DANMARKS OG GRØNLANDS GEOLOGISKE UNDERSØGELSE RAPPORT 2016/62

Mapping of seabed geology and bathymetry in Alssund, Sønderborg

Seismic and acoustic mapping for The Green Water Research Project

Matthew Owen & Jørgen O. Leth

GEOLOGICAL SURVEY OF DENMARK AND GREENLAND
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Content

1. Summary

The Green Water Research Project (GWRP) has asked GEUS to perform a combined geological and bathymetrical survey using high-resolution and high-accuracy multibeam bathymetry, side scan sonar and sub-bottom profiler data in Alssund in Sønderborg. The combination of information on the seabed sediment types and thickness and a detailed bathymetry has shown that at suitable locations for siting the prototype of heat exchange installation are available. There are extensive areas where the water depth exceeds 18 m with sandy or gravelly sediments present. However, the seismic data shows evidences of the presence of gas in large areas of the sub-surface, indicating the presence of fine grained, muddy sediments.

A basin adjacent to the SDU Sønderborg campus seems to be one of the most suitable locations, with water depths reaching 23.6 m and sandy sediments appearing. Steep gradients encountered on the channel margin and the risk of slope failure during or after pipeline installation could be a concern here. An alternative potential area for the project an infilled channel has been designated in Alssund west of Odden.

It is strongly recommended to perform a sediment sampling programme to verify the seismic and acoustic interpretations.

2. Introduction

The Green Water Research Project (GWRP), run by the University of Southern Denmark (SDU) and the Mads Clausen Institute (MCI) in Sønderborg will use the thermal energy stored in seawater to supply buildings with heating and cooling via a submarine pipe and seawater intake. Using high-resolution and high-accuracy multibeam bathymetry, side scan sonar and Innomar sub-bottom profiler data a high quality geological interpretation of the Alssund in Sønderborg will allow a feasibility assessment of the installation. The combination of information on the seabed sediment types and thickness and a detailed bathymetry will support the considerations if suitable locations for siting of the installation are available.

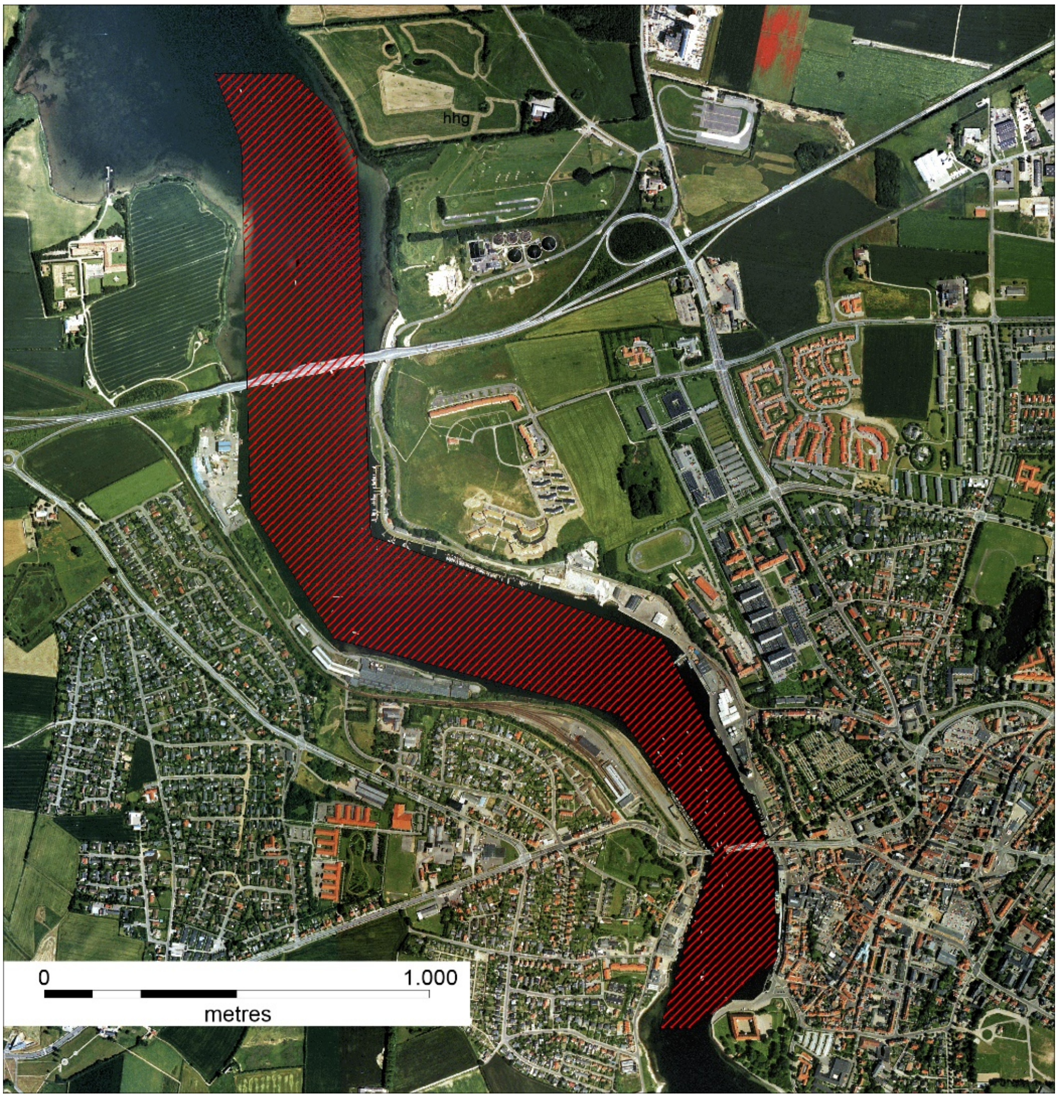

***Figure 1**: Site overview with the area of interest in Alssund shown as red hatched lines.*

3. Survey

Work was undertaken at Sønderborg aboard the GEUS vessel "*M/S Maritina*" between the 3rd and the 4th of October 2016. The GEUS survey team consisted of three persons: one technician (Lars Georg Rödel) who was responsible for mobilisation and instrument handling/repair, one geologist (Matthew Owen), and one senior geologist (Jørn Bo Jensen) who was responsible for survey planning, data acquisition and subsequent processing. Weather conditions were excellent throughout operations, with light wind, flat sea state and no precipitation.

3.1 Mobilisation and demobilisation

The vessel mobilised alongside at Sønderborg on the evening of the 3rd of October and the morning of the 4th of October 2016, with installation of the Innomar sub-bottom profiler and the Edgetech 6205 combined side scan sonar and multibeam echo sounder and associated motion sensors. The vessel was demobilised on the evening of the 4th of October 2016. The mobilisation and demobilisation was completed in good time and without incident.

3.2 Diary of events and equipment operation

Table 1: *Sønderborg survey diary of events.*

Date and time (UTC)	Event and comment
03/10/2016 15:00	*M/S Maritina* arrives in Sønderborg.
03/10/2016 20:00	Mobilisation of *M/S Maritina commences.*
03/10/2016 21:30	Finish work for the day.
04/10/2016 06:30	Return to vessel in morning to finish mobilisation.
04/10/2016 10:03	Mobilisation complete, start survey acquisition.
04/10/2016 15:44	Pause in site survey to perform bathymetry Patch Test on wreck.
04/10/2016 16:08	Patch Test completed, resume survey.
04/10/2016 17:00	Survey completed, vessel alongside to commence demobilisation.
04/10/2016 20:00	Vessel demobilisation completed.

Summary details of the equipment deployed during survey are presented in Table 2.

Table 2: *Details of equipment deployed and operation during survey.*

Item	Description	Comment
Edgetech 6205	Combined side scan sonar and multibeam echo sounder, mapping water depth and seabed reflectivity.	Both side scan and echo sounder performed well, with excellent data quality observed.
Innomar SES-2000	Parametric sub-bottom profiler, mapping sub-surface layers.	The system performed well, with data of good quality, though gasified sediments prevented signal penetration in some areas.

Valeport SVP	Sound Velocity Profiler	Sound velocity profiles taken at regular intervals for bathymetry values calibration.
GPS C-Nav3050	DGPS navigation system	GPS receiver providing sub-meter, precise point positioning accuracy.
Applanix POS MV	MRU motion sensor	Positioning and motion compensation system for the multibeam sonar system.

3.3 Data acquisition

As detailed in Table 1 the survey was undertaken on the 4th of October 2016 and all equipment performed well. A total of 32.2 km of line data were acquired (excluding the Patch Test). The survey plan consisted of mainlines running parallel to the channel and crosslines running diagonally across the channel. Mainlines were spaced 25 to 35 m apart to ensure full coverage from bathymetric data. An overview is shown in Figure 2. Both side scan sonar and bathymetry data had full coverage of the site.

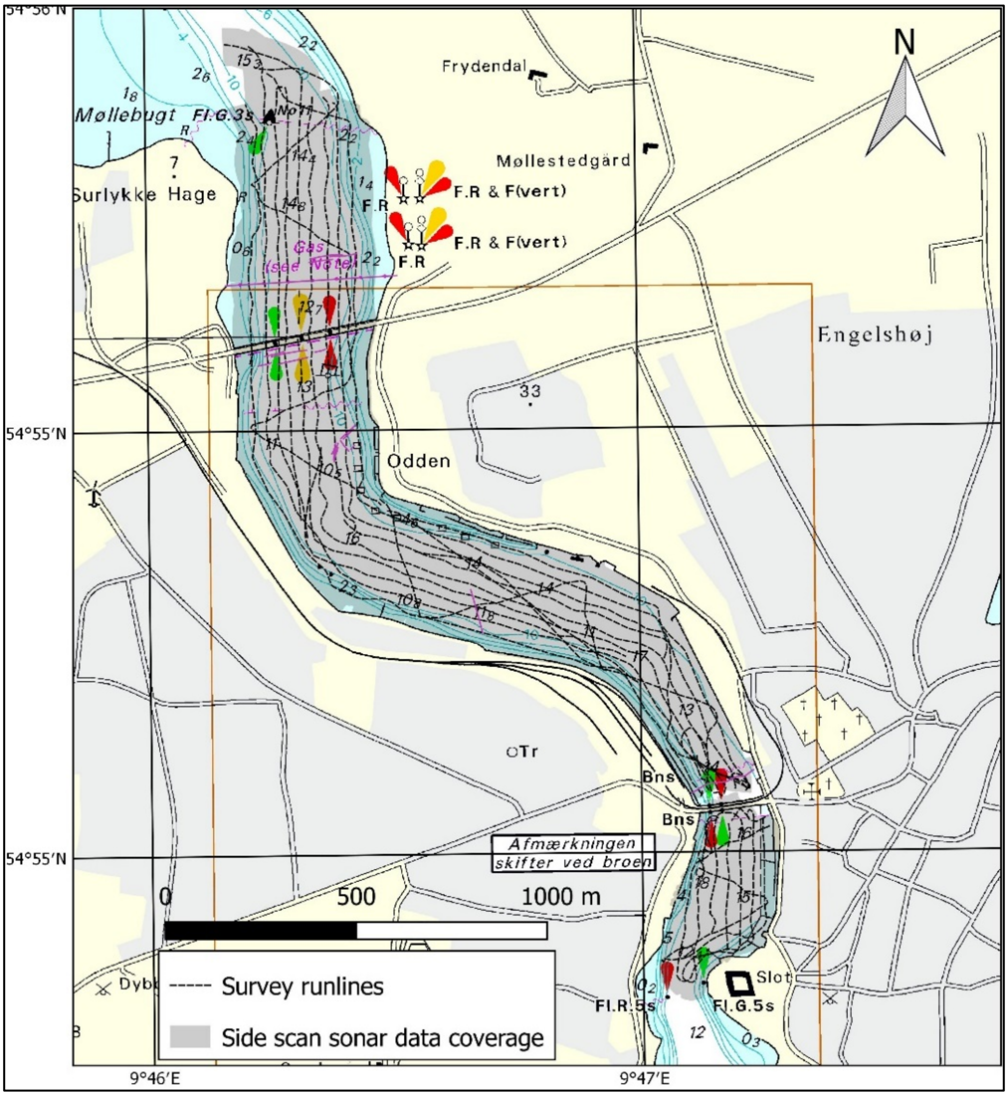

Figure 2: Survey runlines and side scan sonar coverage for the Green Water survey. Background map is the nautical chart no. 155.

3.4 Survey ship configuration

The survey utilised the *M/S Maritina*, a 31 foot vessel that is ideal for seismic surveys and sampling in near-shore and inland waters. The vessel performed well during the survey.

Figure 3: *Survey vessel M/S Maritina alongside at Sønderborg.*

4. Results

4.1 Bathymetry

Figure 4 shows an overview of the mapped high-accuracy bathymetry within the Green Water site at Sønderborg. Also shown in figure 4 (dashed lines) are the locations of the more detailed bathymetric imagery shown in Figure 5, Figure 6 and Figure 7.

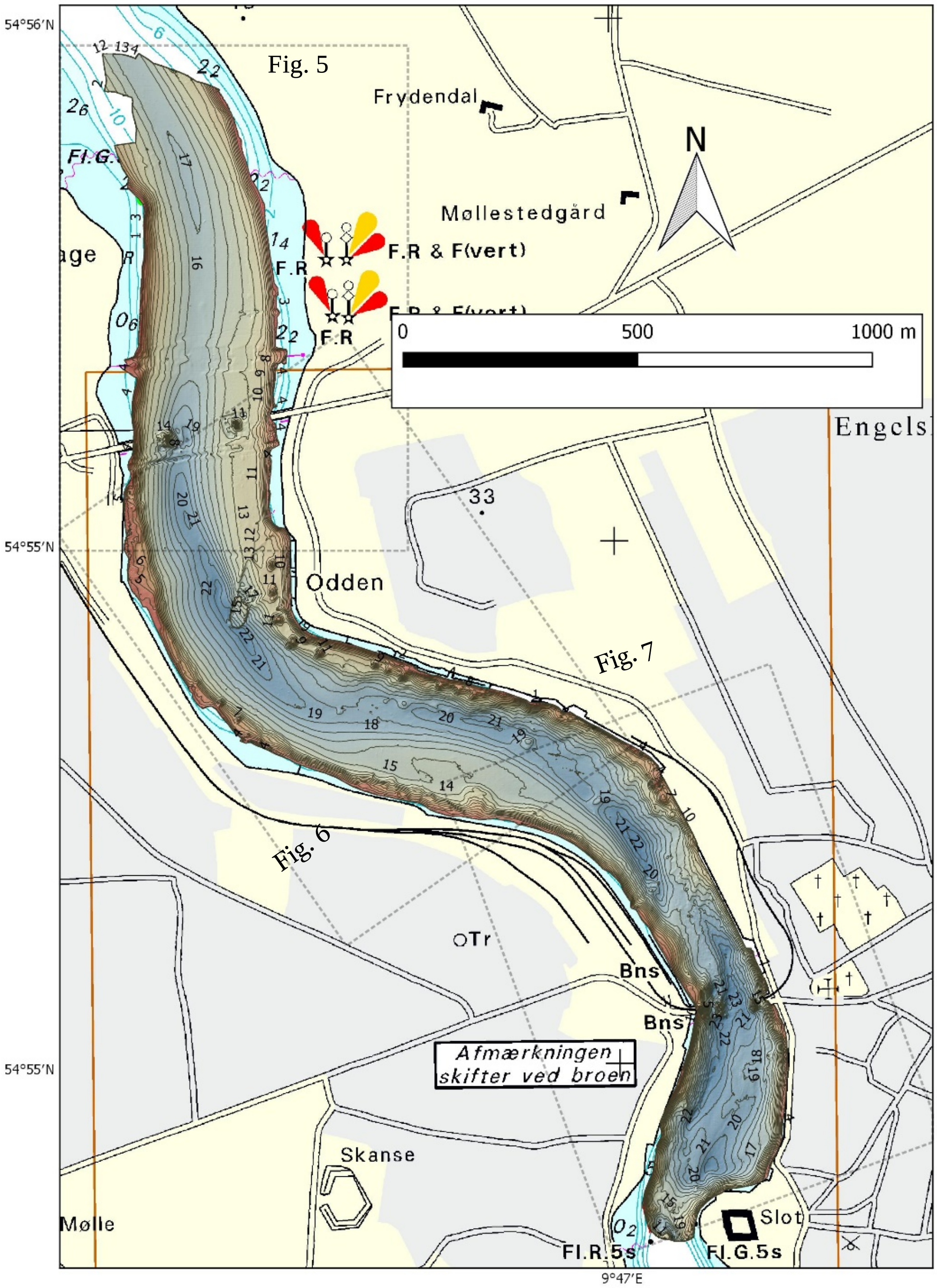

Figure 4: *Bathymetry overview showing locations of Figures 5, 6 and 7.*

The bathymetry of the surveyed area in Alssund, in general, is characterized as a narrow channel with a steep slope on both sides. The maximum water depth of about 23 m has been mapped in the southern part around Kong Chr. D. X's Bro and in a deep west of Odden with depth around 20-22 m.

Shown in Figure 5, north of the motorway bridge water depths are generally <17 m. South of the bridge, there are four areas where the water depth exceeds 20 m, these are shown in more detail in Figure 6 and Figure 7.

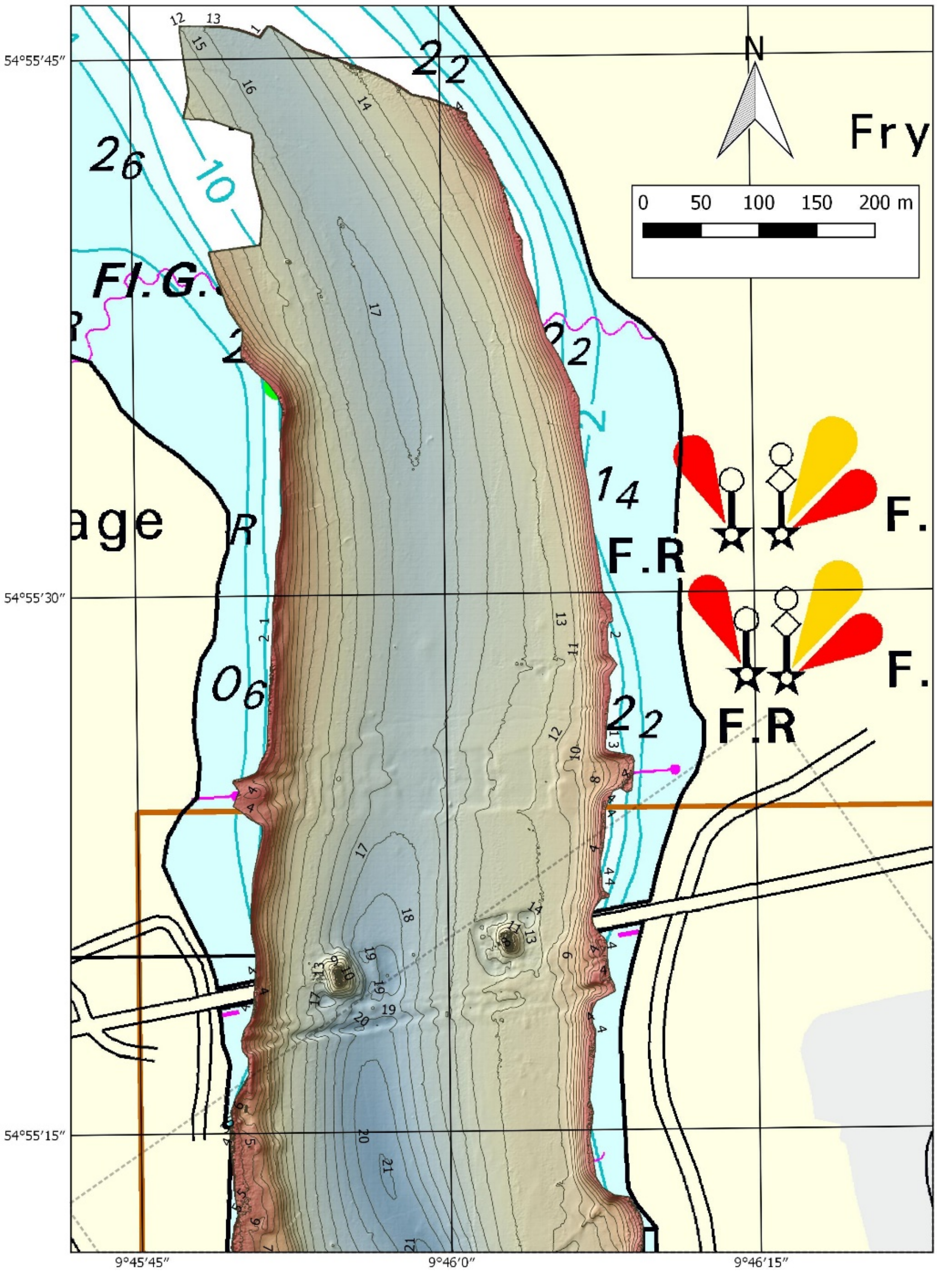

***Figure 5:** Detailed bathymetry from north of survey site.*

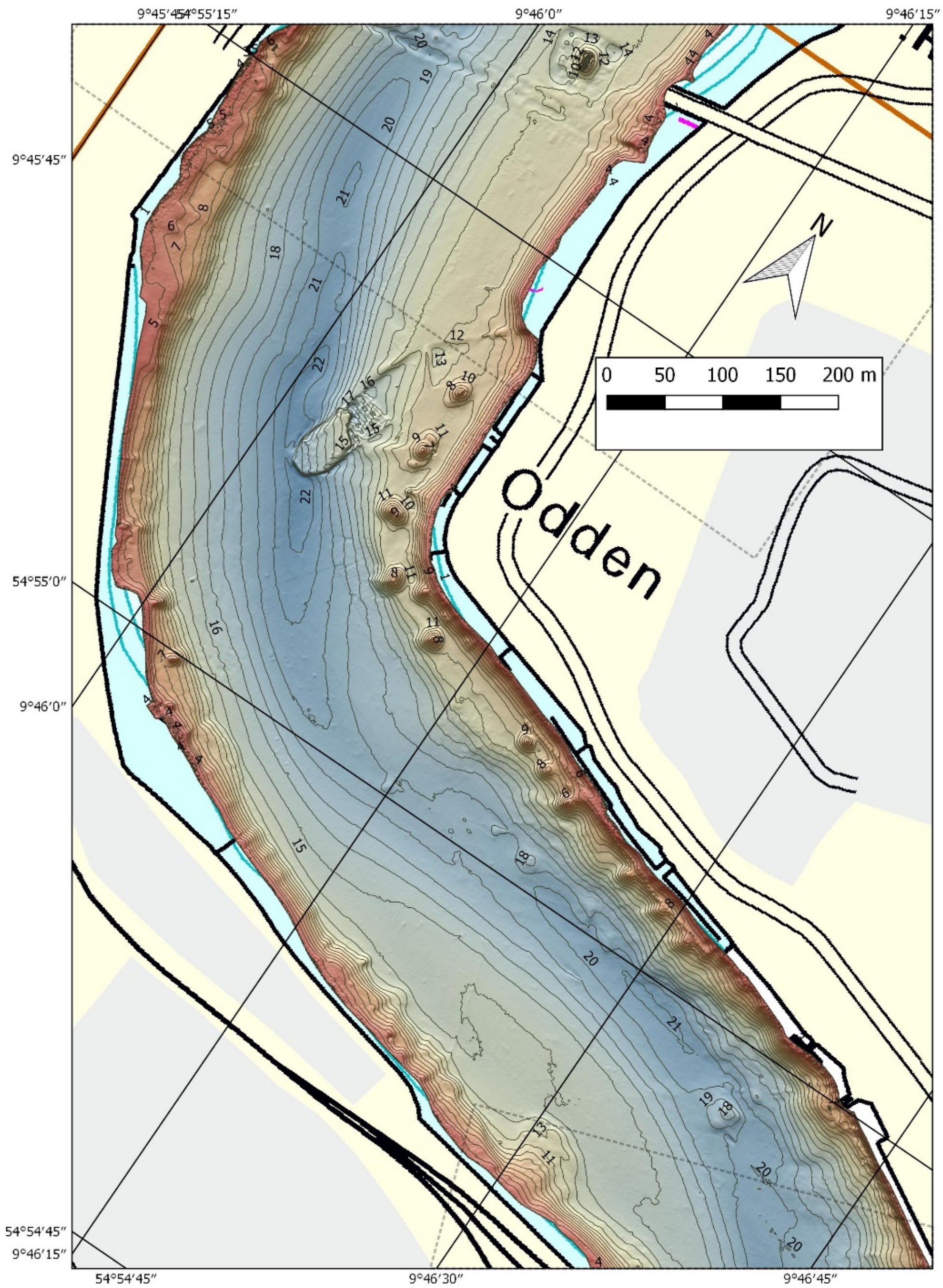

Figure 6: *Detailed bathymetry from centre of survey site.*

The first of these is an elongate depression running from immediately south of the motorway bridge for approximately 500 m to a location southwest from Odden. Here depths reach 22 m and, as discussed in section 4.2, a large wreck is encountered.

A second area is found a few hundred meters further southeast from this area near the eastern bank of the Alssund. The maximum depth is 21 m and its southern termination is marked by a mound with a relief of some 3 m. South of which is the third area with water depths >20 m. This area, visible in Figure 7, has a maximum water depth of 23 m, is located in the centre of the channel adjacent the SDU Sønderborg campus. Finally, the area south of the Sønderborg bridge generally exhibits water depths of 20 m or greater.

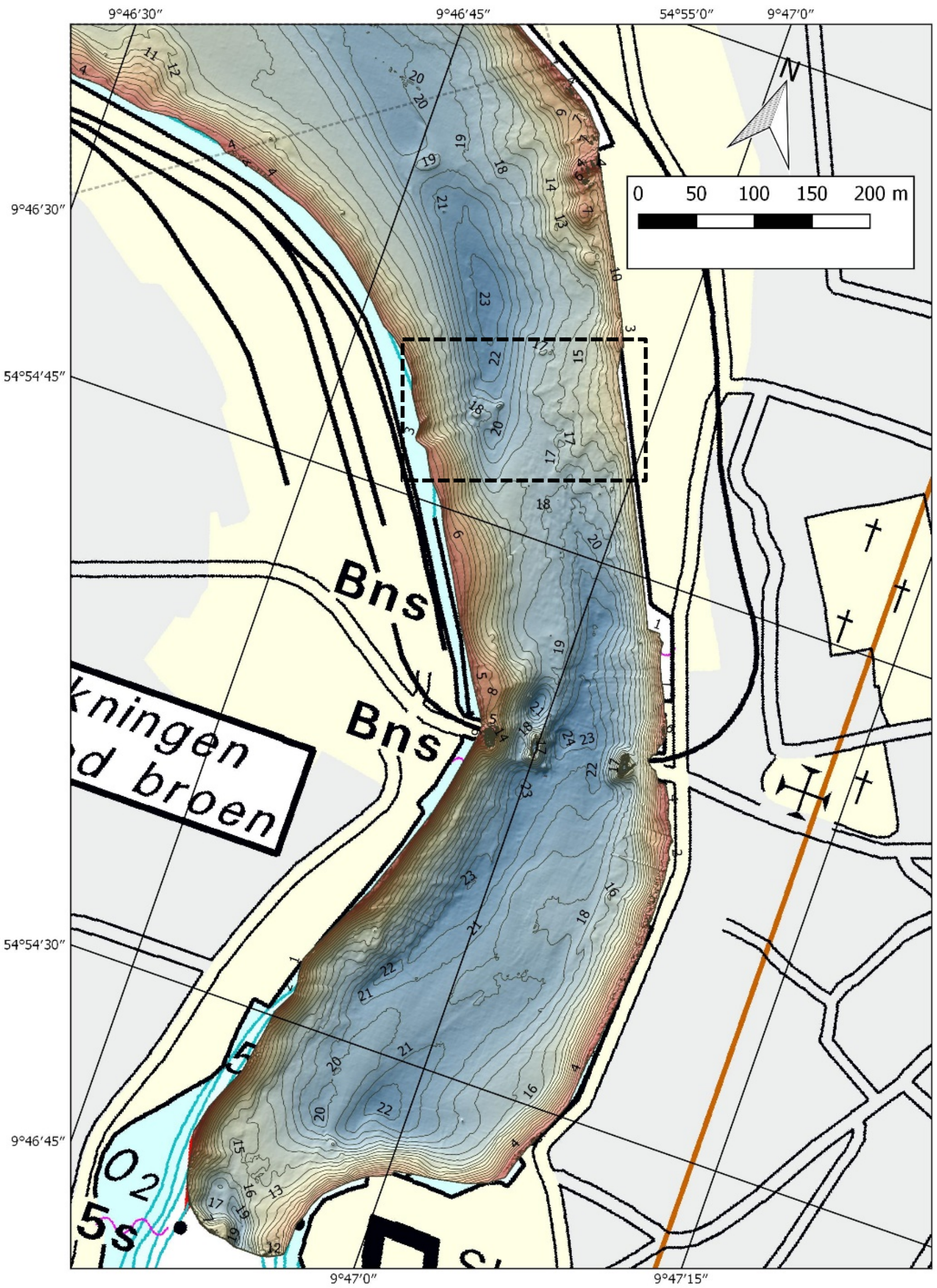

Figure 7: *Detailed bathymetry from south of survey site. Dashed box indicates location of Figure 8.*

In addition to areas of significant water depth, the bathymetry data also identify areas of notable seabed morphology. These include the spherical mound-like features adjacent to areas of mooring (inferred to be rock berms) as well as two seabed scars that are associated with downslope mounded features. These are interpreted as slope failure locations and an example of the southernmost is shown in Figure 8.

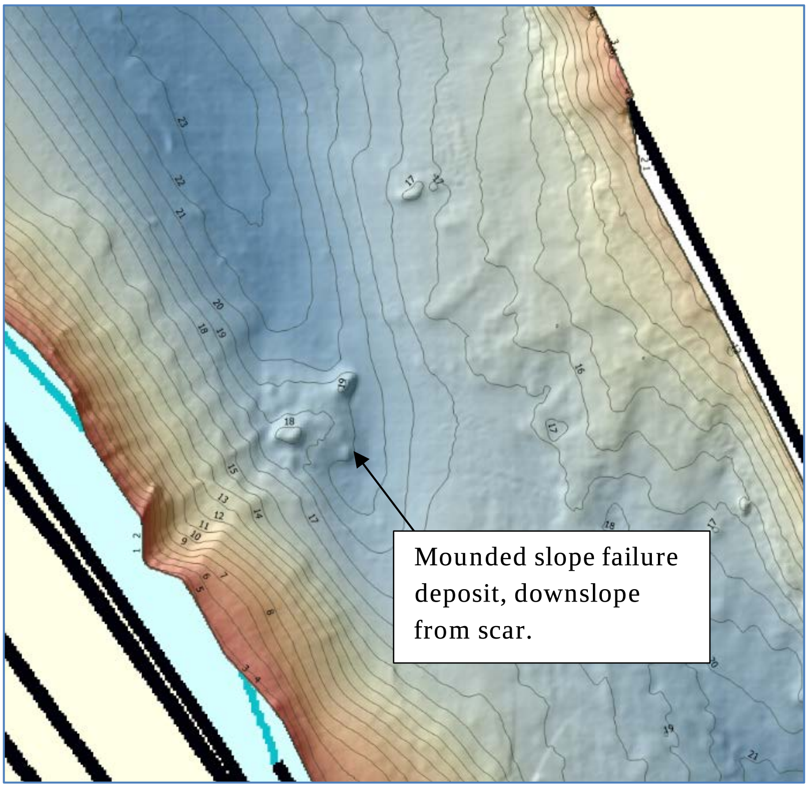

Figure 8: *Slope failure example from the south of the survey area.*

4.1.1 Bathymetry 3D-scene

Based on the high-accuracy multibeam echo sounder data it is possible to visualize the bathymetry as a 3D-flight-through video. A screenshot from this movie is shown in Figure 9 below. The full video file is delivered along with the report.

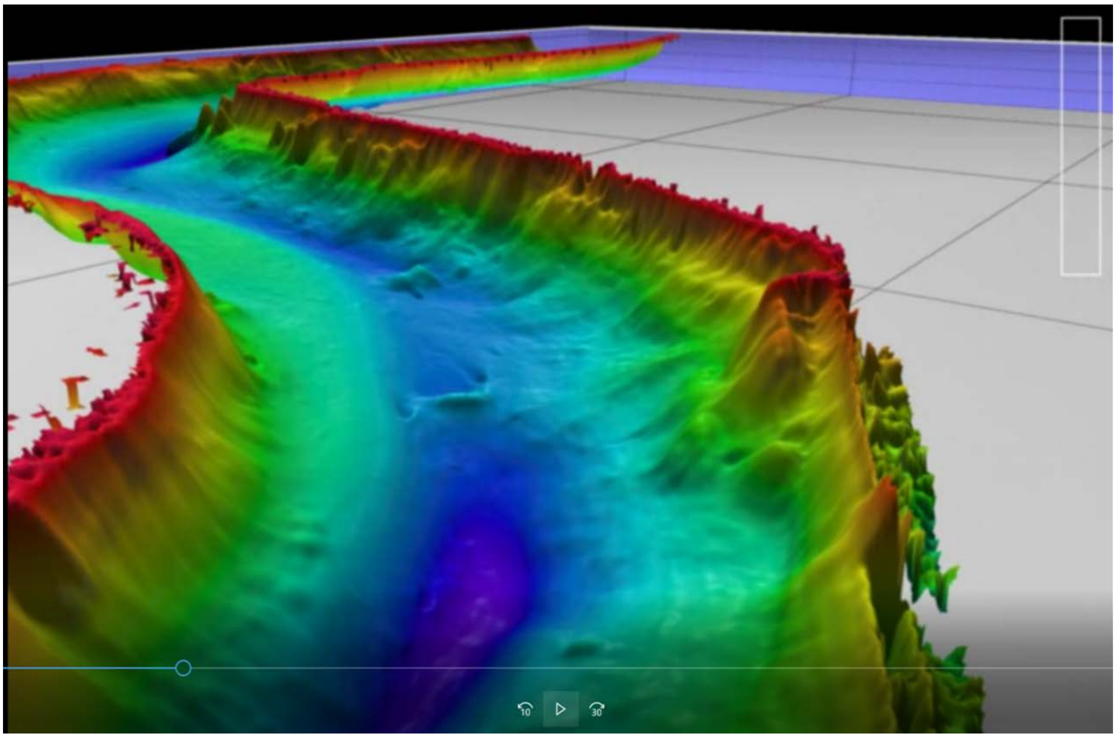

Figure 9: *Screenshot from the 3D-visualization video.*

4.1.2 Gradients

Figure 10 shows gradients within the survey site, as calculated from the acquired bathymetry.
As can be seen gradients are low north of the motorway bridge, but they increase in the south, particularly on the channel margin where gradients of >20° are common. The centre of the Alssund channel, in general, has gradients of <7.5°, though where the channel narrows adjacent the SDU campus steeper gradients are encountered.

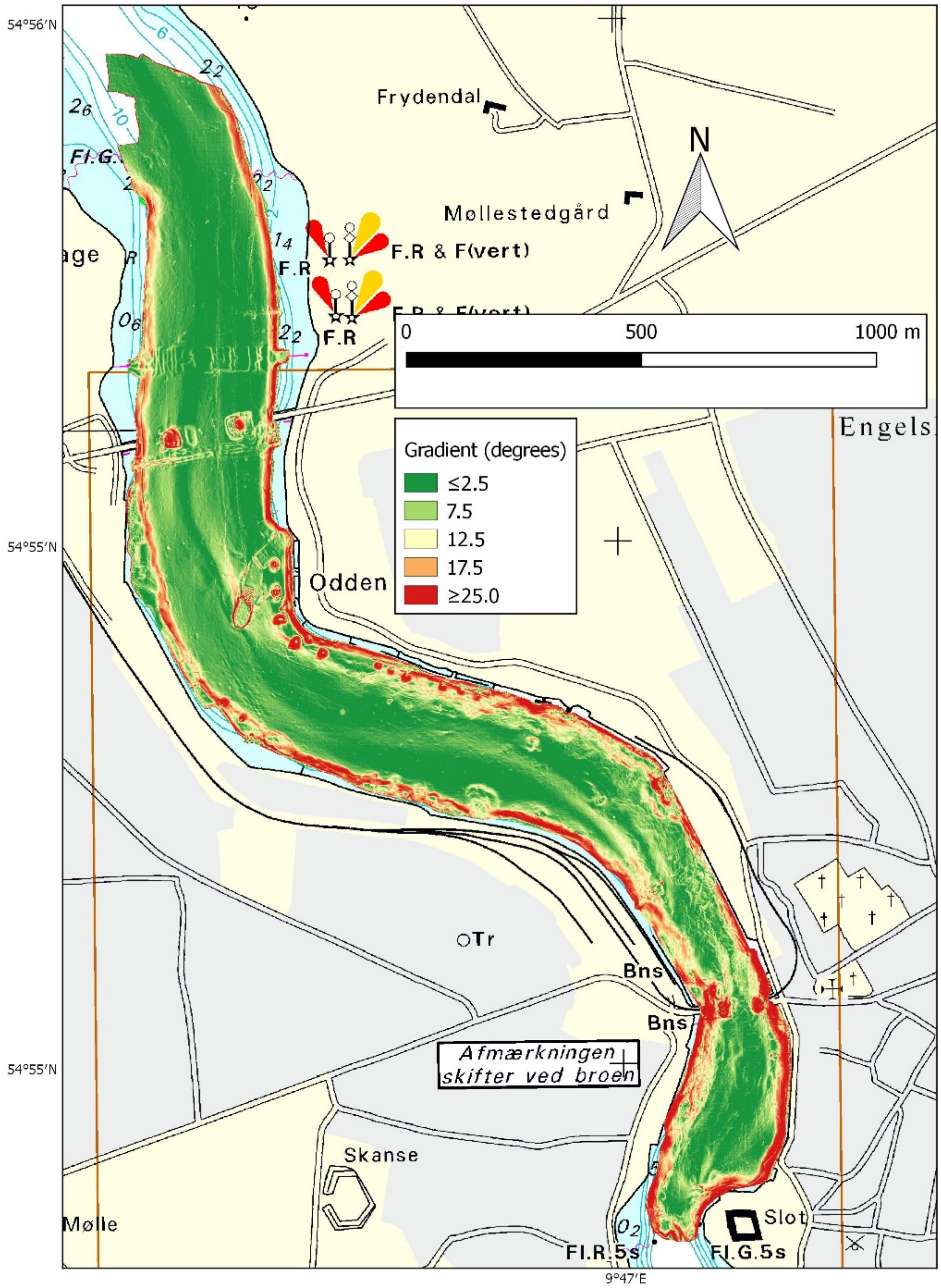

Figure 10: *Gradients within the survey site.*

4.2 Side scan sonar

Figure 11 shows the side scan sonar reflectivity map for the Alssund, dashed boxes show the location of interpretation shown in the subsequent figures. Darker areas show higher reflectivity, generally an indication of coarser material (e.g. gravel), whereas the lighter areas indicate lower reflectivity potentially indicative of fine sand or mud.

At present these interpretations have not been ground truthed by sampling and as such should be regarded as provisional. Identification of larger items such as boulders, anthropogenic structures and wrecks is less dependent on ground truthing and as such, this interpretation may be considered more reliable.

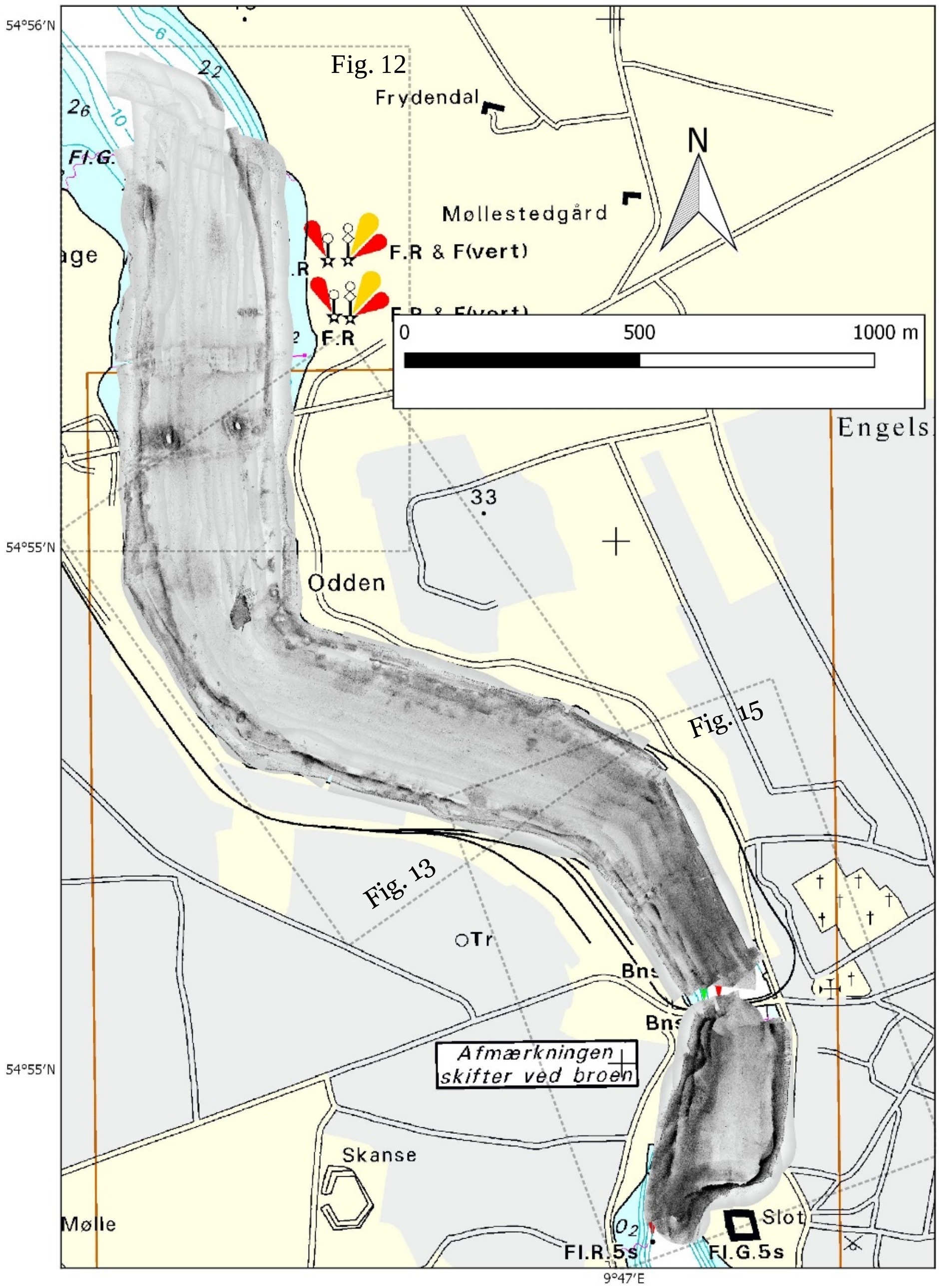

Figure 11: Side scan sonar overview, showing locations of seabed interpretation Figures 12, 13 and 15.

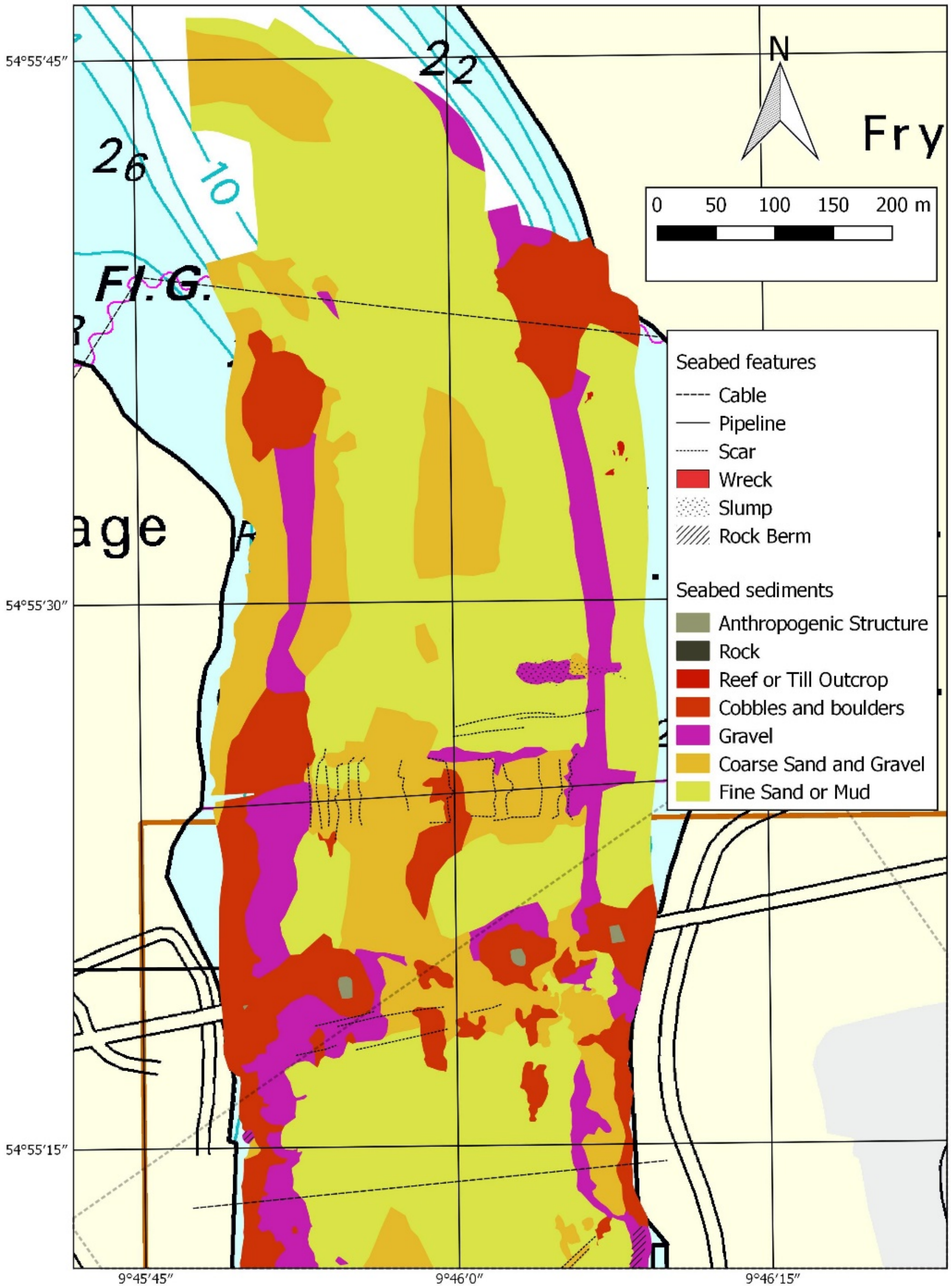

Figure 12: *Seabed interpretation from the north of the survey site. Note that sediment types have not been ground truthed and classifications can be subject to error.*

Shown in Figure 12, the seabed to north of the site is predominantly characterised as either fine sand or mud and coarse sand and gravel. There are also significant areas of cobbles and boulders located toward the channel margins. An area of seabed scarring is noted to cross the channel in the same location as the pipeline noted on the nautical chart. In addition, a small slump feature is apparent on the eastern margin.

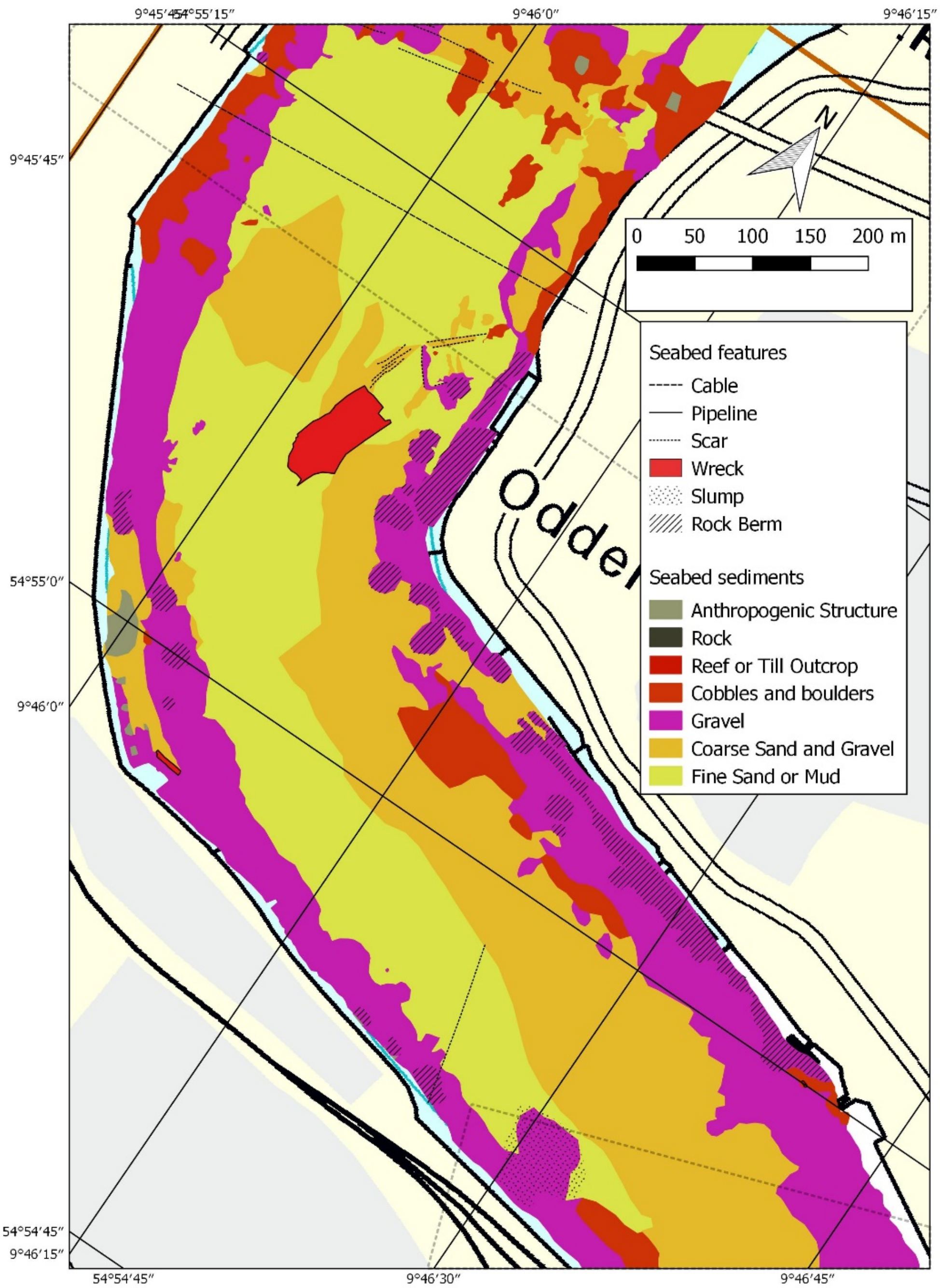

Figure 13: *Seabed interpretation from the centre of the survey site. Note that sediment types have not been ground truthed and classifications can be subject to error.*

Interpreted side scan sonar data for the centre of the site is shown in Figure 13. Here there are large areas of seabed interpreted as fine sand or mud, coarse sand and gravel and gravel. There are limited areas of cobbles and boulders. Discussed briefly in section 4.1, a slump feature is interpreted in the far south of the area on the western margin of the channel.

In addition to these natural features, there are a number of significant anthropogenic features. A large wreck (potentially of a jack-up barge) is observed approximately 100 m west of Odden; this feature is approximately 80 m long and 40 m wide. This object is shown in detail in Figure 14.

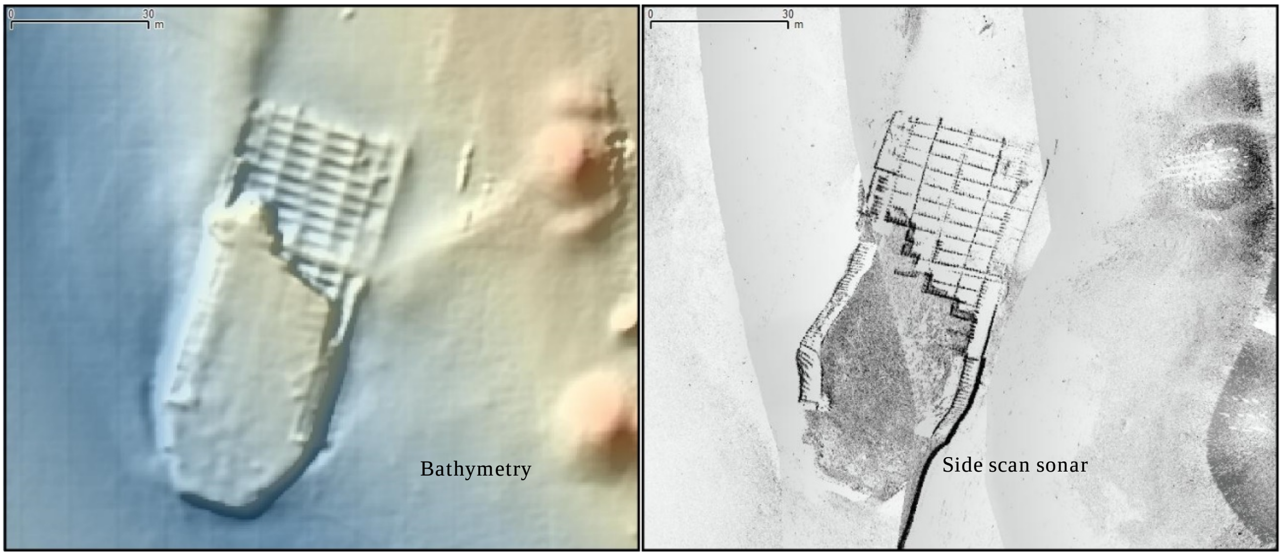

Figure 14: *Bathymetry and side scan sonar data examples showing the large wreck located west of Odden.*

There are two other smaller wrecks observed close to the channel margin in this area. The locations and dimensions of which are shown in Table 3.

Table 3: *Locations of interpreted wrecks (Co-ordinates metres WGS 84 UTM 32N).*

Object type	Easting	Northing	Dimensions (m, L x W x H)	Comment
Wreck	549200.0	6086025.8	88.8 x 35.2 x 3.0	Probable Jack-up
Wreck	549243.1	6085711.7	24.4 x 4.5 x 0.6	Barge or mooring structure
Wreck	549852.7	6085799.7	5.8 x 1.4 x 2.1	Probable dinghy

Reflecting its setting in a town, there are a large number of mooring structures and associated rock berms observed running parallel, and near, to the shore.

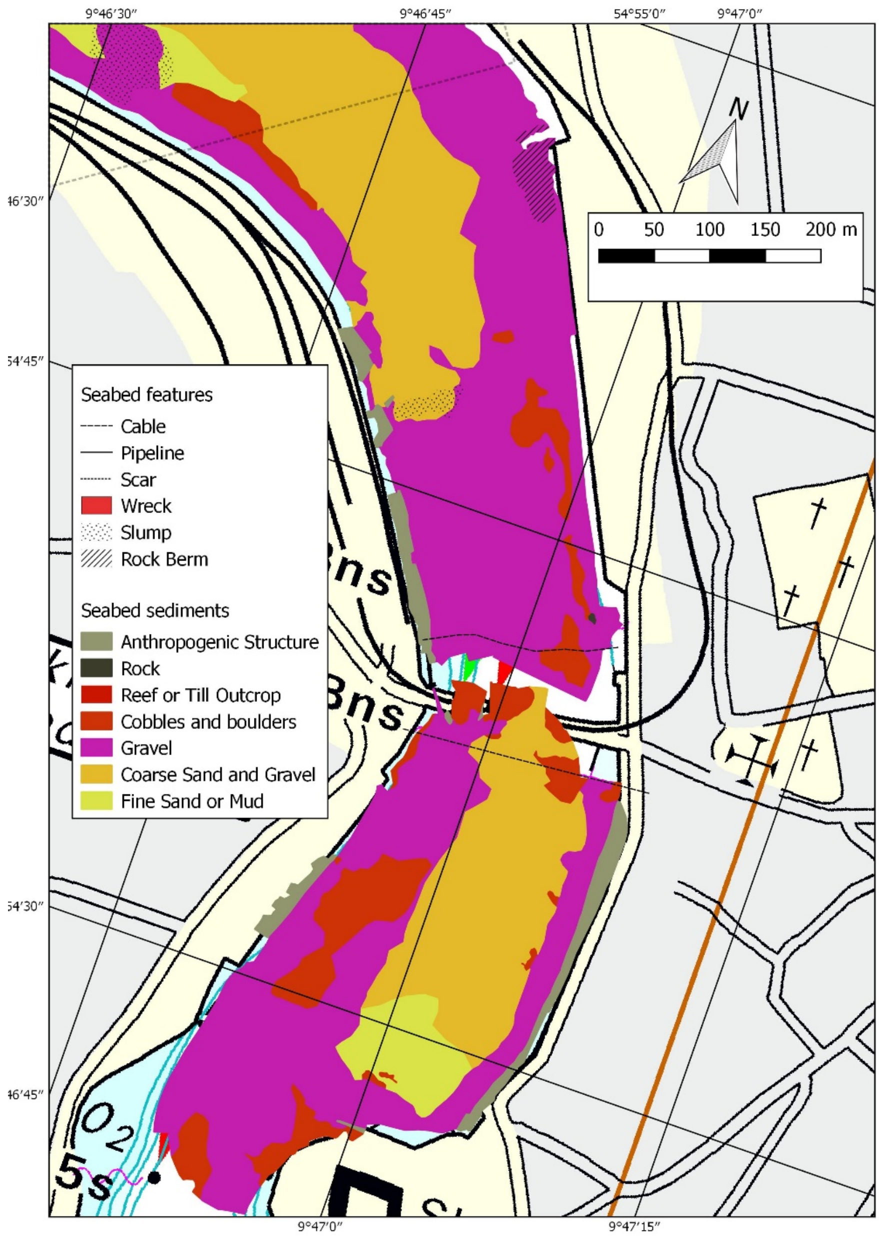

Figure 15: *Seabed interpretation from the south of the survey site. Note that sediment types have not been ground truthed and classifications can be subject to error.*

Figure 15 shows the seabed interpretation from the south of the survey site. Seabed sediments are interpreted to coarsen, with sediments predominantly interpreted to consist of gravel and coarse sand and gravel. There are some limited areas of cobbles and boulders interpreted. The slump feature shown in Figure 8 is present on the western channel margin in this area and is located immediately downslope from some anthropogenic structures.

Two cables are located in this area, one (observed during the survey) immediately north of the bridge and the second (not observed during the survey, but the position obtained from the nautical chart) located immediately south of the bridge. As with the centre of the site, the channel banks in this area are commonly associated with anthropogenic structures.

4.3 Sub-bottom profiling

Sedimentary unit characteristics can be interpreted on the basis of reflectivity and geometry, as well as the unit's position in relation to its geological context. In this study, the shallow sub-surface geology of the Alssund has been interpreted using Innomar, reflection seismic, data.

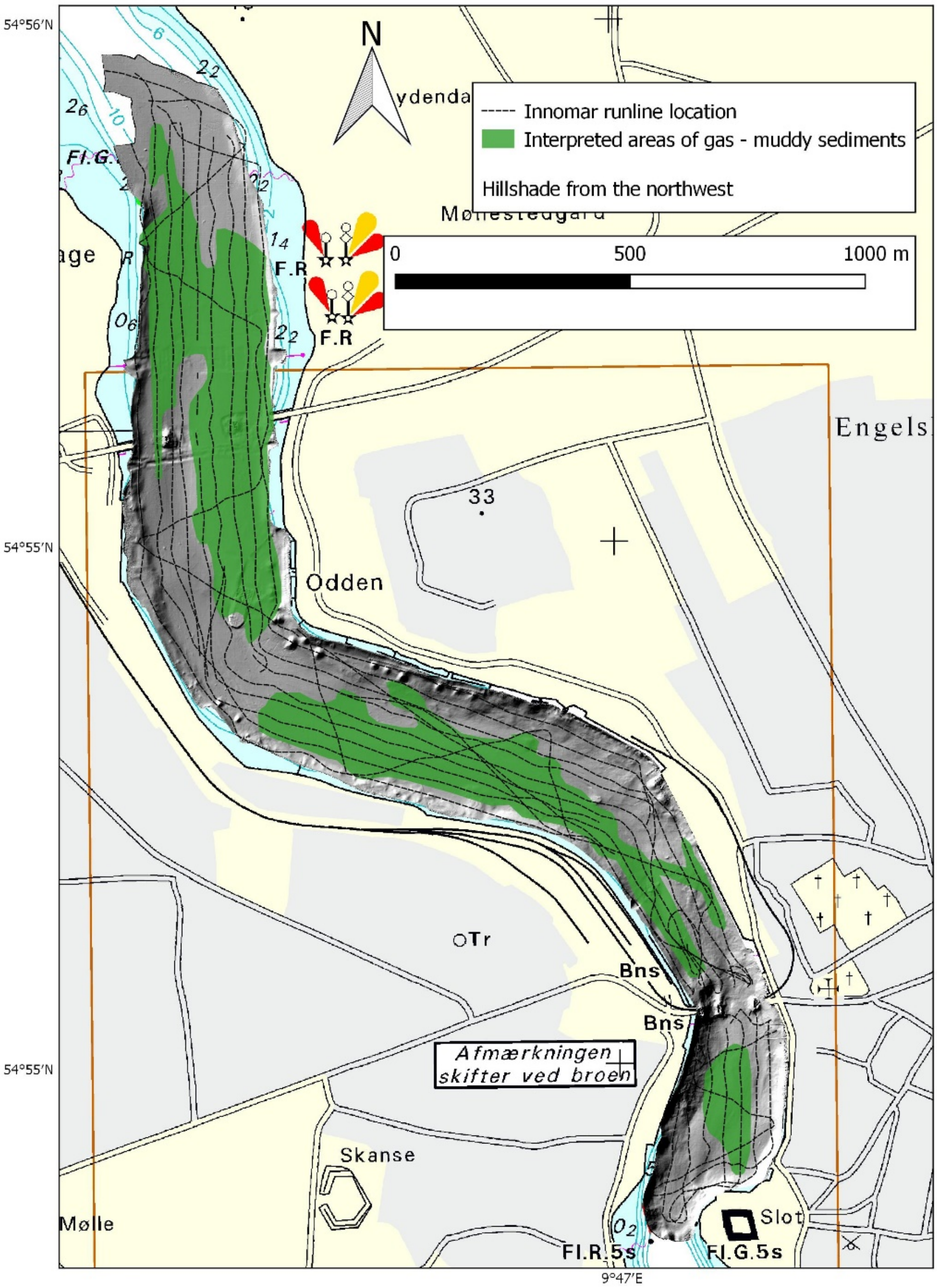

Figure 16: *Extent of gasified sediments interpreted from Innomar data.*

Shown in Figure 16, an initial observation is the presence of gasified sediments. This gas affects the Innomar sub-surface data by obscuring geological features and reducing the extent to which the data can be interpreted. However, as this gas is highly likely to be biogenic the presence of gas provides strong support for the presence of muddy sediments as opposed to sandy.

Two geological units have been interpreted where data is not obscured by gas. Shown in Figure 17, a surficial sandy unit is visible from the centre to the south of the survey area. This unit is interpreted to be relatively thin, with a maximum observed thickness of 4.0 m though it is generally present in a thickness of 1.0 to 2.5 m. It is observed to thicken in three distinct locations shown in Figure 17. From the seismic reflection pattern the sediments most likely consist of sand (Figure 18). However, borings are needed to verify the composition.

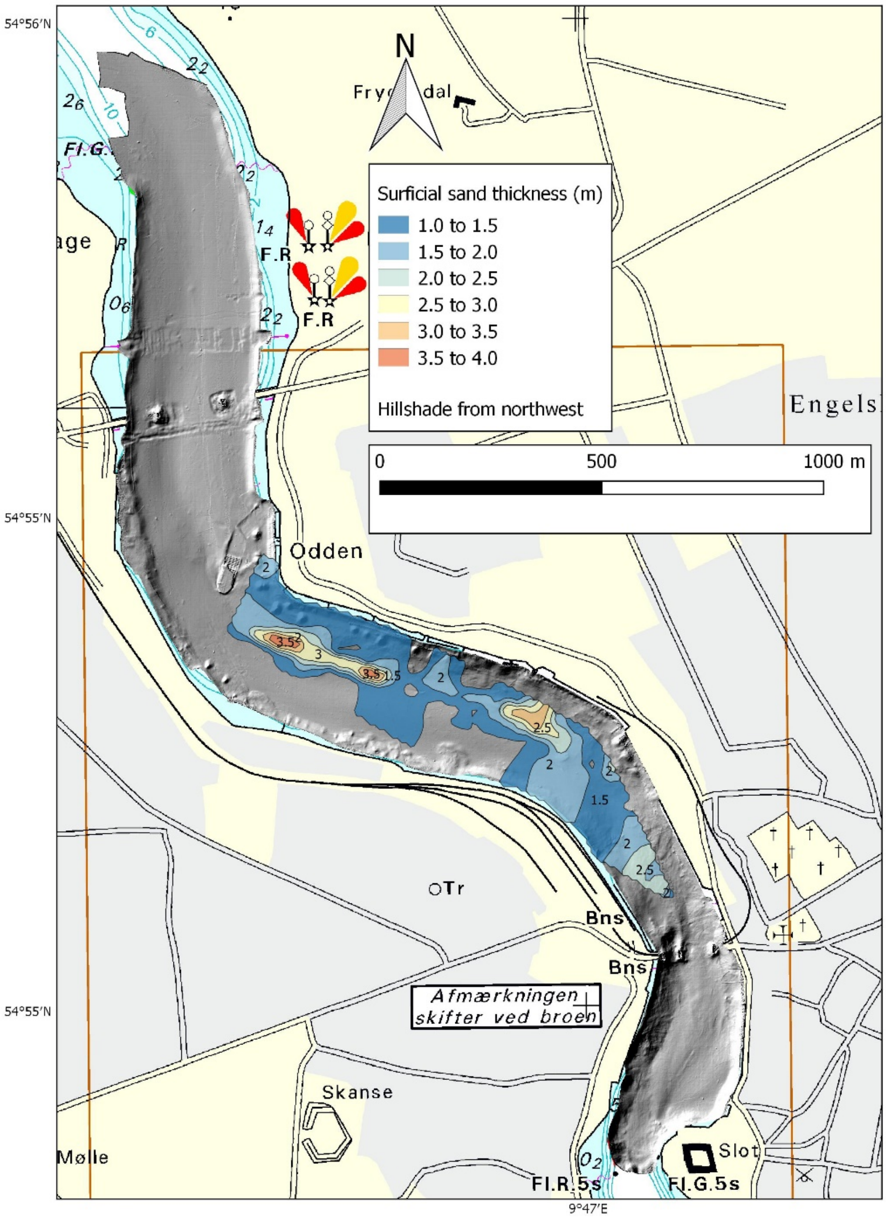

Figure 17: *Thickness of the interpreted surficial sand unit on top of the hill shaded bathymetry.*

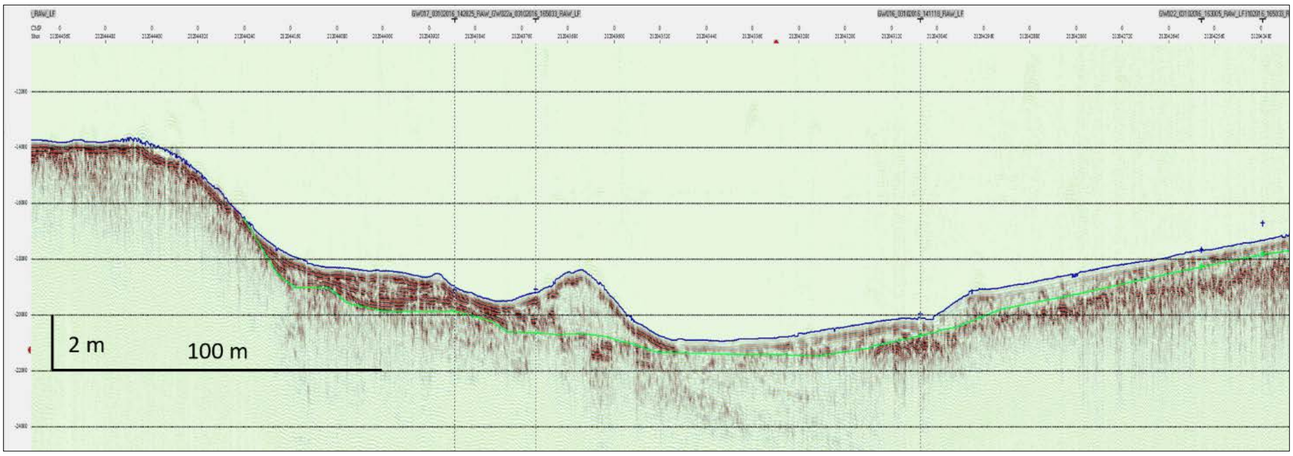

Figure 18: *Seismic section showing the surficial sand unit as reflected from the Innomar data (see also Figure 17).*

Further north, extending south from the motorway bridge, an area interpreted to consist of glacial channel fill is observed; the extent of which is plotted in Figure 19. This unit reaches a maximum thickness of 14 m, though it is commonly >9 m thick. The composition of this deposit is, however, unclear due to the lack of verification from borings, but most likely the seismic layering reflects interlayered sand/gravel with fine grained sediments (Figure 20).

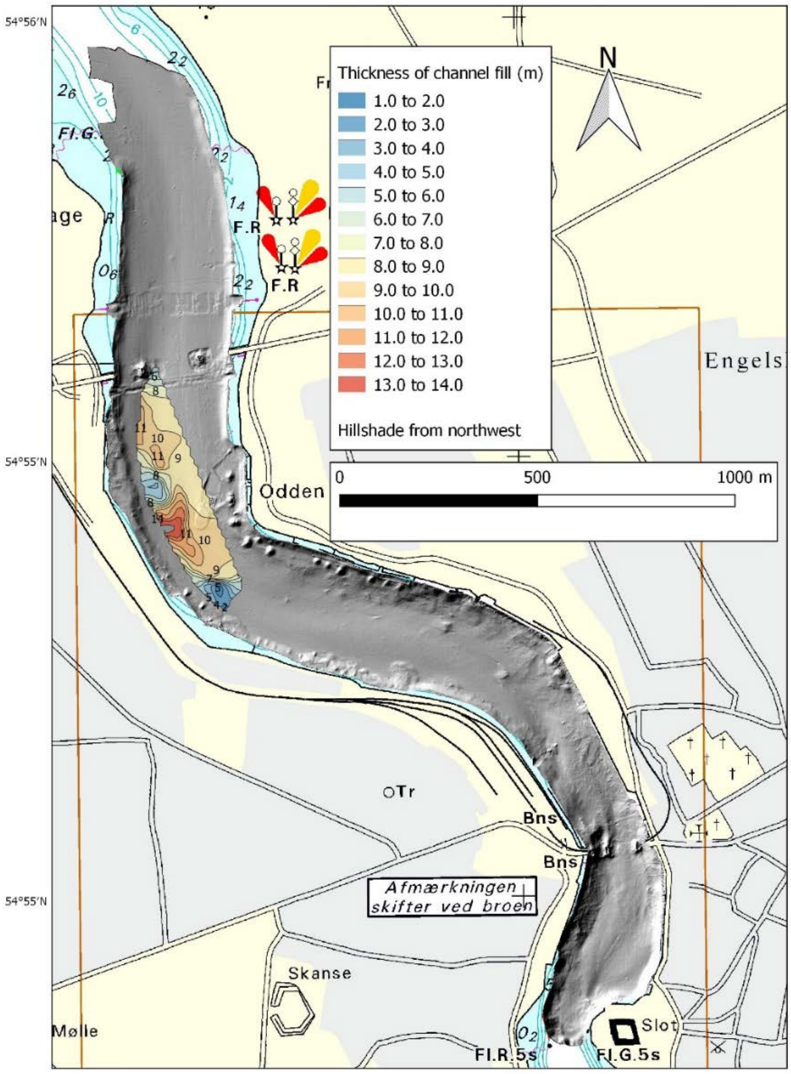

Figure 19: *Thickness of interpreted channel fill unit on top of the hill shaded bathymetry.*

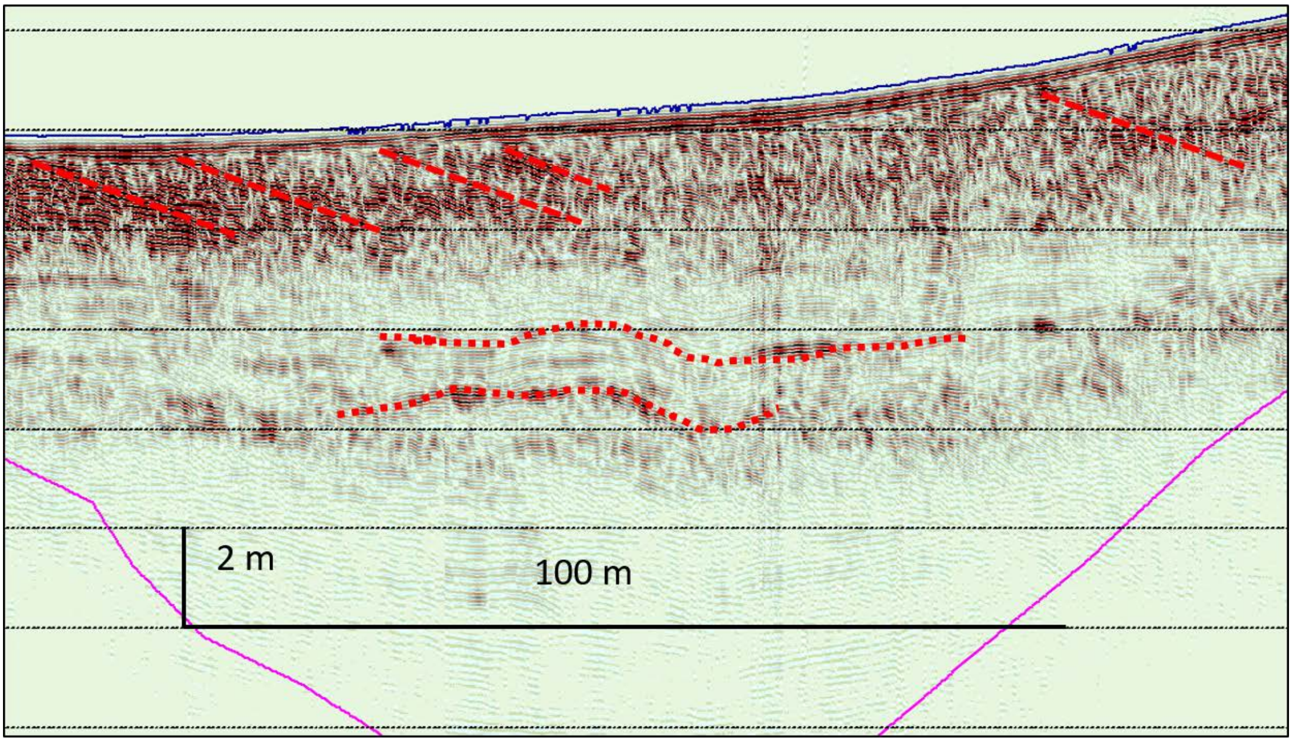

Figure 20: *Seismic section showing the glacial channel fill unit as reflected from the Innomar data (see also Figure 19).*

5. Potential for pipeline installation in Sønderborg

Shown in section 4 of this report it seems that there is good potential for the installation of the prototype pipeline within the Alssund:

- Water depths exceed the required 18 m in a number of locations.
- A number of these coincide with areas of sediment that are interpreted to be sandy or gravelly on the basis of side scan sonar data, which Innomar data shows may have a thickness of 2.0 to 4.0 m.
- The majority of the seabed is free from obstruction.

This potential is summarised in Figure 21, where areas with >18 m water and sandy or gravelly seabed sediments are shown.

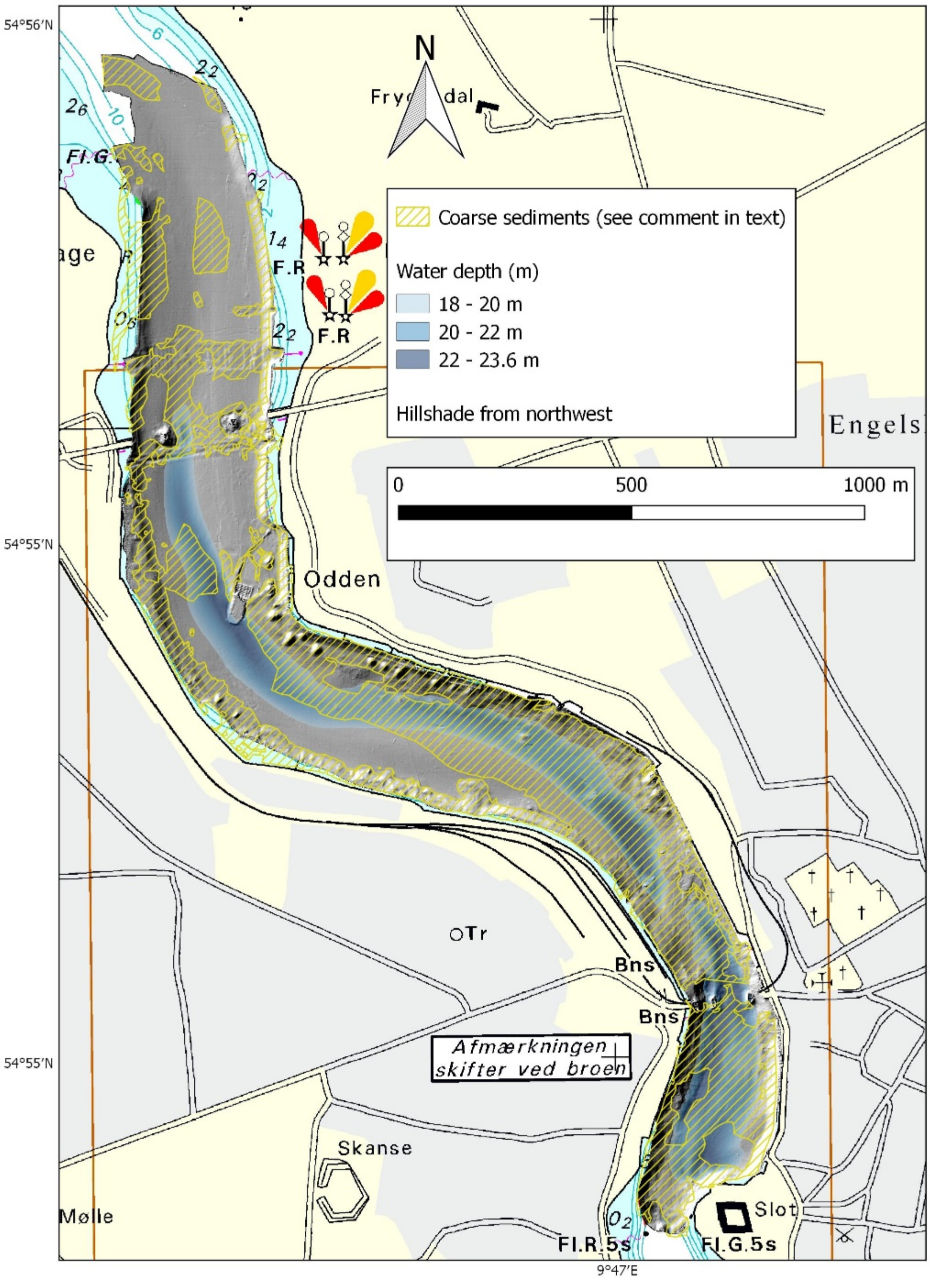

Figure 21: *Areas of >18 m water depth and coarse sandy or gravelly sediments (as interpreted from side scan sonar data).*

A particularly suitable area appears to be the small basin (with maximum water depth 23.6 m) located adjacent to the SDU Sønderborg campus. Sub-bottom Innomar data appears to show 2.0 m of sandy sediment in this location and the side scan sonar data (see Figure 15) also supports the presence of coarser sands and gravel. However, this sediment interpretation is not yet ground truthed and core samples should be acquired to verify this interpretation.

A concern in this area is the seabed gradient on the channel margin, which is very steep with gradients >20° encountered. If pipe flexibility and minimum bend radius allows, it may be possible to avoid the steeper slopes via micro-routing. The use of horizontal directional drilling (HDD) would also negate the impact of these slopes on installation.

The presence of a slope failure is noted on the western channel margin on slopes above the southern end of this small basin. The provenance of this feature is not established (when it occurred and whether it was initiated by natural or anthropogenic factors) but its presence indicates, along with the other slope failures in the survey area, that the slopes may be prone to failure. As such, the risk of further failures should be assessed before commencement of pipeline installation work.

A further potential site is located 200 m southeast from the large wreck. Here water depths of 20 m coincide with interpreted sediment thickness of 3 m and seabed sediments interpreted to consist of coarse sand or gravel.

6. Conclusions and recommendations

On the basis of the results of a geophysical and hydrographic survey of the Alssund it appears that there are suitable locations for the installation of a prototype pipeline for heat exchange. There are extensive areas where water depth exceeds 18 m and where seabed sediments appear to be sandy or gravelly. Interpretation of the sub-surface geology is complicated by the presence of gas but this data also supports the presence of sand.

Discussed in section 5, a basin adjacent to the SDU Sønderborg campus seems to be one of the most suitable locations, with water depths reaching 23.6 m and seabed sediments appearing to consist of coarser sand and gravel. The main concerns in this area are the steep gradients encountered on the channel margin and the risk of slope failure during or after pipeline installation.

6.1 Recommendations for future work

This assessment is based on remotely acquired data (bathymetry, side scan sonar and Innomar reflection seismic) and the interpretations presented have not been verified by ground truthing. As such, the acquisition of sediment samples is strongly advised. Additionally this study has not assessed the engineering feasibility of any location and, as such, once a specific site has been selected a more detailed local survey alongside an engineering assessment is advised.

Specific recommendations are presented below:

1. Acquistion of core and grab sediment samples to verify the geophysical interpretation.
2. Once the site and pipeline route has been selected, to perform an additional detailed survey to improve knowledge of the ground conditions for installation (e.g. route centre line sub-bottom data and core samples).
3. To engage a suitably qualified contractor to undertake an engineering feasibility assessment and to finalise route planning.