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Oskarshamn site investigation

Detailed marine geological survey of the sea bottom outside Simpevarp

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Keywords: Marine geology, Sonar, seismic, Echo sounding.

Abstract

This document reports the findings gained through a detailed marine geological survey of the seabed outside Simpevarp. The survey is part of the site investigation at Oskarshamn and was carried out by the Geological Survey of Sweden (SGU) in close collaboration with Geosigma AB and the University of Stockholm as sub consultants. The survey comprised detailed hydro acoustic mapping controlled by video inspection of the seabed and sediment sampling. The work was performed during the period October 2002 to May 2003.

The fieldwork resulted in approximately 190 km survey lines, whereof about 70 km was surveyed from a smaller survey launch and the remaining 120 km from the R/V Ocean Surveyor. In addition to this 47 bottom inspections with video camera were carried out. Where possible, sediment sampling was also done at these locations. Four piston corer cores, 5 Gemini samples for chemical analysis of pollutants and 30 grab samples were taken. Side scanning sonar data from all survey lines were compiled into sonar mosaics. Based on the interpreted and compiled survey data a marine geological map showing the distribution of different types of seabed material was produced.

The distribution of different types of seabed in the primary survey area is in the main governed by the morphology of the bedrock surface and by a high exposure to sea waves and currents. Thus c 53% of the seabed consist of bedrock outcrops, to a high extent covered by residual stones and boulders, c 42% of glacial clay covered by thin sand/gravel, c 3% of mobile fine sand and c 0.6% of till. Younger clays have not been observed in the primary survey area.

In the areas covered by an additional survey order (Herrholmsfjärden and Figeholmsviken) younger clays are present in the seabed to a substantial extent. In parts of these clay areas, sedimentation of gyttja and clay still occur.

Sammanfattning

Föreliggande dokument rapporterar resultaten av en detaljerad maringeologisk undersökning av havsbotten utanför Simpevarp. Undersökningen ingår i platsundersökningen vid Oskarshamn och utfördes av Sveriges geologiska undersökning (SGU) i nära samarbete med Geosigma AB och Stockholms Universitet (SU) som underkonsulter. Undersökningen som omfattade en detaljerad hydroakustisk kartering kontrollerad med videoinspektion av havsbotten och sedimentprovtagning genomfördes under tiden oktober 2002 till maj 2003.

Fältundersökningen resulterade i totalt 190 km mätlinjer varav 70 km utfördes från en mindre arbetsbåt och resterande 120 km från S/V Ocean Surveyor. Som kontroll av mätresultaten utfördes 47 videoinspektioner av havsbotten kombinerade med sedimentprovtagning där så var möjligt. 5 kolvlodskärnor, 5 Geminiprover för miljökemisk analys och 30 gripskopsprover erhölls. Side scanning sonardata från samtliga mätlinjer sammanställdes till sonarmosaiker. Baserat på det tolkade och sammanställda undersökningsmaterialet framställdes en maringeologisk karta som redovisar fördelningen mellan berggrund och olika typer av sediment i havsbottenytan.

Fördelningen av olika material i havsbottenytan inom det primära undersökningsområdet styrs huvudsakligen av berggrundsytans morfologi och av den kraftiga påverkan av havsvågor och strömmar havsbotten inom området är utsatt för. Sålunda utgörs ca 53 % av havsbotten av berggrund med residualmaterial i form av stenar och block, ca 42 % av glacial lera under ett tunt lager sand/grus, ca 3 % av rörlig finsand och ca 0,6 % av morän. Yngre leror har inte observerats inom det primära undersökningsområdet.

I de områden som täcks av tilläggsbeställningar, Herrholmsfjärden och Figeholmsviken, har yngre leror en betydande utbredning i havsbotten. Inom delar av dessa leromården fortgår nysedimentation av ler och gyttja.

Contents

1 Introduction

This document reports the findings gained by the Detailed Marine Geological Survey outside Simpevarp, which is one of the activities performed within the site investigation at Oskarshamn. The work was carried out in accordance with activity plan AP PS 400-02-17. In Table 1-1 controlling documents for performing this activity are listed. Both activity plan and method descriptions are SKB's internal controlling documents.

The survey was carried out by the Geological Survey of Sweden (SGU) in close collaboration with Geosigma AB and the University of Stockholm as sub consultants. The survey comprised detailed hydro acoustic mapping controlled by sediment sampling. The work was performed during the period October 2002 to May 2003. The investigated area is shown in Figure 1-1.

Data are stored in the primary data bases SICADA and GIS and that they are traceable by the activity plan number. However some depth information data are restricted to be used by Swedish authorities and special safety formulas must be filled in to get access to data.

Table 1-1. Controlling documents for the performance of the activity.

Activity plan	**Number**	**Version**
Detaljerad maringeologisk undersökning av havsbotten utanför Simpevarp.	AP PS 400-02-017	1.0
Method descriptions	**Number**	**Version**
Maringeologisk undersökning	SKB MD 260.001	1.0

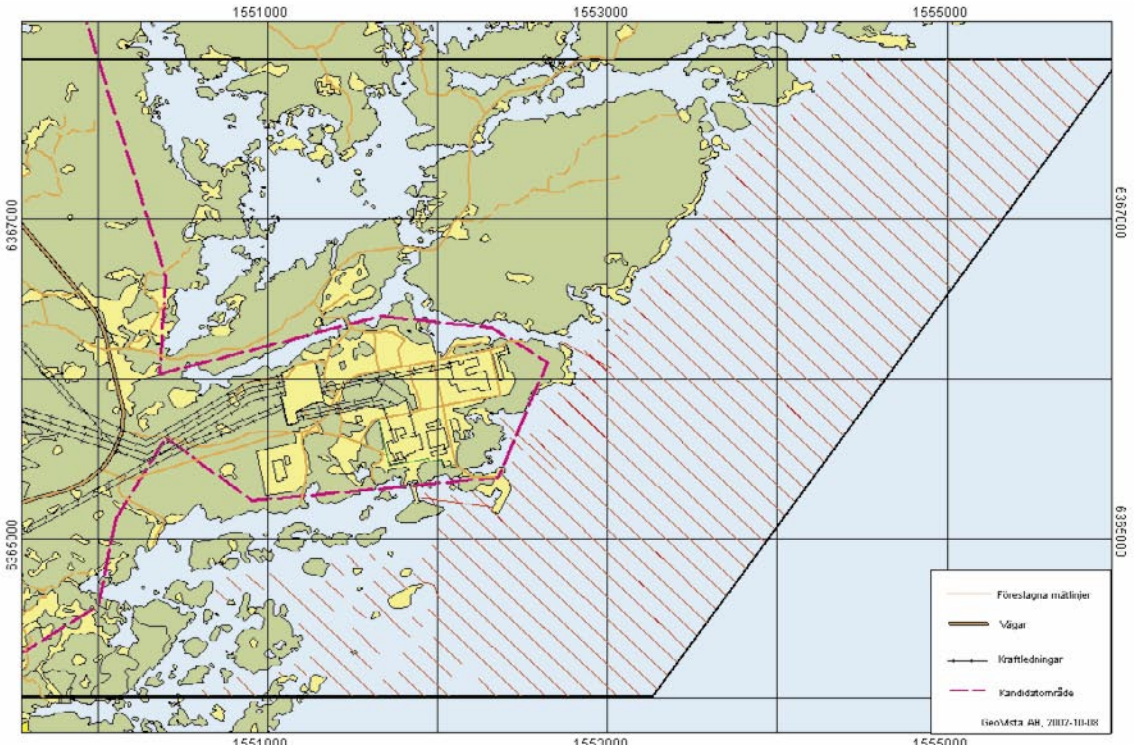


Figure 1-1. *Area of marine geological investigation in the sea outside Simpevarp.*

2 Objective and scope

The main aims of the marine geological survey are to map:

- The morphology of the sea bottom.
- The morphology of the underlying bedrock surface.
- The horizontal and vertical extension of the sediments.
- Indications on neotectonic bedrock displacements.

3 Equipment

3.1 Description of equipment

Two sets of field survey equipment were used, one set for water depths greater than 6 m and one for water depths ranging between six and tree metres.

3.1.1 Water depths greater than 6 m, primary survey area

- Survey vessel: S/V Ocean Surveyor.
- Positioning, survey monitoring and depth logging: LEICA MX 12 channel DGPS receiver, EPOS RDS corrections, EIVA NaviPac survey computer system.
- Echo sounding: Simrad EA 200, 200 kHz.
- Sub bottom profiler: Edo Western HiPac 7 kHz / GeoAcoustic SE2000S datalogger.
- Reflection seismics: EG&G Uniboom, Marshall Acoustic six channel Trout streamer, Triton-Elics Delph Seismic six channel data logger.
- Side scanning sonar: Klein 500 kHz / Triton-Elics ISIS data logger.
- Sediment samplers: 1 m gravity corer, 6 m piston corer, heavy grab sampler and Gemini corer.
- Under water video camera.

3.1.2 Water depths greater than 6 m, secondary survey area

- As above except for the side scanning sonar equipment: a Benthos SIS 1000 system was used.

3.1.3 Water depths between six and tree metres

- Survey vessel: A water jet powered 6.5 m survey launch.
- Positioning, survey monitoring and depth logging: ASHTECH differential GPS receiver, EPOS RDS corrections, Meridata survey computer system.
- Echo sounding: Foruno / Reson 200 kHz.
- Sub bottom profiler: EdgeTech Chirp Profiler 3–9 kHz / Meridata Multi-mode Sonar System.
- Reflection seismics: Benthos Bubble Pulser one channel / Meridata Multi-mode Sonar System.
- Side scanning sonar: Klein 500 kHz / Meridata Multi-mode Sonar System.
- Sediment samplers: small grab sampler and Gemini corer.

3.1.4 Equipment for analyses and interpretation

The equipment for analyses and interpretation consists, in short, of:

- Software for survey planning, data interpretation, geometric correction, production and delivery of spatial databases (mainly Micro Station / Intergraph MGE 5.07, IRAS-C 8.0, ESRI ArcView 3.2 and software specially developed for SGU).
- Software for handling and storing sediment sample descriptions (mainly Microsoft Access 97).

4 Execution

4.1 General

The assignment was performed according to the method description SKB MD 260.001 (SKB internal document), with the exemption of the areas outside the primary investigation area (1,000 m line spacing instead of 100 m).

Surveying in areas with water depth greater than 6 m was conducted from the survey vessel S/V Ocean Surveyor. In areas with water depth between 3 to 6 m a smaller survey launch was used. Surveying was performed along pre planned survey lines. The survey included echo sounding, sediment echo sounding, reflection seismic and side scanning sonar.

In the areas outside the primary investigation area the survey lines had a spacing of 1 km and not 100 m as in the detailed investigation area. Within these areas a long-range side scanning sonar was used instead of the high-resolution sonar used in the detailed investigation. In areas where the actual water depth was much shallower than indicated in the nautical charts, the survey area and line planning was adjusted according to the physical conditions. The systems were used in parallel with digital recording of all data, and position of each system. All survey lines were documented in a protocol and the continued work with each profile was followed up in this protocol. Any changes or problems were also noted in the protocol. After quality control of each survey line the data was converted and the profile preliminary interpreted. At this stage suitable sampling sites were selected.

Sampling was done to verify the geological interpretation of the acoustic data and to solve interpretation problems. Different types of sampling methods were used: in soft sediments 1 and 6 m corers were used. The 6 m cores give a stratigraphical profile at the sampling site. Coarser sediments were sampled with a grab sampler. Before sampling the sea bottom, the sampling site was filmed with an under water video camera and notations were made in a protocol. The camera position aboard the ship is the same as the piston corer station. Grab samples, gravity cores and Gemini cores were taken through the moon pool in the centre of the ship. Each sample is described to a database. The database contains a main table for technical data, positions, water depth, time and sampling method etc. To this table are linked tables containing sediment description data, sub sample data including sub sample weight etc. Normally the samples are photographed.

4.2 Preparations

- Function testing of the equipment.
- With the exception of the positioning and water depth measurements the data is used qualitatively rather than quantitatively. Calibration is thus not used.
- The positioning equipment is checked against a fix point on land.
- Echo sounding measurement was controlled against known water depths. Sound velocity in water is measured with a specially designed CTD-probe. Information from an automatic water level gauge situated within the survey area, supplied by the Swedish meteorological and hydrological institute (SMHI), was used to measure changes in sea water level in the area during the survey.

4.3 Execution of measurements

4.3.1 Positioning and coordinate system

Positioning during the fieldwork was performed using LEICA and ASHTECH differential GPS receivers. The navigational data were recalculated from the receivers NMEA-strings in longitude/latitude to the Swedish RT-90 2.5 W map projection and also adjusted for the location of the towed sensors.

From April 1, 2000 the built in error in the GPS system was decreased from about +/– 50 m to the metre level. This means that the quality of the receiver is now the dominant factor for accurate positioning, and also that the use of differential receivers is less important. However, the use of differential receivers may help to reduce atmospheric disturbances. The differential 12 channel ASHTECH G12 and LEICA receivers used for the present survey is regarded as accurate to the metre level. The differential corrections were based on the EPOS system.

4.3.2 Survey principles and instrumentation

Instrumentation for reflection profiling in the range above c 10 kHz are mostly referred to as echo sounders, whereas those in the range 3–10 kHz are called sediment sounders. Technically they are very similar, using ceramic transmitters which usually also serve as receivers. Below c 3 kHz it becomes necessary to use other types of transmitters; air guns, water guns and various types of high voltage transmitters. These low frequency systems, referred to as seismic profilers, also require separate receivers in the form of hydrophone arrays.

Sediment sounding. The sediment sounders are capable of penetrating mud, clay, silt and fine sand, under favourable conditions down to more than 50 m below the seafloor. They rarely penetrate till, however. Chirp sounding constitutes transmission of a computer-controlled frequency sweep, and a computer decoding of the echoed sweep. The chirp technology is an efficient way to increase the energy output while keeping rather low transmission amplitudes. In the present case the chirp soundings provided clear records of the uppermost mud sediments and the glacial varved clays. Exceptions were those areas where the mud sediments were gas-charged.

4.3.3 Environmental parameters

Velocity determinations. The sound velocity in the water at the time of the survey is essential for the evaluation of the echo sounding records. The required data – depth, salinity and temperature may either be determined by measurements performed exclusively for the purpose or achieved from oceanographical observations. The essential parameter for calculation of the water velocity in fresh water bodies is the temperature that was measured during the present survey. For the evaluation of the present recordings a water velocity of 1,460 m/s was used.

4.3.4 The data acquisition system

Data acquisition parameters used for surveying with R/V Ocean Surveyor is shown in Table 4-1 and for the smaller survey launch in Table 4-2.

Table 4-1. Data acquisition parameters used for surveying with R/V Ocean Surveyor.

Channel/ Instrument	Record length (ms)	Frequency range (kHz)	Pulse length (ms)	Trigger rate (ms)	Sampling rate (kHz)
Uniboom	250	0.5–1.5	0.5	500	5
EDO Western	250	3.5/7	0.2	500	20
Klein Sonar	100	500	0.02	100	16
SIS 1000	1,000	100–120	5	1,000	8

Table 4-2. Data acquisition parameters used for surveying with the smaller survey launch.

Channel/ Instrument	Record length (ms)	Frequency range (kHz)	Pulse length (ms)	Trigger rate (ms)	Sampling rate (kHz)
Bubblepulse	150	No filter	2.0	150	16
Chirp	150	3–9.5	30	150	16
Sonar	125	500	0.02	175	16

The digital depth data from the instruments were stored in separate computer files, and GPS positional data in a separate file. Before storage, the positional data strings (NMEA – GPGGA) were converted to X/Y-coordinates in the RT-90 map system. Furthermore, the 3-dimensional layout of the instruments during the survey was recorded on file in order to facilitate coordinate calculation of positions and instrument depth for each shotpoint.

4.4 Data handling, analyses and interpretation

4.4.1 Depth measurements

Depth along the survey lines was measured using echo sounder. Data were stored in ASCII-format with x, y, z, time and date. Information from an automatic water level gauge situated within the survey area, supplied by SMHI was used to correct the measured data from changes in sea water level in the area during the survey. The depth measurements were used to make a digital terrain model over the area. Data from the sea chart and the geological map were used to correct the model from differences between the survey lines.

4.4.2 Seismic and sediment echo sounding data

Data are primarily stored in SEG-Y format. After conversion to image raster format, each file is quality controlled and accepted or, if rejected, data is collected again at this survey line. After quality control, the resulting position file is filtered. Position data and line number from each survey line are collected in a graphic file, which is transformed to Arc View shape format. The survey data are transformed to image format and the seismic and sediment echo sounding data are interpreted simultaneously to graphic data. The acoustic stratigraphy is interpreted to geological lithology. The information from the sediment sampling is used in the interpretation. The quality of this work depends to a high degree on the experience and skill of the interpreting geologist. Knowledge of the local geology and sedimentology are important.

The interpreted sections are transformed to ASCII files with x, y, z co-ordinates and geological code. These time based files are recalculated to meter based sections in the same format. Information about the sound velocity in different materials is based on literature studies. From these sections a graphical data set is produced, showing the geological material at the sea bottom along the survey lines. Table 4-3, presents a few rows of data from a seismic section.

Data was then re-arranged to fit into a format suitable for the SICADA database. An ID-code referring to SKB:s internal project documentation was added to each seismic line. Each row in Table 4-4 corresponds to one stratigraphic unit. The values in the marin_seis_code column were translated into the soil_c and genes_c codes, according to SKB standards. One explanatory column was also added; marin_seis_text (in Swedish).

The Digital Terrain Model (DTM) describing bedrock topography was produced from the interpreted geological sections in ASCII-format. Where the geological sections occurred more sparsely, some supportive iso-lines were drawn manually to strengthen the DTM. At locations where bedrock outcrops at sea-bottom which is evident from the geological interpretation/side-scan sonar images, data from the more accurate ship echosounder was used. From this data a Triangulated Irregular Network (TIN) was created and in turn converted to a USGS DEM raster through a tension spline function.

Table 4-3. Example data from seismic section.

Shot number	Easting (RT90 2.5V),	Northing (RT90 2.5 V)	No of strati-graphic units	Code for 1:st seismic unit	Depth below sea level	Code for 2:nd seismic unit	Depth below sea level	Base-ment code	Depth below sea level
1	1633074.82	6705875.34	3	6	–16.4989	76	–18.6815	99	–50.5240
2	1633077.25	6705877.28	3	6	–16.1821	76	–18.5062	99	–51.1702
3	1633079.68	6705879.22	3	6	–15.8653	76	–18.3312	99	–51.8162
4	1633082.11	6705881.16	3	6	–15.5483	76	–18.1563	99	–52.4631

Table 4-4. Marine seismic stratigraphy adapted to the SICADA database format.

(ID-code)	Shot_point_ ID (number)	Depth_from (m)	Depth_to (m)	Soil_c (code)	Genes_c (code)	Marin_ seis_c (code)	Marin_seis_ text (text)
LSM000325	1	0.00	15.35		42	6	Vatten
LSM000325	1	15.35	21.12	12	3	66	Moränlera
LSM000325	1	21.12				99	Kristallin berggrund
LSM000325	2	0.00	16.25		42	6	Vatten
LSM000325	2	16.25	17.3	29	8	19	glacial lera
LSM000325	2	17.3	23.55	12	3	66	Moränlera
LSM000325	2	23.55				99	Kristallin berggrund

4.4.3 Side scanning sonar

Sonar data are primarily stored in SEG-Y format. After conversion to image raster format, each file is quality controlled and accepted or, if rejected, data is collected again along this survey line. After quality control, the resulting position file is filtered. Acoustic data is corrected for slant range and geographically positioned in registered raster strip files. The resulting strip files are mosaiced together in 2.5×2.5 km squares each representing one fourth of an economical map for the primary survey area and in 5×5 km squares in the regionally measured area. The mosaics are named according to the system used by the Swedish land survey. They are transferred to geo referred tiff images with 25 cm pixel size for the primary survey area and the pixel size of 1 m for the additional areas. The mosaics are interpreted to produce a geological map of the seabed sediments. To support the interpretation, data from the seismic and sediment echo sounding, sediment sampling, water depths and other background data are used. The interpretation is based on the different responses from different geological materials. Bedrock shows up as dark and rough areas while unconsolidated sediments give a pale and "soft" impression. Important factors for an accurate geological mapping are the understanding of how the sonar signal interacts with the morphology and geology of the sea bottom, the effect of "shadowing", and an overall knowledge about the geology in the area.

4.4.4 Seabed samples

Sample data are first stored in an MS Access database. Relevant tables were exported and re-mapped according to SKB lexicon tables; sampling_equipment_c, soil_c, soil_prefix_c and genes_c. In general, re-mapping of values was carried out in the same manner as the seismic stratigraphy. Two data-sets were delivered to SKB, one with the activity codes and one containing the sample data. An explanatory column ("kommentar") was added to the latter.

4.5 Nonconformities

Outside the primary investigation area 1,000 m line spacing was used instead of 100 m.

5 Results

All data are stored in the primary data bases SICADA and GIS and they are traceable by the activity plan number. However some depth information data are restricted to be used by Swedish authorities and special safety formulas must be filled in to get access to data.

5.1 Survey lines

The fieldwork resulted in approximately190 km survey lines, whereof about 70 km was measured from the smaller boat and the remaining 120 km from the R/V Ocean Surveyor, Appendix 1.

5.2 Sampling points

In addition to this 47 bottom inspections with video camera were carried out, Appendix 2. Where possible, sediment sampling was also done at these locations. Four piston core samples, 5 Gemini samples (whereof 3 from the small boat) and 30 samples with the large grabber were taken. The information is also delivered in Arc View line shape format (“linjer”), with the line number as attribute data. The information from the sediment sampling is stored in an Access database with geographical, technical and geological data. A subset of the information in this database is also delivered in Arc View point shape format (“prov”), with attribute data on ID, x, y, z, date, sampling platform, sampling method, penetration and short geological description of the sample, Appendix 3. Each of the sampling points taken from R/V Ocean Surveyor are filmed with under water video camera and stored on VHS tape. A copy of the tape has been delivered. Data about the film sequences (start/stop time, ID no and short notations on what can be seen) are noted in a form.

5.3 Side scanning sonar mosaics and geological sections

The sonar mosaics converted to Geotiff format are delivered to SKB, Appendix 4. Each mosaic is named after the geographical position on the economical map according to the National Land Survey of Sweden. The sections with interpreted geological stratigraphy are delivered as two ASCII files named line_surveying_simpevarp.txt and stratigraphy_data_ simpevarp.txt.

5.4 Marine geological map

The maps on bottom material, Appendix 5, (“bomatr”) are delivered in Arc View shape format, with thin layers (“tunt”) and ripples (if existing). In the outer, regionally mapped area the data sets have the suffix reg, and in the inner detailed area the suffix det (ex. bomatr_reg.shp). Bottom morphology is delivered as 5 m equidistant line shape set and a terrain model in USGS DTM.

5.4.1 The primary survey area

Outcrops of crystalline bedrock comprise c 53% of the seabed in the primary survey area. The bedrock surface governs both the morphology of the seabed in the area and the distribution of the Quaternary sediments. The larger bedrock lineaments, as indicated by morphology and the distribution of outcrops, run roughly parallel to the coastline, trending roughly from SW towards NE. Practically all of the nine video inspections of bedrock outcrops undertaken, show a high frequency of boulders and stones all richly overgrown by Mytilus edulis on top of the bedrock surface.

The dominant main sediment (thickness exceeding 0.5 m) in the area, c 42% coverage, is glacial clay, here including clays deposited in the Baltic ice lake, the Yoldia sea and the Ancylus lake. The Baltic ice sea clay usually is brownish and may contain silty or sandy horizons. The Ancylus clay on the other hand is usually grey with sulphide stains. The glacial clay is everywhere covered by a thin, one to a few decimetres, layer of sand and gravel, occasionally with a content of stones. The thickness of the glacial clay generally varies between 1–5 m. In some fracture valleys it may reach 5–10 m or as most, up to 13 m.

Post glacial fine sand as main sediment (thickness exceeding 0.5 m) covers c 3% of the primary survey area. The fine sand generally occurs on valley bottoms and other deeper areas. It is highly mobile is probably re-deposited by currents during hard weather periods.

Till, is only to a small extent, less than 0.6% of the total area, exposed in the seabed, and then generally adjacent to bedrock outcrops. Below the glacial clay the till has a greater extent and usually a thickness of 1–5 m, in a few instances up to 10 m. The delineation of the boundary between till and bedrock with a stone and boulder cover is somewhat uncertain. It has not been possible to confirm the presence of till by sediment sampling at any location in the area. The data given concerning the distribution and thickness of till is thus solely based in interpretation of seismic and sub bottom profiler records.

Taken as a whole the composition of the sea bed in the primary survey area, e.g. the absence of younger fine grained sediments and the presence of sand ripples at several locations, indicates a high energy environment, strongly influenced by currents and sea waves.

5.4.2 The additional survey areas

The additional survey area situated east and north east of and in contact with the primary survey area shows great similarities with this. Outcropping bedrock and glacial clay covered by thin sand dominates. In the south-eastern part of the area however till occur in the seabed to a larger extent. The thickness of this till deposit mostly varies between 10–15 m.

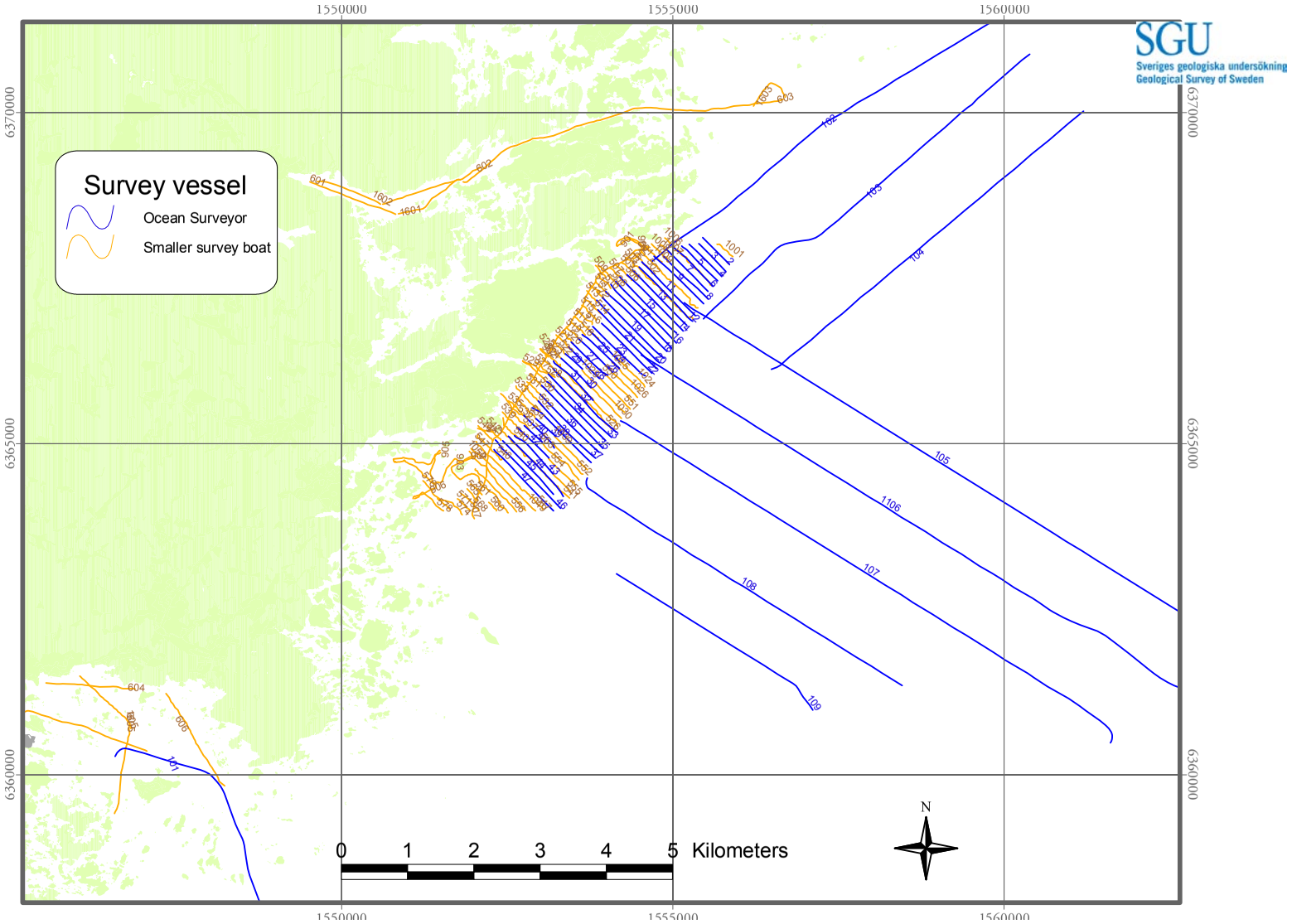
In the additional area outside Figeholm post glacial clay occur in areas protected from sea wave action. The clay has a thickness of 1 to 3 m and a content of gas. A sample from the deposit shows a clay gyttja or gyttja composition and indicates recent sedimentation.

Clay gyttja with a content of gas are also present in the additional area Granholmsfjärden situated north of Äspö. The thickness of these deposits is normally between 1 and 5 m.

5.5 Ongoing sedimentation

In the primary survey area there are no areas with ongoing sedimentation. In the areas covered by an additional survey order (Herrholmsfjärden and Figeholmsviken) ongoing clay sedimentation is more common in the areas with postglacial clay. In these areas Gemini coring and environmental analyses was done. These results will be reported separately. No map on ongoing sedimentation will thus be produced.

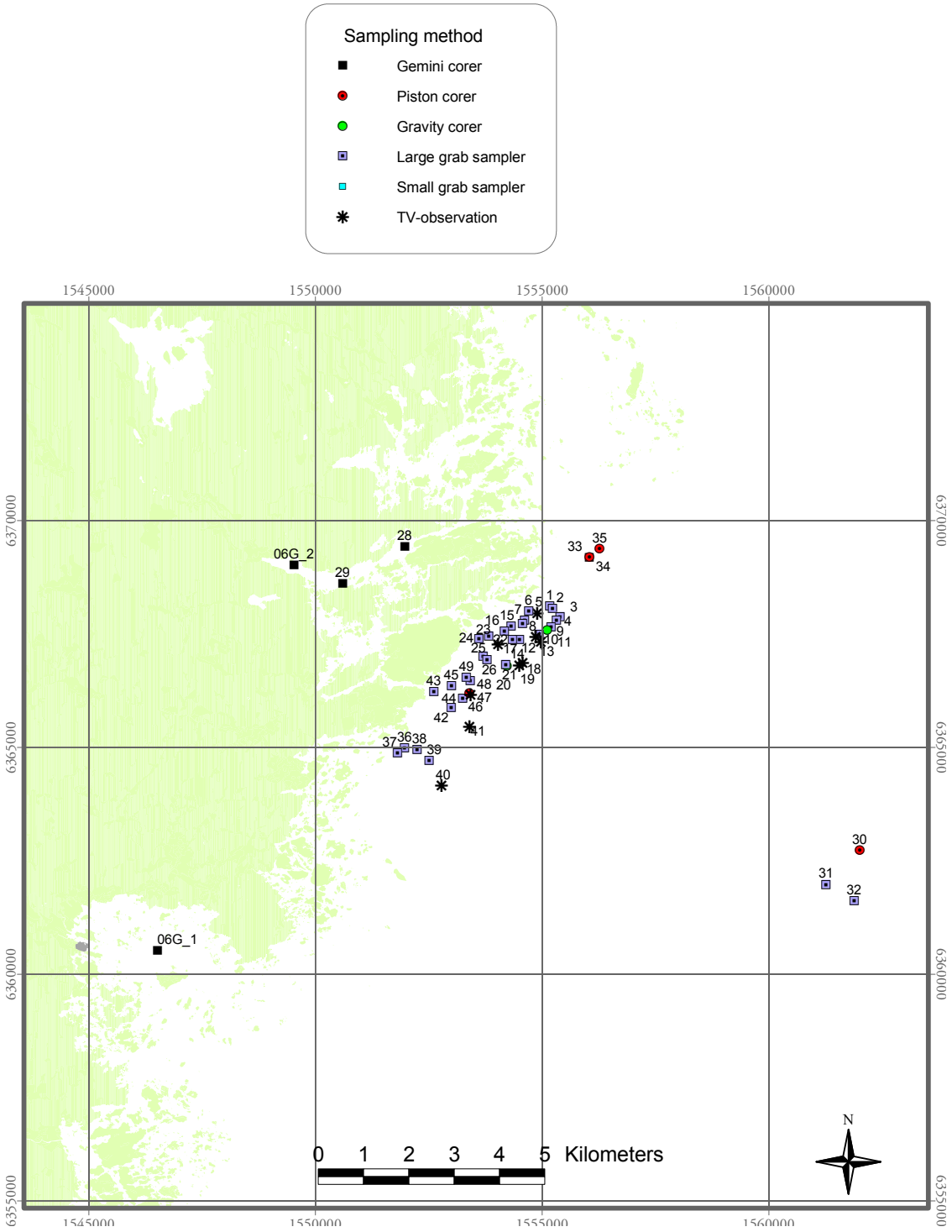
Map showing the survey lines



Appendix 2

Map showing the sampling points

SGU
Sveriges geologiska undersökning
Geological Survey of Sweden



Appendix 3

Comprehensive table on sediment sample information

SKB ID	SGU ID	Sampling method	Survey vessel	Date	Northing (RT90 2.5W)	Easting (RT90 2.5W)	Elevation m	Core length cm	Material	Soil_c	Short description	Description
PSM002088	06G0001	Gemini corer	Ocean Surveyor	2002-10-27	6360423.0	1546890.0	–8.30	50	Mud	31	pg.Gy	Postglacial gyttja
PSM002089	06G0002	Gemini corer	Small survey boat	2002-10-29	6368928.0	1549903.0	–4.50	30	Mud	31	pg.Gy	Postglacial gyttja
PSM002117	06H0029	Gemini corer	Small survey boat	2002-10-29 12:10	6368523.0	1550974.0	–5.50	30	Mud	31	pg.Gy	Postglacial gyttja
PSM002125	06H0037	Large grab sampler	Ocean Surveyor	2002-10-31 08:44	6364776.0	1552186.9	–12.60	20	Sand	15	pg.f-S	Postglacial fine sand
PSM002124	06H0036	Large grab sampler	Ocean Surveyor	2002-10-31 08:27	6364888.5	1552342.4	–15.80	20	Sand	15	pg.m-S	Postglacial medium sand
PSM002116	06H0028	Gemini corer	Small survey boat	2002-10-29	6369323.0	1552346.0	–9.50	30	Mud	31	pg.Gy	Postglacial gyttja
PSM002126	06H0038	Large grab sampler	Ocean Surveyor	2002-10-31 09:40	6364847.2	1552616.9	–25.50	25	Silt	23	pg.Gy/pg.g-Si	Thin postglacial gyttja over coarse silt
PSM002127	06H0039	Large grab sampler	Ocean Surveyor	2002-10-31 10:02	6364608.5	1552881.7	–12.40	50	Rock	15	Bl/Bu	Boulders over bedrock
PSM002131	06H0043	Large grab sampler	Ocean Surveyor	2002-10-31 11:35	6366132.5	1552985.0	–9.40	30	Sand	15	pg.g-S	Postglacial coarse sand
PSM002128	06H0040	TV-observation	Ocean Surveyor	2002-10-31 10:34	6364052.9	1553153.2	–7.50	0	Rock	15	Bu	Bedrock
PSM002130	06H0042	Large grab sampler	Ocean Surveyor	2002-10-31 11:17	6365769.5	1553373.6	–18.00	15	Sand	15	pg.f-S	Postglacial fine sand
PSM002133	06H0045	Large grab sampler	Ocean Surveyor	2002-10-31 12:04	6366254.6	1553375.9	–15.20	40	Clay	29	pg.g-S//gl.L	Thin postglacial coarse sand over glacial clay
PSM002132	06H0044	Large grab sampler	Ocean Surveyor	2002-10-31 11:51	6365973.3	1553624.7	–15.30	15	Sand	15	pg.f-S	Postglacial fine sand

SKB ID	SGU ID	Sampling method	Survey vessel	Date	Northing (RT90 2.5W)	Easting (RT90 2.5W)	Elevation m	Core length cm	Material	Soil_c	Short description	Description
PSM002137	06H0049	Large grab sampler	Ocean Surveyor	2002-10-31 14:01	6366441.8	1553702.4	–14.70	15	Clay	29	St/gl.L	Stones over glacial clay
PSM002134	06H0046	6 m piston corer	Ocean Surveyor	2002-10-31 12:35	6366092.5	1553769.8	–15.80	575	Clay	29	S/Si/gl.L	Thin postglacial sand over thin silt over glacial clay
PSM002129	06H0041	TV-observation	Ocean Surveyor	2002-10-31 11:05	6365345.9	1553774.6	–15.60	0	Rock	15	Bu	Bedrock
PSM002136	06H0048	Large grab sampler	Ocean Surveyor	2002-10-31 13:51	6366372.6	1553788.7	–17.00	35	Clay	29	S//gl.L	Thin postglacial sand over glacial clay
PSM002135	06H0047	TV-observation	Ocean Surveyor	2002-10-31 13:40	6366064.5	1553798.8	–6.60	0	Rock	15	Bu	Bedrock
PSM002113	06H0024	Large grab sampler	Ocean Surveyor	2002-10-26 15:48	6367289.3	1553981.9	–19.30	25	Sand	15	(Gy.)//pg.f-S.	Thin postglacial gyttja over fine sand
PSM002114	06H0025	Large grab sampler	Ocean Surveyor	2002-10-26 16:17	6366917.6	1554075.9	–18.60	20	Clay	29	(pg.gr.f-S.)/gl.L	Thin postglacial gravely fine sand over glacial clay
PSM002115	06H0026	Large grab sampler	Ocean Surveyor	2002-10-26 16:35	6366827.0	1554159.3	–17.20	20	Sand	15	pg.f-S	Postglacial fine sand
PSM002112	06H0023	Large grab sampler	Ocean Surveyor	2002-10-26 15:35	6367361.8	1554199.0	–12.90	0	Rock	15	st.Bl./B	Stones and boulders over bedrock
PSM002111	06H0022	TV-observation	Ocean Surveyor	2002-10-26 15:00	6367173.3	1554400.8	–13.90	0	Rock	15	B	Bedrock
PSM002105	06H0016	Large grab sampler	Ocean Surveyor	2002-10-26 13:22	6367460.8	1554542.0	–19.10	26	Clay	29	pg.f-S/gl.L	Thin postglacial fine sand over glacial clay
PSM002110	06H0021	Large grab sampler	Ocean Surveyor	2002-10-26 14:48	6366731.4	1554572.5	–11.10	0	Rock	15	st.Bl./B	Stones and boulders over bedrock
PSM002109	06H0020	1 m gravity corer	Ocean Surveyor	2002-10-26 14:35	6366698.7	1554601.0	–16.70	25	Gravel	18	pg.S/(st.Gr)/gl.L	Thin postglacial sand over thin stony gravel over glacial clay
PSM002104	06H0015	Large grab sampler	Ocean Surveyor	2002-10-26 13:01	6367570.4	1554692.4	–19.10	25	Sand	15	pg.f-S	Postglacial fine sand
PSM002106	06H0017	Large grab sampler	Ocean Surveyor	2002-10-26 13:48	6367274.5	1554724.9	–15.40	50	Rock	15	pg.st.gr.S/gl.L/B	Thin postglacial stony gravel over thin glacial clay over bedrock
PSM002108	06H0019	TV-observation	Ocean Surveyor	2002-10-26 14:24	6366714.7	1554868.3	–8.40	0	Gravel	18	st.Bl.	Boulders and stones

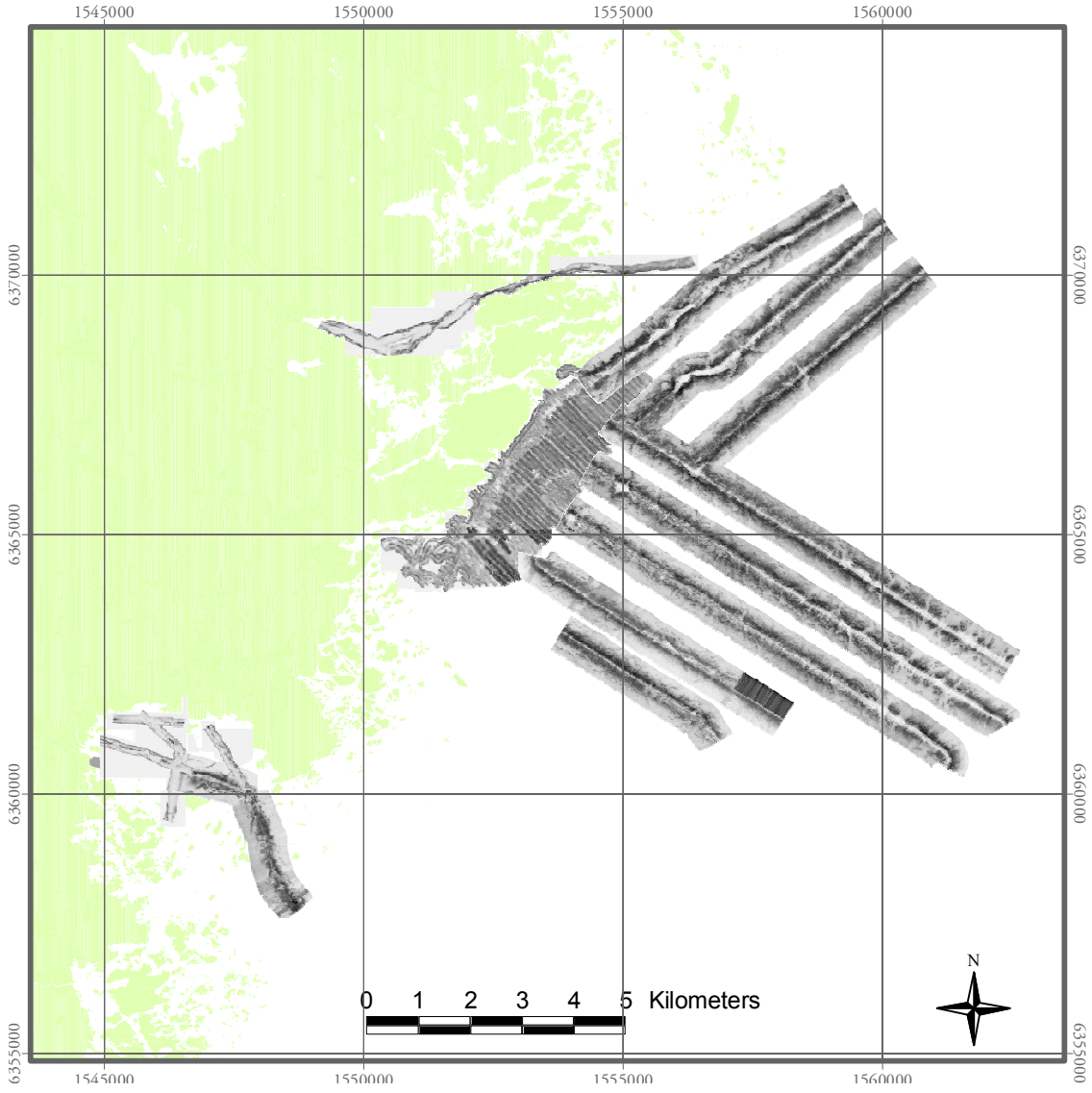
SKB ID	SGU ID	Sampling method	Survey vessel	Date	Northing (RT90 2.5W)	Easting (RT90 2.5W)	Elevation m	Core length cm	Material	Soil_c	Short description	Description
PSM002103	06H0014	Large grab sampler	Ocean Surveyor	2002-10-24 17:51	6367274.3	1554879.3	–21.50	30	Clay	29	pg.S/gl.L	Thin postglacial sand over glacial clay
PSM002097	06H0008	Large grab sampler	Ocean Surveyor	2002-10-24 14:46	6367634.7	1554940.3	–16.20	15	Gravel	18	pg.gr.St	Postglacial gravel and stones
PSM002107	06H0018	TV-observation	Ocean Surveyor	2002-10-26 14:09	6366766.9	1554943.6	–8.70	0	Gravel	18	st.Bl.	Boulders and stones
PSM002096	06H0007	Large grab sampler	Ocean Surveyor	2002-10-24 14:19	6367694.7	1554992.3	–17.10	15	Rock	15	pg.st.gr.g-S//gl.L/B	Thin postglacial stony gravely coarse sand over thin glacial clay over bedrock
PSM002095	06H0006	Large grab sampler	Ocean Surveyor	2002-10-24 13:55	6367901.4	1555077.7	–20.60	30	Clay	29	pg.f-S/gl.L	Thin postglacial fine sand over glacial clay
PSM002101	06H0012	TV-observation	Ocean Surveyor	2002-10-24 16:41	6367335.5	1555237.5	–13.10	0	Rock	15	pg.St/B	Boulders and stones
PSM002094	06H0005	TV-observation	Ocean Surveyor	2002-10-24 13:45	6367866.1	1555268.0	–16.50	0	Rock	15	B	Bedrock
PSM002100	06H0011	Large grab sampler	Ocean Surveyor	2002-10-24 16:20	6367398.2	1555308.5	–20.20	40	Clay	29	(pg.g-S)/gl.L	Thin postglacial coarse sand over glacial clay
PSM002102	06H0013	TV-observation	Ocean Surveyor	2002-10-24 16:54	6367232.1	1555344.5	–12.20	0	Rock	15	pg.St/B	Boulders and stones
PSM002099	06H0010	1 m gravity corer	Ocean Surveyor	2002-10-24 16:04	6367491.2	1555487.2	–13.10	15	Rock	15	pg.gr.St/B.	Thin postglacial gravel and stones over bedrock
PSM002090	06H0001	Large grab sampler	Ocean Surveyor	2002-10-24 10:57	6368018.0	1555546.0	–22.70	40	Clay	29	(pg.m-S.f-G.g-S//gl.L	Thin postglacial medium sand over thin fine gravel over thin gravely sand over glacial clay
PSM002098	06H0009	Large grab sampler	Ocean Surveyor	2002-10-24 15:51	6367550.0	1555573.4	–14.20	15	Gravel	18	pg.gr.St	Postglacial gravel and stones
PSM002091	06H0002	Large grab sampler	Ocean Surveyor	2002-10-24 11:31	6367955.9	1555602.0	–17.20	40	Clay	29	(pg.gr.st.g-S)//gl.L	Thin postglacial gravely stony coarse sand over glacial clay
PSM002093	06H0004	Large grab sampler	Ocean Surveyor	2002-10-24 13:04	6367708.4	1555691.1	–28.50	30	Silt	23	pg.f-S	Postglacial fine sand

SKB ID	SGU ID	Sampling method	Survey vessel	Date	Northing (RT90 2.5W)	Easting (RT90 2.5W)	Elevation m	Core length cm	Material	Soil_c	Short description	Description
PSM002092	06H0003	Large grab sampler	Ocean Surveyor	2002-10-24 12:00	6367785.5	1555773.3	–29.10	40	Silt	23	pg.m-S f-S	Thin postglacial medium sand over fine sand
PSM002121	06H0033	Gemini corer	Ocean Surveyor	2002-10-30 17:45	6369090.0	1556416.2	–42.80	47	Mud	31	pg.Gy	Postglacial gyttja
PSM002122	06H0034	6 m piston corer	Ocean Surveyor	2002-10-30 18:18	6369090.6	1556416.2	–43.00	153	Clay	29	pg.Gy/pg.S//gl.L	Thin postglacial gyttja over thin postglacial sand over glacial clay
PSM002123	06H0035	6 m piston corer	Ocean Surveyor	2002-10-30 19:54	6369279.6	1556641.3	–40.90	494	Silt	23	pg.f-S/pg.sk.f-L/ l.si.f-S/s.L/gl.L	Postglacial fine sand over postglacial clay with shell fragments over clayey fine sand over sandy clay over glacial clay
PSM002119	06H0031	Large grab sampler	Ocean Surveyor	2002-10-30 13:58	6361881.5	1561638.0	–38.00	20	Clay	29	f-S//gl.L	Thin postglacial fine sand over glacial clay
PSM002120	06H0032	Large grab sampler	Ocean Surveyor	2002-10-30 14:38	6361524.2	1562257.2	–29.40	15	Sand	15	S//Mn?	Thin postglacial sand over till?
PSM002118	06H0030	6 m piston corer	Ocean Surveyor	2002-10-30 13:32	6362626.3	1562378.7	–38.90	550	Clay	29	pg.f-S/gl.L	Thin postglacial fine sand over glacial clay

Appendix 4

Map showing the side scanning sonar mosaics

SGU
Sveriges geologiska undersökning
Geological Survey of Sweden



Appendix 5

Map showing the marine geological map

SGU
Sveriges geologiska undersökning
Geological Survey of Sweden