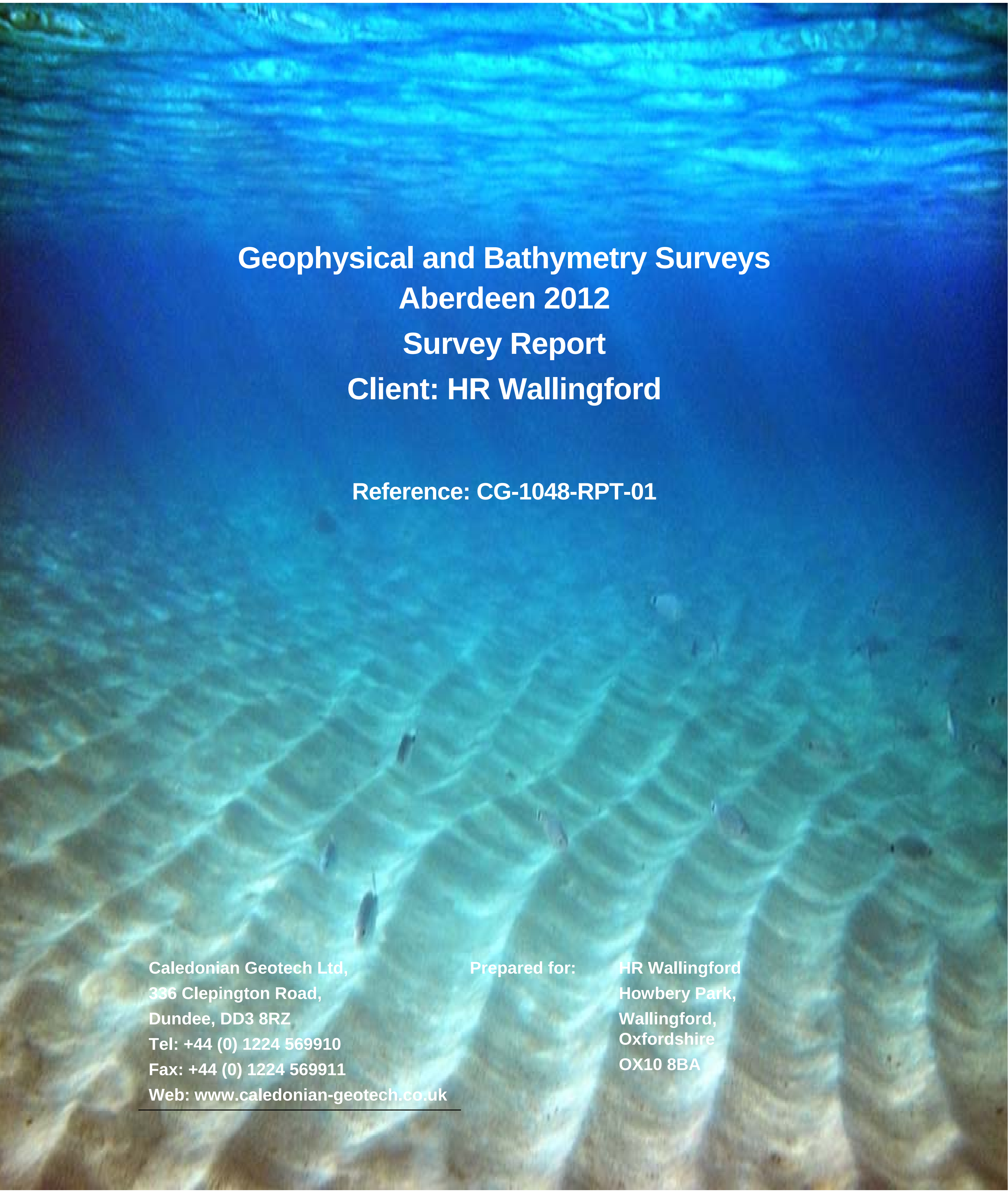
ABERDEEN HARBOUR
EXPANSION PROJECT
*November 2015*

*Volume 3:*
*Technical*
*Appendices*

# APPENDIX 6-D GEOPHYSICAL AND BATHYMETRY SURVEYS

Caledonian Geotech



# Geophysical and Bathymetry Surveys Aberdeen 2012

## Survey Report

## Client: HR Wallingford

**Reference: CG-1048-RPT-01**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# 1 Introduction

Caledonian Geotech Ltd (CG) was contracted by HR Wallingford to conduct a Survey to allow the suitability of dredging to be assessed within Nigg Bay. CG deployed the survey vessel Surveyor 2 to site to conduct the works. This document provides details of the equipment, personnel and methods adopted by CG to complete the scope of work in a safe and reliable manner and presents the results of the survey.

The site is located offshore in Nigg Bay, south of Aberdeen Harbour and comprises an area of approximately 1.8km$^2$ at 57°07‘55”N 02°03‘25”W (Figure 1). The primary objective was to identify and map the hard rock interface across the site and to produce Bathymetry data across the site; and identify location of seawater outfall. The exposed glacial deposits in the upper part of the cliffs have been designated as a Site of Special Scientific Interest.

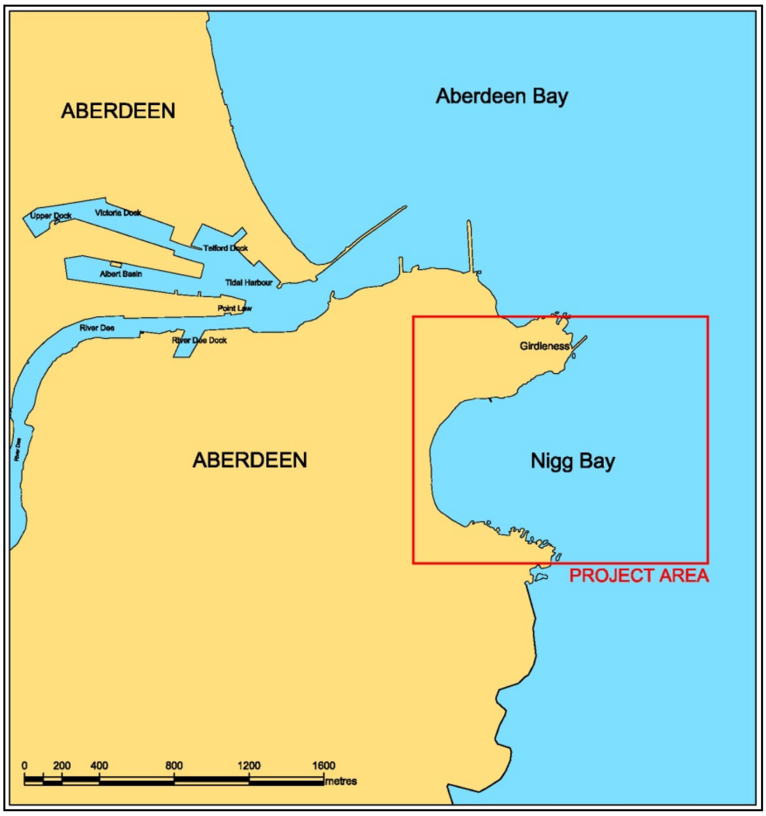



**Figure 1: Nigg Bay location**

The geophysical survey was conducted using an interferometric sonar system (Geoacoustics Geoswath) which provides bathymetric data and sidescan sonar imagery. The geotechnical survey involved the detection and mapping of the boundary between the seabed marine deposits and the underlying glacial till; and identifying the bed rock interface. This was achieved by a survey plan utilising a towed sparker and hydrophone system.

Seabed sampling (grab sampling) was conducted across the site to determine geotechnical properties. A total of 3 sites were sampled. CG provided a qualified sampling specialist onsite for the duration of the sampling programme with all samples subsequently analysed at a suitably accredited laboratory.

Mobilisation for the survey work commenced on 10th August 2012 and the survey was completed on the 23rd August with the vessel demobilised on the 31st August.

The key elements within the scope of work included the following:

- Conduct of HAZID in advance of mobilisation (09/08/2012)
- Production of Project HSE Plan, HAZID Results and Survey Procedure (14/08/2012)
- Delivery of *Surveyor 2* to Aberdeen Harbour, with the vessel being launched at East Commercial Quay and berthed within the Albert Basin (10/08/2012)
- Mobilisation of survey systems onto Surveyor 2 (13/08/2012 - 17/08/2012)
- Set up of systems and testing of interfacing and positioning (14/08/2012-17/08/2012)
- Field calibrations (15/08/2012 – 17/08/2012)
- Deploy tide and current meters (19/08/2012)
- Conduct Sub Bottom Profiler survey (19/08/2012 - 22/08/2012)
- Conduct Bathymetry survey (19/08/2012 - 22/08/2012)
- Conduct Sidescan Sonar survey (19/08/2012 - 21/08/2012)
- Conduct seabed sampling by Van Veen grab deployed by hand (21/08/2012)
- Demobilisation of *Surveyor 2* (31/08/2012)

# 2 Geological Setting of Nigg Bay

The superficial sediments within the survey area are Holocene sands, underlain by horizontally bedded silts, sands and gravels. These are classified by British Geological Survey (BGS) as Quaternary Marine Beach Deposits comprising sands, silts and gravels. However Nigg Bay is a former channel of the River Dee, which has been partially infilled with glacial tills and sediments associated with the last Ice Age. The channel is carved into the underlying bedrock and reported to descend to up to 40 m below sea-level. Part of the upper cliffs of Nigg Bay is an area classified as a Site of Special Scientific Interest (SSSI) owing to the glacial sediments within the surrounding cliffs, some of which have been transported from as far as Scandinavia.

The bedrock which encircles the bay comprises of Dalradian Psammites and Semipelites, originally formed in shallow seas as sedimentary rocks and transformed by low grade metamorphism, igneous intrusions have subsequently altered the sequence. The igneous rock within the survey area is unnamed but is estimated as Archaean to Silurian in Period. It was originally formed by silica poor magma. Subsequently these rocks have undergone metamorphism associated with the Caledonian Orogeny, which began in the late Cambrian and continued into the Silurian with the closing of the Iapetus Ocean, caused by the collision of Laurentia and Baltica.

### 2.1.1 Historical Geotechnical Investigations

Historical borehole logs were obtained from British Geological Survey by HR Wallingford (BGS, 2010). These boreholes are presented in a GeoRecords Plus+ report (Report Id: BH_116126_1). From this report three relevant boreholes were identified for use during the sub bottom profiler data correlation and are presented in the following table.

| BGS Ref | Date | Location | |
|---|---|---|---|
| | | Easting | Northing |
| NJ90SE7807/7 | 1973 | 397045 | 804546 |
| NJ90SE7807/11 | 1974 | 397444 | 804167 |
| NJ90SE7807/17 | 1974 | 397709 | 804184 |

# 3 Definitions and Abbreviations

| Term | Description |
|---|---|
| Company/Employer | HR Wallingford |
| CG | Caledonian Geotech Limited |
| C-O | Computed minus Observed (correction from a calibration) |
| DTM | Digital Terrain Model |
| ETRS89 | European Terrestrial Reference Frame as adopted by UK Ordnance Survey mapping purposes using GPS |
| GNSS | Global Navigation Satellite System |
| GPS | Global Positioning System |
| MBES | Multi Beam Echo Sounder |
| OSGB36 | Ordnance Survey of Great Britain 1936 (UK Geodetic datum and mapping system) |
| OSTN02 | Ordnance Survey Transformation Network |
| PPE | Personal Protective Equipment |
| STAR | Safety Task and Responsibility |
| SBP | Sub Bottom Profile |
| SVP | Sound Velocity Profile |
| TVG | Time Variable Gain |
| VRS | Virtual Reference Station |
| WGS84 | World Geodetic System 1984 |

# 4 Survey Methodology

Personnel mobilised to Aberdeen Harbour and resided at a Hotel within close proximity to Aberdeen Harbour and travelled to the survey location daily.

Following mobilisation and quayside tests, wet tests of the subsea equipment were conducted within the vicinity of the harbour area. Operations commenced upon Client acceptance of vessel, hardware and acceptable data recovery. Onboard assessment of data quality was undertaken during the survey operations.

A Gyro Calibration, DGPS Health Check and Offset Survey was undertaken by RPS-Oceanfix International whilst the SII was berthed at Aberdeen Harbour on 15th August 2012 (Appendix VIII).

Geodetic parameters used for the survey positioning and charting are detailed in the following table:

| Horizontal | |
|---|---|
| Spheroid and Datum | WGS84 |
| Projection | UTM Zone 30 North |
| Semi Major Axis | 6378137.00m |
| Central Meridian | 03° 00’ 00” W |
| Latitude of Origin | 0° North |
| Longitude of Origin | 3° West |
| False Easting | 500000 m |
| False Northing | 0 m |
| **Vertical** | |
| Datum | Chart Datum (Lowest Astronomical Tide ) |

The following Work Instructions were used for reference during relevant activities:

| Document No | Document Title | Originator |
|---|---|---|
| CGIM-SUI-010A | Survey QC & General Guidelines for Nearshore Survey Work Installation | CG |
| CGIM-SUI-020 | Geodetic Guidelines | CG |
| CGIM-SUI-030A | Vessel mobilisation, De mobilisation & Calibration | CG |
| CGIM-SUI-031 | Vessel Dimensional Control Survey | CG |
| CGIM-SUI-040 | Calibrations & Checks – Positioning & Heading Reference Units Work Instructions | CG |
| CGIM-SUI-100 | DGPS Set up and Online QC Work Instruction | CG |
| CGIM-SUI-120 | Set up and Operation of EIVA Navipac Work Instruction | CG |
| CGIM-SUI-200 | Heading Ref Unit (HRU)/Gyrocompasses | CG |

| Document No | Document Title | Originator |
|---|---|---|
| CGIM-SUI-220 | Multibeam Echo Sounders | CG |
| CGIM-SUI-250 | Sub-bottom Profiler | CG |
| CGIM-SUI-330 | Grab Sampling | CG |
| CGIM-SUI-400 | Offshore Reporting & Chartering Work Instruction | CG |
| CGIM-SUI-410 | Tidal Computation | CG |

### 4.1.1 Survey Line Plan

The survey area is approximately 1.8 $km^2$ and is defined at its northern and southern seaward offshore extents as Lat 02° 02’ 15.59”, Lon 57° 08’ 22.74” and Lat 02° 02’ 15.59”, Lon 57° 07’ 37.89”. Survey lines were designed perpendicular to the coast line (east/west) with tie lines (north/south) designed to cross over or lie in close proximity to locations of historical borehole investigations. Actual lines were dictated by environmental aspects (weather and as found water depth) as well as Client direction. The designed survey lines are shown on Figure 2 with actual survey lines shown on Chart 1.

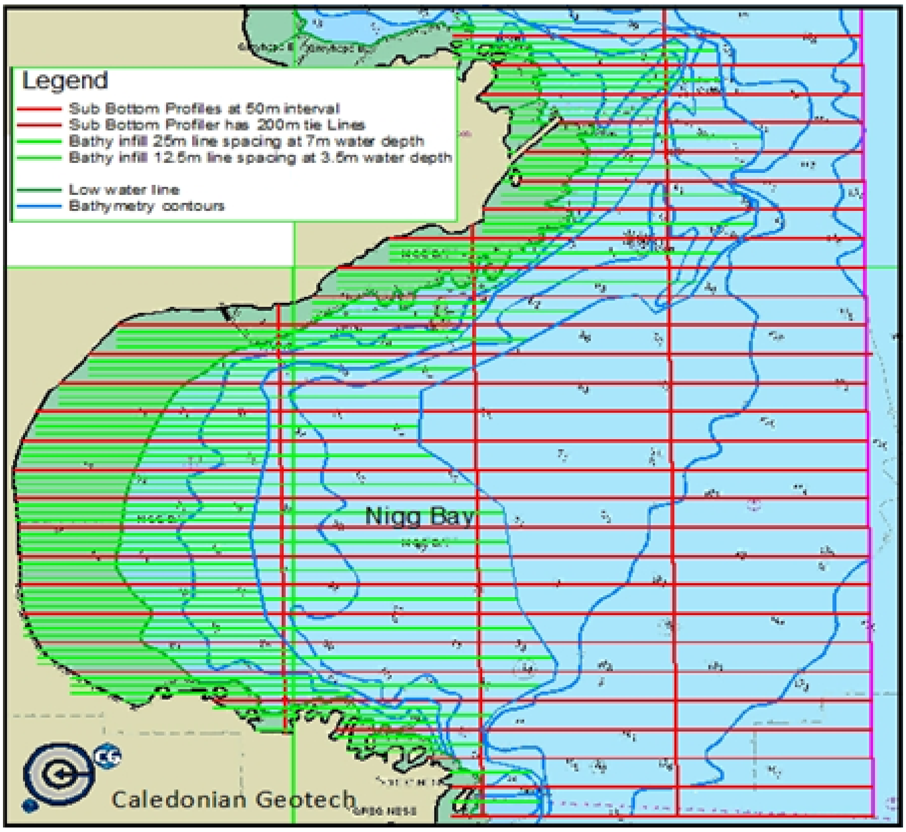



**Figure 2 Geophysical Survey lines layout**

### 4.1.2 Sub Bottom Profiler

The main Sub Bottom Profile survey lines obtained have a North/South orientation with 100 metres separation with additional cross-lines in an East/West orientation with a 25 metres separation.

The system comprised a towed sound source (sparker) and hydrophone array; and a digital recording system. The sparker was deployed on the port side of the SII and securely fixed to the hull, aiding navigation in shallow waters. The hydrophone was deployed from the forward davit on the opposing side of the vessel, in line with the vessel, where it was subjected to minimum wake and aiding safe navigation of the vessel in shallow water.

The digital recording system and power source was located within the wheelhouse of the survey vessel. The recording system permitted real time QC of data during survey operations. Unprocessed data was recorded, unaffected from user.

Sparker data was acquired in CODA as a .cod file. These were replayed applying band pass filters and TVG as a sgy. This was loaded into Seismic+ adding on the fixed layback to calculate the common midpoint of the towing array. The sub bottom data quality was generally very good. Some ambient noise was observed but a band pass filter (500-3000Hz) removed most of this during processing. The seismic velocity used for interpreting the sediments was 1600ms.

The R1 and Top of Rock horizons were picked using Coda and then exported as XYZ data files; these were created as depth below seabed. For both R1 and Top of Rock, the water depths from the Bathymetry data were then added to make these relative to LAT (lowest astronomical tide). The R1 and Top of Rock horizons were gridded using Eiva NaviModel2, at a cell size of 5m, with a collar width of 30m.

To combine the Top of Rock and Bathymetry data, the Bathymetry XYZ files were trimmed to the areas where rock was visible at the surface, this trimmed XYZ data was then merged with the Top of Rock XYZ data, these were then gridded using Eiva NaviModel2, as they were single line data sets they were gridded at 5m cell size with a 30m collar width, to give good coverage. The contours were then created form these grids and exported to an AutoCAD DXF file.

#### 4.1.3 Bathymetry

The Bathymetric survey was conducted utilising a Geoacoustics Geoswath Plus Swath Bathymetry system. The transducer head was mounted directly to the hull of the offshore survey vessel, deployed through a moon pool located on the vessel’s centre line. Vessel motion was removed from the recorded data by means of a Motion Reference Unit which was collocated with the MBES transducer head.

Pre survey calibration of the Bathymetry system was carried out in accordance with the manufacturer’s standard operating procedures.

Bathymetry data was acquired in conjunction with all Sub Bottom Profile (SBP) survey lines with 100 metre separation in a north/south and 25 metre east/west direction throughout the site. To reduce the need for unnecessary infill and to mitigate risks associated with shallow water operations two continuous lines were run at high water, in opposing directions following the coastline of the Bay.

Regular Sound Velocity Profiles (SVP) were undertaken through the course of the survey and the SVP profiles applied within the MBES system. All SVP profiles were recorded (Appendix (II)). All bathymetry was reduced to Chart Datum initially using predicted tides.

The data which was collected using the Geoacoustics Geoswath system was imported into the GS+ 50r Processing Suite. The individual sensor data was checked and de-spiked as required, i.e. Vessel Track, Pitch/Roll etc, with the Tidal reductions being applied to the depth values.

The data was then replayed through the GS+ software, there are a set of 4 filter options which were applied, these clean the data to remove any noise, outliers, or spurious points caused by external environmental factors. These are then saved as Individual Swath files.

The cleaned data is then gridded at an interval of 0.1 metres; this gridding also merges all the different survey runs into one integrated DTM. From this DTM the Bathymetry contours and Geo-referenced Image are created and exported for charting. The Geoswath Plus system is an Intereferometric sonar. It provides Side Scan Sonar data and Bathymetry data from the same swath.

#### 4.1.4 Sidescan Sonar

The acquisition of high frequency sidescan sonar data was acquired simultaneously with the Geoswath Plus System.

Side scan sonar data was acquired in Geoswath and then output in XTF format. The files were seabed tracked and TVG was applied and each file was mosaiced in CODA version 5.8. Each line was reviewed in the waterfall display to identify any potential debris items. Seabed features were digitised in Auto CAD Map and exported as DXF's for charting. The range acquired was between 60m and 80m and is considered of good quality for the duration of the survey.

#### 4.1.5 Sediment Sampling

Sediment sampling was undertaken using a grab sampler at each current meter deployment site. Each sample was issued to an accredited laboratory for particle size distribution testing as per BS1377 Part 2 1990. The grab sampler was deployed from SII by hand and rope.

Survey Equipment: Van Veen Grab Sampler 2L

#### 4.1.6 Personnel and Equipment

Survey personnel employed during this project are detailed in the following table.

| Description | Number |
|---|---|
| Project Manager | James Hailstones |
| Party Chief | Dan Massey / Rikki Kerchall |
| Geophysicist | Angela Simpson |
| Survey Engineer | Malcolm Mitchell |
| Geotechnical Coordinator | Marion Duff |
| Vessel Skipper | Peter West |
| Vessel Engineer | Wojciech Ciesla |

Survey equipment used during this project are detailed in the following table.

| Equipment Type | Quantity | |
|---|---|---|
| | Operational | Spare |
| *Surveyor 2* Survey Vessel | 1 | 0 |
| Survey safety boat (inflatable boat) | 1 | 0 |
| Veripos LD2 Position System | 1 | 1 |
| EIVA NaviPac Survey/Positioning Software | 1 | 1 |
| TSS Meridian Surveyor Gyrocompass | 1 | 0 |
| Geoacoustics Geoswath Plus Interferometrics System | 1 | 0 |
| Applied Acoustics Squid 500 and hydrophone | 1 | 0 |
| CODA Octopus DA200 Sonar Acquisition System | 1 | 0 |
| Valeport Midas 606 CTD Probe | 1 | 0 |
| Valeport 106 Current Meter | 3 | 0 |
| Valeport WLR | 2 | 0 |
| Van Veen Grab Sampler | 1 | 0 |

# 5 Discussion of Results

### 5.1.1 Bathymetry

All depths referred to below are reduced to Chart Datum using observed tides logged at Aberdeen Harbour.

The tide gauge is located on the south east corner of Waterloo Quay, Aberdeen Docks. The tide gauge equipment is housed in a brick building. The equipment consists of a pneumatic bubbler system with two full tide and mid-tide pressure points mounted on steelwork attached to a pile under the quay. All three pressure lines are monitored.

While two tide gauges were deployed at the survey site, the data from the Aberdeen based gauges was found to be of better overall quality and subsequently this was used for tidal reduction purposes.

The Northern and Southern edges of the bay show rock outcrops with the Western portion being the shallowest, gradually deepening Eastward.

The sewage outfall pipe was not observed on the Bathymetry data. No existing infrastructure was identified from the Bathymetry data and no features except for those relating to the local geology were observed within the survey area.

The vessel surveyed as shallow as safely possible and attained shoal readings of between +1m to -1m chart datum. The deepest extent of the survey area was approximately -22m Chart Datum.

Bathymetry data was of good quality with no gaps between lines. The technical specifications for the Geoswath by Kongsberg Geoacoustics LTD indicate that the maximum swath width is 390m and provides a data coverage of up to 12 times the water depth.[1]

### 5.1.2 Seabed Features

Two seabed types were identified from the side scan sonar data. The first sediment type is a uniform sandy seabed with occasional areas of sand waves (ripples), less than 0.8m in height with wavelengths between 10m and 14m (Figure 3). The second seabed type is an undulating rocky outcrop with high relief, strong backscatter and numerous boulders and pinnacles protruding from the seabed (Figure 4).

The bedforms identified in Chart 2 and Chart 3 are sinuous sand waves. At locations No.1 and No.2 the direction of transport is interpreted as south by southwest. This corresponds to long shore drift which comprises of mainly southward sediment transport along the Aberdeenshire coast (JNCC, 2011). Closer to the shoreline at location No.3, no bedforms such as sand waves could be determined from the data. It should be noted that the current velocity at this location slower when compared to the current velocity at locations No.1 and No.2 (see Section 5.3).

[1] Kongsberg Geoacoustics LTD (2012) GeoSwath Plus GeoAcoustics. http://www.km.kongsberg.com/ks/web/nokbg0397.nsf/AllWeb/E35EA810E2804876C12574BE004E0876/$file/GeoAcoustics-GeoSwath-Plus-data-sheet.pdf?OpenElementide Swath Bathymetry

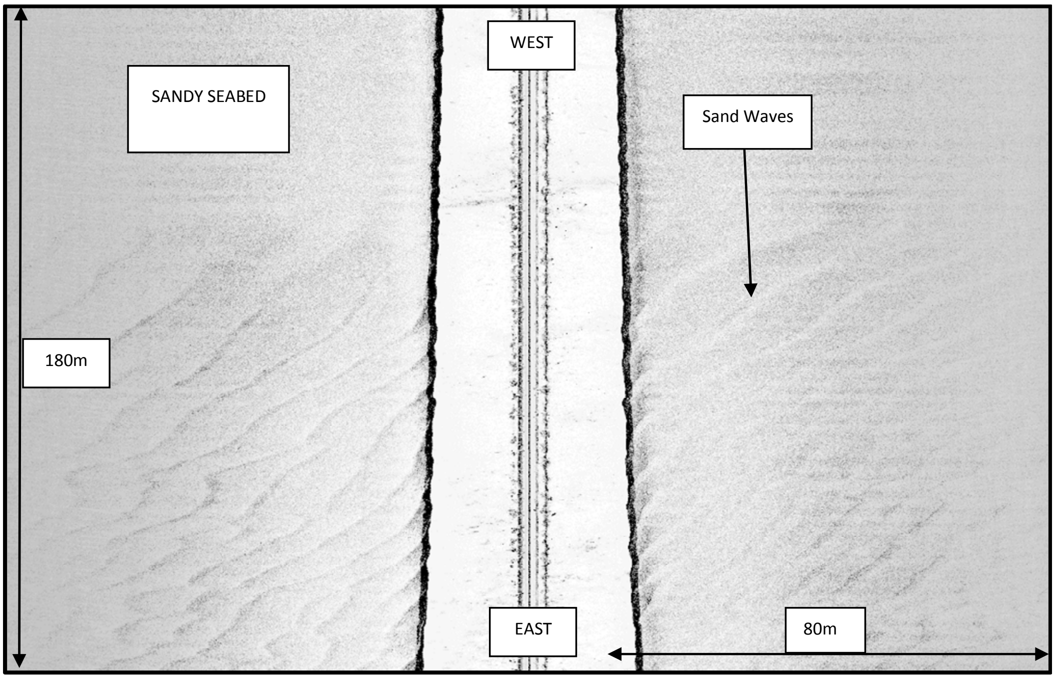



**Figure 3: Side scan sonar data example from main survey line NB_SB_022**

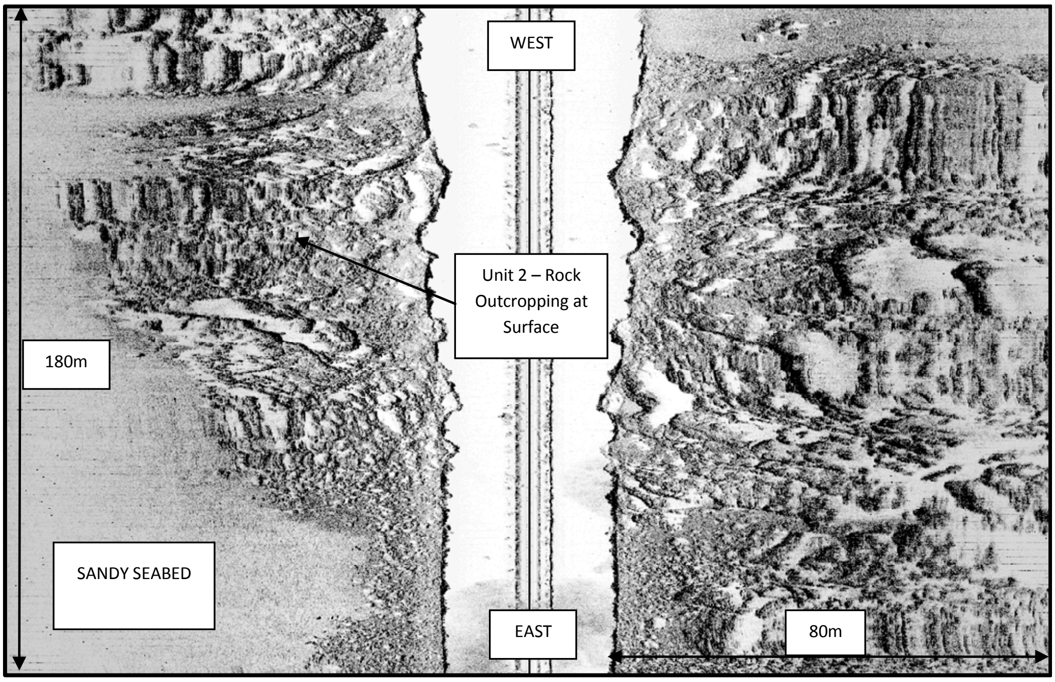



**Figure 4: Side scan sonar data example from main survey line NB_SB_004**

The rocky seabed is observed in the northern and southern extremities of the survey area and this delimits the sandy, rippled seabed sediments in the centre of the site. Seabed grab samples were taken at three locations. The seabed samples comprised of sand with a small percentage of silt (<5%) and gravel (<1%). This correlates well with the interpretation of the side scan sonar (Figure 5). The mosaic in Figure 5 has been produced with a positive polarity.

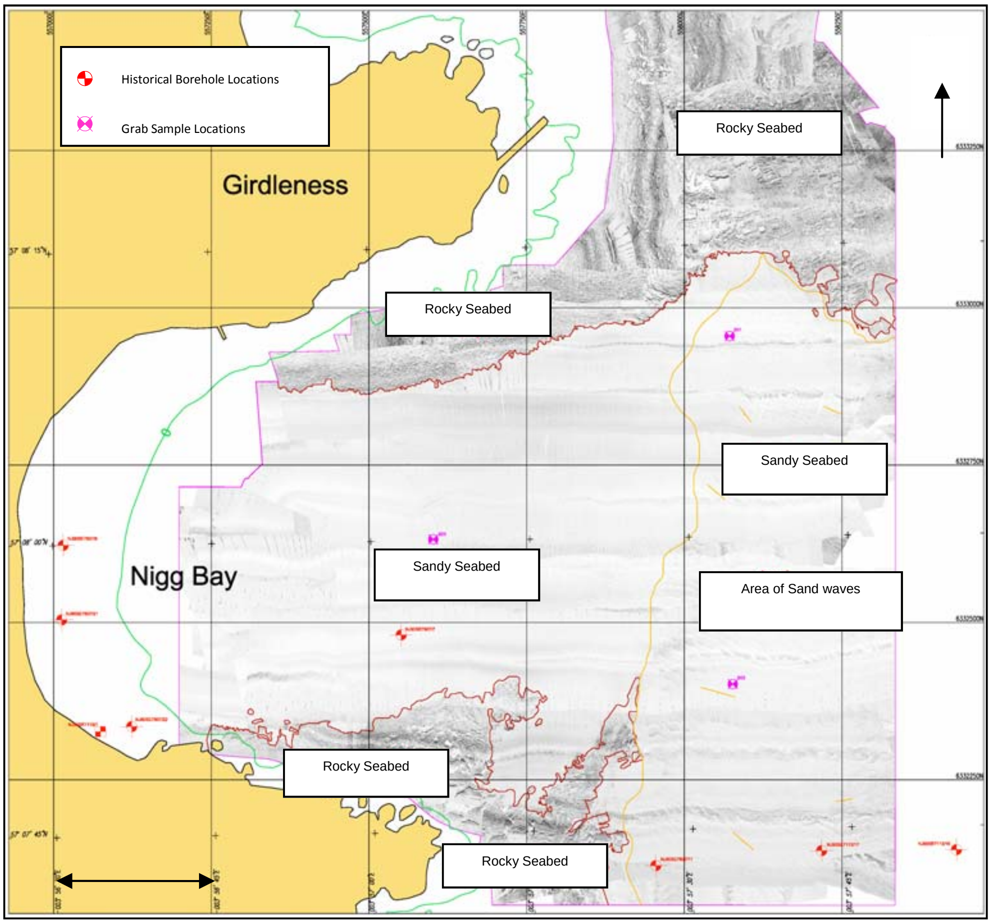



**Figure 5: Side scan sonar mosaic showing seabed sediments**

The sewage outfall pipe was not observed on the side scan sonar data and no distinguishable hyperbola was identified from the sub bottom data. No existing infrastructure was identified from the side scan sonar data and no contacts except for those relating to the local geology were observed within the survey area.

### 5.1.3 Expected Lithology

The expected lithology has been derived from seismic characteristics and correlated with available borehole data.

**Table 1 Expected Lithology of Nigg Bay**

| UNIT | Seismic Characteristics | Borehole Lithology | Geological Period and Epoch | Age Millions of Years | Min and Max Thickness |
|---|---|---|---|---|---|
| UNIT 1 | Sub parallel to parallel reflectors. Reflector R1 picks out the top of seismically chaotic lenses within the unit. | Sand, silt, gravel and cobbles | **Quaternary** Pleistocene to Holocene | Recent to <2 | 0 to 30 m |

| UNIT | Seismic Characteristics | Borehole Lithology | Geological Period and Epoch | Age Millions of Years | Min and Max Thickness |
|---|---|---|---|---|---|
| UNIT 2 | This unit has a low acoustic impedance. It exhibits chaotic reflectors. Beyond this unit no further reflectors can be seen. | Granite and Gneiss | **Archaean to Silurian** associated with the Caledonian Orogeny | 650 to 450 | Base of unit not seen, no thickness derived. |

## 5.2 Sediment Boundary Detection Survey

### 5.2.1 Sub Bottom Profiler Data

Unit 1

This unit comprises predominantly horizontal, parallel to sub parallel, moderately strong to strong reflectors within which a band of chaotic reflectors beneath R1 can be seen. The thickness of this unit and the chaotic layer beneath R1 varies throughout the site. This unit is interpreted as bedded sand, silt, gravel and cobbles. This unit is comprised of Quaternary marine sediments, glacial tills and gravels. R1 picks out a strong reflector below which numerous hyperbolae can be seen, interpreted as a coarse gravelly layer within this unit. The base of this unit is delimited by an irregular boundary which represents a period of erosion.

Unit 1 varies in thickness and is not present in the in the northern and southern extremities where the bedrock is at surface and within the centre of the site within a trough the sediments have a maximum thickness of 30m.

R1 provides a minimum depth of sediments in Unit 1; this may overly the top of the bed rock in some areas. Therefore R1 can be used as an absolute minimum depth of expected sediments and a cautious estimate, and "Top of Rock" can be followed as a more interpretive estimate of the top of the bedrock (which cannot always be followed where it is below the multiple.)

Unit 2

Unit 2 is uniform, characterised by moderate to very weak, chaotic reflectors interpreted as a solid rock body with low acoustic impedance. The unit is at seabed in the southern and northern extremities of the survey area and in the centre of the site a moderate reflector is frequently, but not always observed marking out the top of the unit. The upper limit of Unit 2 represents an unconformity, Unit 1 having been deposited much later. The base of Unit 2 cannot be seen and therefore thickness cannot be determined. A 3D representation of Unit 2, depth below seabed, is given in Figure 6.

This bedrock is present throughout the site. The eroded, weathered upper margin of the bedrock is undulating and irregular. In the most inshore area of the site, to the west it is difficult to distinguish from the overlying coarse gravels.

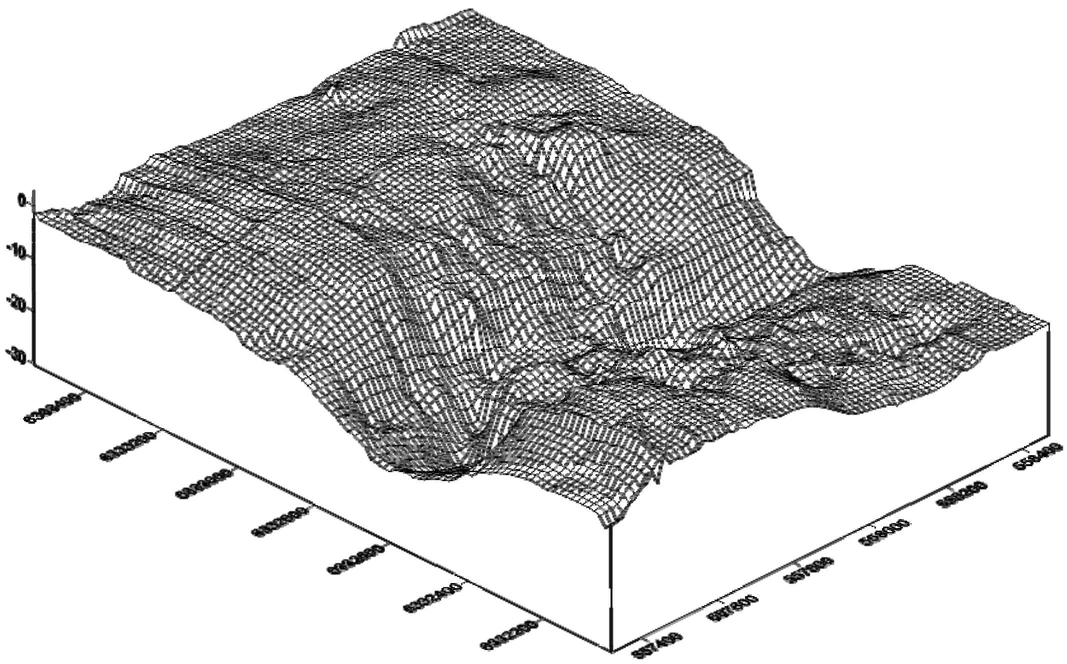



**Figure 6: 3D representation of the top of Unit 2, depth below seabed**

#### 5.2.2 Borehole Correlation

The sub bottom profiler data has been correlated with the supplied borehole data and is presented in the data examples below. These examples are for correlation only and should not be used interpretation. Three boreholes tie in with three survey lines with the largest offset being less than 3m, Figure 7 shows borehole locations and sub bottom profiler lines. Boreholes NJ90SE7/11 and NJ90SE7113/17 correlate well with the expected lithologies derived from the sub bottom data. Borehole NJ90SE7/11 (Figure 8 to Figure 10) reports a veneer of fine to medium sand underlain by cobbles and gravels to a depth of 4m below seabed. From this depth to the end of the borehole is weathered gneiss. This correlated well with the sub bottom profiler data for this area.

Borehole NJ90SE7113/17 (Figure 11 to Figure 13) reports sand and gravel to a depth of 6.3m and slightly to moderately weathered granite to a depth of 7.0m, beyond this no core was recovered until a depth of 9.5m at which point weathered metamorphic granite is logged until the end of the borehole. This correlates well with the sub bottom data for this area.

Borehole NJ90SE7807.7, detailed in the Figure 14 and Figure 15 below is the borehole which correlates least well with the sub bottom profiler data. At 23.8m below seabed the sub bottom data indicates that the bedrock should be present. However there is no logged change within the borehole until 25.25m below seabed and the unit is classified as gravel, cobbles and boulders, the mineralogy and identification of the boulders is not listed, this may be the top of bedrock which is partially weathered with some overlying gravel and cobbles. The reflector R1 which shows a change from parallel reflectors to numerous hyperbolae is also not represented in the borehole (Figure 16). This log lacks the detail of the other boreholes, reporting from 2.44m below seabed to 25.25m below seabed as sandy, clayey silt with cobbles with no differentiating layers within this unit.

There are two points which must be stated regarding the confidence in predicting the top of the bedrock within the centre of the site.

Firstly the borehole NJ90SE7807/7 lacks the same level of detail when compared to the other boreholes within this site. The seismic characteristics identified within the data are not represented in the borehole log. It is possible that the cobbles and boulders recorded are in fact weathered granite or gneiss. Due to this inconsistency, this borehole log has been disregarded in the interpretation of the seismic data.

Secondly, the bedrock within the centre of the site frequently disappears beyond the multiple. Confidence in any horizons identified beyond the multiple of single channel sub bottom data is very low. Therefore confidence is limited to areas where the rock horizon has been identified above the seabed multiple, which is denoted by the water depth of that area.

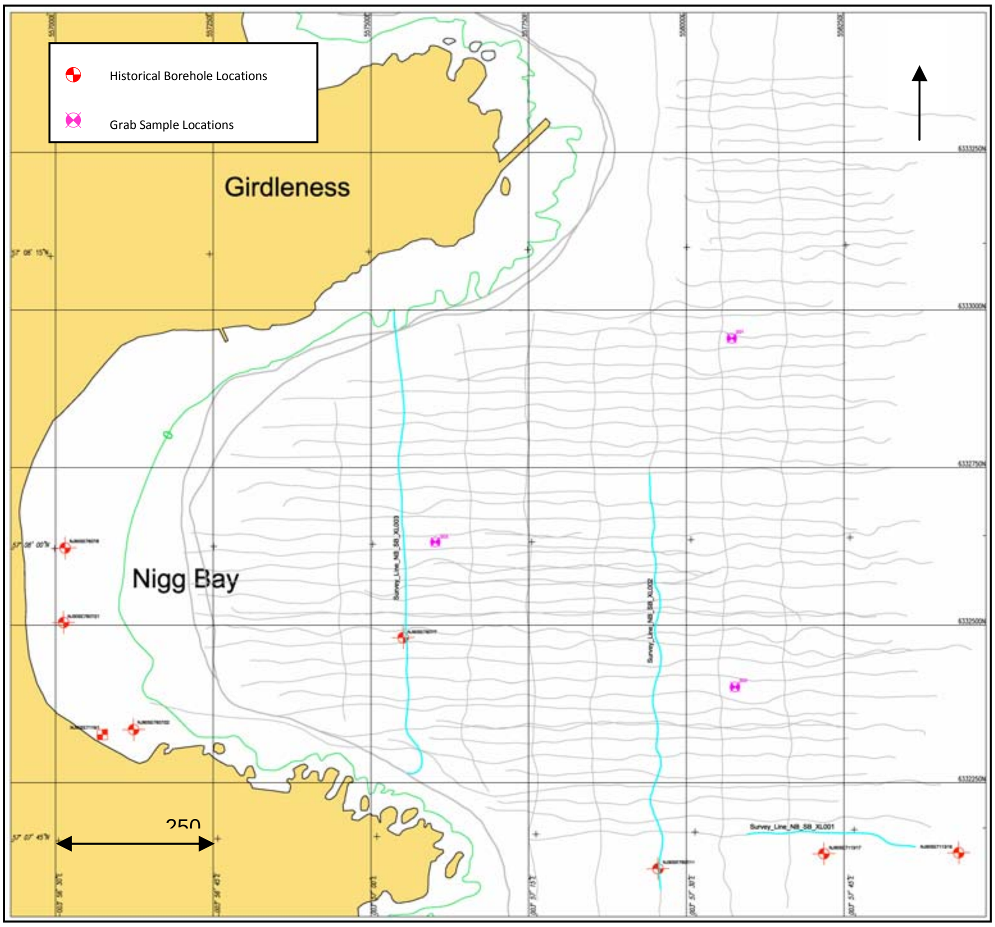



**Figure 7: Track plot from Seismic+ showing the Boreholes in Relation to the SBP lines**

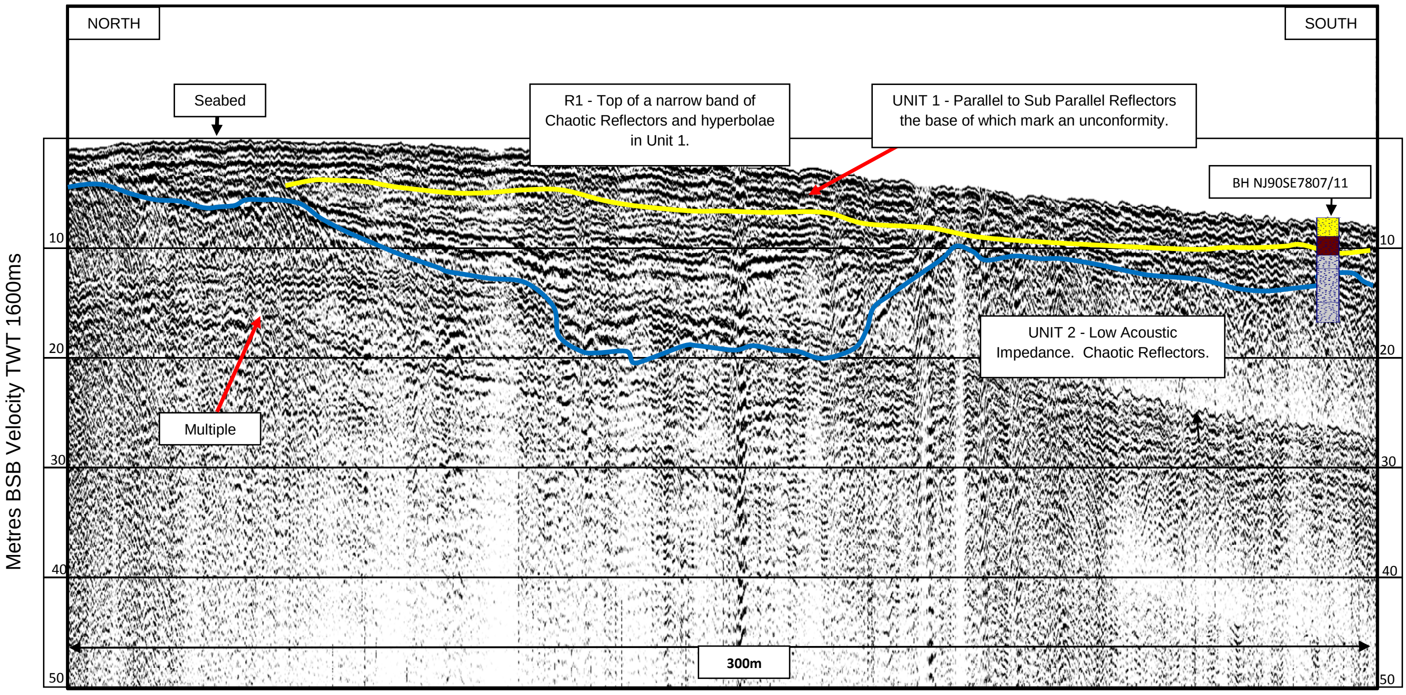



**Figure 8: Sub Bottom Profiler Data Example, Survey Line NB_SB_XL_002 and Borehole NJ90SE7807/11**

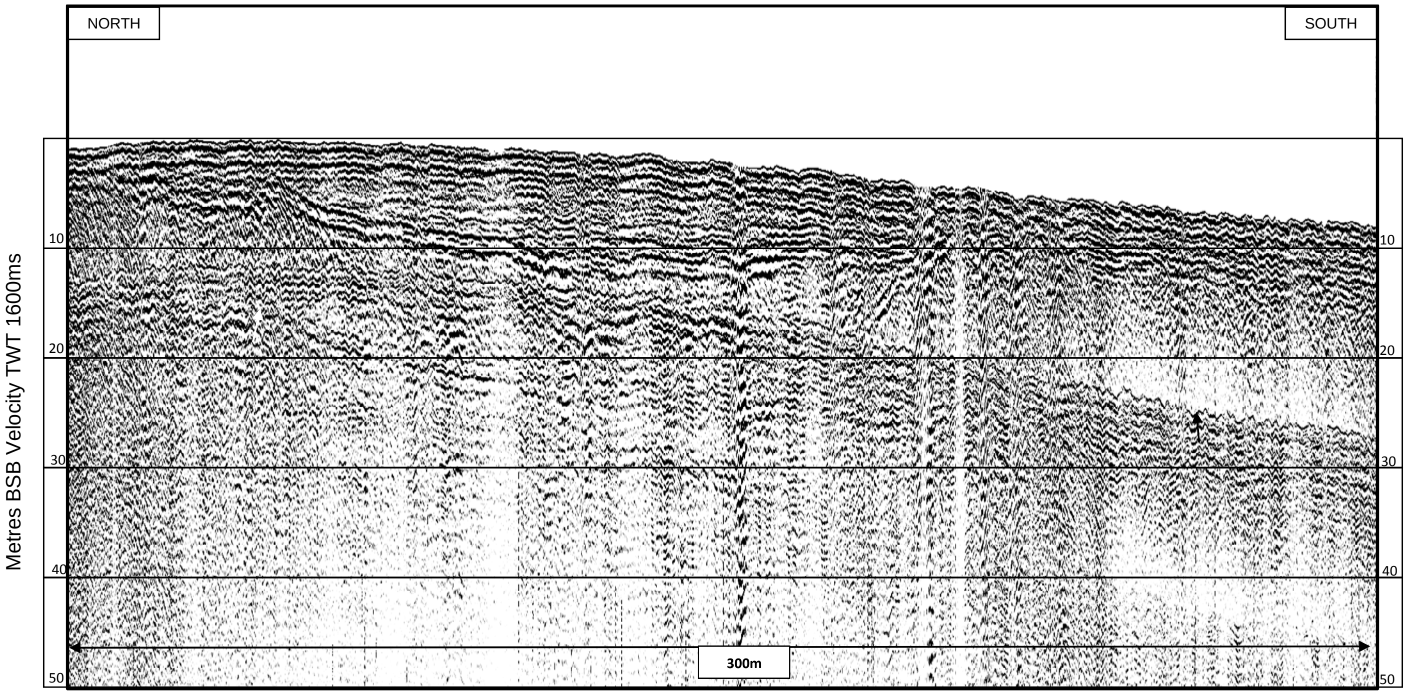
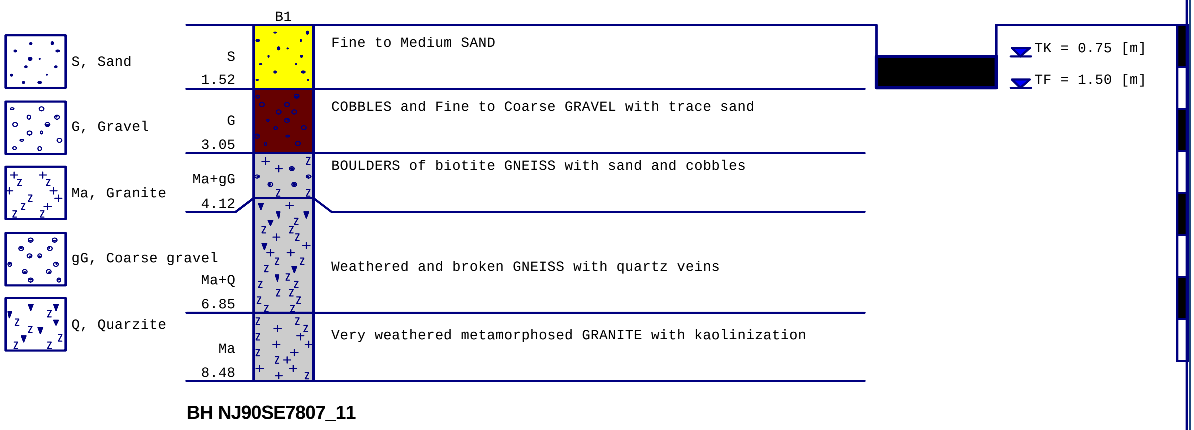



**Figure 9: Sub Bottom Profiler Data Example, Survey Line NB_SB_XL_002**




From Aberdeen Sewage Disposal Tunnelled Outfall Report on Site Investigation

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**Figure 10: Borehole NJ90SE7807.11 reproduced in BOHR[2]**

[2] BOHR is a graphical software package used for logging boreholes and trial pits.

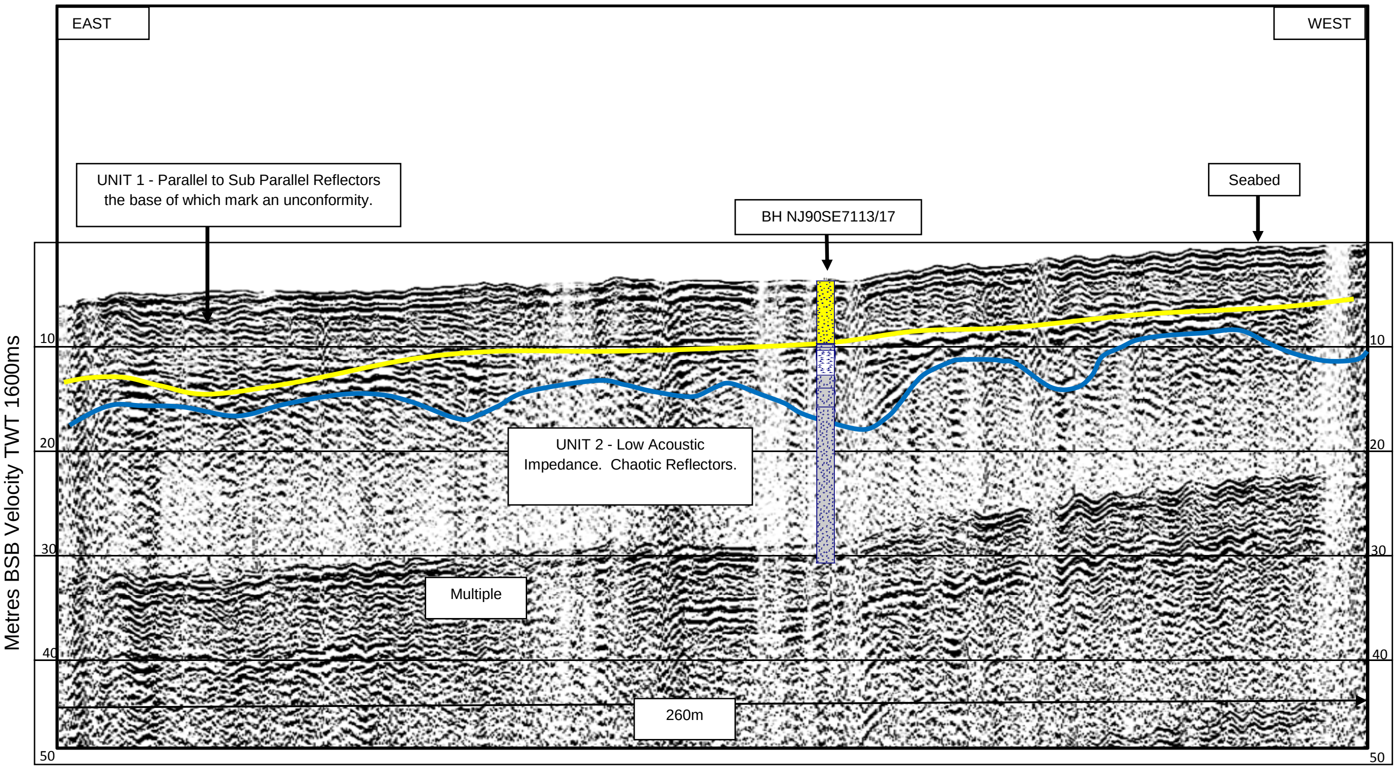



**Figure 11: Sub Bottom Profiler Data Example, Survey Line NB_SB_001 and Borehole NJ90SE7113/17**

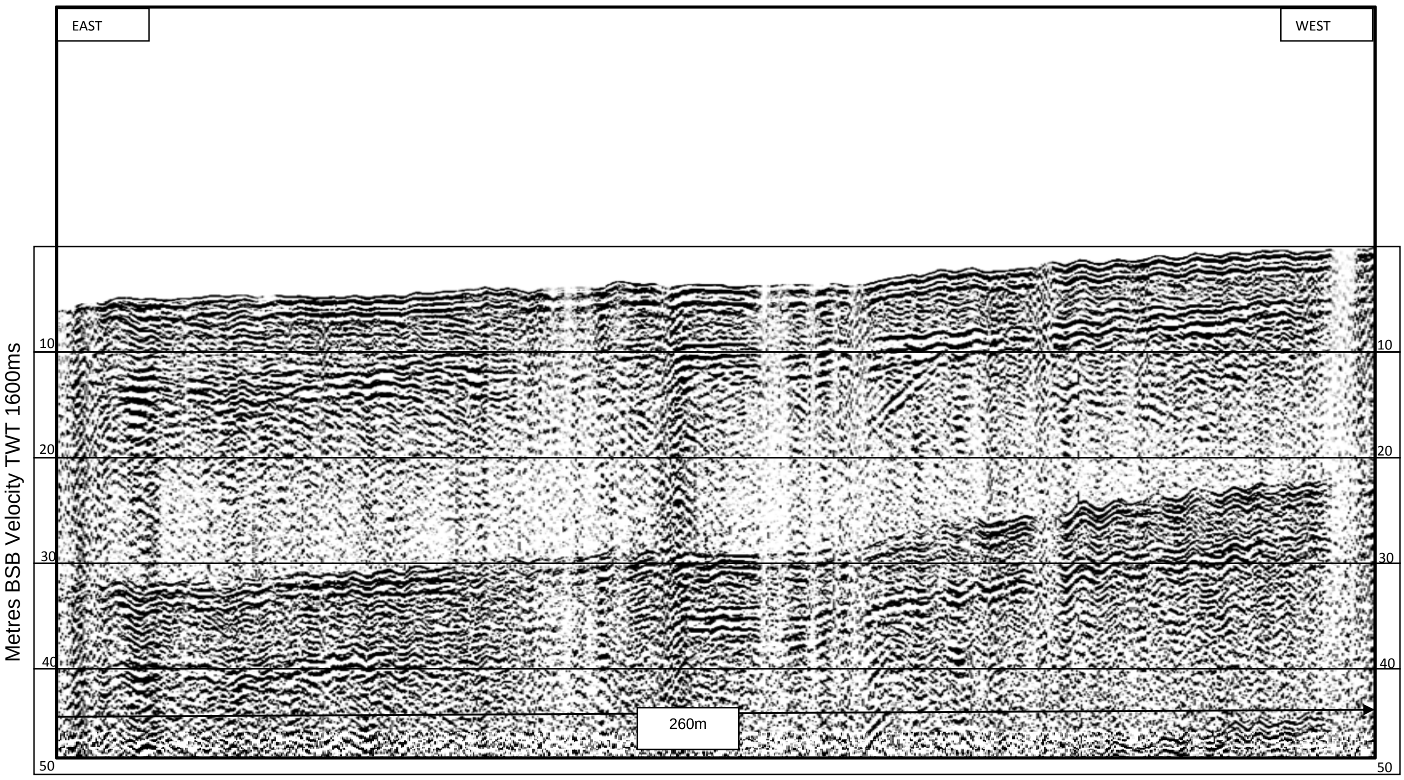
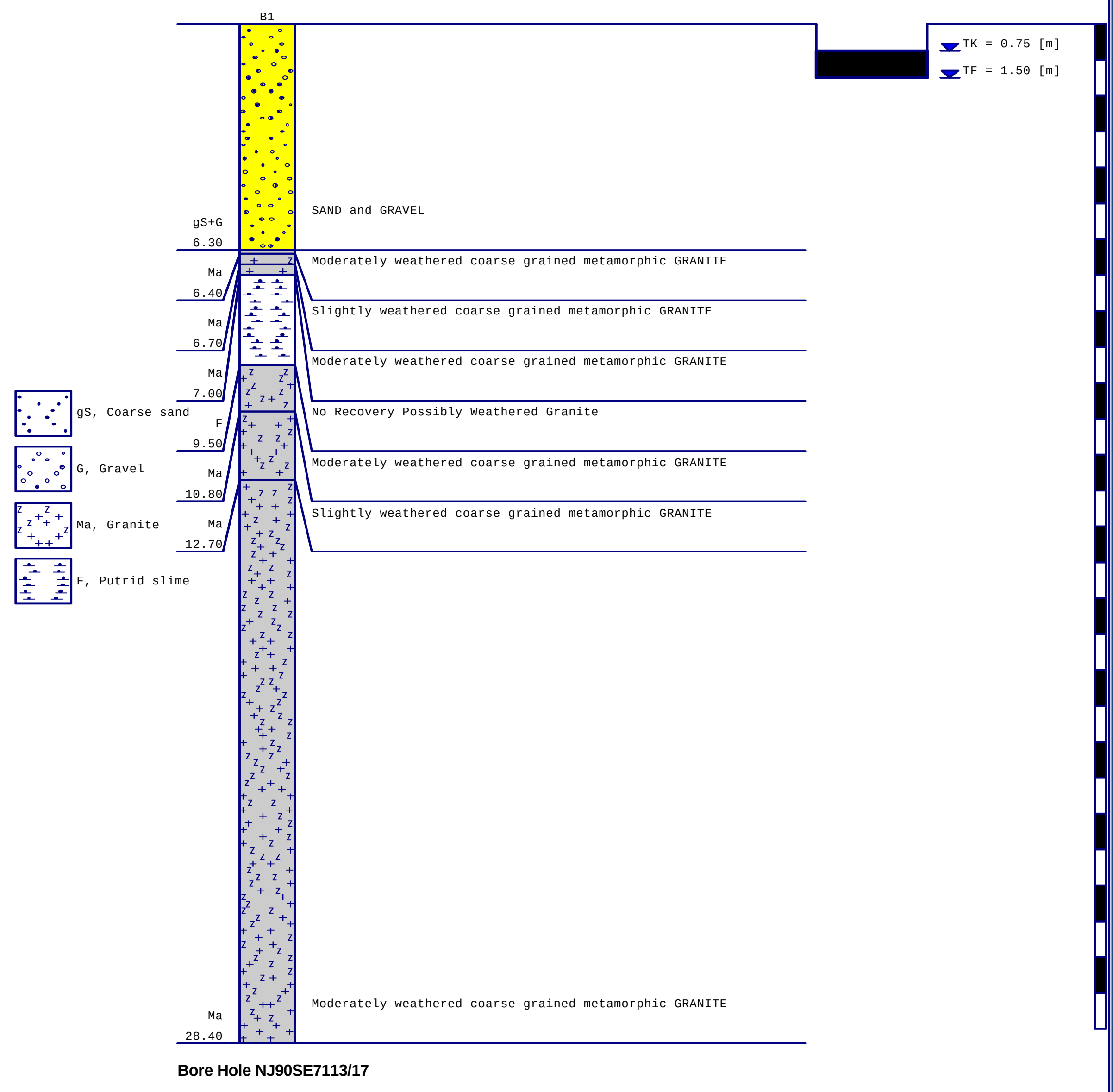



**Figure 12: Sub Bottom Profiler Data Example, Survey Line NB_SB_ 001**




| From Aberdeen Sewage Disposal Tunnelled Outfall Report on Site Investigation | |
|---|---|
| Scale 1:125 | Title: |
| File: | Date: 26 August 2012 |
| Page No.: | Project: |

**Figure 13: Borehole NJ90SE780717 reproduced in BOHR**

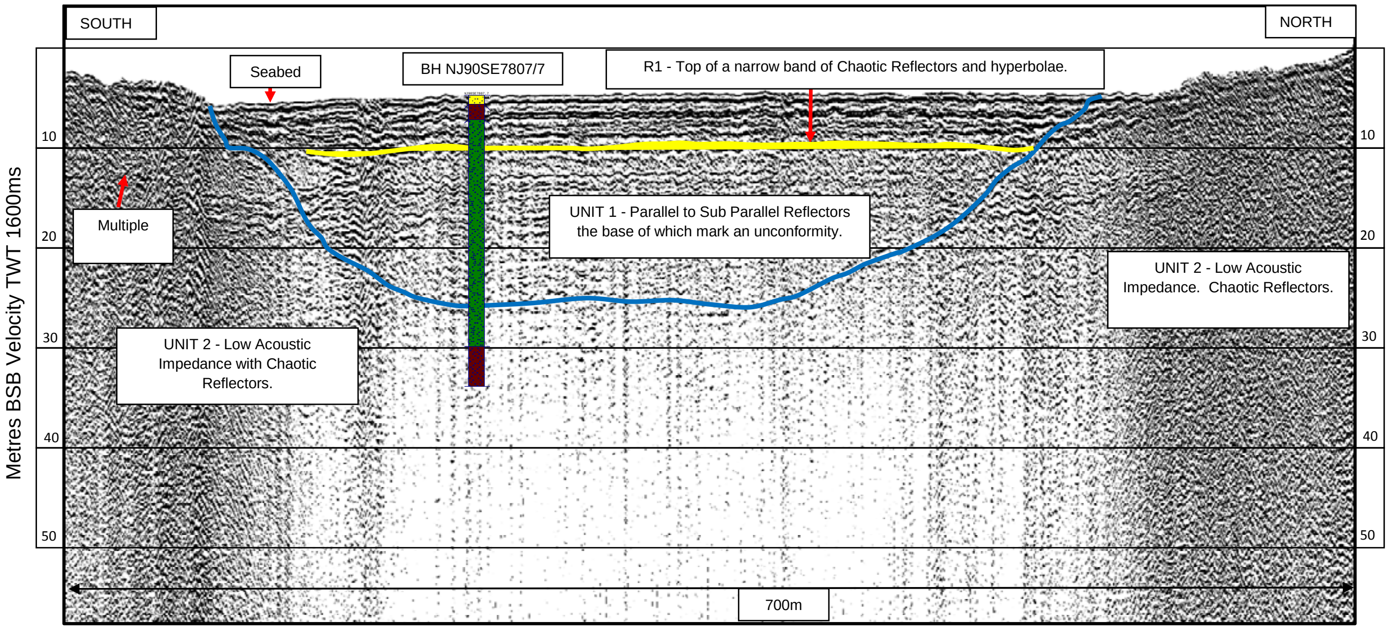



**Figure 14: Sub Bottom Profiler Data Example, Survey Line NB_SB_XL_003 and Borehole NJ90SE7807/7**

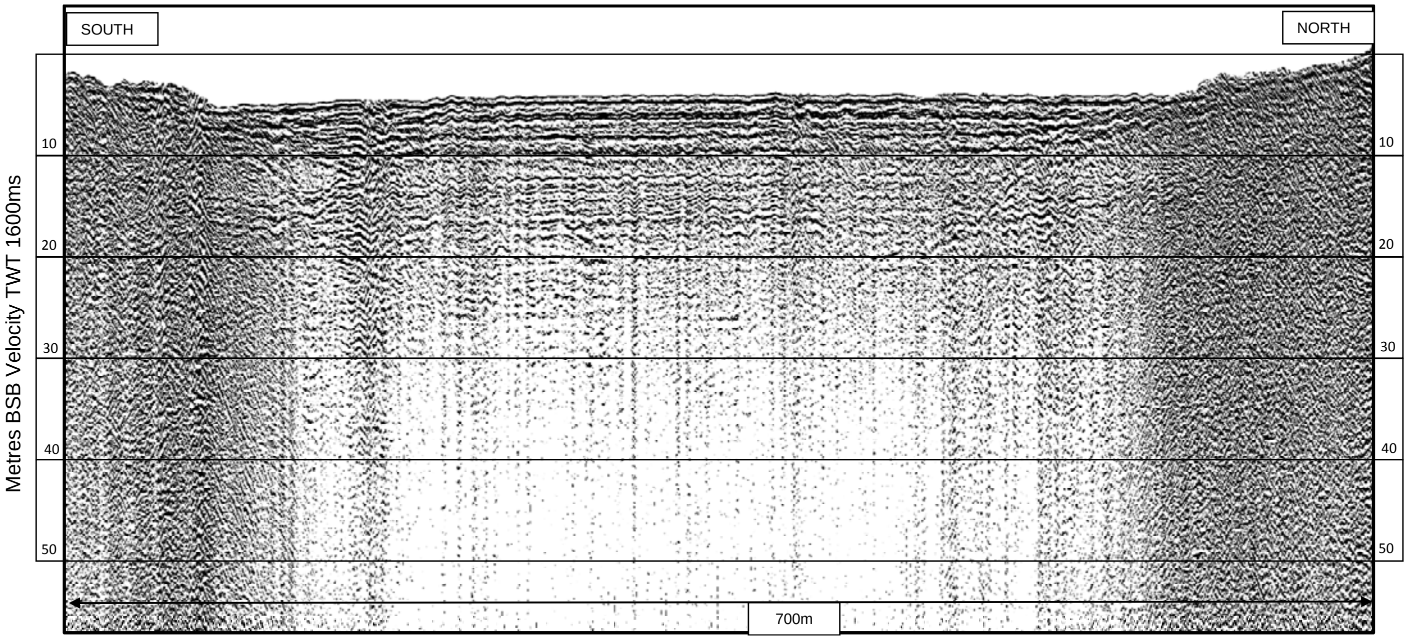



**Figure 15: Sub Bottom Profiler Data Example, Survey Line NB_SB_XL_003**

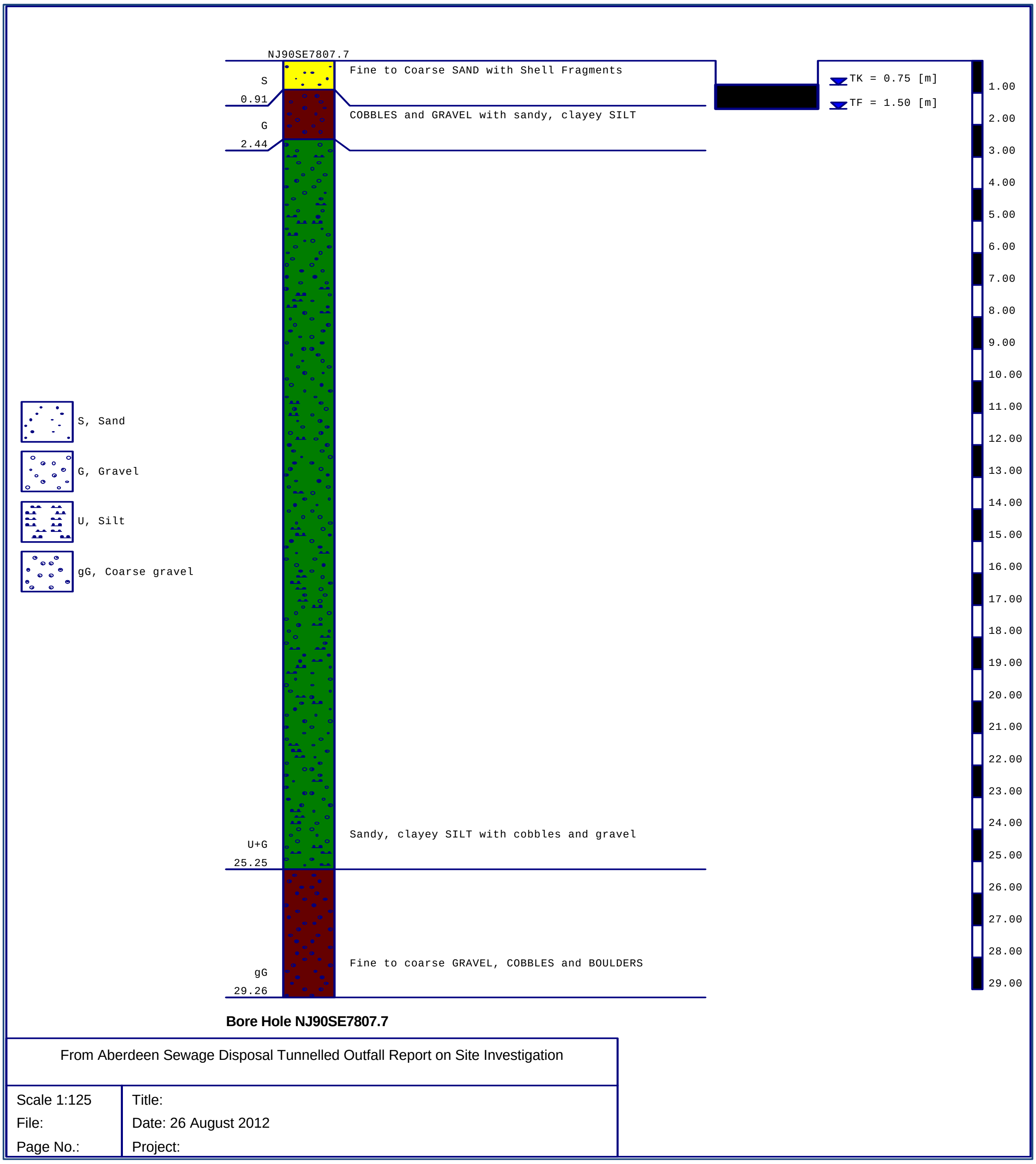



**Figure 16: Borehole NJ90SE7807.7 reproduced in BOHR**

## 5.3 Current Monitoring Results

The current meters were deployed at three locations within the site area and recorded both current flow direction (degrees) and current velocity (m/s). The current meter data pertained to water motions at one depth at the position of each current meter mooring location. The flow direction and velocity readings were obtained every three seconds. The average flow directions and current velocity range for each meter is given in the following table and displayed in Figure 17 to Figure 22. Due to the large amount of data recorded the current meter and flow direction has been displayed using a data interval of 1 hour.

| Current Meter | Location | | Height above seabed level (m) | Average Current Directions | | Velocity (m/s) |
|---|---|---|---|---|---|---|
| | Longitude (degrees, minutes, seconds) | Latitude (degrees, minutes, seconds) | | Flood Tide | Ebb Tide | |
| 1 | 057°08'10"N | 002°02'25"W | 4.5 | 190º | 34º | 0.037 – 0.774 |
| 2 | 057°07'52"N | 002°02'26"W | 6.0 | 192º | 23º | 0.024 – 0.936 |
| 3 | 057°08'00"N | 002°02'54"W | 3.0 | 289º | 36º | 0.023 – 0.193 |

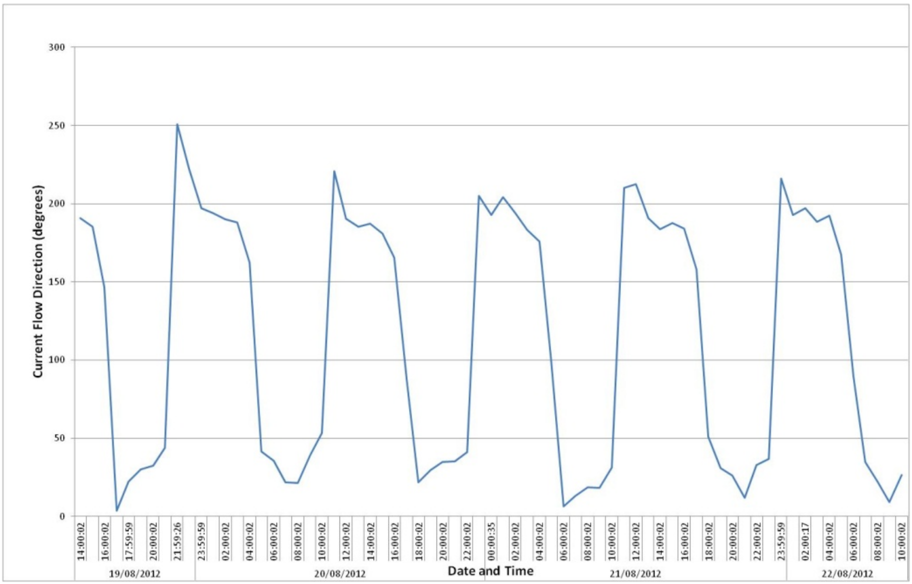



**Figure 17: Current flow direction recorded at Current Meter No.1**

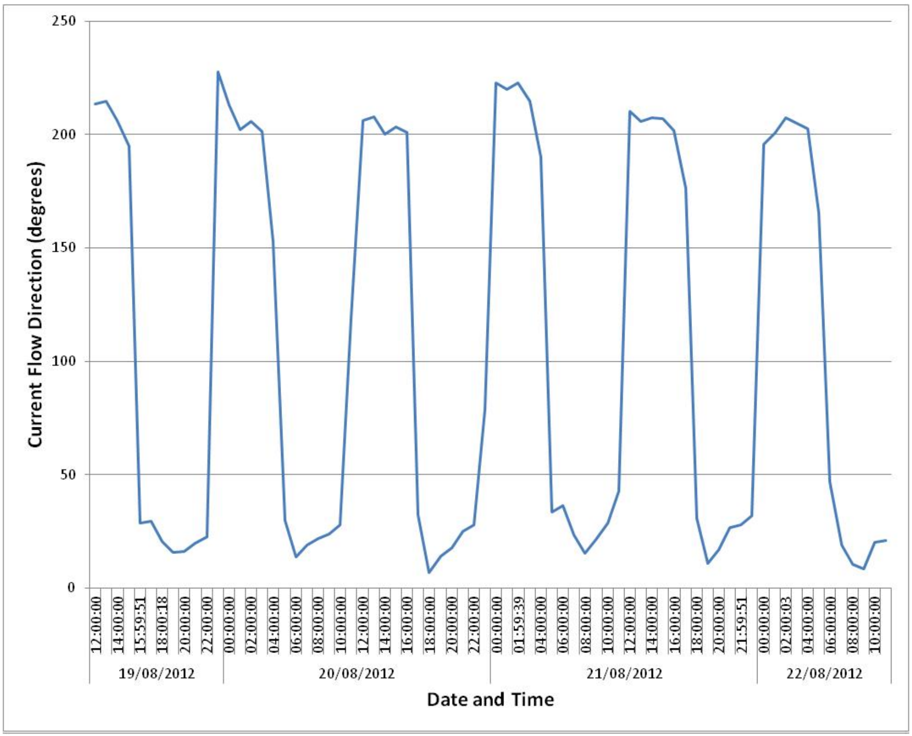



**Figure 18: Current flow direction recorded at Current Meter No.2**

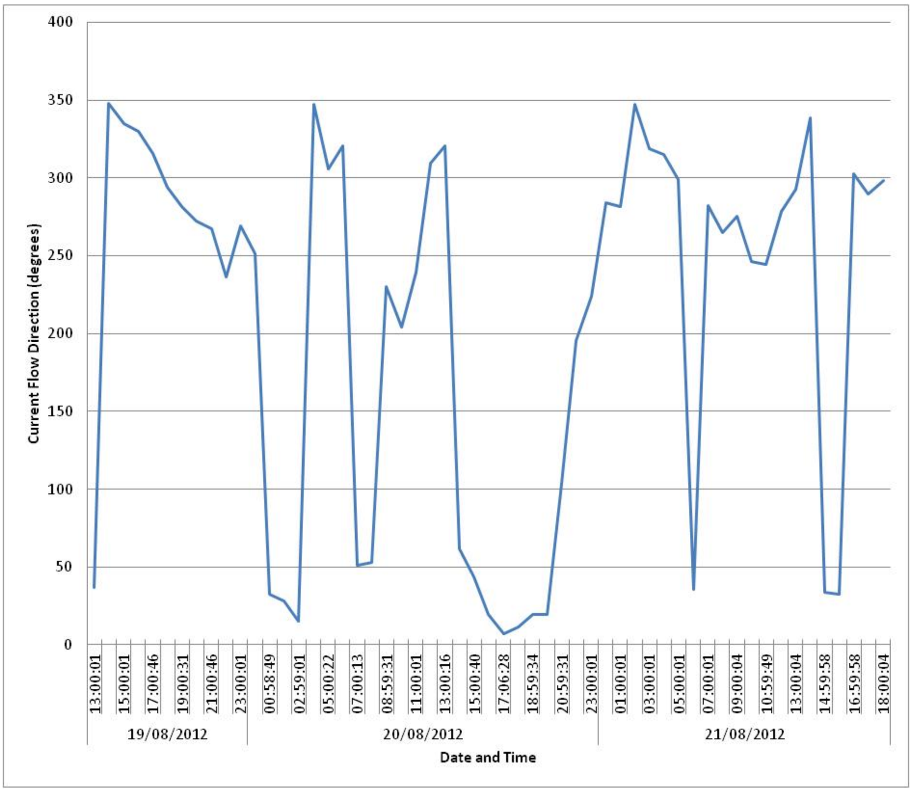



**Figure 19: Current flow direction recorded at Current Meter No.3**

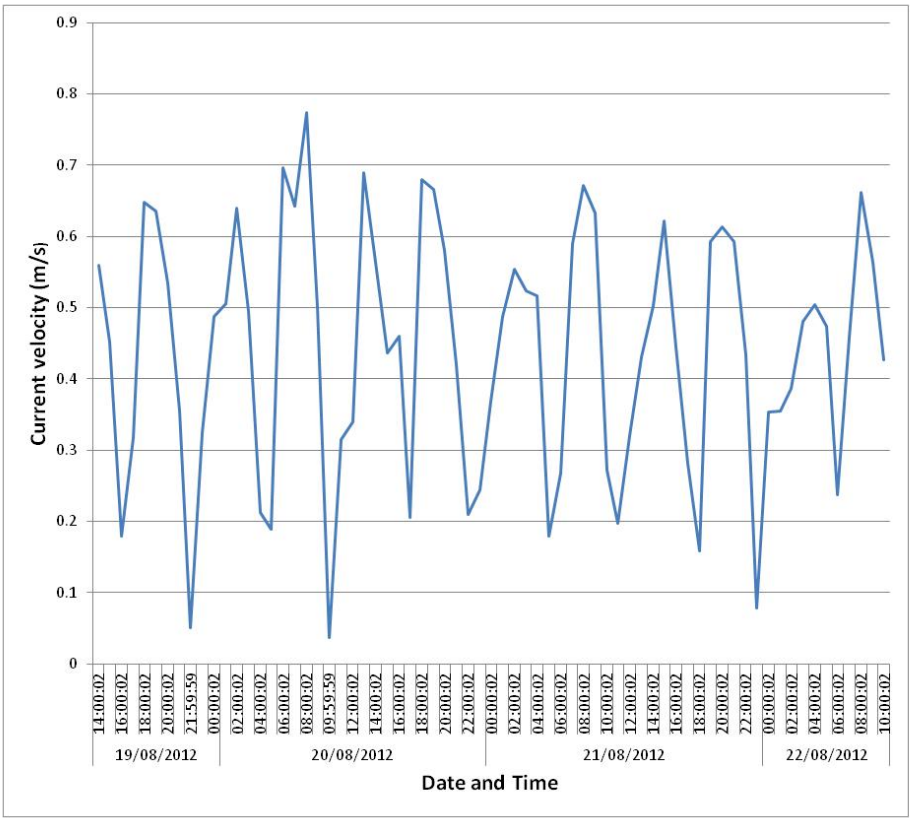



**Figure 20: Current velocity recorded at Current Meter No.1**

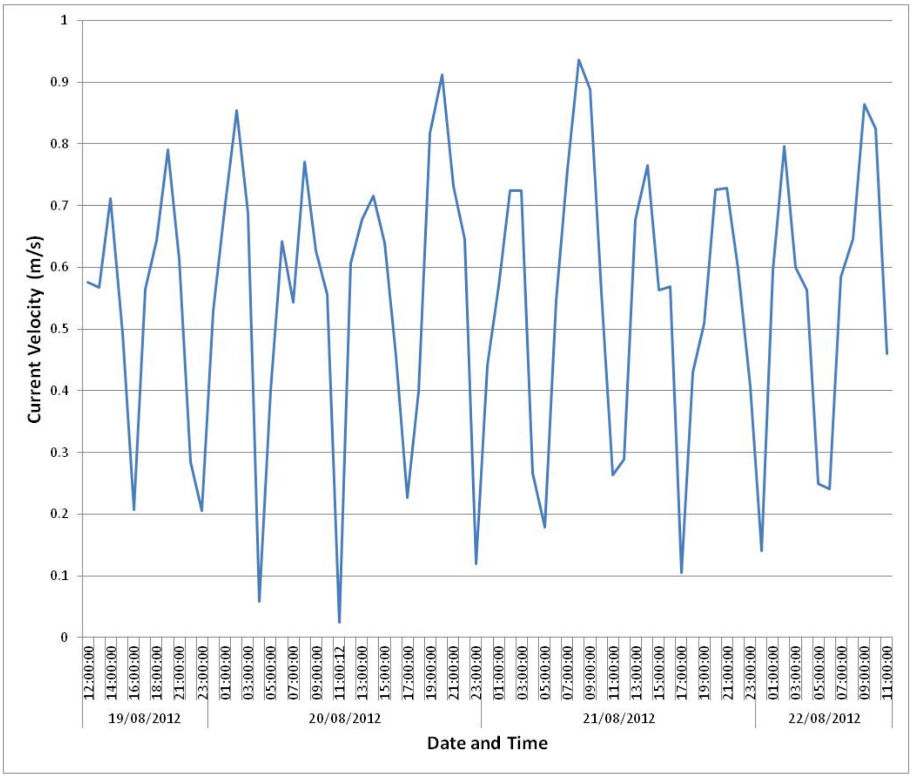



**Figure 21: Current velocity recorded at Current Meter No.2**

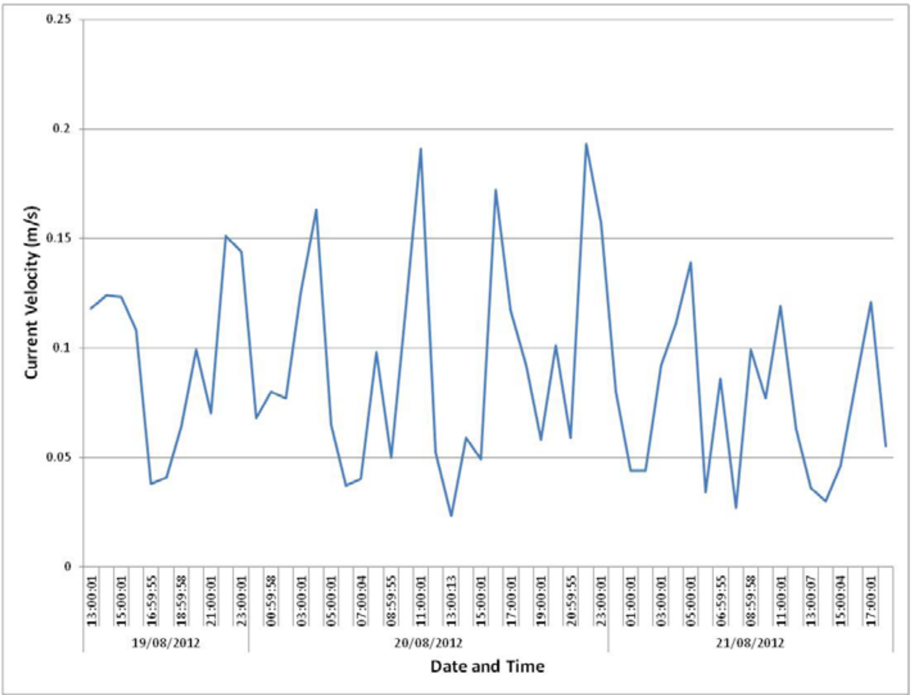



**Figure 22: Current velocity recorded at Current Meter No.3**

The average flood current direction recorded in Current Meters No.1 and No.2 indicates a south by south-westwards flow. The average ebb tide recorded at each of current meter locations indicated an average direction of north by north-east. The direction of the average flood tide data appears to correspond with the modelled coastal circulation around Scotland and in the North Sea given in Scotland's Marine Atlas (Marine Scotland, 2011).

An Admiralty Diamond located 11km east of Stonehaven[3] gives a peak spring tidal current of 0.7m/s and a peak neap current of 0.35m/s although it should be noted that current velocities closer to the shoreline are likely to be weaker (SNH, 2000). Current flows during a high tide are in a southerly direction with a mean spring rate of 0.6m/s (SNH, 2000). Again the direction of the average flood tide data and average current velocities appear to correspond with SNH (2000).

Current Meter No.3 indicated a west by south-west direction for the flood tide. This difference in flow direction and average velocity maybe the result of the current meter's location closer to the shoreline, the shape of Nigg Bay and it's bathymetry.

## 5.4 Seabed Sampling Results

Three seabed samples were obtained and underwent particle size distribution (PSD) testing which are summarised in the following table.

[3] Stonehaven is located 24 km south of Nigg Bay.

| Sample | Location | | Particle Size (%) | | | Description |
|---|---|---|---|---|---|---|
| | Longitude (degrees, minutes, seconds) | Latitude (degrees, minutes, seconds) | Silt | Sand | Gravel | |
| 1 | 057°08'10"N | 002°02'25"W | 0.1 | 99.6 | 0.3 | slightly silty, slightly gravelly SAND |
| 2 | 057°07'52"N | 002°02'26"W | 1.9 | 98.1 | 0.0 | slightly silty SAND |
| 3 | 057°08'00"N | 002°02'54"W | 4.2 | 95.7 | 0.1 | slightly silty, slightly gravelly SAND |

The PSD test certificates are located within Appendix V.

# 6 Operational Summary

Mobilisation for the project commenced on 10/08/12 with the vessel transported from its base in Dundee to the East Commercial Quay at Aberdeen Harbour. Bad weather for the subsequent week meant that Data Acquisition activities couldn't start until a weather window presented itself.

Offshore activities commenced on 19/08/12 with the deployment of current meters tide gauges. Data acquisition activities commenced on 20/08/12 and were completed by 22/08/12.

Current meters and tide gauges were recovered and the vessel put on standby in Aberdeen harbour until the full coverage obtained by the bathymetry system could be qualified. The demobilisation and removal of the vessel from Aberdeen back to Dundee was accomplished by 31/08/12.

# 7 Safety

## 7.1 Documentation

The following safety documentation was issued to CG project staff prior to joining the vessel and was made available onboard for the duration of the project.

| Document No | Document Title | Originator |
|---|---|---|
| IM-HSP-019 | Health and Safety Policy | CG |
| IM-HSM-00 | Health and Safety Manual | CG |
| IM-HSP-01 | Management of Change | CG |
| IM-HSP-02 | Reporting and Investigation of Accidents & Incidents | CG |
| IM-HSP-04 | Safety Meetings & Tool Box Talks | CG |
| IM-HSP-07 | Smoking | CG |
| IM-HSP-08 | Stress, Bullying and Harassment | CG |
| IM-HSP-12 | Travel & Security | CG |
| IM-HSP-13 | Manual Handling | CG |
| IM-HSP-14 | The Workstation & Display Screen Equipment | CG |
| IM-HSP-15 | Hazardous Substances | $S^3$ |
| IM-HSP-16 | Personal Protective Equipment | $S^3$ |
| IM-HSP-17 | Electricity | $S^3$ |
| IM-HSP-18 | Noise | $S^3$ |
| IM-HSP-19 | Use of Plant & Machine Tools | $S^3$ |
| IM-HSP-20 | Portable Hand Tools | $S^3$ |
| IM-HSP-22 | Hot Work | $S^3$ |

## 7.2 Risk Assessment

The Survey Team Leader conducted a pre project Risk Assessment addressing hazards likely to be encountered during the survey and/or related operations. The Vessel Master and all other personnel involved in operations were in attendance during this process and a copy available to read.

## 7.3 Toolbox Talks

Prior to commencing an operation, the Survey Team Leader ensured a Toolbox Talk was conducted with all personnel involved, covering all salient points of the operation, including safety, hazards, prevailing environmental conditions, and communication procedure.

## 7.4 STAR Cards

All S³ (CG) personnel were issued with STAR (safety task and responsibility) cards. The purpose of STAR cards is document potential risks at any worksite prior to operations commencing. STAR cards are issued to all personnel working on operational worksites, regardless if or CG worksite or clients.

## 7.5 Personal Protective Equipment (PPE)

Appropriate PPE was worn at all times when working on deck, aloft or outboard of the vessel railings. The CG personnel proposed for the project had, or had access, to the following protective clothing.

- Hard Hat
- Safety Boots
- Safety Glasses
- Safety Gloves
- Life Jackets

# 8 Systems Performance

## 8.1 Positioning System

The Veripos LD2 positioning system performed well throughout the survey giving consistent accurate positioning of the vessels common reference point and offset positions of towed and pole mounted sensors. The twin antennas mounted on the vessel also provided an accurate heading output for vessel steering and data logging.

## 8.2 Bathymetry and Sidescan Sonar

The Geoacoustics Geoswath is an interferometric sonar system which gives side scan imagery and bathymetric data, performed well throughout the survey. The advantage of a pole mounted system which combines the Sidescan sonar and Multibeam transducers on one head removes the requirement to tow a Sidescan fish and increases the manoeuvrability of the vessel.

Bathymetry data was of good quality with no gaps between lines. The technical specifications for the Geoswath by Kongsberg Geoacoustics LTD indicate that the maximum swath width is 390m and provides a data coverage of up to 12 times the water depth.[4]

The hull mounting of this system has provided very accurate position and heading information, however at times of strong tides the crabbing of the vessel has produced smear which affected, to a certain extent, some quality of the data. The resolution of the system is smaller than 1m, while no targets of this size were identified sand ripples of less than 1m in height were frequently observed. The range acquired was between 60m and 80m and is considered of good quality for the duration of the survey.

## 8.3 Applied Acoustics Squid 500 Sparker

The Applied Acoustics Squid 500 transmitted a lower frequency acoustic pulse rate of four per second at 250 Joules and recorded reflections from the seabed and below.

Sparker data was acquired in CODA as a .cod file. These were replayed applying band pass filters and TVG as a sgy. This was loaded into Seismic+ adding on the fixed layback to calculate the common midpoint of the towing array.

The sub bottom data quality was generally very good. Some ambient noise was observed but a band pass filter (500-3000Hz) removed most of this during processing. Marginal weather produced some cavitation but all affected survey lines were rerun. Penetration was good and limited by the bedrock and the multiples, an effect of working in a shallow water area.

## 8.4 Valeport Current Meters

The Valeport 106 Current Meters are a lightweight flow meter suitable for shallow depths. The units were deployed using a weight to keep them on the seabed and a line attached to a buoy which kept

[4] Kongsberg Geoacoustics LTD (2012) GeoSwath Plus GeoAcoustics. http://www.km.kongsberg.com/ks/web/nokbg0397.nsf/AllWeb/E35EA810E2804876C12574BE004E0876/$file/GeoAcoustics-GeoSwath-Plus-data-sheet.pdf?OpenElementide Swath Bathymetry

them upright and facilitated recovery. Current velocity and flow direction was recorded on a three second interval with the data then logged once every 5 minutes internally and then downloaded to computer upon each unit's recovery to deck.

During deployment, the percentage of current flow data recovered from each of the meters ranged from 98.1% to 100%. The percentage of current direction data recovered from Current Meters No.1 and No.2 was 98.1% and 99.9% respectively. The percentage of current flow direction recovered from Current Meter No.3 was 59.2%.

It should be noted that Valeport advise that the 106 Current Meter requires no calibration and only requires to be in good working order.

## 8.5 Valeport WLR (Water Level Recorder)

The Valeport WLR's are a lightweight pressure reading unit. The units were coupled to the Current Meter rigging for deployment. Water level was recorded on a one second interval with the data logged once every 5 minutes internally and then downloaded to computer upon each unit's recovery to deck.

During deployment, the percentage of data recovered from WLR at location No.3 was 100% between 16:51 on 19$^{th}$ August 2012 and 19:08 on 21$^{st}$ August 2012. WLR at location No.2 failed to record data during deployment.

Comparison to logged tide data at Aberdeen Harbour showed that this data was not of sufficient quality for use for Bathymetry and therefore the Aberdeen Harbour data was substituted for use instead.

## 8.6 Van Veen Grab

The Van Veen grab recovered good samples at all three sample locations (see Photographs 1 to 3).


**Photograph 1: Geotechnical Sample No.1**


**Photograph 2: Geotechnical Sample No.2**


**Photograph 3: Geotechnical Sample No.3**

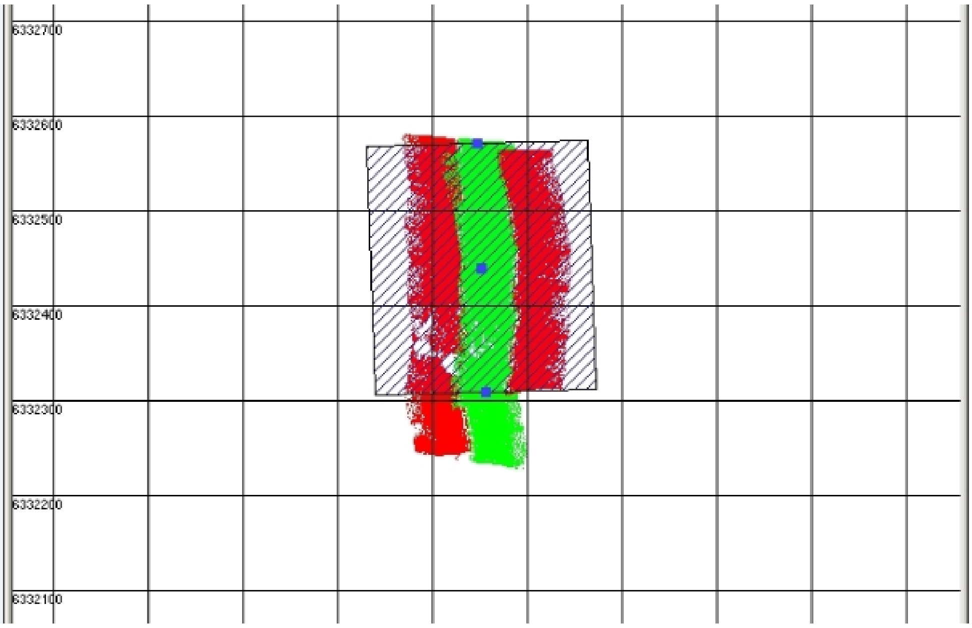
The geotechnical testing undertaken on the seabed samples indicated that sediment is slightly silty, slightly gravelly medium grained Sand. These results agreed well with the geological interpretation from the sensor data.

# References

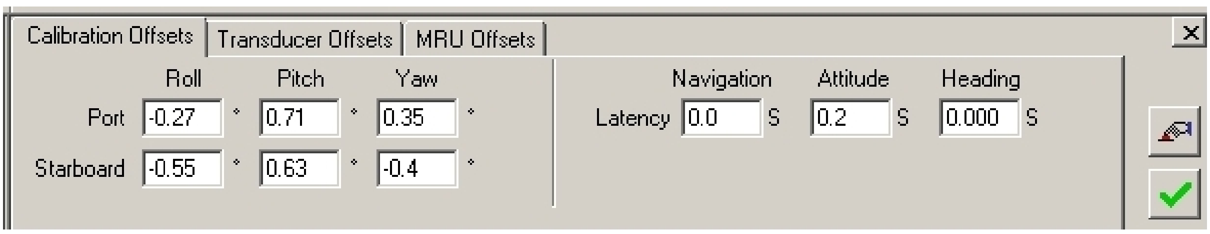
1) BGS, (2010). GeoRecords Plus+ report (Report Id: BH_116126_1), British Geological Survey, Keyworth, UK.
2) Dawson, A. (2009). Nigg Bay to Cove Coastal Footpath Geology and Geomorphology, Aberdeen Institute of Coastal Science and Management. http://homepages.abdn.ac.uk/d.green/FINAL%20Nigg%20Cove%20Coastal%20Path%20Nov%202009.pdf
3) Gordon, J.E. (2007), NIGG BAY, Volume 6 Quaternary of Scotland Chapter 14. Eastern Highland Boundary, Geological Conservation Review http://jncc.defra.gov.uk/pdf/gcrdb/GCRsiteaccount178.pdf
4) Marine Scotland (2011), Scotland's Marine Atlas, The Scottish Government. http://www.scotland.gov.uk/Publications/2011/03/16182005/0
5) JNCC ( 2011), Coastal Geomorphology of Scotland, GCR Database, The Geological Conservation Review, Joint Nature Conservation Committee. http://jncc.defra.gov.uk/default.aspx?page=4175&block=23
6) SNH (2000). Coastal Cells in Scotland: Cell 2 – Fife Ness to Cairnbulg Point. http://www.snh.org.uk/pdfs/publications/research/144.pdf

# Appendix (I) Calibrations

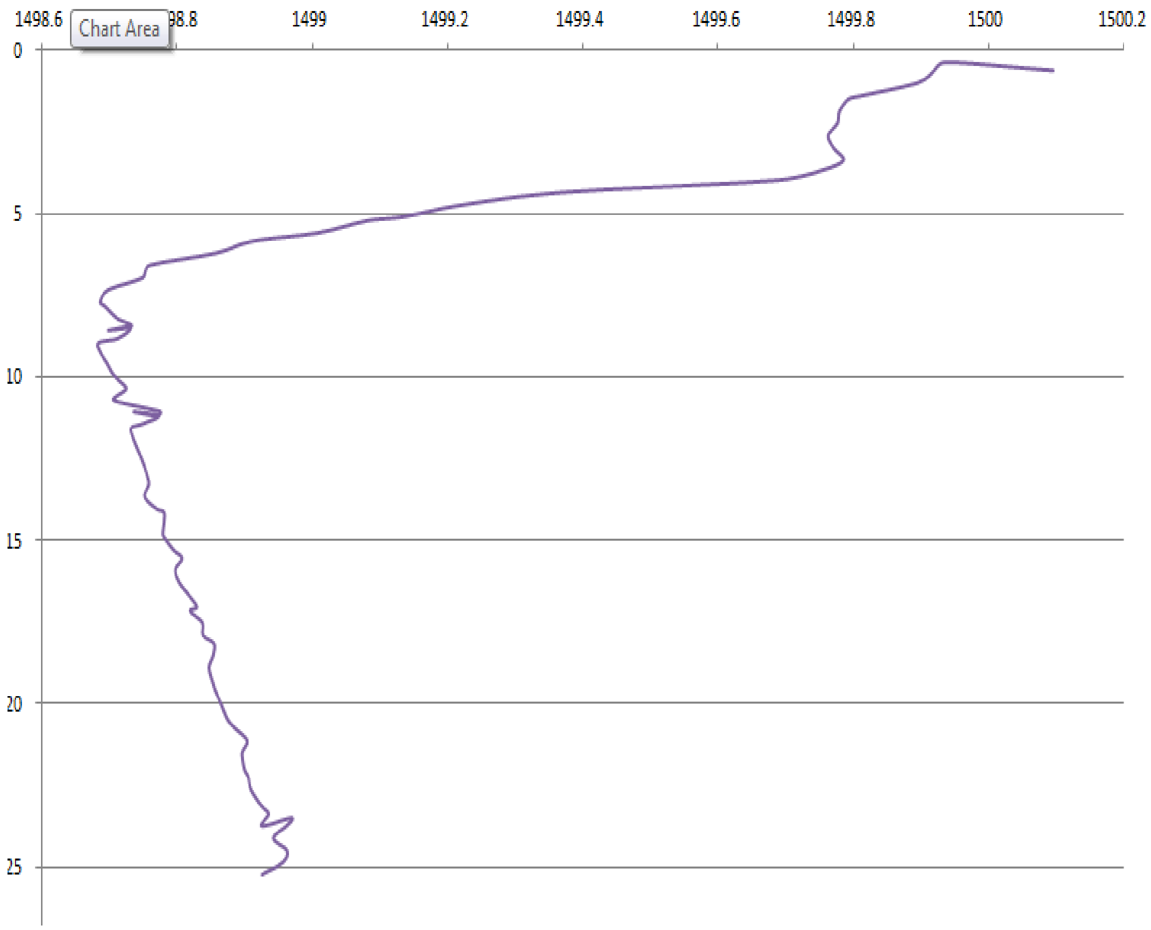
The interferometric sonar system was calibrated using Geoacoustics Geoswath+ recommended calibrations procedures using acquired survey data. The calibration procedure consists of 3 lines in opposing directions and applied to the data set in post processing. The calculations are made as part of a semi-automatic process in which the Latency, Roll, Pitch and Yaw are corrected for.




The following screen grab shows the calibration offsets directly from Geoswath+ used for processing of bathymetry:

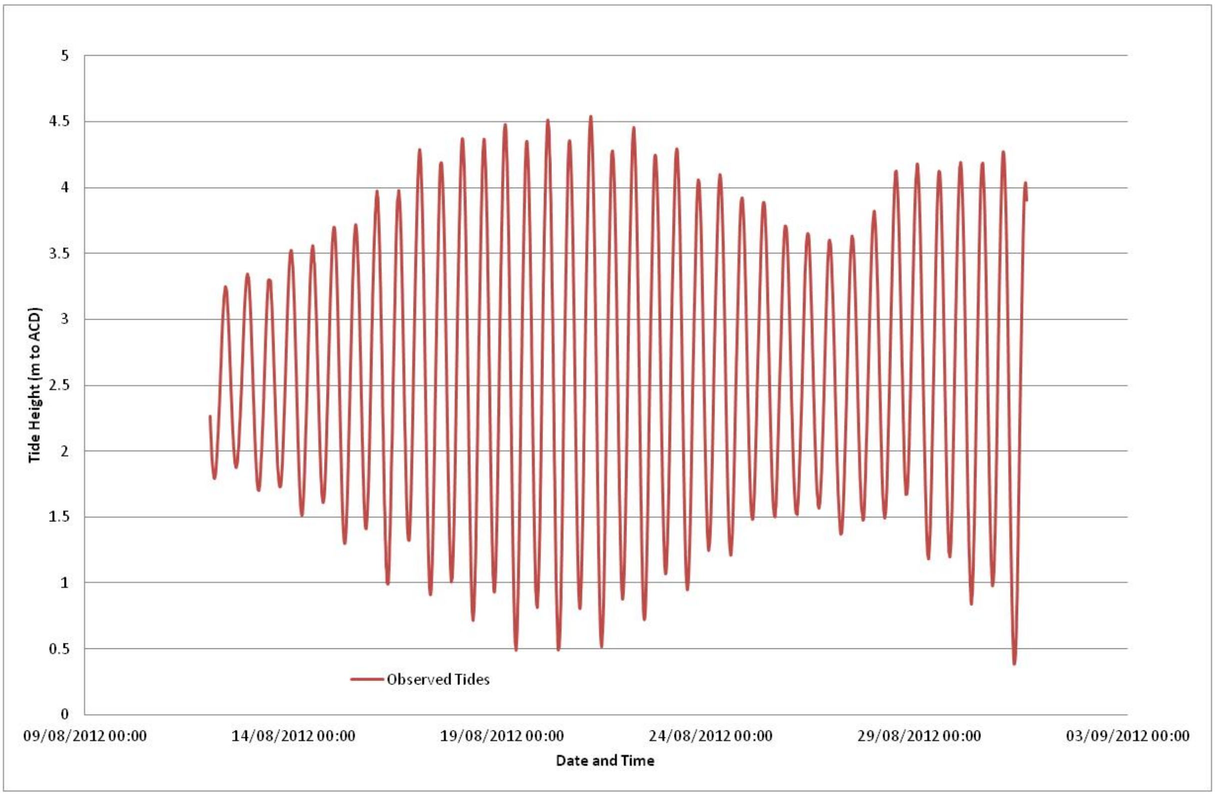


# Appendix (II) SVP Curve



# Appendix (III) Tide Curve

The graph below shows the tidal curve observed at Aberdeen harbour.



# Appendix (IV) Vessel Surveys

A series of Survey's were performed during mobilisation to:

- Determine the 'True' heading of the vessel using simultaneous measurements from 2 total station setups onshore to prisms on the centre line of the vessel.
- Compare the derived 'True' headings with the gyro readings in order to derive C-O values.
- Take timed observations to the DGPS antennas from the shore control in order to derive the 'absolute' antenna position.
- Determine the offsets from CRP to the points of interest.

Gyro Calibration

Reflector targets were fitted on the bow and stern over the vessel centreline. The total stations were set up on the control stations and observations were taken at 60 second intervals (a minimum of 60 shots).

During observation Gyro readings were simultaneously recorded onboard the vessel. These logged values were then compared with the corresponding calculated headings to determine an average C-O correction.

The table below shows the correction determined.

| Gyro | Average Computed Heading | Average Observed Heading | C-O | St. Dev. |
|---|---|---|---|---|
| Meridian Surveyor | 8.71° | 7.19° | 1.52° | 0.19° |

DGPS Verification

Observations were taken at 30 second intervals (a minimum of 60 timed) from known station located onshore to reflector targets fitted to the DGPS antennas.

During observations DGPS antennas readings were simultaneously recorded onboard the vessel. These logged values were then compared with the corresponding calculated coordinates.

The table below shows the corrections determined.

| DGPS Antenna | Average Computed Position (WGS 84 UTM 30 CM 3° W) | | Average Observed Position (WGS 84 UTM 30 CM 3° W) | | C – O (St. Dev.) | |
|---|---|---|---|---|---|---|
| | Easting [m] | Northing [m] | Easting [m] | Northing [m] | Easting [m] | Northing [m] |
| Priority 1 | 555150.57 | 6333689.93 | 555150.53 | 6333689.89 | 0.04 (0.04) | 0.05 (0.05) |
| Priority 2 | 555147.07 | 6333691.95 | 555146.98 | 6333691.86 | 0.09 (0.12) | 0.09 (0.17) |

Offset Survey

Offset survey was carried out on the Surveyor II vessel. The following table summarises offsets from CRP to the points of interest required by the client.

The MRU Unit was placed in the moon pool and was not accessible for the total station. Reference point was established on a bar next to moon pool and the offsets from this reference point to the CRP were tape measured and applied in the software during processing. See figures below for explanation.

| Point | X [m] | Y [m] | Z [m] | Description |
|---|---|---|---|---|
| 50 | 0.000 | 0.000 | 0.000 | CRP = MRU top centre |
| 31 | 0.000 | -0.105 | 1.850 | Ref. point |
| 32 | -0.775 | -4.990 | 1.612 | CP stern handrail |
| 33 | 0.725 | -0.517 | 3.092 | Fore DGPS antenna bottom centre |
| 34 | -1.024 | -4.174 | 3.506 | Aft DGPS antenna bottom centre |
| 35 | 0.725 | -0.517 | 3.162 | Fore DGPS antenna phase centre L1 |
| 36 | -1.024 | -4.174 | 3.576 | Aft DGPS antenna phase centre L1 |
| 37 | 0.725 | -0.517 | 3.151 | Fore DGPS antenna phase centre L2 |
| 38 | -1.024 | -4.174 | 3.565 | Aft DGPS antenna phase centre L2 |
| 43 | -1.366 | - | - | Mean PORT edge |
| 44 | 1.063 | - | - | Mean STBD edge |
| 45 | - | - | 1.342 | Mean handrail level |

Figure: Offsets to CRP (top view)

Figure: Offsets to CRP (side view)

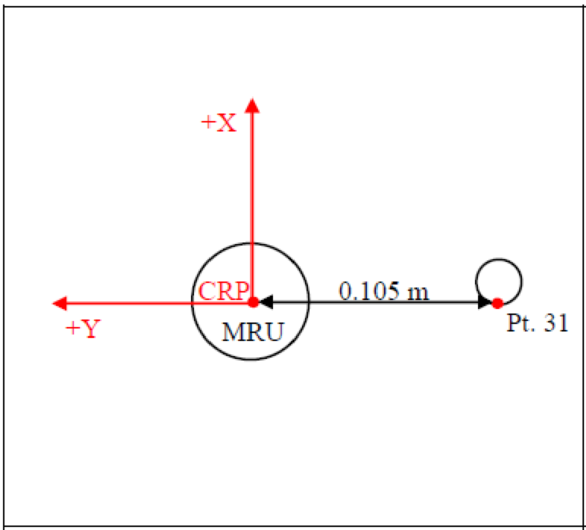



*Figure 2: Offsets to CRP (top view)*

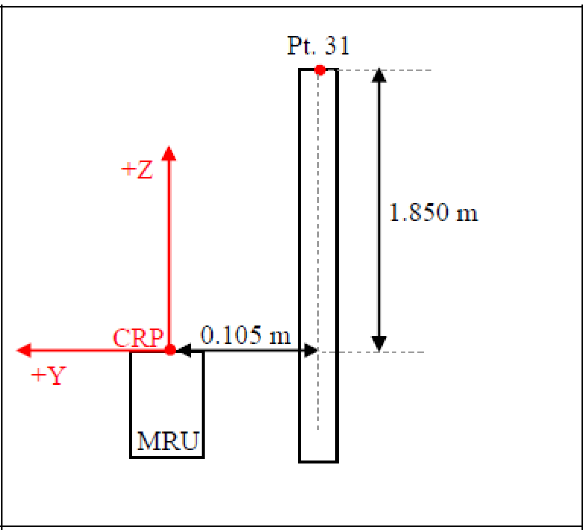
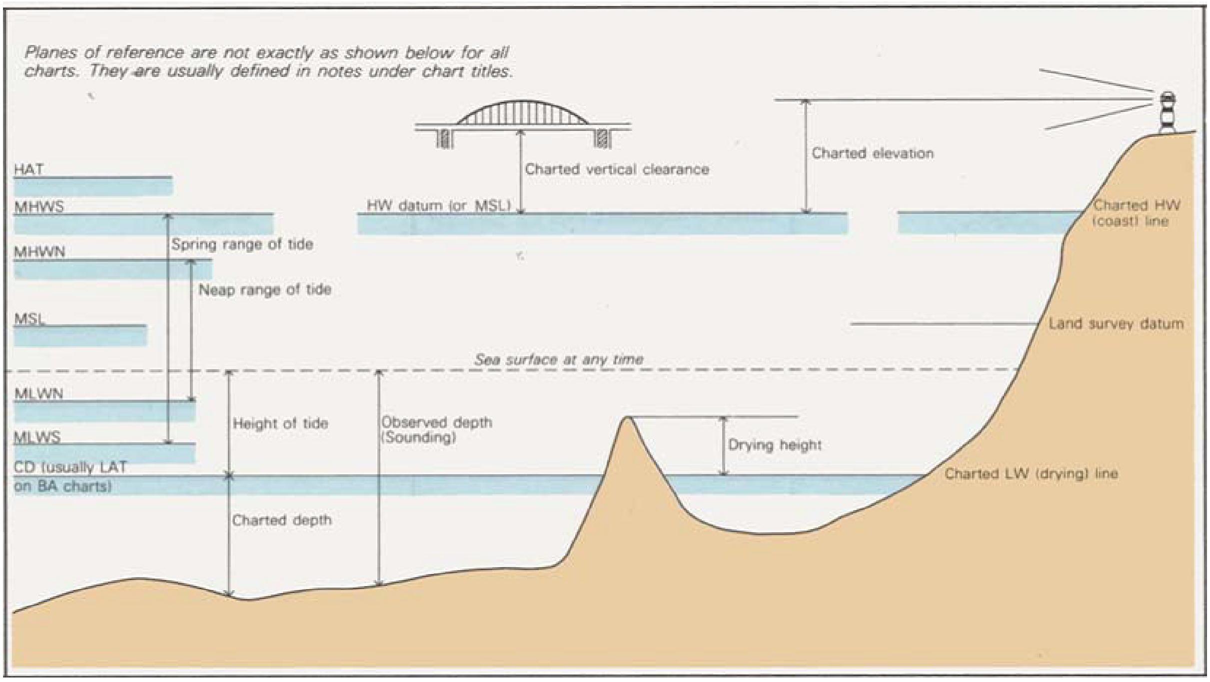



*Figure 3: Offsets to CRP (side view)*

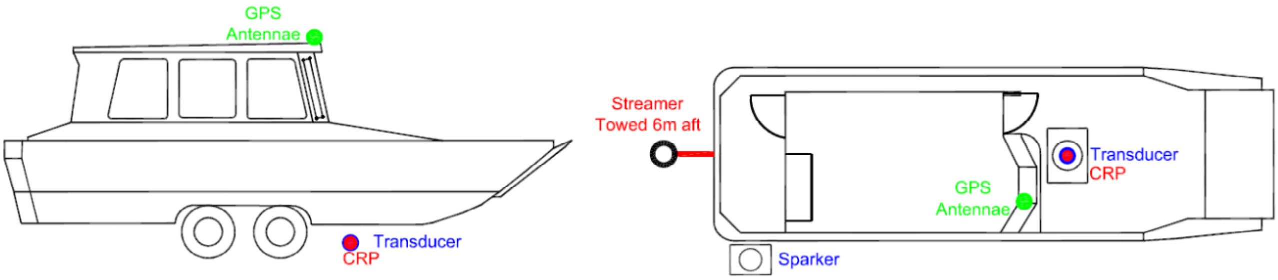
# Appendix (V) Geotechnical Testing Results

# Appendix (VI) Vertical Datum and Tidal Levels



# Appendix (VII) Vessel Offset Diagram

Visual Offset Inspection




| Offsets | X | Y | Z |
|---|---|---|---|
| **GPS Antenna** | 0.73 | -0.52 | 3.09 |
| **Transducer** | 0.00 | 0.00 | 0.00 |

# Appendix (VIII) Gyro Calibration, DGPS Health Check and Offset Survey

# Appendix (IX) Equipment Specification

Specification sheets for the following survey equipment used during this project as detailed in the following table are given in this appendix.

| Equipment Type |
|---|
| Veripos LD2 Position System |
| EIVA NaviPac Survey/Positioning Software |
| TSS Meridian Surveyor Gyrocompass |
| Geoacoustics Geoswath Plus Interferometrics System |
| Applied Acoustics Squid 500 and hydrophone |
| CODA Octopus DA200 Sonar Acquisition System |
| Valeport Midas 606 CTD Probe |
| Valeport 106 Current Meter |
| Valeport WLR |