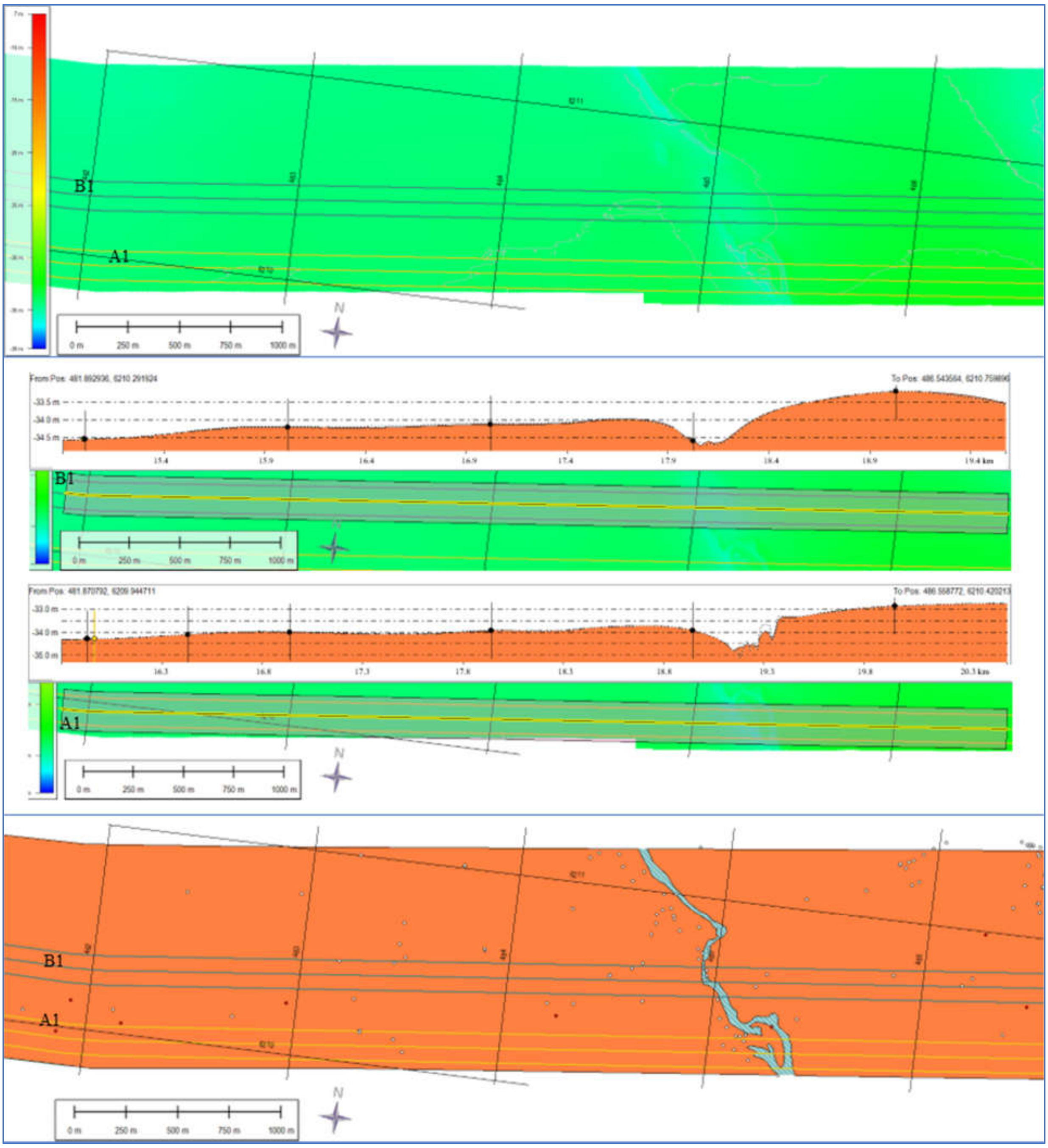
Section X472-X476.5 km: transition to the deepest zone of the route - the moraine plain, where the terrain is relatively flat, boulders and magnetic anomalies are almost invisible. The terrain slopes evenly towards the east.



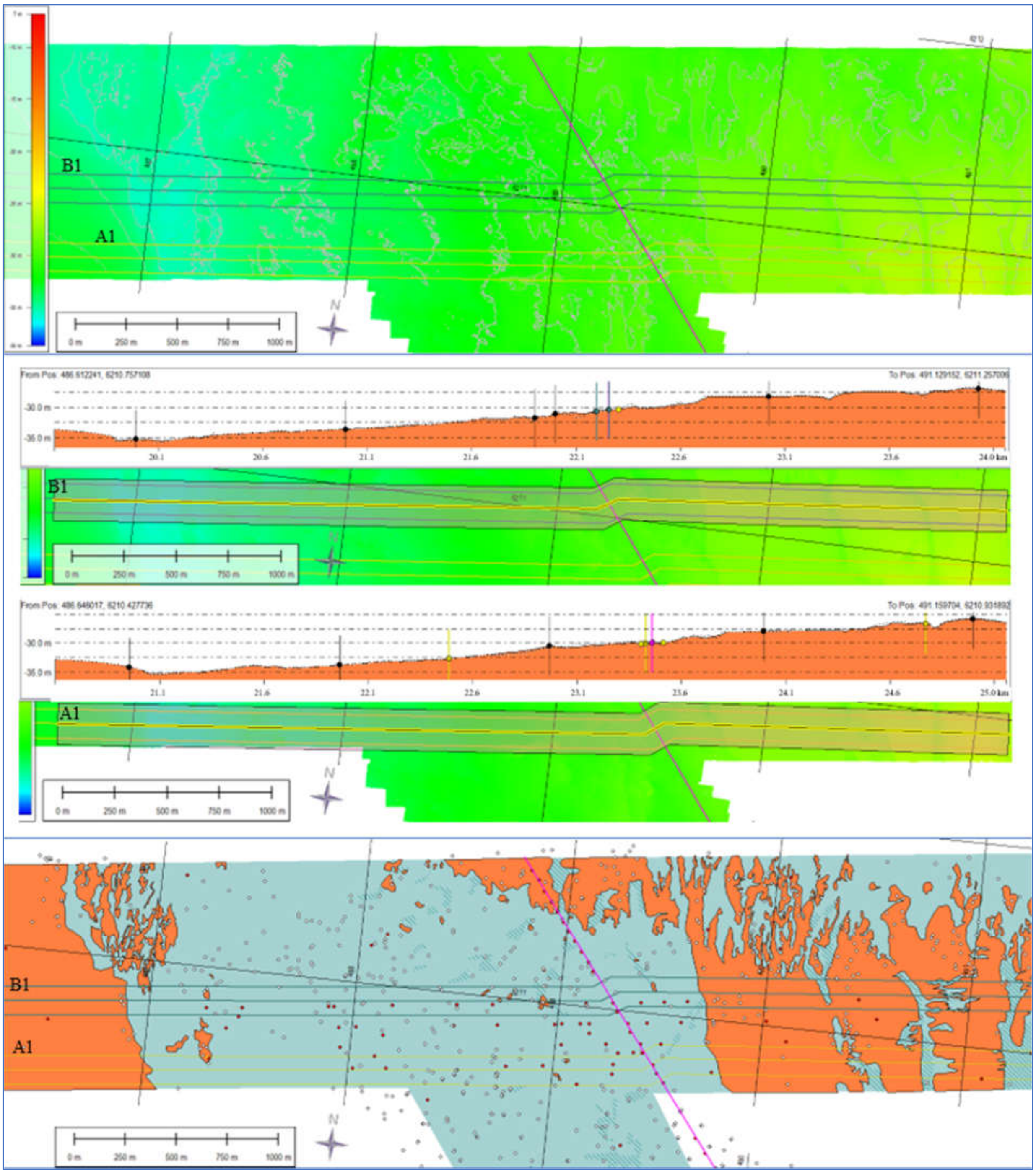
Section X476.5-X481.5 km: the deepest zone of the route - moraine plain, where the terrain is relatively flat, boulders and magnetic anomalies are almost invisible. The terrain slopes evenly towards the east. The route crosses the telecommunication cable, the intersections are clearly marked by the linear arrangement of characteristic magnetic anomalies.



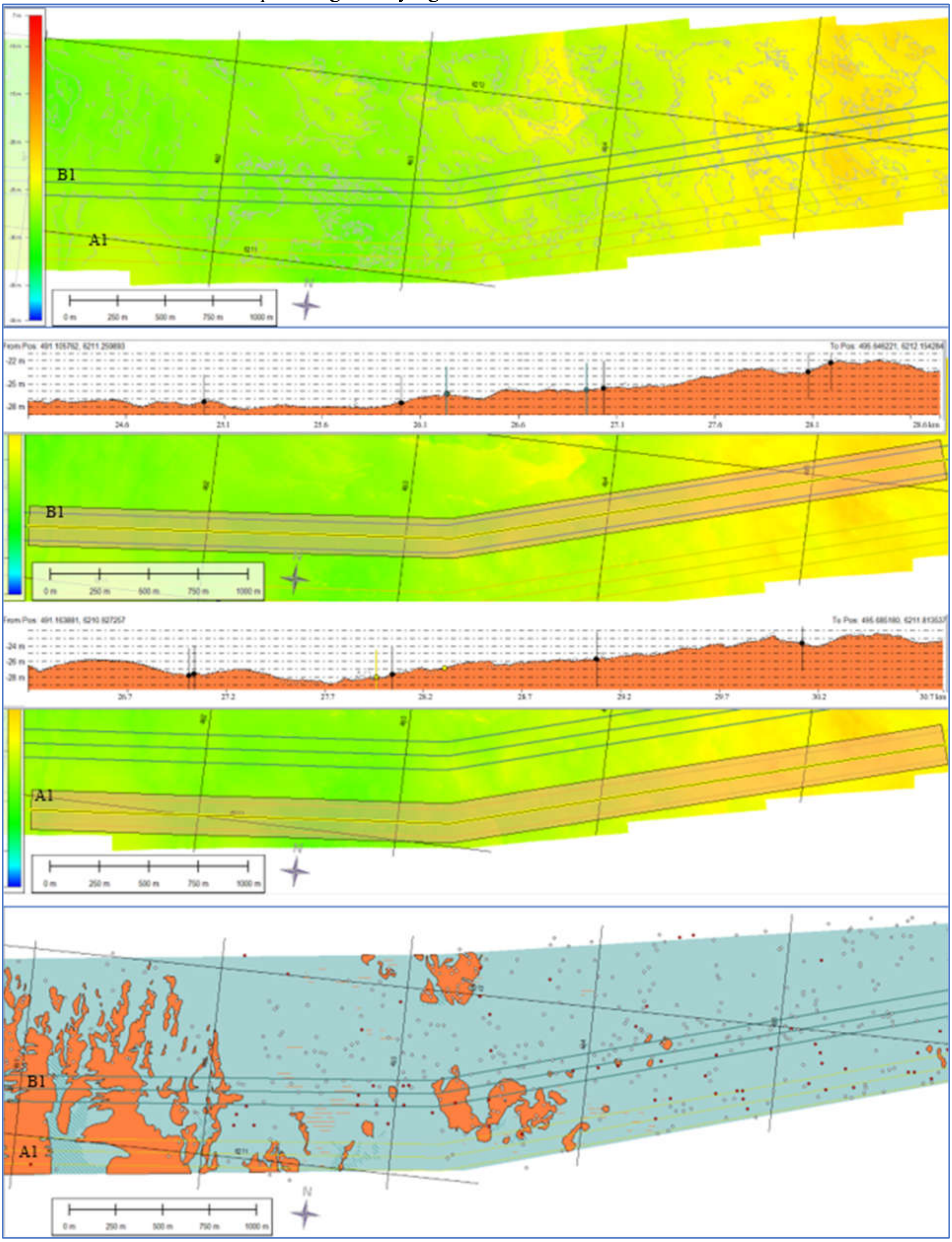
Section X481.5-X486.5 km: the flat relief of the moraine plain continues, single boulders are more often met; in the eastern part - a 1 m deep ravine is observed on the route, which crosses the entire research corridor. The ripples formed in ravine testify to active bottom currents in this section, the relief begins to rise again.



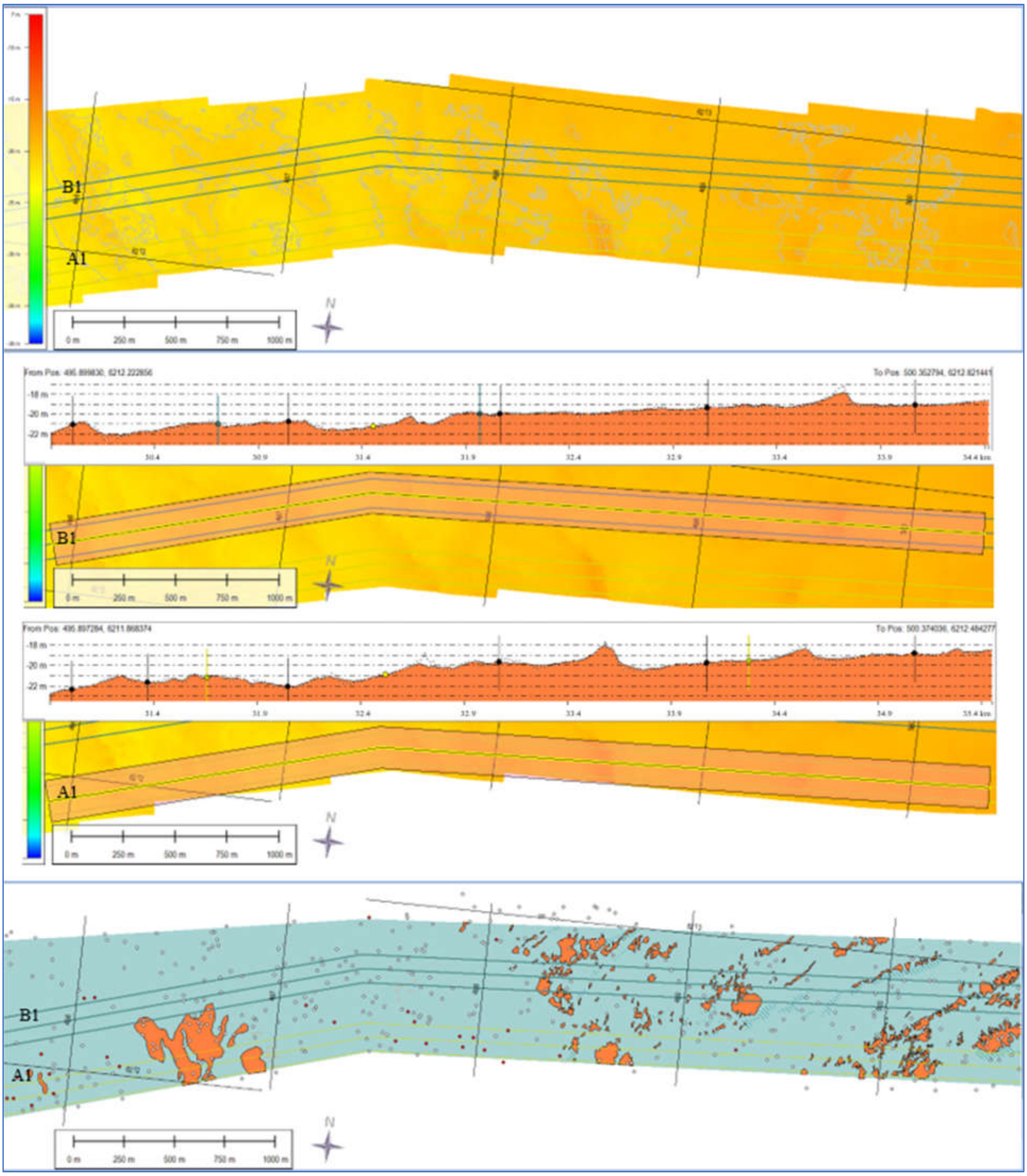
Section X486.5 - X491 km: the route passes into fields of coarse sediments, possibly weathered moraine, with abundant boulder accumulations, fields of ripples of coarse sediments, in the eastern part clear stretches of washed moraine with characteristic changing forms of ripples and eroded moraine fields residuals. This section also foresees the crossing of the second telecommunication cable, which is also fixed by magnetic anomalies.



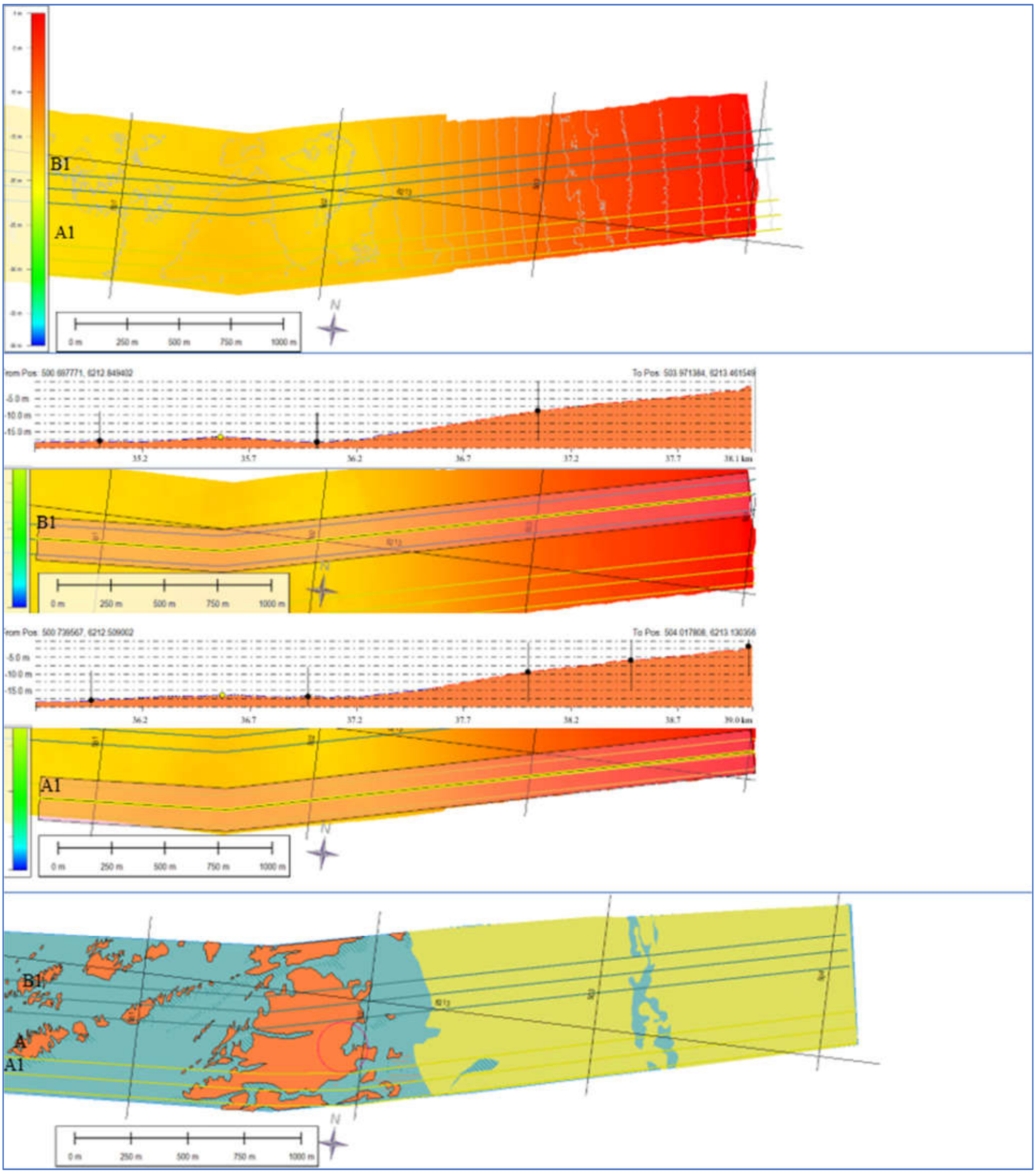
Section X491 - X495.5 km: zone of coarse sediments, possibly weathered moraine fields, with abundant boulder accumulations. Characteristic exertional relief forms of the observation are fields of moraine ridges (drumlins), in some places, ridges of coarse sediments are visible. Moraine ridges are quite expressive hills of a dozen/several meters long and several meters high, so it is recommended to take this into account when planning the laying of cables.



Section X495.5 - X500.5 km: zone of coarse deposits, possibly weathered moraine sections, with abundant boulder accumulations and relict moraine hills. The relief is quite variable, with expressive ups and downs, the height of which can reach 2-3 meters.



Section X500.5 - X504 km: the terrain smoothly transitions to the nearshore plain, moraine fields are replaced by nearshore sand fields - a dynamic zone with sand bars. An unidentified, possibly anthropogenic object has been identified in the middle part of the section, therefore the route of the proposed nearest cable is drawn 100 m from the possible obstacle.



Additional cabling route alternatives

Alternatives A2, A3 and A4 (for the connection of the "Pirmas etapas" OWP park) and B2, B3 and B4 (for the connection of the "A plotas" OWP) are partially formed (the western part coincides with A1 and B1 up to the mark of ~ X488 km) by the northern (in the southern part of the Lithuanian-Latvian border) infrastructure corridor, and the remaining parts of the route are formed further south - parallel to the planned Harmony Link corridor (from the north (respectively A2 and B2) and south (respectively A3 and B3), and to the south of the Šventoji port roadstead (A4 and B4) (Fig. 23).

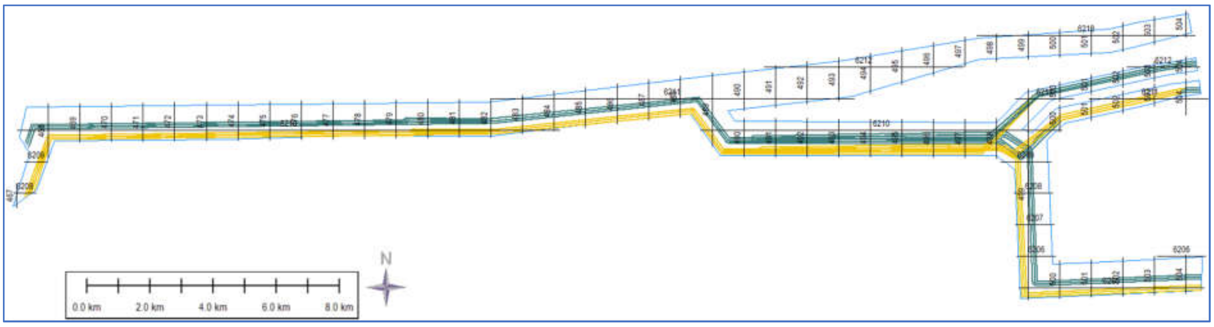
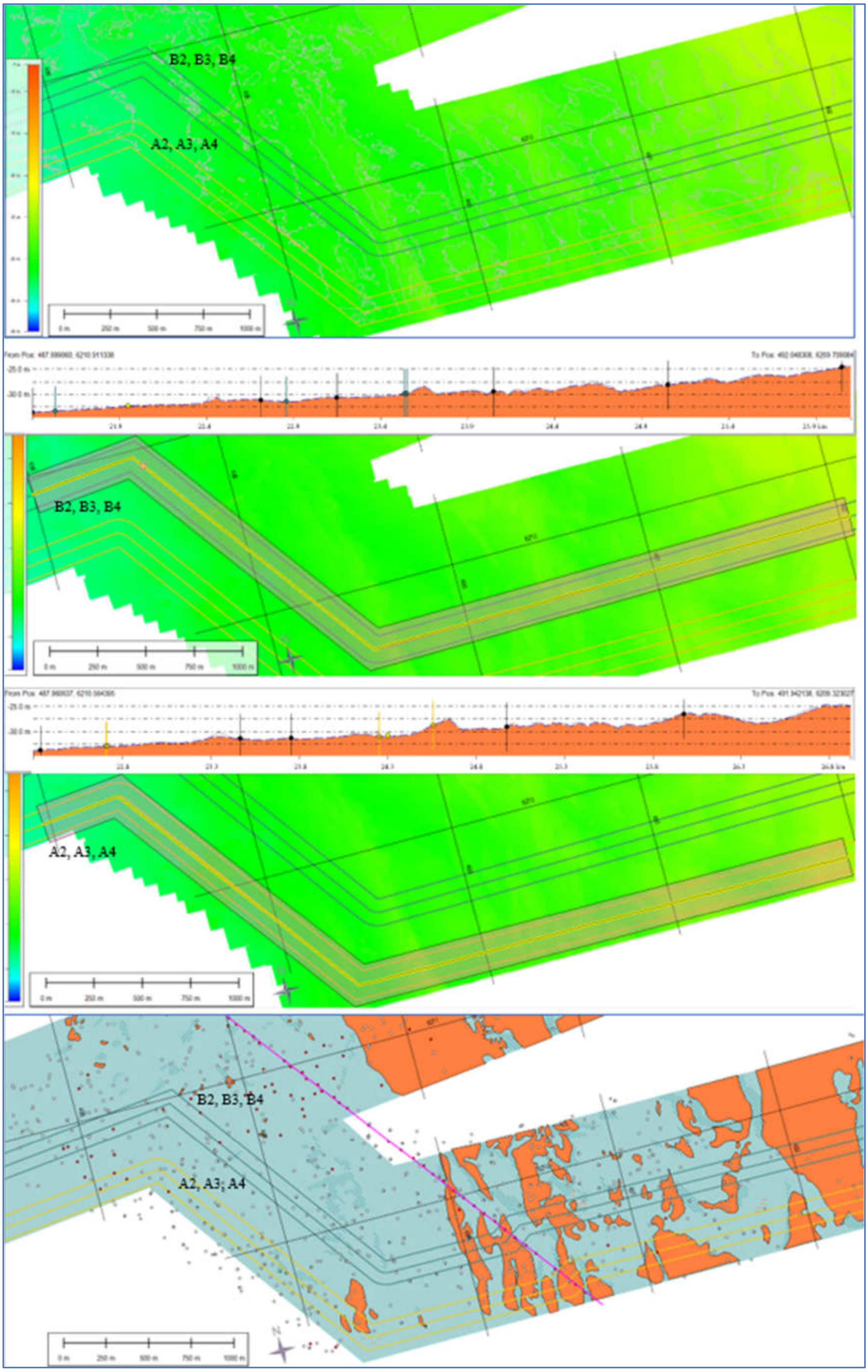


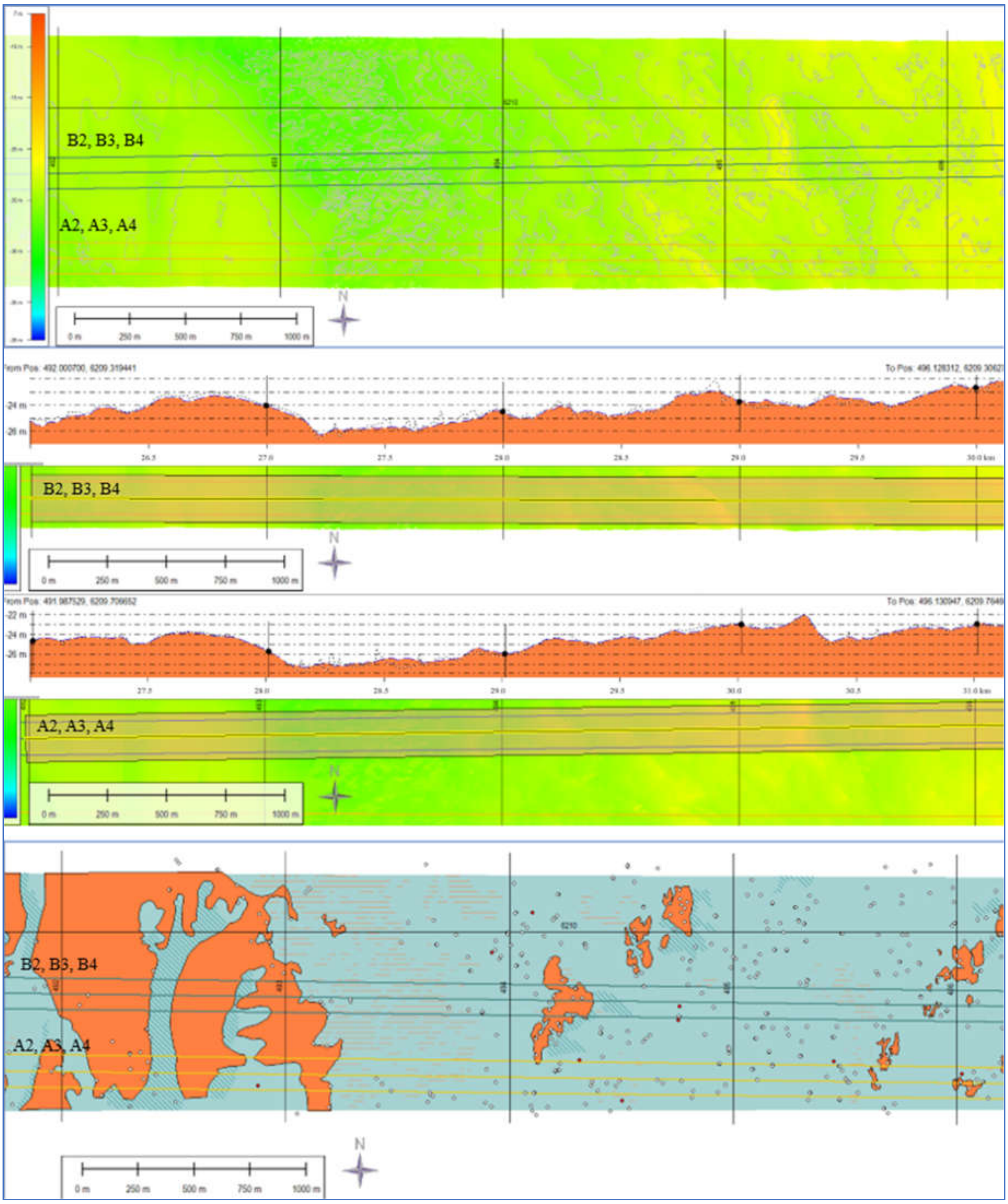
Fig. 23. Proposed additional alternatives of the cabling routes

Section X488 - X492 km: the route passes into fields of coarse sediments, possibly weathered moraine, with abundant boulder accumulations, fields of coarse sediments, in the eastern part clear sections of washed moraine with characteristic changing forms of moraine ridges and drumlins. This section also foresees the crossing of the second telecommunication cable, which is also fixed by magnetic anomalies.

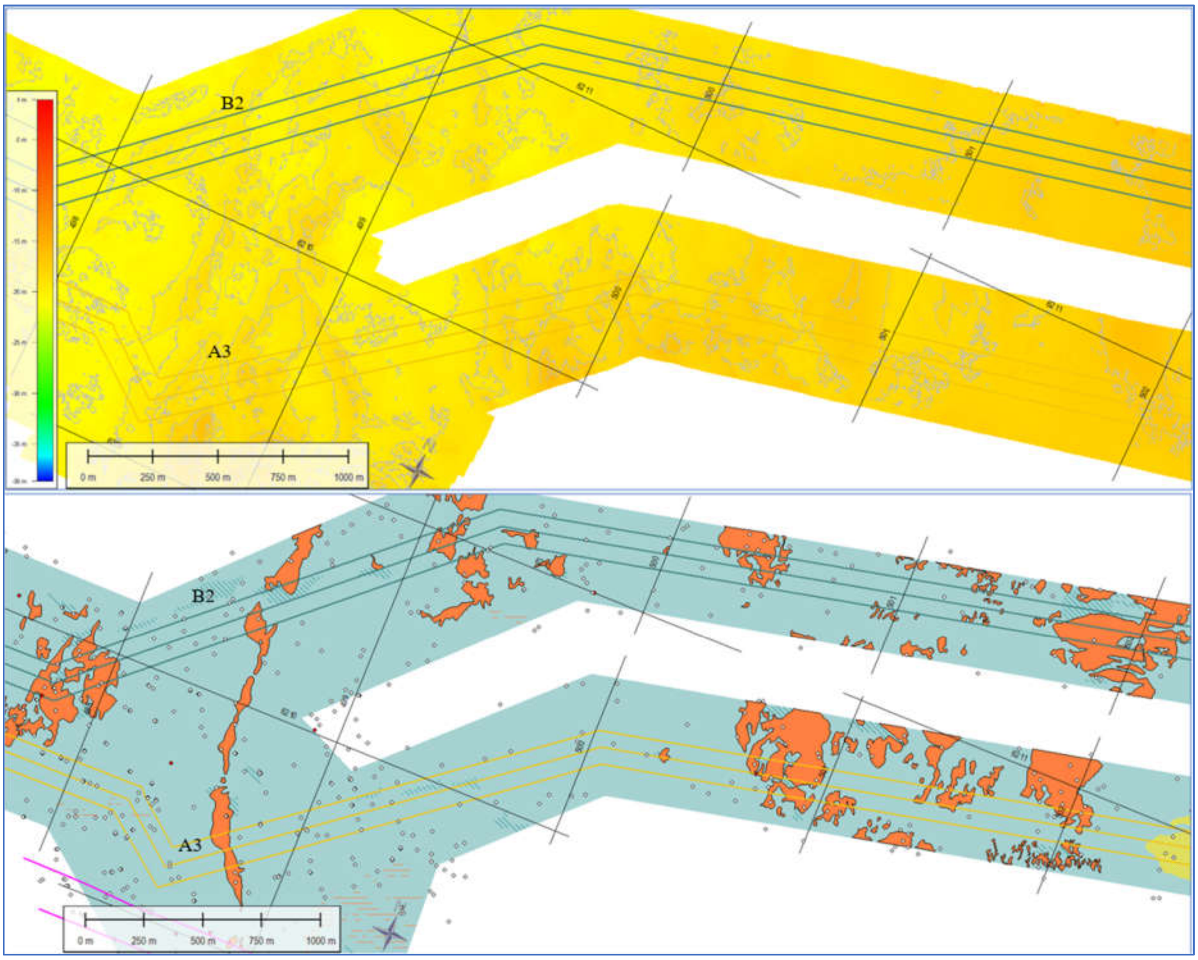


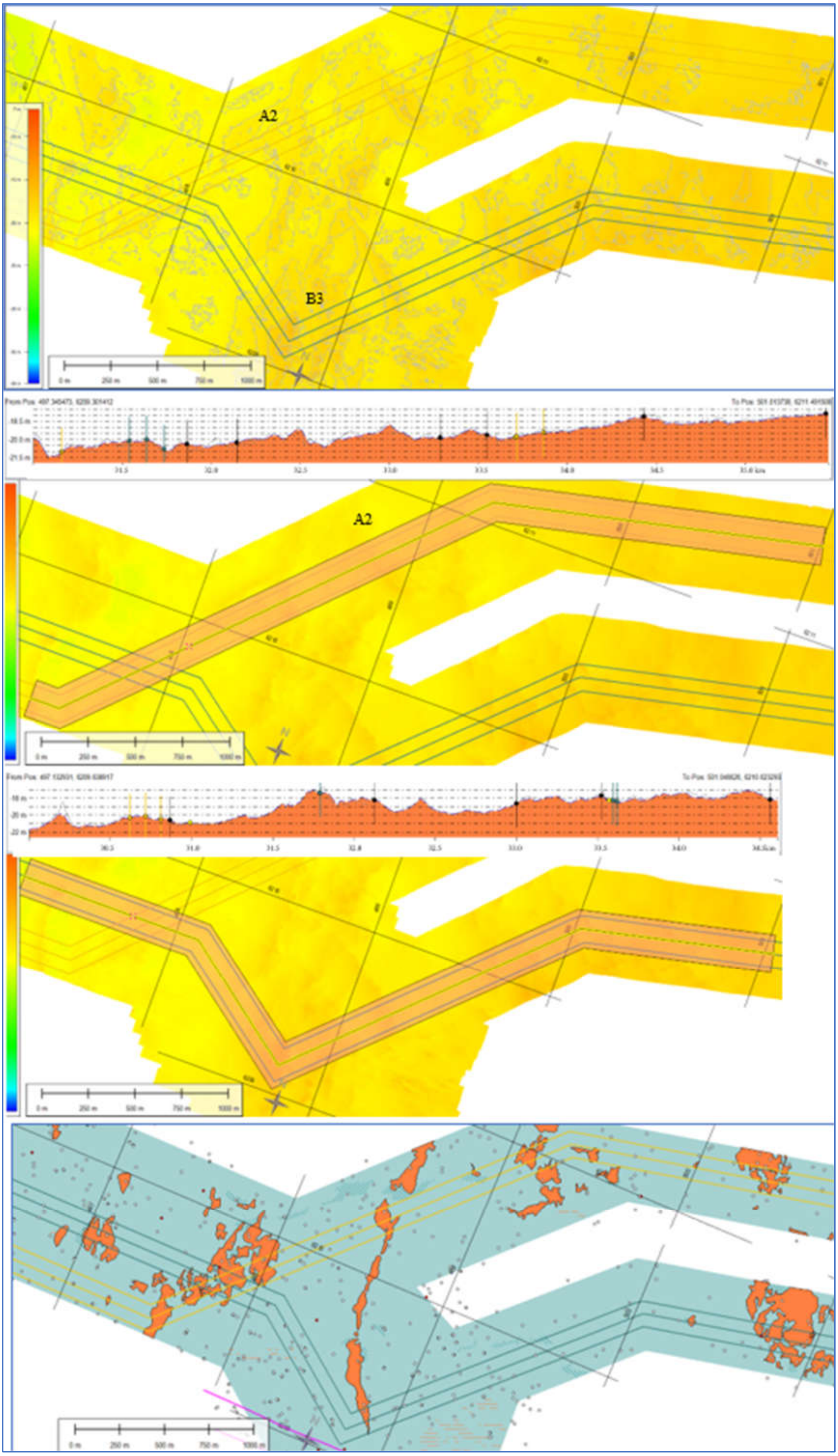
B2, B3, B4
A2, A3, A4
0 m
250 m
500 m
750 m
1000 m
-25.0 m
-30.0 m
B2, B3, B4
A2, A3, A4
B2, B3, B4
A2, A3; A4

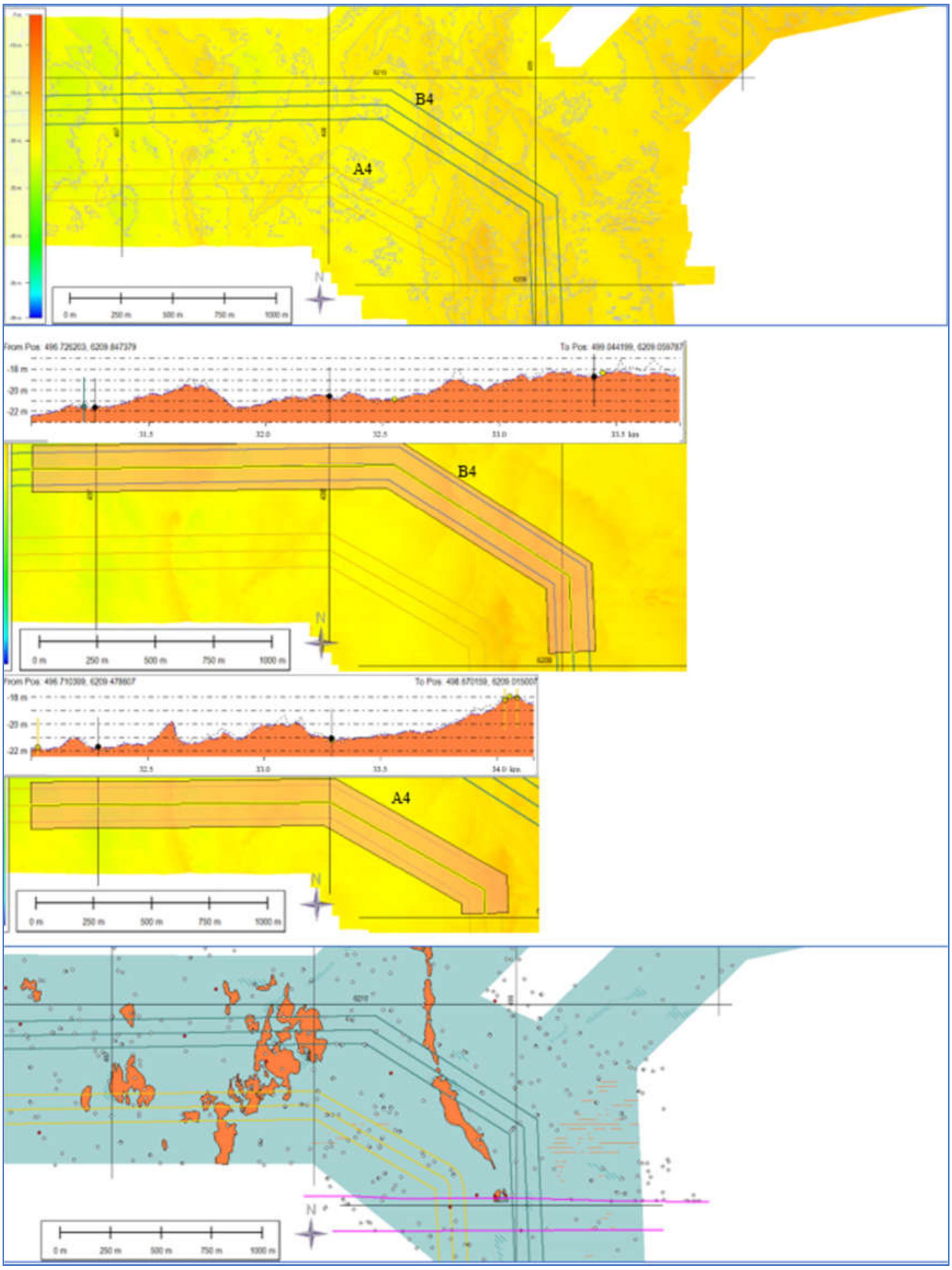
Section X492 - X496 km: area of coarse sediments, possibly weathered moraine fields, with abundant boulder accumulations. Characteristic exertional relief forms of the observation are fields of moraine ridges (drumlins), in some places, ridges of coarse sediments are visible. Moraine ridges are quite expressive hills of a dozen/several meters long and several meters high, so it is recommended to take this into account when planning the laying of cables.



Section X496 - X502 km: The route splits into two parts - north and south of the planned Harmony Link corridor. All alternatives to cableways branch out here. Area of coarse deposits, possibly weathered moraine sections with abundant boulder accumulations and relict moraine hills. The relief is quite steep, with expressive ups and downs, the height of which can reach 1-3 meters. Alternatives A3, A4 and B3, B4 will potentially involve crossing the Harmony Link HVDC cable.

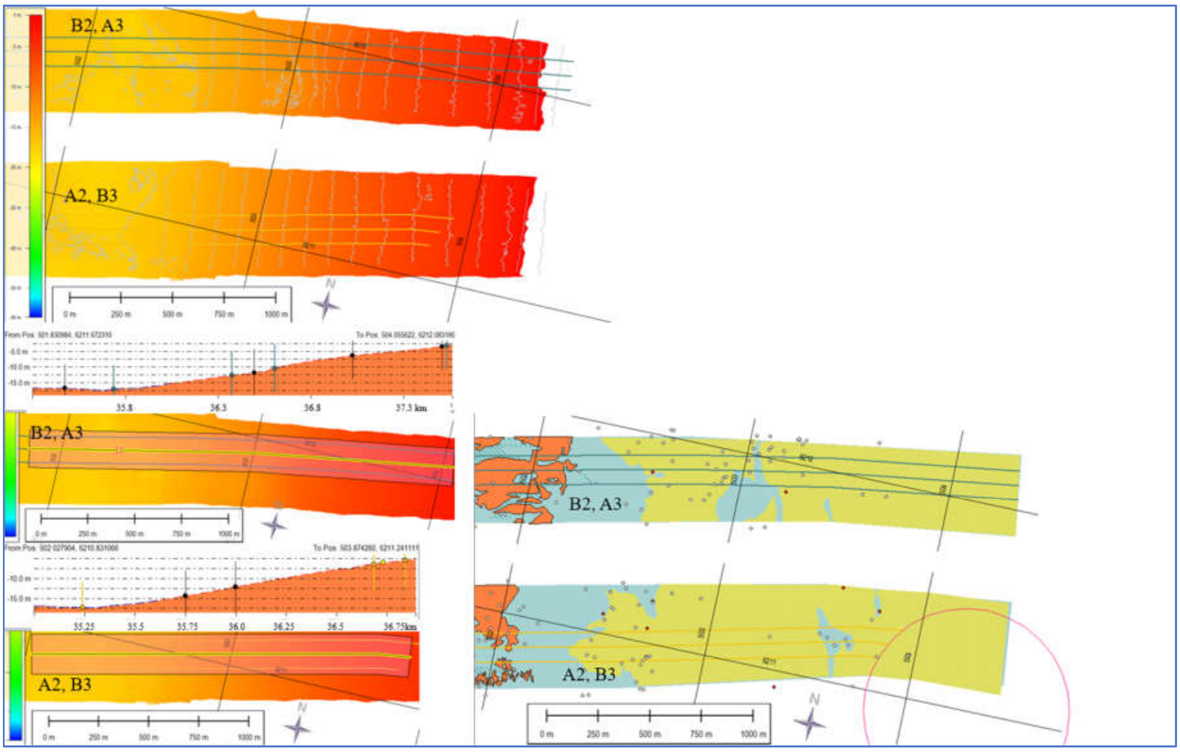



A2
B3
A2

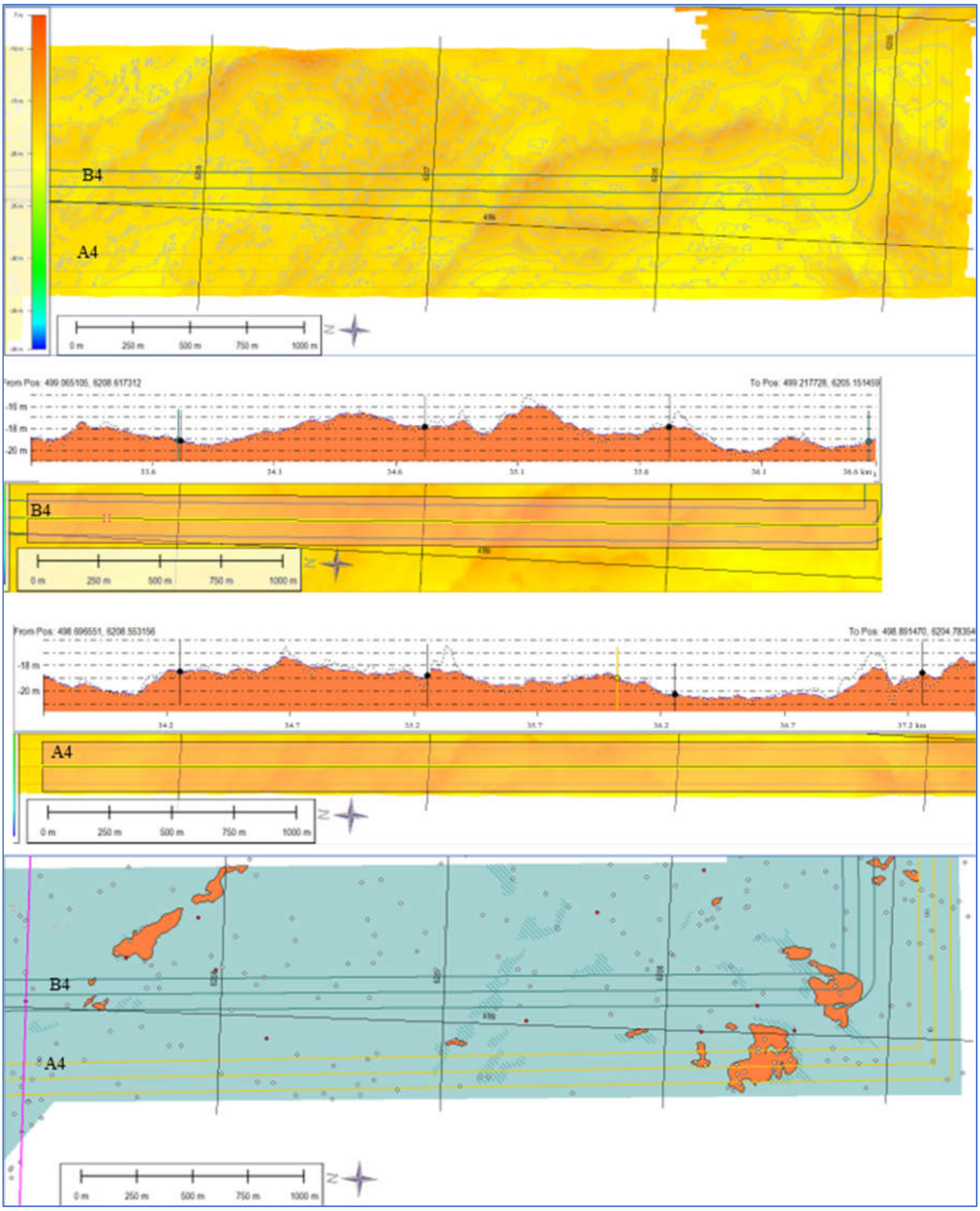


B4
A4
0 m
250 m
500 m
750 m
1000 m
N
From Pos: 496.726203, 6209.847379
To Pos: 499.044199, 6209.059787
-18 m
-20 m
-22 m
31.5
32.0
32.5
33.0
33.5 km
B4
From Pos: 496.710309, 6209.478607
To Pos: 498.670159, 6209.015007
32.5
33.0
33.5
34.0 km
A4

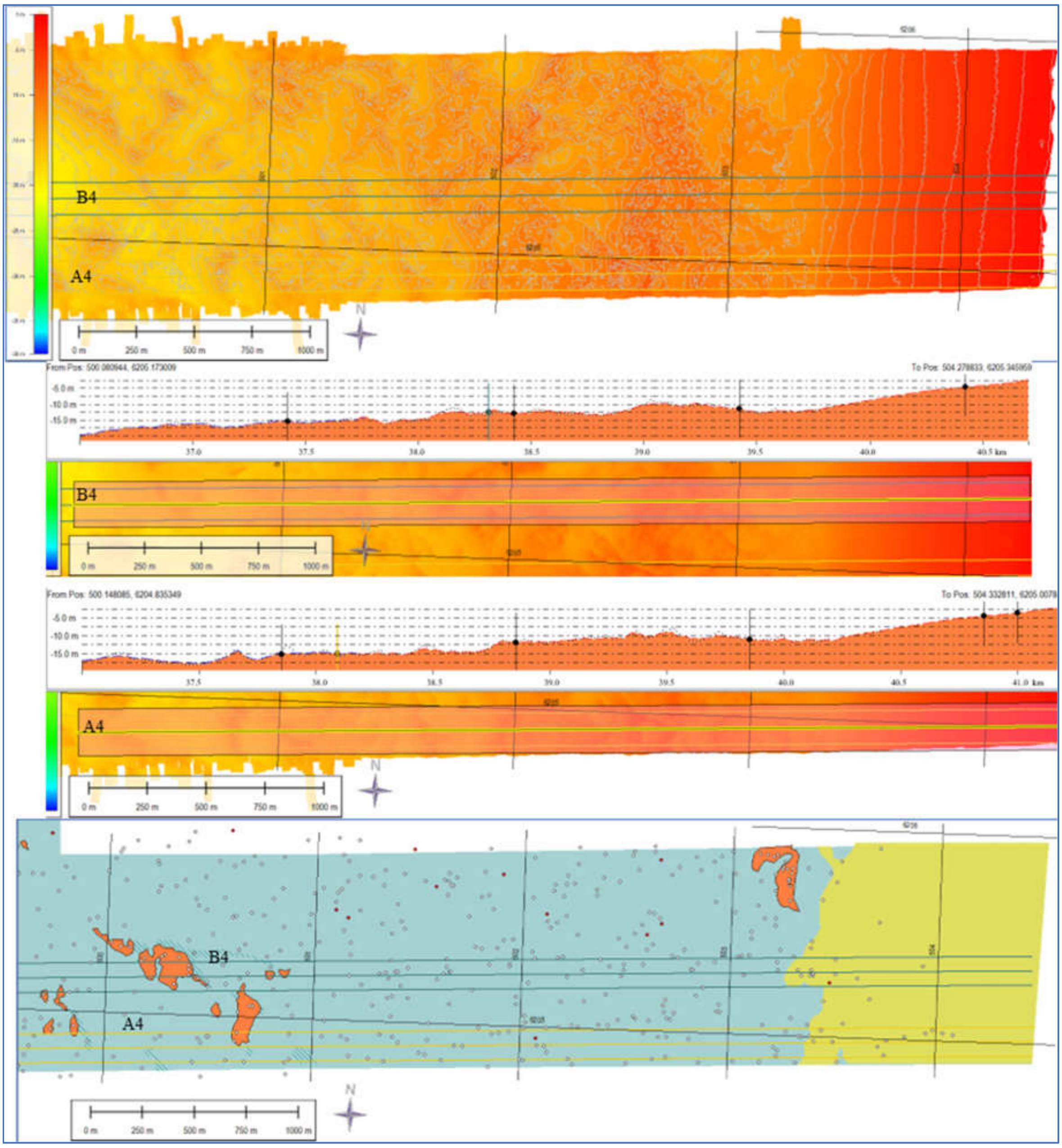
Section X502 - X504.5 km: The route splits into two parts, north and south of the planned Harmony Link corridor. The relief smoothly transitions to the nearshore plain, moraine fields are replaced by nearshore sand fields - a dynamic zone with sand bars.



Section Y6209-Y6205 km: area of coarse deposits, possibly weathered moraine with abundant boulder accumulations. The relief is quite variable, with expressive ups and downs, the height of which can reach 1-2 meters.



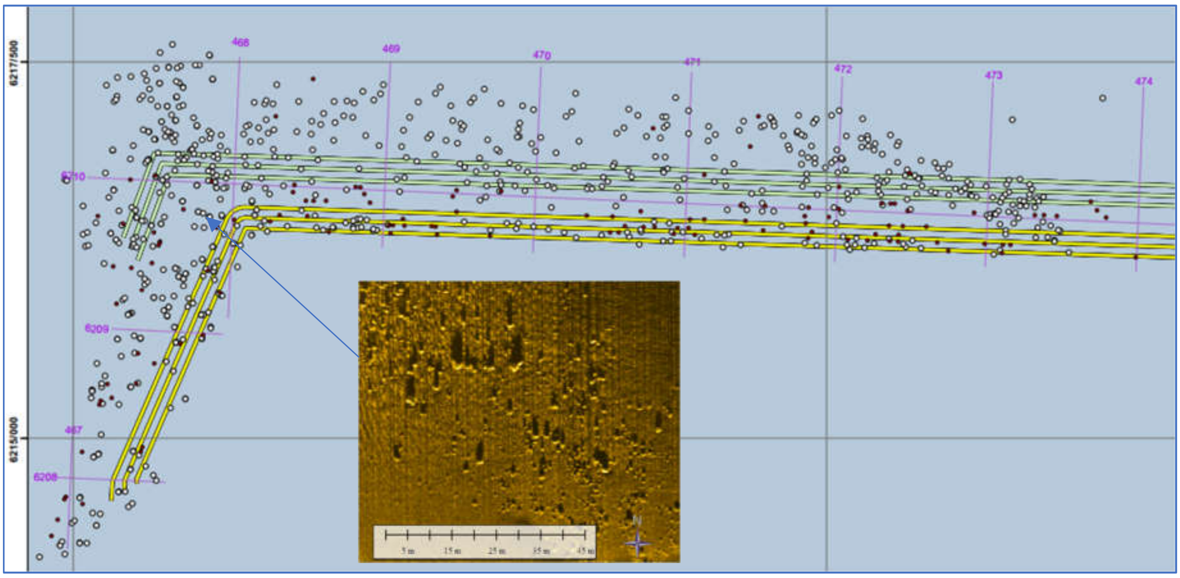
Section X502 - X504.5 km: The route runs south of the Šventoji port roadstead. Most of it is covered with deposits of weathered moraine, many boulders. The relief smoothly transitions to the nearshore plain, moraine fields are replaced by coastal sand fields - a dynamic zone with sand bars.

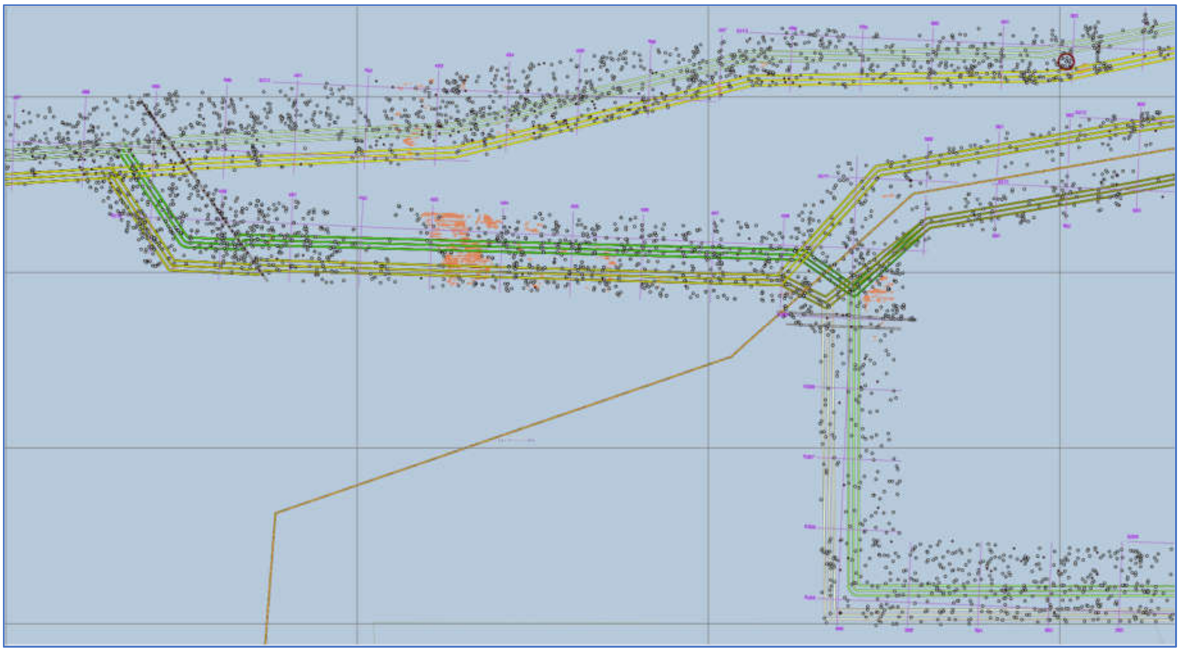


Identified areas of risks

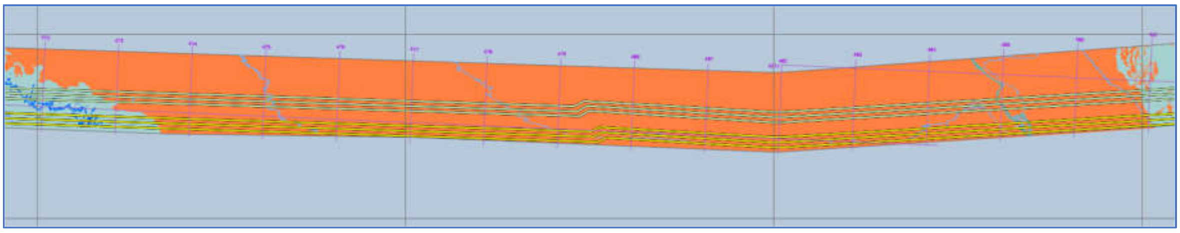
The main problematic sections are related to the geological-geomorphological conditions of the research area, intersections with other infrastructure objects and possible obstacles on the seabed (natural and possibly anthropogenic).

Geologically, the fields of boulder accumulations and hard-bottom moraine are the most difficult for cable laying (the characteristics of moraine deposits will be specified during geological research - research of the next stage). Boulders are most common in uplands, where outcrops of deposits of glacial origin are common: they are especially abundant in the western X467 - X473.5 km and the eastern X487-X503 km track section, where the diameter of individual boulders can reach several meters.

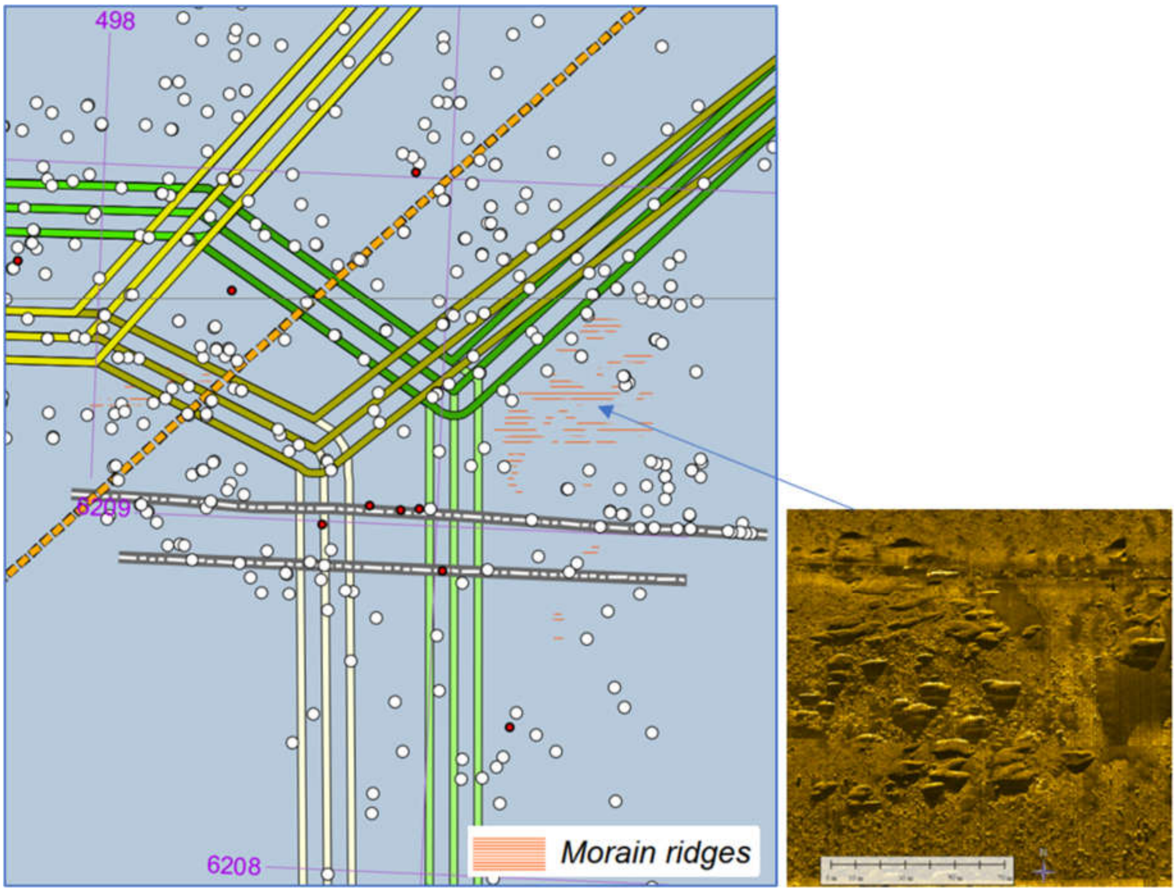


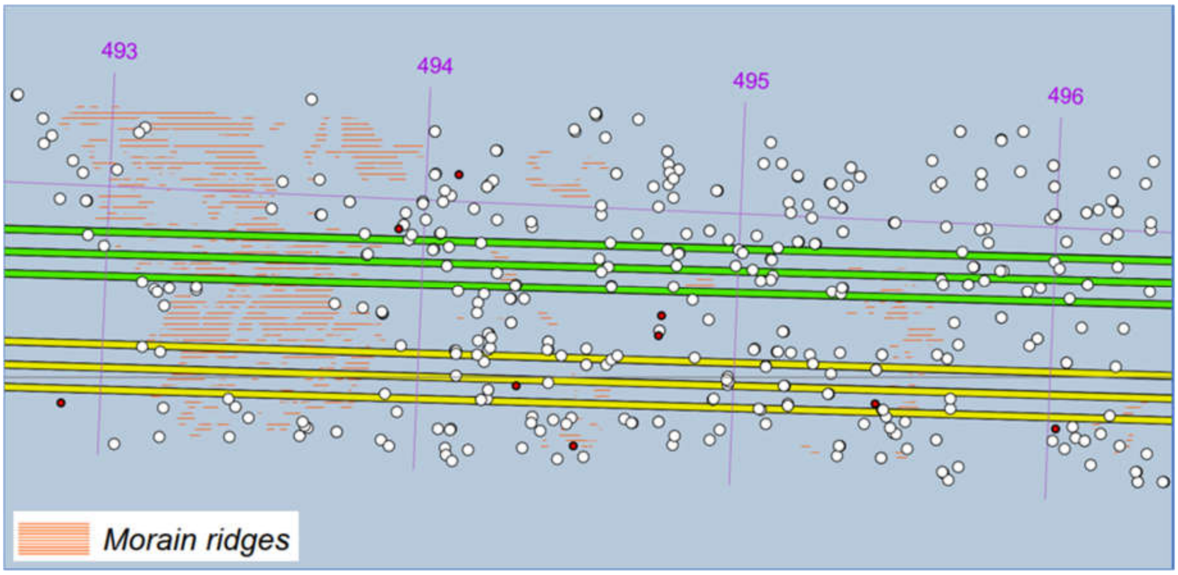


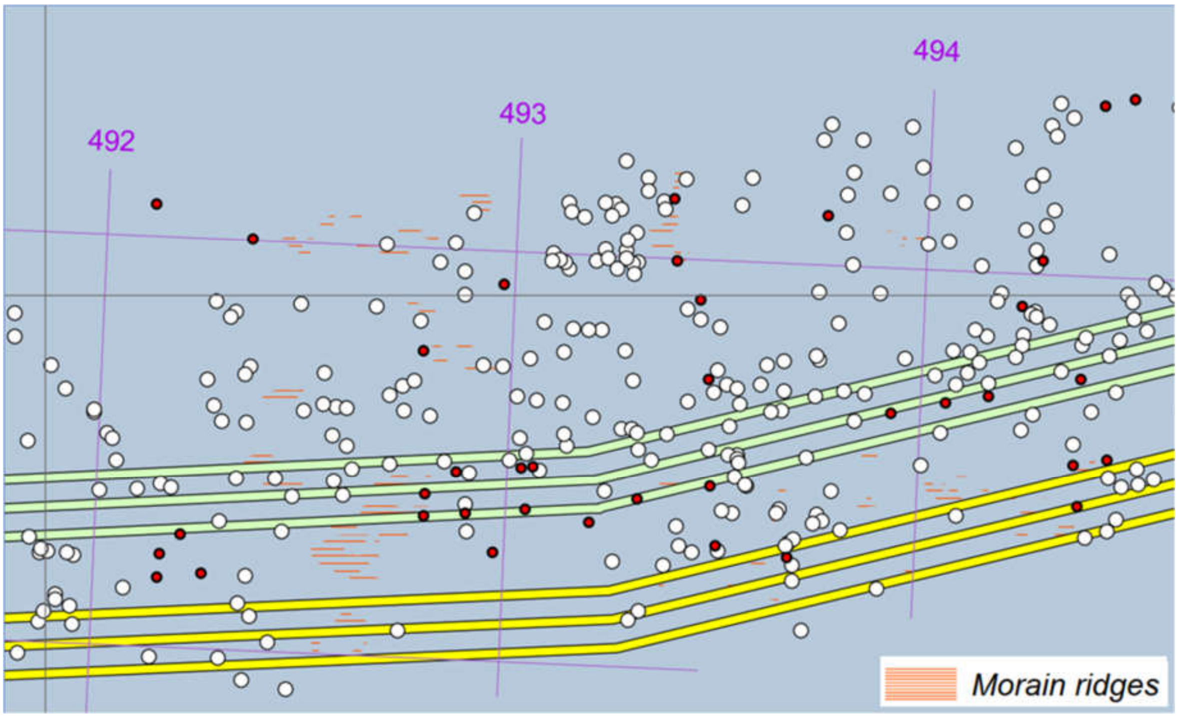
A solid moraine base is characteristic of the central part of the area (~X472 – X487 km section), where a uniform moraine plain is observed. The composition and geomechanical properties of these deposits were not investigated at this stage of research, but the characteristic reflections of the acoustic signal indicate the presence of a hard bottom in this section.



From the geomorphological point of view, it is most important to pay attention to the places of sudden relief changes/jumps, which are related to the areas of distribution of moraine ridges and the appearance of local erosive gullies in the areas of intense currents. Accumulations of moraine ridges are most clearly expressed in two zones: X499-X500/ Y6209-Y6210 square, where the A/B 4th and A/B 3rd alternative routes branch off; In the X493-X496 km section (A/B on alternative route 2, 3 and 4) and on the X492-X494 km section (A/B on alternative route 1):

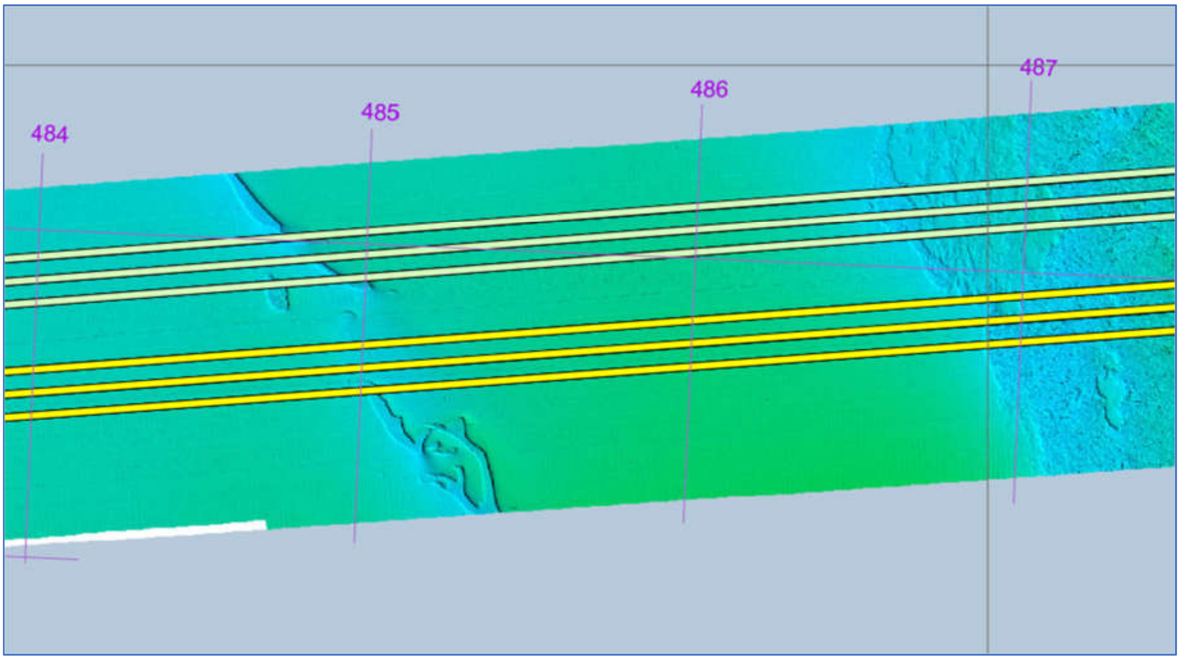


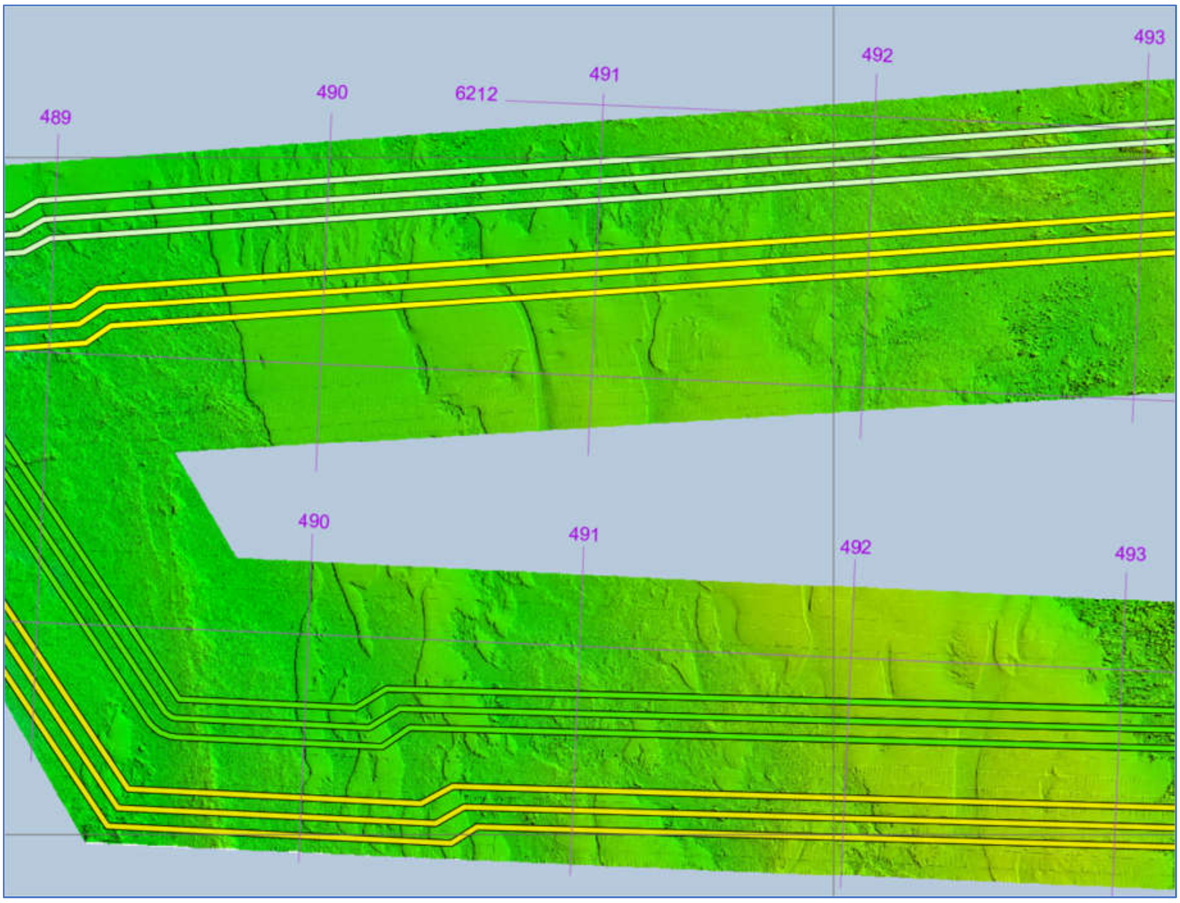




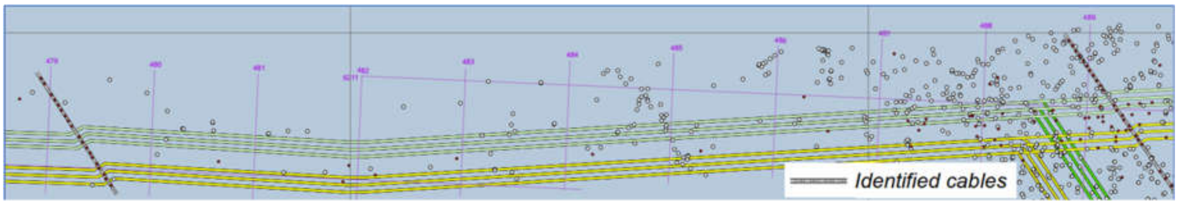
The moraine ridges are usually distributed in groups, and individual hills can be tens of meters long and up to 5-6 meters high, so when laying cables, it is necessary to carefully choose the trajectories to avoid the largest clusters and the highest concentration zones of the hills.

Other erosive forms are also evident in the relief - ravines up to 1-2 meters deep and several hundred meters wide, where ripples are often observed, which testify to the activity of flowing water. Such ridges are quite clearly visible at ~X485, ~X487 and in the section between km X489-X493. These zones are not characterized by a particularly high complexity of the terrain, but they can be important for the selection/non-selection of the route.

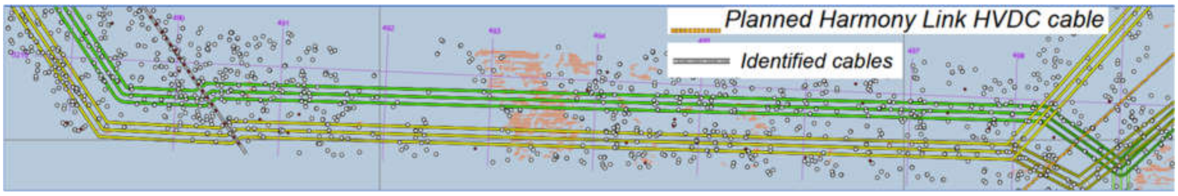




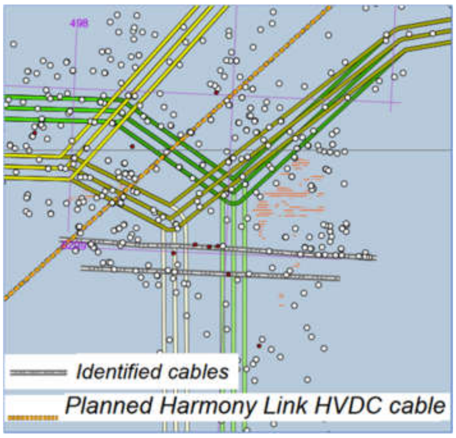
Existing and planned engineering infrastructure facilities would inevitably have to be crossed along the possible cable routes. For Alternatives A/B 1 and/or 2, two such crossings are foreseen: at ~X479.5 and ~X489.5 km (these are existing telecommunication cables):



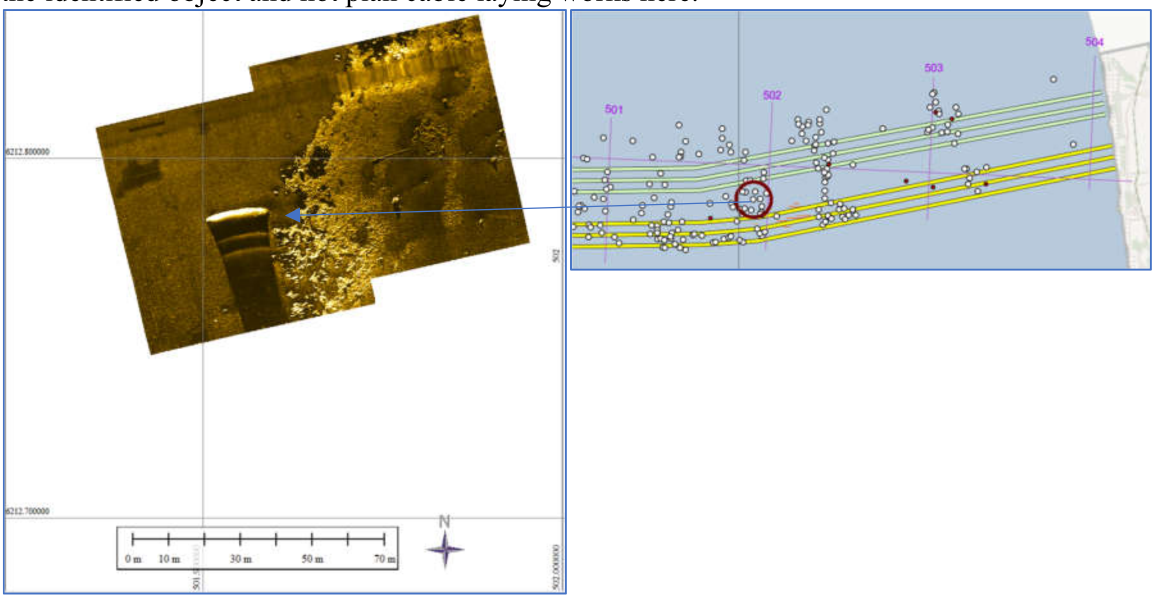
if you choose A/B 3 alternatives, in addition to crossing the telecommunication cables described above at ~X490.5 km, you would also have to cross the future Harmony Link HVDC cable (preliminarily at ~ X498.5 km mark):



and in the case of A/B alternative 4, the existing telecommunication cables would have to be crossed two times (the second time at ~Y6209 km), i.e. a total of 5 crossings with other linear infrastructure (including the future Harmony Link HVDC cable) would be required:



At the nearshore ~ X502 km marker - A/B 1 alternative route, one object of possible anthropogenic origin was also discovered. The length of the object is 16.5 m, and the width is about 3.5 m. Until more detailed investigations are carried out, it is suggested to leave the 100 m safety zone around the identified object and not plan cable laying works here.



Annexes

- Nr.1. Sea depth scheme
- Nr.2. Slope along the route
- Nr.3. Seafloor side scan mosaic
- Nr.4. Preliminary lithological scheme
- Nr.5. Residual magnetic field and magnetic anomalies
- Nr.6. Preliminary scheme of cabling routes and obstacles on the seafloor

Data deliverables

Depth data provided using Lithuanian elevation system reference level - LAS07. In digital format provided:

Seabottom morphology and sea depth – MBES folder	• **Unprocessed MBES data in *.GSF format;** • **Raw MBES data in original format;** • **Depth grid of 0.5 m x 0.5 m in ASCII *.xyz and GIS *.asc format;** • **3D seabed morphology in raster *.TIF format;** • **Isobaths with 1m spacing in GIS *.shp format;** • **Sound velocity profiles in ASCII *.txt and *.vel format**
Side scan sonar profiles – SSS folder	• **Raw SSS data in *.xtf format;** • **Boundaries of lithological bodies, sand ripples and moraine ridges in GIS *.shp format;** • **Processed SSS data in raster *.TIF format;** • **Positions of the seafloor obstacles in GIS *.shp format**; • **Identified anthropogenic objects in raster *.TIF format;**
Magnetic field – MAG folder	• **Raw MAG data in ASCII *.xyz format;** • **Total magnetic field, residuals, mag_depth and actuial magnetic field in *.grd format**; • **Residual magnetic field in GIS *.shp and raster *.TIF format**; • **MAG anomalies in GIS *.shp format;** • **Depth of MAG in GIS *.shp format;**
Sub bottom structure – SBP folder	• **SBP profiles in *.SEG-Y format** • **SBP actual track lines in *.shp format**
Recommended positions of vibro coring and CPT – CPT_vibro folder	• **Recommended positions of vibro coring and CPT in GIS *.shp and *.xls format.**
General GIS layers – GIS layers folder	• **SBP/MBES/SSS/MAG planned survey tracks in GIS *.shp format;** • **SBP/MBES/SSS/MAG actual survey tracks in GIS *.shp format;** • **Preliminary cable routes alternatives in GIS *.shp format;** • **Route mileage references as UTM 34N grid in GIS *.shp format.**
Report and annexes – Report folder	• **Survey report;** • **Maps in Annexes**