FYRSKEPPET
OFFSHORE AB

Fyrskeppet Offshore

Bilaga M18: Dumping Grounds Report

Clinton® Marine Survey

DUMPING GROUNDS REPORT

GEOPHYSICAL SURVEY

2022062-FYR-CMS-FYR_DUMPINGREP

REVISION 2

FYRSKEPPET OFFSHORE AB

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REVISION HISTORY

Revision	Issue	Date	Check	Approval	Client Approval
02	Updates	2023-04-14	RD	PL	
01	For client review	2023-03-15	RD	PL	
00	For client review	2023-03-15	RD	PL	

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Responsibility	Position	Name
Content	Geophysicist	Erik Wennerholm
Check	Geophysical Manager	Robin Dymlind
Approval	Project Manager	Philip Ljungström

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ABBREVIATIONS

DGPS	Differential Global Positioning System
DTM	Digital Terrain Model
ETRS	European Terrestrial Reference System
FFT	Fast Fourier Transformation
FMGT	Fledermaus Geocoder Toolbox
FLO	Fisheries Liaison Officer
gmS	Gravelly muddy sand
GNSS	Global Navigation Satellite System
GPS	Global Positioning System
gS	Gravelly sand
IGS	International GNSS Service
IMU	Inertial Measurement Unit
ITRF	International Terrestrial Reference Frame
kHz	Kilohertz
LAT	Lowest Astronomical Tide
MAG	Magnetometer
MBES	Multibeam Echo Sounder
MRU	Motion Reference Unit
mS	Muddy sand

msG	Muddy sandy gravel
MSL	Mean Sea Level
MSGL	Mega scale glacial lineations
MSS	Mean Sea Surface
M/V	Motor Vessel
OWP	Offshore Wind Park
PPP	Precise Point Positioning
PPS	Pulse Per Second
PTU	Passive Transmitter Unit
QA	Quality Assesment
QC	Quality Control
RMS	Root-mean-square
ROV	Remotely Operated Vehicle
RTK	Real Time Kinematic
S	Sand
SBP	Sub Bottom Profiler
sG	Sandy gravel
SIS	Seafloor Information System
SSS	Side Scan Sonar
SV	Sound Velocity
SVP	Sound Velocity Profile
SVS	Sound Velocity Sensor
THU	Total Horizontal Uncertainty
TPU	Total Propagated Uncertainty
TVU	Total Vertical Uncertainty
USBL	Ultra-Short Baseline
UTM	Universal Transverse Mercator
VORF	Vertical Offshore Reference Frame
WGS	World Geodetic System

1. INTRODUCTION

1.1. Project Overview

A new windfarm is planned at the Fyrskeppet area in the Bay of Bothnia. This survey acquired multibeam echo sounder (MBES), Backscatter (BCS) and Sub Bottom Profiling (SBP).

The purpose of the survey is partly to map the seabed surface and the subsoil with focus on seabed analysis, technical development, surface sediments and archaeology inventory, sediment layers and any obstacles that may affect the installation of the coming windfarm. A total area of 535 km^2 has been surveyed.

The project area is located North East of the bank 'Finngrundsbanken', in the Bay of Bothnia. The area is located North East of Gävle. There is a Natura 2000 area ('Finngrundet Östra Banken') next to the project area.

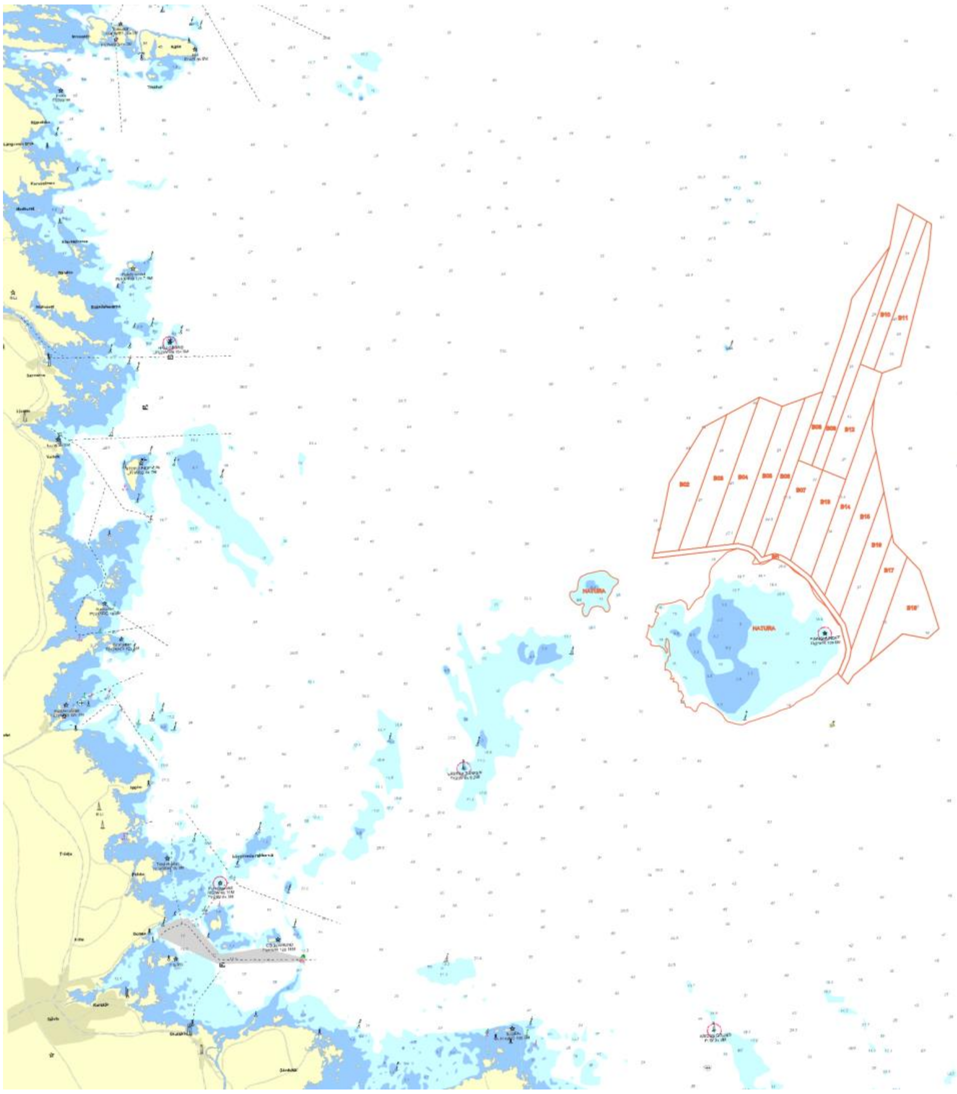

Figure 1 Location overview of the Fyrskeppet project area

1.2. Key personnel

Table 1 Clinton Key Personnel

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1.3. Purpose of Document

The purpose of this report is to summarize the Fyrskeppet survey results and interpretations, and to present the findings related to potential dumping areas.

1.4. Reference Documents

Table 2 lists all documents that are referenced in the report and provide further information on procedures and results not presented in this report.

Table 2 Reference documents

Document Title:	Document Number:	Document Owner:
Mobilisation and Calibration Checklist	2022062_WPD_Fyrskeppet_Inspection_Test	Clinton
Mobilisation and Calibration Report	Calibration Report Skyborn Renewables Fyrskeppet 2022 Northern Wind_	Clinton
Project Manual	2022062_WPD_Fyrskeppet-PEP	Clinton
HSEQ-Manual	2022062_WPD_Fyrskeppet-HSEQMAN-	Clinton
Operations Report	2022062-FYR-CMS-FYR-OPERREP_00	Clinton
Survey Report	2022062-FYR-CMS-FYR_SURVEYREP_00	Clinton

1.5. Products

Table 3 lists the products that are delivered together with the report.

Table 3 Delivered products

Product	Format
MBES grids	TIF, xyz

MBES point clouds	laz
Contact list	shp, xls
Kingdom Project	Project folder
Sgy files	sgy
Seabed texture	shp
Seabed morphology	shp
Backscatter mosaic	TIF
Trackplots	Shp
Tiles	Shp
MBES raw data	all
Sound velocity profile	asvp
Shaded relief	TIF

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2. GEODETIC INFORMATION

2.1. Geodetic Datum and Grid Coordinate System

The geodetic datum and projection parameters are presented in Table 4 and Table 5.

Table 4 Geodetic Parameters

Datum Parameters ETRS89	
Spheroid	GRS 80
Semi Major Axis	6 378 137.000
Semi Minor Axis	6 356 752.314
Inverse Flattening	298.25722
Eccentricity Squared	0.0066924801

Table 5 Projection Parameters

Projection Parameters	
Projection	SWEREF 99 TM
Central Meridian	15° 00’ 00’’E
Latitude origin	00° 00’ 00’’
False Northing	0m
False Easting	500 000m
Central Scale Factor	0.9996
Units	Metres

Data has been acquired in ITRF2014 and transformed to ETRS89 in NaviEdit using a 7-parameter 3D-Helmert transformation model (Figure 2). The accuracy of the transformation formula is 1-2 cm. The transformation parameters have been calculated for epoch 2022.5, and this is the most recent epoch for which calculated transformation parameters are available based on ITRF2014. Further details on the transformation can be found in “L.Jivall Simplified transformations from ITRF2014/IGS14 to ETRS89 for maritime applications”

$$\begin{pmatrix} X \\ Y \\ Z \end{pmatrix}_{ETRS\,89} = \begin{pmatrix} \Delta X \\ \Delta Y \\ \Delta Z \end{pmatrix} + (1+\delta)\ \mathbf{R} \begin{pmatrix} X \\ Y \\ Z \end{pmatrix}_{ITRF}$$

$$\mathbf{R} = \mathbf{R}_Z \mathbf{R}_Y \mathbf{R}_X = \begin{pmatrix} \cos\omega_Z & \sin\omega_Z & 0 \\ -\sin\omega_Z & \cos\omega_Z & 0 \\ 0 & 0 & 1 \end{pmatrix} \begin{pmatrix} \cos\omega_Y & 0 & -\sin\omega_Y \\ 0 & 1 & 0 \\ \sin\omega_Y & 0 & \cos\omega_Y \end{pmatrix} \begin{pmatrix} 1 & 0 & 0 \\ 0 & \cos\omega_X & \sin\omega_X \\ 0 & -\sin\omega_X & \cos\omega_X \end{pmatrix}$$

$$\mathbf{R} = \mathbf{R}_Z \mathbf{R}_Y \mathbf{R}_X = \begin{pmatrix} 1 & \omega_Z & -\omega_Y \\ -\omega_Z & 1 & \omega_X \\ \omega_Y & -\omega_X & 1 \end{pmatrix}$$

Figure 2 The 7-parameter 3D-Helmert transformation

Table 6 Transformation Parameters ITRF2014 to ETRS89 Baltic Sea epoch 2022.5

Transformation from ITRF2014 epoch 2022.5 to ETRS89	
Shift X (m)	1.01673
Shift Y (m)	1.22806
Shift Z (m)	-0.85601
Rotation X (“)	0.041514
Rotation Y (“)	-0.022120
Rotation Z (“)	-0.037257
Scale (ppm)	-0.01452

2.2. Vertical Datum

Data (MBES) has been reduced to the vertical reference RH2000 by using a post-processed kinematic PPP (Precise Point Positioning) solution and the SWEN17 geoid model. A positive up, negative down frame of reference is used for all deliverables, i.e. all depths are negative below RH2000.

2.3. Time Protocol

All survey systems on board the vessels were in UTC, together with all displays, logbooks and overlays. The daily progress report was referenced to UTC.

3. SURVEY OPERATION

This is a short summary of the equipment, field work and progress during the survey operation. Further information can be found in the Mobilization and Calibration Report and the Operational Report.

3.1. Vessel

More detailed information on the vessels, their reference frames and sensor alignments can be found in the Mobilization and Calibration Report.

3.1.1. M/V Northern Wind

The vessel Northern Wind is a high-resolution, aluminium hulled, survey vessel with a permanent spread for geophysical and hydrographical work. The vessel is 19.5 m and is well suited for surveys in shallow waters as well as offshore as it can operate 24/7.

3.2. Equipment

Table 7 includes a summary of the equipment used in the project.

Table 7 Equipment used during the project on M/V Northern Wind

Equipment	
Positioning & Attitude	Seapath 330+ with Hemisphere H10 corrections from an Atlas Link demodulator
Secondary positioning	Fugro 9205 with Fugro G2 corrections
Multibeam Echo Sounder	Kongsberg EM2040D 0.35°x0.7^0 at 400 kHz
Sub Bottom Profiler	Innomar SES-2000 Medium 100 kHz Primary Frequency
Sound Velocity Sensor	Valeport mini SVS
Moving Sound Velocity Profiler	Valeport SVX2
Sound Velocity Profiler	Valeport Swift SVP

4. PROCESSING

The methods and parameters used during the processing are presented in Survey Report, 2022062-FYR-CMS-FYR_SURVEYREP.

5. RESULTS

The results from the data interpretation of the Fyrskeppet area are presented in the sections below.

5.1. Potential Dumping Grounds

The Fyrskeppet survey area was investigated for suitable locations for dumping softer sediments. The products and instruments used are described in the main survey report.

The results presented in this report are based on MBES, backscatter and SBP data and products.

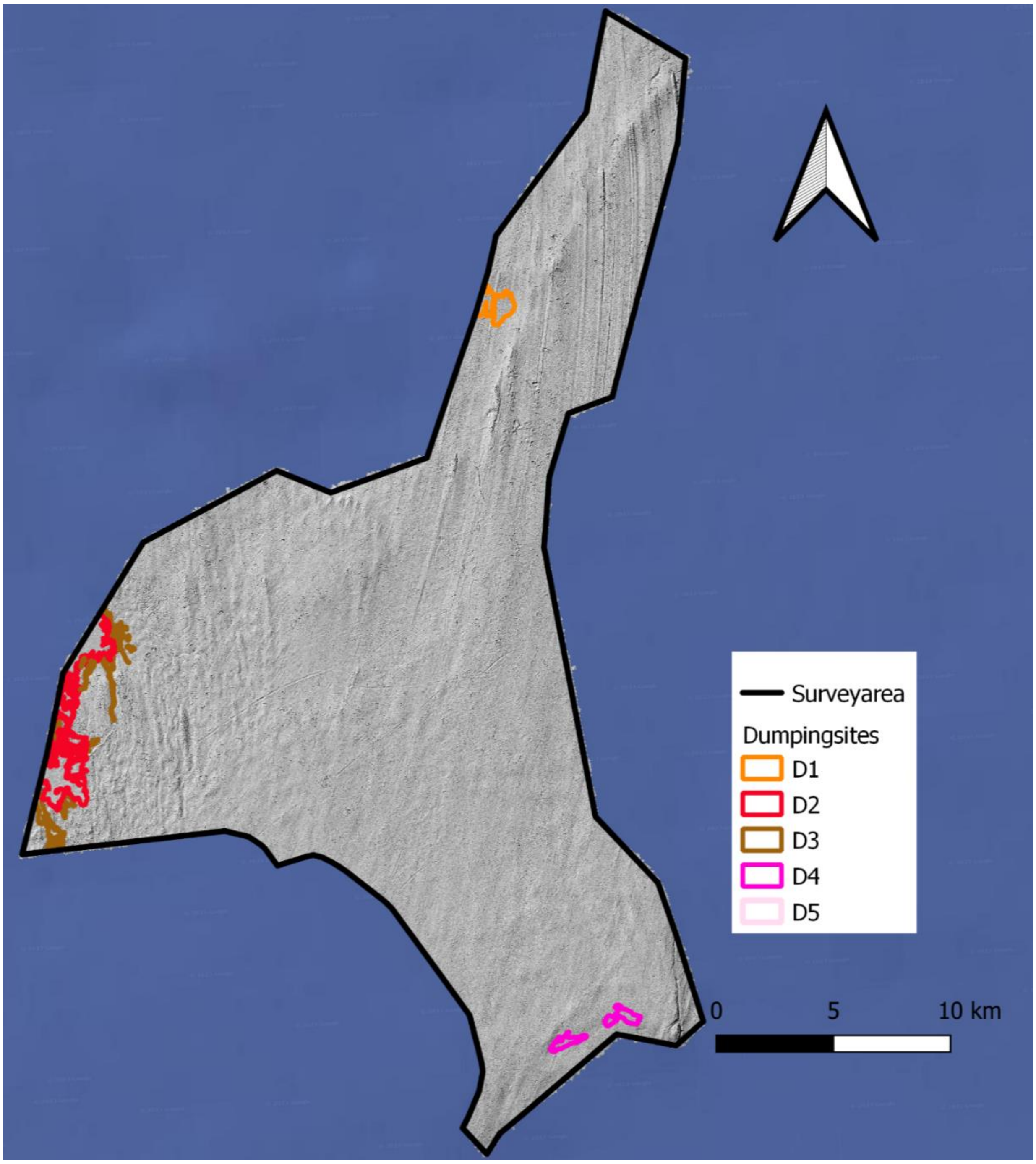

Figure 3 Overview of the proposed dumping sites in the Fyrskeppet survey area, the underlying layer is a hillshade.

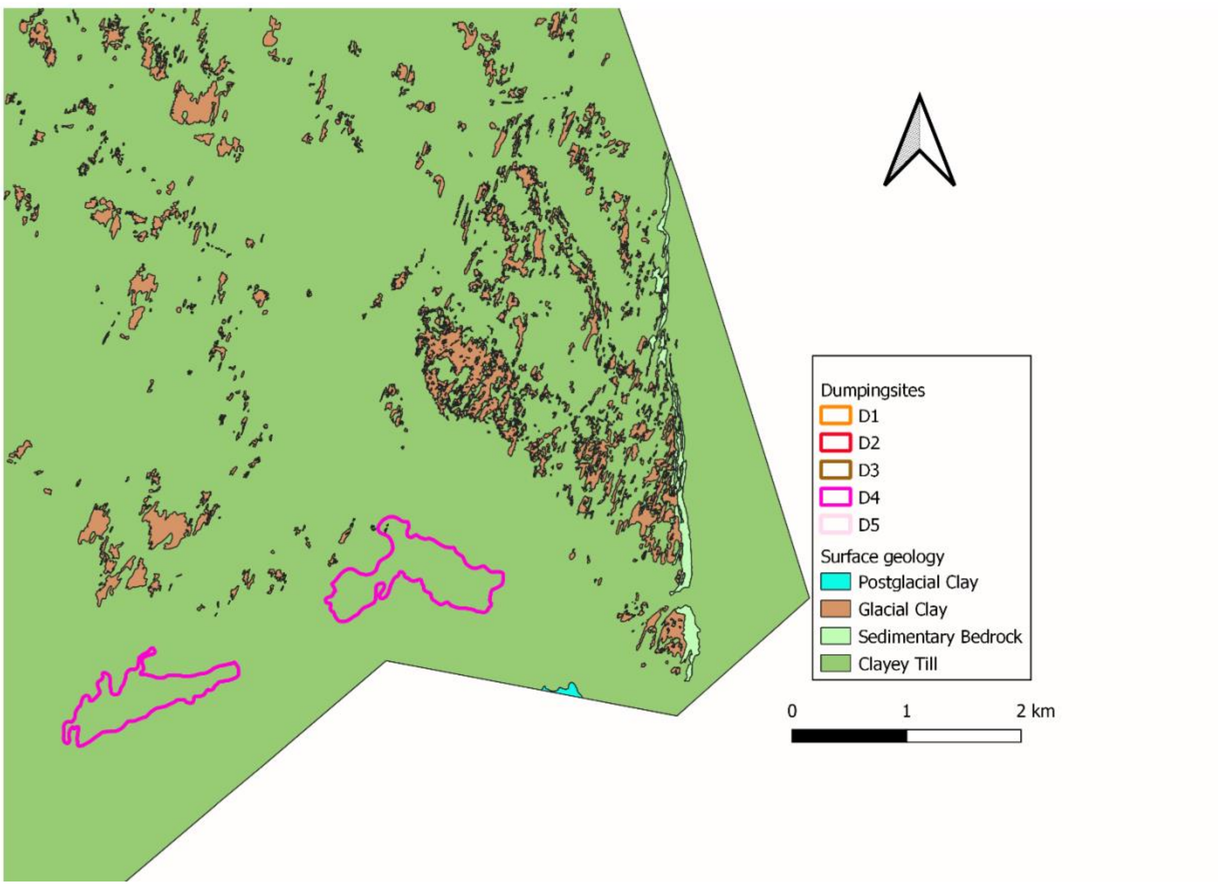

Figure 4 The easternmost dumping area overlying the surface geology interpretation

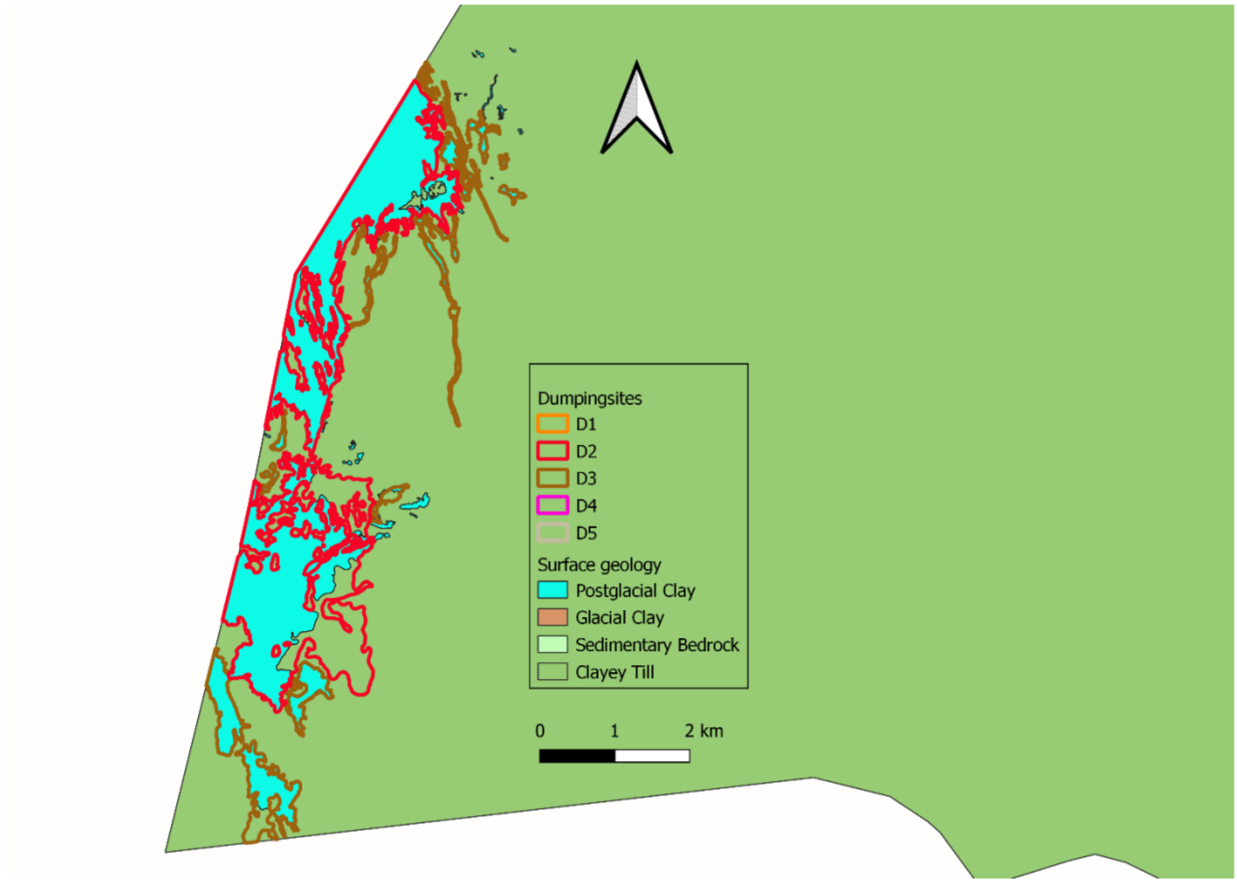

Figure 5 The westernmost dumping area overlying the surface geology interpretation

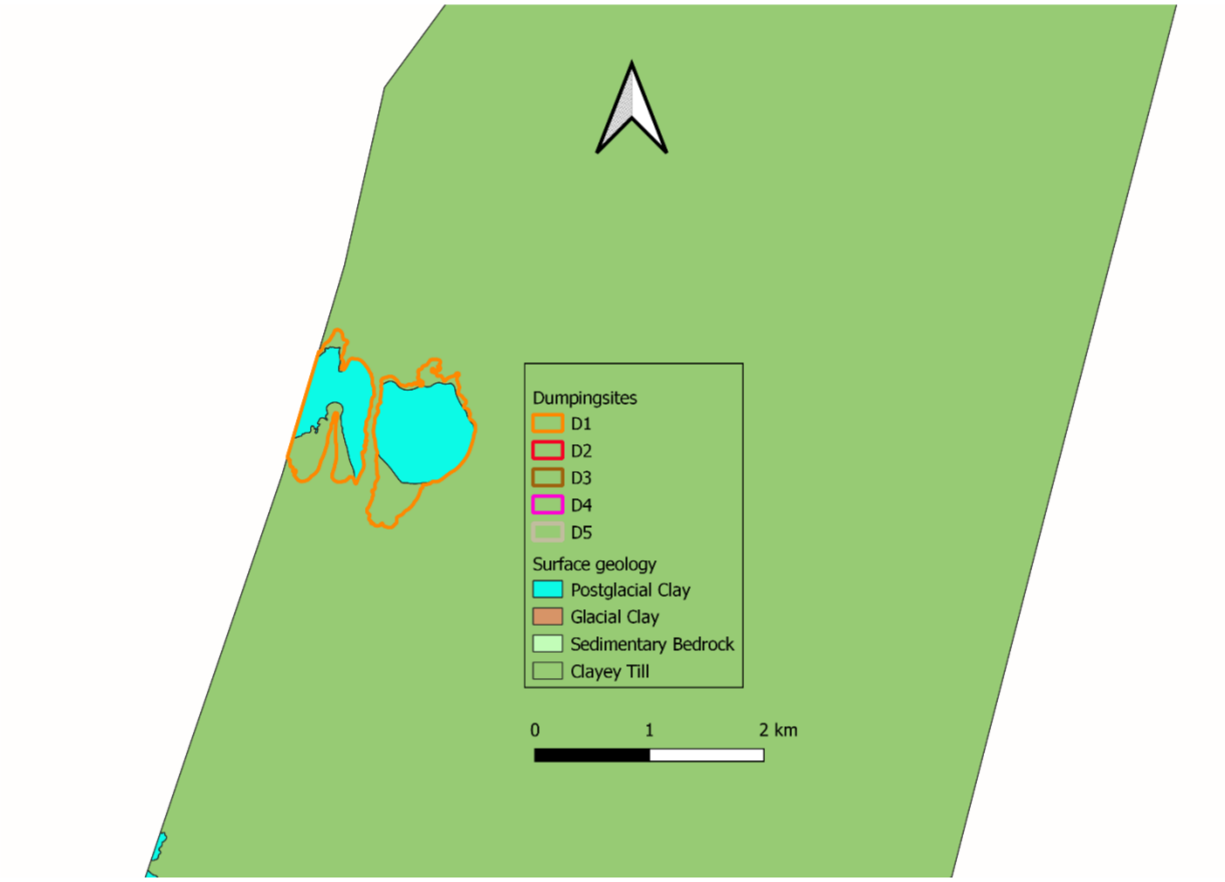

Figure 6 The northernmost dumping area overlying the surface geology interpretation

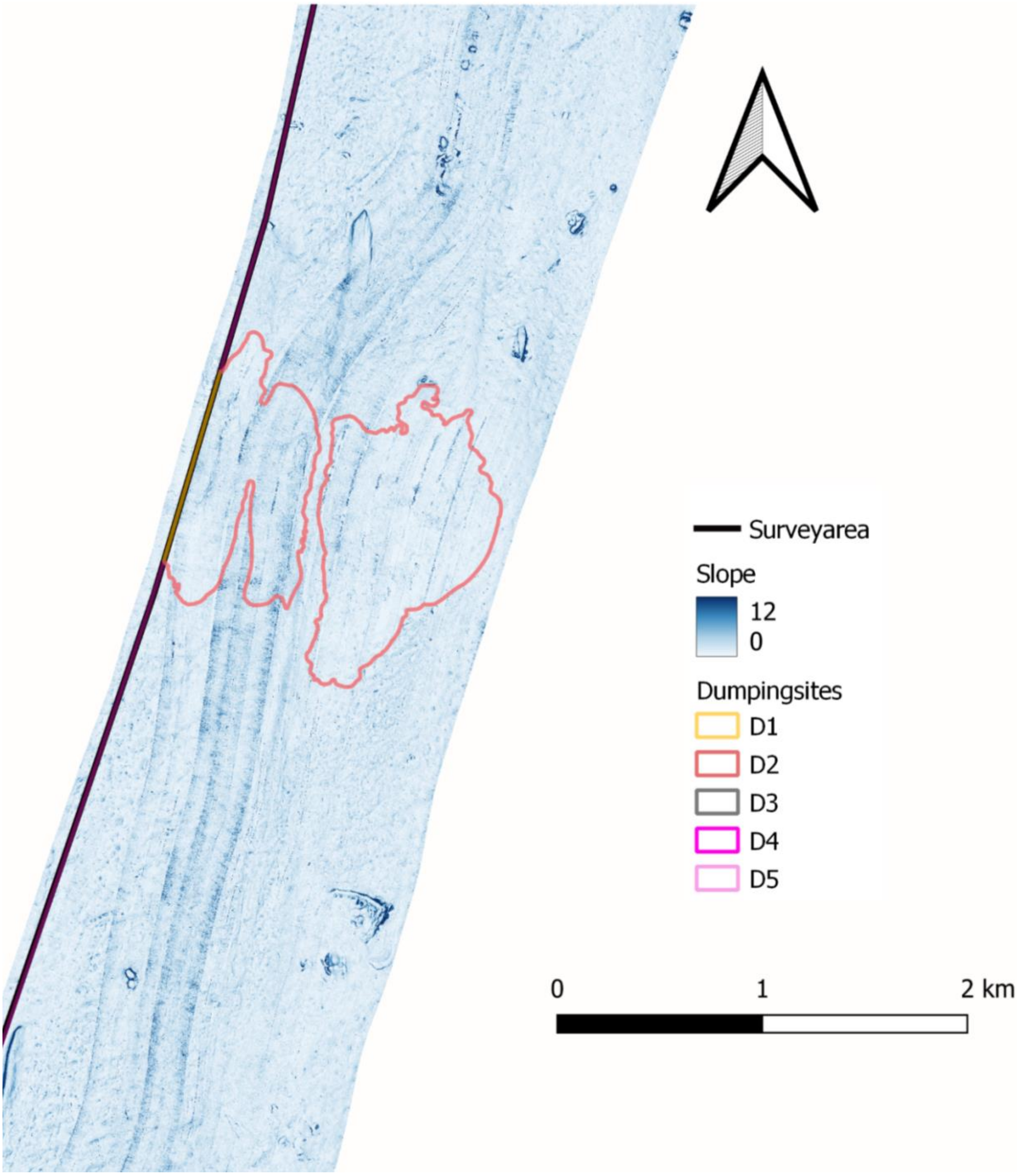

Figure 7 Northernmost dumping site slope map

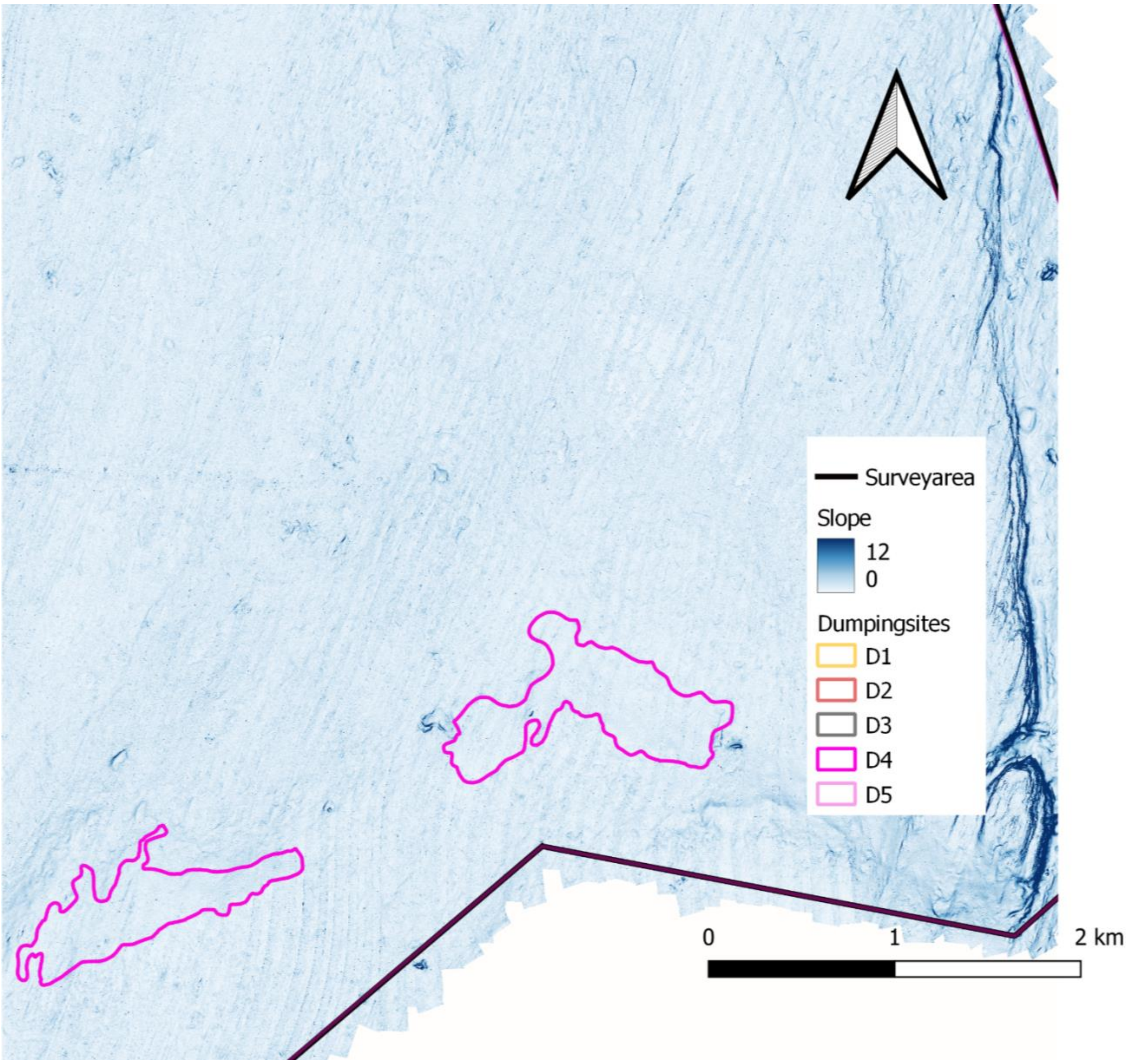

Figure 8 Slope map of the easternmost dumping area of Fyrskeppet

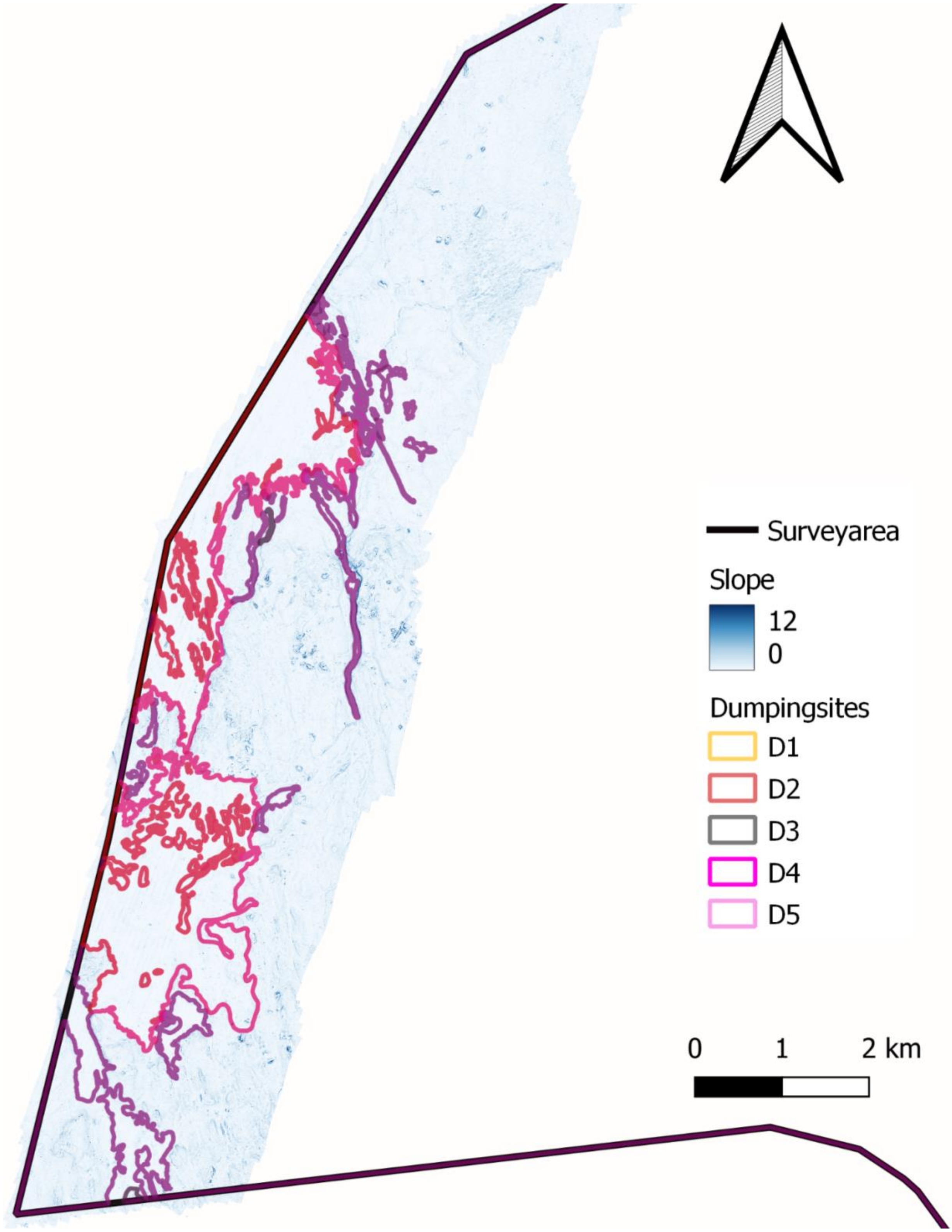

Figure 9 Westernmost dumping site area slope map

6. INTERPRETATIONS AND UNCERTAINTIES

6.1. Dumping site interpretation

The Fyrskeppet proposed dumping sites for soft sediments (Figure 3) were established by utilizing a few criteria: sediment type, slope, extent, sediment depth and existing morphology. This resulted in five categories for areas, where D1 is thought to be more suitable and D5 less so.

The desirable traits for each of these categories were as follows: Sediment type, areas that were classified as postglacial clay were the most suitable, as this means there is some sediment retention already. Slope: The less the better, conversely if there were sloping surfaces in the proximity to the dumping area it can be seen as beneficial. Extent: The larger the better for practical reasons. Sediment depth: a greater or homogenous existing sediment thickness is desired, as it shows there is an ability to retain it to some extent. Morphology: often tied to the slope criteria, if there is a feature that somehow shields or acts as a natural boundary against currents it could be beneficial.

The areas that have been designated as D1 is located in the northern part of the Survey (Figure 6). Situated in a (slight) natural slump that has been filled up by postglacial clay. The sediment thickness is homogenous and comparable across the areas (Figure 10). The two areas are similar in size, most likely been deposited in the same event and would have been joined if not for a Massive Scale Glacial Lineation (MSGL) cutting through them. Depending on the currents in the area this morphological feature might aid the stability of dumped sediments, it at least contributes to a general increase in the slope directly surrounding the D1 areas. The downside of D1 is that their extents are limited in comparison to the westernmost D2 areas.

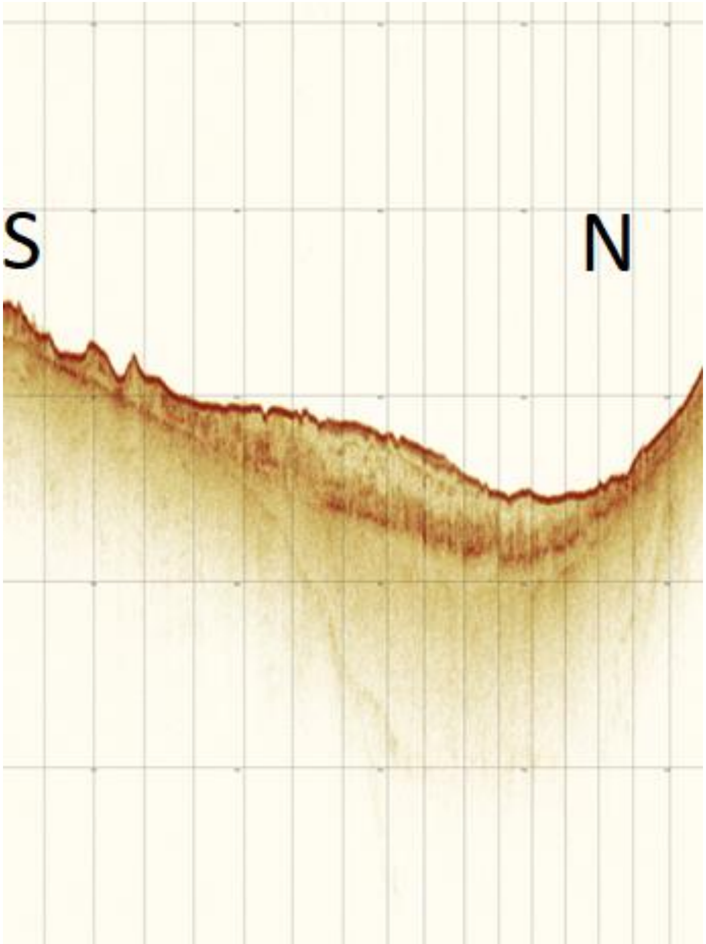

Figure 10 SBP profile B08_MI006_063408 of the D1 area showing increasing surface sediment depth. Each box is 100 M wide and 5 M tall.

The area designated as D2 is in the westernmost part of The Fyrskeppet survey (Figure 5). The area is the largest of the categorized areas, consisting of the most widespread “deposits” of postglacial clay. The area continues further west outside of the survey boundaries.
The area seems to be a drainage structure that has eroded into the underlying layer of glacial clay and clayey till (Figure 9) which then at a later stage has been filled with postglacial clay. The sediment depth and continuity of the layer is heterogenous throughout the area, at its greatest depths the sediment thickness is comparable to that of the area designated D1 (Figure 11). The area is flat with the only “containing” features being slight edges of glacial clay where the postglacial clay coverage is ending or where the original structure ends. This also applies to locations where the glacial clay is exposed above the postglacial clay within the area (Figure 9).

The areas designated D3 are the “limbs” or channels of the same drainage structure as D2 (Figure 9), however, they are distant from the body of postglacial clay. Their relatively small size and distance to the main body makes them less practical to dump sediments into.

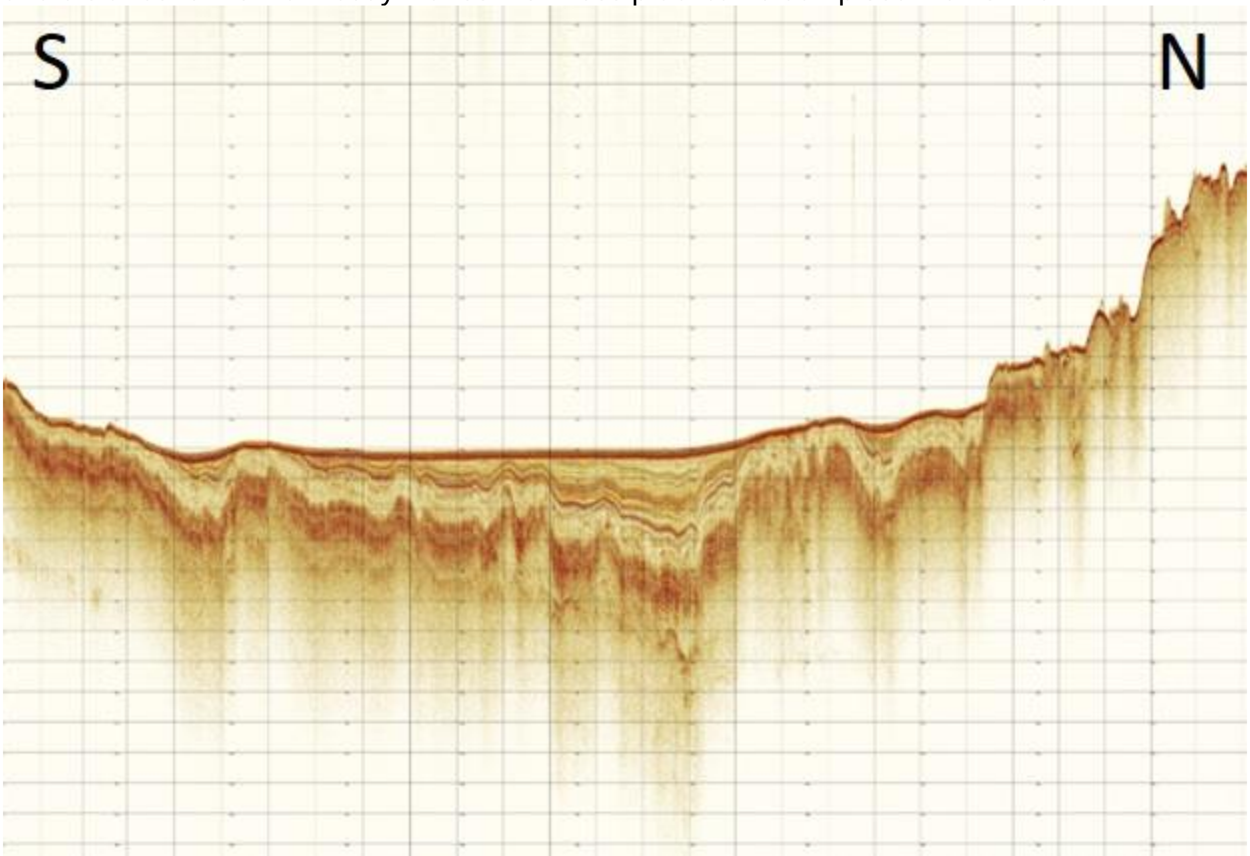

Figure 11 SBP data fromB02_ML033_060959 a part of D2 showing the thickness and variation of surface sediment. Each box is 100M wide and 1M tall

The area designated D4 is in the eastern part of the Fyrskeppet survey. The two areas in this category is interpreted to be considerably sandier than other areas in the survey, which is also the main reason for selecting them as potential dumping sites (Figure 12). The area is in a flat area directly south of a “very slight” slope (Figure 8) with no nearby morphological features or considerable depth to the underlying glacial clay.

The area designated D5 is everywhere else in the survey area. Consisting of Glacial clay and clayey till it is not well adapted for dumping of softer sediments.

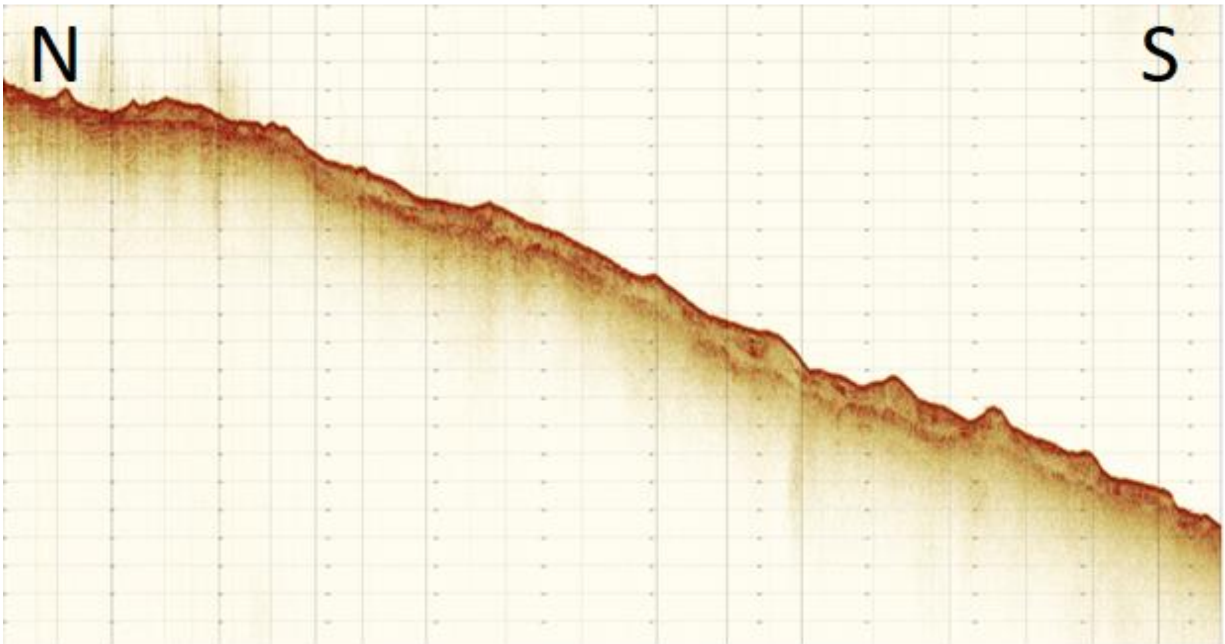

Figure 12 SBP data from B18_ML032_20220731_115234, D4 showing the thickness and variation of the surface sediment. Each box is 100M wide and 1M tall

7. DISCUSSION

The Fyrskeppet survey area is a place of great glacial features. The Bothnian sea has not been experiencing much alteration and deformation of the seafloor since the last glaciation, meaning that the existing glacial features are seen almost in the state as they were formed (Winterhalter, 1972). This is validated in this survey, where many glacial landforms have been discovered ranging from MSGLs to moraines and eskers, to scour marks and gouges from icebergs ploughing the seabed, to glacial clay protruding to the surface. Only in relatively small areas are softer postglacial clay and loose sand found. In general, the surface is instead very hard. Most of the survey area consists of clayey till with no to little sedimentation. Hard glacial clay is found in the eastern part. Softer material is only found in depressions, like iceberg scour marks. These areas seem to be sandier and ripples can be found. The western side is quite different from the eastern. Instead of hard glacial clay, there is softer postglacial clay. This is an area where particles are allowed to sediment.

Because of the sediment types and general morphology of the survey area finding dumping areas that are objectively well suited for this purpose, the areas that have been discussed in this report have drawbacks if there are ambitions to dump vast amounts of sediments, as they simply are not sizeable enough.

The different datasets gathered in the Survey have yielded several locations that may be suitable for dumping softer sediments. However, the underwater currents have not been investigated by Clinton and currents can make or break the validity of a potential dumping site. The D1 and D2 areas are exchangeable in “quality” depending on the potential current. If there is little or no activity on the seafloor D2 has a larger surface area that can be utilized for dumping.

All different interpretations and datasets within this report and the main survey report are subject to potential errors. This is pertaining to the interpretations and especially rankings of this report, all of which have been made subjectively. Both are subject to change depending on the characteristics and what kind of sediments that will potentially get dumped at the location.

8. CONCLUSION

The Fyrskeppet survey area is heavily dominated by glacial landforms and sediments. Most of the surface geology consists of clayey till. The surficial cover of the clayey till consists of various amounts of sand, gravel and cobbles. Local areas consist of sand ripples or boulder fields.

The initial overview of the area has yielded areas which may be suitable for dumping in the East,West and North of the survey area. The Northern and Western Areas looks more promising and either site might be the more viable depending on purpose and in situ conditions.

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