Femern Belt Fixed Link
Sediment sampling and analysis

Survey and Data Report

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Client: DHI Water • Environment • Health

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Introduction

This project was conducted under a contract with DHI Water · Environment · Health. It is part of a larger project for investigating the area where a fixed link between Denmark and Germany is to be constructed. The fixed link will connect Denmark (Rødbyhavn) with Germany (Puttgarden at Fehmarn Island), Fig. 1.
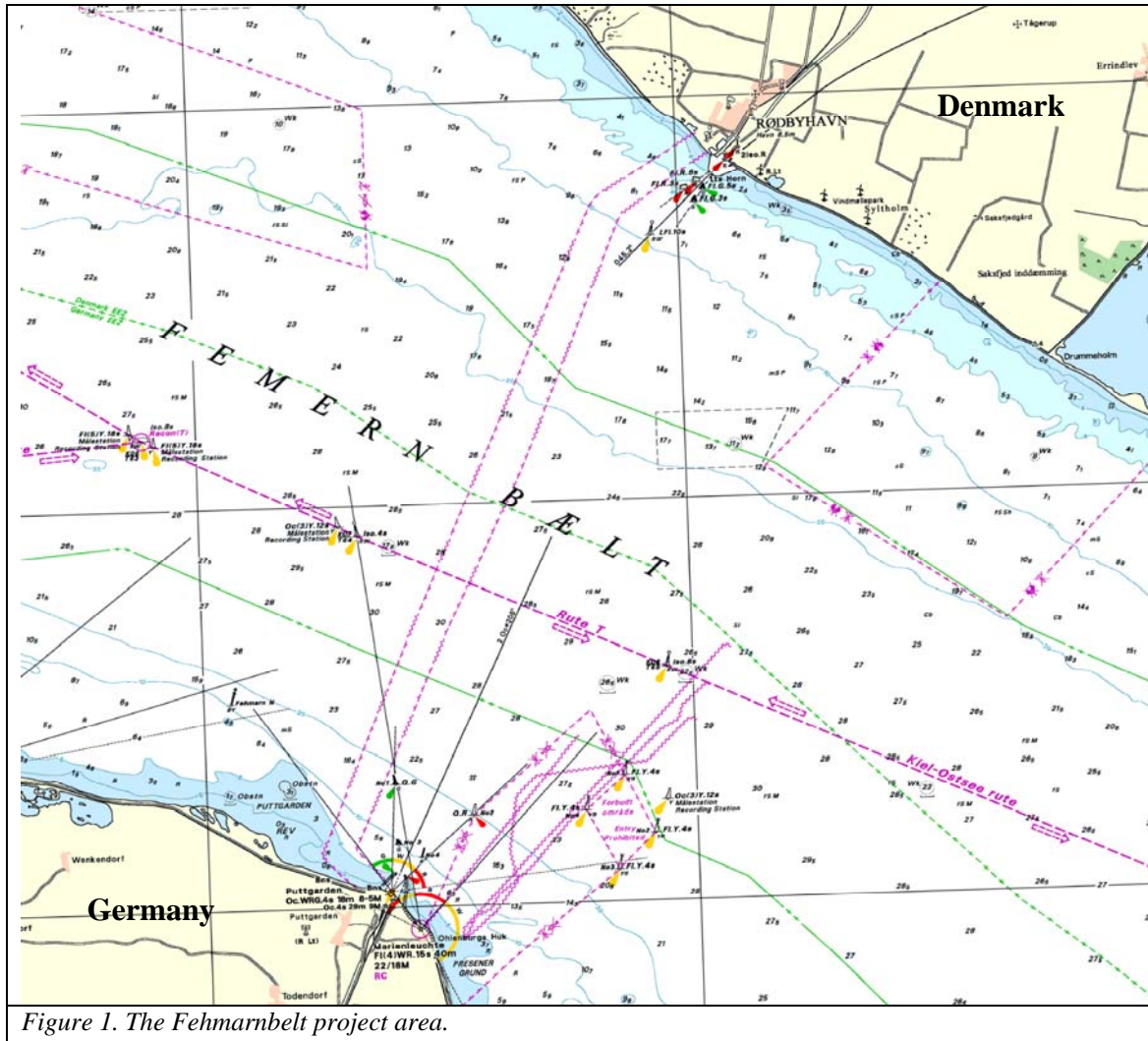

Figure 1. The Fehmarnbelt project area.

GEUS has been contracted to perform several geological and geophysical investigations in the Fehmarnbelt project. This report will present the results of surface sediment sampling and basic sediment analyses from locations along coastal zone profiles at the Danish and the German side.

The report includes the survey procedure, the analyses performed, and the results. All results are included in the DVD that accompanies this report.

Field work

Two main coastal zone regions have been investigated in the project, the Danish side (offshore Rødby harbour) and the German side (offshore Puttgarden harbour). The required survey areas are ~ 5-6 km of coastline from 6 m depth contour up to shoreline. The survey area for both the Danish and the German sides is shown in Fig. 2.

The field work operation for this part of the project started at the 29th of April 2009 and lasted until the 14th of July 2009.
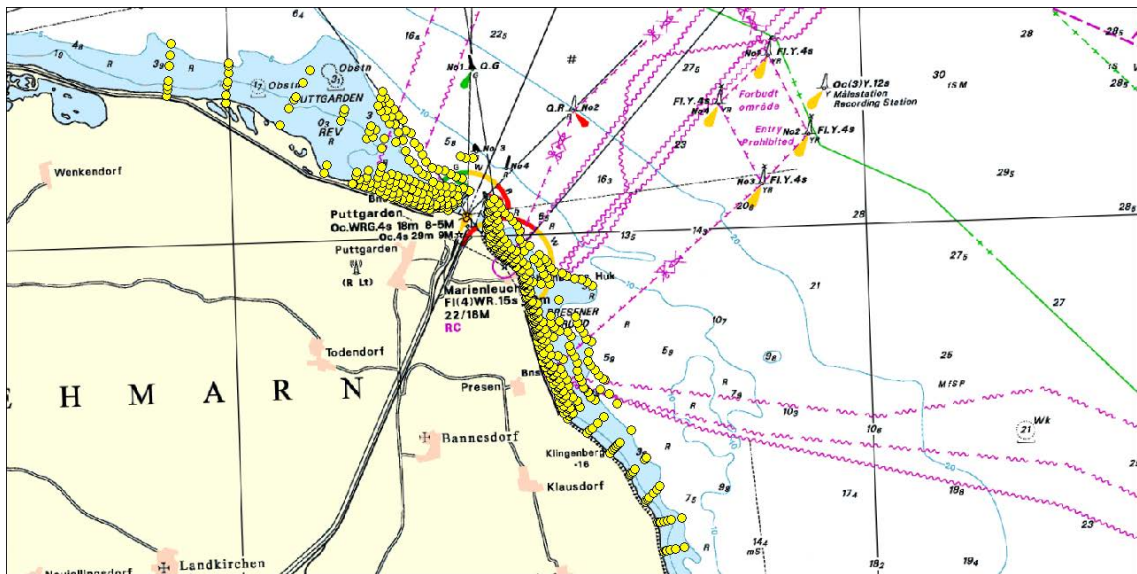

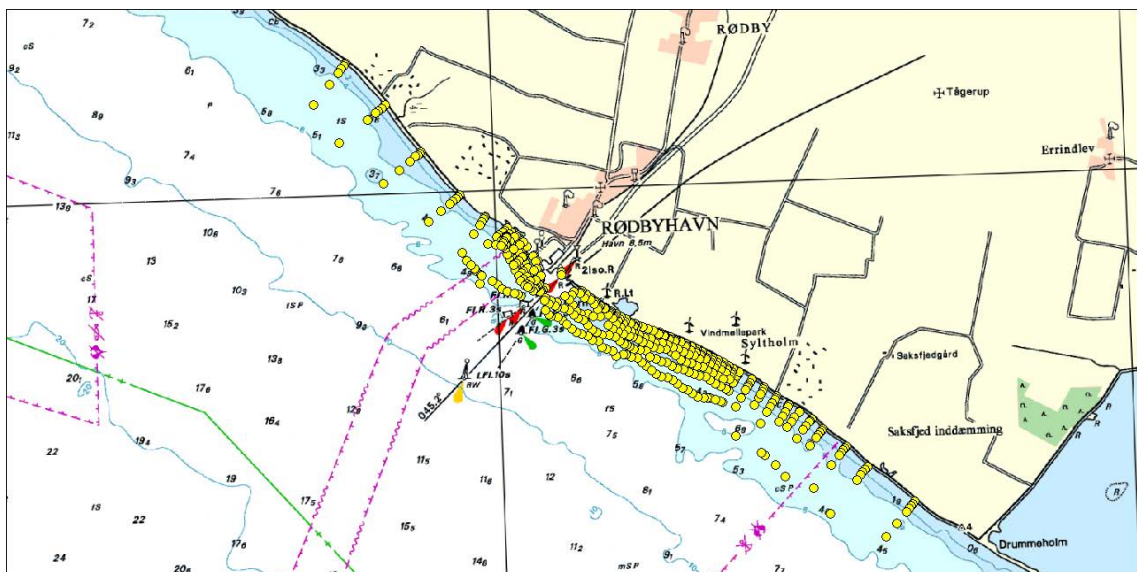*Figure 2.A. Sampling points (yellow dots) along profiles near Puttgarden Harbour.*

Figure 2.B. Sampling points (yellow dots) along profiles near Rødby Harbour.

Navigation

All sampling was positioned by RTK GPS system. The system is installed by Dansurvey and further information about the RTK GPS can be found in the attached document: Appendix I.

Sediment sampling

The small GEUS survey vessel "GEUS II" was used as platform for sediment sampling throughout the sampling campaign in the nearshore survey of Fehmarn Belt (Figs. 3, 4). In the onshore area, at position 0 m, samples were collected by means of a hand shovel as described below.

Figure 3. Fehmarn Belt 2009, GEUS II, Rødby Harbour.

Methods used at the coast

At the coast, (Position 0 m) the samples were collected by means of a hand shovel (Fig. 5). The samples only include sediment from the uppermost few centimeters of the beach/seabed. The samples were collected in plastic bags with reference numbers. The sampling positions (0 m) were located in the profile lines using a GPS.
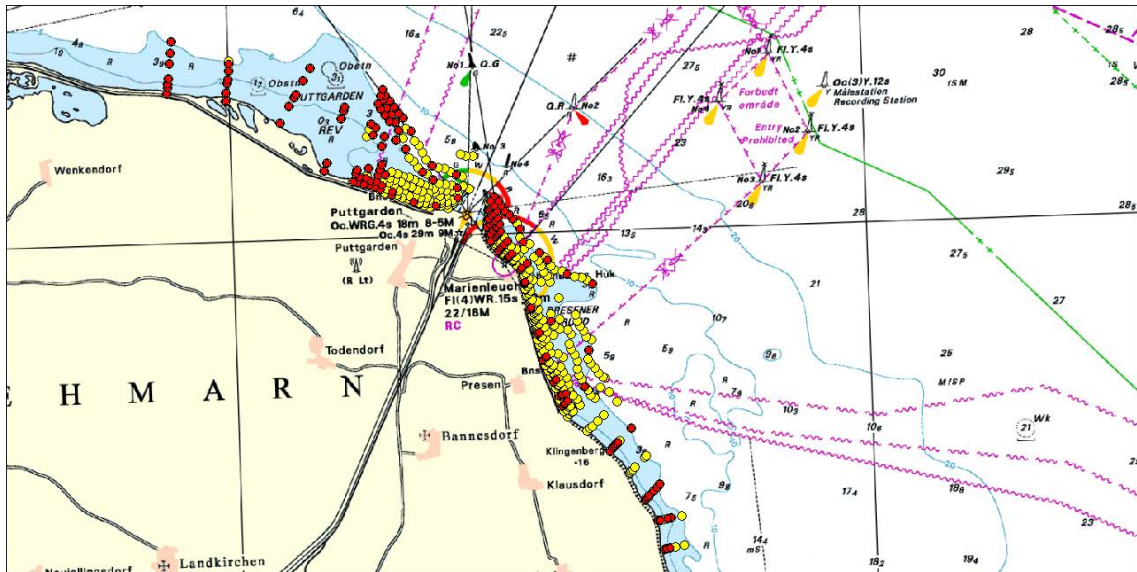
Figure 4.A. Sampling points near Puttgarden with sediment analysis data (red dots).
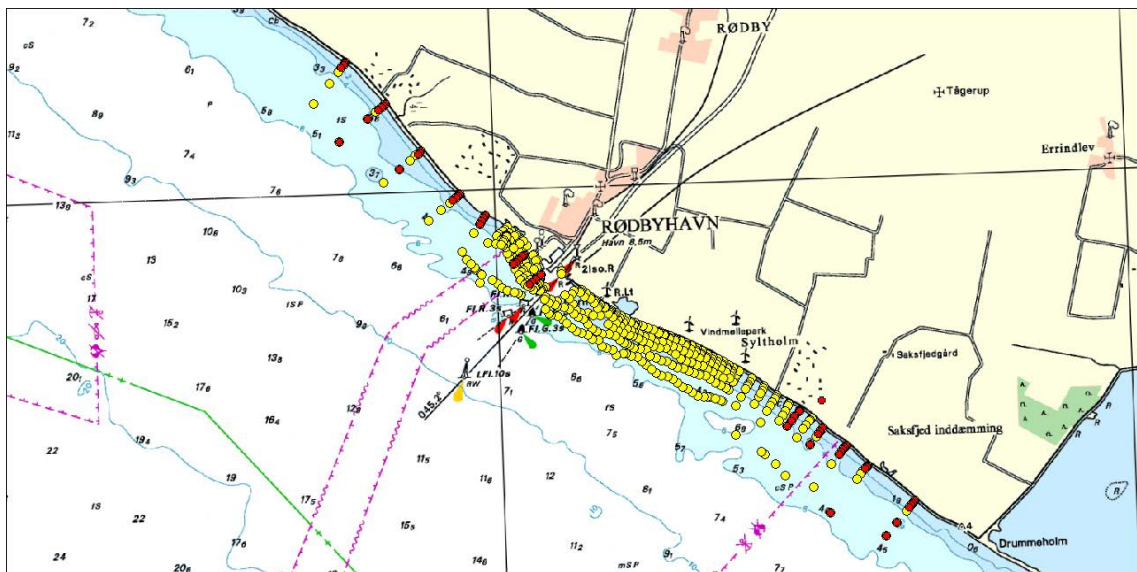
Figure 4 B. Sampling points near Rødby Harbour with sediment analysis data (red dots).

Figure 5: Fehmarn Belt 2009, Sediment sampling at the coast.

Methods used offshore

The samples at 1 m, 2 m, 3 m, 4 m, 5 m, and 6 m water depth were collected by means of a 250 cm^2 Van Veen grab (Fig. 6) from GEUS II. The samples were collected in plastic bags with a reference number.

Figure 6: Fehmarn Belt 2009, Van Veen grab used for sediment sampling.

Sample description and analysis methods

A total of 972 positions were selected for sampling. Out of these, 297 were selected for grain size analysis and only 6 of these have been analysed for fine-grained materials by means of Andreasen Pipette Analysis. A preliminary description of the samples has been made in the field and a photo was taken of each sample for documentation. The descriptions and photos are documented on a DVD attached to this document.

When received, the samples were registered with the following five categories:
- sampling date
- locality and sampling ID
- laboratory number in succession
- client
- analysis requirements

Remaining analysis material is only kept for 14 days after reporting.

Water content determination

The water content is determined in percentage of natural condition sample weight. The samples are dried at 105° C to constant weight. The analyses are carried out partly to the standard DS 405.11 and partly to DS 204 (se references).

Loss on ignition determination

The organic content and the content of chemically-bonded water are determined with the loss on ignition analysis. The loss on ignition is determined in weight % of material dried at 105° C. The analyses are carried out partly to the standard DS 405 and partly to DS 204 (se references).

Grain size distribution

The analysis is carried out in two phases:

Sieve analysis:
The total sample is dried and washed through a 0,063 mm sieve. The resulting sediment is sieved through a sieve column from 4 mm to 0,063 mm with ½ phi intervals, which corresponds to 14 sieves. The analysis is performed according to the standard DS/EN 933-1 extended by sieves to the ½ phi scale and test portion mass 0,1 kg.

Andreasens pipette method:
The particle size distribution of fractions smaller than 0.063 mm is determined by the Andreasens pipette method based on Stokes law using gravity sedimentation in 0,002 M Sodiumpyrophosphate. $Na_4P_2O_7 \cdot 10 H_2O$. The total particle size distribution is obtained by combining the Andreasens pipette method with the sieve analysis.

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Data

All samples are listed with a short description and a hyperlink to the sample photos in the sediment sampling data base accompanying this report on a DVD. An example of the data format is shown in Table 1. In table 2 (on accompanying DVD), the water content, loss on ignition and grain size data are listed. The grain size distribution shows the distribution of sand, silt and clay in the samples (example of data plot in fig. 7).

| work sheet 4 | Serial | Area | Sample | SAMLPE POSITION | | | Sample description | | PHOTOS | | |
Date	No	No	No	Easting	Northing	Depth m.u.s.l		En/Age	SAM.	east	west
06/07/2009	899	DK-4	423-0	650980	6059085	0	SAND: coarse-med, poorly sorted, ST gravelly (L,B)	Ma/Pg	Yes		
17/06/2009	67	DK-4	423-1	650967	6059074	1	SAND: coarse-med, poorly sorted, W shells fragments (L,O,B)	Ma/Pg	Yes		
20/05/2009	68	DK-4	423-2	650954	6059065	2	SAND: fine-med., sorted, W shells, W silt, OS (L,O,B)	Ma/Pg	Yes		
20/05/2009	69	DK-4	423-3	650895	6059017	3	SAND: fine-med., well sorted, W shells, W silt, OS (L,O,B)	Ma/Pg	Yes		
20/05/2009	70	DK-4	423-4	650840	6058974	4	SAND: fine-med., well sorted, W shells, W silt, OS (L,O,B)	Ma/Pg	Yes		
20/05/2009	71	DK-4	423-5	650799	6058942	5	SAND: fine-med., well sorted, W shells, W silt (L,O,B)	Ma/Pg	Yes		
20/05/2009	72	DK-4	423-6	650440	6058657	6	STON: HB; W gravels, W sea weed (D,B)	GL/Gc	Yes		
06/07/2009	900	DK-4	427-0	651155	6059096	0	SAND: fine-med, poorly sorted, W gravels (L,B)	Ma/Pg	Yes		
17/06/2009	73	DK-4	427-1	651128	6059079	1	SAND: coarse-med, poorly sorted, W shells fragments (L,O,B)	Ma/Pg	Yes		
20/05/2009	74	DK-4	427-2	651004	6058977	2	SAND: fine-med., well sorted, W shells (L,O,B)	Ma/Pg	Yes		
20/05/2009	75	DK-4	427-3	650900	6058894	3	SAND: fine-med., Well sorted ((L,O,B)	Ma/Pg	Yes		
20/05/2009	76	DK-4	427-4	650868	6058870	4	SAND: fine-med., well sorted, W shells (L,O,B)	Ma/Pg	Yes		
20/05/2009	77	DK-4	427-5	650832	6058841	5	SAND: fine-med., well sorted, W shells (L,O,B)	Ma/Pg	Yes		
20/05/2009	78	DK-4	427-6	650530	6058602	6	NS, (HB)		No		
06/07/2009	901	DK-4	431-0	651212	6059011	0	SAND: fine-med, poorly sorted, W gravels (L,B)	Ma/Pg	Yes		
21/06/2009	79	DK-4	431-1	651180	6058991	1	SAND: fine-med., sorted, W shells, W gravels (L,O,B)	Ma/Pg	Yes		
20/05/2009	80	DK-4	431-2	651043	6058880	2	SAND: fine-med., Well sorted (L,O,B)	Ma/Pg	Yes		
20/05/2009	81	DK-4	431-3	650971	6058822	3	SAND:fine-med., well sorted (L,O,B)	Ma/Pg	Yes		
20/05/2009	82	DK-4	431-4	650938	6058796	4	SAND: mid., sorted, W shells (L,O,B)	Ma/Pg	Yes		
20/05/2009	83	DK-4	431-5	650888	6058757	5	SAND; Very fine, ST silty, sorted, sandy, W gravel, OS (O,G)	Ma/Pg	Yes		
20/05/2009	84	DK-4	431-6	650602	6058530	6	NS, (HB)		No		
06/07/2009	902	DK-4	435-0	651187	6058865	0	SAND: fine-med, poorly sorted, W gravels (L,B)	Ma/Pg	Yes		
21/06/2009	85	DK-4	435-1	651150	6058837	1	SAND: fine-med., sorted, W shells, W gravels (L,O,B)		Yes		
20/05/2009	86	DK-4	435-2	651110	6058806	2	SAND: fine-med., Well sorted, (L,O,B)	Ma/Pg	Yes		
20/05/2009	87	DK-4	435-3	651029	6058741	3	SAND:fine-med., well sorted (L,O,B)	Ma/Pg	Yes		
20/05/2009	88	DK-4	435-4	650967	6058691	4	SAND:fine-med., well sorted, W shells, W silt, OS	Ma/Pg	Yes		
20/05/2009	89	DK-4	435-5	650925	6058659	5	SAND:fine-med., sorted, W shells, W silt, OS	Ma/Pg	Yes		
20/05/2009	90	DK-4	435-6	650691	6058473	6	STON: W shell, W plants, (HB)	GL/Gc	Yes		

En=environment, GL=Glacier, Gc=Glacial, Pg= postglacial, Ma=marine, Rc=recent , NES=not enough sample, HB=Hard bed,OS=organic substance NS= No sample, W=with ST= Strongly L=Light, D=Dark, B=Brown, O=Olive, G=Grey, BL=Black, R=Red

Table 1. Example of description sheet from the sediment sampling data base accompanying this report on a DVD.
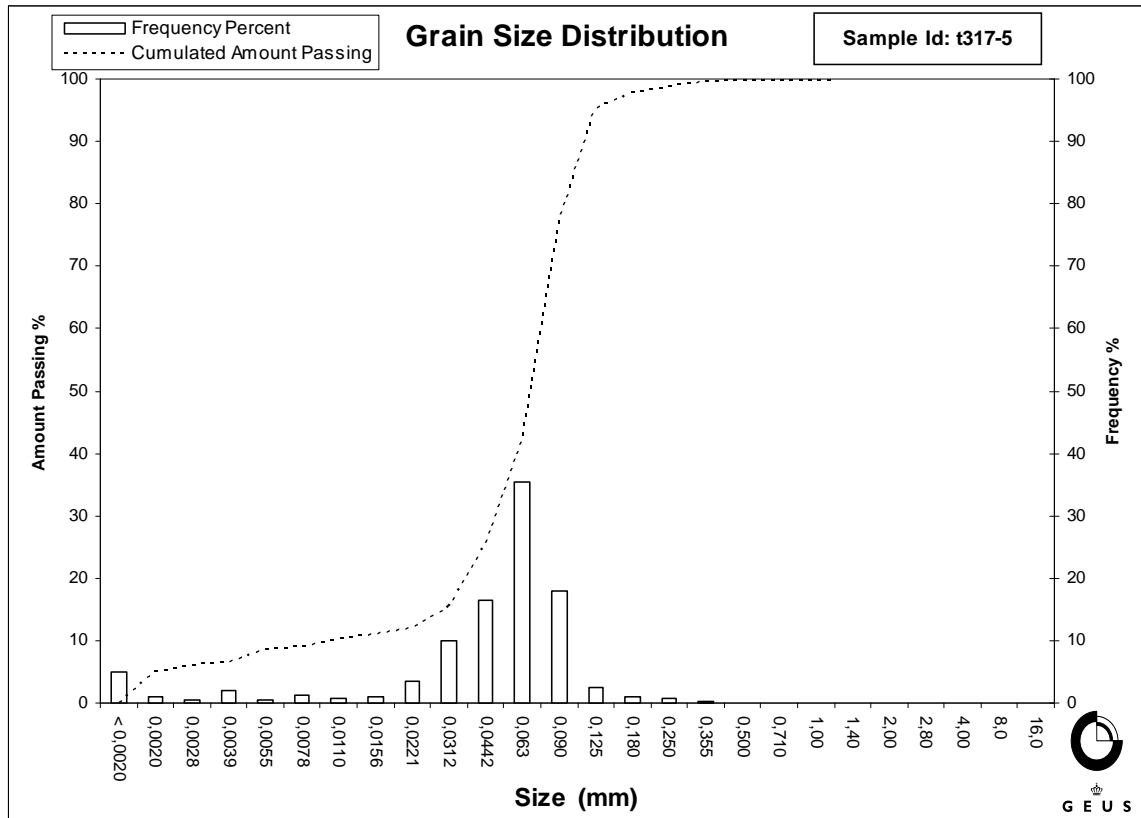
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Figure 7. Example of grain size distribution plot from Sample no. T317-5

References

Dansk Standard DS 204. Tørstof og gløderest. Dansk Standardiseringsråd, Kbh.1980.

Dansk Standard DS 405.11. Vandindhold. Dansk Standardiseringsråd, Kbh.1978.

Dansk Standard DS/EN 933.1. Kornstørrelsesfordeling bestemt ved sigteanalyse. Dansk Standard, 2004.

GEUS – forskrift. Andreasens pipettemetode.

Appendix I.

RTK DGPS information (Dansurvey)

Client: **GEUS**
   Lars Rödel

Femern campaign.
RTK: Reference stations.

Positioning Systems

Ref: Femern
              Date:19-06-2009
              Ver: final_ver1

Prepared by   John Dahl
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1. INTRODUCTION

EON operates one RTK reference station at Rødsand-2HR2. The RTK reference signal are broadcasted to all vessels via UHF, at frequency 449.100Mhz
This reference station is intended to be used initially throughout the area.

The base line is 10-28 km for the reference station at Rødbyhavn. The worst case accuracy is 5.5cm (XYZ, Equipment spec: 1.5cm+1.5ppm)

Starting with in-survey and geological investigations in 2006, this reference station has been used for the entire work.

The reference station coordinates has been verified by a chartered surveyor, using GPSnet-DK. Survey report can be requested.

For additional information, report malfunctioning etc.
Please contact Dansurvey.
Phone +45 45354585.
Mail jd@dansurvey.dk

2. GEODETIC PARAMETERS.

Geodetic Parameters: **UTM-EUREF-89. Zone 32N**
                                               Vertical reference, DVR90

As there is no official transformation between WGS84 and EUREF89 at Rødsand 2, a 7 parameter transformation cannot be provided.
Presently work concerning a transformation between WGS84 and EUREF89 is in progress by officials. (KMS)

3. HEIGHT REDUCTION TO VERTICAL REFERENCE DVR-90.

The geoids model DVR-90 is an attempt to be MSL in 1990±10y. The model is accurate for the in-ways Danish water, and may not be absolute accurate to MSL at the Fermen area
In 2004, officials decided at all surveys, charts, C-maps and construction work shall use DVR-90 as vertical reference.

The height reduction to DVR90 can be carried out in one of three ways.
a.) The official geoids model, filename 'dvr90g2002.01'
This is a binary data file, which can only be handled by GPS manufactures and acquisition software,, which equipment are custom designed to import this file format.
b.) Fixed separation. A fixed separation can be calculated by use of the official program KMSTrans2007.
c.) Use interpolation model in sub-contractors acquisition software.

Link to Transformation software.:
http://www.kms.dk/English/Geodesy+and+Surveying/Transformation/

Download the program KMSTrans2008, and the responding geoids model dvr90g2202.01

4. PRIMARY POSITIONING SYSTEM. (ROVER)

The primary positioning system shall be RTK using GPS L1/L2. The GNSS receiver shall be capable of operating at long baselines
The accuracy archived all depends on the rover supplied by the subcontractor.

Please pay notice to the installation of the rover antenna. The GNSS antenna should have best possible free view to the horizontal above 12 degrees. Alternative there's a risk that the rover measurements gets unstable, running on multi path signals.¨

The elevation mask on the rover should be set to 12'. Our experiences indicates that - using not too low elevating mask when working on long baselines with different GNSS antennas.

The UHF antennas must be mounted in sufficient height to receive the reference at Rødbyhavn, (Line of sight) and further the antennas must have free horizontal view to avoid obstructions to block out the signal.

The UHF radio shall have 1-way connection only on the serial connection. This to insure the vessels rover can't cause the UHF radio to transmit, and by this interfere/jam the signals from the reference stations.

A positioning verification shall be carried out and demonstrated prior to the contractual work is initiated.
All systems and software used for navigation and transformation to DVR-90, shall be included in the verification.
 (GNSS receiver, Acquisition software, Vessel reference unit, Vessel local reference measurement, etc.).

5. RØDBYHAVN RTK. REFERENCE, SPECIFICATION.

ID1: Reference Station: Rodbyhavn	
Station Name	**Station ID No: 1** Short ID: Rodbyhavn Long ID: Rodsand2
Reference Station co-ordinates. Geo_EUref 89 (WGS84) (WGS84)	Lat 54 39'18,81503 N Lon 11 20'57,32698 E Ellipsoid h = 90,314 m (Ant. APM to APC = 0.054+0.002m) Base-station h. 90.370 m (Entered value)
Reference Station co-ordinates. EUref 89 UTM Zone 32N	N 6058961.349 m. E 651550.376 m. DVR_90 h = 51.865 m. Geoide sep. 38.449 m (DVR90)
GNSS RTK receiver.	AD-Navigation model DC201B. L1/L2 GPS/GLONASS RTK receiver.
Measurements sent.	CMR format. (Reference coordinates = Antenna APC) GPS CA/L1,+P/L2, GLONASS L1 Update rate 5 hz. Time slot. 0.5 Period 0.25sec TX delay, 0.0s,
TX UHF radio specifications.	Telemetry: Satel 3AS Epic **Frequency 449.100 Mhz**, No addressing. TX power 10watt. Baud rate (Air) 19200. Omni directional antenna. (5db)
Rover telemetry: RX UHF Radio. (Recommended)	Telemetry: Satel 3AS Epic. Space diversity (Two antennas) **Frequency 449.100 Mhz**, . No addressing. Baudrate (RS232) 19200. Programmable. RS232 Connector DB9-F. RXd pin2.GND pin5. **Pin 3 (TX) must not be terminated due to risk of interference.**
Additional Information.	a.) DC-UPS, 30hours back up at 24volt. b.) Internet connection, fixed IP c.) GSM alarm & control. (SMS)

Figure 1: Rødbyhavn
         GNSS antenna (LH) & UHF.
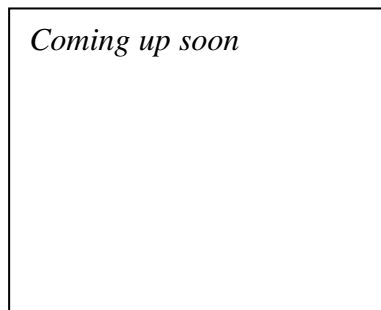
6. PUMPESTATION: RTK. REFERENCE, SPECIFICATION.

ID2 Reference Station: Pumpestation	
Station Name	**Station ID No: 2** Short ID: PumpeStation Long ID: Rodsand2
Reference Station co-ordinates. Geo_EUref 89 (WGS84) (WGS84)	Lat 54 04.65043N Lon 11 28 18.00532 E Ellipsoid h = 45.5157m (Ant. APM to APC = 0.054m) Base-station h. 45.5697 m (Entered value)
Reference Station co-ordinates. EUref 89 UTM Zone 32N	N 6055086.8232 m. E 659591.4277 m. DVR_90 h = 7.154 m. Geoid sep. 38.3615 m (DVR90)
GNSS RTK receiver.	AD-Navigation model DC201B. L1/L2 GPS/GLONASS RTK receiver.
Measurements sent.	CMR format. (Reference coordinates = Antenna APC) GPS CA/L1,+P/L2, GLONASS L1 Update rate 2 hz. TX delay, 0.25s, 0.25 time slot. Period 0.5sec
TX UHF radio specifications.	Telemetry: Satel 3AS Epic **Frequency 449.100 Mhz**, No addressing. TX power 10watt. Baud rate (Air) 19200. Omni directional antenna. (3db)
Rover telemetry: RX UHF Radio. (Recommended)	Telemetry: Satel 3AS Epic. Space diversity (Two antennas) **Frequency 449.100 Mhz**, . No addressing. Baudrate (RS232) 19200. Programmable. RS232 Connector DB9-F. RXd pin2.GND pin5. **Pin 3 (TX) must not be terminated due to risk of interference.**
Additional Information.	a.) Internet connection, fixed IP b.) Not 24 hours accessible