Appendix E2 – Metocean and Geophysical Surveys

Seagreen Wind Energy

July 2012

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This appendix contains the following reports relating to metocean and geophysical surveys undertaken across the Seagreen Project area.

- Part I – Firth of Forth Offshore Wind Farm Development Project Geophysical Results Report (GEMS, December 2010)
  (**NOTE**: Appendices to this report are not included and can be provided on request)

- Part II - Firth of Forth Offshore Wind Farm Export Cable Geophysical Survey (Osiris Projects, October 2011)

- Part III – Summary of Seagreen Firth of Forth Metocean Surveys to Date (Intertek Metoc, June 2011)

- Part IV – Winter Metocean Survey: Phase I Interim Report (Partrac, March 2012)

Part I

Firth of Forth Offshore Wind Farm Development Project
Geophysical Results Report

(GEMS, December 2010)

GEOPHYSICAL RESULTS REPORT

PHASE 1

FIRTH OF FORTH OFFSHORE (ROUND 3) WIND FARM
DEVELOPMENT PROJECT

PREPARED FOR

SEAGREEN WIND ENERGY LIMITED

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GLOSSARY OF TERMS AND ABBREVIATIONS

A list of abbreviations that may have been used within the main body of the report

ATT	Admiralty Tide Table
BSB	Below Sea Bed
C-O	Computed - Observed
CAD	Computer Aided Design
CM	Central Meridian
DF	Dual Frequency
DGPS	Differential Global Positioning System
GSL	GEMS Survey Ltd
GPS	Global Positioning System
HF	High Frequency
HSE	Health Safety and Environment
KHz	Kilohertz
km	Kilometre
LAT	Lowest Astronomical Tides
LF	Low Frequency
m	Metre
MBES	Multibeam Echo Sounder
MRU	Motion Reference Unit
MSL	Mean Sea Level
MV	Motor Vessel
OPM	Offshore Project Manager
OTS	Over the Side
QA/QC	Quality Assurance / Quality Control
QINSy	Quality Integrated Navigation System
SBP	Sub Bottom Profiler
SSS	Side Scan Sonar
SVP	Sound Velocity Profile
UK	United Kingdom
UTC	Universal Time Co-ordinated

UTM	Universal Transverse Mercator
WGS84	World Geodetic System 1984

EXECUTIVE SUMMARY

Bathymetry

Summary	Value	Location
Max Depth	86.2m LAT	556 400E, 6 278 000N (northwest)
Min Depth	32.5m LAT	563 000E, 6 273 600N (mid-west)
Max Slope	17%	556 750E, 6 278 880N (northwest)

The maximum depths across the site (85m LAT) are observed towards the inshore areas in the northwest, where a channel cuts across in a northeast to southwest orientation. As expected from the desk top study, the majority of the Phase 1 area is within 40m – 60m LAT. The shallowest areas are observed along the north-south oriented Scalp Bank observed in the mid-west of the area.

Seabed Features

Seabed sediments have been classified using an adapted Folk Classification (R.L. Folk, 1954) and are interpreted to consist of gravelly SAND (higher reflectivity) and slightly gravelly SAND (lower reflectivity) across the entire area. Five grab sampling locations were undertaken as per Table 6.

Megaripples are the predominant feature within the seabed features, with isolated sandwaves in the western area. Boulders are prevalent across the area, and are either represented as isolated boulders or clusters on the charts.

Three wrecks identified from the Seazone data were observed within the area.

Geology

The geology in the survey area is complex with a well defined boundary between Triassic bedrock and Quaternary sediments in the east, and the west marked by a more chaotic internal structure, where the boundary between bedrock and overlying formations is blurred to non-existent and the differentiation between different Quaternary stratigraphic units is not always possible. The area just west of the centre of the site is characterized by a deep north-south trending trough where the bedrock has been deeply eroded and the hollow has been infilled with a thick succession of Quaternary sediments. The eastern approaches of this trough mark the approximate boundary between what is described in this report as the east and the west of the site. All charts have been produced combining the well-defined horizons in the east with inferred horizons in the west which are depicted as dashed lines (for the exact delimitations of the well-defined and inferred horizons for each formation, please refer to the appropriate charts).

In this report, the superficial sediments derived from the pinger data and the sediments of the Forth Formation derived from the sparker data have been combined to form undifferentiated Holocene sediments, as both are found to comprise predominantly SANDs and are difficult to differentiate as outlined below.

1. INTRODUCTION

GEMS Survey Ltd (GEMS) have been contracted by Seagreen Wind Energy Limited to conduct a geophysical survey in the Firth of Forth zone, as shown in Figure 1.

Firth of Forth is a Round 3 offshore wind farm development by Seagreen Wind Energy Limited, (COMPANY), a partnership between Scottish and Southern Energy plc and Fluor Limited, the UK operating arm of Fluor Corporation.

The Firth of Forth Zone is situated off the south-eastern coast of Scotland and lies approximately 25km offshore east of Fife Ness and 25km NE of the Isle of May immediately outside Scottish territorial waters. The area is bounded to the west by the coast of Scotland and to the east by the Central North Sea.

The proposed wind farm covers an area of 2,852 square km. The development zone is planned to comprise up to 4GW offshore wind capacity in up to 7 separate project areas comprising Wind Turbine Generators (WTGs), Met Masts, Metocean Buoys, Offshore Substation Platforms (OSPs) and submarine cables.

The site comprises of three areas of investigation, as illustrated below. The surveys will be undertaken in three phases, namely:

- Phase 1 Completed in 2010
- Phase 2 Sites 2a, & 2b To be undertaken by 2012
- Phase 3 To be undertaken by 2014

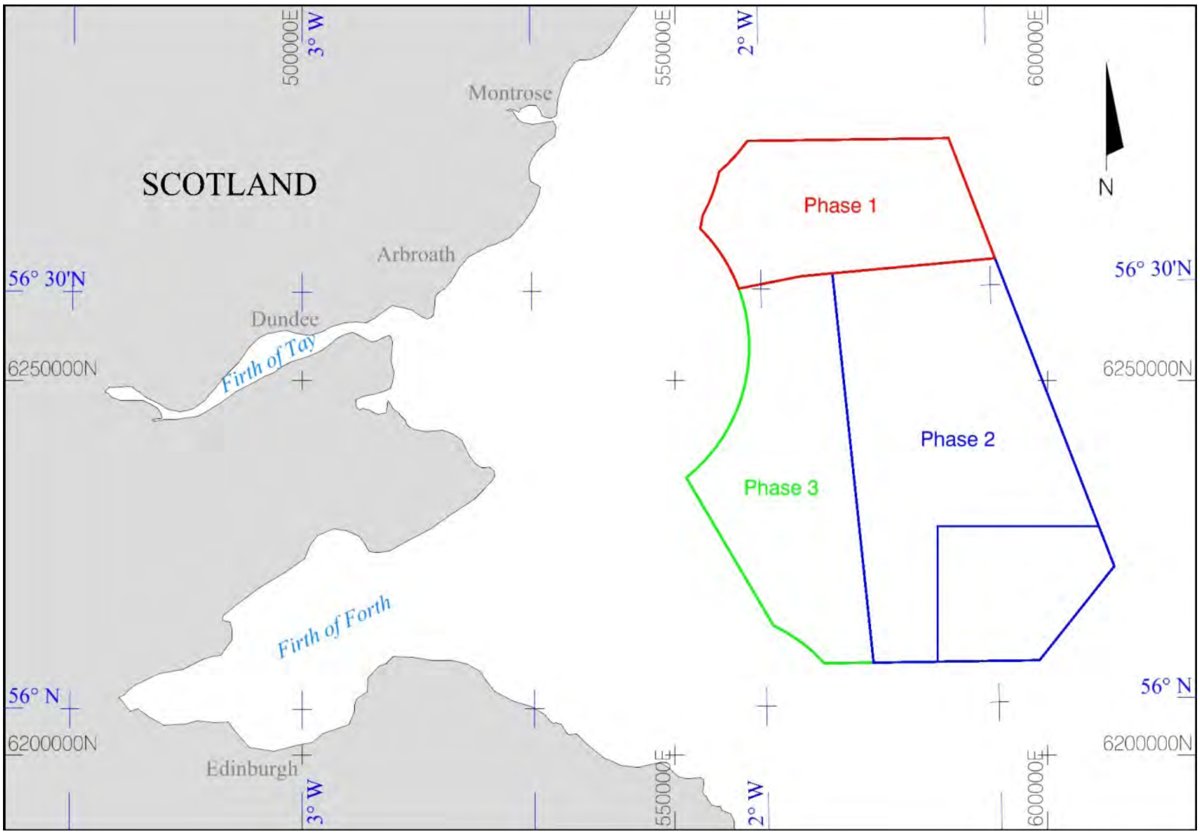


Figure 1 Survey Area

2. SCOPE OF WORK

2.1 Site Definition

The proposed site boundary points are defined in Table 1.

Table 1 Co-ordinates of Phase 1

Area	Point	Easting	Northing	Longitude	Latitude
Phase 1	1	559730.75	6281924.33	-2.025139	56.677608
	2	586720.43	6282293.81	-1.584646	56.676701
	3	592965.00	6266284.00	-1.486500	56.525666
	4	566974.00	6263883.00	-1.907000	56.508666
	5	558583.20	6262232.91	-2.048321	56.500869
	6	558147.06	6263311.79	-2.055164	56.510614
	7	557655.64	6564364.77	-2.062914	56.520134
	8	557109.03	6265392.70	-2.071571	56.529434
	9	556509.40	6266388.95	-2.081101	56.538456
	10	555859.47	6267352.72	-2.091461	56.547191
	11	555159.39	6268281.11	-2.102649	56.555614
	12e	554411.16	6269172.24	-2.114633	56.563706
	13	553408.52	6270232.95	-2.130727	56.573349
	14	553751.82	6271995.86	-2.124774	56.589147
	15	554493.60	6273479.25	-2.112385	56.602386
	16	555092.49	6274922.99	-2.102324	56.615285
	17	555585.17	6276392.79	-2.093981	56.628430
	18	555959.99	6277834.59	-2.087560	56.641337
	19	556929.57	6278704.39	-2.071561	56.649034
	20	558016.20	6279813.36	-2.053593	56.658862
	21	558777.92	6280691.80	-2.040969	56.666658

2.2 Survey Requirements

For the detailed geophysical survey over Phase 1, within the Firth of Forth survey area, the data coverage had to be sufficient to ensure full bottom coverage over the survey area.

Line spacing was 100 metres and lines started and ended 200 m beyond the area of full data overlap.

Perpendicular cross lines within the survey area were undertaken at an interval distance of 2000 m in the east, and 1000m in the west.,

The objectives of the geophysical survey were to:

A. Acquire data that conforms to International Hydrographic Office S44 Standard Order 1a surveys (IHO S44 5th Edition, Feb 2008) with regards to error budgets.

B. Measure sea bed topography and morphology and identify the nature of the seabed sediments - in particular the height, length and slopes of sand-waves (bathymetry, side-scan sonar).

C. Re-interpretation of the gathered bathymetry data to determine seabed habitat types and locate biogenic features, by means of an Acoustic Ground Discriminating System (AGDS). This work shall be completed in the Contractors offices post fieldwork. It should be noted that habitat, fishing, benthic, ornithological and/or cetacean studies were not included in the Scope of Work.

D. Undertake shallow geophysical surveys (using Sub-bottom Pinger and Surface towed sparker to identify sub-bottom geology to a depth of approximately 70 metres below seabed, and for the data to be used to design a subsequent programme of geotechnical sampling and boreholes.

E. Identify the location, extent and nature of any impediments to the installation of Wind Farm turbines, such as wrecks, debris on seafloor, rock outcrop, other cables, pipelines etc (side-scan sonar, bathymetry and magnetometry). It should be noted that detailed surveys for the detection of unexploded ordnance (UXO) was not included in this work scope.

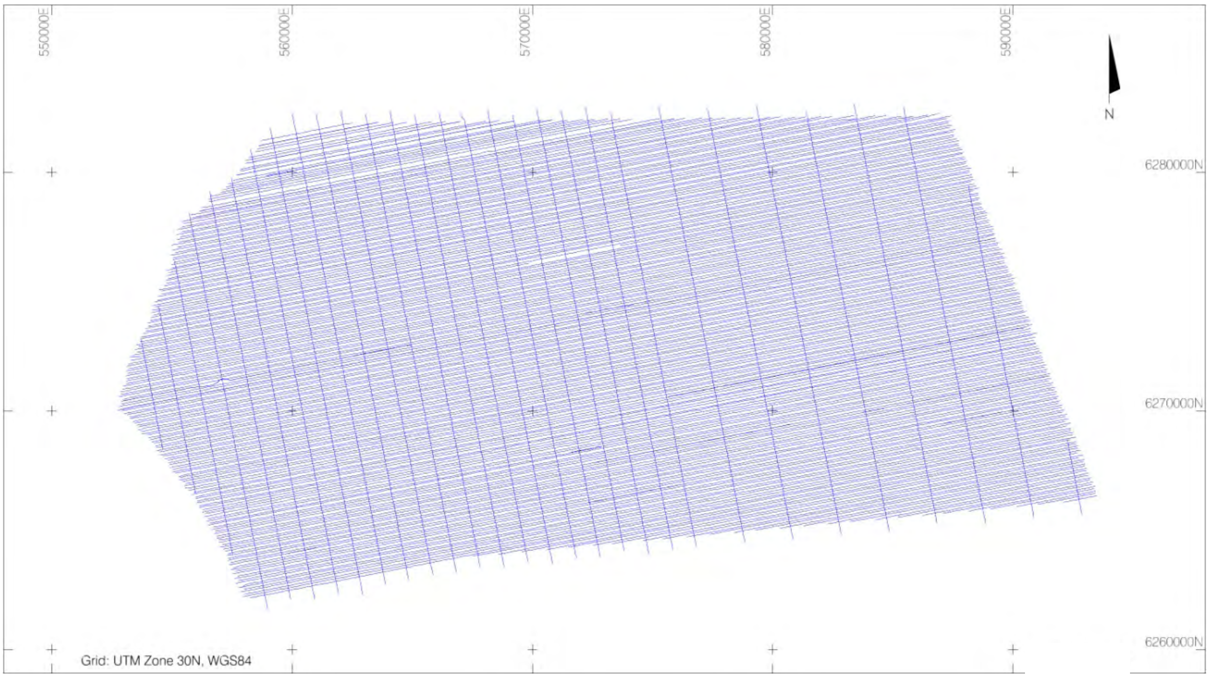


Figure 2 As-Surveyed Line Plan

3. PROJECT CONTROL

Geodetic parameters and datum transformation listed in Table 2 Table 3 were provided by Seagreen.

3.1 Horizontal Datum

Table 2 Geodetic Parameters

Working Spheroid	
Datum:	WGS84
Spheroid:	WGS84
Semi-major, a:	6378137.000000
Semi-minor, b:	6356752.314245
Flattening, 1/f:	298.2572235630
First Eccentricity, e^2:	0.00669438
Second Eccentricity, e'^2	0.00673950

Working Projection	
Projection:	UTM (North Oriented)
Projection Type:	Transverse Mercator
Zone:	Zone 30 N
Longitude Origin:	003° 00’ 00.000” W
Latitude Origin:	0° 00’ 00.000” N
False Easting:	500000.0000
False Northing:	0
Scale Factor on CM:	0.999600
Units:	m

3.2 Vertical Datum

Data are presented as per the definitions in Table 3.

Table 3 Vertical Datum Definitions

Data Type	Units
Bathymetry	metres below Lowest Astronomical Tides (m LAT). Tides corrected using Admiralty predicted tides for the secondary port of Arbroath, and co-tidal / co-range corrections taken from Admiralty chart 5058 LAT derived using the VORF model supplied by Seagreen. For more details of tidal corrections see Operations Report.
Geology	metres below seabed (m BSB)

3.3 Time Datum

All data were acquired, and logs completed with reference to UTC. Daily Progress Reports were completed in UTC time.

3.4 Units

All units are measured and quoted with the International System of Units (SI) unless otherwise stated.

4. BATHYMETRY

The bathymetry across the Phase 1 area displays evidence of the seabed characteristics as displayed in the side scan sonar, and also within the sub-bottom data. In general the seabed depths and slopes are not considered hazardous to turbine installation or stability; however care should be taken near localised sandwave features to the west of the site. Data were acquired using a SEA SWATH*plus* system.

A summary of depths and slopes across Phase 1 is listed in Table 4

Table 4 Bathymetry Summary

Summary	Value	Location
Max Depth	86.2m LAT	556 400E, 6 278 000N (northwest)
Min Depth	32.5m LAT	563 000E, 6 273 600N (mid-west)
Max Slope	17%	556 750E, 6 278 880N (northwest)

The maximum depths across the site (85m LAT) are observed towards the inshore areas in the northwest, where a channel cuts across in a northeast to southwest orientation. As expected from the desk top study, the majority of the Phase 1 area is within 40m – 60m LAT. The shallowest areas are observed along the north-south oriented Scalp Bank observed in the mid-west of the area. An overview of bathymetry is presented in Figure 3.

Slopes across Phase 1 have been analysed with reference to Table 5 and are presented in Figure 4.

Table 5 Slope Catogories

% Slope Range	Slope Range	Descriptor
0% to 5%	0˚ to 2.9˚	slightly
6% to 10%	3˚ to 5.9˚	gently
11% to 15%	6˚ to 8.9˚	moderately
16% to 20%	9˚ to 11.9˚	steeply
≥20%	≥12˚	very steeply or extremely

There are no very steeply/extremely sloping areas within Phase 1. There are limited areas of steeply sloping seabed, although these are exclusively related to either the channel feature in the northwest, or the isolated sandwaves within the western area. These slopes are in excess of those identified during the desk stop study which estimated slopes to be in the order of 2˚ over the channel.

The majority of the site can be classified as slightly sloping, with slopes ranging from 0 to 5%, which agrees with the desk top study identified slope values. In areas of megaripples, localised gentle slopes have been identified.

The bathymetry was able to identify features of the seabed surface also observed within the geophysical data sets, this included:

- Isolated sand waves (discussed in section 5.2)
- Megaripples (discussed in section 5.2)
- Sediment changes (discussed in section 5.1 and 5.4)

Examples of the depths and slopes across these features are displayed in the relevant sections, and also Figure 5 and Figure 6.

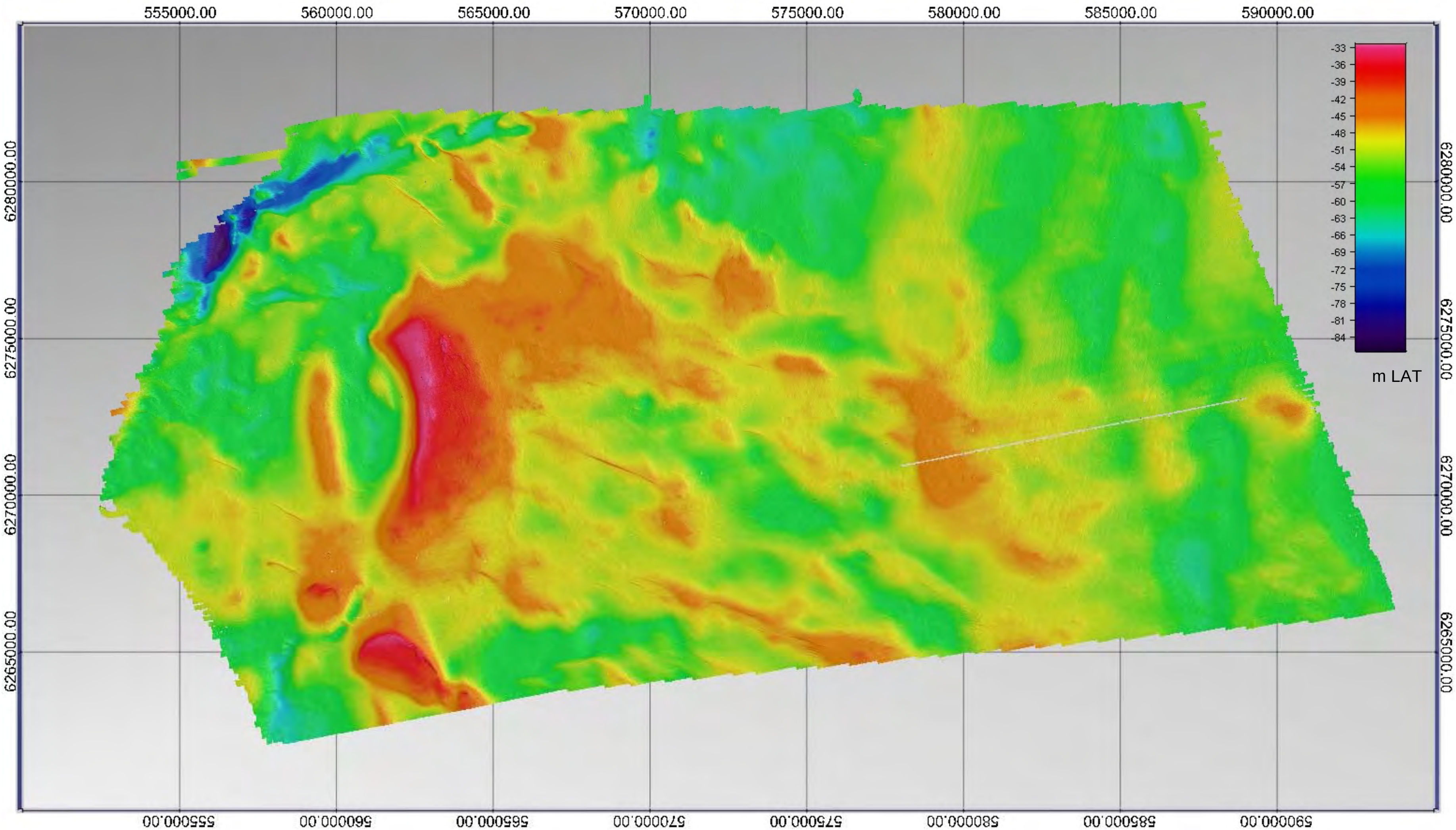


Figure 3 Overview of bathymetry across Phase 1

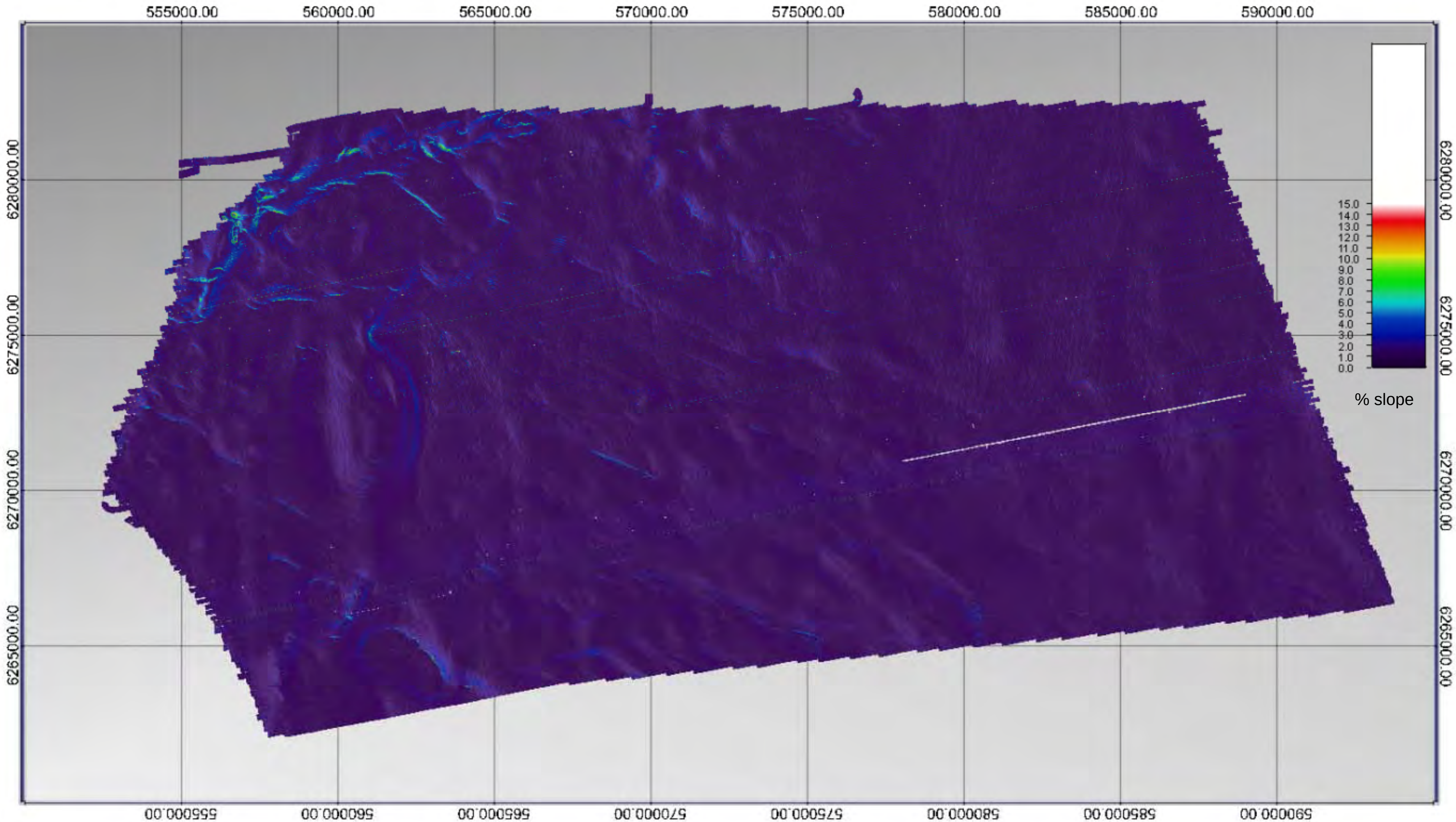


Figure 4 Overview of slopes across Phase 1

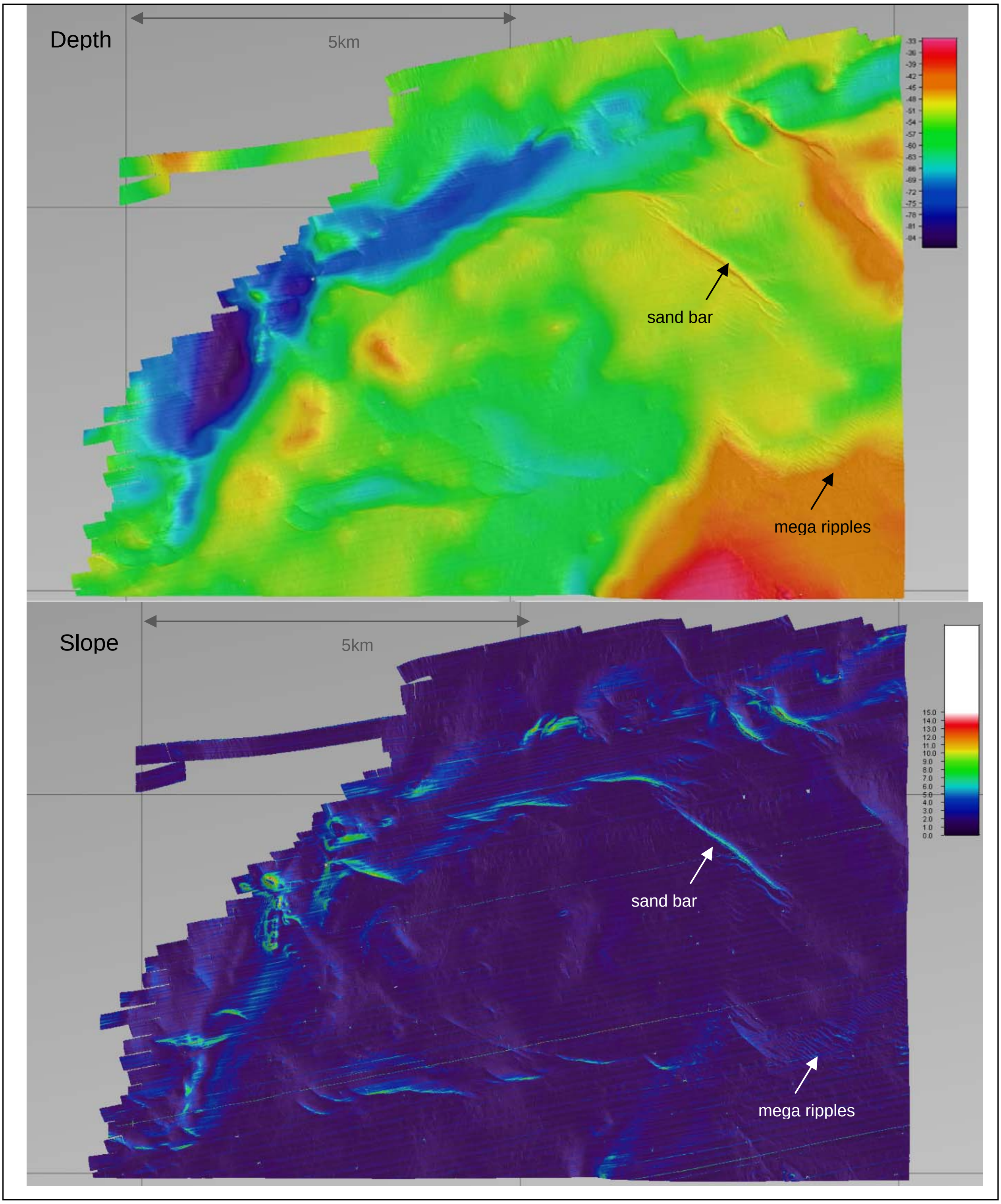


Figure 5 Comparison between depth and slope over northwestern channel

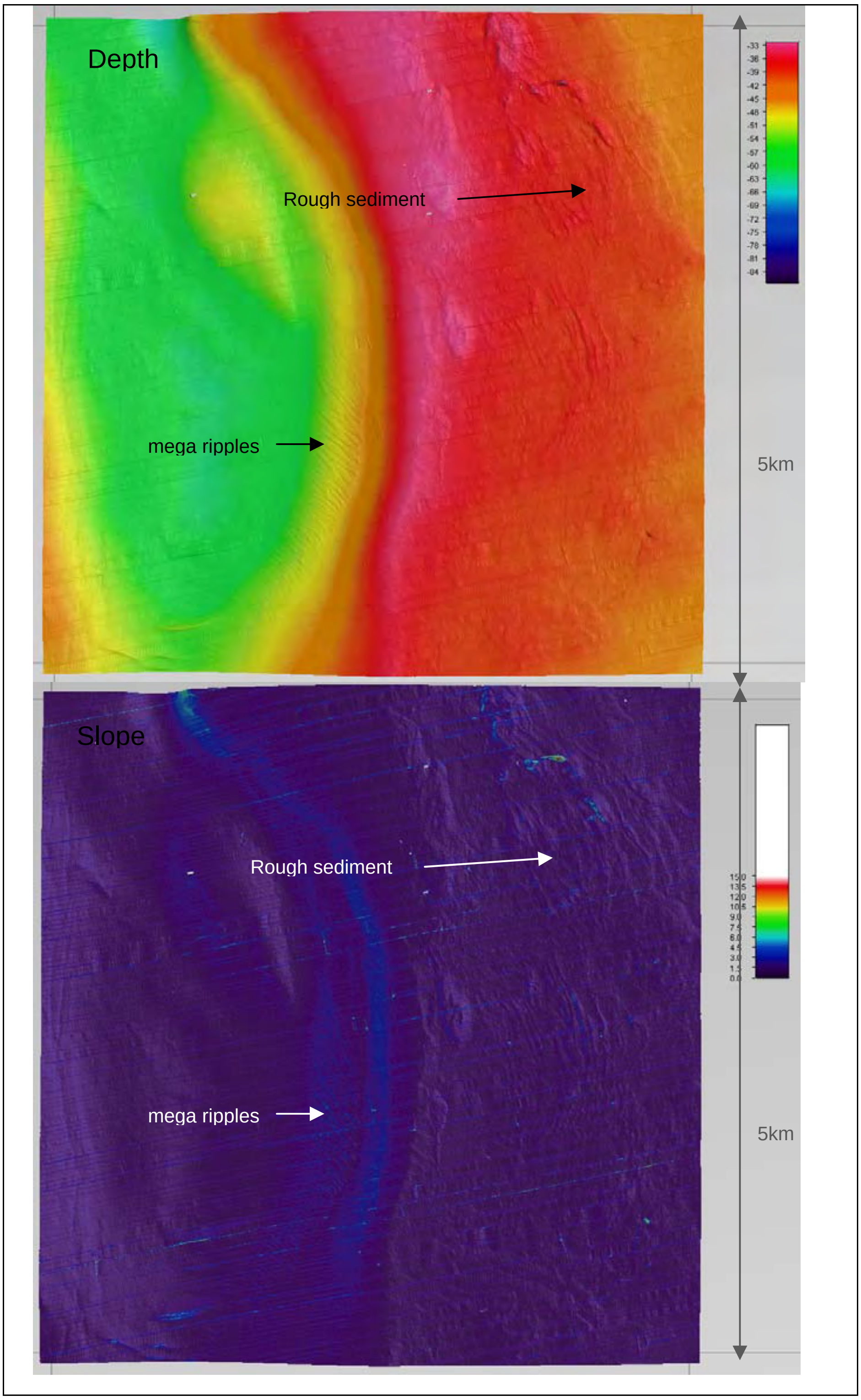


Figure 6 Slopes observed over Scalp Bank

5. SEABED FEATURES

Side scan sonar and magnetometer data were reviewed in conjunction with the bathymetry to identify bedforms and contacts on the seabed. Side scan sonar data were acquired with an Edgetech MP4200 sonar. A Marine Magnetics SeaSpy magnetometer was towed 10m behind the side scan sonar towfish, and both data sets were processed within the InfoX suite of software.

5.1 Sediment Overview

Seabed sediments were expected to comprise of gravelly SANDs to SANDs from information supplied within the desk top study. Sediments were classified using the reflectivity from the side scan sonar information, combined with targeted grab sampling to confirm classifications. An overview of sediment classification across the site is provided in Figure 11.

Seabed sediments have been classified using an adapted Folk Classification (R.L. Folk, 1954) Figure 7 and are interpreted to consist of gravelly SAND (higher reflectivity) and slightly gravelly SAND (lower reflectivity) across the entire area. Five grab sampling locations were undertaken as per Table 6.

The sediment collected in Grab Sample 3 (Figure 9) is inconsistent with the projected area wide sediment cover. The description observes a Sandy GRAVEL as opposed to the area wide sediment cover of Gravelly SAND. The percentage difference in Sand/Gravel content can be attributed to localised variations in sediment cover. The AGDS in this local area confirms these subtle variations in Sand/Gravel percentage not depicted in the SSS mosaic. The coarsening of the sample can also be attributed to the presence of Gravel which can prevent the closure of the grab sampler jaws allowing the fines content (in this case sand) to be partially washed out on recovery. This is certainly what occurred on the second attempt, when no sand content was returned. The position provided is for the successful third attempt grab. The area sediment cover remains as Gravelly SAND as this is believed to be representative of the area as a whole.

The sediment collected in Grab 4 is a Gravelly SAND as opposed to the area wide Slightly Gravelly SAND. The percentage gravel of a Gravelly SAND is 5-20% compared to <5% for a Slightly Gravelly SAND. Localised variations are expected within the areas of megaripples in particular due to the nature of sediment transport which sorts the sediment material, leaving coarser material in the troughs, what is expected to have been sampled. The area sediment cover remains as Slightly Gravelly SAND as this is believed to be representative of the area as a whole especially given the abundance of megaripples across the area.

Grab sample images were reviewed by GEMS environmental team. On inspection of grab sample 3 which was initially classed offshore as containing *Sabellaria spinulosa*, the environmental team consider that there are numerous *Pomatoceros sp.* worm casts evident on gravel/pebble fractions in the image, and potentially some small members of the Ascidiacea, but that there is no evidence of *Sabellaria spinulosa* visible within the grabs.

The Scalp Bank area is subject to a net erosional regime, however there is no discernable change to the reflectivity in the side scan sonar data, possibly due to a veneer of Holocene sediments covering the area.

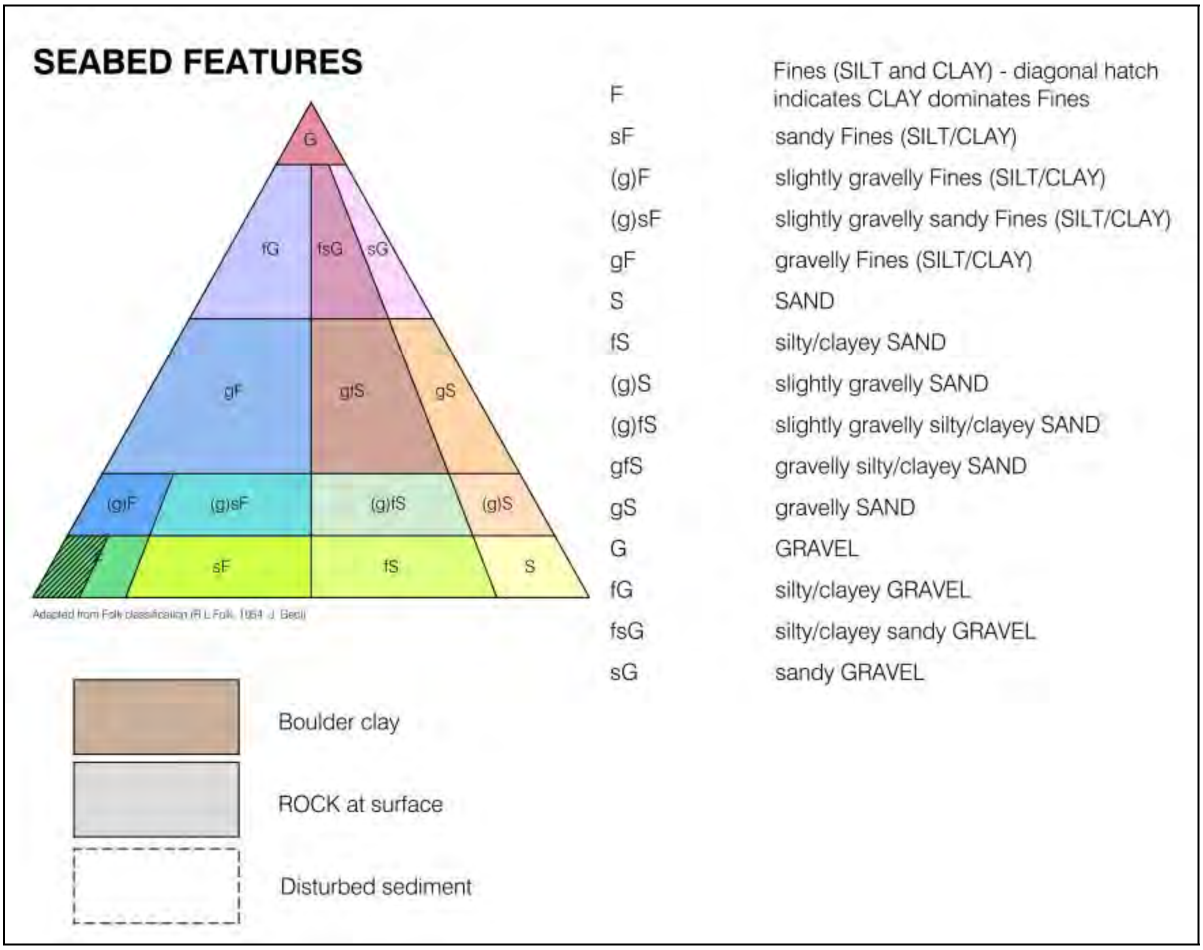


Figure 7 Adapted Folk Sediment Classifications

Table 6 Grab Samples and Analysis

Grab	Easting	Northing	Description
GRAB 1	559 792	6 278 060	Well graded gravelly SAND. Gravel grade comprises of shell, largest shell fragment ~20mm. Composition is a mix of lithic and biogenic material.
GRAB 2	562 732	6 277 742	Well graded slightly gravelly SAND. Gravel grade comprises shell fragments. Largest shell fragment ~12mm. No lithic fragments.
GRAB 3 (attempt 3)	578 787	6 280 129	Sandy GRAVEL. Large sub-rounded lithic clasts ~25mm.
GRAB 4	582 037	6 279 386	Well graded gravelly SAND. Gravel grade comprises shell fragments, largest ~12mm. Composition is a mix of biogenic and lithic material.
GRAB 5	586 615	6 275 485	Well graded slightly gravelly SAND. Gravel grade comprises shell fragments, largest shell fragment ~25mm.

Figure 8 Grab Sample GRAB 1- gravelly SAND

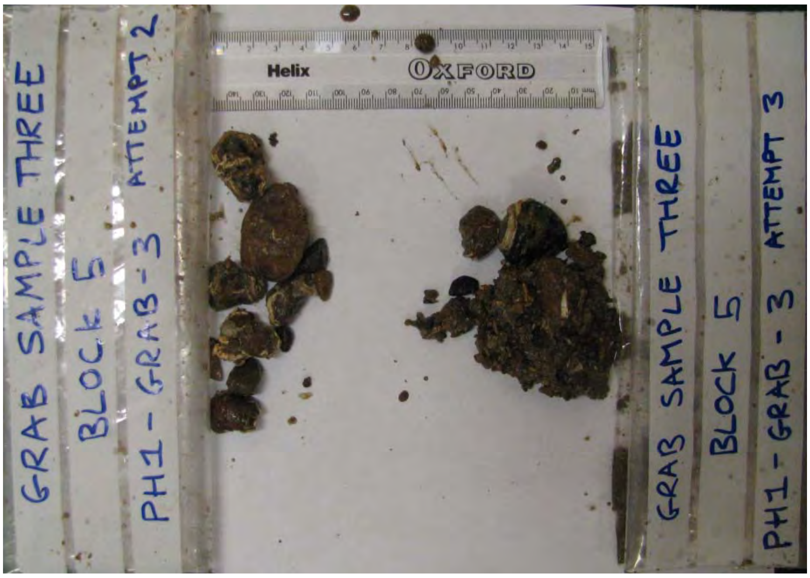


Figure 9 Grab Sample GRAB 3 - sandy GRAVEL

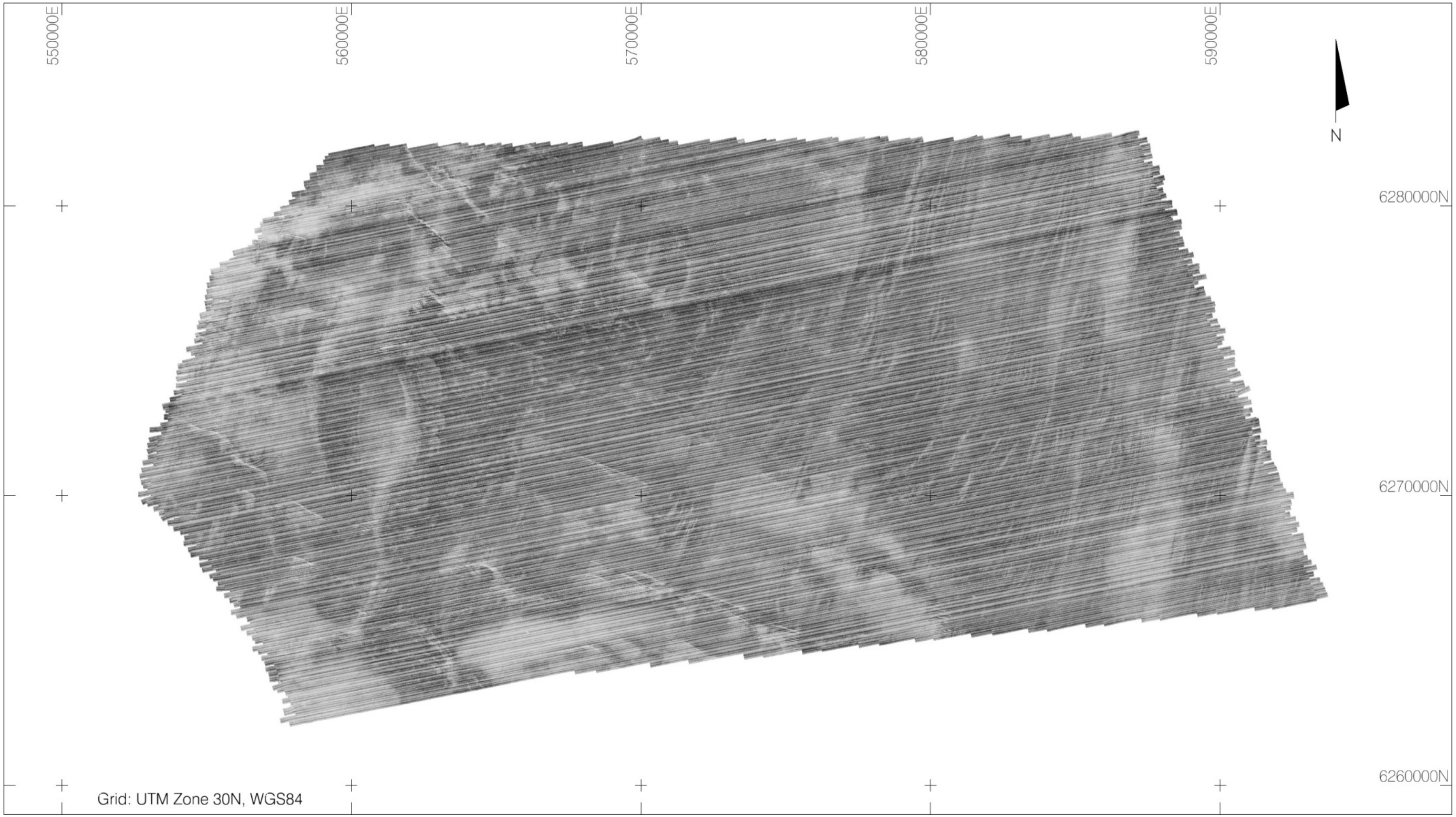


Figure 10 Side Scan Sonar Mosaic

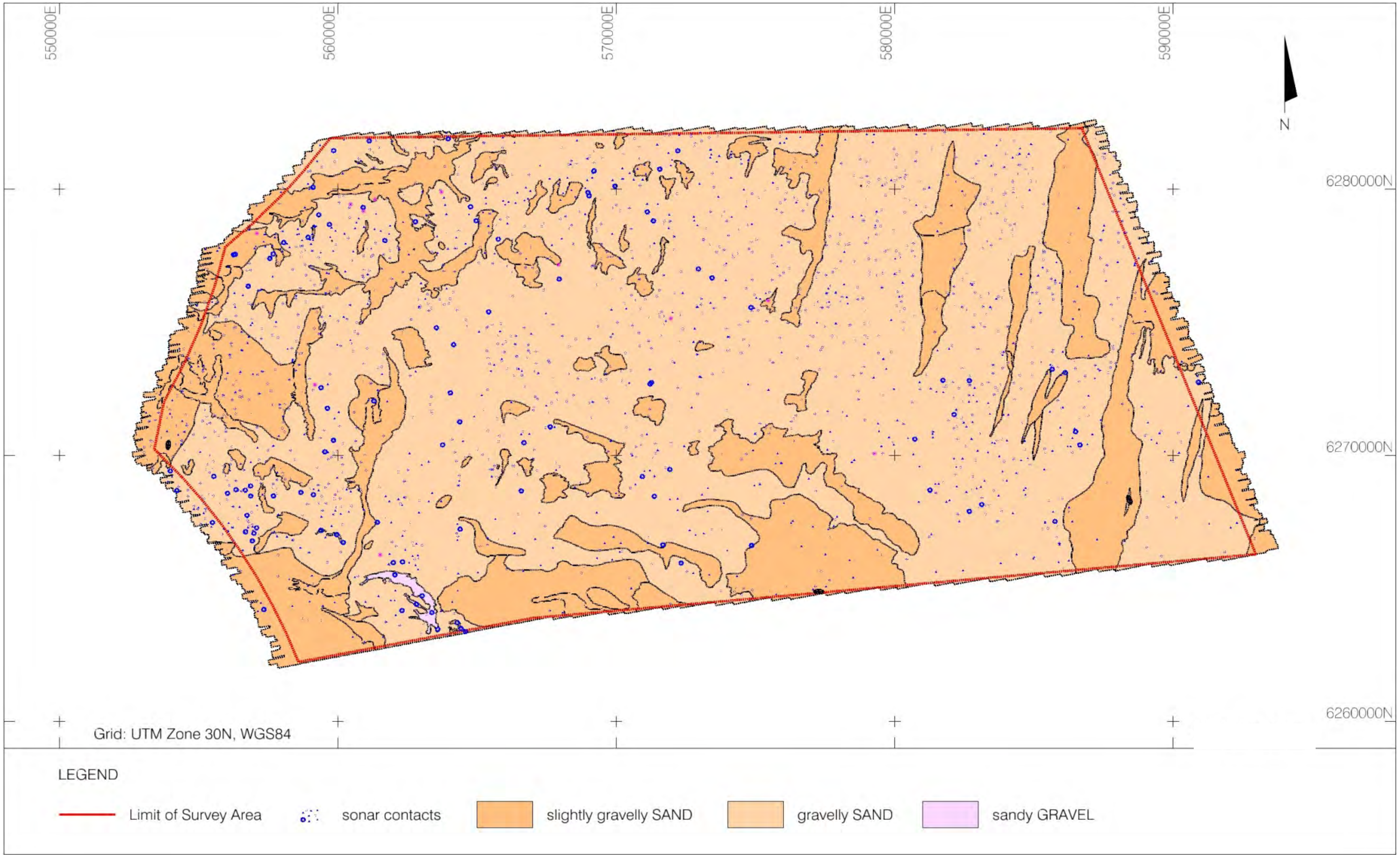


Figure 11 Interpreted Sediment Classifications (blue symbols represent sonar contacts)

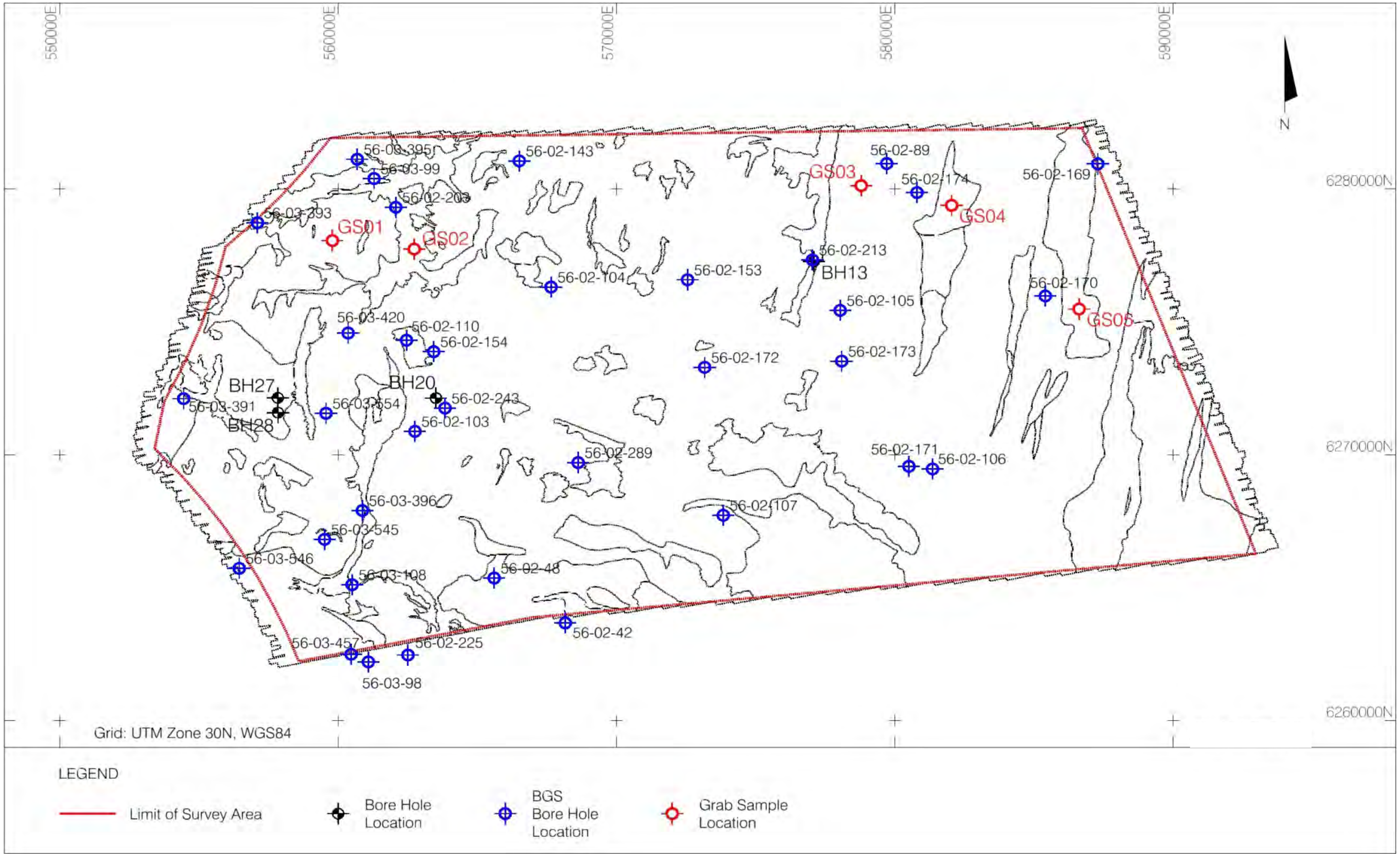


Figure 12 Grab Sample Location Overlain on Side Scan Digitising

5.2 Sediment Transportation

Across the Phase 1 survey area, three main features were identified which relate to sediment transportation:

1. Megaripples
2. Sandwaves
3. Boulder fields

All these features are characteristics of the various stages of sediment transportation, the most obvious of which are the megaripples identified in the data. Definitions of terms used are supplied in Table 7.

The Desk Top Study (ref APP_8768_01_3_3_Rev1) and relevant BGS charts (1986a), identify that the majority of the site is subject to sediment transportation, with the dominant flow pattern approximately parallel to the coastline in a north-northeast to south-southwest (and reciprocal) direction with tidal flow. Currents are strong enough to move and potentially erode medium sand grade material. The seabed characteristics encountered in this survey are in agreement with this statement.

Table 7 Sediment Transport Definitions

Terminology	Definition
Ripple	Undulations (<0.5m λ) produced by fluid movement (waves and currents) over sediments
Megaripple	Undulations (0.5m to 25m λ) produced by fluid movement (waves and currents) over sediments
Sandwave	Undulations (>25m λ) produced by fluid movement (waves and currents) over sediments

5.2.1 Erosion

Not identified in the desk top study, are that parts of the western survey area appear to be subject to a net erosion regime. Over the large Scalp Bank in the mid-west area, Holocene sediments appear to have been gradually abraded away, resulting in widespread exposure of boulders at the surface (Figure 14 to Figure 16). These boulders are thought to derive from the glacial deposits of the Quaternary sedimentation.

Isolated boulders and boulder fields, found elsewhere across the site, may have been previously exposed through similar erosion processes, see Figure 13. Several boulder clusters along with large areas of widely dispersed boulders are observed in northern and central parts of the survey area. Boulder clusters are also observed across the southern half of the area, but these instances are not as large as those in the northern half.

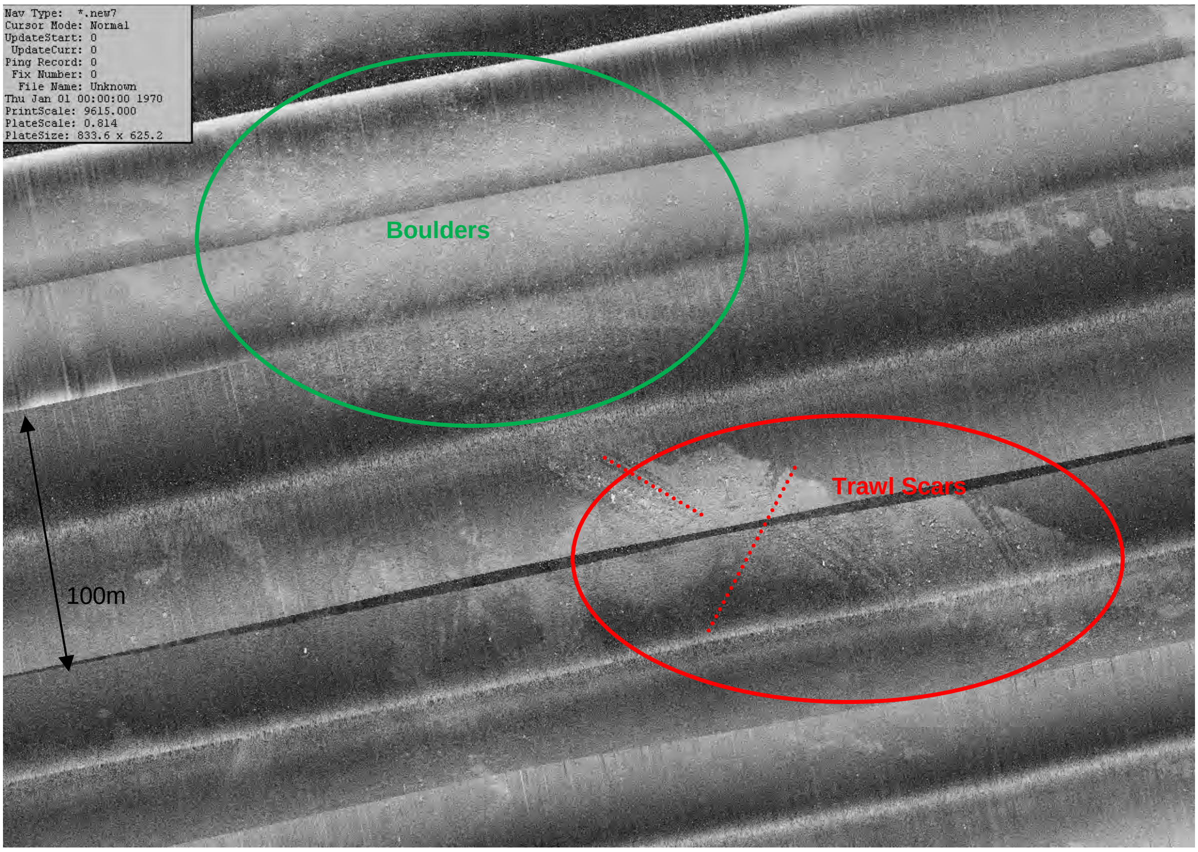


Figure 13 Boulder Field (centred on 567 000E, 6 273 900N) showing Trawl Scars

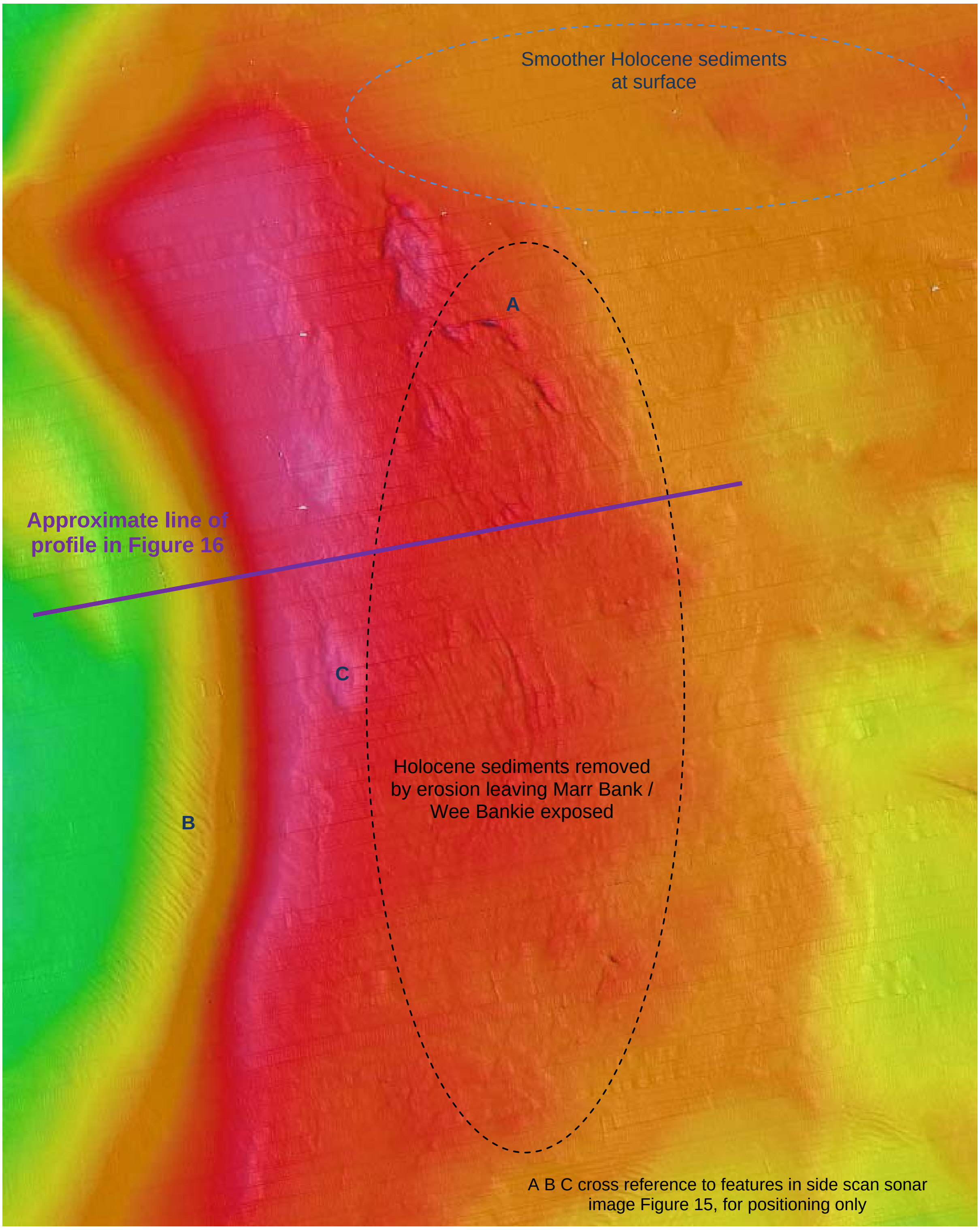


Figure 14 Holocene sediments removed leaving Marr Bank / Wee Bankie Exposed (bathymetry)

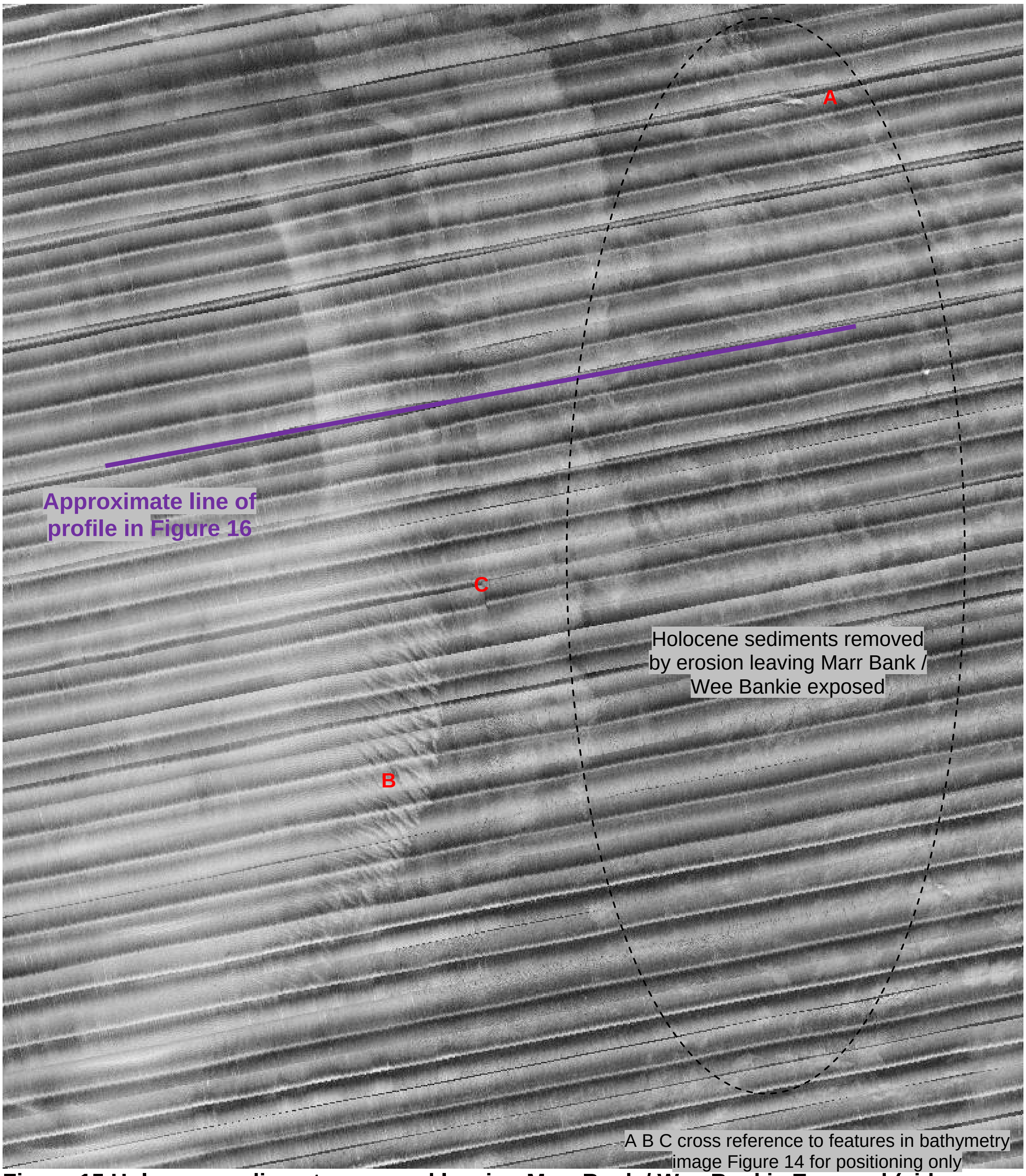


Figure 15 Holocene sediments removed leaving Marr Bank / Wee Bankie Exposed (side scan sonar)

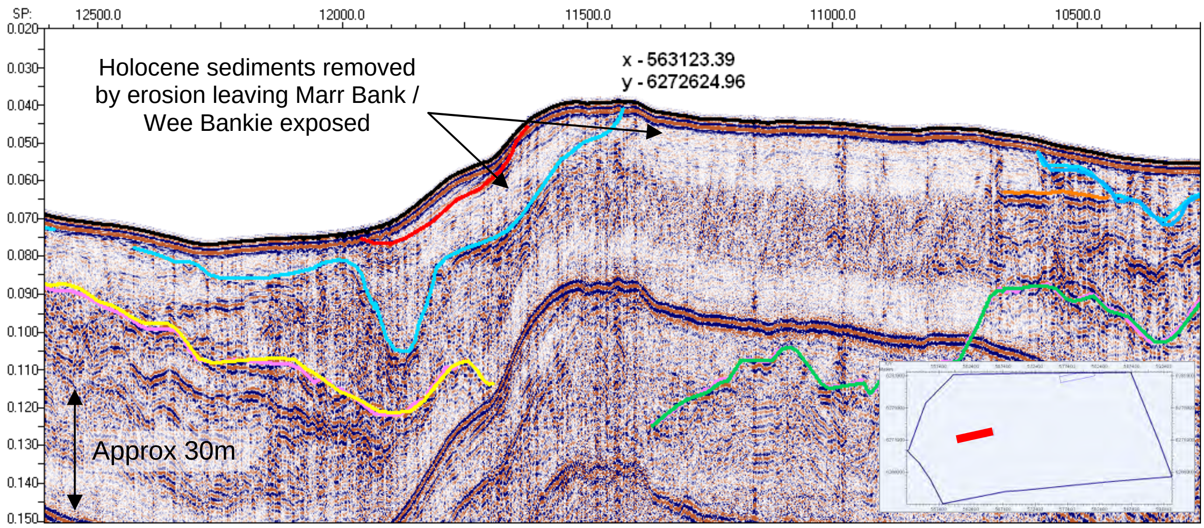


Figure 16 Erosion of Holocene Sediments (Scalp Bank)

The desk top study identifies an area of erosion over the higher ground in the northeast extreme of the area, however study of the acquired data does not show as defined an erosion area as in the Scalp Bank. The bathymetry clearly identifies the raised seabed, and also displays the north-northeast to south-southwest striated features observed in the side scan sonar. The geology from the sparker does show sediment thinning, however it is not as pronounced as the example in the west, see Figure 17 (proc_106B3-S - Eastern end of the line).

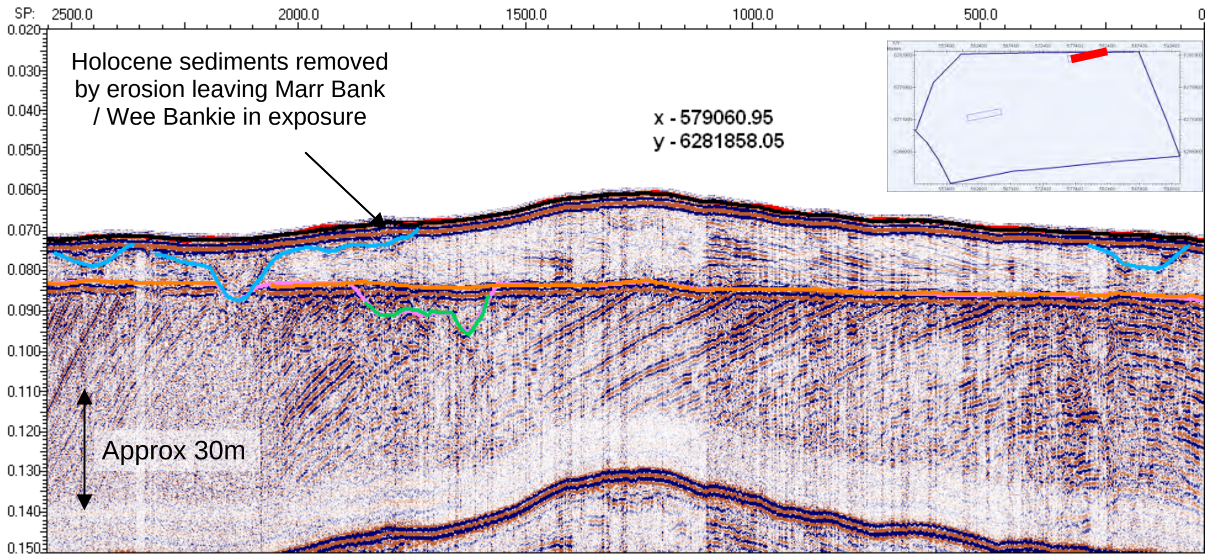


Figure 17 Erosion of Holocene Sediments (northeast) - Line proc_106B3-S

5.2.2 Transportation

Megaripples predominantly comprising slightly gravelly SAND are dominant across much of the site. The crests of the megaripples are oriented perpendicular to the coast line (north-northwest to south-southeast), suggesting sediment movement parallel to the coast.

The bedforms are in general symmetrical, suggesting that sediment does not have one dominant direction of flow, but rather moves tidally parallel to the coast. There is a slight change in the pattern of sediment build up either side of the Scalp Bank in the mid-west, with sediment build up to the south of bedforms west of the bank; suggesting northward dominant flow, and to the north of bedforms east of the bank; suggesting southward dominant flow. However this is not conclusive and these interpretations are by no means confirmed.

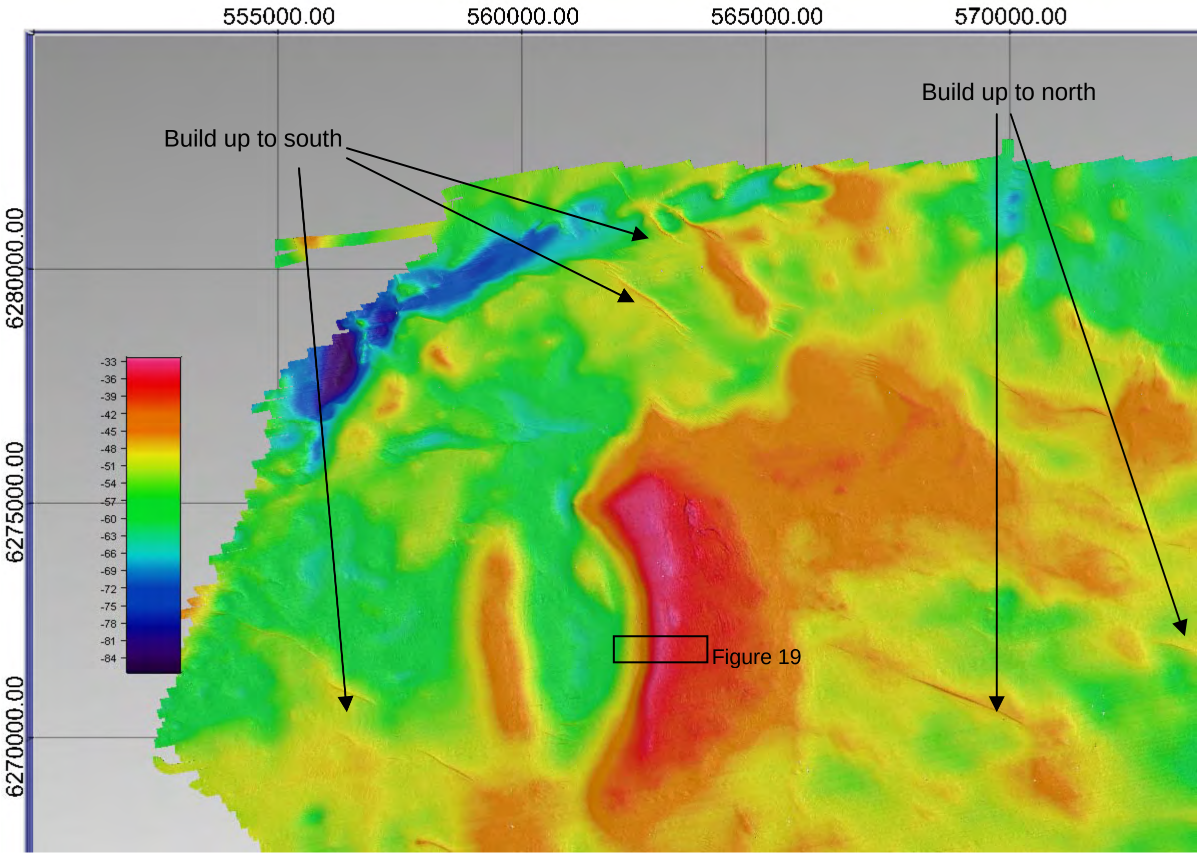


Figure 18 Sediment Transportation Direction

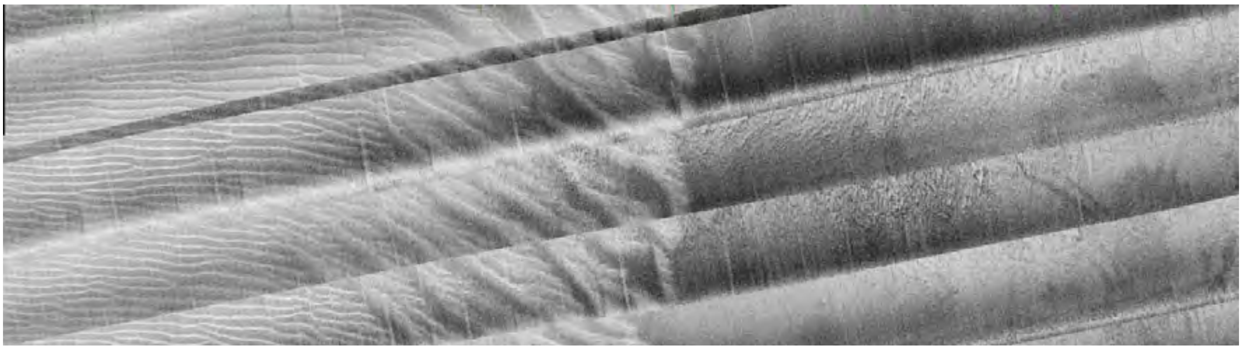


Figure 19 Megaripples (small, left merging to large, middle), and boulder field (right) over Scalp Bank

The height of the megaripples is generally less that 0.5m, which is not anticipated to pose a major hazard to turbine site selection or installation. The larger megaripples have gently sloped sides, up to 6-7%.

In the west of the site, large isolated sandwave features are observed with approximately the same orientation as the megaripples. These reach up to 10m in height from surrounding seabed, see Figure 20 and the sides of which are steeply sloped, as discussed in Section 4.

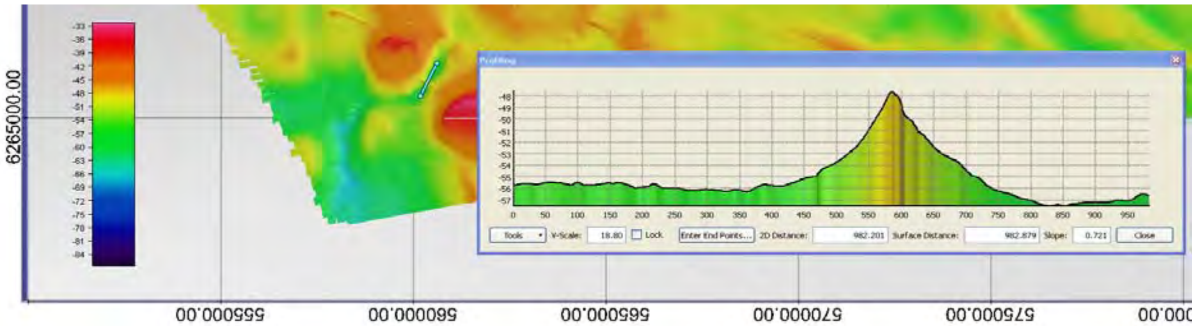


Figure 20 Profile over Sandwave

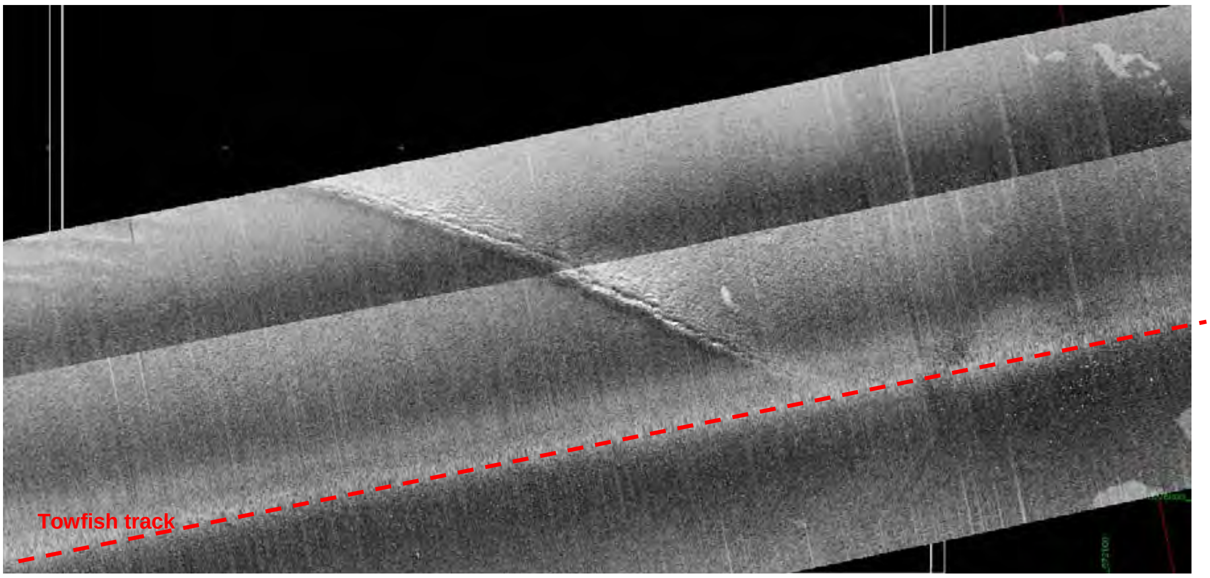


Figure 21 Sandwave as observed in the Side Scan Sonar

5.2.3 Deposition

There were no significant areas of deposition noted during the survey, and none were expected from the desk top study.

5.3 Contacts

The majority of sonar contacts identified in the side scan sonar records were classified as boulders, thought to be of glacial origin. "Isolated boulders" and boulder clusters are present throughout the area, although within the areas of significant megaripples their presence is lessened.

Other smaller contacts not within boulder fields have been classified as "sonar contact". This does not preclude them from being boulders, but for smaller objects it is virtually impossible to exactly define the nature of the object beyond its dimensions. All contacts were reviewed in conjunction with the magnetometer data, and correlations are listed in the target database where appropriate. Examples of pertinent contacts are displayed in Figure 22 to Figure 27.

Figure 22 Contact 0104-1240, linear debris

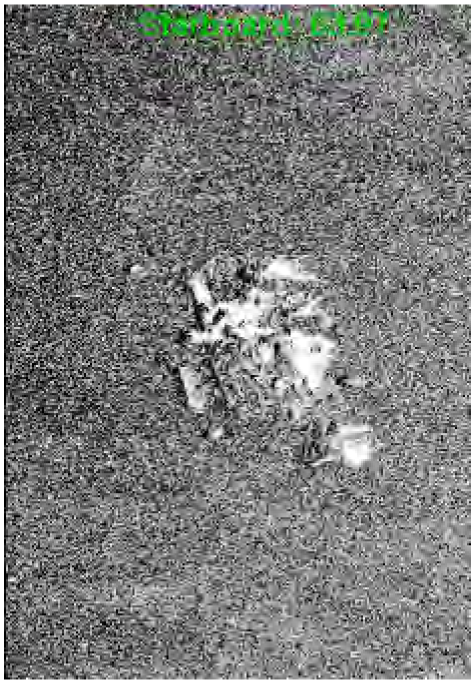


Figure 23 Contact 0107-1061 Possible rock outcrop (outwith Phase 1 area boundary)

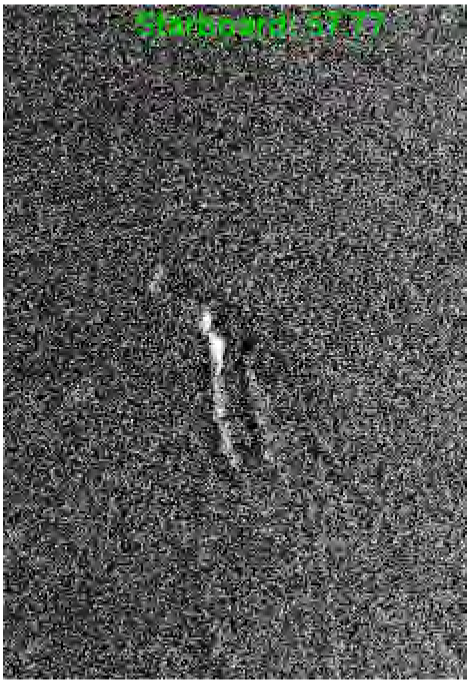


Figure 24 Contact 0101-1032, depression

Figure 25 Contact 0101-1098, sonar contact, unknown

NB, all images are approximately 30m x 20m

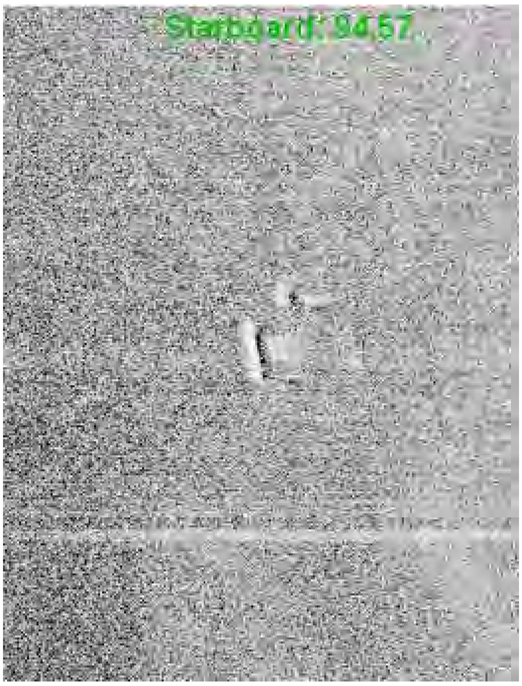


Figure 26 Contact 0111-1006, linear contact

NB, all images are approximately 30m x 20m

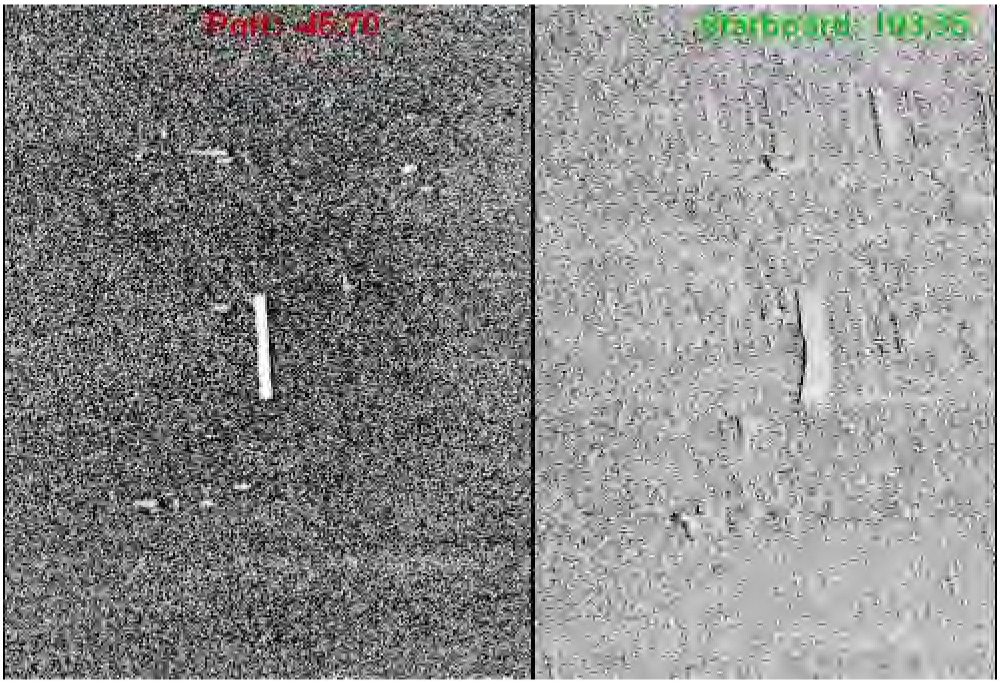


Figure 27 Contact 0101-1089 (2 images), linear debris with magnetic signature

Some magnetometer contacts do not correlate with side scan sonar contacts, and these are most likely objects in shallow burial.

Although it was not possible to target all boulders across the site, boulders dominant in the record were picked as ‘Isolated Boulders’ (Figure 28) or Boulder Clusters (e.g. Figure 29).

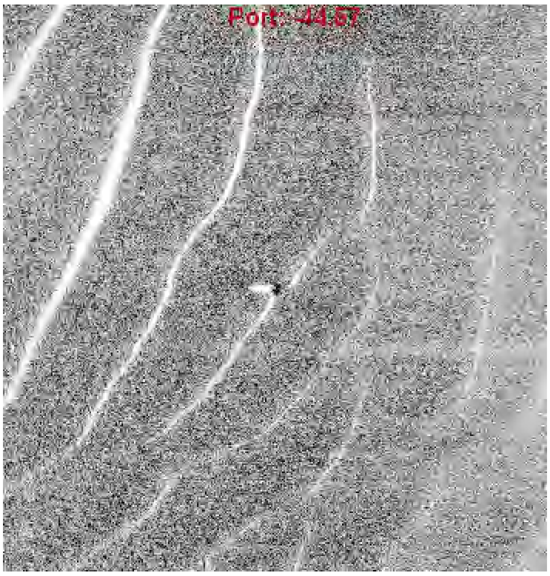


Figure 28 Isolated Boulder (1.5m x 1.0m x 1.5m)

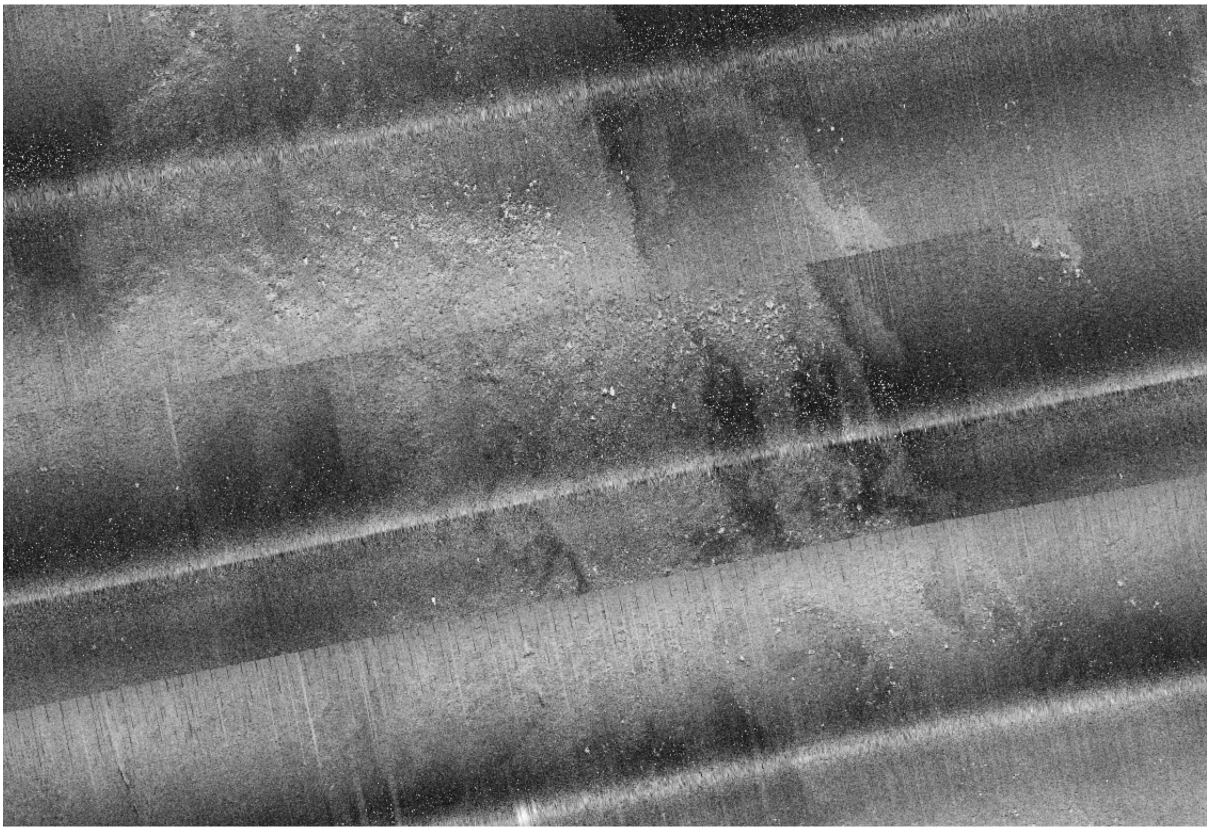


Figure 29 Boulder Clusters

All sonar contacts have been displayed with their dimensions on the seabed features charts.

Other non-geological contacts in the area include trawl scars, which were observed in the middle to southeast of the area, see Figure 31. (Trawl) scars are identified by the acoustic shadow and reflectivity pattern they present on the side scan record, and can be differentiated from raised features such as sand bars by looking at the pattern of shadow relative to the fish, explained in Figure 30. Other than the occasional trawl scar, there was little evidence of fishing activity within the Phase 1 area; there was no disruption to survey within area due to fishing activity.

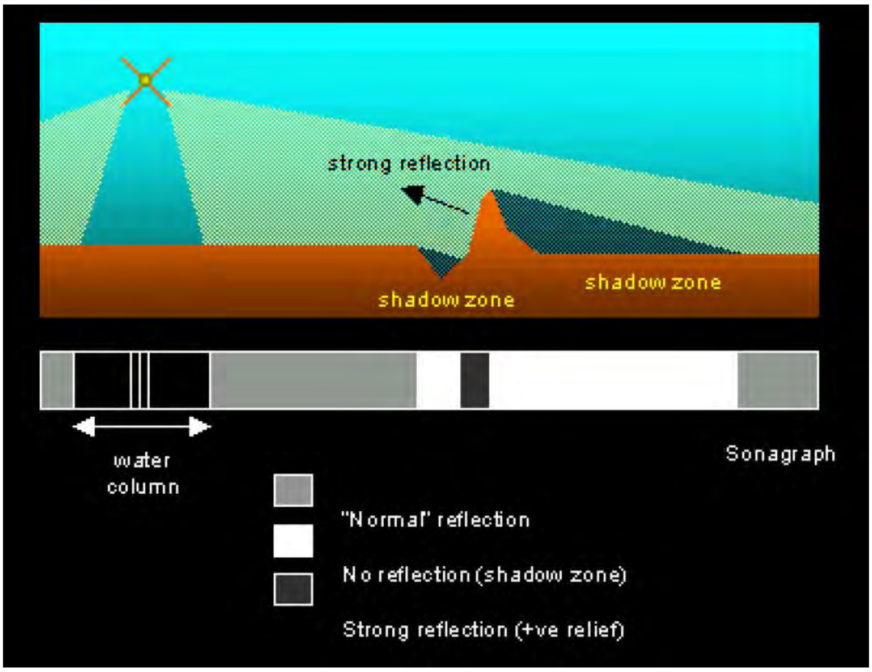


Figure 30 Basic principles of side scan sonar interpretation

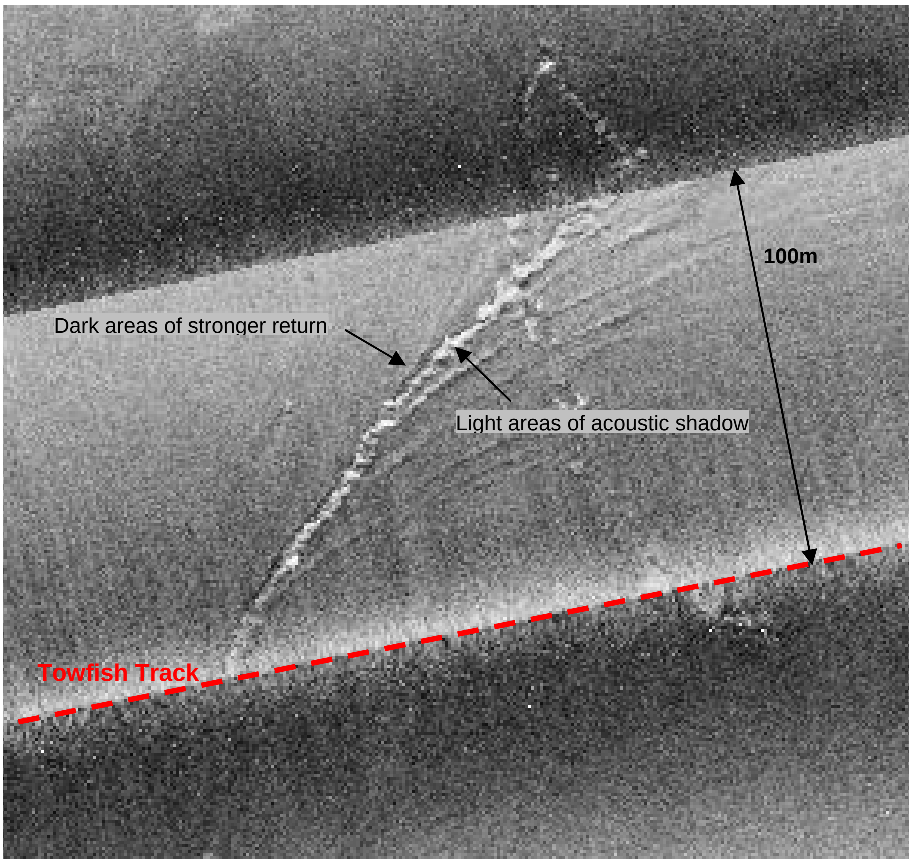


Figure 31 Trawl scars observed in Block 10 SSS record

It is not possible to determine the age of a trawl scar from a side scan record. In gravels and sands scars can remain on the seabed until finer sediments infill, however the edges of the scar do appear to be sharp and defined in the record which suggests that it has not been subject to significant erosion or abrasion from the passing water volume.

5.3.1 Observed Wrecks

Three wrecks were identified across the Phase 1 survey area, as listed in Table 8 below. All wrecks were boxed in on the seabed to observe high quality data from all sides. Wrecks were aligned with the Seazone data supplied as part of the desk top study, and information where available is provided in Table 8.

Table 8 As-Found Wreck List

Wreck ID	Easting	Northing	Length	Width	Height	Probable Seazone ID	Probable Wreck Name	Year Sunk	Image
0107-1231	553 908	6 270 382	31.0	7.5	6.3	637000004278841 / 223000004899281	unknown	unknown	Figure 32
0111-1157	588 423	6 268 332	95.0	13.0	3.0	637000004388579 / 154000006704752	HMS St Briac	1942	Figure 33
0112-1014	577 240	6 264 891	30.0	7.4	2.0	637000004388581 / 154000006705936	unknown	unknown	Figure 34

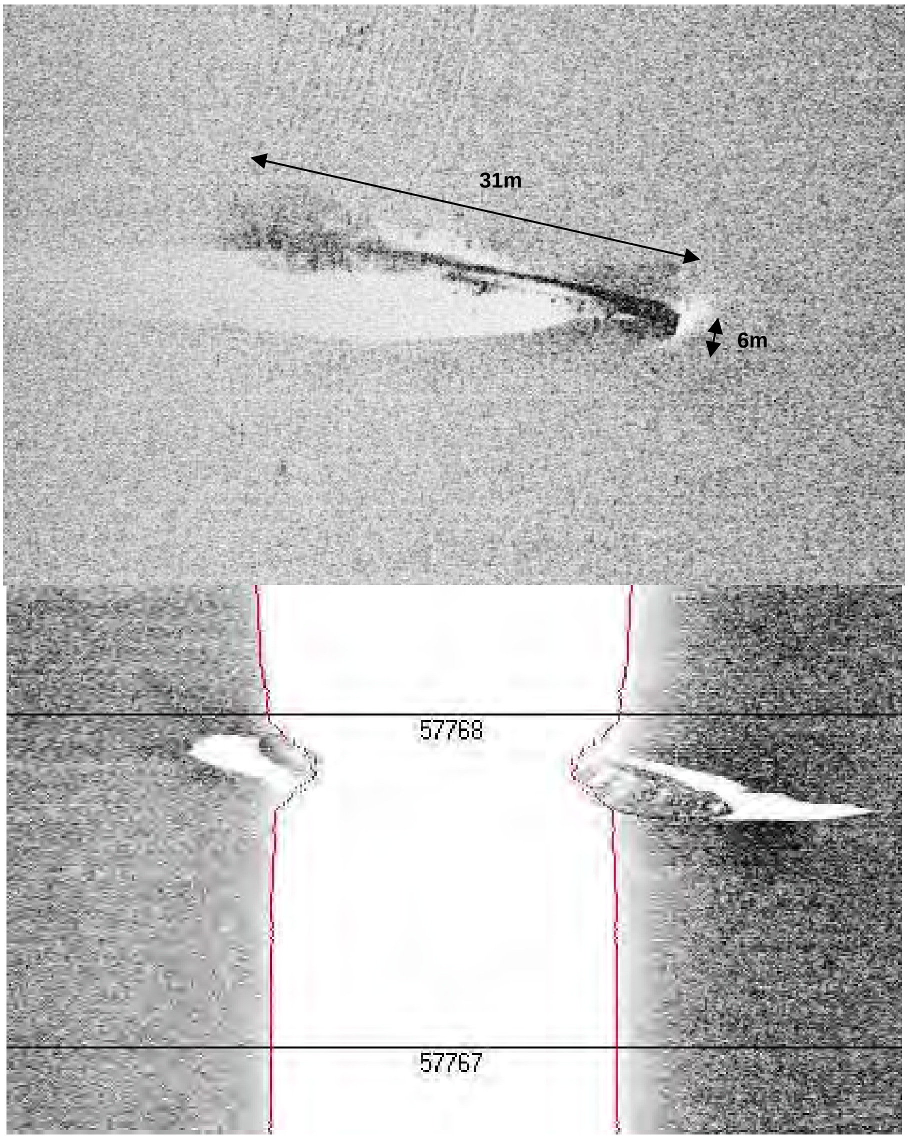


Figure 32 Side Scan Sonar Records of Wreck 0107-1231

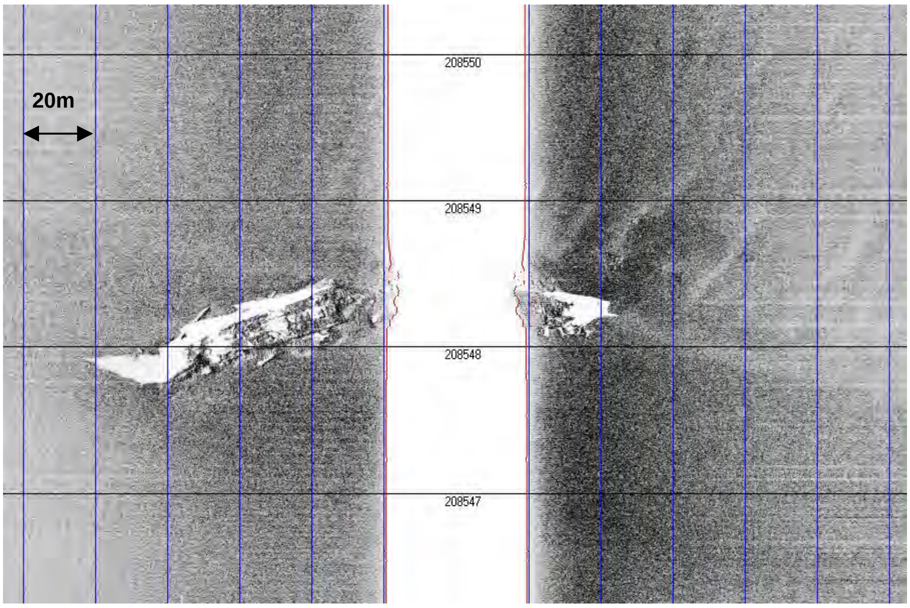


Figure 33 Side Scan Sonar Record of Wreck 0111-1157

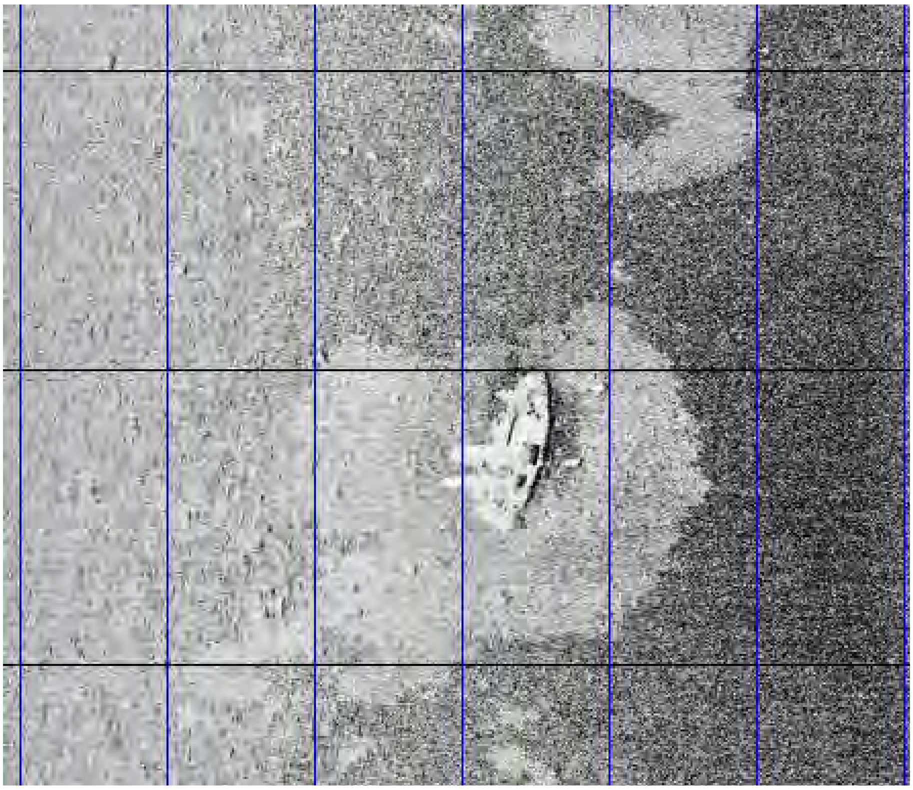


Figure 34 Side Scan Sonar Record of Wreck 0112-1014

The observed positions of the wrecks closely match the charted positions provided as part of the desk top study.

5.4 Acoustic Ground Discrimination

The acoustic discrimination system uses properties from the swath back scatter data to classify the sediments on the seabed. The system used was QTC Sideview, which provides information on seabed class, and the confidence and probability of that interpretation.

QTC is an unsupervised system, meaning that the system is unable to determine the exact sediment and environmental types on the seabed, rather it groups together areas with acoustically similar properties, which can later be ground truthed.

The system was able to identify the changes in sediment types as digitised from the side scan sonar, but it was also able to identify a subtle transition zone from one sediment type to another which was not overly apparent from the side scan sonar. In the mid areas of the site, this transition zone is quite complex and what at first appeared to be 2 basic sediment types can be broken down into more complex areas.

Figure 35 Overview of AGDS classifications, excluding predominant soil type

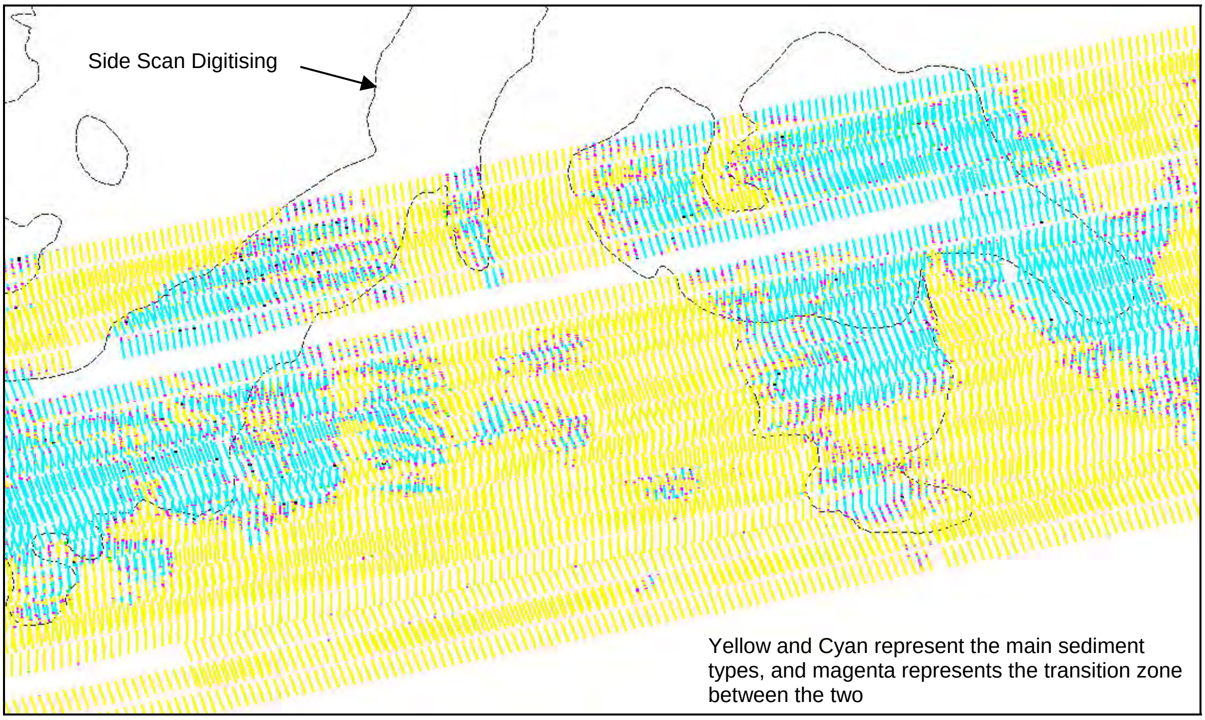


Figure 36 AGDS Interpretation overlain onto Side Scan Sonar Digitising

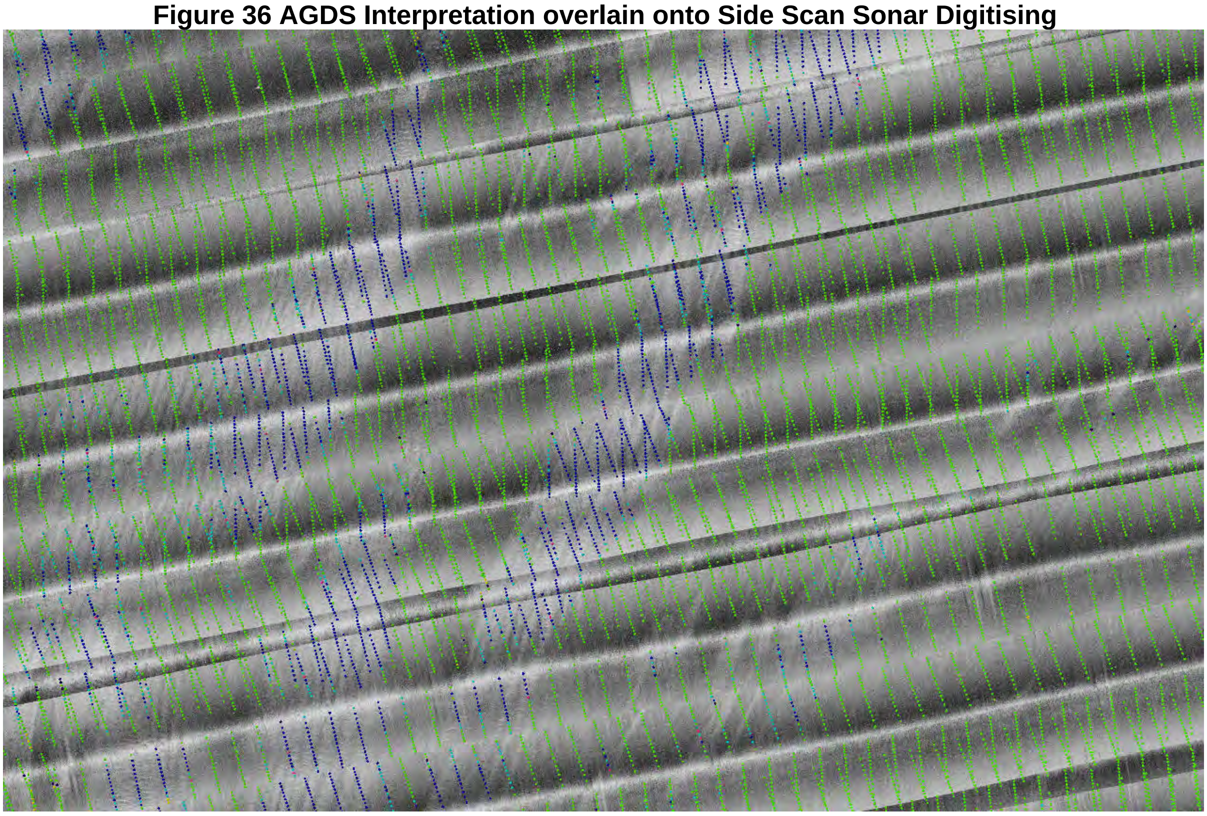


Figure 37 AGDS Overlain onto Mosaic, with clear correlation between the high and low reflectivity

When compared to the bathymetry, the data correlates well with the changes in depth, identifying differing sediments along the slopes, and in the west specifically, changes in properties in the dips have a good correlation to the depth and slope.

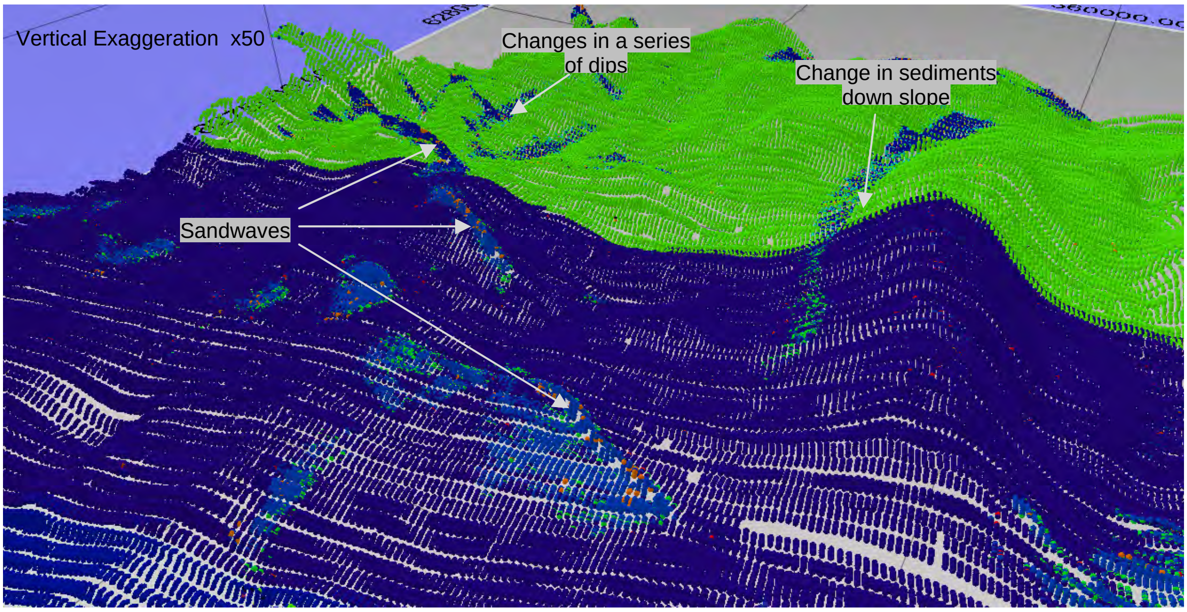


Figure 38 Perspective View of AGDS Shown by Depth

On top of the Scalp Bank in the mid-west area, there appears to be at first look noise in the data in the extremes of the swath, however this does not extend eastwards along the survey lines, and is thought to correlate to the area of more textured seabed associated with the erosion of the Holocene sediments, and is possibly indicating subtle changes in the underlying sediment type.

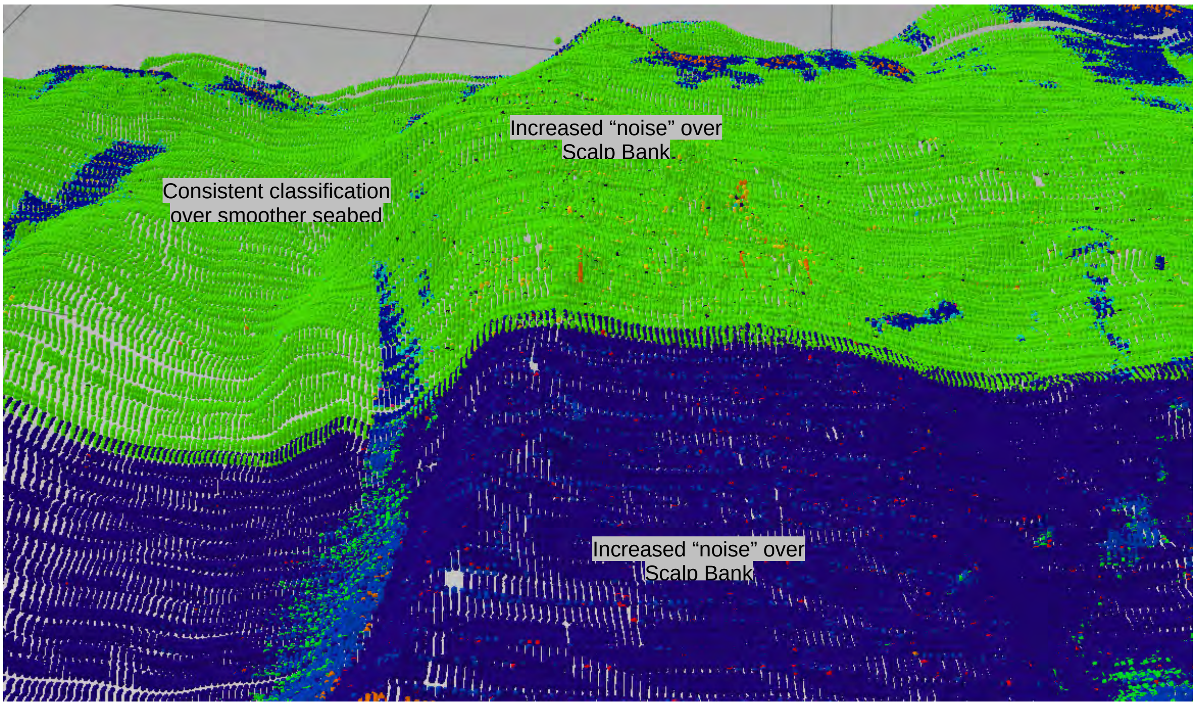


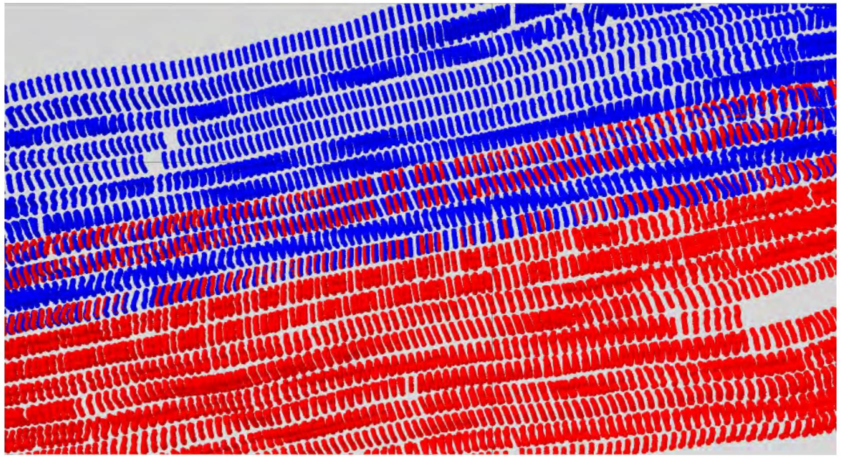
Figure 39 Perspective View of Increased Noise Over Scalp Bank

Ground truthing was performed in 5 areas across the Phase 1 area, and as such, preliminary sediment types can be associated with resultant class information from the QTC system.

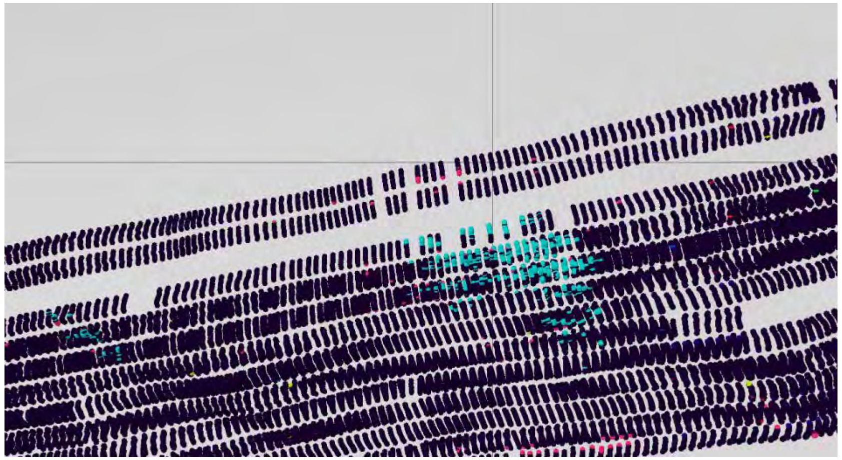
The AGDS confirms that the majority of the site can be classed as gravelly SANDS containing some lithic and biogenic material. Identification of the remaining areas will be confirmed with the environmental campaign.

The QTC system is only able to perform "cluster analysis" (the process by which it assigns classes to the back scatter data), to survey data acquired with the same pulse length. Over the course of the survey, the pulse length was changed as the system was re-calibrated. This results in the output files having different ID values for the same sediment type.

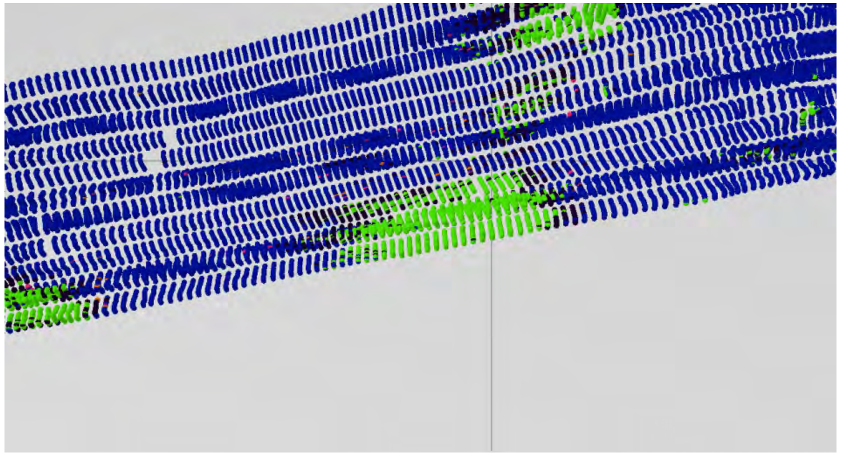
Data were processed in batches by acquisition block, and filtering applied to each. Subtle changes in online acquisition settings mean that the resultant classifications are also not entirely comparable between acquisition blocks. An example of this is seen in Figure 38 and Figure 39, where the dominant sediment class changes from being represent by green to being represented by blue. Features and changes within acquisition blocks are still completely apparent, and there is also good correlation between areas surveyed twice at differing pulse lengths (over-lap between data sets), as shown in Figure 40.



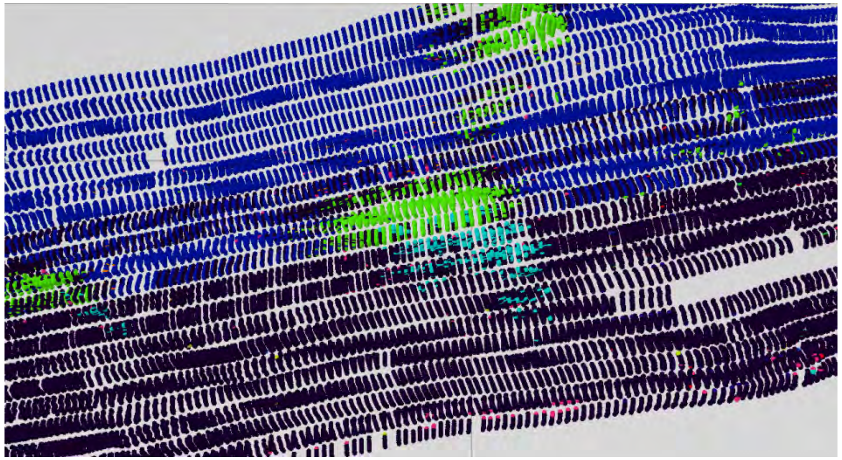
Coverage of Block 9 File ID 9 (blue) and File ID 15 (red)



AGDS class results for File ID 15



AGDS class results for File ID 9



Class results combined, showing strong correlation

Figure 40 Comparison between AGDS Processing Files

6. GEOLOGY

The depth charts for shallow soils and the Triassic bedrock, and profiles every (nominal) three kilometres and are presented in the Appendices.

Pinger and sparker sub-bottom profiler data were collected on all lines to achieve excellent coverage.

Pinger data achieved a penetration of up to 6 metres and produced data of sufficient quality to map the base of the Holocene sediments (comprising superficial sediments and Forth Formation) where they are found close to the surface. The pinger dataset was interpreted on every line in SMT Kingdom and the Holocene sediments identified were then exported into the sparker SMT Kingdom project.

Sparker data was processed in *ProMAX* to improve the signal-to-noise ratio and apply Band-Pass filtering and Time-Varying Gain to the record. Maximum penetration was achieved to below the first seabed multiple. The seabed return showed a thickness of approximately 4ms TWT (two-way travel time) thus not resolving thin layers of sediment at the surface. The sparker dataset was interpreted in SMT Kingdom and combined with the Holocene reflector derived from the pinger dataset. A velocity of 1800ms^{-1} has been used for time-depth conversion for all reflectors.

Throughout this description, the terms "east" and "west" are used to describe the site. This boundary is the approximate boundary between the Marr Bank formation and the Wee Bankie formation, and is delineated as shown in Figure 41.

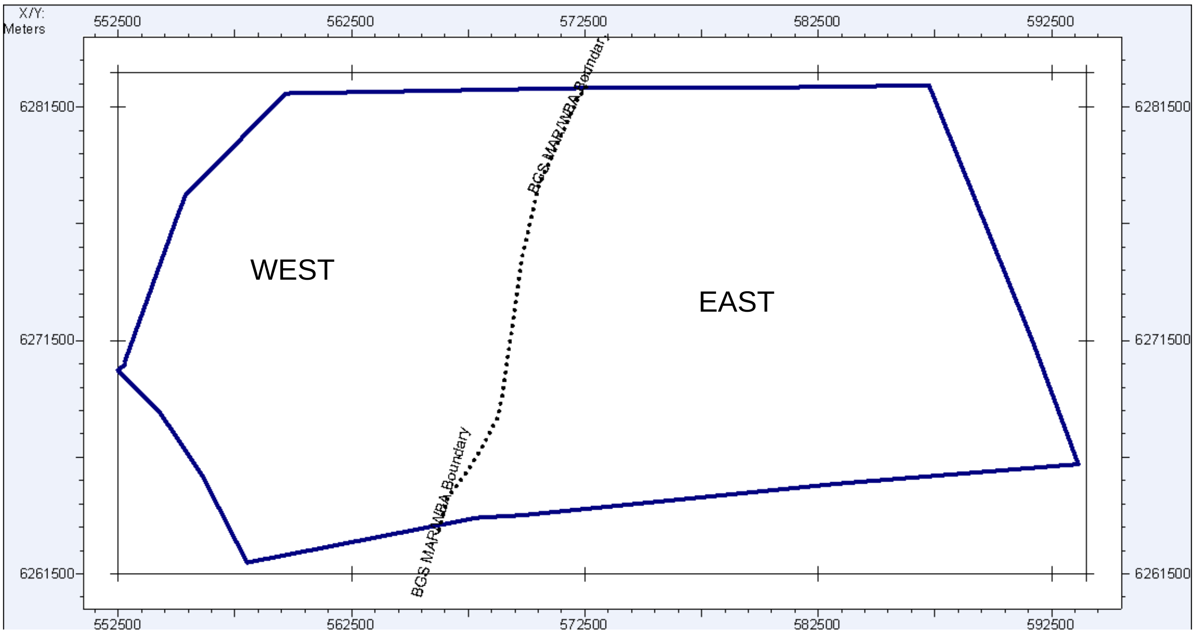


Figure 41 Delineation of "east" and "west"

6.1 Overview

The geology in the survey area is complex with a well defined boundary between Triassic bedrock and Quaternary sediments in the east, and the west marked by a more chaotic internal structure, where the boundary between bedrock and overlying formations is blurred to non-existent and the differentiation between different Quaternary stratigraphic units is not always possible. The area just west of the centre of the site is characterized by a deep north-south trending trough where the bedrock has been deeply eroded and the hollow has been infilled with a thick succession of Quaternary sediments. The eastern approaches of this trough mark the approximate boundary between what is described in this report as the east and the west of the site. All charts have been produced combining the well-defined horizons in the east with inferred horizons in the west which are depicted as dashed lines (for the exact delimitations of the well-defined and inferred horizons for each formation, please refer to the appropriate charts).

In this report, the superficial sediments derived from the pinger data and the sediments of the Forth Formation derived from the sparker data have been combined to form undifferentiated Holocene sediments, as both are found to comprise predominantly SANDs and are difficult to differentiate as outlined below.

Stratigraphic units and the sediments they comprise have been derived from the BGS charts for this area, including the Tay Forth and the Marr Bank sheets (both *Sea Bed Sediments* and *Quaternary*) as well as the Devil's Hole *Quaternary* sheet and the BGS Offshore report for the Central North Sea. Information from the supplied desktop study and BGS seabed sample and borehole information have also been integrated into this report. The BGS borehole data for BH13 and BH20 are displayed in Figure 42 and the information derived from all boreholes has been used to aid interpretation. Locations for sediment sample and borehole locations are displayed in Table 10.

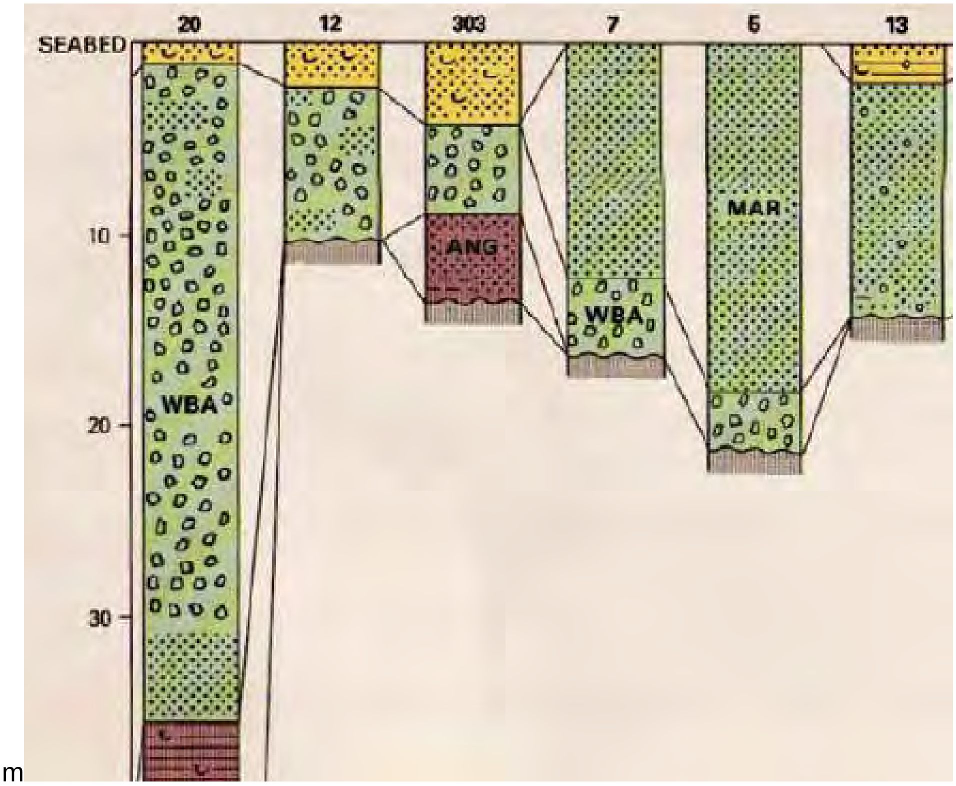


Figure 42 BGS Borehole Interpretations (BH13 to BH20)

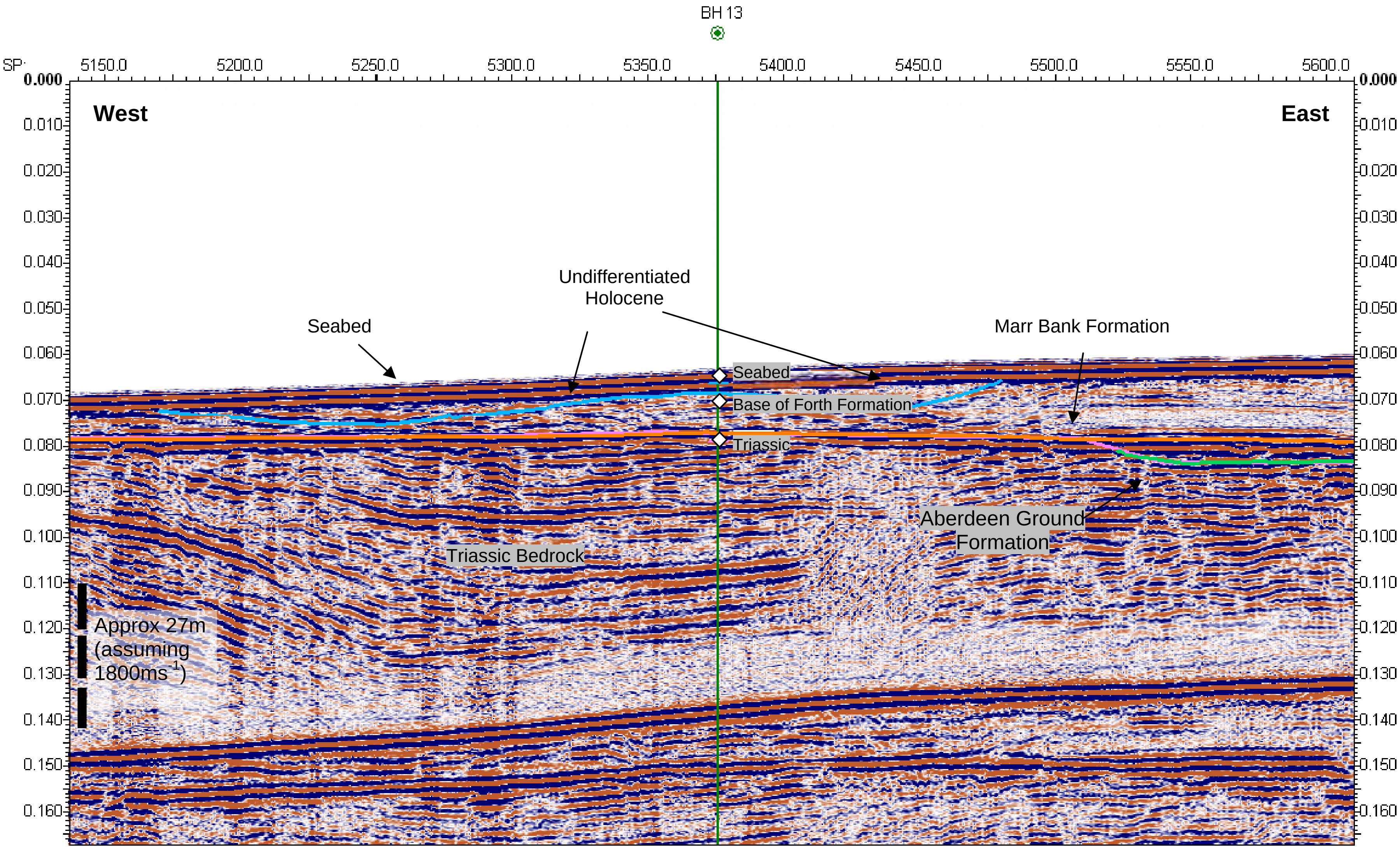


Figure 43 BH 13 overlaid onto Sparker SEGY (146B6_C-S)
[Borehole Offset from line: 115m SSE]

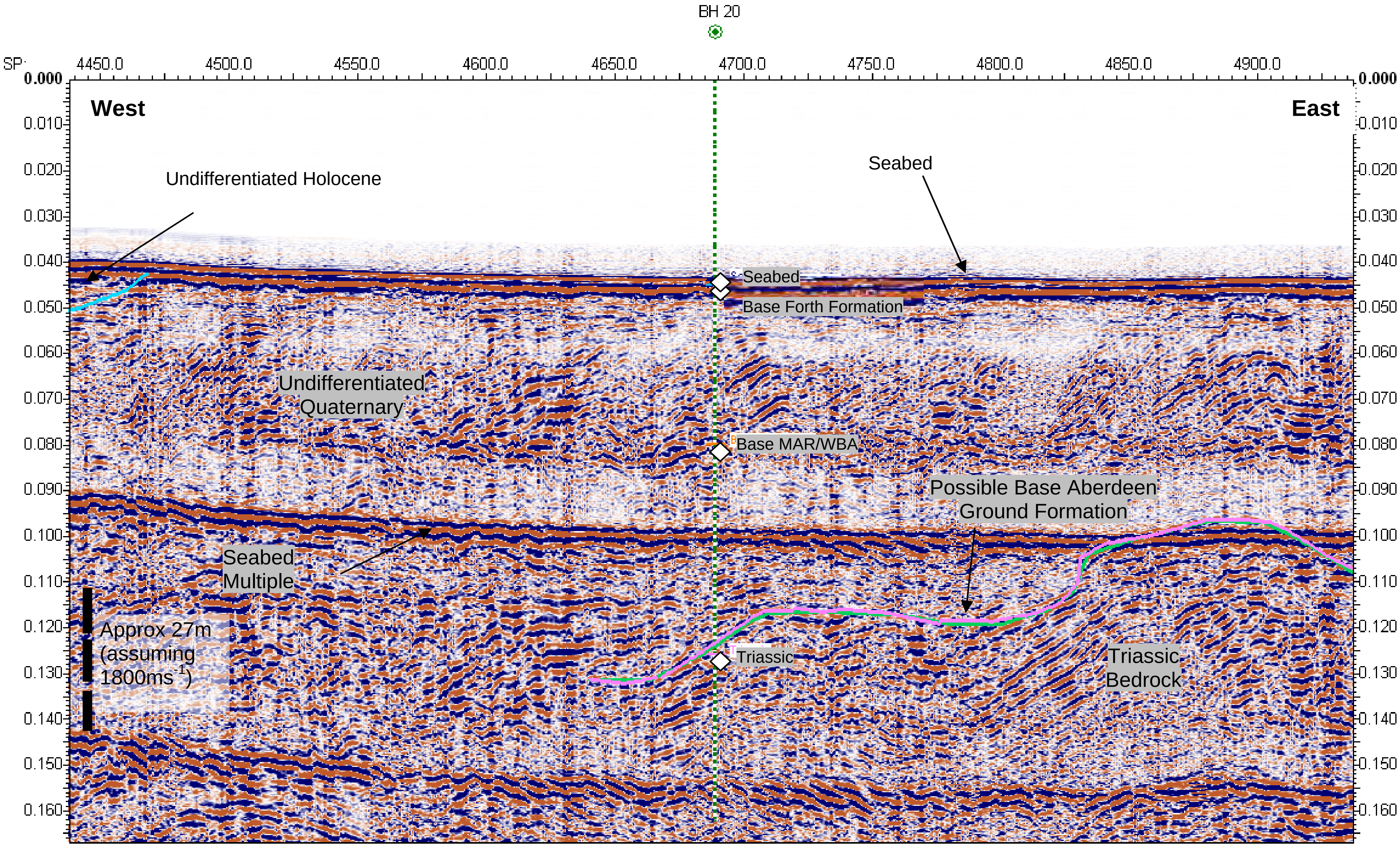


Figure 44 BH 20 overlaid onto sparker SEGY (173B7-S). Very complex region with significant interference from seabed multiple [Borehole Offset from Line: 183m NNW]

A summary for the geology in the survey area is presented below using a combination of BGS chart data and seismic data collected on-site.

Table 9 Geological Summary

Stratigraphy		**Depth (metres BSB)**	**Properties**	**Predicted Soils**
Holocene	Undifferentiated Holocene	Generally less than 0.5m thick	Superficial sediments: thin veneer of sediments generally less than 0.5m thick and locally absent.	SAND, slightly gravelly sand, gravelly sand and also some small patches of sandy GRAVEL
		Up to 35m to base of formation	Forth Formation: occurs as blanket spreads or occupies depositional hollows on the surface of the Wee Bankie Moraine, or late Weiselian channels. Internal erosion surfaces common. Mainly amorphous; some well-layered sediments in north and west. Present across most of the site.	SAND, fine grained, well to poorly sorted, soft to firm, olive to grey brown, with lithic pebbles, shells and shell fragments in variable amounts and some possible MUD/SILT towards its base. Fluviomarine.
	Wee Bankie Formation	Up to 63m to base of formation	Sheet-like deposit on rugged bedrock topography. Seismically amorphous, with occasional point source reflectors. Covers most of west of area; grades into Marr Bank Formation. **Generally <20m thick, up to 40m thick in some places.**	BOULDER CLAY, hard, dark grey to red-brown, gravelly, angular to rounded clasts, with thin interbeds of sand and pebbly sand. Basal till.
	Marr Bank Formation	0 to 38m to base of formation	Sheet-like deposit on flat basal surface. Seismically mainly amorphous with some faint mostly parallel layering. Covers most of east of area; grades into Wee Bankie Formation.	SAND, fine grained, poor to well sorted, soft to firm, grey to red-brown with abundant lithic granules and pebbles. Locally silty. Glaciomarine.
	Aberdeen Ground Formation	In excess of 85m to base of formation in places	Occurs at blanket spreads or occupies hollows of the underlying bedrock. Sub-parallel reflectors with transparent sections. Present across less than half of the site.	Interbeds of MUD, hard, brown to grey, and SAND, fine to coarse grained. Glaciomarine.
Triassic	Triassic group	more than 85m to top of formation in places	Underlying bedrock. Heavily folded and faulted. Strongly deformed succession of parallel reflectors with transparent sections. Present across whole site.	Red SANDSTONES, SILTSTONES, MUDSTONES AND MARLS, flat to current-bedded with sporadic thin bands of gypsum, intra-formational conglomerate and disseminated pseudomorphs after halite.

6.2 EAST

In the East of the survey area, the *undifferentiated Holocene* sediments are found to be extensive and form generally north-south trending channels with depths of up to 22m. They are characterised by erosional bases that cut into the underlying Marr Bank/Wee Bankie formations occasionally penetrating the Aberdeen Ground Formation and often cutting into the Triassic bedrock. The base of the Holocene sediments is not always well defined (Figure 49), and they do not show any internal structure, but strong internal erosion surfaces – these are thought be either the base of the overlying superficial sediments or internal erosion surfaces within the Forth Formation; the BGS (1985) states that internal erosion surfaces are common within this formation. This makes it difficult to differentiate between superficial sediments and sediments of the Forth Formation and they have thus been combined to undifferentiated Holocene sediments. BGS (1984a) suggests that surface sediments in the survey area form a thin veneer of generally less than 0.5m (Table 10). These Holocene sediments are thought to comprise mostly SAND with some finer sediments towards the base of the formation although superficial seabed sediments show a higher GRAVEL content and form some gravelly patches as identified in the Side Scan Sonar data (Section 5).

Below the Holocene sediments, a sheet-like layer of *Marr Bank (MAR)* and *Wee Bankie (WBA)* Formations is present throughout most of the site. It rests unconformably on underlying sediments and is marked by a strong basal reflector which is characteristically flat for the Marr Bank Formation; the Wee Bankie Formation forms a thin veneer on the irregular underlying bedrock, but is locally hummocky and forms discrete mounds and ridges. Seismically, both units mainly show transparent sediments with no internal structure, although some faint internal layering is visible within the sands of the Marr Bank Formation, while occasional diffraction hyperbolae, likely to be caused by boulders, are seen within the Wee Bankie Formation. The depth to the base of these sediments is generally greater in the east where it is up to 30m. The sediments thin towards the centre and the north of the site (where it is often too thin to be resolved within the seabed return) with one localised deeper pocket of 39.5m south of the centre as well as a narrow north-south trending band deepening up to a maximum depth of 63m, where the unit is thought to fill the eroded tops of synclines within the Triassic bedrock. BGS (1994) describes a lateral transition between the Marr Bank Formation (glaciomarine SAND) to the east and the Wee Bankie Formation (boulder CLAY) to the west. It is challenging to map the boundary between the Marr Bank and the Wee Bankie formations, see Drawings and detailed discussion in section 6.3. According to BGS (1985) the Marr Bank Formation is thought to comprise mainly fine grained SAND with abundant lithic granules and pebbles, whereas the Wee Bankie Formation is thought to represent hard boulder CLAY.

The *Aberdeen Ground Formation (ANG)* is identified as a channel deposit as well as a sheet-like deposit and rests between the overlying Marr Bank/Wee Bankie Formations and the Triassic bedrock. It is not ubiquitous across the whole site and covers some of the east and the south as a sheet-like deposit. It also appears as a north-south trending channel of up to 75m depth below seabed in the east of the survey area, and as a deep cut and fill immediately east of the trough. The sheet-like deposits are characterised by strong parallel reflectors and where it occurs as a channel deposit, it shows strong to medium-strong parallel bedding interspersed with transparent sections and prograding dipping reflectors (Figure 45). The Aberdeen Ground Formation is thought to comprise interbeds of hard MUD and coarsely interlayered SAND.

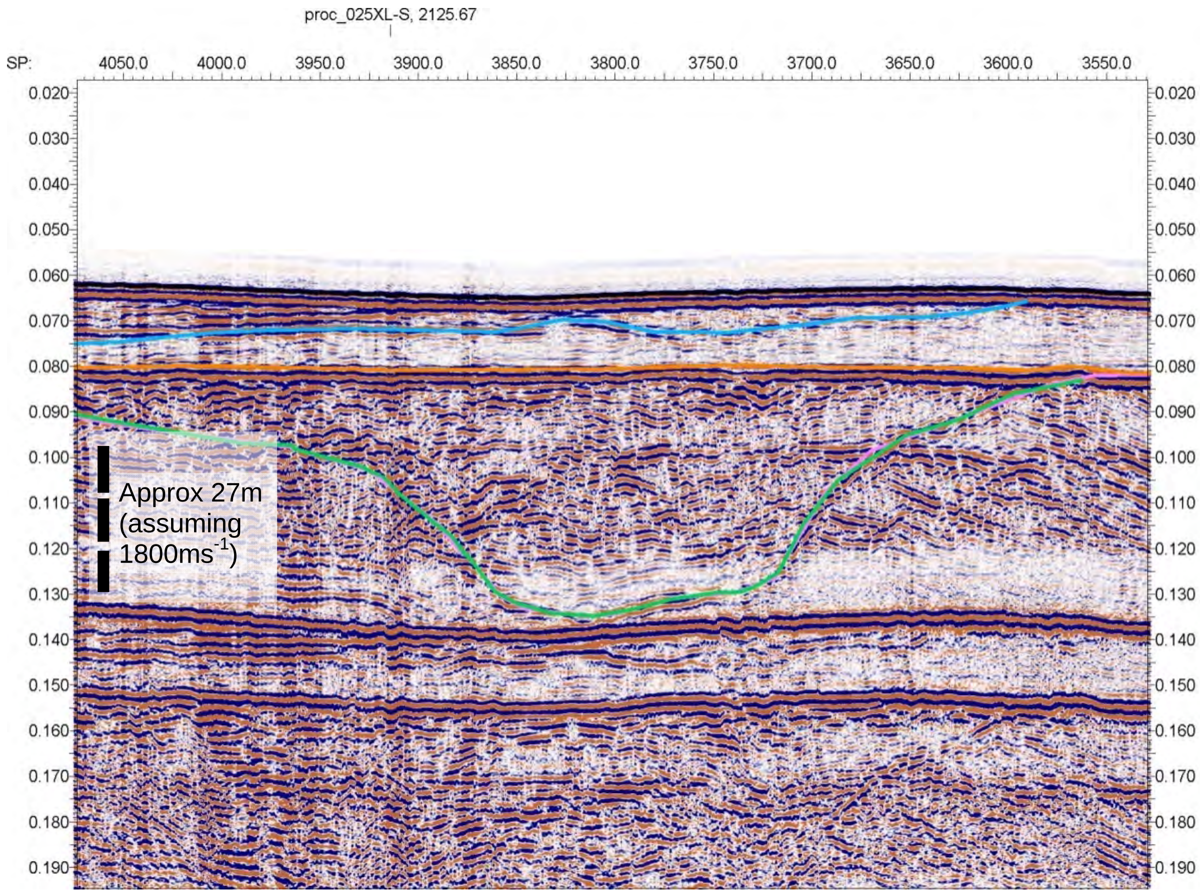


Figure 45 Aberdeen Ground Formation channel deposits

The *Triassic Bedrock* underlays the Quaternary geology across the entire site and is the deepest unit penetrated by the sparker. It forms a well-layered unit with transparent sections and is heavily folded and faulted (Figure 46).

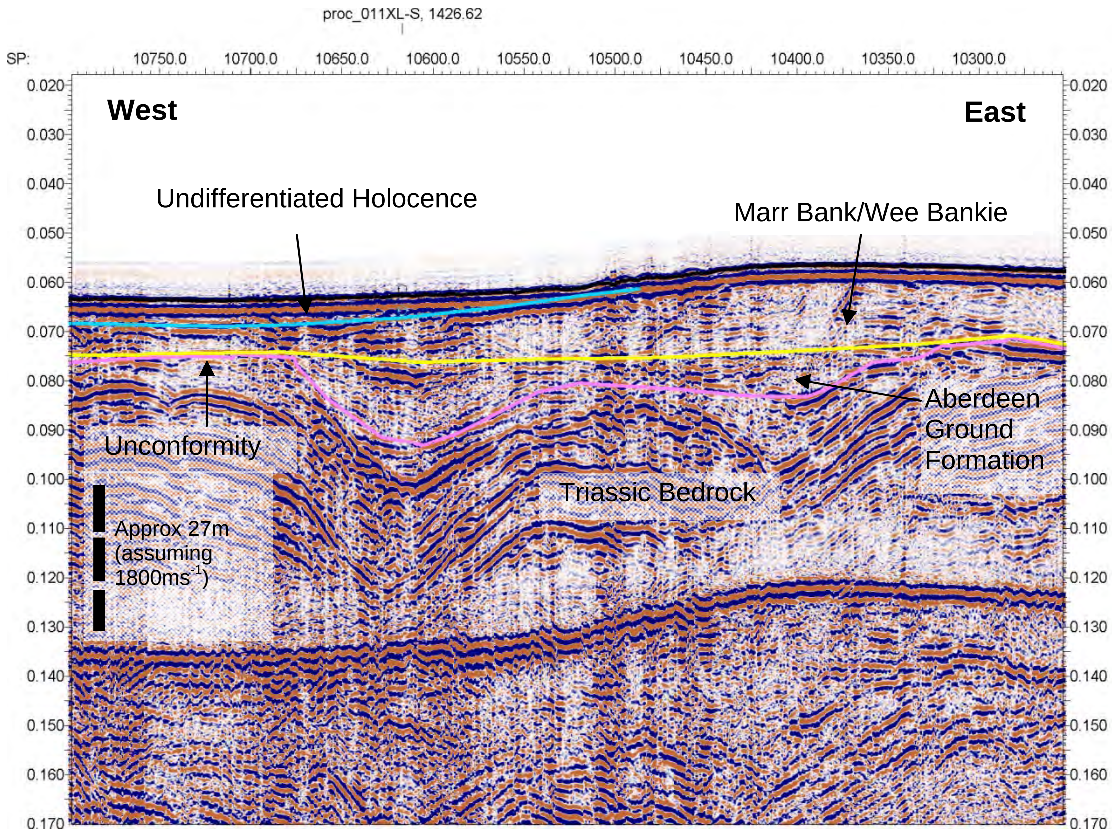


Figure 46 Triassic Bedrock displaying heavily folded and faulted character

Its top is marked by a pronounced unconformity throughout most of the east of the site, where it is found at a depth of approximately 10m and is found at or close to the seabed in the north and centre of the site. According to the BGS geological descriptions, the Triassic bedrock is thought to comprise red SANDSTONES, SILTSTONES, MUDSTONES AND MARLS which are flat to current-bedded with sporadic thin bands of gypsum, intra-formational conglomerate and disseminated pseudomorphs after halite.

6.3 WEST

In the west of the survey area, the succession of sediments as described for the east of the site remains the same, but boundaries between units are more indistinct and should be treated with caution.

Firstly, the differentiation between the Forth Formation and the underlying Wee Bankie Formation is more complex, as diffraction hyperbolae within the boulder CLAY can easily be mistaken as the edges of Forth Formation channels. Furthermore, where the bedrock is at or near the surface, only the base of the overlying formations is visible (the top is not resolved as it is found within the first return) and it is difficult to estimate what formation is present, especially as a rugged erosional surface at the top of the bedrock could be caused by either the Wee Bankie Formation or the Forth Formation.

Secondly, the bedrock in the west of the area appears to be less deformed and shows more sub-parallel bedding rather than the pronounced faulting and folding visible further east. The top of the bedrock is also not as well defined here, due to its often rugged nature in combination with the low lateral resolution. Additionally, as the bedrock consists of a succession of well layered sediments interspersed with thick units of transparent sediments, it is often challenging to map where transparent sediments are thought to be present at the top. This means that mapping the top of the bedrock becomes more ambiguous than in the east, but it also means that the differentiation between the bedrock and the Aberdeen Ground Formation is more difficult. The Aberdeen Ground Formation is generally found as either a thin sheet between the bedrock and the overlying Marr Bank/Wee Bankie formations, or as a thick unit of parallel reflectors interspersed with transparent sections, which are draped over the underlying bedrock. Thus, it is possible that more localised sheet-like areas of Aberdeen Ground Formation have not been imaged on the data and thus have not been mapped. Also, in the far southwest corner of the site, it is possible that thick layers of Aberdeen Ground Formation are present that have not been resolved by the data due to significant interference from the seabed multiple (Figure 47).

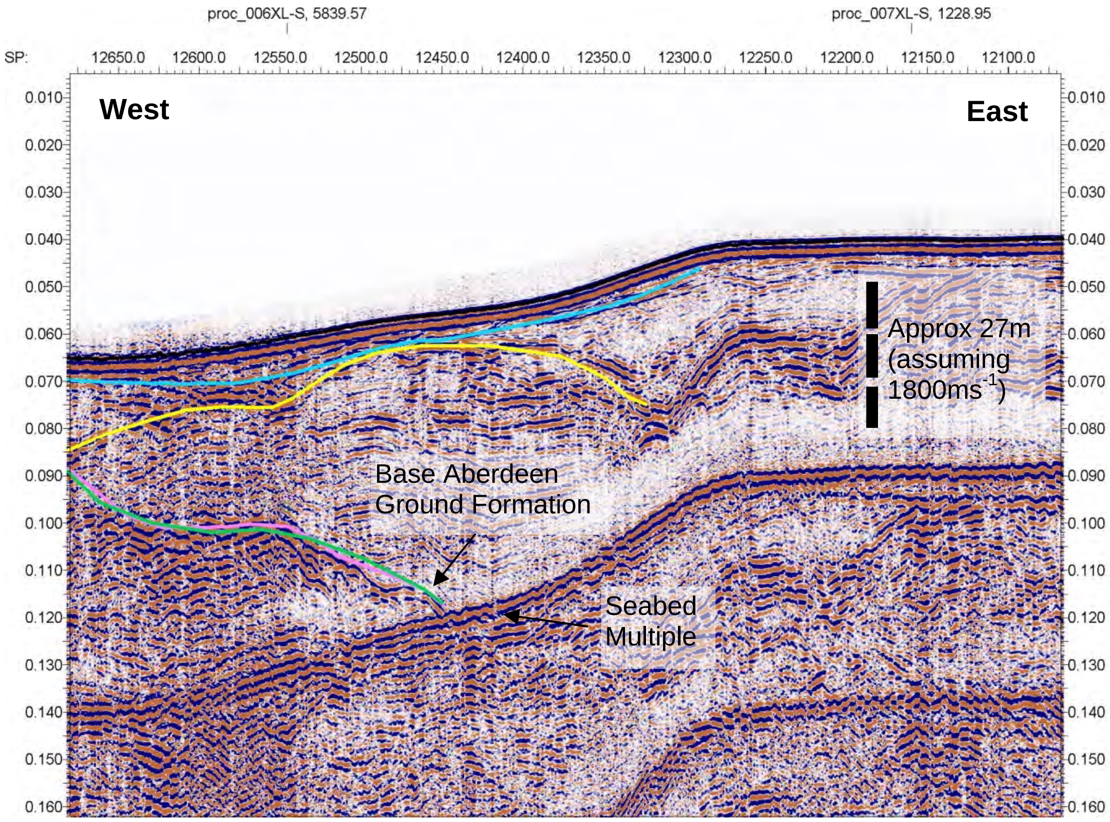


Figure 47 Possible occurrence of thick layers of Aberdeen Ground Formation not resolved due to interference from seabed multiple

Generally, units have been mapped as inferred reflectors in the west to show the ambiguity of the interpretation (dashed lines on charts and lighter colours on profiles) – the Triassic bedrock has been mapped for almost the entire area, but it was not possible to map Quaternary sediments to the same extent. Where the base of the Aberdeen Ground Formation was mapped, its top has also always been mapped and is defined by either the Wee Bankie/Marr Bank formations or rarely the Forth Formation. Where it was not possible to distinguish between the Quaternary units, sediments are to be treated as undifferentiated Quaternary sediments (Figure 49, Figure 51). This implies a greater likelihood for Marr Bank/Wee Bankie Formation and Forth Formation where the bedrock is near the surface and a higher probability for Aberdeen Ground Formation where it is found at greater depth.

The interpretation in an area in the southwest of the site, approximately delimited by main line 232 and cross line XL15, is even more ambiguous than the remainder of the western part of the site. In this area, the differentiation between bedrock and possible Aberdeen Ground Formation is almost impossible – the bedrock has been mapped for its shallowest possible occurrence, but a thick succession of Aberdeen Ground Formation in parts of the area is possible. Also, most of the Quaternary sediments have been left as undifferentiated as it is not possible to distinguish between Aberdeen Ground Formation and Wee Bankie Formation within channels of the bedrock.

In the west of the site, the *undifferentiated Holocene* sediments are present across most of the area as channels as well as sheet-like deposits; their base varies from well-defined to extremely blurred. In the north, a southwest to northeast trending channel is visible which is filled with well-layered sediments and up to 24m thick. Further south, a more extensive north-south trending channel with almost transparent and occasionally faintly layered sediments is visible; it shows a depth of up to 34.5m. In the west and south, the unit appears more sheet-like, displaying amorphous sediments in the west (Figure 48) and strong internal layering in the south (Figure 49). The (undifferentiated) Holocene sediments are thought to comprise mostly SAND, although a higher occurrence of finer sediments is likely, as indicated by the well-layered units; the superficial seabed sediments comprise a higher GRAVEL content and form some gravelly patches in the area, as evidenced by grab sample and side scan sonar data.

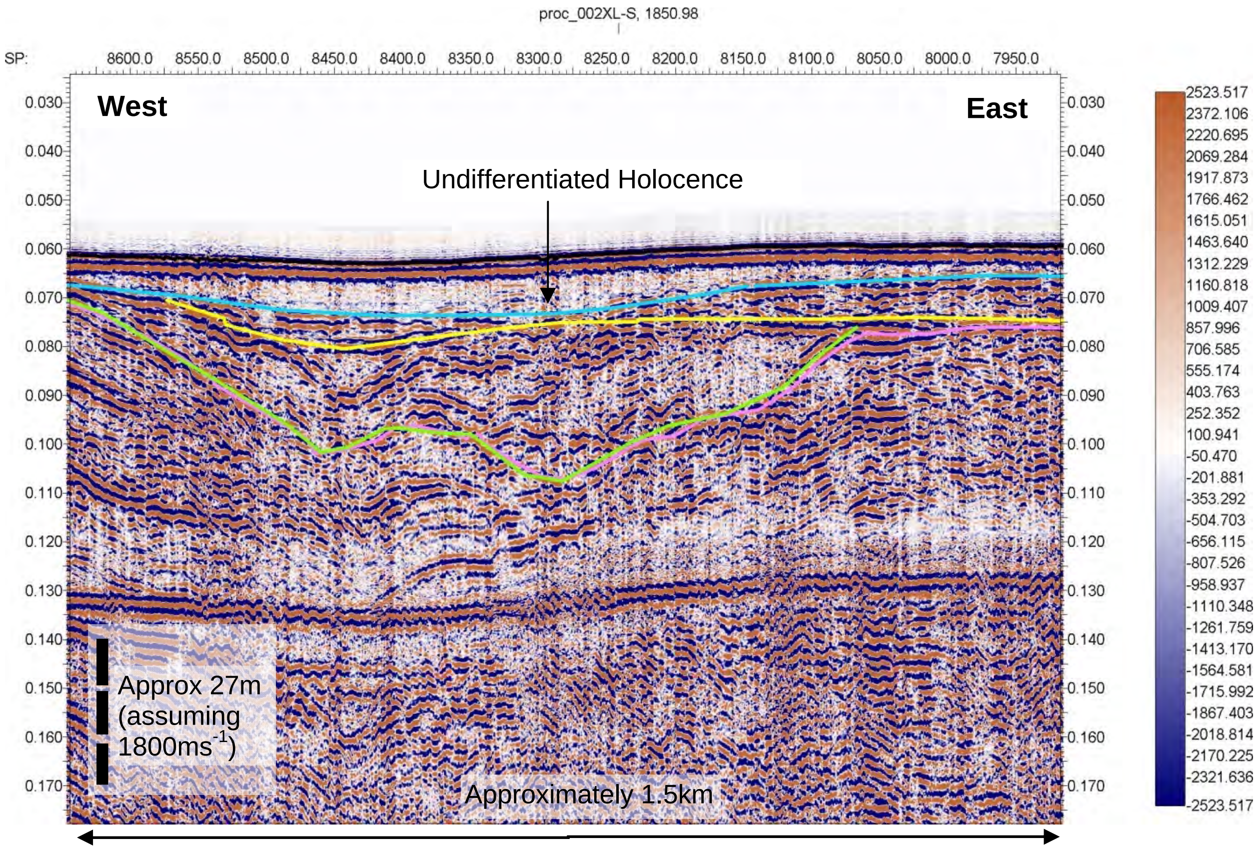


Figure 48 Data example line 180B8_2: West of site displaying amorphous nature of undifferentiated Holocene sediments

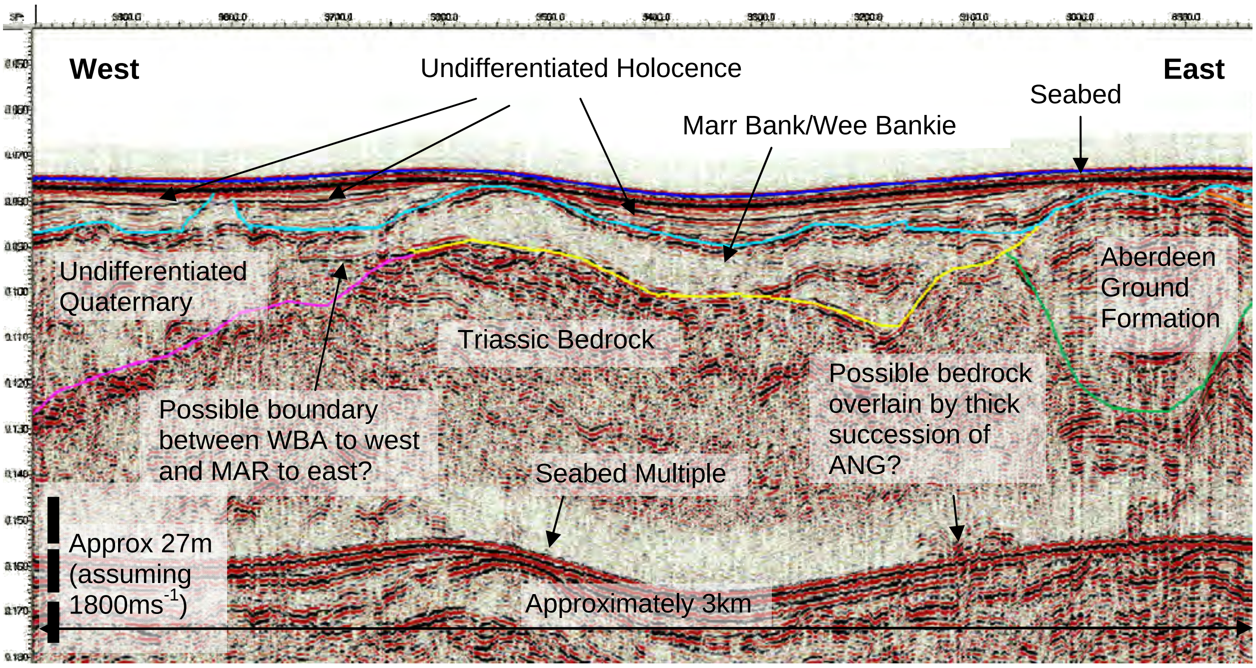


Figure 49 Data example: line 246 (all reflectors are inferred apart from the Holocene; bedrock is defined by the lowest reflectors; two way travel time on left hand scale with 1 ms equivalent to approximately 0.9 metres at 1800 m/s)

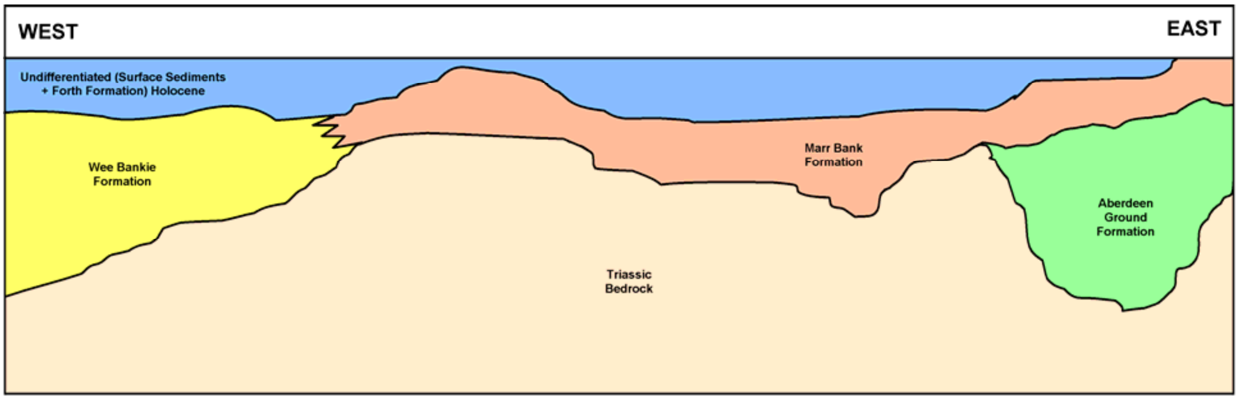


Figure 50 Schematic Cross Section displaying possible boundary between Marr Bank and Wee Bankie Formations

At the approaches of the trough, west of the centre of the site, the formation underlying the Holocene sediments shows distinct ruggedness at its base as well as pronounced internal diffractions and is interpreted as the *Wee Bankie Formation* for the west of the site, apart from an area in the south where the transition between Marr Bank to the east and Wee Bankie to the west is thought to be visible and coincides with the BGS boundary (Figure 49, Figure 51). A schematic interpretation of this boundary in relation to the other geological units is depicted in Figure 51.

The Wee Bankie Formation is thought to reach great thickness within both the extensive north-south trending trough, and the smaller trough further south; at the approaches of these troughs, it is difficult to map as its base is often hidden within or just above the seabed multiple, and its edge is mostly unresolved. The formation has only been mapped in some areas in the west, but is thought to be much more extensive. Often it is not possible to map its base or distinguish it from the Forth Formation or the Aberdeen Ground Formation and sediments have to be treated as undifferentiated Quaternary.

In the west of Phase 1, the *Aberdeen Ground Formation* is present as a north-south channel-like feature trending north-south. This feature is visible north of and flanking the large trough west of the centre of the site and also found south of it. It has been encountered at great thickness in BH20 in the centre of the trough. In the north of the trough, it is well-layered and exhibits draping over the underlying bedrock; at the flanks of the trough, it is often seen to cross-cut the bedrock and does not always show internal layering – its base within the troughs is often not resolved as it is found near or below the multiple. This formation is thought to be more extensive towards the south, especially south and west of the smaller trough in the south where it is not resolved by the data. It also occurs as a smaller cut and fill in the far west of the area and is potentially present in channels within the bedrock (which have been left as undifferentiated Quaternary) and as a thin sheet-like deposit, especially at the central/western flank of the trough. Where the Aberdeen Ground Formation has been mapped, it was also attempted to map its top – this is either defined by the base of the Marr Bank/Wee Bankie Formation or, where this is not present, by the base of the undifferentiated Holocene sediments. The Aberdeen Ground Formation is thought to comprise interbeds of hard MUD and coarsely interlayered SAND.

The Triassic bedrock in the west of the area is generally less deformed and shows more sub-parallel reflectors interspersed with thick transparent sections; it is often found at or close to the surface and shows some channelling, especially in the far north, far west and the south of the area. Where it is found close to the seabed, its top is often not resolved by the data, either because it is found within the seabed return or not well defined – this means that the bedrock in the western side of the survey could be closer to the surface than mapped on the charts. However, in the far southwest corner, as outlined above, it is potentially found at much greater depth overlain by a thick succession of Aberdeen Ground Formation, see Figure 49 and Figure 51. Based on BGS information, the Triassic bedrock is expected to comprise red SANDSTONES, SILTSTONES, MUDSTONES AND MARLS which are flat to current-bedded with sporadic thin bands of gypsum, intra-formational conglomerate and disseminated pseudomorphs after halite.

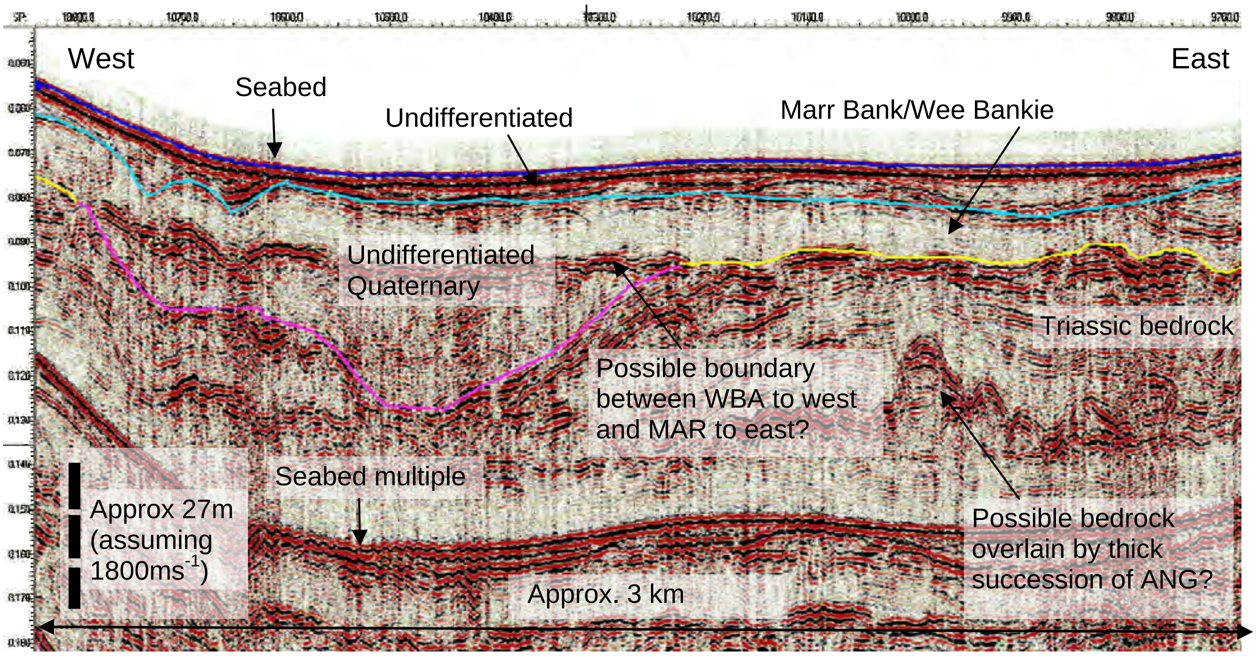


Figure 51 Data example: line 254 (all reflectors are inferred; bedrock is defined by the lowest reflectors; two way travel time on left hand scale with 1 ms equivalent to approximately 0.9 metres at 1800 m/s)

Integration of sediment samples/shallow cores in the survey area

The transition between the Marr Bank (sand) and the Wee Bankie (boulder clay) formations is very difficult to map. Often, there is little difference in seismic attributes; it is equally difficult to map the formations by using the properties of their basal reflectors as the flat base of the Marr Bank Formation is often cut and eroded by the Forth Formation (which is often faint and not visible) and indistinguishable from the base of the Wee Bankie Formation (overlying a more irregular bedrock). In the centre and north of the site, the bedrock is overlain by a thin succession of Quaternary sediments and only the bases of overlying formations are visible thus making it impossible to determine the nature of the Quaternary sediments. Further south (approximately south of line 234, Figure 49 and Figure 51), the Quaternary succession is thicker, but differentiation is still arduous. It is impossible to determine whether the Marr Bank Formation forms a separate unit above a “cut and fill” filled with Wee Bankie Formation (this coincides with the boundary drawn by the BGS, but indicates that the change between Marr Bank and Wee Bankie Formation is not lateral as suggested by the BGS) or whether the cut and fill consists of sediments of the Aberdeen Ground Formation. The boundary is mapped on the Marr Bank Quaternary geology sheet, but comparison with BGS sediment samples shows that possible BOULDER CLAY is thought to be present much further to the east (Table 10), in samples 56-02-105, 56-02-106 and 56-02-107. Seismic sections at the sample sites show undifferentiated Holocene sediments (Forth Formation only) on top of transparent, almost structureless sediments that are more indicative of sand than boulder clay. It is possible that some mud and silt is present at the base of the Forth Formation in these areas and has been mistaken for boulder clay, but it is equally possible that the transition from boulder clay to sand cannot be mapped as a single boundary, but rather as a wider transition zone between sediments stretching further East than the BGS boundary and schematic boundary (Figure 50) indicate.

Table 10 BGS seabed sample data within and in the vicinity of the survey area (BHGS: Grab sampler; GC: Gravity corer; V: Vibrocore)

Sediment sample	Sampler	Easting	Northing	Surface sediments	Shallow soils
BH 20	BH	563 512.9	6 272 134.2	-	-
BH 13	BH	577 086.8	6 277 278.3	-	-
56 - 02 - 42	GS, GC	568 158.7	6 263 673.5	fine grey SAND	medium shelly yellowish SAND
56 - 02 - 48	V	565 603.3	6 265 363.0	fine grey SAND (to 0.7m depth)	stiff silt with rounded pebbles: BOULDER CLAY (to 2.4m depth)
56 - 02 - 89	GS	579 704.5	6 280 961.1	medium to coarse shelly SAND	
56 - 02 - 103	GS, V	562 758.2	6 270 881.6	coarse gravelly SAND (to 1m depth)	red sandy CLAY, probably BOULDER CLAY (to 1.1m depth)
56 - 02 - 104	GS, GC	567 646.1	6 276 312.1	coarse SAND (to 0.5m depth)	red very hard silty MUD, probably BOULDER CLAY (to 0.9m depth)
56 - 02 - 105	GS, V	578 032.7	6 275 434.2	coarse shelly SAND (to 0.6m depth)	red brown silty CLAY, probably BOULDER CLAY (to 0.8m depth)
56 - 02 - 106	GS, GC, V	581 350.3	6 269 469.1	very coarse GRAVEL	red sticky CLAY, probably BOULDER CLAY (to 0.6m)
56 - 02 - 107	GS, GC	573 832.6	6 267 726.6	medium gravelly SAND (to 0.3m depth)	very compact red brown silty CLAY, probably BOULDER CLAY (to 0.6m depth)
56 - 02 - 110	GS	562 454.8	6 274 310.4	shelly GRAVEL	
56 - 02 - 143	GS	566 505.0	6 281 059.9	medium to coarse shelly SAND	
56 - 02 - 153	GS	572 550.2	6 276 586.4	coarse shelly gravelly SAND	
56 - 02 - 154	GS	563 433.1	6 273 880.8	medium shelly SAND	
56 - 02 - 169	GS, GC	587 287.5	6 280 949.2	very coarse shelly SAND	shelly SAND
56 - 02 - 170	GS, GC	585 401.9	6 275 976.9	fine to medium shelly SAND	shelly SAND
56 - 02 - 171	GS	580 500.7	6 269 567.5	coarse shelly SAND	SAND (to 0.3m)
56 - 02 - 172	GS	573 165.3	6 273 290.5	medium shelly SAND	
56 - 02 - 173	GS	578 085.9	6 273 524.6	coarse shelly SAND	
56 - 02 - 174	GS	580 792.9	6 279 865.2	medium shelly SAND	

Sediment sample	Sampler	Easting	Northing	Surface sediments	Shallow soils
56 - 02 - 203	GS, GC	562 067.9	6 279 313.2	brown shelly SAND	muddy SAND with rounded pebbles
56 - 02 - 213	GS	577 036.6	6 277 337.5	fine to medium shelly SAND	
56 - 02 - 225	GS	562 505.3	6 262 467.3	medium shelly SAND	
56 - 02 - 243	GS	563 838.6	6 271 757.3	coarse shelly gravelly SAND	
56 - 02 - 289	GS, V	568 620.0	6 269 709.4	fine to medium shelly SAND	dark brown firm SILT and CLAY
56 - 03 - 98	GS	561 083.2	6 262 208.3	medium shelly SAND	
56 - 03 - 99	GS	561 290.5	6 280 392.8	medium shelly SAND	
56 - 03 - 108	V/GC	560 500.4	6 265 113.2	medium grey shelly SAND (to 0.3m depth)	compact medium SAND (to 0.9m depth)
56 - 03 - 391	GS, GC	554 450.7	6 272 114.3	fine SAND	GRAVEL (to 0.1m depth)
56 - 03 - 393	GS, GC	557 100.9	6 278 734.1	fine SAND	SILT (to 0.44m depth)
56 - 03 - 395	GS, GC	560 684.8	6 281 119.9	sandy GRAVEL	dark smelly sandy SILT (?)
56 - 03 - 396	GS	560 868.7	6 267 904.9	slightly sandy GRAVEL	
56 - 03 - 419	GS, GC	553 412.1	6 269 105.3	medium to coarse gravelly SAND	medium brown plastic fine silty CLAY
56 - 03 - 420	GS, GC	560 358.0	6 274 582.6	medium to coarse gravelly SAND	reddish brown very stiff pebbly slightly sandy CLAY, probably BOULDER CLAY
56 - 03 - 457	GS	560 464.6	6 262 495.5	fine grey muddy SAND	
56 - 03 - 545	GS	559 509.8	6 266 819.1	coarse shelly SAND	
56 - 03 - 546	GS, GC	556 445.7	6 265 727.3	fine to medium shelly SAND	SAND (0.1m) on dark brown soft to very soft slightly sandy CLAY
56 - 03 - 554	GS	559 562.7	6 271 563.3	medium shelly SAND	

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Part II

Firth of Forth Offshore Wind Farm Export Cable

Geophysical Survey

(Osiris Projects, October 2011)

FIRTH OF FORTH OFFSHORE WIND FARM EXPORT CABLE

GEOPHYSICAL SURVEY

VOLUME 2 - REPORT

C11020

October 2011

OSIRIS PROJECTS
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REPORT AUTHORISATION AND DISTRIBUTION

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CONTENTS

APPENDICES

ABBREVIATIONS

BGS	British Geological Survey
CD	Chart Datum
E	East
LAT	Lowest Astronomical Tide
N	North
nT	nanoTesla
S	South
SOW	Scope of Works
W	West
m	Metres
MMO	Marine Mammal Observer
UXO	Unexploded Ordnance
USBL	Ultra Short Base Line

1. INTRODUCTION

1.1 Project Overview

On the instructions of Seagreen Wind Energy, Osiris Projects were commissioned to undertake a detailed geophysical survey along two proposed cable export route corridors, from the Firth of Forth offshore wind farm development to a landing at Arbroath (Northern Route) and Carnoustie (Southern Route). The site is situated in the central North Sea, approximately 30km southeast of Montrose on the southeast coast of Scotland. The development site covers an area of 2852 km^2 and will have an installed capacity of 3.5GW, once all 3 phases have been installed. Phase 1 is the northern most of these areas, where pre-construction survey works were completed in 2010. The export cable route enters the development area at the southern boundary of the Phase 1 development.

The Northern Route is approximately 33km in total length, with KP 0.000 at the landfall at Arbroath and KP 32.775 at the boundary of the development area. The Southern Route is approximately 40km in total length with KP 0.000 at the landfall at Carnoustie and KP 39.510 at the boundary of the development area. The routes share a common offshore point (538747.8mE, 6269865.3mN, WGS84, UTM 30N) corresponding to KP16.415 on the Northern Route and KP23.150 on the Southern Route.

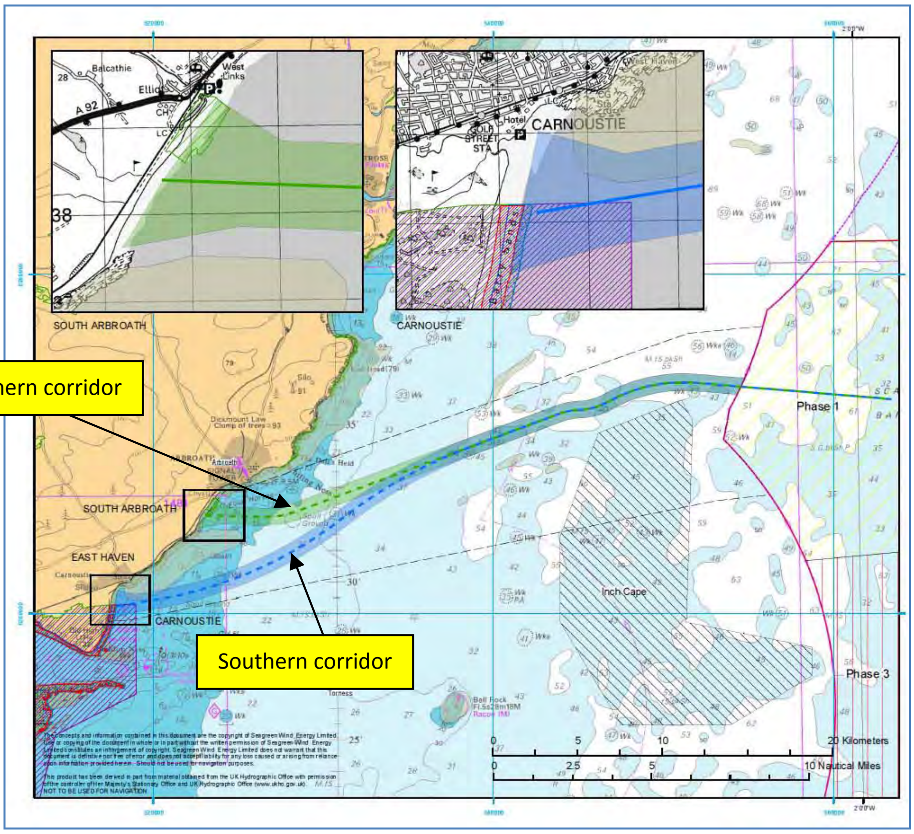


Figure 1: Firth of Forth Offshore Wind Farm, Export Cable Route Corridor - Location Plan

The main objectives of the survey were:

- Acquire data that conforms to IHO S44 Standard Order 1a Surveys (to 40m), with regards to error budgets.
- Measure seabed topography and morphology and identify the nature of the seabed sediments.
- Undertake shallow geophysical surveys using sub-bottom profiler to identify sub-seabed geology, to provide data for the design of a subsequent programme of geotechnical sampling, in particular to derive cable burial assessment (typically to 20m below seabed).
- Identify the location, extent and nature of any impediments to the installation of the export cables such as wrecks, sea floor debris, rock outcrops and other cables/pipelines.

These objectives were achieved by utilising multibeam echo sounder, side scan sonar, marine magnetometer and surface-towed 'boomer' sub-bottom profiler, run simultaneously on all survey lines.

It should be noted that the Southern Route terminates within the restricted area of the Barry Buddon firing range. The range operates a 'clear range procedure' and there is no restriction on the right to transit through the range at any time. However, during times of operation red flags and flashing lights are displayed on the shoreline. It is therefore advised that before any future activities are planned within the range boundary, that the range is contacted and a safe method of work is adopted.

The survey was undertaken using Osiris Projects own dedicated survey vessels, MV Freja and SV Chartwell during the period 22nd June to 5th July 2011, with MV Freja surveying the inshore sections to the 30m contour (which approximates to the 3 nautical mile limit within the survey areas) and SV Chartwell surveying offshore of the 3 nautical mile limit.

Volume 1, the Operations report, details the operational parameters, locations, times and techniques utilised during survey operations. This volume (volume 2) contains the results and interpretation, together with the individual route alignment charts.

All positions are expressed as WGS84 UTM 30 N coordinates, throughout this report. All heights are quoted relative to LAT, defined from the UKHO VORF data.

1.2 Operational Summary

The export cable route corridors were planned with a total of 11 longitudinal lines at 100m line spacing, covering a corridor 1km wide. Lines were generated at 50m line spacing from inshore of the 20m contour for multibeam coverage, where required. The survey lines were projected 200m into the development area to ensure adequate overlap. The Southern Route corridor overlapped into the northern corridor by 200m except for the route centreline, which was extended to the common offshore point to aid geological centreline profiling during the processing and reporting phase of the project.

The mobilisation of MV Freja began on the 22nd June 2011, in Montrose Harbour. Wet testing and equipment calibrations were completed on the 24th June and survey operations commenced on the afternoon of the 24th June 2011.

During the mobilisation phase a navigation check was completed on the 23rd June 2011 at Auchmithie (Passive Station ID C1NO6543). A GeoSwath multibeam echo sounder calibration was conducted over a charted ship wreck, located at the edge of Lunan Bay and a USBL calibration was performed in the same area, again on the 23rd June 2011. Further information pertaining to the vessel calibrations can be found in Section 3 of this report.

Data acquisition began on 24th June and was completed on the 3rd July 2011, with the vessel being demobilised on the 5th July 2011. MV Freja was operated from Montrose for the duration of the survey works on a 12 hour basis. Typical transit times were 45 minutes or less.

SV Chartwell arrived in Montrose on the 23rd June 2011. Initially the vessel was mobilised on the 26th June 2011 for benthic operations, comprising grabs, drop down camera and trawl operations for the Institute of Estuarine Coastal Studies (IECS) (12 hour operations). The benthic operations were carried out on the 27th June 2011, with the equipment being demobilised from the vessel on the 28th June 2011. The vessel was then subsequently mobilised for marine survey works between the 28th and the 30th June 2011, with the wet tests and calibrations being completed on the 1st July 2011. During the mobilisation phase a navigation check was completed on the 25th June 2011. A Reson 7101 multibeam echo sounder calibration was conducted over a charted ship wreck at the edge of Lunan Bay and a USBL calibration was performed in the same area again on the 30th June 2011. Further information pertaining to the vessel calibrations can be found in Section 3 of this report.

During the mobilisation, the vessel experienced generator problems caused by blocked water intakes. This was attributed to the amount of water column debris comprising of plastic bags, marine growth and other general debris being ‘sucked’ into the intakes. A full HSE dive team visited the vessel on 3 occasions during the mobilisation and reported that this was a regular occurrence to smaller vessels within Montrose Harbour. No time was lost as a consequence of these problems during the geophysical phase of the works, but the benthic operational day was delayed by 3 hours, whilst a dive team cleared the intakes.

Geophysical work commenced on the 1st July 2011 with survey works being completed on the 4th July 2011 on a 24 hour basis. The vessel was demobilised on the 5th July 2011, in Arbroath.

Summary Survey Statistics

	Mob/Demob hh:mm	***Working*** hh:mm	***Weather*** hh:mm	***Breakdown*** hh:mm	***Other*** hh:mm	***Line*** Kilometres
MV Freja	42:05 26.98%	97:30 62.50%	09:45 6.25%	06:15 4.00%	00:25 0.27%	108.4km (N) 239.9km (S)

MV Chartwell (Benthic)	13:00 47.27%	11:30 41.82%	00:00 0.00%	03:00 10.91%	00:00 0.00%	NA
MV Chartwell (Geophysics)	46:30 35.91%	74:00 57.14%	00:00 0.00%	09:00 6.95%	00:00 0.00%	302.7km (N) 68.2km (S)

In addition, a total of 3 areas of interest were boxed-in, as per the contract specifications. These included one area of disturbed seabed (thought to be isolated boulders at 530616mE, 6266967mN) and two possible uncharted wrecks (530737mE, 6265874mN and 524021mE, 6262272mN). There are several charted wrecks within the vicinity of the cable route, with only two listed as occurring within the cable route corridor. These include the 'Margaret Rae', a trawler located at 538631mE 6269697mN and an unknown wreck at 551861mE 6273289mN.

2. GEOLOGY OF SITE

The solid geology beneath the proposed cable route corridors comprises a thick sequence of sandstones, siltstones and mudstones of Lower (Emsian) and Upper (Famennian) Devonian ages. To the east of approximately KP10.00 on the northern corridor and KP15.5 on the southern corridor, these Devonian rocks are, in turn, overlain by undifferentiated Permo-Triassic rocks.

According to the BGS (Section 4, references i and ii), these rocks are overlain by Pleistocene deposits of Quaternary age, comprising variable materials ranging from soft clayey silts/silty clays of the Forth Formation to possibly hard gravelly clays/clayey gravels of the Wee Bankie Formation.

The soft clayey silts/silty clays can be up to 40m thick and are more prevalent in the western sections of the route corridors, whereas the hard gravelly clays/clayey gravels are thought to represent glacial tills and are generally present throughout the area, reaching thicknesses of up to 40m in places. These Quaternary deposits are frequently overlain by very thin finer grained surface sediments, generally less than 2.0m thick. These materials comprise gravelly sands/sandy gravels or clayey gravelly sands, which may exhibit very little variation in character with the underlying Quaternary strata.

The current geological model for this section of the central North Sea is summarised below:

Approximate thicknesses of Units	Unit	Member	Anticipated Soil Type
<2m	Holocene	N/A	Silty or gravelly sands to sandy gravels, with occasional clayey, gravelly sands on part of northern corridor.
<5m – 40m	Holocene to Quaternary - Forth Formation	St Andrews Bay Member	Estuarine gravelly clayey sands and silty clays, to fluviomarine clayey sands and silts.
<5m – 30m	Quaternary - Forth Formation	Largo Bay Member	Interbedded marine clays, silty clays and silts, with rare gravel.
Generally <10m, locally up to 20m	Quaternary – St Abbs Formation	N/A	Glaciomarine silty and gravelly clays.
<5m – 40m	Quaternary – Wee Bankie Formation	N/A	Hard sandy and gravelly Till, with interbedded fluvial sands and gravelly sands. Locally coarse sands and gravels in erosion channels.
N/A	Permo-Triassic Bedrock	Undivided	Generally sandstones and/or mudstones.
N/A	Upper Devonian Bedrock	Clashbenny Formation	Sandstone, locally conglomeratic at base.
N/A	Lower Devonian Bedrock	Strathmore Group	Sandstone, locally conglomeratic, overlying siltstone and mudstone.

N.B. The B.G.S data indicates that the St Andrews Bay member (Upper) of the Forth Formation was deposited during the late Quaternary and Holocene periods.

3. RESULTS

Drawing nos C11020-01a to C11020-01d (Northern route corridor) and C11020-02a to C11020-02e (Southern route corridor) are the Route Alignment charts, which have been produced at a scale of 1:10000 for bathymetry, seabed features and sub-bottom profiling. Drawing nos C11020-01b to -01d and -02c to -02e present data common to both route corridors, which merge at a common offshore point (538747.8mE 6269865.3mN WGS84 UTM 30N), corresponding to KP 16.415 on the Northern Route and KP 23.150 on the Southern Route.

3.1 Northern Route Corridor

3.1.1 Bathymetry

Processed bathymetric data is presented at a horizontal scale of 1:10000 on panel 1 of each of the Route Alignment charts. The data has been contoured at a vertical interval of 1.0m and is reduced to Lowest Astronomical Tide (LAT).

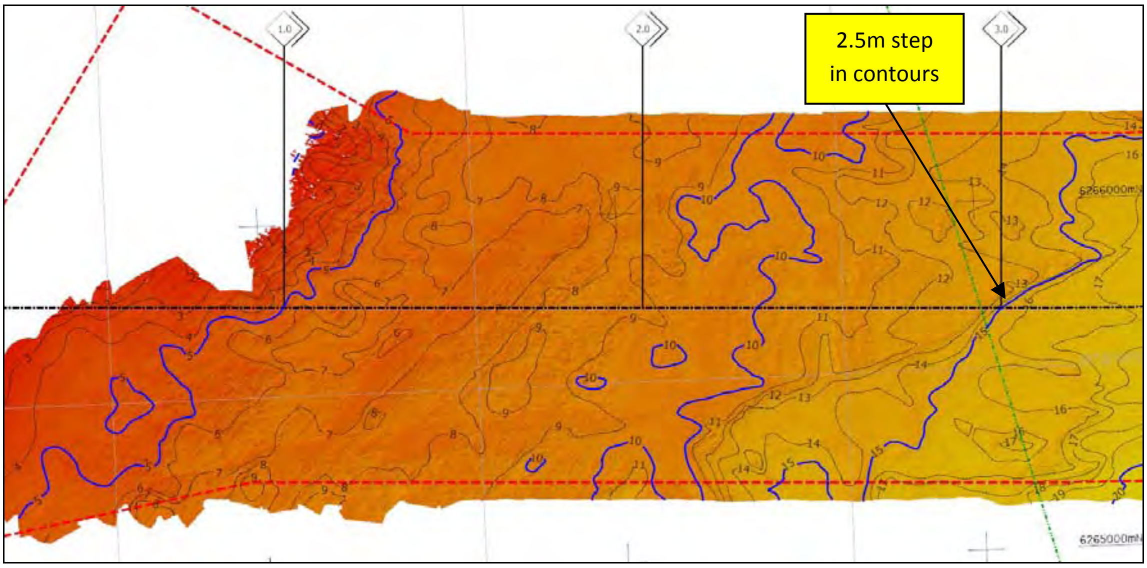


Figure 2: Northern Route - Shaded Relief bathymetry image of inshore section

(Refer to charts for colour/depth scale)

Seabed levels along the Northern Route corridor range from 0.4m above LAT, in the northern section of the corridor, close to KP1.0, to approximately 69.0m below LAT in the extreme N of the combined corridor at KP29.854. It was not possible to survey inshore of approximately KP0.38, due to a combination of very shallow water and outcropping bedrock.

From the inshore limits of the bathymetry data at KP0.38 to approximately KP3.5, the seabed is very irregular across a broad rock outcrop, which crosses the whole of the corridor. The irregular bedrock surface comprises a series of hard ridges (and their associated hollows), which are generally orientated NE-SW, standing up to 1.5m higher than the surrounding seabed. Localised gradients of up to 4.0° were noted inshore of KP1.00, where the ridges appear slightly larger and also around KP3.00, where there is a marked 2.5m 'step' in the bedrock surface, which then becomes much less irregular; possibly denoting the boundary between Upper and Lower Devonian strata. Along the proposed route centre line, seabed levels deepen across this rocky surface from 2.7m below LAT at KP0.374, to approximately 19.0m below LAT at KP3.5.

Between KP3.5 and approximately KP5.6, seabed levels across the northern section of the corridor deepen from NW-SE, due to the presence of a broad rocky ridge, which extends from the northern limits of the corridor to approximately 190m S of the route centre line, between KP5.52 and KP5.9 (see Figure 3, below).

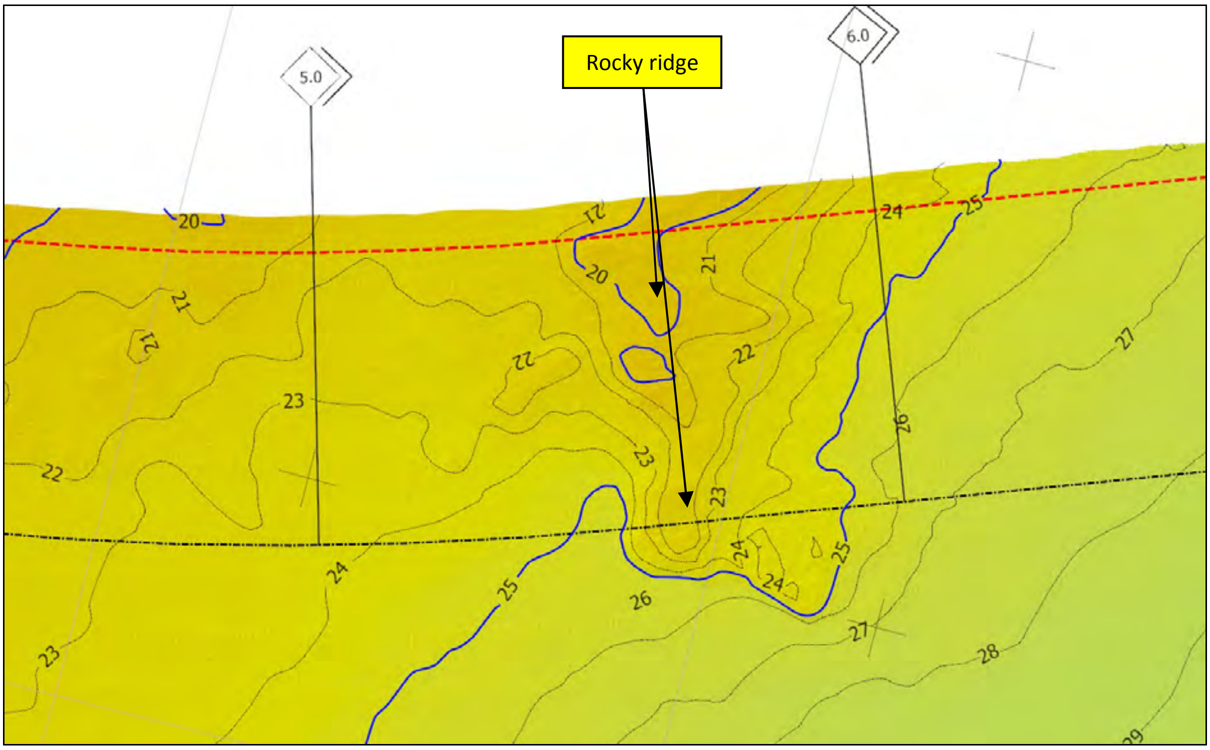


Figure 3: Northern Route - Shaded Relief bathymetry image – KP5.0 to KP6.0

Localised seabed gradients of up to 3.0° are present on both the western and eastern sides of this rocky ridge, with the steepest local gradients seen between KP5.518 and KP5.580 and again between KP5.565 and KP5.562. To the S of the ridge, the seabed dips gently from WNW-ESE at maximum gradients of less than 1.0°.

To the E of the rocky ridge, seabed levels dip very gently towards the SE, before veering towards the E at approximately KP9.5, veering further towards the ENE at approximately KP9.75, from 25.0m below LAT at KP6.0 to 36.0m below LAT at KP9.75.

To the ENE of KP9.75, seabed levels fall further to reach 45.0m below LAT, close to KP14.45. At approximately this point, the very gentle seabed gradient (<0.25°) begins to gradually steepen as a seabed depression is approached, with levels deepening to 60.0m below LAT, close to KP17.0, at an average gradient of 0.35°. This natural depression lies mainly to the N of the route centre line, between KP16.0 and KP18.0. Traversing along the route centre line, seabed levels begin to shallow again to the ENE of KP17.25, with the eastern edge of the seabed depression marked by a series of gravelly ridges. One of these steeply-sided features crosses the route centre line obliquely between KP17.5 and KP18.0, where localised gradients of up to 9.5° were noted (see Figure 4, below).

A broader gravelly ridge feature crosses the southern section of the route corridor between KP19.0 and KP20.0, with the steepest parts of the feature crossing the proposed centre line between KP19.0 and KP19.15 (shallowing seabed) and between KP19.56 and KP19.82 (deepening seabed). Maximum seabed gradients of 1.75° and 2.5° were noted on the western and eastern sides, respectively, as measured along the proposed centre line.

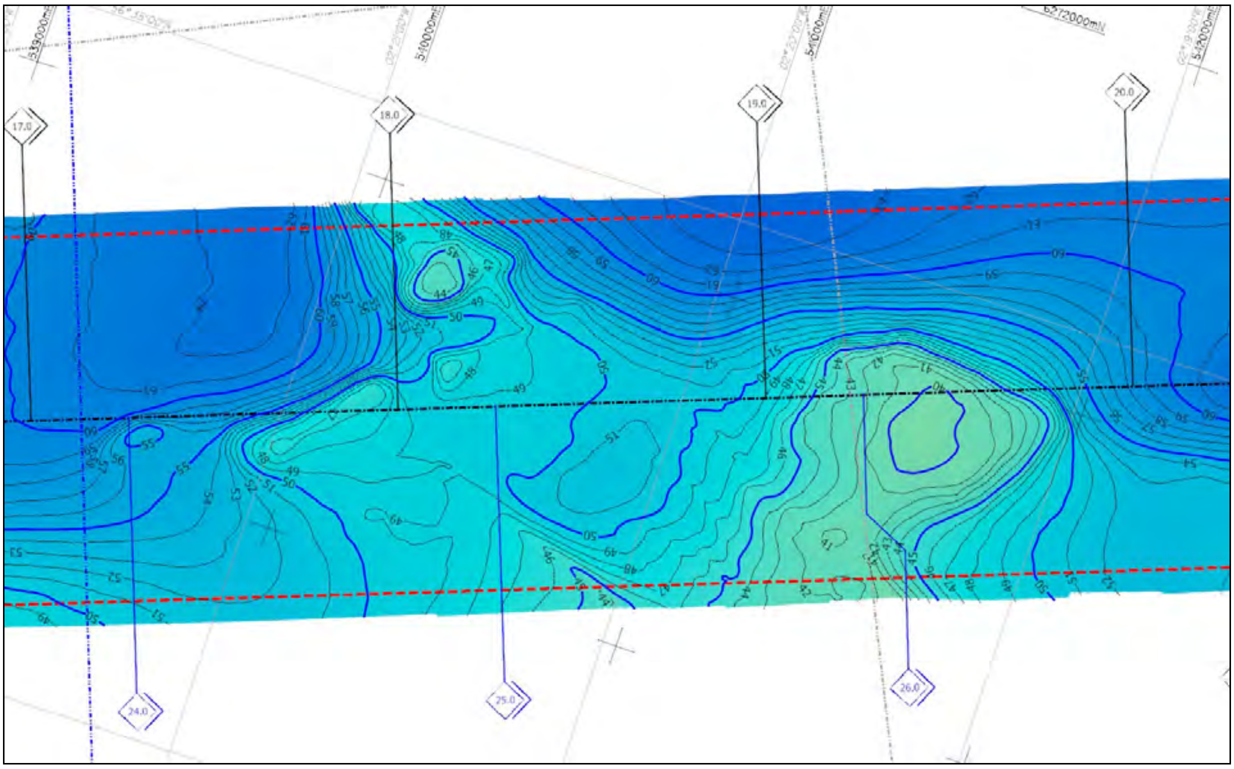


Figure 4: Northern Route - Shaded Relief bathymetry image – KP17.0 to KP20.0

From KP20.0 to the offshore end of the proposed route at KP33.36, seabed levels within the route corridor undulate between 39.0m below LAT and 69.0m below LAT, as the route crosses a series of frequently broad, steeply-sided ridges or mounds of gravelly sands/sandy gravels.

The steepest gradients on the upslope and downslope sides of these features were noted below;

KP22.18 to KP22.39 (0.9°); KP22.885 to KP23.018 (0.4°); KP23.831 to KP24.056 (2.5°);

KP24.893 to KP25.050 (2.6°); KP25.75 to KP25.876 (0.9°); KP27.983 to KP28.158 (0.7°);

KP28.88 to KP29.038 (1.1°); KP29.202 to KP29.332 (0.9°); KP29.837 to KP29.909 (1.6°); KP30.043 to KP30.212 (1.8°); KP30.348 to KP30.497 (1.2°); close to KP30.837 (2.2°) and KP30.87 to KP31.00 (1.3°). These gradients are measured along the proposed route centre line, which frequently crosses the individual features obliquely. The individual features are likely to have steeper gradients, when measured perpendicular to the relevant slopes.

3.1.2 Seabed Features

The results of the Side Scan Sonar survey are presented on panel 2 of each of the Route Alignment charts. These are presented at a horizontal scale of 1:10000, with seabed classifications derived from a combination of an interpretation of the sonar, bathymetry and sub-bottom data sets.

Bed form terminology used in this section is based on the following approximate definitions (Oxford Dictionary of Earth Sciences, 1999).

Definition	Height (m)	Wavelength (m)
Ripple	<0.1	<1.0
Megaripples	0.1 – 3.0	1.0 – 30
Sand waves	3.0 – 15.0	30 – 500

The side scan sonar data indicate that variable, generally granular sediments are present at seabed level across much of the Northern Route, with the exception of the inshore section, where outcropping rock is dominant. These granular sediments are interpreted as ranging from very silty fine to coarse grained sands, with variable shell content, to coarser grained sandy gravels, with occasional cobbles and (generally small) boulders.

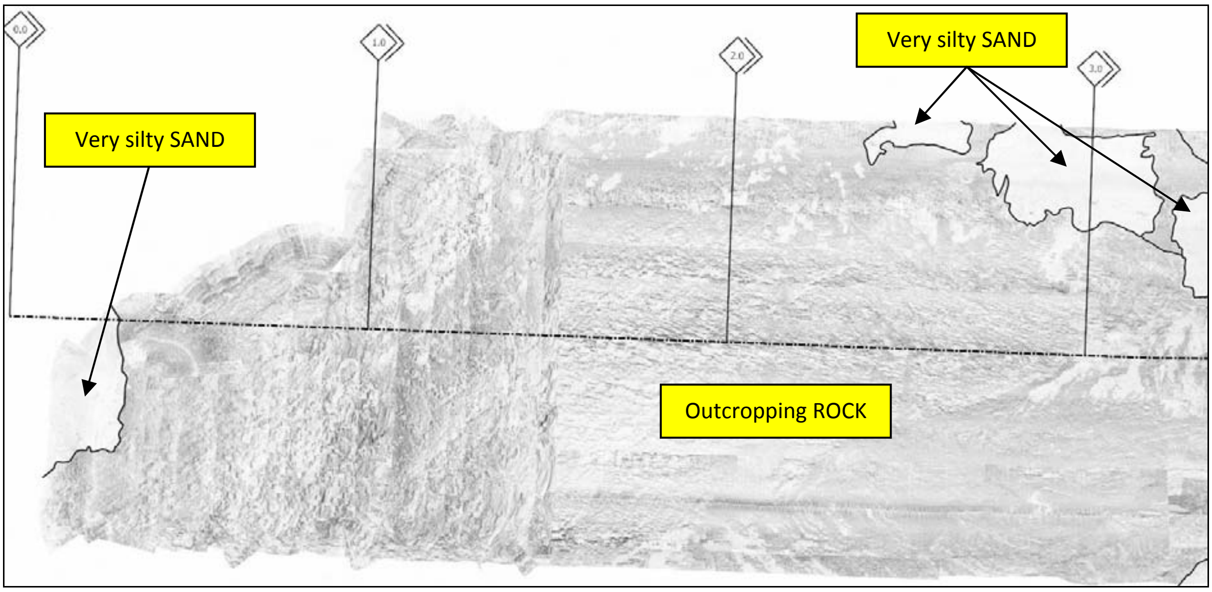


Figure 5: Northern Route - Outcropping rock across most of the inshore section

Figure 5 above, indicates the patchy distribution of finer grained sandy sediments (paler shades) across the inshore section of the Northern Route.

The seabed across much of the inshore section of the Northern Route (out to approximately KP3.60) comprises mainly outcropping bedrock, with irregular patches of very silty sand. The bedrock surface is very irregular, exhibiting numerous ridges and probably isolated boulders derived from the underlying Devonian sandstones.

To the ENE of KP3.60, the bedrock surface becomes covered by a large irregular expanse of silty fine sands, which traverses the proposed centre line from NW to SE.

Between KP4.1 and KP6.4, much of the northern section of the Northern Route comprises generally shallow bedrock, with a patchy veneer of granular sediments (see Figure 6, below). To the south of the proposed route centre line, the seabed sediments comprise generally thin silty fine sands, with irregular patches of sandy gravels. Between KP6.4 and KP9.3, the generally thin seabed sediments across the northern section comprise elongate areas of sandy gravels, interspersed with patchy fine sands. Conversely, the seabed sediments to the S of the proposed route centre line comprise generally featureless silty fine sands.

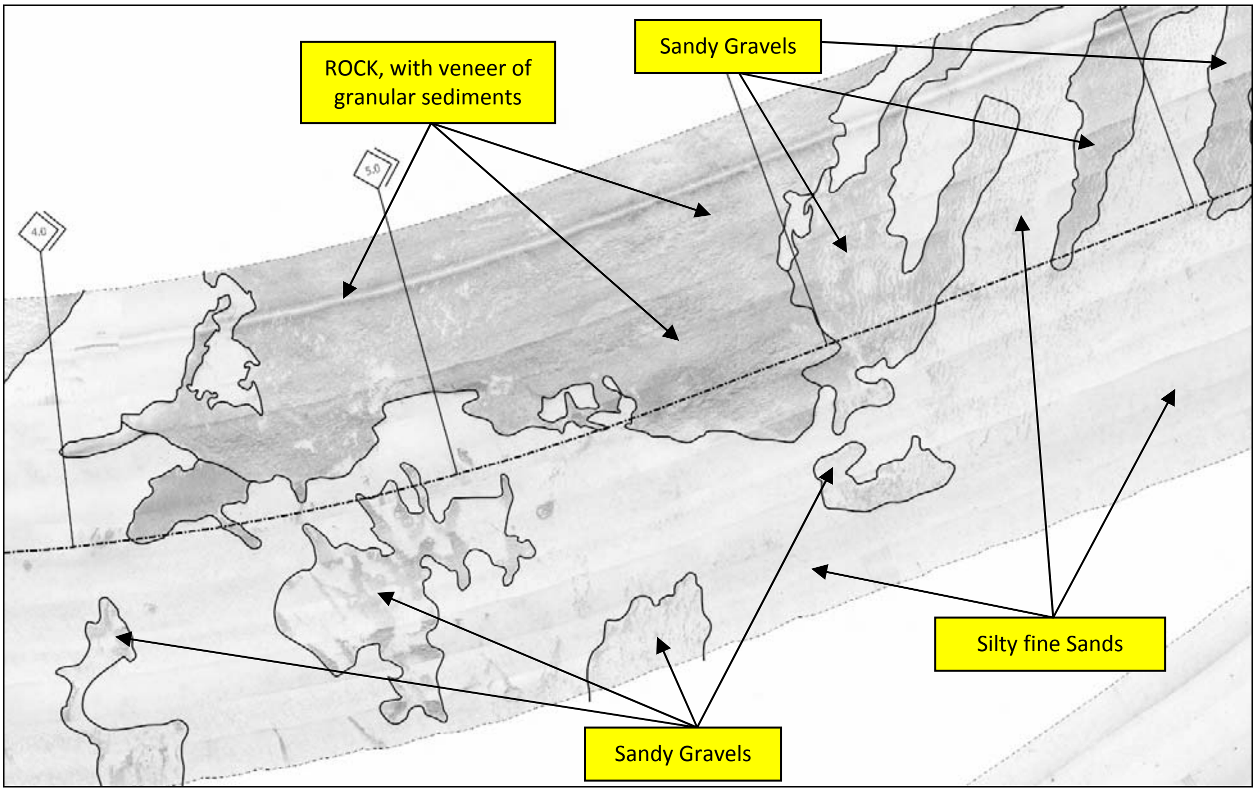


Figure 6: Northern Route - Distribution of seabed sediments between KP4.0 and KP7.0

These finer grained sediments extend across the whole of the route corridor between KP9.5 and approximately KP16.0, where the expanse of silty fine sands is broken by a number of irregular patches of coarser grained, fine to medium sands, followed to the NE of KP18.0 by larger patches of much coarser sandy gravels, with frequent small boulders. It is likely that these coarser grained materials are representative of strata of the underlying Wee Bankie Formation, which are known to comprise stiff, frequently granular till, with interbedded sands and gravelly sands. Figure 7, below shows the distribution of these outcrops of possible Wee Bankie sediments between KP16.0 and KP22.0.

These patches of coarse grained sediments exhibit strong relief, forming ridges or mounds, which frequently stand up to 20.0m above the intervening seabed depressions, with the finer grained materials between the coarser patches often exhibiting megaripple bed forms. These generally low-order bed forms are orientated NW-SE or WNW-ESE, stand up to 0.4m high and have an average wavelength between 7.0m and 15.0m.

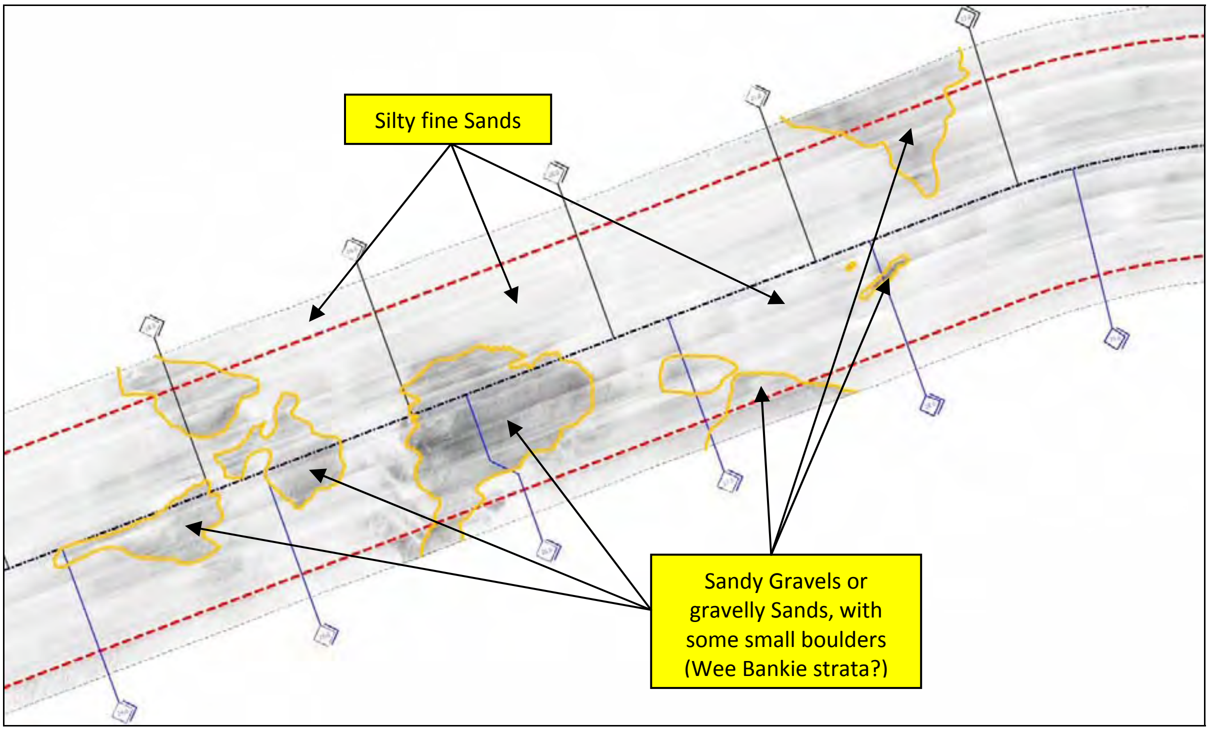


Figure 7: Northern/Combined Route – Possible Wee Bankie Formation strata between KP16.0 and KP22.0

The finer grained silty sands extend further to the E, with further patches of coarser grained, possible Wee Bankie sediments present out to approximately KP24.0, where a 750 – 1280m wide band of (probably) dense sandy gravels crosses the route corridor from NNE to SSW and crosses the proposed centre line between KP23.926 and KP25.196. This broad band of coarser sediments also exhibits strong relief, with several mounds and ridge features present, which stand up to 20.0m above the intervening seabed depressions. Megaripples are present across much of the seabed to the NW and SE of this area of coarse sediments. These bed forms are again orientated NW-SE or WNW-ESE, stand up to 0.4m high and have an average wavelength between 7.0m and 15.0m.

The finer grained silty sands extend eastwards, with a number of other areas of coarse grained, possible Wee Bankie Formation sediments crossing the route centre line between KP25.2 and the end of the route corridor at approximately KP32.867.

Figure 8, below shows the distribution of these possible Wee Bankie sediments between KP24.0 and KP33.0.

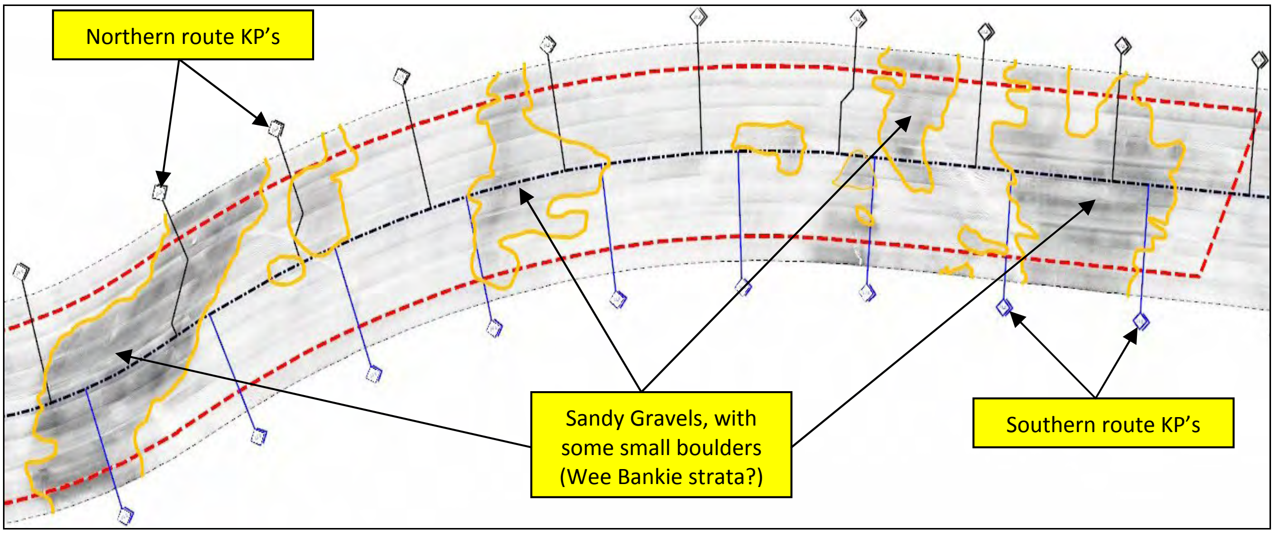


Figure 8: Northern/Combined Route – Possible Wee Bankie Formation strata between KP24.0 and KP33.0

The interpreted Wee Bankie sediments outcrop along the route centre line between KP25.76 and KP26.01, between KP26.118 and KP26.126, between KP27.282 and KP28.323, between KP29.4 and KP29.733, between KP30.088 and KP30.199, between KP30.374 and KP30.635, and finally, between KP31.269 and KP32.462. Many of these Wee Bankie 'outcrops' again exhibit strong relief, and are flanked by irregular areas of megaripple bed forms. These features are orientated between NNW-SSE and WNW-ESE; stand up to 0.4m high and have average wavelengths between 6.0m and 15.0m.

A total of 456 sonar targets were noted along the combined route corridors. Most of these appear to be small boulders, with a maximum dimension of <1.0m, although some larger boulders were also noted.

Similarly, a total of 72 magnetic anomalies were noted within the corridors. These range in size from 0.6 – 7713.1nT (nanoTesla).

Only a few of the sonar targets appear to have associated magnetic anomalies, and these are shown in table 1, below;

I.D.	Eastings (m)	Northings (m)	Latitude UTM30	Longitude UTM30	Length (m)	Width (m)	Height (m)	Description/Associated Magnetic Anomaly
S048	526533.5	6265153.2	3.320821°N	42.900052°E	nml	nmw	nmh	Small point contact (M059)
S050	526546.2	6265163.9	3.320898°N	42.900122°E	nml	nmw	nmh	Small point contact (M059)
S051	526562.0	6265179.4	3.320992°N	42.900222°E	nml	nmw	nmh	Small point contact (M059)
I.D.	**Eastings (m)**	**Northings (m)**	**Latitude UTM30**	**Longitude UTM30**	**Length (m)**	**Width (m)**	**Height (m)**	**Description/Associated Magnetic Anomaly**
S398	551793.2	6273065.6	3.477121°N	42.957256°E	132	30	11	Unknown wreck (M072)

Table 1: Sonar targets with associated magnetic anomalies in Northern/Combined route

According to the wreck listings provided by the Client, only 2/3 wrecks are thought to be present within the proposed corridors. The original wreck listing indicates a wreck of unknown origin to be present at 551861mE, 6273289mN, KP30.2 on the Northern Route. An actual wreck (target S398 - 132m x 30m x 11m) was noted at KP30.14, centred at approximately 551793mE, 6273066mN, some 228m SSW of the above position. This feature has a very large associated magnetic anomaly (M072 – 688.0nT)

Sonar targets S048, S050 and S051 have been classed as 'small point contacts', with maximum dimensions of less than 1.0m and which lay very close to the southern boundary of the Northern Route at approximately KP3.5; however, magnetic anomaly M059 (10.3nT) lies nearby, indicating some ferrous debris is present.

A number of sonar targets lie within 10.0m of the proposed route centre line (and these are shown in table 2, below;

I.D.	Eastings (m)	Northings (m)	Latitude UTM30	Longitude UTM30	Length (m)	Width (m)	Height (m)	Description
S225	540136.8	6270390.8	3.404683°N	42.936784°E	0	0	0	Small point contact (<1m)
S229	540146.4	6270381.0	3.404747°N	42.936728°E	0	0	0	Small point contact (<1m)
S233	540193.2	6270414.4	3.405030°N	42.936948°E	2.9	2	0.8	Probable boulder
S282	545470.9	6272055.7	3.437679°N	42.948836°E	0	0	0	Small point contact (<1m)
S340	546734.2	6272490.2	3.445478°N	42.951938°E	0	0	0	Small point contact (<1m)
S386	550261.2	6273592.5	3.467287°N	42.959926°E	3.9	2	0.4	Probable boulder
S387	550263.3	6273597.4	3.467298°N	42.959957°E	0	0	0	Small point contact (<1m)
S389	550436.0	6273598.6	3.468385°N	42.960026°E	0	0	0	Small point contact (<1m)

Table 2: Sonar targets lying within 10.0m of proposed route centre line

Fishing activity was identified as a number of trawl scars, which are present across both proposed routes, starting near the routes convergence point at 538747.8mE 6269865.3mN WGS84 UTM 30N), corresponding to KP16.415 on the Northern Route and KP23.150 on the Southern Route. No other significant seabed features were observed.

A complete set of sonar targets and magnetic anomalies are presented in Appendix 2 to this report, together with a Client-provided wreck listing, indicating any associated sonar/magnetic features and any uncharted wrecks, which were found during the survey.

3.1.3 Sub-Bottom Profiling

The processed sub-bottom profiling data are presented as Isopachytes (Total Sediment Thickness to base of Holocene/ Forth Formation) on panel 3 of each of the Route Alignment charts. These are all presented at a scale of 1:10000 and are contoured at a vertical sediment thickness interval of 2.0m.

The sub-bottom data indicate that bedrock is present at seabed over the whole of the Northern Route corridor, out to approximately KP3.3. Within this inshore area, occasional patches of generally fine grained sediments are present as a local veneer, where seen.

A complex buried channel feature traverses the route centre line from WNW-ESE between KP3.3 and KP5.5, before veering back across the route centre line to the E of KP6.0. This feature is up to 48.0m deep in places and is infilled by Quaternary sediments, which are likely to be initially from the St Abbs Formation (see Figure 9, below).

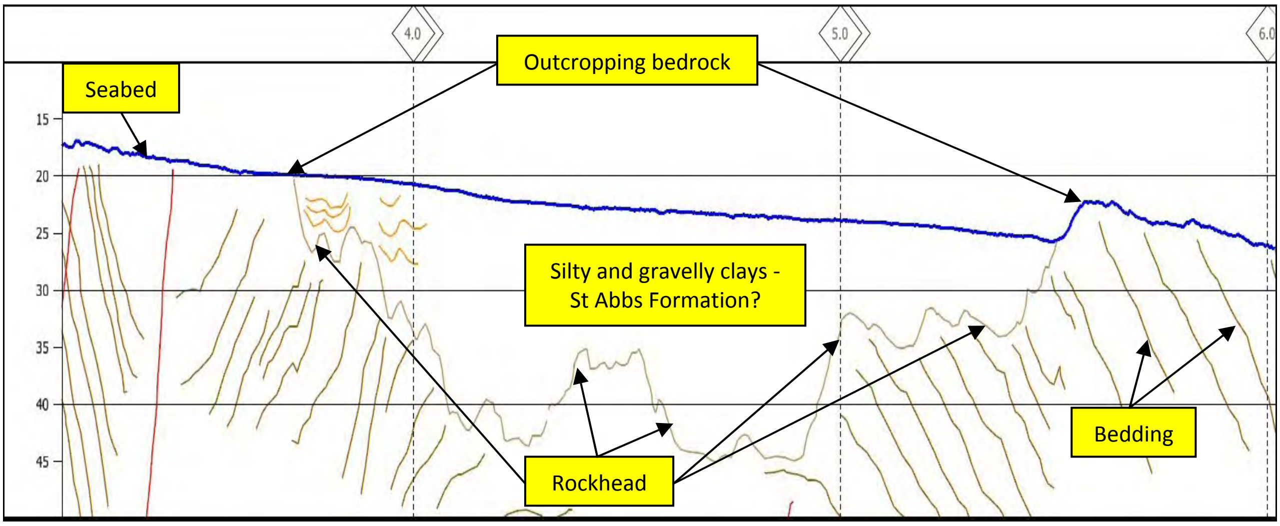


Figure 9: Northern Route - section of interpreted profile between KP3.0 and KP6.0, showing buried channel

In the northern section of the corridor, between KP6.0 and KP9.12, the bedrock surface generally lies between 0.0m and 14.0m below seabed, deepening to between 20.0m and 40.0m in the southern section. The bedrock surface is covered by a variable thickness of likely finer grained sediments of the St Abbs Formation; with a probable veneer of more recent (Holocene) sands at seabed. A localised rock outcrop is present in the extreme N of the corridor, between KP8.58 and KP9.12.

The data also indicate that sediments of the Forth Formation become present at seabed to the E of KP7.5, with the 0.0m contour crossing the proposed route centre line from ENE-WSW between KP6.0 to the S and KP9.0 to the N. These sediments generally comprise sands, or silty sands, which generally increase in thickness towards the SSE, reaching thicknesses of over 30.0m in the S of the Northern Route corridor, at KP10.0.

An area of shallow gas is present, trapped in the upper sediment layers of the Forth Formation, between KP9.85 and KP15.25. This area of gas is noted as occasional high amplitude reflections, but mostly as a general ‘blanking’ of any underlying sediment structure. The gas front appears to lie above the centre of the deepest section of the buried channel feature, which may indicate a deep-seated source for the gas. Along the proposed centre line, the gas front lies between 4.4m and 10.3m below seabed, between KP10.215 and KP12.357 (see Figure 10, below).

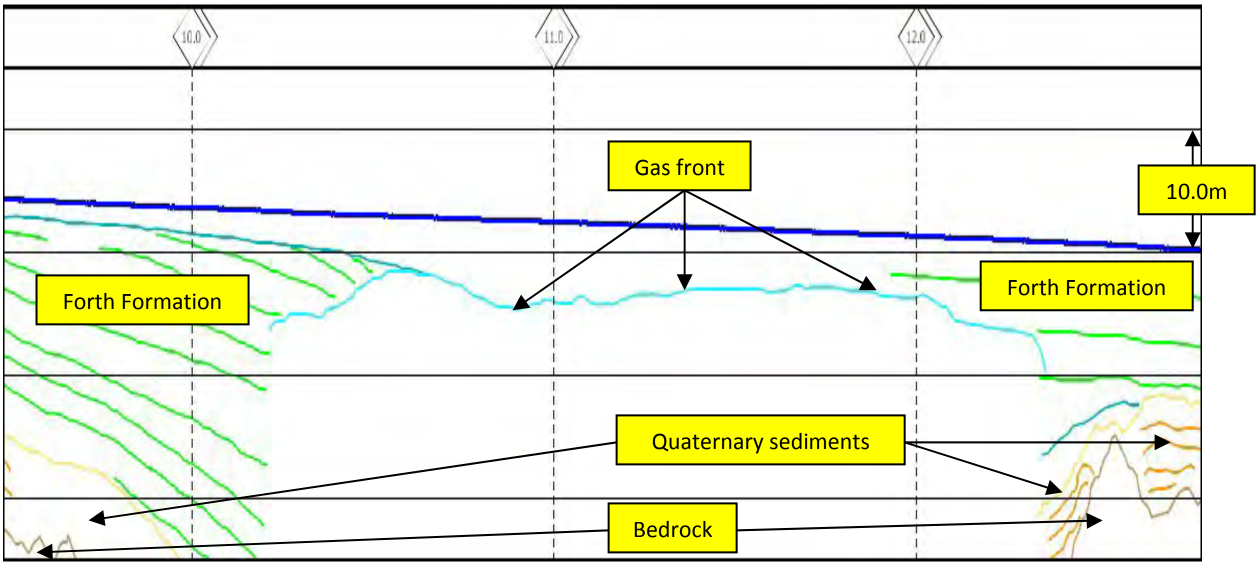


Figure 10: Northern Route - section of geological profile between KP9.5 and KP10.8

To the E and ESE of the gas front, the Forth Formation sediments gradually become thinner, as the underlying Quaternary sediments/bedrock surface shallows. These generally fine grained sediments thin to approximately 4.0m at KP16.0 (along the proposed centre line), thickening again to a maximum of 16.0m at KP17.0, before rapidly thinning to 0.0m at KP17.25, where bedrock or, more likely, granular sediments of the Wee Bankie Formation lay at seabed.

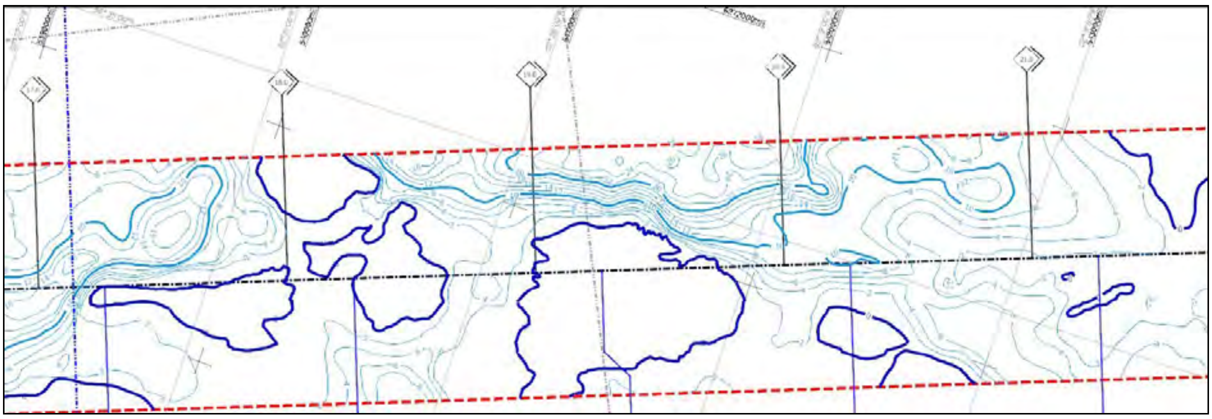


Figure 11: Northern Route - section of isopachyte chart between KP16.9 and KP21.7

A number of these large isolated outcrops of Quaternary sediments are present between KP 16.00 and KP22.0 and again between KP23.5 and KP28.35 (see Figure 11, above and Figure 12, below). The sub-bottom data indicate that the very irregular bedrock surface generally lies close below the surface of the Quaternary materials, although it is frequently difficult to identify rockhead, due to the very dense nature of the Wee Bankie deposits. It is likely that clayey Quaternary sediments of the St Abbs Formation lie between the Forth Formation sediments and the Wee Bankie deposits/bedrock.

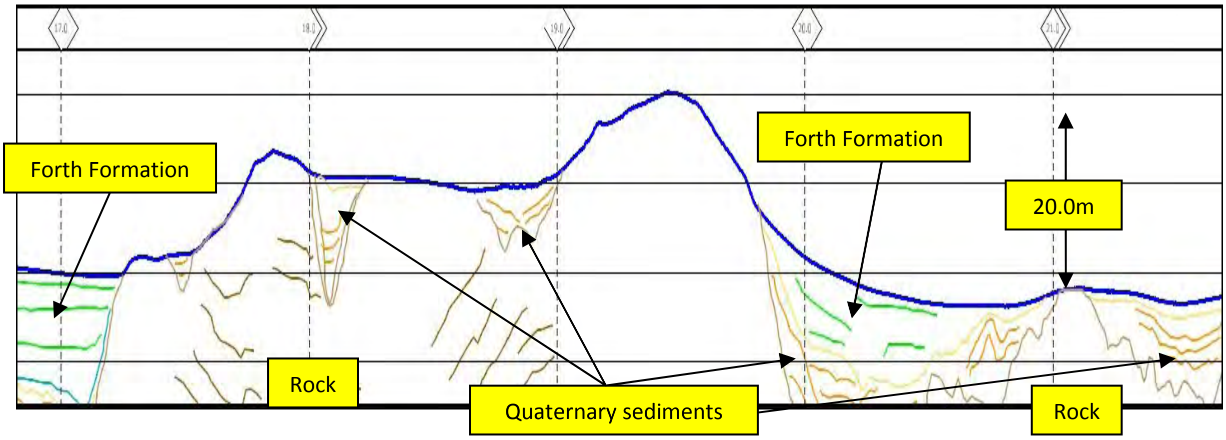


Figure 12: Northern Route - section of geological profile between KP16.9 and KP21.7

The Forth Formation sediments are absent to the E of KP22.0, with the Wee Bankie deposits forming a broad, NE-SW orientated outcrop, which crosses the whole width of the route corridor between KP23.928 and KP25.195. Several outcrops of Wee Bankie deposits are present to the E of KP25.195, with a general veneer of finely granular sediments covering the Wee Bankie deposits/bedrock, out to the offshore end of the route at KP32.865.

A table showing sections along the proposed route centre line, where sediment cover has been interpreted as either absent, or 'less than 2.0m' is presented in section 3.1.5 of this report.

3.1.4 Magnetometer

The results of the processed magnetometer data can be found as a series of annotated anomalies on panel 2 of drawing nos C11020-01a to C11020-01d (Northern route corridor), the Route Alignment charts.

Figure 13, (below), is a plot of residual magnetic field for the section of the Northern Route between KP3.0 and KP6.0. Colour shading was used to more easily visualise areas of varying magnetic field. The pseudo-colour plot indicates the presence of a buried channel feature – seen as a broad zone in varying intensities of green and brown, which crosses the route centre line from WNW to ESE between KP4.0 and KP5.0. Recent observations (*References; iii*) indicate that these mainly Holocene palaeochannels are identifiable, due to the formation of weakly magnetic iron sulphides under favourable conditions. Figure 13a, below is the same as Figure 13, with the contours for the interpreted bedrock surface added.

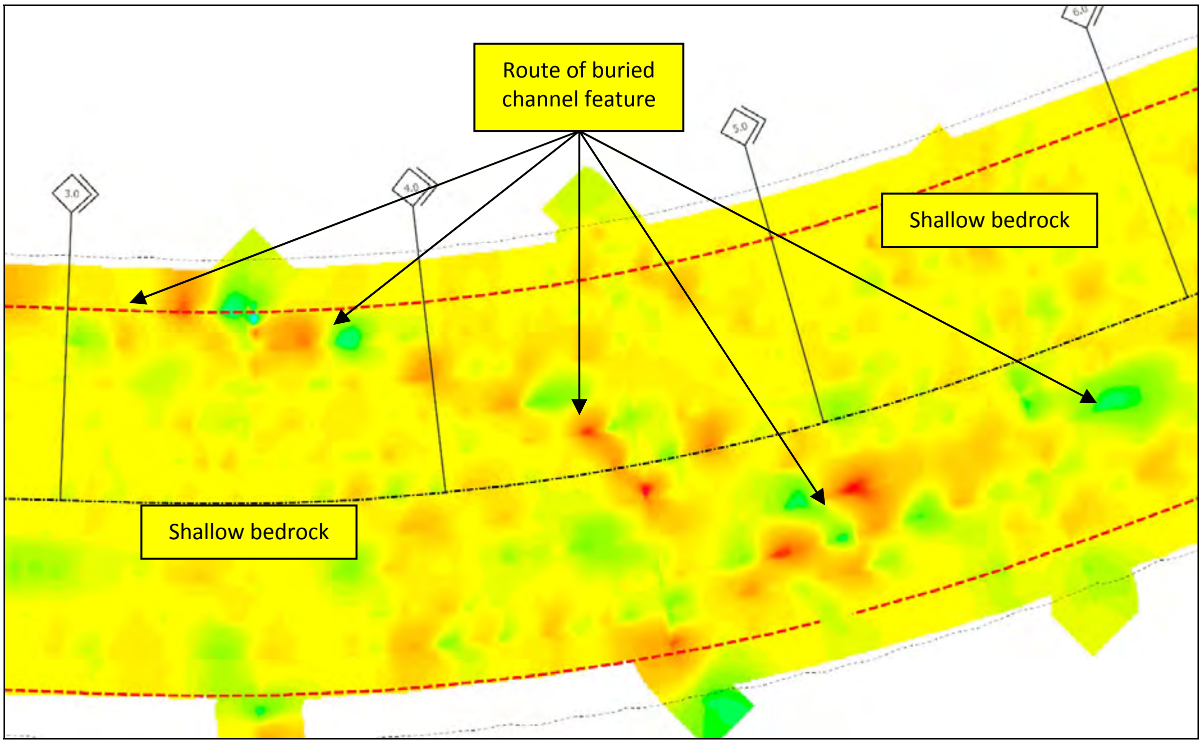


Figure 13: Northern Route - Map of residual Magnetic Field between KP5.0 and KP6.0

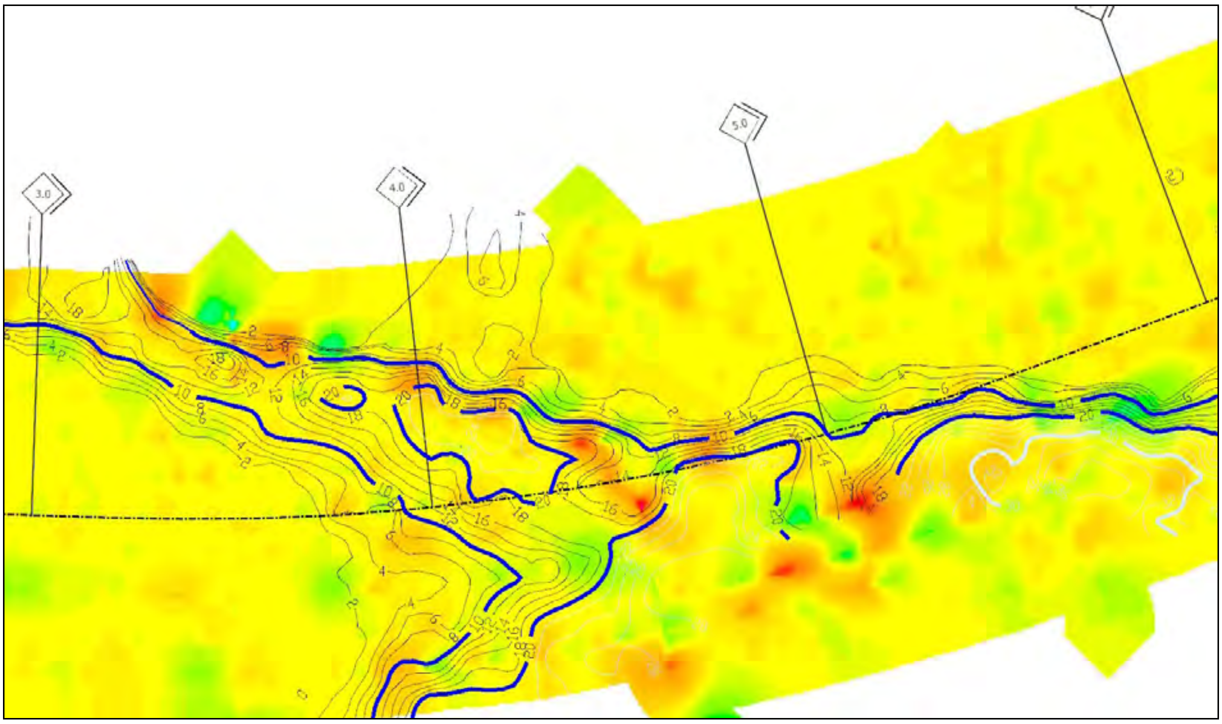


Figure 13a: Northern Route - Map of residual Magnetic Field between KP5.0 and KP6.0 with top of bedrock contours added

A total of 72 magnetic anomalies were identified from the processed magnetometer data. The data has been assessed for any correlation between sonar and magnetometer targets and this is indicated in the table above and the individual listings in Appendix 2 to this report.

A number of 'significant' targets (>10nT) are present within the Northern Route corridor and these are listed below;

I.D.	Eastings (m)	Northings (m)	Latitude UTM30	Longitude UTM30	Width (m)	Amplitude (nT)	Description/Associated Sonar Target
M051	525412.9	6265626.9	3.313597°N	42.902566°E	4.2	16.9	Positive Monopole
M052	525436.6	6265626.4	3.313746°N	42.902571°E	4.9	18.2	Negative Monopole
M054	525601.5	6266305.0	3.314551°N	42.906777°E	15.2	19.2	Positive Monopole
M058	526567.4	6266145.3	3.320692°N	42.906131°E	114.2	28.2	Dipole
M059	526582.1	6265138.4	3.321133°N	42.899979°E	128.5	10.3	Negative Monopole (S048/S050/S051)
M072	551785.5	6273129.5	3.477049°N	42.957643°E	643.3	688.0	Complex Dipole (S398) - wreck

Most of the magnetic anomalies found along the Northern Route corridor lay between KP0.00 and KP3.00. The presence of the 'significant' targets indicated above may suggest that localised ferrous debris may be present at their individual locations, although it is also possible that some of these may be related to the underlying geology.

Anomaly M072 (688.0nT) relates to a very large charted wreck (sonar target S398 – 132m x 30m x 11m), which lies in the southern section of the corridor at approximately KP30.16.

3.1.5 Installation Constraints

The table below indicates where rock or potentially 'hard' materials lie at or within 3.0m of seabed:

KP	KP	(Soft) Forth Formation Sediment cover (m)	(Hard) Quaternary sediment cover (m)	Comment
from	to			
0.000	3.603	0.00	0.00	Rock outcrop
3.603	3.735	0.00	0.00 - 3.00	St Abbs Formation
5.473	5.503	0.00	0.00 - 3.00	St Abbs Formation
5.503	6.013	0.00	0.00	Rock outcrop
6.013	6.259	0.00	0.00 - 3.00	St Abbs Formation
6.314	6.427	0.00	0.00 – 3.00	St Abbs Formation
6.444	6.497	0.00	0.00 – 3.00	St Abbs Formation
6.510	6.538	0.00	0.00 – 3.00	St Abbs Formation
7.009	7.059	0.00	0.00 – 3.00	St Abbs Formation
17.211	17.471	0.00 - 3.00		Forth/St Abbs/Wee Bankie Formations
17.509	18.013	0.00	0.00 – 3.00	St Abbs then Wee Bankie outcrop
18.013	18.170	0.00 - 3.00		Forth/St Abbs Formations
18.170	18.242	0.00 - 3.00		Forth/St Abbs/Wee Bankie Formations
18.242	18.644	0.00	0.00 – 3.00	Likely Wee Bankie outcrop
18.644	18.733	0.00	0.00 - 3.00	St Abbs/Wee Bankie Formations
18.733	18.976	0.00	0.00 – 3.00	St Abbs Formation
18.976	19..818	0.00	0.00 - 3.00	St Abbs/Wee Bankie Formations
19.818	19.834	0.00 - 3.00		Forth/St Abbs Formations
20.666	20.957	0.00 – 3.00		Forth/St Abbs Formations
20.957	21.187	0.00 - 3.00		Forth/St Abbs/Wee Bankie Formations
21.187	21.760	0.00 – 3.00		Forth/St Abbs Formations
21.760	23.928	0.00 - 3.00		Forth/St Abbs/Wee Bankie Formations
23.928	25.124	0.00	0.00 - 3.00	Likely Wee Bankie outcrop
25.124	25.377	0.00	0.00 - 3.00	St Abbs Formation

KP	KP	(Soft) Forth Formation Sediment cover (m)	(Hard) Quaternary sediment cover (m)	Comment
from	to			
25.377	27.289	0.00	0.00 – 3.00	St Abbs/Wee Bankie Formations
27.289	28.394	0.00	0.00 – 3.00	Likely Wee Bankie outcrop
28.394	29.373	0.00	0.00 - 3.00	St Abbs/Wee Bankie Formations
29.373	29.777	0.00	0.00 - 3.00	Likely Wee Bankie outcrop
29.777	30.012	0.00	0.00 - 3.00	St Abbs/Wee Bankie Formations
30.012	30.177	0.00	0.00 - 3.00	Likely Wee Bankie outcrop
30.177	30.450	0.00	0.00 - 3.00	St Abbs/Wee Bankie Formations
30.450	30.758	0.00	0.00 - 3.00	Likely Wee Bankie outcrop
30.758	31.344	0.00	0.00 - 3.00	St Abbs/Wee Bankie Formations
31.344	32.464	0.00	0.00 - 3.00	Likely Wee Bankie outcrop
32.464	33.368	0.00	0.00 – 3.00	St Abbs/Wee Bankie Formations

In addition to the areas of shallow bedrock/'hard' Quaternary sediments shown in the above table, a number of other potential obstructions are mentioned in sections 3.1.2, 3.1.3 and 3.1.4, above. These include a number of sonar targets, which lie within 10.0m of the proposed route centre line (all within the combined route section) and these are shown in the table below;

I.D.	Eastings (m)	Northings (m)	Latitude UTM30	Longitude UTM30	Length (m)	Width (m)	Height (m)	Description
S225	540136.8	6270390.8	3.404683°N	42.936784°E	nml	nmw	nmh	Small point contact (<1m)
S229	540146.4	6270381.0	3.404747°N	42.936728°E	nml	nmw	nmh	Small point contact (<1m)
S233	540193.2	6270414.4	3.405030°N	42.936948°E	2.9	2	0.8	Probable boulder
S282	545470.9	6272055.7	3.437679°N	42.948836°E	nml	nmw	nmh	Small point contact (<1m)
S340	546734.2	6272490.2	3.445478°N	42.951938°E	nml	nmw	nmh	Small point contact (<1m)
S386	550261.2	6273592.5	3.467287°N	42.959926°E	3.9	2	0.4	Probable boulder
S387	550263.3	6273597.4	3.467298°N	42.959957°E	nml	nmw	nmh	Small point contact (<1m)
S389	550436.0	6273598.6	3.468385°N	42.960026°E	nml	nmw	nmh	Small point contact (<1m)

3.2 Southern Route Corridor

2.2.5 Bathymetry

Processed bathymetric data is presented at a horizontal scale of 1:10000 on panel 1 of each of the Route Alignment charts. The data has been contoured at a vertical interval of 1.0m and is reduced to Lowest Astronomical Tide (LAT).

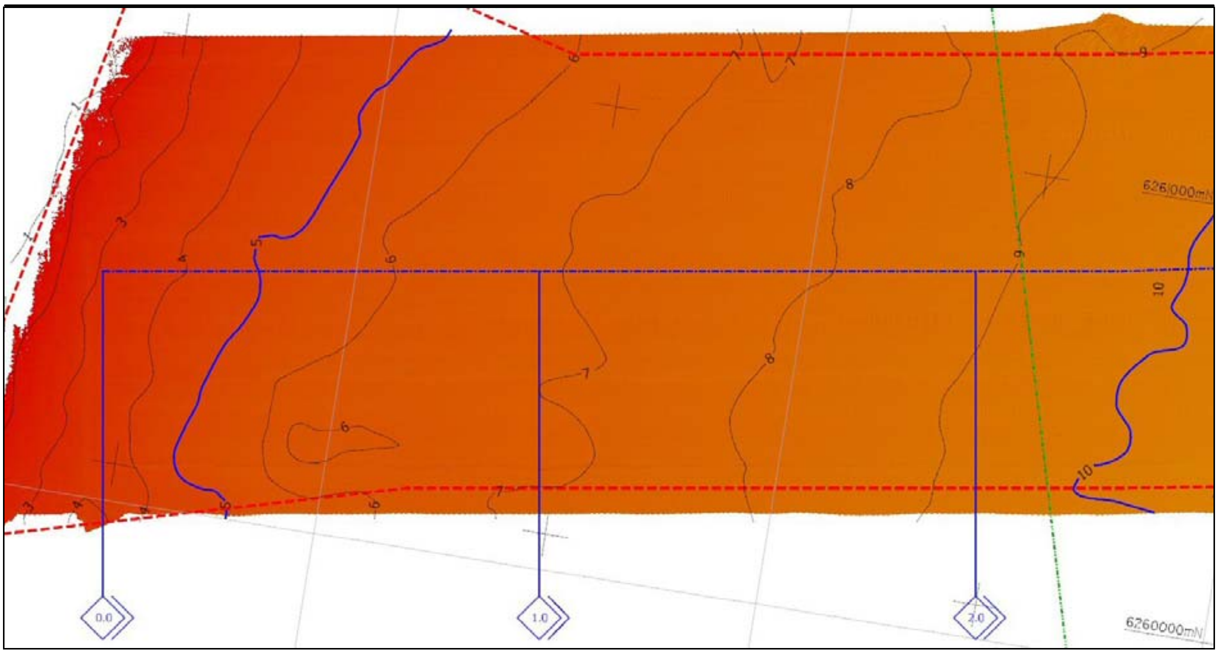


Figure 14: Southern Route – Shaded Relief bathymetry image of inshore section
(Refer to charts for colour/depth scale)

Seabed levels along the Southern Route corridor range from approximately 3.0m below LAT, close to KP0.0, to approximately 69.0m below LAT in the extreme N of the combined corridor at KP36.56.

Inshore of KP0.00, seabed levels dip gently to the ESE across a relatively flat sandy seabed, from 1.0m below LAT to 3.0m below LAT, at an average gradient of 0.6°. From KP0.00 to the 5.0m below LAT contour at KP0.356, the seabed gradient decreases to 0.3°, before decreasing further still to less than 0.2° between KP0.356 and KP20.4, where the seabed level lies at 42.0m below LAT.

At approximately this point, the very gentle seabed gradient begins to gradually steepen as a seabed depression is approached, with levels deepening to 60.0m below LAT at KP23.69, at an average gradient of 0.35°. This natural depression lies mainly to the N of the route centre line, between KP22.75 and KP24.48. Traversing along the route centre line, seabed levels begin to shallow again to the ENE of KP24.00, with the eastern edge of the seabed depression marked by a series of gravelly ridges. One of these steeply-sided features crosses the route centre line obliquely between KP24.3 and KP24.45, where localised gradients of up to 9.5° were noted.

A broader gravelly ridge feature crosses the southern section of the route corridor between KP25.67 and KP26.6, with the steepest parts of the feature crossing the proposed centre line between KP25.73 and KP25.885 (shallowing seabed) and between KP26.29 and KP26.55 (deepening seabed). Maximum seabed gradients of 1.75° and 2.5° were noted on the western and eastern sides, respectively, as measured along the proposed centre line.

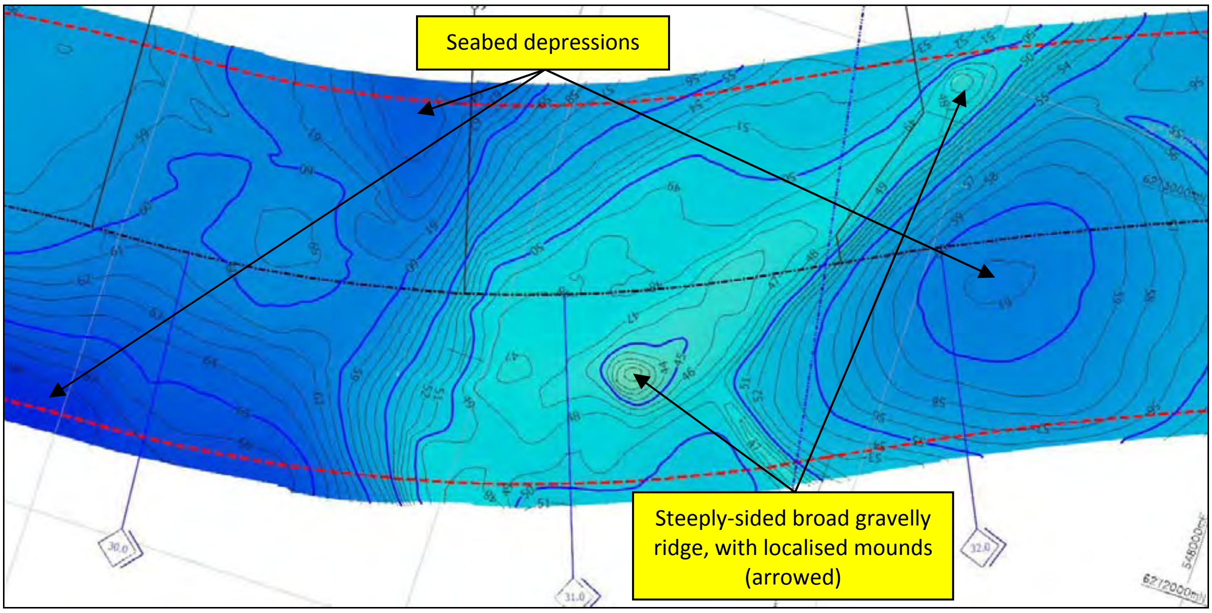


Figure 15: Southern Route – Shaded Relief bathymetry image – KP30.0 to KP32.0

From KP26.5 to the offshore end of the proposed route at KP40.096, seabed levels within the route corridor undulate between 39.0m below LAT and 69.0m below LAT, as the route crosses a series of frequently broad, steeply-sided ridges or mounds of gravelly sands/sandy gravels (see Figure 15, above). The steepest gradients on the upslope and downslope sides of these features were noted below;

KP28.918 to KP29.119 (0.9°); KP29.617 to KP29.753 (0.4°); KP30.566 to KP30.821 (2.5°);

KP31.626 to KP31.787 (2.6°); KP32.48 to KP32.614 (0.9°); KP34.72 to KP34.893 (0.7°);

KP35.618 to KP35.774 (1.1°); KP35.937 to KP36.068 (0.9°); KP36.575 to KP36.647 (1.6°);

KP36.778 to KP36.947 (1.8°); KP37.085 to KP37.299 (1.2°); close to KP37.566 (2.2°) and

KP37.607 to KP37.735 (1.3°). These gradients are measured along the proposed route centre line, which frequently crosses the individual features obliquely. The individual features are likely to have steeper gradients, when measured perpendicular to the relevant slopes.

3.2.2 Seabed Features

The results of the Side Scan Sonar survey are presented on panel 2 of each of the Route Alignment charts. These are presented at a horizontal scale of 1:10000, with seabed classifications derived from a combination of an interpretation of the sonar, bathymetry and sub-bottom data sets.

Bed form terminology used in this section is based on the following approximate definitions (Oxford Dictionary of Earth Sciences, 1999).

Definition	Height (m)	Wavelength (m)
Ripple	<0.1	<1.0
Megaripples	0.1 – 3.0	1.0 – 30
Sand waves	3.0 – 15.0	30 – 500

The side scan sonar data indicate that variable, generally finely granular sediments are present at seabed level across much of the proposed route corridors, with occasional patches of outcropping rock present in the extreme northern section of the Southern Route. These sediments are interpreted as ranging from very silty fine to coarse grained sands, with variable shell content, to coarser grained sandy gravels, with occasional cobbles and (generally small) boulders. The seabed across the whole of the Southern Route corridor, (out to approximately KP21.2) comprises mainly fine, or silty fine sands. Some irregular rock outcrops lay just to the N of the corridor, between KP1.2 and KP2.6, suggesting that the finely granular sediment cover is relatively thin in that area. A number of small sonar contacts were noted, and these are likely to be small boulders, with a maximum dimension of <1.0m.

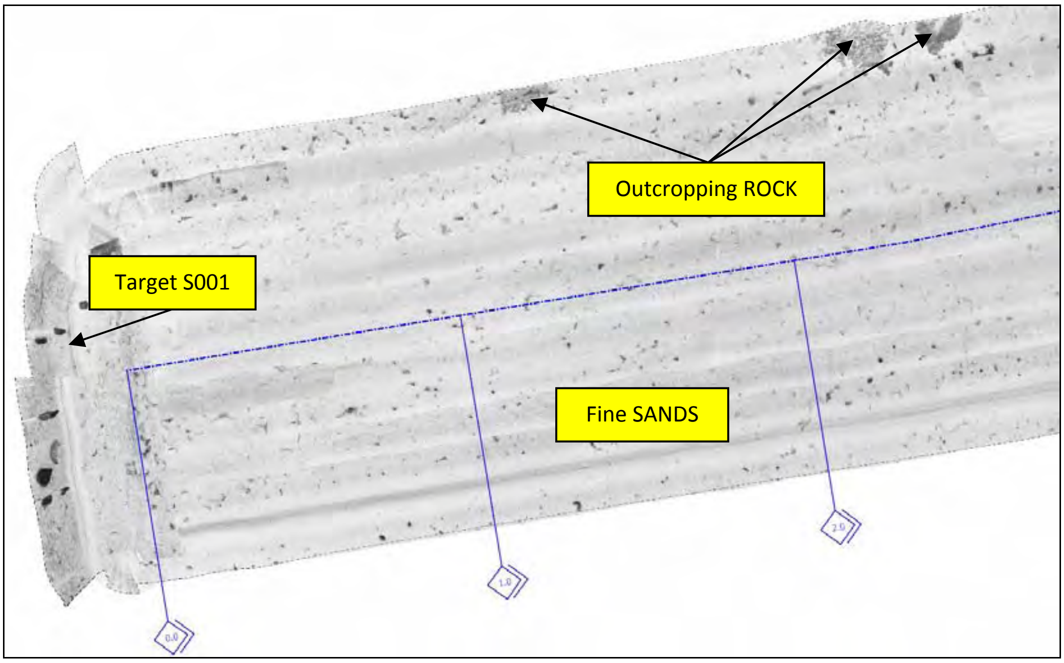


Figure 16: Distribution of sediments across the inshore section of the Southern Route

Figure 16 above, is a section of the sonar mosaic, which indicates the distribution of finer grained sandy sediments across the inshore section of the Southern Route, with the darker areas indicating where bedrock is at, or very close to seabed.

Sonar target S001 (14.5m x 6.0m x 0.0m), which lies approximately 127m inshore of KP0.00 at 517778.4mE, 6260502.3mN, is described as an 'unknown feature'. However, this has an extremely large associated magnetic anomaly (M003 – 1686.4nT), indicating that a large amount of ferrous material is present (see Figure 17, below and Data Examples in Appendix 3). This may represent some partially buried debris, or possibly an unmarked diffuser from an outfall pipe, although no information was available to confirm this.

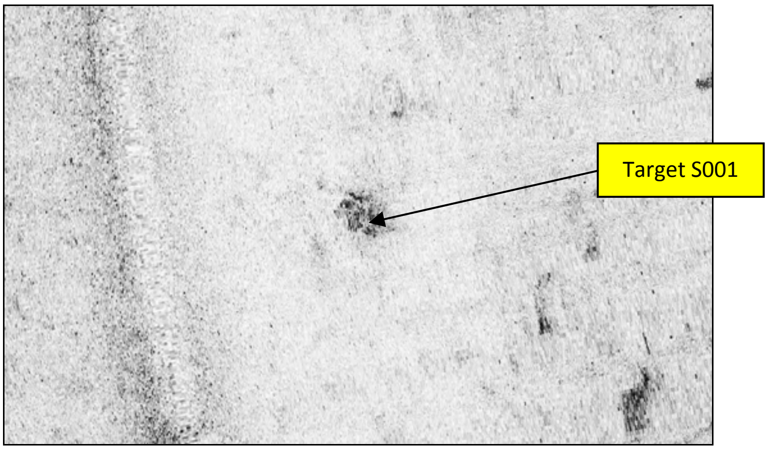


Figure 17: Close up image of sonar target S001

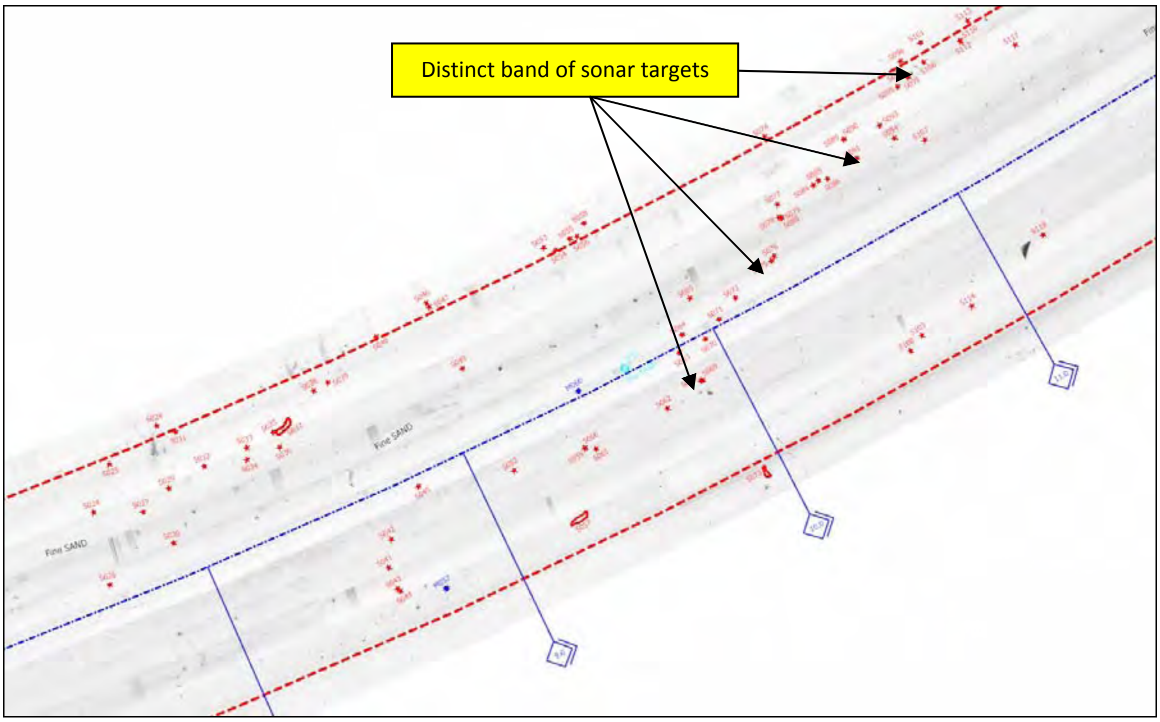


Figure 18: Southern Route – Distribution of seabed sediments between KP8.0 and KP11.0

A significant number of sonar targets lie to the N of the proposed route centre line between

KP7.6 and KP9.8; with a distinct band of targets crossing the proposed centre line from SSW to NNE between KP9.8 and KP10.15 (see Figure 18, above). These may relate to a likely thinning of sediment cover towards the NW. A small wreck (target S190) is present approximately 436m NW of the proposed route centre line at KP14.33.

The long expanse of silty fine sands is finally broken to the NE of KP21.2, with a number of irregular patches of coarser grained sands present, followed to the NE of KP24.0 by larger areas of sandy gravels and occasional small boulders. This is the result of a thinning of the Holocene sands/Forth Formation deposits, relating to a shallowing of the underlying glacial deposits (see Figure 19, below).

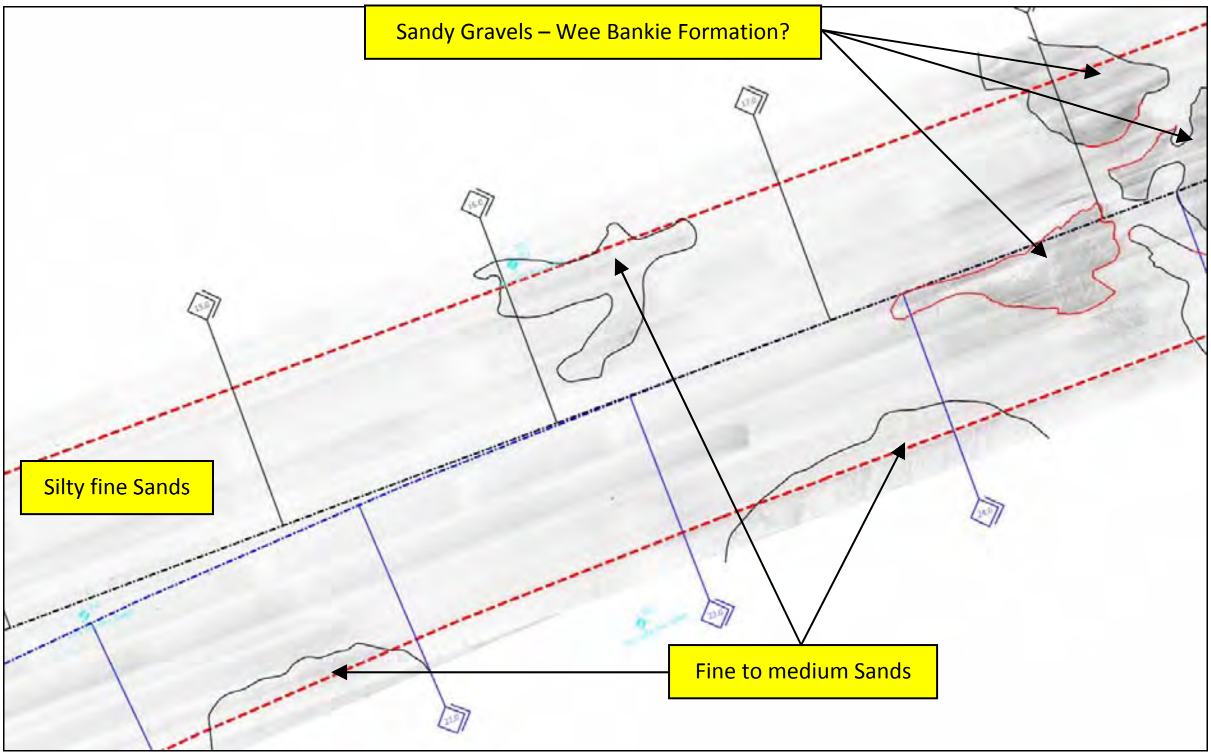


Figure 19: Southern Route – Distribution of seabed sediments between KP22.0 and KP25.0

It is likely that these coarser grained materials are representative of strata of the underlying Wee Bankie Formation, which are known to comprise stiff, frequently granular till, with interbedded sands and gravelly sands.

These patches of coarse grained sediments exhibit strong relief, standing up to 20.0m above the surrounding seabed, with the finer grained materials between the coarser patches frequently exhibiting megaripple bed forms. These generally low-order bed forms are orientated NW-SE or WNW-ESE, stand up to 0.4m high and have an average wavelength between 7.0m and 15.0m.

The finer grained silty sands extend further to the E, with further patches of coarser grained, possible Wee Bankie sediments present out to approximately KP30.66, where a 750 – 1280m wide band of (probably) dense sandy gravels crosses the route corridor from NNE to SSW, crossing the proposed centre line between KP30.66 and KP31.93. This broad band of coarser sediments also exhibits strong relief, with a number of large mounds present, which stand up to 20.0m above the surrounding seabed. Megaripples are present across much of the seabed to the NW and SE of this area of coarse sediments. These bed forms are again orientated NW-SE or WNW-ESE, stand up to 0.4m high and have an average wavelength between 7.0m and 15.0m.

The finer grained silty sands extend eastwards, with a number of other areas of coarse grained, possible Wee Bankie Formation sediments crossing the route centre line between KP31.93 and the end of the route corridor at approximately KP39.601.

The interpreted Wee Bankie sediments outcrop along the route centre line between KP32.490 and KP32.743, between KP32.854 and KP32.979, between KP34.017 and KP35.058, between KP36.131 and KP36.470, between KP36.822 and KP36.932, between KP37.109 and KP37.371, and finally, between KP38.004 and KP39.194. Many of these Wee Bankie 'outcrops' again exhibit some relief, and are flanked by irregular areas of megaripple bed forms. These features are orientated between NNW-SSE and WNW-ESE, stand up to 0.4m high and have average wavelengths between 6.0m and 15.0m.

A total of 456 sonar targets were noted along the combined route corridors. Most of these appear to be small boulders, with a maximum dimension of <1.0m, although some larger boulders were also noted.

Similarly, a total of 72 magnetic anomalies were noted within the corridors. These range in size from 0.6 – 7713.1nT (nanoTesla).

Very few of the sonar targets appear to have associated magnetic anomalies, and these are shown in table 2 below;

I.D.	Eastings (m)	Northings (m)	Latitude UTM30	Longitude UTM30	Length (m)	Width (m)	Height (m)	Description/Associated Magnetic Anomaly
S001	517778.4	6260502.3	3.267232°N	42.868625°E	14.5	6	0	Unknown seabed feature (M003)
S018	524016.2	6262267.9	3.305951°N	42.881543°E	26	11	6	Probable Wreck (M043)
S019	524075.4	6262316.7	3.306308°N	42.881862°E	15	3	0	Debris from Wreck (M043)
S190	530740.8	6265874.8	3.347082°N	42.905911°E	31	12	2.5	Probable Wreck (M066)
S398	551793.2	6273065.6	3.477121°N	42.957256°E	132	30	11	Unknown wreck (M072)

Table 3: Sonar targets with associated magnetic anomalies within Southern/Combined route

According to the wreck listings provided by the Client, only 3 wrecks are thought to be present within the proposed corridors. The original wreck listing indicates a wreck of unknown origin to be present at 551861mE, 6273289mN, KP36.96 on the Southern Route. An actual wreck (target S398 – 132m x 30m x 11m) was noted at KP36.9, centred at approximately 551793mE, 6273066mN, some 228m SSW of the above position. This feature has a very large associated magnetic anomaly (M072 – 688.0nT)

Sonar target S190 at KP14.22 (see Data Examples in Appendix 3) is clearly a wreck (31.0m x 12.0m x 2.5m), which is not included in the listings provided. This feature also has a very large associated magnetic anomaly (M066 – 181.3nT). Similarly, sonar targets S018 and S019 at KP6.45 are a wreck (26.0m x 11.0m x 6.0m) and possible localised debris. It has an extremely large associated magnetic anomaly (M043 – 7713.1nT), which indicates that a large amount of ferrous material is present (i.e. the wreck was of mainly iron construction). A high frequency sonar image of this feature is presented in the Data Examples in Appendix 3 to this report. This suggests that the wreck is partially scattered and includes some cabling or a possible anchor chain.

A number of sonar targets lie within 10.0m of the proposed route centre line (all within the combined route section) and these are shown in the table below;

I.D.	Eastings (m)	Northings (m)	Latitude UTM30	Longitude UTM30	Length (m)	Width (m)	Height (m)	Description
S225	540136.8	6270390.8	3.404683°N	42.936784°E	nml	nmw	nmh	Small point contact (<1m)
S229	540146.4	6270381.0	3.404747°N	42.936728°E	nml	nmw	nmh	Small point contact (<1m)
S233	540193.2	6270414.4	3.405030°N	42.936948°E	2.9	2	0.8	Probable boulder
S282	545470.9	6272055.7	3.437679°N	42.948836°E	nml	nmw	nmh	Small point contact (<1m)
S340	546734.2	6272490.2	3.445478°N	42.951938°E	nml	nmw	nmh	Small point contact (<1m)
S386	550261.2	6273592.5	3.467287°N	42.959926°E	3.9	2	0.4	Probable boulder
S387	550263.3	6273597.4	3.467298°N	42.959957°E	nml	nmw	nmh	Small point contact (<1m)
S389	550436.0	6273598.6	3.468385°N	42.960026°E	nml	nmw	nmh	Small point contact (<1m)

Table 4: Sonar targets lying within 10.0m of proposed route centre line

Fishing activity was identified as a number of trawl scars, which are present across both proposed routes, starting near the routes convergence point at 538747.8mE 6269865.3mN WGS84 UTM 30N), corresponding to KP 16.415 on the Northern Route and KP 23.150 on the Southern Route. No other significant seabed features were observed.

A complete set of sonar targets and magnetic anomalies are presented in Appendix 2 to this report, together with a Client-provided wreck listing, indicating any associated sonar/magnetic features and any uncharted wrecks, which were found during the survey.

3.2.3 Sub-Bottom Profiling

The processed sub-bottom profiling data are presented as Isopachytes on panel 3 of each of the Route Alignment charts. These are all presented at a scale of 1:10000 and are contoured at a vertical sediment thickness interval of 2.0m.

The sub-bottom data indicate that, between KP0.00 and KP2.65 bedrock is present at seabed only as three small isolated outcrops, which lie just outside the northern boundary of the Southern Route.

Elsewhere across this inshore area, the seabed comprises a generally featureless expanse of fine sand, or silty fine sand, with occasional small boulders (Holocene/Forth Formation). These materials are generally between 2.0m and 4.0m thick, out to approximately KP8.0. It is not possible to accurately delineate any discontinuity, which separates the more recent Holocene sediments from the underlying Forth Formation materials.

The bedrock surface dips roughly N-S in this inshore section, towards a deep buried channel feature, which is approximately 14.0m deep at KP0.00. The data indicates that the buried channel is at least partially infilled by bedded clays of the St Abbs Formation (see Figure 20, below).

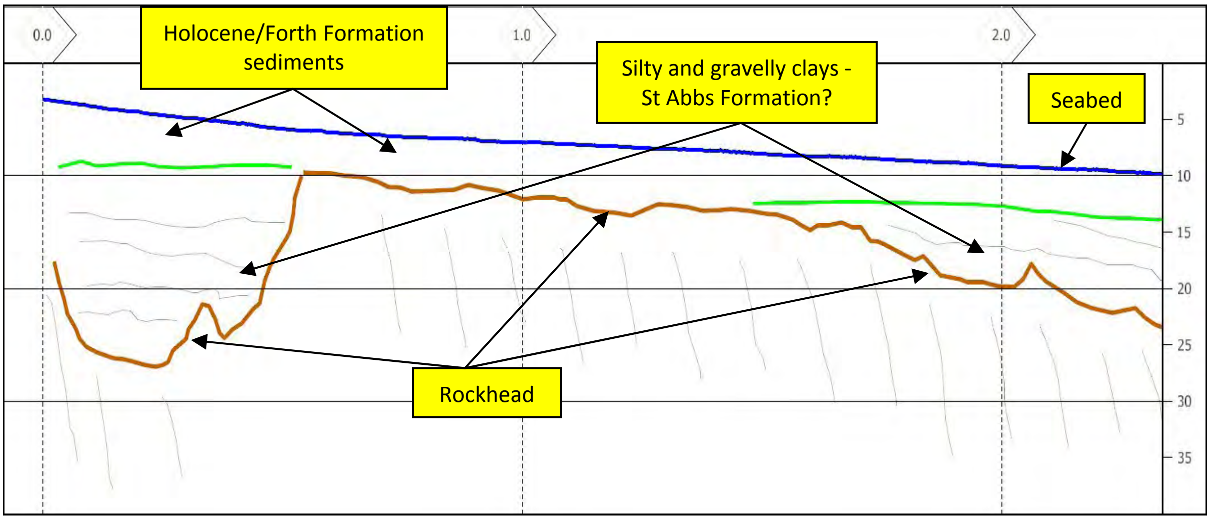


Figure 20: Southern Route – inshore section of interpreted profile, showing buried channel at KP0.0

The buried channel forms a curvilinear feature, which initially runs NW-SE, before veering eastwards and then towards the ENE offshore of KP5.0, crossing the proposed route centre line between KP4.0 and KP6.0. The bedrock surface in the inshore section is very irregular, mainly due to the relatively steep bedding, as seen on the individual profiles.

The fine grained sediments of the Holocene/Forth Formation thin to less than 2.0m between KP6.2 and KP8.05, where they are generally underlain by the clayey sediments of the St Abbs Formation (see Figure 21, below).

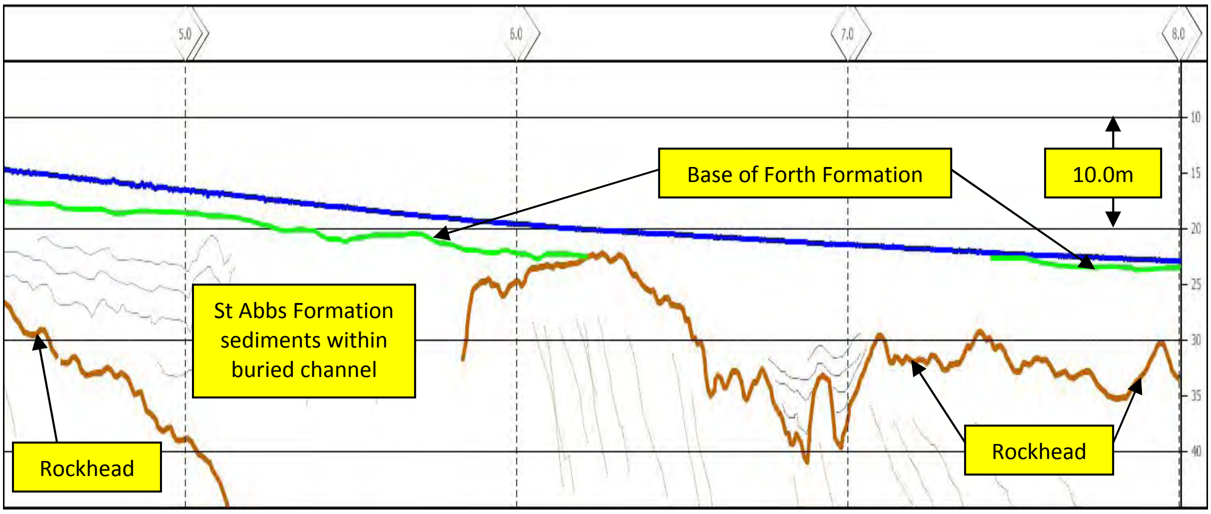


Figure 21: Southern Route – buried channel between KP5.0 and KP6.0, with thinning Forth Formation strata

To the E of KP8.05, the Forth Formation sediments become much thicker, as the underlying Quaternary sediments and bedrock surfaces dip once again into a much broader buried channel feature, which is a larger extension of the inshore buried channel feature seen at KP0.00 and again between KP4.0 and KP6.0.

An area of shallow gas is present in the upper sediment layers, between KP17.148 and KP18.012. This area of gas is noted as occasional high amplitude reflections, but mostly as a general 'blanking' of any underlying sediment structure. The gas front appears to lie above the centre of the deepest section of the buried channel feature, which may indicate a deep-seated source for the gas. Along the proposed Southern Route centre line, the gas front lies between 5.3m and 14.8m below seabed (see Figure 10, below).

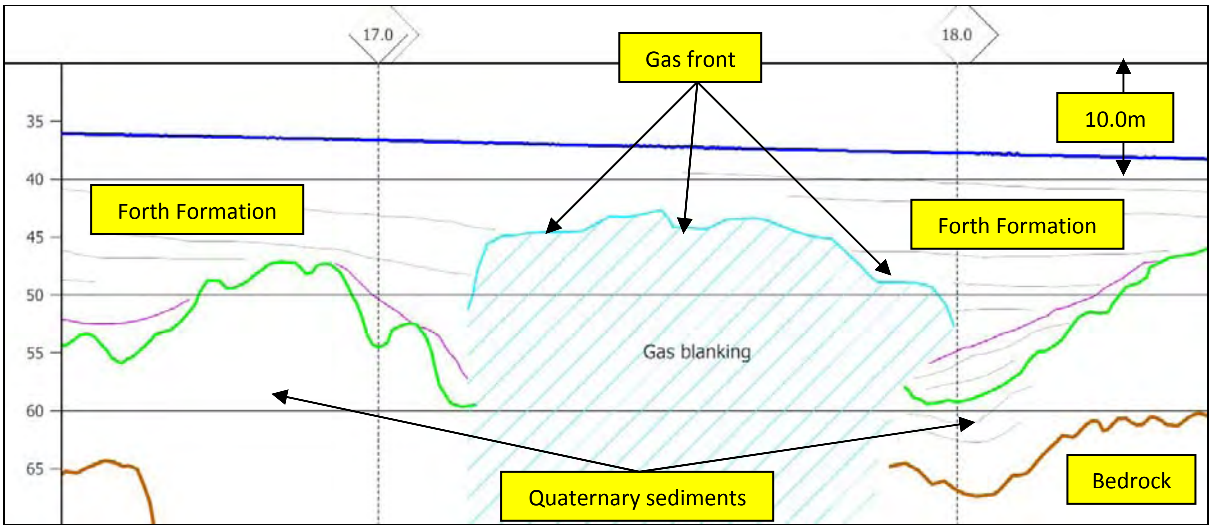


Figure 22: Southern Route – section of geological profile between KP16.5 and KP18.5

To the E and ESE of the gas front, the Forth Formation sediments gradually become thinner, as the underlying Quaternary sediments/bedrock surfaces shallow. These generally fine grained sediments thin to approximately 4.0m at KP22.725 (along the proposed centre line), thickening again to a maximum of 16.0m at KP23.79, before rapidly thinning to 0.0m close to KP24.0, where bedrock or, more likely, granular sediments of the Wee Bankie Formation lay at seabed.

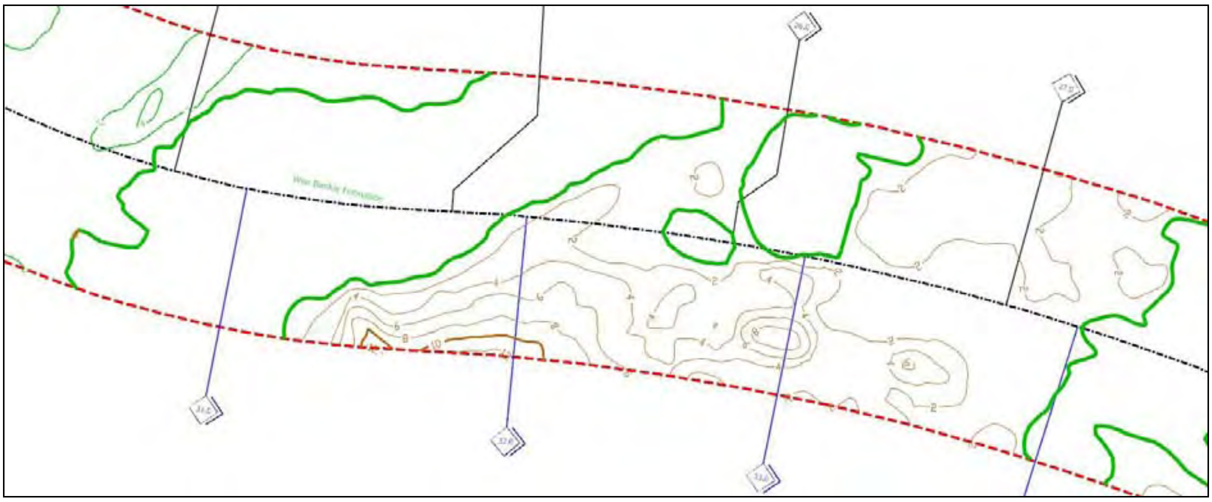


Figure 23: Southern Route – section of isopachyte chart between KP30.0 and KP34.5

A number of these large isolated outcrops of Quaternary sediments are present between KP 22.7 and KP28.5 and again between KP30.65 and KP35.06 (see Figure 23, above).

The sub-bottom data indicate that the very irregular bedrock surface generally lays close below the surface of the Quaternary materials, although it is frequently difficult to identify rockhead, due to the very dense nature of the Wee Bankie deposits. It is likely that clayey Quaternary sediments of the St Abbs Formation lie between the Forth Formation sediments and the Wee Bankie deposits/bedrock.

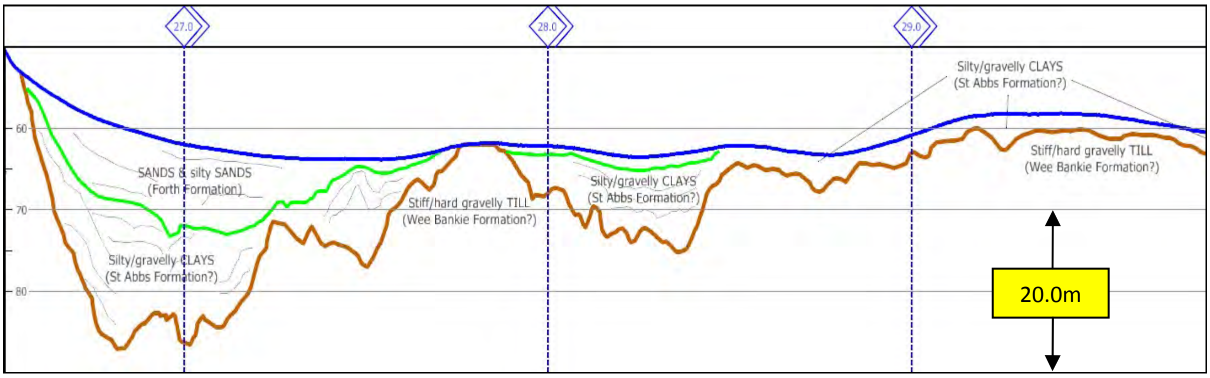


Figure 24: Southern Route – section of geological profile between KP26.6 and KP29.8

The Forth Formation sediments are absent to the E of KP30.65, with the Wee Bankie deposits forming a broad, NE-SW orientated outcrop, which crosses the whole width of the route corridor between KP30.65 and KP31.93. Several outcrops of Wee Bankie deposits are present to the E of KP31.93, with a general veneer of finely granular sediments covering the Wee Bankie deposits/bedrock, out to the offshore end of the route at KP39.601.

A table showing sections along the proposed route centre line, where sediment cover has been interpreted as either absent, or 'less than 2.0m' is presented in section 3.1.5 of this report.

3.2.4 Magnetometer

The results of the processed magnetometer data can be found as a series of annotated anomalies on panel 2 of drawing nos C11020-02a to C11020-02c (Southern route corridor), the Route Alignment charts.

The data has been assessed for any correlation between sonar and magnetometer targets and this is indicated in the table above and the individual listings in Appendix 2 to this report.

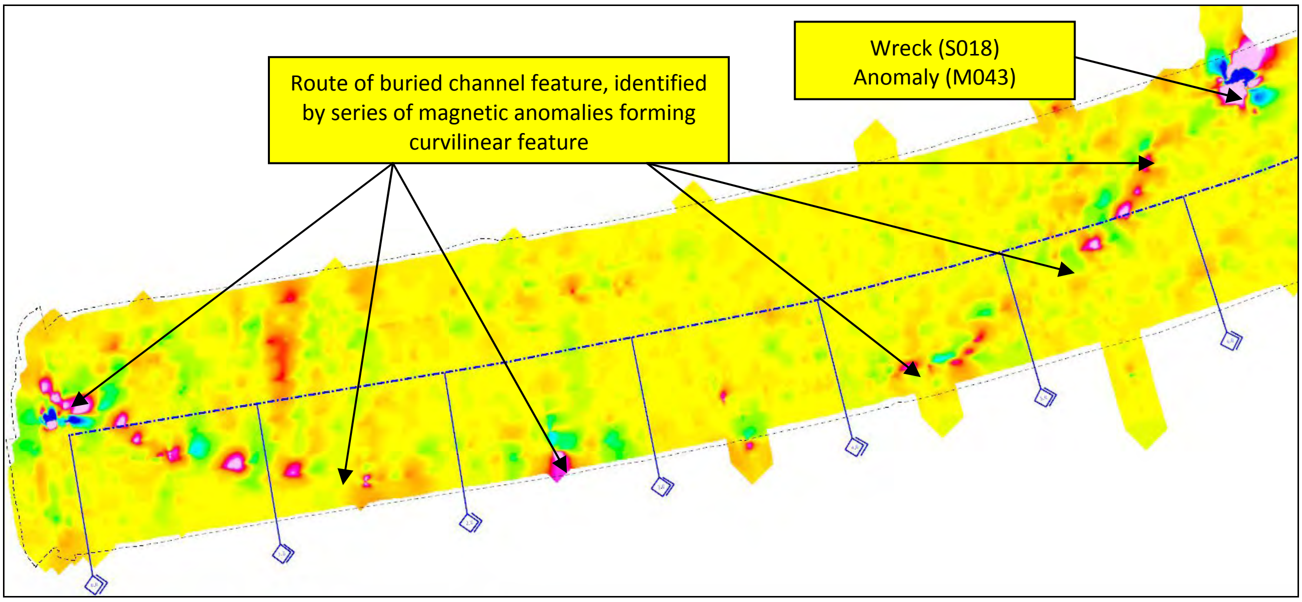


Figure 25: Map of residual Magnetic Field for inshore section of Southern Route – KP0.0 to KP6.0

Figure 25, (above), is a plot of residual magnetic field for the whole of the Section 1 area. Colour shading was used to more easily visualise areas of varying magnetic field, which include areas of large magnetic gradients around the sites of known (and unknown) wrecks. The pseudo-colour plot also indicates the presence of a buried channel feature – seen as a series of anomalies (in varying intensities of green, magenta and brown on the above figure) forming a curvilinear feature. Recent observations (*References; iii*) indicate that these mainly Holocene palaeochannels are identifiable, due to the formation of weakly magnetic iron sulphides under favourable conditions.

Figure 25a, below is the same plot as above, with the contours for the interpreted bedrock surface added.

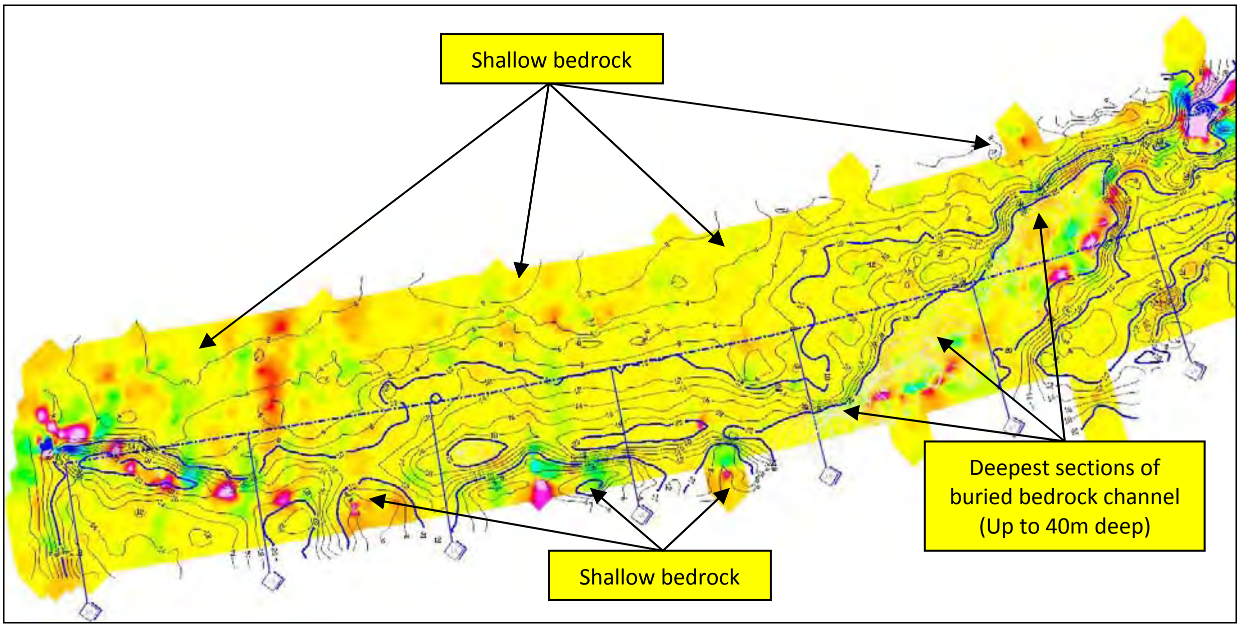


Figure 25a: Map of residual Magnetic Field for inshore section of Southern Route – KP0.0 to KP6.0
with top of bedrock contours added

A number of 'significant' targets (>10nT) are present within the Southern Route corridor and these are listed below;

I.D.	Eastings (m)	Northings (m)	Latitude UTM30	Longitude UTM30	Width (m)	Amplitude (nT)	Description/Associated Sonar Target
M003	517792.2	6260503.3	3.267319°N	42.868636°E	84.3	1686.4	Complex Dipole (S001)
M004	517792.6	6260965.5	3.267164°N	42.871465°E	21.1	15.0	Dipole
M005	517891.7	6260497.7	3.267947°N	42.868635°E	29.7	193.4	Dipole
M011	521101.8	6260875.2	3.288057°N	42.872030°E	23.1	15.3	Asymmetric Dipole
M013	521301.6	6260724.2	3.289369°N	42.871174°E	15.1	13.5	Asymmetric Dipole
M014	521349.7	6260617.2	3.289709°N	42.870535°E	28.4	46.9	Asymmetric Dipole
M015	521380.9	6260742.1	3.289862°N	42.871310°E	21.4	10.2	Dipole
M018	521469.0	6260403.3	3.290534°N	42.869267°E	153.7	36.3	Dipole
M021	521576.3	6261092.2	3.290975°N	42.873519°E	11.3	21.6	Positive Monopole
M025	521797.3	6261023.9	3.292391°N	42.873176°E	26.5	27.6	Dipole
M026	521826.2	6261145.5	3.292531°N	42.873930°E	16.9	13.8	Dipole
M027	521848.6	6260724.1	3.292817°N	42.871359°E	26.3	11.7	Dipole
M031	522215.0	6260813.6	3.295097°N	42.872031°E	20.6	12.6	Positive Monopole
M041	523485.3	6260745.0	3.303129°N	42.872043°E	45.4	17.4	Negative Monopole
M043	524055.4	6262302.5	3.306186°N	42.881768°E	350.0	7713.1	Complex Dipole (S018/S019) – wreck
M044	524137.0	6262129.7	3.306761°N	42.880738°E	34.1	24.1	Positive Monopole
M066	530737.9	6265883.0	3.347061°N	42.905959°E	214.6	181.3	Dipole (S190)
M072	551785.5	6273129.5	3.477049°N	42.957643°E	643.3	688.0	Complex Dipole (S398) – Wreck

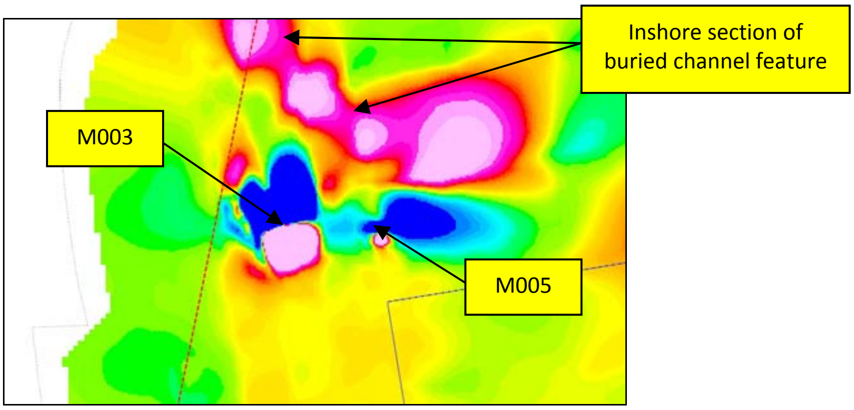


Figure 26: Map of residual Magnetic Field for Southern Route, inshore of KP0.0

Anomaly M003 lies some 127m NW (inshore) of KP0.00. Figure 26, above indicates the size and shape of the feature, which appears to be related to a localised area of 'disturbed' seabed (sonar target S001).

Many of the magnetic anomalies found along the Southern Route corridor lay between KP3.00 and KP6.00. Anomalies M014 (46.9nT) and M018 (36.3nT) are large, localised features, which may indicate the presence of localised buried ferrous debris, as no surface features (sonar targets) were noted at those locations.

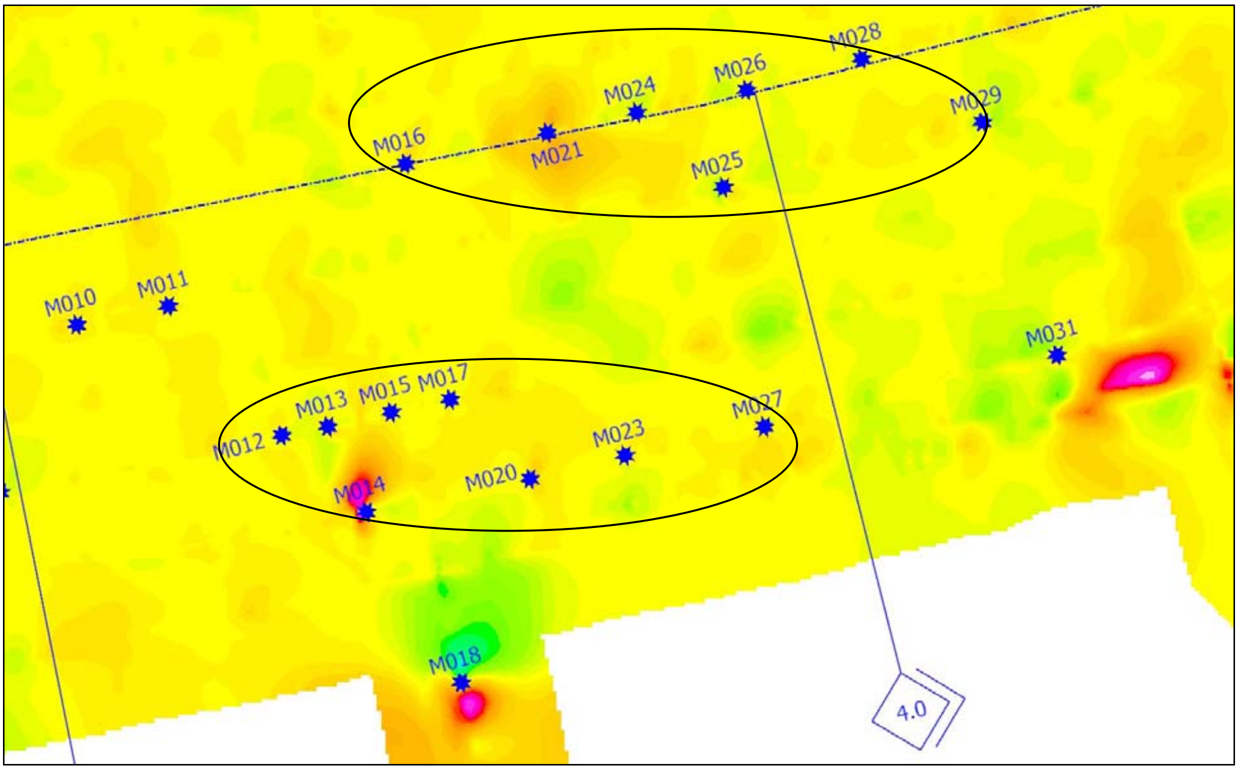


Figure 27: Southern Route, KP3.0 to KP4.5, showing possible clusters of anomalies

A number of anomalies (M16, M21, M24, M26 and M28) lay very close to the proposed route centre line between KP3.53 and KP4.17. Of these 5 features, 2 (M21 – 21.6nT and M26 – 13.8nT) can be deemed 'significant'. Along with anomalies M25 (27.6nT) and M29 (6.8nT), they form a potential cluster of features, which may indicate the presence of widely scattered ferrous debris (see Figure 27, above).

A similar potential cluster of anomalies (M12 – M15, M17, M20, M23 and M27) lies some 300 – 435m to the S of the proposed centre line, between KP3.34 and KP3.93 (see Figure 28, below). Of these 8 features, 4 (M13 – 13.5nT, M14 – 46.9nT, M15 – 10.2nT and M27 – 11.7nT) can be deemed 'significant'. Once again, this possible cluster of anomalies may also indicate the presence of ferrous debris, possibly scattered around anomalies M13, M14 and M15.

An extremely large and complex anomaly (M43 – 7713.1nT) lies some 480m to the N of the proposed centre line at approximately KP6.45. This is related to the presence of sonar targets S018 and S019, which is probably a wreck. Anomaly M44 lies some 198m to the ESE and may be related (scattered ferrous debris). Similarly, anomaly M66 (181.3nT) is a large anomaly related to an uncharted wreck (target S190). This feature lies approximately 440m NW of the proposed route centre line at KP14.25 (see Figure 28, below).

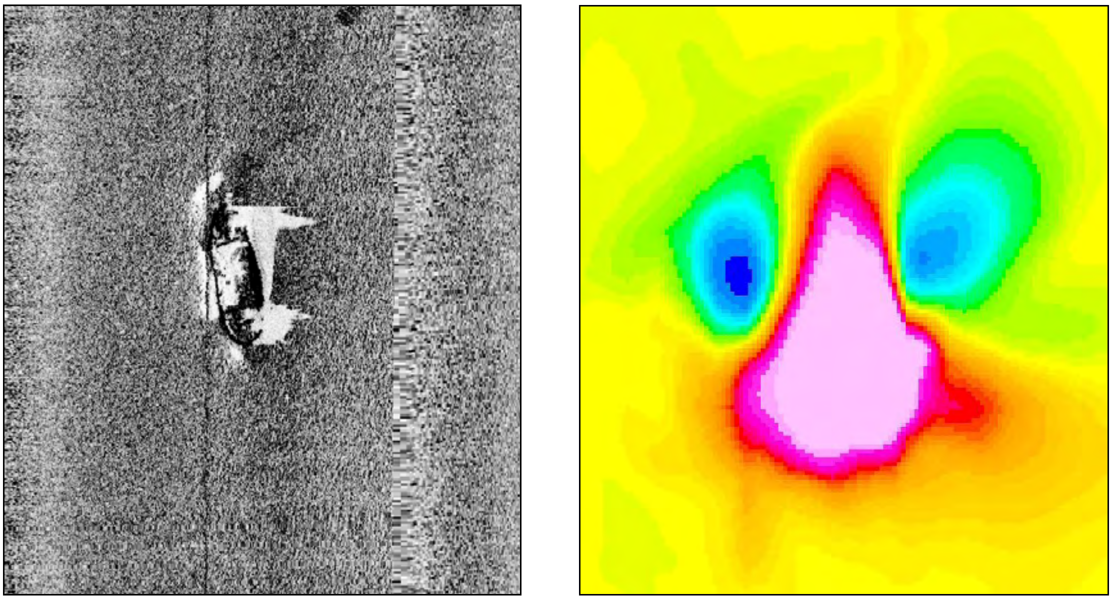


Figure 28: Southern Route, Sonar target S190 (left), with associated anomaly M66 (right)

Anomaly M70 (5.0nT) is a relatively minor feature, which lies within 6.0m of the proposed route centre line at KP21.74.

Finally, anomaly M072 (688.0nT) relates to a very large charted wreck (sonar target S398 – 132m x 30m x 11m), which lies in the southern section of the (combined) corridor at approximately KP36.9 (see Figure 29, below).

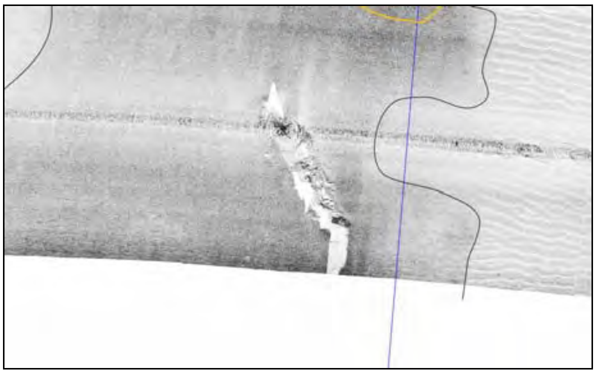
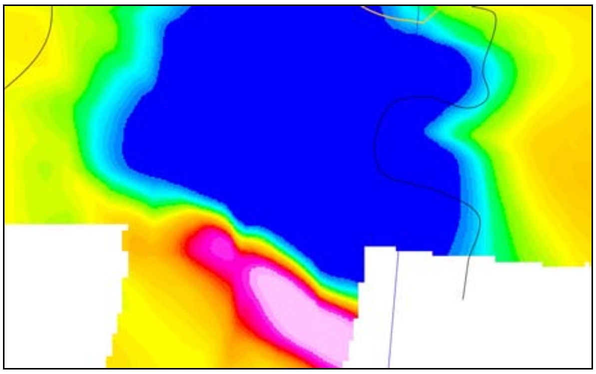



Figure 29: Southern Route, Sonar target S398 (left), with associated anomaly M72 (right)

3.2.5 Installation Constraints

The table below indicates where rock or potentially 'hard' materials lie at or within 3.0m of seabed:

KP	KP	(Soft) Forth Formation Sediment cover (m)	(Hard) Quaternary sediment cover (m)	Comment
from	to			
2.981	3.667	0.00 - 3.00		Forth/St Abbs Formations
4.349	6.178	0.00 - 3.00		Forth/St Abbs Formations
6.178	6.337	0.00 - 3.00		Forth/St Abbs Formations over bedrock
6.337	8.167	0.00 - 3.00		Forth/St Abbs Formations
23.944	23.985	0.00 - 3.00		Forth/St Abbs Formations over bedrock
23.985	24.157	0.00	0.00 - 3.00	Wee Bankie/possible shallow bedrock
24.157	24.279	0.00	0.00 - 3.00	St Abbs/Wee Bankie Formations over rock
24.279	24.731	0.00	0.00 - 3.00	Wee Bankie/possible shallow bedrock
24.731	24.972	0.00 - 3.00		Forth/St Abbs/Wee Bankie Formations over bedrock
24.972	25.404	0.00	0.00 - 3.00	Wee Bankie/possible shallow bedrock
25.404	25.470	0.00 - 3.00		Forth Formation over rock
25.711	25.753	0.00 - 3.00		Forth Formation over rock
25.753	26.552	0.00	0.00 - 3.00	Likely Wee Bankie outcrop
26.552	26.574	0.00 - 3.00		Forth/St Abbs/Wee Bankie Formations
27.631	27.770	0.00 - 3.00		Forth/St Abbs/Wee Bankie Formations
27.770	27.854	0.00	0.00 - 3.00	Likely Wee Bankie outcrop
27.854	28.491	0.00 - 3.00		Forth/St Abbs Formations
28.491	28.701	0.00	0.00 - 3.00	St Abbs/Wee Bankie Formations
28.701	28.827	0.00	0.00 - 3.00	St Abbs Formation
28.827	30.126	0.00	0.00 - 3.00	St Abbs/Wee Bankie Formations
30.126	30.663	0.00 - 3.00		Forth/St Abbs/Wee Bankie Formations
30.663	31.837	0.00	0.00 - 3.00	Likely Wee Bankie outcrop
31.837	32.455	0.00	0.00 - 3.00	St Abbs/Wee Bankie Formations
32.455	33.012	0.00	0.00 - 3.00	Likely Wee Bankie outcrop
33.012	34.023	0.00	0.00 - 3.00	St Abbs/Wee Bankie Formations
34.023	35.131	0.00	0.00 - 3.00	Likely Wee Bankie outcrop
35.131	36.113	0.00	0.00 - 3.00	St Abbs/Wee Bankie Formations
36.113	36.510	0.00	0.00 - 3.00	Likely Wee Bankie outcrop
36.510	36.747	0.00	0.00 - 3.00	St Abbs/Wee Bankie Formations
36.747	36.913	0.00	0.00 - 3.00	Likely Wee Bankie outcrop
36.913	37.181	0.00	0.00 - 3.00	St Abbs/Wee Bankie Formations
37.181	37.490	0.00	0.00 - 3.00	Likely Wee Bankie outcrop
37.490	38.076	0.00	0.00 - 3.00	St Abbs/Wee Bankie Formations

KP	KP	(Soft) Forth Formation Sediment cover (m)	(Hard) Quaternary sediment cover (m)	Comment
from	to			
38.076	39.200	0.00	0.00 - 3.00	Likely Wee Bankie outcrop
39.200	39.268	0.00	0.00 - 3.00	St Abbs/Wee Bankie Formations
39.268	40.092	0.00	0.00 - 3.00	St Abbs Formation

In addition to the areas of shallow bedrock/'hard' Quaternary sediments shown in the above table, a number of other potential obstructions are mentioned in sections 3.2.2, 3.2.3 and 3.2.4, above. These include a number of sonar targets, which lie within 10.0m of the proposed route centre line (all within the combined route section) and these are shown in the table below;

I.D.	Eastings (m)	Northings (m)	Latitude UTM30	Longitude UTM30	Length (m)	Width (m)	Height (m)	Description
S225	540136.8	6270390.8	3.404683°N	42.936784°E	nml	nmw	nmh	Small point contact (<1m)
S229	540146.4	6270381.0	3.404747°N	42.936728°E	nml	nmw	nmh	Small point contact (<1m)
S233	540193.2	6270414.4	3.405030°N	42.936948°E	2.9	2	0.8	Probable boulder
S282	545470.9	6272055.7	3.437679°N	42.948836°E	nml	nmw	nmh	Small point contact (<1m)
S340	546734.2	6272490.2	3.445478°N	42.951938°E	nml	nmw	nmh	Small point contact (<1m)
S386	550261.2	6273592.5	3.467287°N	42.959926°E	3.9	2	0.4	Probable boulder
S387	550263.3	6273597.4	3.467298°N	42.959957°E	nml	nmw	nmh	Small point contact (<1m)
S389	550436.0	6273598.6	3.468385°N	42.960026°E	nml	nmw	nmh	Small point contact (<1m)

Finally, a number of magnetic anomalies (M16, M21, M24, M26 and M28) lay very close to the proposed Southern Route centre line between KP3.53 and KP4.17. Of these 5 features, 2 (M21 – 21.6nT and M26 – 13.8nT) can be deemed 'significant'. Along with anomalies M25 (27.6nT) and M29 (6.8nT), they form a potential cluster of features, which may indicate the presence of widely scattered ferrous debris.

4. REFERENCES

i) Tay Forth, — Sheet 56°N - 04°W, British Geological Survey, 1:250,000 Series, Solid Geology / Seabed Sediments and Quaternary Geology

ii) The Geology of the central North Sea — Gatcliff, R.W., Richards, P.C., Smith, K., Graham, C.C., McCormac, M., Smith, N.J.P., Long, D., Cameron, T.D.J., Evans, D., Stevenson, A.G., Bulat, J., Ritchie, J.D., B.G.S., United Kingdom Offshore Regional Report, 1994

iii) Holocene Sulphur Rich Palaeochannel Sediments, etc. — Brown A.G., Ellis, C. Roseff, R. Journal of Archaeological Science 37 (2010) pp 21 – 29.

iv) An Introduction to Applied and Environmental Geophysics — J. M. Reynolds, John Wiley & Sons, 1997

v) Oxford Dictionary of Earth Sciences — Allaby, A. & Allaby, M., pp599, Oxford University Press, 1999.

vi) Deal Data Registry — http://www.ukdeal.co.uk/

vii) Kingfisher Information Services — http://www.kisca.org.uk

APPENDICES

APPENDIX 1

CHARTING

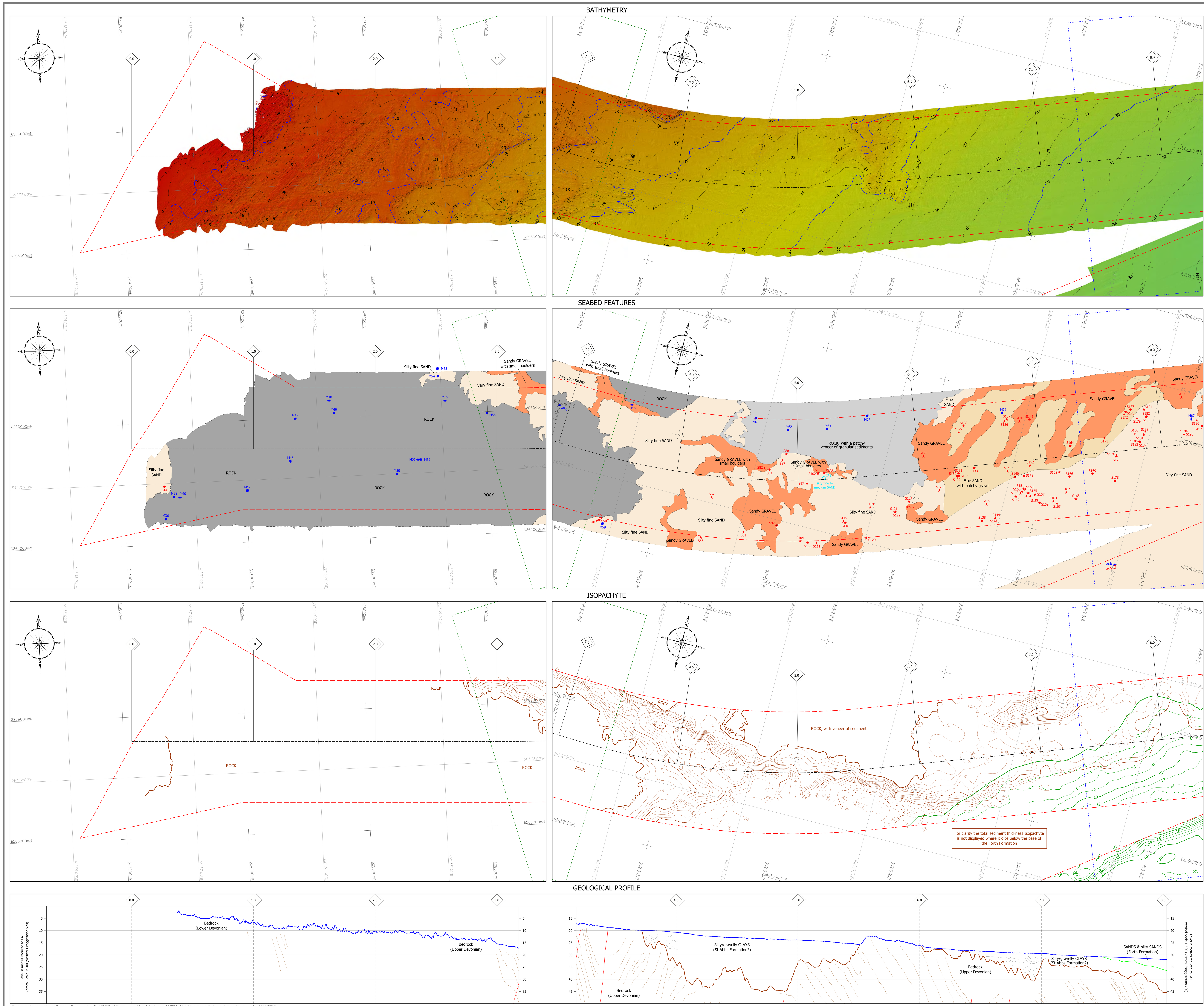
Route Alignment Charts

Northern Route Corridor

C11020-01a	-	KP0.000 to KP8.340
C11020-01b	-	KP7.338 to KP17.138
C11020-01c	-	KP16.137 to KP25.983
C11020-01d	-	KP24.959 to KP34.335

Southern Route Corridor

C11020-02a	-	KP0.000 to KP8.316
C11020-02b	-	KP7.304 to KP17.140
C11020-02c	-	KP16.134 to KP25.966
C11020-02d	-	KP24.963 to KP34.816
C11020-02e	-	KP33.806 to KP43.135



LEGEND:

GENERAL

- Limits of Survey Area
- Kilometre post markers
- Proposed export cable route centreline - Northern option
- Kilometre post markers
- Proposed export cable route centreline - Southern option
- Limits of overlap for previous and next alignment chart
- Limits of overlap for previous and next alignment panel

BATHYMETRY

- Major contours at 5m intervals reduced to LAT
- Minor contours at 1m intervals reduced to LAT

Shaded relief bathymetry scale bar — Depth in metres reduced to LAT: -2 0 5 10 15 20 25 30 35 40 45 50 55 60 65 70

SEABED FEATURES

- Limit of side scan
- Seabed feature boundary
- Fine SAND
- Medium SAND
- Coarse SAND
- Gravelly SAND
- Sandy GRAVEL
- ROCK with a veneer of sediment
- ROCK
- Glacial gravel ridge crests
- S123 Sonar target, with identifier
- S234 Linear sonar target, with identifier
- M12 Magnetic anomaly, with identifier
- 12300 Admiralty wreck, with identifier
- IF4 Grab sample, with identifier and description
- Megaripples (NW-SE Along Crest Orientation; 5-12m Wavelength; <0.5m Height)

ISOPACHYTE - TOTAL SEDIMENT THICKNESS TO BASE OF FORTH FORMATION

- Major contours at 5m intervals of total sediment thickness above base of Forth Formation
- Minor contours at 1m intervals of total sediment thickness above base of Forth Formation

ISOPACHYTE - TOTAL SEDIMENT THICKNESS TO TOP OF BEDROCK or WEE BANKIE FORMATION

- Major contours at 5m intervals of total sediment thickness above Bedrock or Wee Bankie Formation
- Minor contours at 1m intervals of total sediment thickness above Bedrock or Wee Bankie Formation (dashed lines indicate contours below 20m)

GEOLOGICAL PROFILE

- Seabed
- Internal bedding
- Discontinuity/strong reflector
- Base of Forth Formation
- Rockhead
- Fold plane
- Gas blanking

GENERAL NOTES:

1. Survey conducted by Osiris Projects aboard MV 'Freja' and SV 'Chartwell' during the period 22nd June to 5th July 2011, with MV 'Freja' surveying the inshore and SV 'Chartwell' the offshore section.
2. A seismic velocity of 1650m/s (to base of Holocene) and 1800m/s (to base of Pleistocene) was used for all sub-bottom interpretation.

GEODETIC NOTES:

Projection : UTM, Zone 30
Latitude of Origin : 0° North
Longitude of Origin : 3° West
False Easting : 500000 metres
False Northing : 0 metres
Scale Factor : 0.9996
Ellipsoid : WGS '84
Geodetic Datum : WGS '84

VERTICAL DATUM:

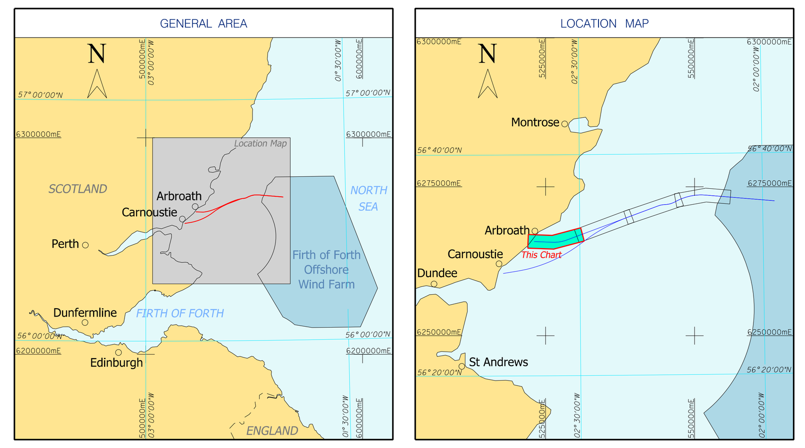
All depths are in metres reduced to Lowest Astronomical Tide (LAT) at site, using VORF geoid separation model derived from the UKHO model.
Please refer to the operations report (Volume 1), section 2.4.2 (Vertical control) for further information.

Location	WGS84 to OD(N)	OD(N) to CD (NP201-11)	CD to LAT	OD(N) to LAT	Geoid - Seperation to LAT	From VORF Model
Arbroath	50.69m	-2.80m	unknown	-2.80m	47.89m	47.80m
Aberdeen	49.74m	-2.25m	0.01m	-2.26m	47.48m	47.47m
Meeting point of proposed routes	N/A	N/A	0.00m	N/A	VORF	47.37m
Offshore extent of cable route	N/A	N/A	0.00m	N/A	VORF	46.85m

HORIZONTAL SCALE:

Scale 1:10,000 (200 0 200 400 600 800 1000 metres)

GENERAL AREA — LOCATION MAP



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Tel : +44 (0)141 224 7083
Website : www.seagreenwindenergy.com

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Osiris Projects — Seabed Mapping & Coastal Survey
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Croft Business Park
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United Kingdom
Tel : +44 (0)151 3281120
Fax : +44 (0)151 3431057
email : enquiries@osirisprojects.co.uk
website : www.osirisprojects.co.uk

CONTRACT TITLE:

FIRTH OF FORTH OFFSHORE WIND FARM EXPORT CABLE GEOPHYSICAL SURVEY

CHART TITLE:

ALIGNMENT CHART - NORTHERN OPTION KP 0.000 to KP 8.340

REVISION:	DATE:	REVISION / DESCRIPTION:	DRAWN:	CHECKED:	APPROVED:
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3					
2					
1					
0	23/08/2011	Draft	HS	HF	JW

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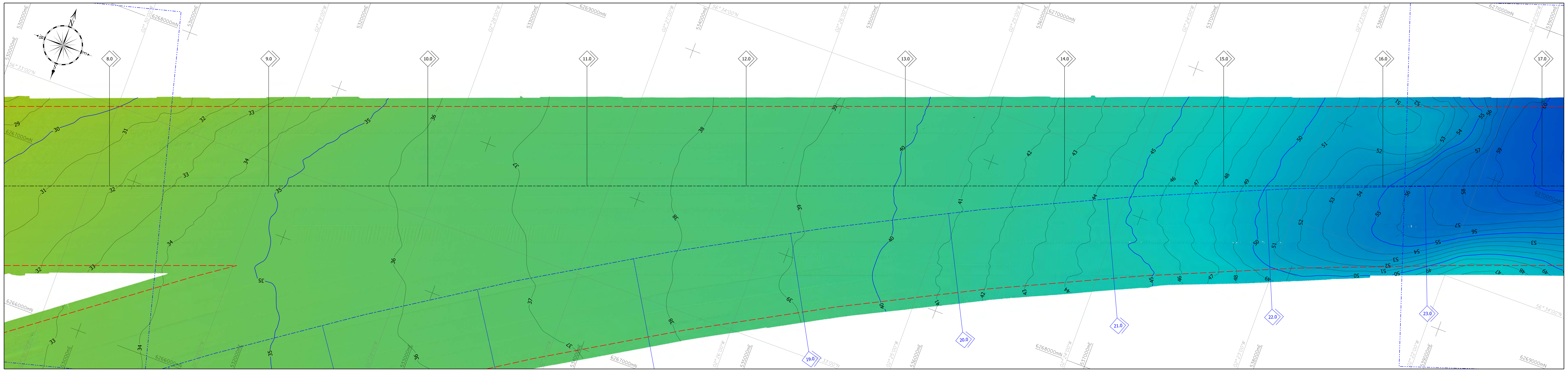
1:10,000	C11020-01a	1 of 9	0

VERTICAL SCALE: 1:500

Original Plot Size A0

BATHYMETRY



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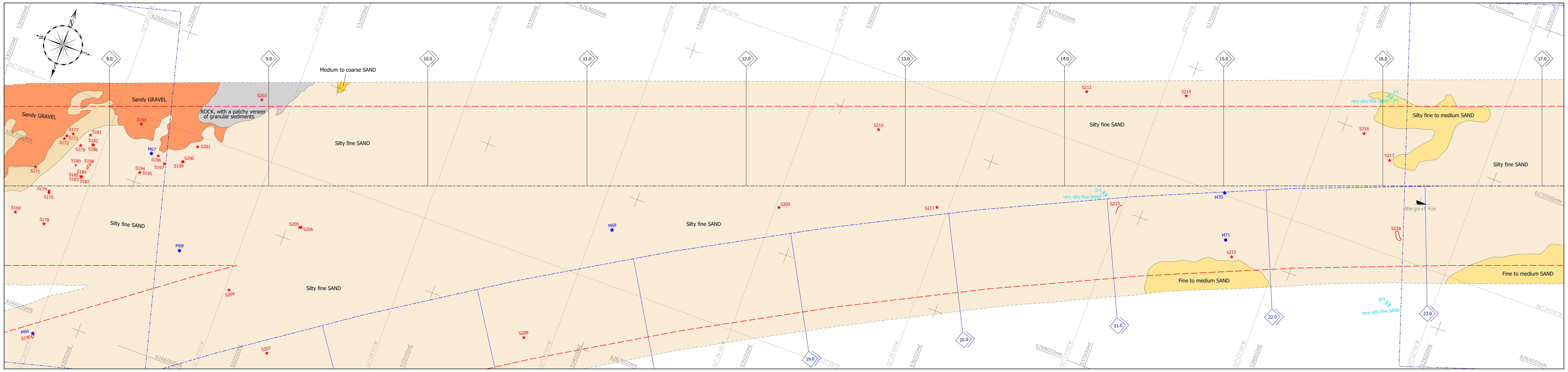
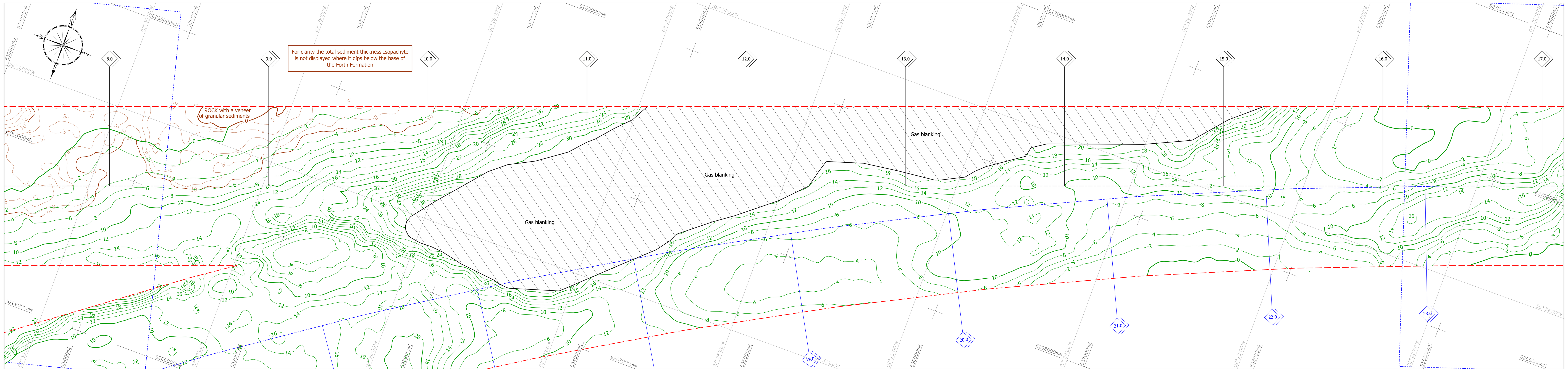
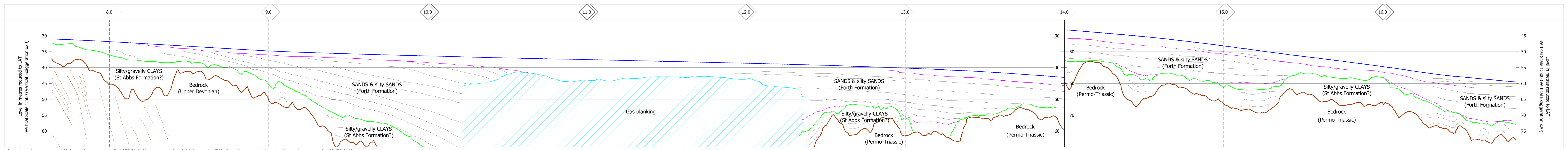


ISOPACHYTE



GEOLOGICAL PROFILE



LEGEND:

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- Internal bedding
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- Base of Forth Formation
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- Fold plane
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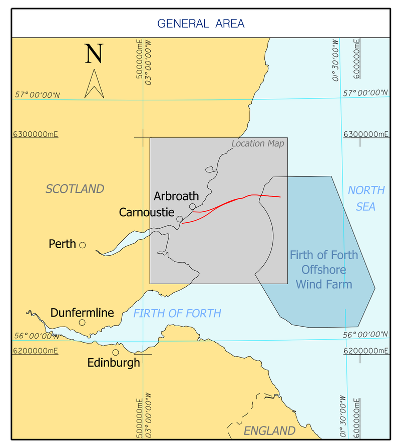
HORIZONTAL SCALE:

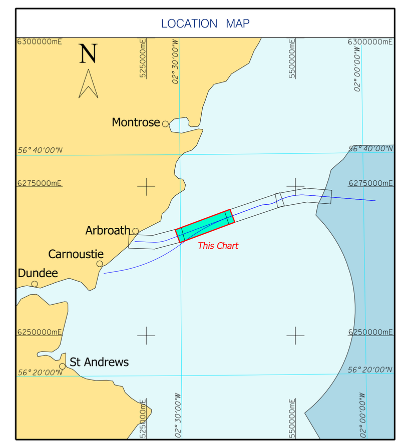
Scale 1:10,000

200 0 200 400 600 800 1000 metres

GENERAL AREA



LOCATION MAP



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Website : www.seagreenwindenergy.com

CONTRACTOR:

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United Kingdom
Tel : +44 (0)151 3281120
Fax : +44 (0)151 3431057
email : enquiries@osirisprojects.co.uk
website : www.osirisprojects.co.uk

CONTRACT TITLE:

FIRTH OF FORTH OFFSHORE WIND FARM EXPORT CABLE GEOPHYSICAL SURVEY

CHART TITLE:

ALIGNMENT CHART - NORTHERN OPTION KP 7.338 to KP 17.138

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CHART: 2 of 9
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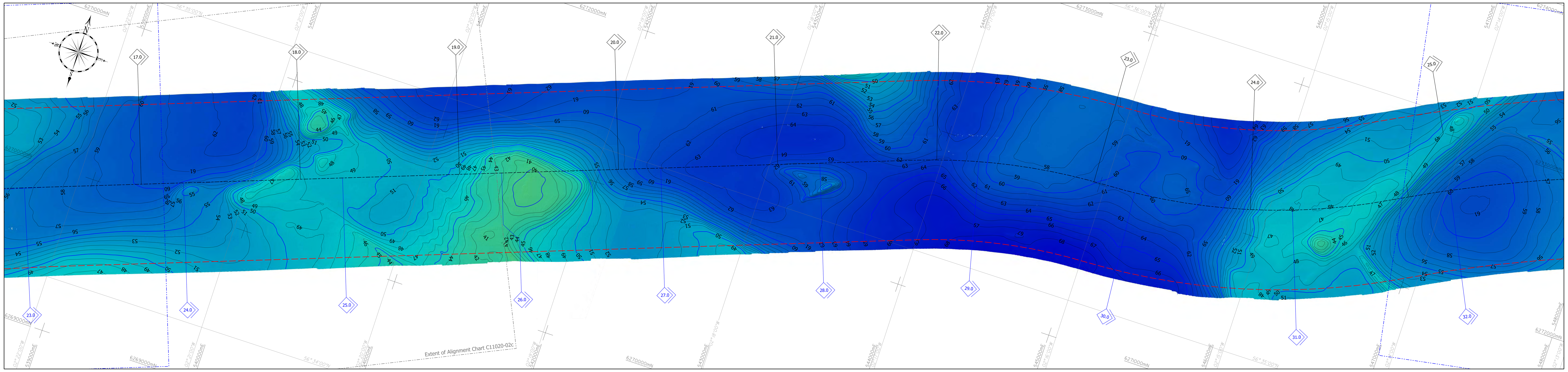

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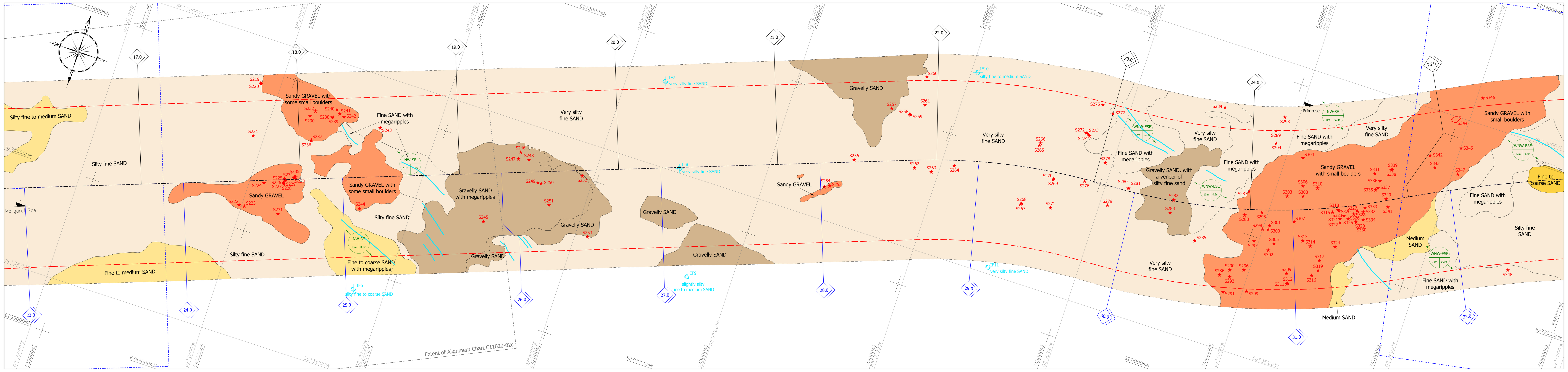

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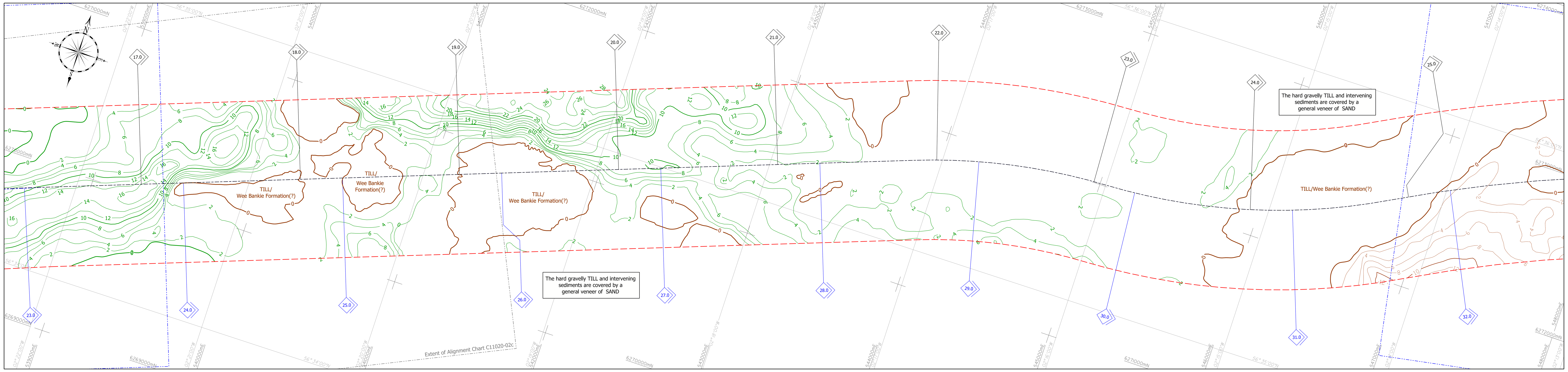
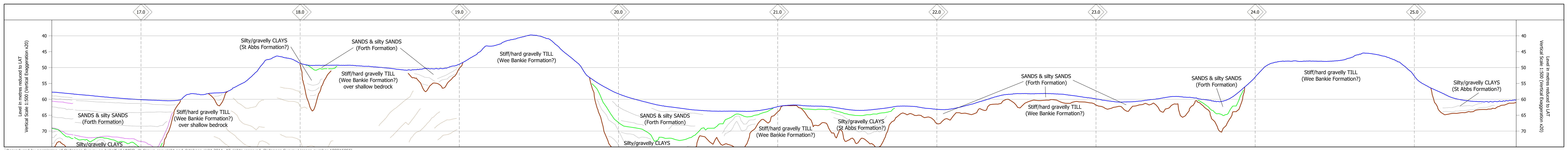


GEOLOGICAL PROFILE



LEGEND:

GENERAL

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- Kilometre post markers
- Proposed export cable route centreline - Southern option
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- Limits of overlap for previous and next alignment panel

BATHYMETRY

- 5 — Major contours at 5m intervals reduced to LAT
- 1 — Minor contours at 1m intervals reduced to LAT

Shaded relief bathymetry scale bar — Depth in metres reduced to LAT: -2 0 5 10 15 20 25 30 35 40 45 50 55 60 65 70

SEABED FEATURES

- Limit of side scan
- Seabed feature boundary
- Fine SAND
- Medium SAND
- Coarse SAND
- Gravelly SAND
- Sandy GRAVEL
- ROCK with a veneer of sediment
- ROCK
- Glacial gravel ridge crests
- S123 Sonar target, with identifier
- S234 Linear sonar target, with identifier
- M12 Magnetic anomaly, with identifier
- 12300 Admiralty wreck, with identifier
- IF4 Grab sample, with identifier and description
- Megaripples (Along Crest Orientation: NW-SE; Wavelength: 5-12m; Height: <0.5m)

ISOPACHYTE - TOTAL SEDIMENT THICKNESS TO BASE OF FORTH FORMATION

- 5 — Major contours at 5m intervals of total sediment thickness above base of Forth Formation
- 1 — Minor contours at 1m intervals of total sediment thickness above base of Forth Formation

ISOPACHYTE - TOTAL SEDIMENT THICKNESS TO TOP OF BEDROCK or WEE BANKIE FORMATION

- 5 — Major contours at 5m intervals of total sediment thickness above Bedrock or Wee Bankie Formation
- 1 — Minor contours at 1m intervals of total sediment thickness above Bedrock or Wee Bankie Formation (dashed lines indicate contours below 20m)

GEOLOGICAL PROFILE

- Seabed
- Internal bedding
- Discontinuity/strong reflector
- Base of Forth Formation
- Rockhead
- Fold plane
- Gas blanking

GENERAL NOTES:

1. Survey conducted by Osiris Projects aboard MV 'Freja' and SV 'Chartwell' during the period 22nd June to 5th July 2011, with MV 'Freja' surveying the inshore and SV 'Chartwell' the offshore section.
2. A seismic velocity of 1650m/s (to base of Holocene) and 1800m/s (to base of Pleistocene) was used for all sub-bottom interpretation.

GEODETIC NOTES:

Projection	: UTM, Zone 30
Latitude of Origin	: 0° North
Longitude of Origin	: 3° West
False Easting	: 500000 metres
False Northing	: 0 metres
Scale Factor	: 0.9996
Ellipsoid	: WGS '84
Geodetic Datum	: WGS '84

VERTICAL DATUM:

All depths are in metres reduced to Lowest Astronomical Tide (LAT) at site, using VORF geoid separation model derived from the UKHO model.
Please refer to the operations report (Volume 1), section 2.4.2 (Vertical control) for further information.

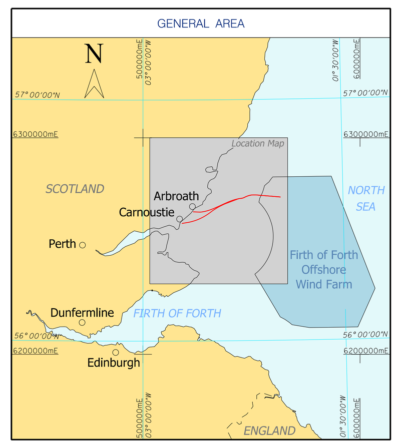
Location	WGS84 to OD(N)	OD(N) to CD (NP201-11)	CD to LAT	OD(N) to LAT	Geoid - Seperation to LAT	From VORF Model
Arbroath	50.69m	-2.80m	unknown	-2.80m	47.89m	47.80m
Aberdeen	49.74m	-2.25m	0.01m	-2.26m	47.48m	47.47m
Meeting point of proposed routes	N/A	N/A	0.00m	N/A	VORF	47.37m
Offshore extent of cable route	N/A	N/A	0.00m	N/A	VORF	46.85m

HORIZONTAL SCALE:

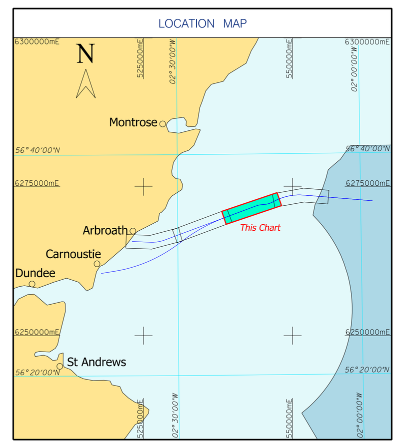
Scale 1:10,000

200 0 200 400 600 800 1000
metres

GENERAL AREA



LOCATION MAP



CLIENT:

Seagreen Wind Energy Limited
55 Vastern Road
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RG1 8BU
Tel : +44 (0)141 224 7083
Website : www.seagreenwindenergy.com

CONTRACTOR:

OSIRIS PROJECTS — SEABED MAPPING & COASTAL SURVEY
Maritime House
4 Brunel Road
Croft Business Park
Bromborough, Wirral
CH62 3NY
United Kingdom
Tel : +44 (0)151 3281120
Fax : +44 (0)151 3431057
email : enquiries@osirisprojects.co.uk
website : www.osirisprojects.co.uk

CONTRACT TITLE:

FIRTH OF FORTH OFFSHORE WIND FARM EXPORT CABLE GEOPHYSICAL SURVEY

CHART TITLE:

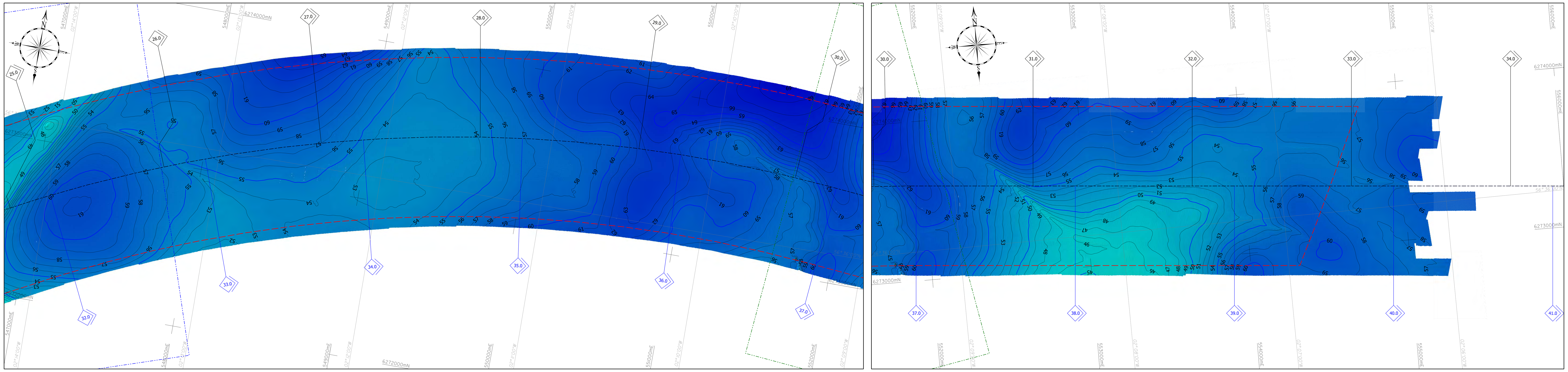
ALIGNMENT CHART - NORTHERN OPTION KP 16.137 to KP 25.983

REVISION:	DATE:	REVISION / DESCRIPTION:	DRAWN:	CHECKED:	APPROVED:
4					
3					
2					
1					
0	23/08/2011	Draft	HS	HF	JW

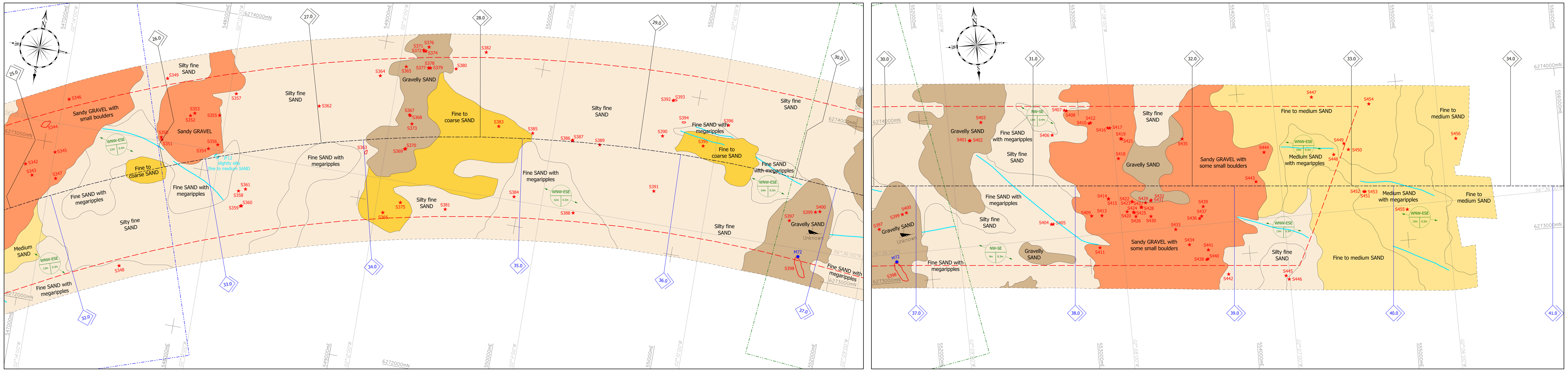
HORIZONTAL SCALE: 1:10,000	CHART NUMBER: C11020-01c	CHART: 3 of 9	REVISION: 0
VERTICAL SCALE: 1:500			

Original Plot Size A0

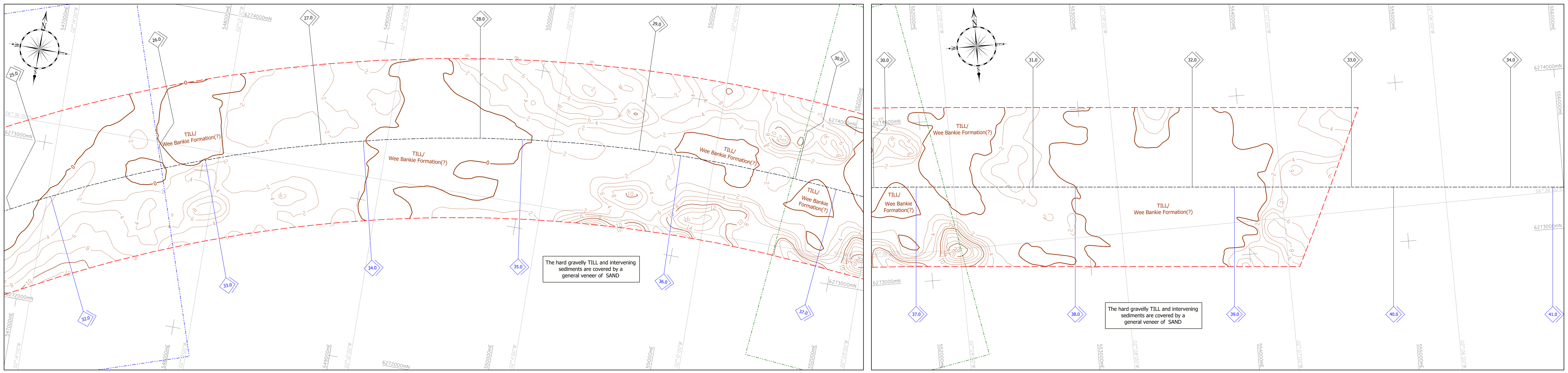
BATHYMETRY



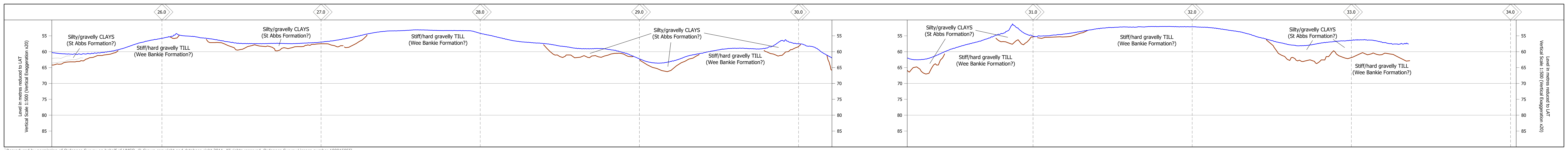
SEABED FEATURES



ISOPACHYTE



GEOLOGICAL PROFILE



LEGEND:

GENERAL

- Limits of Survey Area
- Kilometre post markers
- Proposed export cable route centreline - Northern option
- Kilometre post markers
- Proposed export cable route centreline - Southern option
- Limits of overlap for previous and next alignment chart
- Limits of overlap for previous and next alignment panel

BATHYMETRY

- Major contours at 5m intervals reduced to LAT
- Minor contours at 1m intervals reduced to LAT

Shaded relief bathymetry scale bar — Depth in metres reduced to LAT: -2 0 5 10 15 20 25 30 35 40 45 50 55 60 65 70

SEABED FEATURES

- Limit of side scan
- Seabed feature boundary
- Fine SAND
- Medium SAND
- Coarse SAND
- Gravelly SAND
- Sandy GRAVEL
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- ROCK
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- S123 Sonar target, with identifier
- S234 Linear sonar target, with identifier
- M12 Magnetic anomaly, with identifier
- 12300 Admiralty wreck, with identifier
- IF4 Grab sample, with identifier and description
- Megaripples (Along Crest Orientation; Height; Wavelength)

ISOPACHYTE - TOTAL SEDIMENT THICKNESS TO BASE OF FORTH FORMATION

- Major contours at 5m intervals of total sediment thickness above base of Forth Formation
- Minor contours at 1m intervals of total sediment thickness above base of Forth Formation

ISOPACHYTE - TOTAL SEDIMENT THICKNESS TO TOP OF BEDROCK or WEE BANKIE FORMATION

- Major contours at 5m intervals of total sediment thickness above Bedrock or Wee Bankie Formation
- Minor contours at 1m intervals of total sediment thickness above Bedrock or Wee Bankie Formation (dashed lines indicate contours below 20m)

GEOLOGICAL PROFILE

- Seabed
- Internal bedding
- Discontinuity/strong reflector
- Base of Forth Formation
- Rockhead
- Fold plane
- Gas blanking

GENERAL NOTES:

1. Survey conducted by Osiris Projects aboard MV 'Freja' and SV 'Chartwell' during the period 22nd June to 5th July 2011, with MV 'Freja' surveying the inshore and SV 'Chartwell' the offshore section.
2. A seismic velocity of 1650m/s (to base of Holocene) and 1800m/s (to base of Pleistocene) was used for all sub-bottom interpretation.

GEODETIC NOTES:

Projection	: UTM, Zone 30
Latitude of Origin	: 0° North
Longitude of Origin	: 3° West
False Easting	: 500000 metres
False Northing	: 0 metres
Scale Factor	: 0.9996
Ellipsoid	: WGS '84
Geodetic Datum	: WGS '84

VERTICAL DATUM:

All depths are in metres reduced to Lowest Astronomical Tide (LAT) at site, using VORF geoid separation model derived from the UKHO model.
Please refer to the operations report (Volume 1), section 2.4.2 (Vertical control) for further information.

Location	WGS84 to OD(N)	OD(N) to CD (NP201-11)	CD to LAT	OD(N) to LAT	Geoid - Seperation to LAT	From VORF Model
Arbroath	50.69m	-2.80m	unknown	-2.80m	47.89m	47.80m
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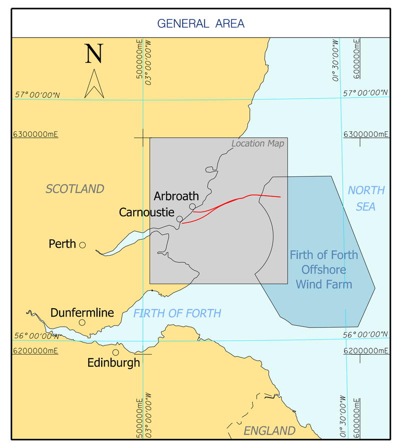
Meeting point of proposed routes	N/A	N/A	0.00m	N/A	VORF	47.37m
Offshore extent of cable route	N/A	N/A	0.00m	N/A	VORF	46.85m

HORIZONTAL SCALE:

Scale 1:10,000 (200 0 200 400 600 800 1000 metres)

GENERAL AREA



LOCATION MAP

CLIENT:

Seagreen Wind Energy Limited
55 Vastern Road
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Tel : +44 (0)141 224 7083
Website : www.seagreenwindenergy.com

CONTRACTOR:

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United Kingdom
Tel : +44 (0)151 3281120
Fax : +44 (0)151 3431057
email : enquiries@osirisprojects.co.uk
website : www.osirisprojects.co.uk

CONTRACT TITLE:

FIRTH OF FORTH OFFSHORE WIND FARM EXPORT CABLE GEOPHYSICAL SURVEY

CHART TITLE:

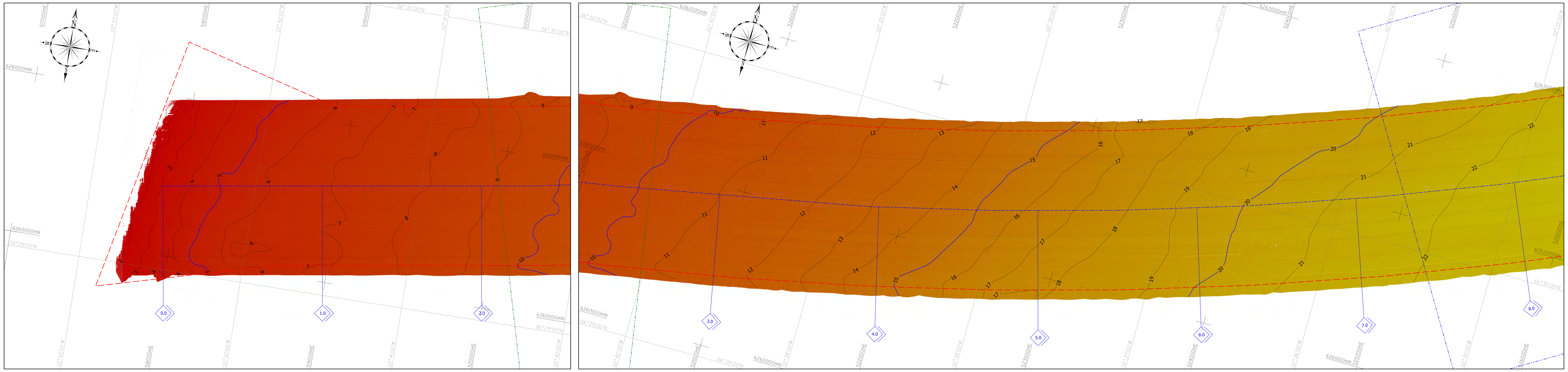
ALIGNMENT CHART - NORTHERN OPTION KP 24.959 to KP 34.335

REVISION:	DATE:	REVISION / DESCRIPTION:	DRAWN:	CHECKED:	APPROVED:
4					
3					
2					
1					
0	23/08/2011	Draft	HS	HF	JW

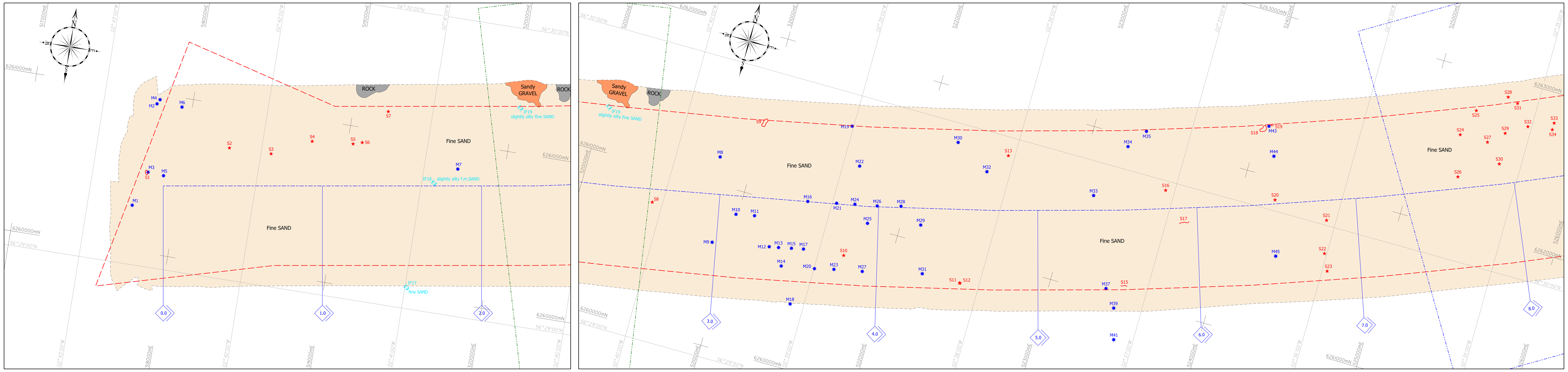
HORIZONTAL SCALE:	1:10,000	CHART NUMBER:	CHART:	REVISION:
VERTICAL SCALE:	1:500	C11020-01d	4 of 9	0

Original Plot Size A0

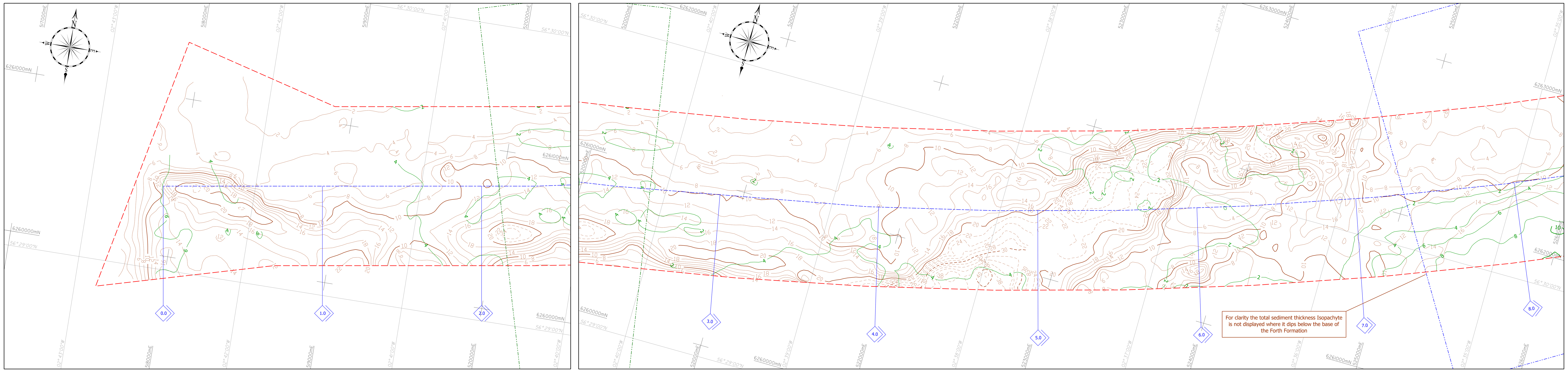
BATHYMETRY



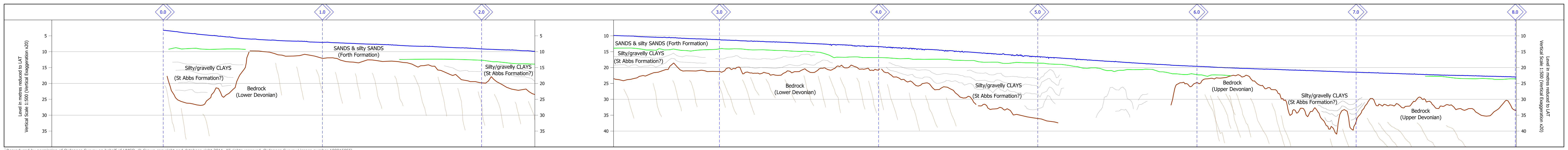
SEABED FEATURES



ISOPACHYTE



GEOLOGICAL PROFILE



LEGEND:

GENERAL

- Limits of Survey Area
- Kilometre post markers
- Proposed export cable route centreline - Northern option
- Kilometre post markers
- Proposed export cable route centreline - Southern option
- Limits of overlap for previous and next alignment chart
- Limits of overlap for previous and next alignment panel

BATHYMETRY

- 5 — Major contours at 5m intervals reduced to LAT
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Shaded relief bathymetry scale bar — Depth in metres reduced to LAT: -2 0 5 10 15 20 25 30 35 40 45 50 55 60 65 70

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- Medium SAND
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- 12300 — Admiralty wreck, with identifier
- IF4 — Grab sample, with identifier and description
- Megaripples (NW-SE; Along Crest Orientation; 5-12m Wavelength; <0.5m Height)

ISOPACHYTE - TOTAL SEDIMENT THICKNESS TO BASE OF FORTH FORMATION

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GEOLOGICAL PROFILE

- Seabed
- Internal bedding
- Discontinuity/strong reflector
- Base of Forth Formation
- Rockhead
- Fold plane
- Gas blanking

GENERAL NOTES:

1. Survey conducted by Osiris Projects aboard MV 'Freja' and SV 'Chartwell' during the period 22nd June to 5th July 2011, with MV 'Freja' surveying the inshore and SV 'Chartwell' the offshore section.
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GEODETIC NOTES:

Projection	: UTM, Zone 30
Latitude of Origin	: 0° North
Longitude of Origin	: 3° West
False Easting	: 500000 metres
False Northing	: 0 metres
Scale Factor	: 0.9996
Ellipsoid	: WGS '84
Geodetic Datum	: WGS '84

VERTICAL DATUM:

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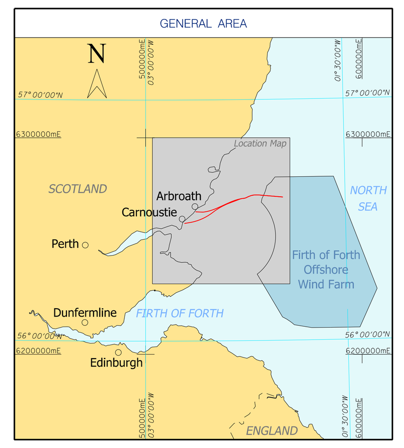
Meeting point of proposed routes	N/A	N/A	0.00m	N/A	VORF	47.37m
Offshore extent of cable route	N/A	N/A	0.00m	N/A	VORF	46.85m

HORIZONTAL SCALE:

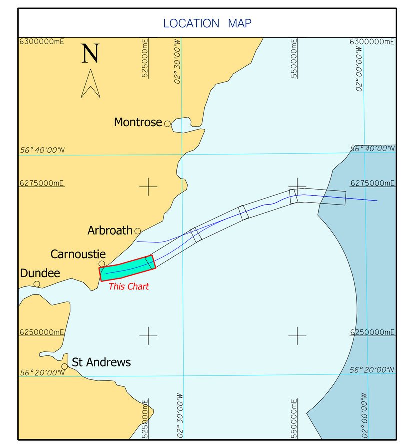
Scale 1:10,000

200 0 200 400 600 800 1000 metres

GENERAL AREA



LOCATION MAP



CLIENT:

Seagreen Wind Energy Limited
55 Vastern Road
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Berkshire
RG1 8BU
Tel : +44 (0)141 224 7083
Website : www.seagreenwindenergy.com

CONTRACTOR:

Osiris Projects — Seabed Mapping & Coastal Survey
Maritime House
4 Brunel Road
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Tel : +44 (0)151 3281120
Fax : +44 (0)151 3431057
email : enquiries@osirisprojects.co.uk
website : www.osirisprojects.co.uk

CONTRACT TITLE:

FIRTH OF FORTH OFFSHORE WIND FARM EXPORT CABLE GEOPHYSICAL SURVEY

CHART TITLE:

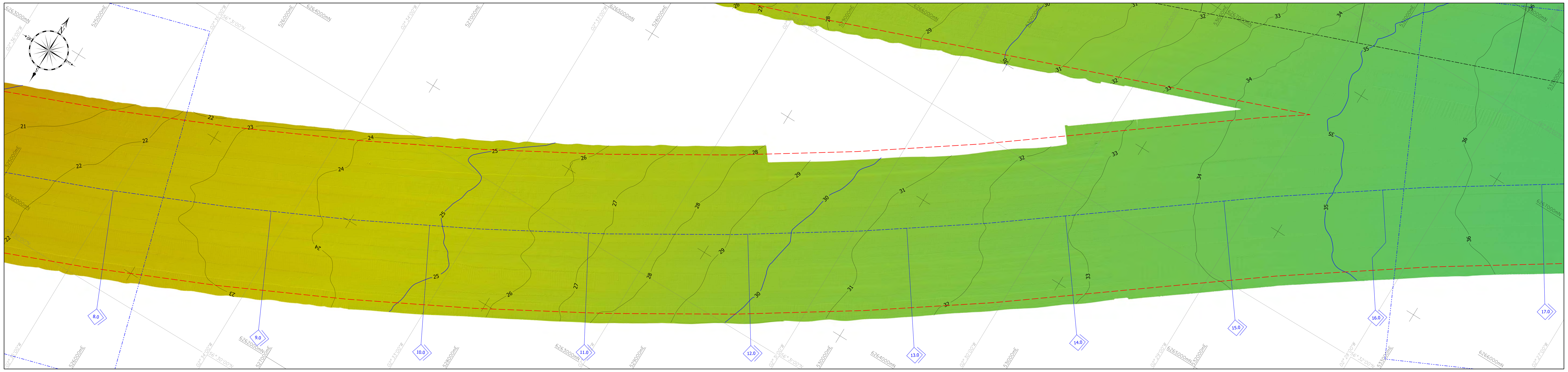
ALIGNMENT CHART - SOUTHERN OPTION KP 0.00 to KP 8.316

REVISION:	DATE:	REVISION / DESCRIPTION:	DRAWN:	CHECKED:	APPROVED:
4					
3					
2					
1					
0	23/08/2011	Draft	HS	HF	JW

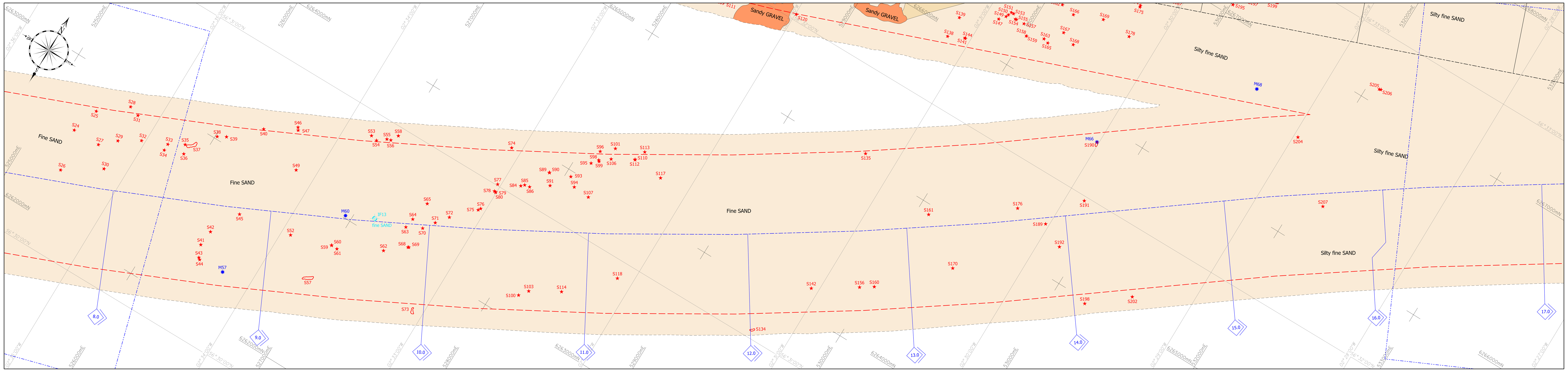
HORIZONTAL SCALE:	VERTICAL SCALE:	CHART NUMBER:	CHART:	REVISION:
1:10,000	1:500	C11020-02a	5 of 9	0

Original Plot Size A0

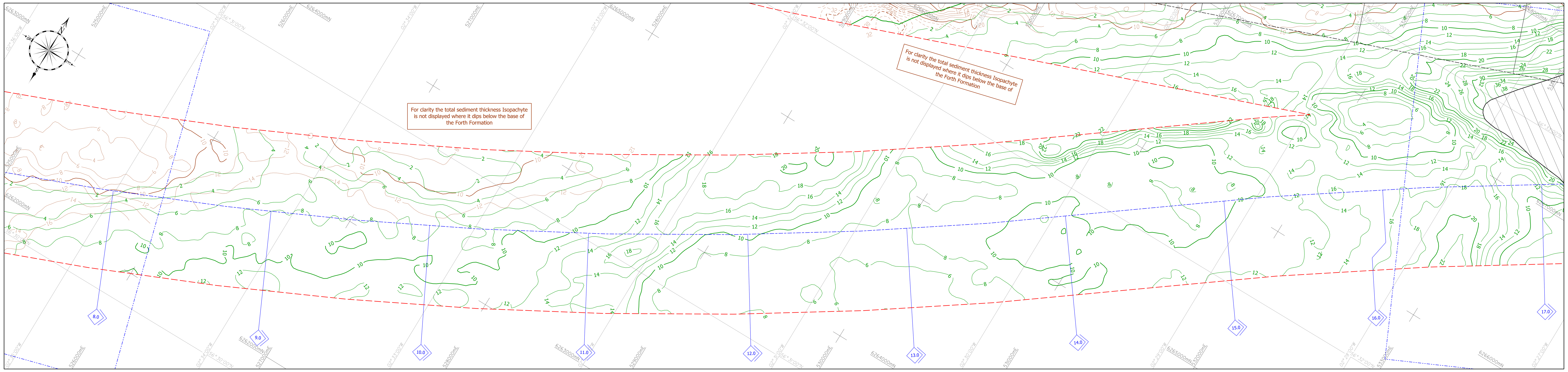
BATHYMETRY



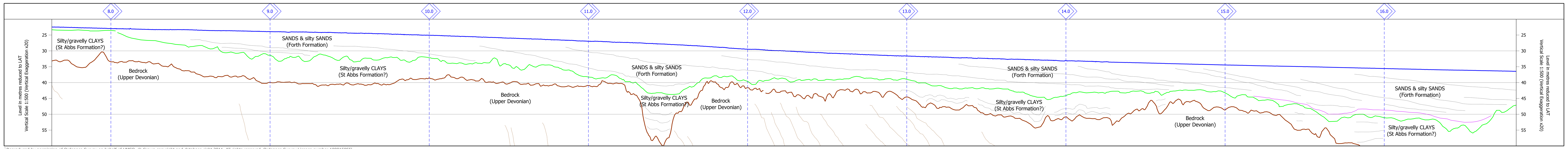
SEABED FEATURES



ISOPACHYTE



GEOLOGICAL PROFILE



LEGEND:

GENERAL

- Limits of Survey Area
- Kilometre post markers
- Proposed export cable route centreline - Northern option
- Kilometre post markers
- Proposed export cable route centreline - Southern option
- Limits of overlap for previous and next alignment chart
- Limits of overlap for previous and next alignment panel

BATHYMETRY

- 5 Major contours at 5m intervals reduced to LAT
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Shaded relief bathymetry scale bar — Depth in metres reduced to LAT: -2 0 5 10 15 20 25 30 35 40 45 50 55 60 65 70

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GEOLOGICAL PROFILE

- Seabed
- Internal bedding
- Discontinuity/strong reflector
- Base of Forth Formation
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- Fold plane
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GENERAL NOTES:

1. Survey conducted by Osiris Projects aboard MV 'Freja' and SV 'Chartwell' during the period 22nd June to 5th July 2011, with MV 'Freja' surveying the inshore and SV 'Chartwell' the offshore section.
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GEODETIC NOTES:

Projection	: UTM, Zone 30
Latitude of Origin	: 0° North
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False Easting	: 500000 metres
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Scale Factor	: 0.9996
Ellipsoid	: WGS '84
Geodetic Datum	: WGS '84

VERTICAL DATUM:

All depths are in metres reduced to Lowest Astronomical Tide (LAT) at site, using VORF geoid separation model derived from the UKHO model.
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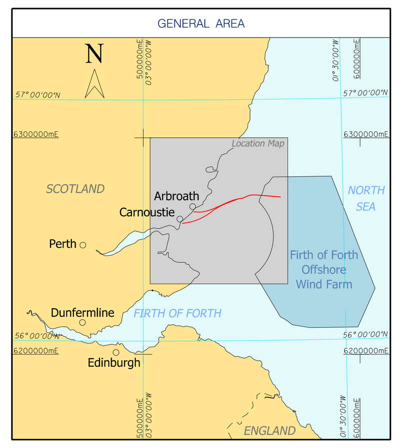
Offshore extent of cable route	N/A	N/A	0.00m	N/A	VORF	46.85m

HORIZONTAL SCALE:

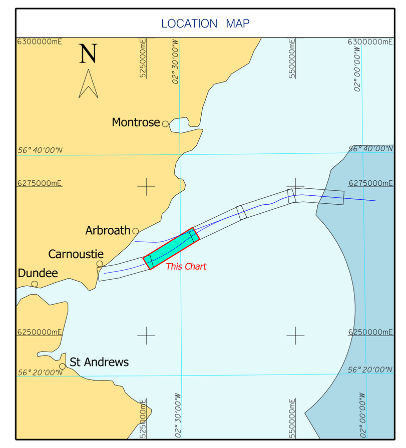
Scale 1:10,000

200 0 200 400 600 800 1000 metres

GENERAL AREA



LOCATION MAP



CLIENT:

Seagreen Wind Energy Limited
55 Vastern Road
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Berkshire
RG1 8BU
Tel : +44 (0)141 224 7083
Website : www.seagreenwindenergy.com

CONTRACTOR:

OSIRIS PROJECTS
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Maritime House
4 Brunel Road
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Tel : +44 (0)151 3281120
Fax : +44 (0)151 3431057
email : enquiries@osirisprojects.co.uk
website : www.osirisprojects.co.uk

CONTRACT TITLE:

FIRTH OF FORTH OFFSHORE WIND FARM EXPORT CABLE GEOPHYSICAL SURVEY

CHART TITLE:

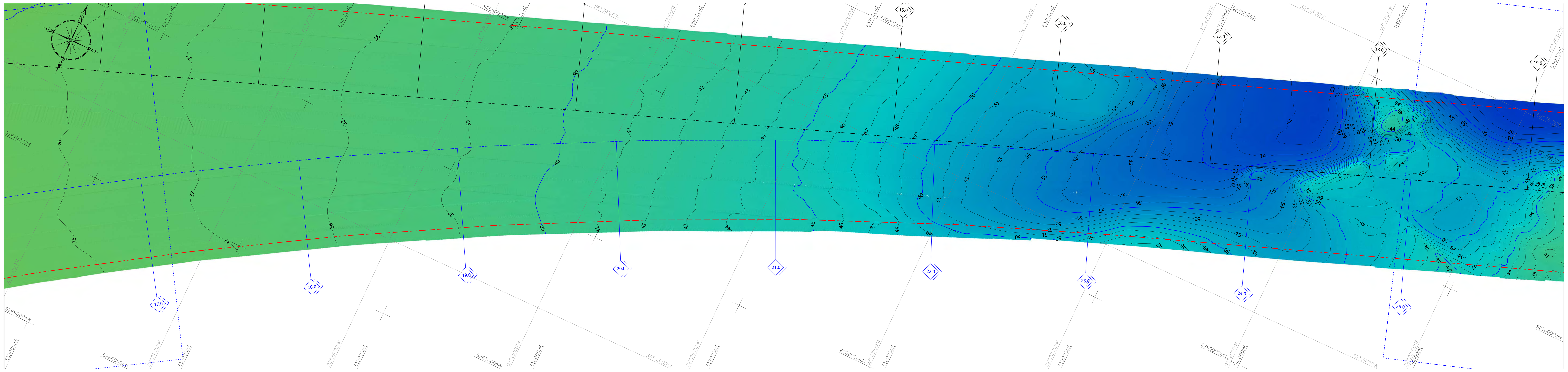
ALIGNMENT CHART - SOUTHERN OPTION KP 7.304 to KP 17.140

REVISION:	DATE:	REVISION / DESCRIPTION:	DRAWN:	CHECKED:	APPROVED:
4					
3					
2					
1					
0	23/08/2011	Draft	HS	HF	JW

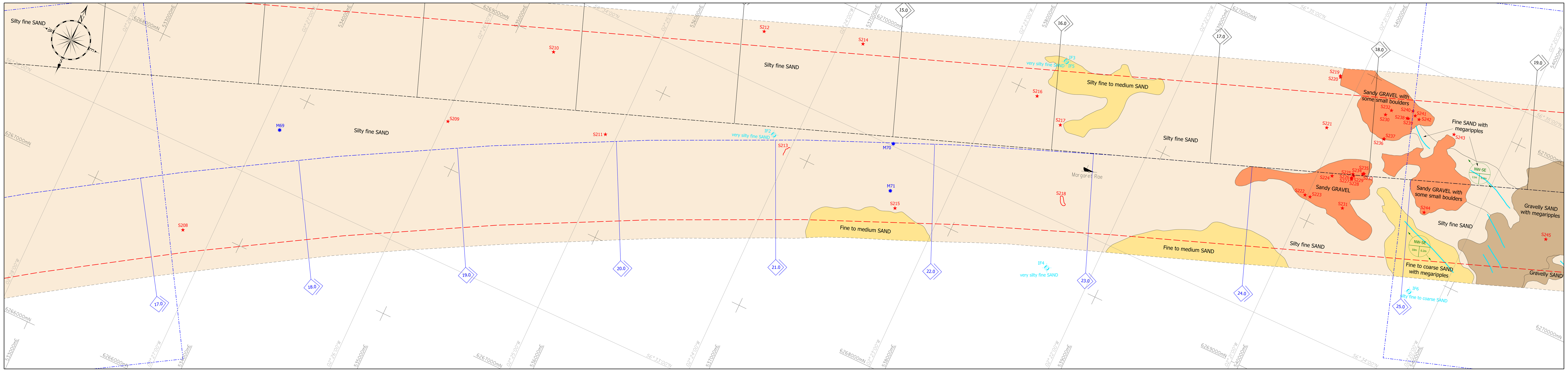
HORIZONTAL SCALE: 1:10,000	CHART NUMBER: C11020-02b	CHART: 6 of 9	REVISION: 0
VERTICAL SCALE: 1:500			

Original Plot Size A0

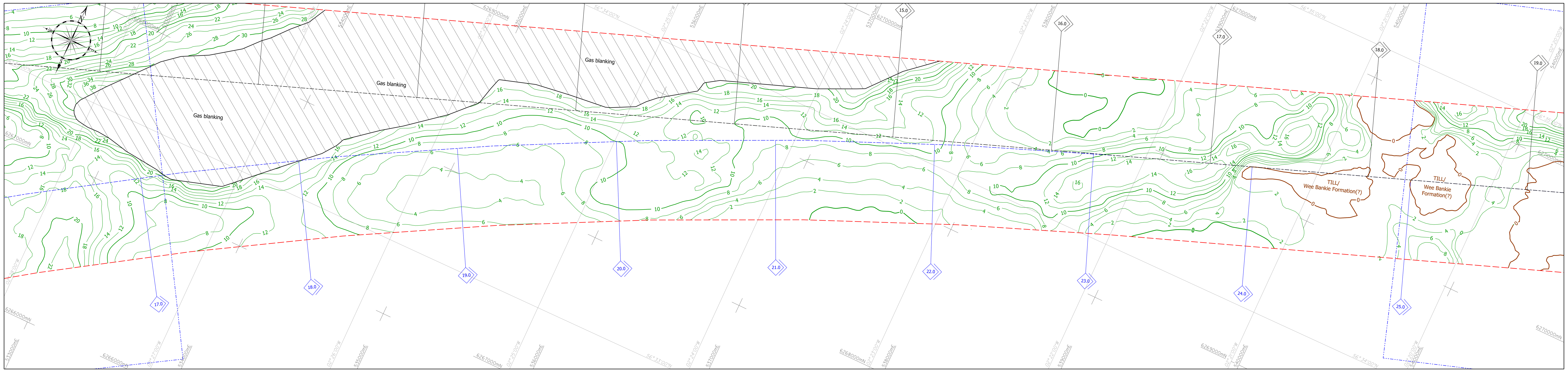
BATHYMETRY



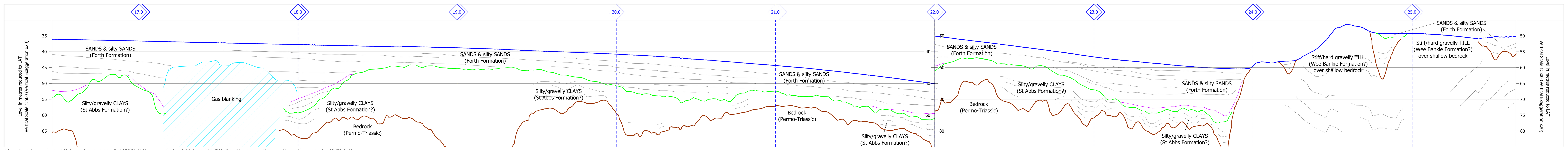
SEABED FEATURES



ISOPACHYTE



GEOLOGICAL PROFILE



LEGEND:

GENERAL
- Limits of Survey Area
- Kilometre post markers
- Proposed export cable route centreline - Northern option
- Kilometre post markers
- Proposed export cable route centreline - Southern option
- Limits of overlap for previous and next alignment chart
- Limits of overlap for previous and next alignment panel

BATHYMETRY
- Major contours at 5m intervals reduced to LAT
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- Shaded relief bathymetry scale bar — Depth in metres reduced to LAT (-2 0 5 10 15 20 25 30 35 40 45 50 55 60 65 70)

SEABED FEATURES
- Limit of side scan
- Seabed feature boundary
- Fine SAND
- Medium SAND
- Coarse SAND
- Gravelly SAND
- Sandy GRAVEL
- ROCK with a veneer of sediment
- ROCK
- Glacial gravel ridge crests
- Sonar target, with identifier
- Linear sonar target, with identifier
- Magnetic anomaly, with identifier
- Admiralty wreck, with identifier
- Grab sample, with identifier and description
- Megaripples

ISOPACHYTE - TOTAL SEDIMENT THICKNESS TO BASE OF FORTH FORMATION
- Major contours at 5m intervals of total sediment thickness above base of Forth Formation
- Minor contours at 1m intervals of total sediment thickness above base of Forth Formation

ISOPACHYTE - TOTAL SEDIMENT THICKNESS TO TOP OF BEDROCK or WEE BANKIE FORMATION
- Major contours at 5m intervals of total sediment thickness above Bedrock or Wee Bankie Formation
- Minor contours at 1m intervals of total sediment thickness above Bedrock or Wee Bankie Formation (dashed lines indicate contours below 20m)

GEOLOGICAL PROFILE
- Seabed
- Internal bedding
- Discontinuity/strong reflector
- Base of Forth Formation
- Rockhead
- Fold plane
- Gas blanking

GENERAL NOTES:

1. Survey conducted by Osiris Projects aboard MV 'Freja' and SV 'Chartwell' during the period 22nd June to 5th July 2011, with MV 'Freja' surveying the inshore and SV 'Chartwell' the offshore section.

2. A seismic velocity of 1650m/s (to base of Holocene) and 1800m/s (to base of Pleistocene) was used for all sub-bottom interpretation.

GEODETIC NOTES:

Projection	: UTM, Zone 30
Latitude of Origin	: 0° North
Longitude of Origin	: 3° West
False Easting	: 500000 metres
False Northing	: 0 metres
Scale Factor	: 0.9996
Ellipsoid	: WGS '84
Geodetic Datum	: WGS '84

VERTICAL DATUM:

All depths are in metres reduced to Lowest Astronomical Tide (LAT) at site, using VORF geoid separation model derived from the UKHO model.
Please refer to the operations report (Volume 1), section 2.4.2 (Vertical control) for further information.

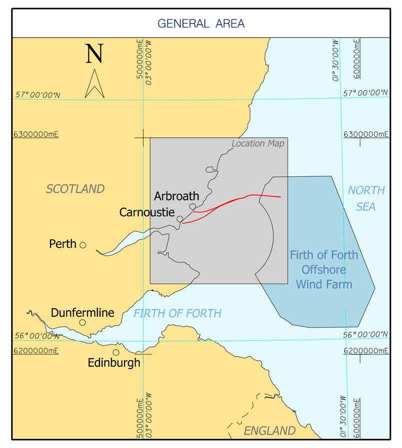
Location	WGS84 to OD(N)	OD(N) to CD (NP201-11)	CD to LAT	OD(N) to LAT	Geoid - Seperation to LAT	From VORF Model
Arbroath	50.69m	-2.80m	unknown	-2.80m	47.89m	47.80m
Aberdeen	49.74m	-2.25m	0.01m	-2.26m	47.48m	47.47m
Meeting point of proposed routes	N/A	N/A	0.00m	N/A	VORF	47.37m
Offshore extent of cable route	N/A	N/A	0.00m	N/A	VORF	46.85m

HORIZONTAL SCALE:

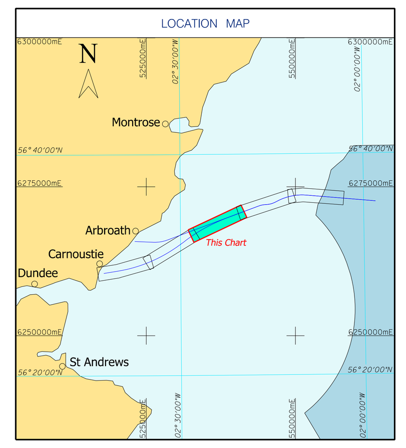
Scale 1:10,000

200 0 200 400 600 800 1000 metres

GENERAL AREA



LOCATION MAP



CLIENT:

Seagreen Wind Energy Limited
55 Vastern Road
Reading
Berkshire
RG1 8BU
Tel : +44 (0)141 224 7083
Website : www.seagreenwindenergy.com

CONTRACTOR:

OSIRIS PROJECTS
SEABED MAPPING & COASTAL SURVEY
Maritime House
4 Brunel Road
Croft Business Park
Bromborough, Wirral
CH62 3NY
United Kingdom
Tel : +44 (0)151 3281120
Fax : +44 (0)151 3431057
email : enquiries@osirisprojects.co.uk
website : www.osirisprojects.co.uk

CONTRACT TITLE:

FIRTH OF FORTH OFFSHORE WIND FARM EXPORT CABLE GEOPHYSICAL SURVEY

CHART TITLE:

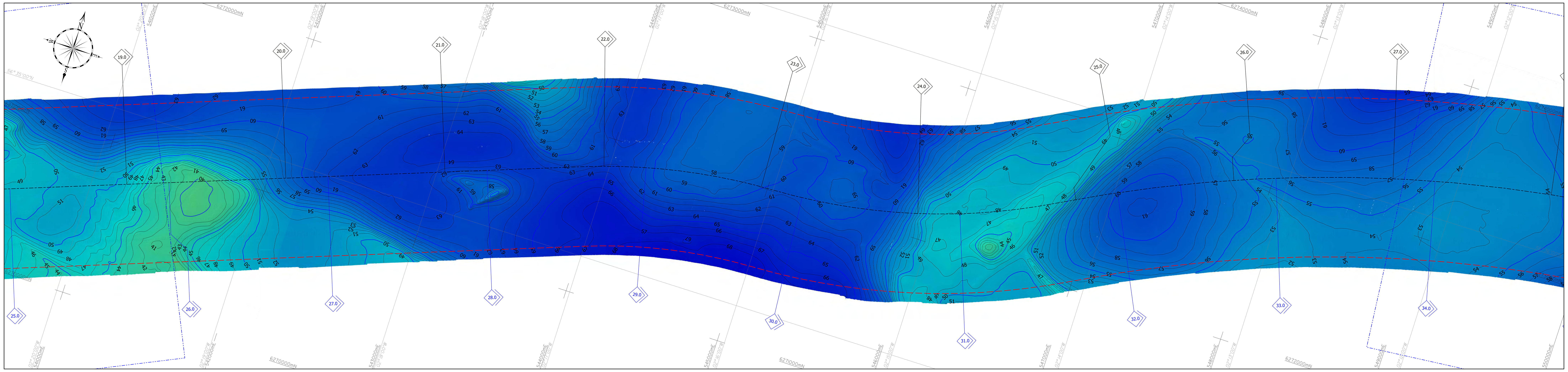
ALIGNMENT CHART - SOUTHERN OPTION KP 16.134 to KP 25.966

REVISION:	DATE:	REVISION / DESCRIPTION:	DRAWN:	CHECKED:	APPROVED:
4					
3					
2					
1					
0	23/08/2011	Draft	HS	HF	JW

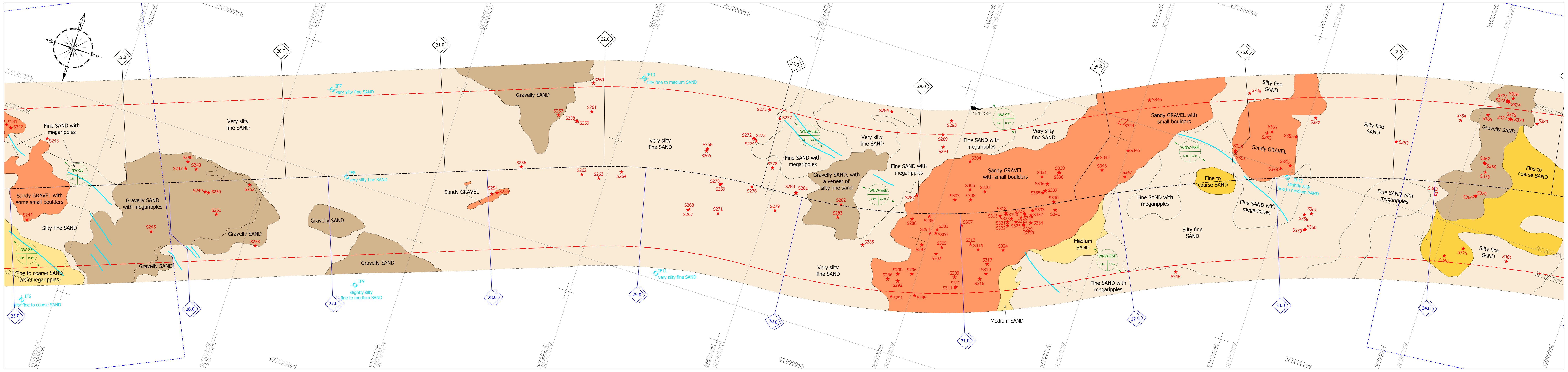
HORIZONTAL SCALE: 1:10,000	CHART NUMBER: C11020-02c	CHART: 7 of 9	REVISION: 0
VERTICAL SCALE: 1:500			

Original Plot Size A0

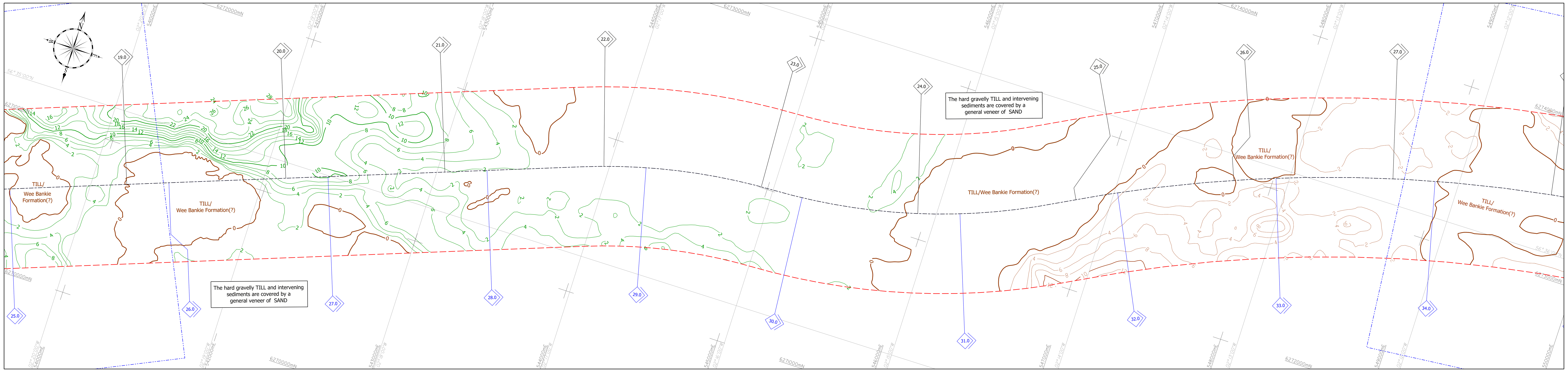
BATHYMETRY



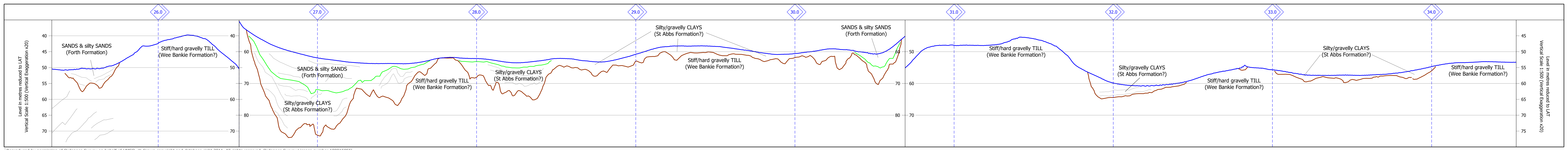
SEABED FEATURES



ISOPACHYTE



GEOLOGICAL PROFILE



LEGEND:

GENERAL

- Limits of Survey Area
- Kilometre post markers
- Proposed export cable route centreline - Northern option
- Kilometre post markers
- Proposed export cable route centreline - Southern option
- Limits of overlap for previous and next alignment chart
- Limits of overlap for previous and next alignment panel

BATHYMETRY

- 5 Major contours at 5m intervals reduced to LAT
- 1 Minor contours at 1m intervals reduced to LAT

Shaded relief bathymetry scale bar — Depth in metres reduced to LAT: -2 0 5 10 15 20 25 30 35 40 45 50 55 60 65 70

SEABED FEATURES

- Limit of side scan
- Seabed feature boundary
- Fine SAND
- Medium SAND
- Coarse SAND
- Gravelly SAND
- Sandy GRAVEL
- ROCK with a veneer of sediment
- ROCK
- Glacial gravel ridge crests
- S123 Sonar target, with identifier
- S234 Linear sonar target, with identifier
- M12 Magnetic anomaly, with identifier
- 12300 Admiralty wreck, with identifier
- IF4 Grab sample, with identifier and description
- NW-SE, 5-12m, <0.5m (Along Crest Orientation, Wavelength, Height) Megaripples

ISOPACHYTE - TOTAL SEDIMENT THICKNESS TO BASE OF FORTH FORMATION

- 5 Major contours at 5m intervals of total sediment thickness above base of Forth Formation
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- 5 Major contours at 5m intervals of total sediment thickness above Bedrock or Wee Bankie Formation
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GEOLOGICAL PROFILE

- Seabed
- Internal bedding
- Discontinuity/strong reflector
- Base of Forth Formation
- Rockhead
- Fold plane
- Gas blanking

GENERAL NOTES:

1. Survey conducted by Osiris Projects aboard MV 'Freja' and SV 'Chartwell' during the period 22nd June to 5th July 2011, with MV 'Freja' surveying the inshore and SV 'Chartwell' the offshore section.
2. A seismic velocity of 1650m/s (to base of Holocene) and 1800m/s (to base of Pleistocene) was used for all sub-bottom interpretation.

GEODETIC NOTES:

Projection	: UTM, Zone 30
Latitude of Origin	: 0° North
Longitude of Origin	: 3° West
False Easting	: 500000 metres
False Northing	: 0 metres
Scale Factor	: 0.9996
Ellipsoid	: WGS '84
Geodetic Datum	: WGS '84

VERTICAL DATUM:

All depths are in metres reduced to Lowest Astronomical Tide (LAT) at site, using VORF geoid separation model derived from the UKHO model.
Please refer to the operations report (Volume 1), section 2.4.2 (Vertical control) for further information.

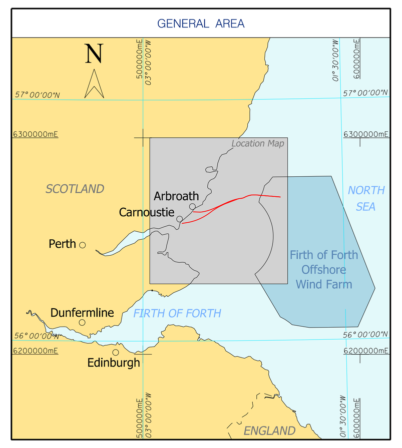
Location	WGS84 to OD(N)	OD(N) to CD (NP201-11)	CD to LAT	OD(N) to LAT	Geoid - Seperation to LAT	From VORF Model
Arbroath	50.69m	-2.80m	unknown	-2.80m	47.89m	47.80m
Aberdeen	49.74m	-2.25m	0.01m	-2.26m	47.48m	47.47m
Meeting point of proposed routes	N/A	N/A	0.00m	N/A	VORF	47.37m
Offshore extent of cable route	N/A	N/A	0.00m	N/A	VORF	46.85m

HORIZONTAL SCALE:

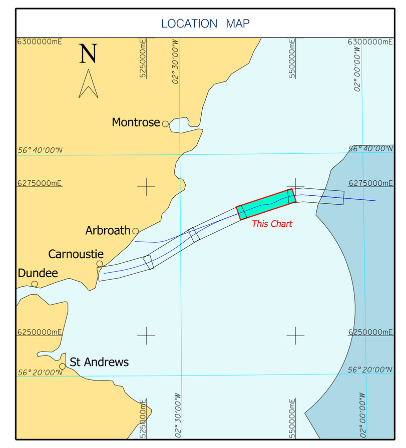
Scale 1:10,000

200 0 200 400 600 800 1000
metres

GENERAL AREA



LOCATION MAP



CLIENT:

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55 Vastern Road
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Tel : +44 (0)141 224 7083
Website : www.seagreenwindenergy.com

CONTRACTOR:

Osiris Projects — Seabed Mapping & Coastal Survey
Maritime House
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Croft Business Park
Bromborough, Wirral
CH62 3NY
United Kingdom
Tel : +44 (0)151 3281120
Fax : +44 (0)151 3431057
email : enquiries@osirisprojects.co.uk
website : www.osirisprojects.co.uk

CONTRACT TITLE:

FIRTH OF FORTH OFFSHORE WIND FARM EXPORT CABLE GEOPHYSICAL SURVEY

CHART TITLE:

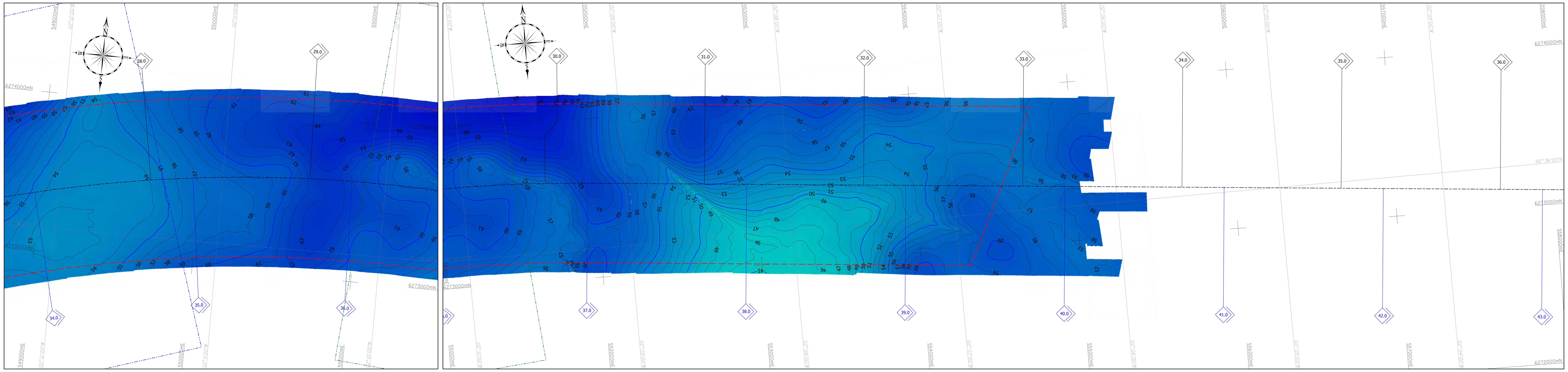
ALIGNMENT CHART - SOUTHERN OPTION KP 24.963 to KP 34.816

REVISION:	DATE:	REVISION / DESCRIPTION:	DRAWN:	CHECKED:	APPROVED:
4					
3					
2					
1					
0	23/08/2011	Draft	HS	HF	JW

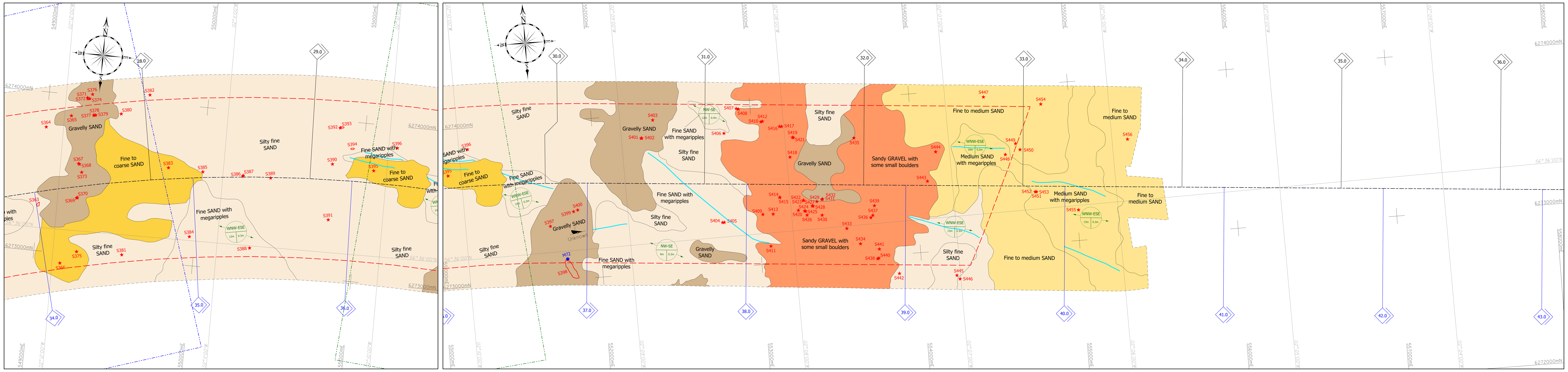
HORIZONTAL SCALE: 1:10,000	CHART NUMBER: C11020-02d	CHART: 8 of 9	REVISION: 0
VERTICAL SCALE: 1:500			

Original Plot Size A0

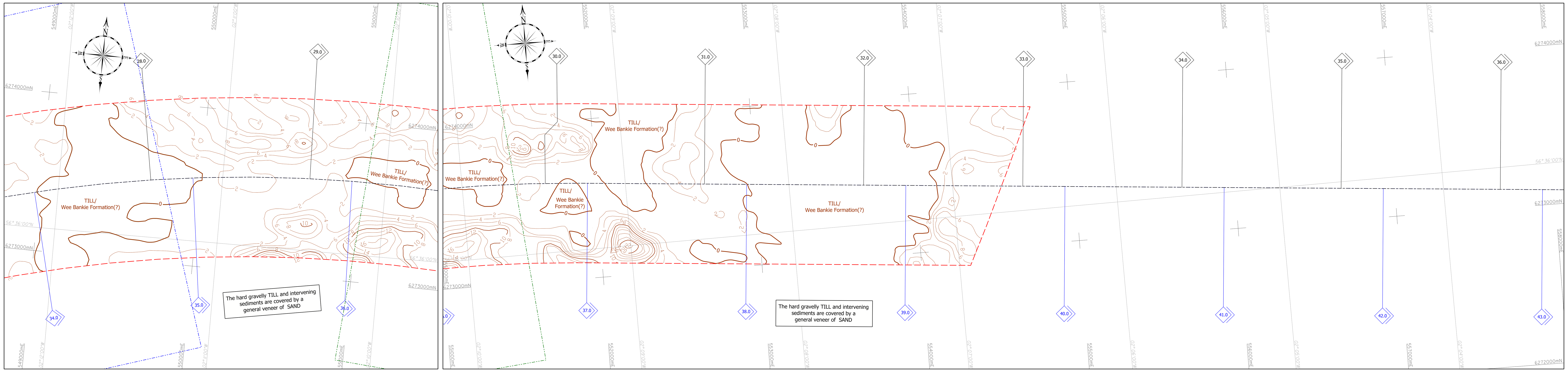
BATHYMETRY



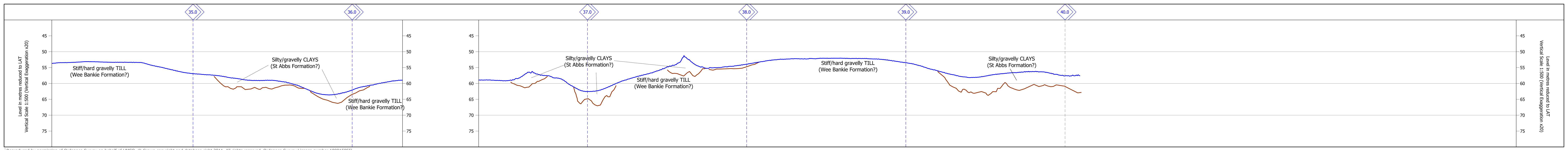
SEABED FEATURES



ISOPACHYTE



GEOLOGICAL PROFILE



LEGEND:

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Longitude of Origin : 3° West
False Easting : 500000 metres
False Northing : 0 metres
Scale Factor : 0.9996
Ellipsoid : WGS '84
Geodetic Datum : WGS '84

VERTICAL DATUM:

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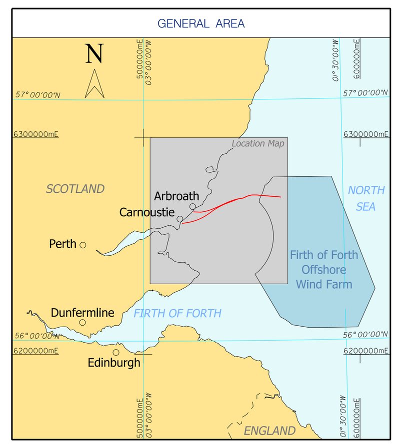
Meeting point of proposed routes	N/A	N/A	0.00m	N/A	VORF	47.37m
Offshore extent of cable route	N/A	N/A	0.00m	N/A	VORF	46.85m

HORIZONTAL SCALE:

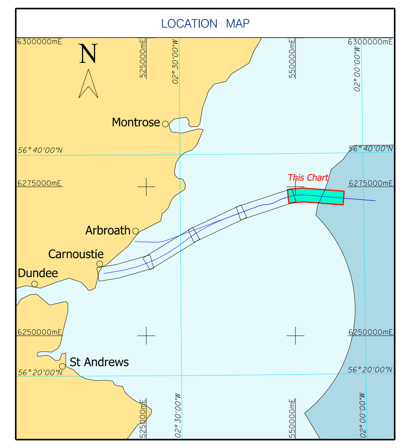
Scale 1:10,000

200 0 200 400 600 800 1000 metres

GENERAL AREA



LOCATION MAP



CLIENT:

Seagreen Wind Energy Limited
55 Vastern Road
Reading
Berkshire
RG1 8BU
Tel : +44 (0)141 224 7083
Website : www.seagreenwindenergy.com

CONTRACTOR:

Maritime House
4 Brunel Road
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Bromborough, Wirral
CH62 3NY
United Kingdom
Tel : +44 (0)151 3281120
Fax : +44 (0)151 3431057
email : enquiries@osirisprojects.co.uk
website : www.osirisprojects.co.uk

CONTRACT TITLE:

FIRTH OF FORTH OFFSHORE WIND FARM EXPORT CABLE GEOPHYSICAL SURVEY

CHART TITLE:

ALIGNMENT CHART - SOUTHERN OPTION KP 33.806 to KP 43.135

REVISION:	DATE:	REVISION / DESCRIPTION:	DRAWN:	CHECKED:	APPROVED:
4					
3					
2					
1					
0	23/08/2011	Draft	HS	HF	JW

HORIZONTAL SCALE: 1:10,000	CHART NUMBER: C11020-02e	CHART: 9 of 9	REVISION: 0
VERTICAL SCALE: 1:500			

Original Plot Size A0

APPENDIX 2

LISTINGS

Sonar Contact Listings

Magnetic Anomaly Listings

Wreck Listings

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Sonar Contact Listings

	Northern Route		Southern Route									
Tag No.	KP	Offset	KP	Offset	Easting	Northing	Latitude UTM30	Longitude UTM30	Length (m)	Width (m)	Height (m)	Description
S001			-0.109	-87.38	517778.4	6260502.3	3.267232°N	42.868625°E	14.5	6	0	Unknown feature
S002			0.416	-238.64	518271.9	6260737.0	3.270263°N	42.870228°E	nml	nmw	nmh	Small point contact (<1m)
S003			0.678	-201.74	518536.2	6260743.2	3.271928°N	42.870355°E	nml	nmw	nmh	Small point contact (<1m)
S004			0.936	-280.05	518778.3	6260862.5	3.273413°N	42.871167°E	nml	nmw	nmh	Small point contact (<1m)
S005			1.193	-263.96	519034.2	6260888.4	3.275018°N	42.871412°E	nml	nmw	nmh	Small point contact (<1m)
S006			1.250	-272.75	519089.3	6260906.4	3.275359°N	42.871540°E	nml	nmw	nmh	Small point contact (<1m)
S007			1.414	-467.23	519219.6	6261125.0	3.276106°N	42.872922°E	nml	nmw	nmh	Small point contact (<1m)
S008			2.580	82.55	520460.6	6260780.8	3.284047°N	42.871235°E	nml	nmw	nmh	Small point contact (<1m)
S009			3.232	-462.57	520993.7	6261442.9	3.287182°N	42.875468°E	41.5	10	0	Possible debris
S010			3.806	318.86	521708.7	6260788.6	3.291913°N	42.871706°E	0	0	0	Small point contact (<1m)
S011			4.522	462.8	522455.8	6260821.4	3.296612°N	42.872160°E	0	0	0	Small point contact (<1m)
S012			4.526	462.95	522459.6	6260822.2	3.296636°N	42.872167°E	0	0	0	Small point contact (<1m)
S013			4.816	-344	522531.8	6261675.3	3.296798°N	42.877412°E	6.4	1.8	0.4	Probable boulder
S014	0.268	312.45			523324.4	6265479.2	3.300487°N	42.900951°E	0	0	0	Small point contact (<1m)
S015			5.527	474.57	523453.9	6261088.8	3.302812°N	42.874136°E	36.9	0	0	Possible rope or cable
S016			5.808	-115.48	523541.6	6261737.4	3.303142°N	42.878135°E	3.4	5.1	1.7	Probable boulder
S017			5.912	91.35	523705.0	6261572.9	3.304229°N	42.877184°E	50.8	0	0	Possible Chain
S018			6.438	-470.49	524016.2	6262267.9	3.305951°N	42.881543°E	26	11	6	Probable Wreck
S019			6.511	-496.29	524075.4	6262316.7	3.306308°N	42.881862°E	15	3	0	Debris from Wreck
S020			6.493	-25.02	524219.0	6261867.5	3.307368°N	42.879162°E	0	0	0	Small point contact (<1m)
S021			6.807	124.78	524565.5	6261833.3	3.309564°N	42.879071°E	7.9	1.1	0.3	Probable boulder
S022			6.780	332.22	524610.2	6261628.9	3.309916°N	42.877835°E	0	0	0	Small point contact (<1m)
S023			6.789	444.36	524657.1	6261526.6	3.310247°N	42.877225°E	0	0	0	Small point contact (<1m)
S024			7.694	-335.46	525225.8	6262580.9	3.313468°N	42.883870°E	0	0	0	Small point contact (<1m)

	Northern Route		Southern Route									
Tag No.	KP	Offset	KP	Offset	Easting	Northing	Latitude UTM30	Longitude UTM30	Length (m)	Width (m)	Height (m)	Description
S025			7.810	-476.01	525281.4	6262754.4	3.313759°N	42.884951°E	0	0	0	Small point contact (<1m)
S026			7.652	-73.8	525284.0	6262322.4	3.313924°N	42.882309°E	0	0	0	Small point contact (<1m)
S027			7.859	-271.42	525402.9	6262582.6	3.314584°N	42.883941°E	0	0	0	Small point contact (<1m)
S028			8.035	-536.77	525450.6	6262891.1	3.314778°N	42.885845°E	0	0	0	Small point contact (<1m)
S029			7.986	-313.88	525494.5	6262667.0	3.315132°N	42.884489°E	3.8	3.4	0.2	Probable boulder
S030			7.923	-127.75	525512.1	6262471.5	3.315310°N	42.883299°E	0	0	0	Small point contact (<1m)
S031			8.088	-489.08	525518.3	6262868.7	3.315212°N	42.885731°E	0	0	0	Small point contact (<1m)
S032			8.133	-335.82	525620.4	6262746.1	3.315899°N	42.885016°E	0	0	0	Small point contact (<1m)
S033			8.300	-335.6	525773.2	6262812.8	3.316838°N	42.885476°E	0	0	0	Small point contact (<1m)
S034			8.282	-296.14	525773.4	6262769.8	3.316854°N	42.885213°E	0	0	0	Small point contact (<1m)
S035			8.408	-348.75	525866.9	6262868.2	3.317410°N	42.885847°E	0	0	0	Small point contact (<1m)
S036			8.407	-289.39	525890.2	6262813.6	3.317575°N	42.885521°E	0	0	0	Small point contact (<1m)
S037			8.453	-352.47	525906.7	6262889.7	3.317654°N	42.885992°E	56	24	0	Unknown seabed appearance
S038			8.600	-426.49	526011.7	6263016.5	3.318271°N	42.886804°E	0	0	0	Small point contact (<1m)
S039			8.658	-432.91	526062.8	6263045.9	3.318583°N	42.887001°E	0	0	0	Small point contact (<1m)
S040			8.900	-507.64	526236.2	6263209.7	3.319619°N	42.888062°E	0	0	0	Small point contact (<1m)
S041			8.592	260.92	526280.1	6262383.6	3.320182°N	42.883024°E	5.1	1.6	0.3	Probable boulder
S042			8.641	172	526289.5	6262484.8	3.320206°N	42.883646°E	3.2	3.4	0.9	Probable boulder
S043			8.591	342.55	526312.1	6262308.5	3.320409°N	42.882575°E	0	0	0	Small point contact (<1m)
S044			8.597	354.62	526323.0	6262300.1	3.320481°N	42.882527°E	0	0	0	Small point contact (<1m)
S045			8.805	40.73	526387.3	6262674.1	3.320757°N	42.884838°E	0	0	0	Small point contact (<1m)
S046			9.113	-541.35	526414.0	6263332.1	3.320698°N	42.888872°E	0	0	0	Small point contact (<1m)
S047			9.116	-522.61	526424.6	6263316.4	3.320770°N	42.888780°E	0	0	0	Small point contact (<1m)
S048	3.461	528.98			526533.5	6265153.2	3.320821°N	42.900052°E	0	0	0	Small point contact (<1m)
S049			9.130	-273.09	526544.6	6263097.2	3.321602°N	42.887480°E	0	0	0	Small point contact (<1m)
S050	3.474	518.44			526546.2	6265163.9	3.320898°N	42.900122°E	0	0	0	Small point contact (<1m)

	Northern Route		Southern Route									
Tag No.	KP	Offset	KP	Offset	Easting	Northing	Latitude UTM30	Longitude UTM30	Length (m)	Width (m)	Height (m)	Description
S051	3.490	503.14			526562.0	6265179.4	3.320992°N	42.900222°E	0	0	0	Small point contact (<1m)
S052			9.138	137.02	526728.8	6262730.7	3.322890°N	42.885301°E	0	0	0	Small point contact (<1m)
S053			9.596	-535.27	526834.8	6263529.2	3.323282°N	42.890222°E	0	0	0	Small point contact (<1m)
S054			9.629	-507.55	526877.2	6263520.0	3.323553°N	42.890181°E	0	0	0	Small point contact (<1m)
S055			9.694	-520.4	526928.6	6263561.2	3.323862°N	42.890450°E	0	0	0	Small point contact (<1m)
S056			9.719	-516.03	526952.9	6263568.9	3.324013°N	42.890505°E	0	0	0	Small point contact (<1m)
S057			9.271	391.73	526959.5	6262558.7	3.324404°N	42.884327°E	70	11	0	Unknown seabed appearance
S058			9.764	-546.45	526978.9	6263616.7	3.324160°N	42.890806°E	0	0	0	Small point contact (<1m)
S059			9.400	174.51	526981.9	6262810.2	3.324458°N	42.885874°E	5	1.6	1.2	Probable boulder
S060			9.402	173.5	526982.7	6262811.7	3.324462°N	42.885883°E	0	0	0	Small point contact (<1m)
S061			9.436	192.8	527022.4	6262809.3	3.324713°N	42.885882°E	0	0	0	Small point contact (<1m)
S062			9.723	179.9	527277.5	6262953.3	3.326272°N	42.886851°E	0	0	0	Small point contact (<1m)
S063			9.852	22.3	527319.6	6263152.8	3.326468°N	42.888086°E	0	0	0	Small point contact (<1m)
S064			9.892	-30.3	527330.6	6263217.8	3.326515°N	42.888487°E	0	0	0	Small point contact (<1m)
S065			9.975	-134.04	527356.9	6263348.4	3.326635°N	42.889295°E	0	0	0	Small point contact (<1m)
S066	4.255	513.58			527391.3	6265234.6	3.326199°N	42.900844°E	0	0	0	Small point contact (<1m)
S067	4.307	175.62			527394.8	6265576.6	3.326103°N	42.902936°E	0	0	0	Small point contact (<1m)
S068			9.874	147.31	527397.1	6263052.2	3.326991°N	42.887496°E	0	0	0	Small point contact (<1m)
S069			9.880	147.49	527402.3	6263054.7	3.327023°N	42.887514°E	0	0	0	Small point contact (<1m)
S070			9.958	22	527413.4	6263201.9	3.327042°N	42.888418°E	0	0	0	Small point contact (<1m)
S071			10.034	-18.44	527462.5	6263273.0	3.327327°N	42.888870°E	0	0	0	Small point contact (<1m)
S072			10.120	-58.81	527520.2	6263348.5	3.327664°N	42.889352°E	0	0	0	Small point contact (<1m)
S073			9.924	539.31	527621.8	6262727.2	3.328520°N	42.885586°E	36	7	0	Unknown seabed appearance
S074			10.497	-516.94	527625.0	6263925.8	3.328125°N	42.892919°E	0	0	0	Small point contact (<1m)
S075			10.297	-117.98	527649.9	6263482.6	3.328435°N	42.890217°E	0	0	0	Small point contact (<1m)
S076			10.313	-127.35	527659.2	6263498.0	3.328489°N	42.890314°E	0	0	0	Small point contact (<1m)

	Northern Route		Southern Route									
Tag No.	KP	Offset	KP	Offset	Easting	Northing	Latitude UTM30	Longitude UTM30	Length (m)	Width (m)	Height (m)	Description
S077			10.417	-284.29	527669.9	6263684.1	3.328492°N	42.891456°E	0	0	0	Small point contact (<1m)
S078			10.399	-240.47	527675.2	6263636.8	3.328542°N	42.891169°E	0	0	0	Small point contact (<1m)
S079			10.407	-235.39	527684.5	6263636.2	3.328600°N	42.891168°E	0	0	0	Small point contact (<1m)
S080			10.407	-232.71	527685.7	6263633.8	3.328608°N	42.891153°E	0	0	0	Small point contact (<1m)
S081	4.569	438.46			527719.1	6265366.3	3.328219°N	42.901762°E	0	0	0	Small point contact (<1m)
S082	4.719	-94.52			527754.2	6265918.7	3.328249°N	42.905152°E	0	0	0	Small point contact (<1m)
S083	4.762	-81.33			527796.9	6265914.5	3.328519°N	42.905140°E	0	0	0	Small point contact (<1m)
S084			10.563	-280.06	527799.0	6263751.9	3.329282°N	42.891915°E	0	0	0	Small point contact (<1m)
S085			10.587	-286.3	527817.0	6263769.2	3.329389°N	42.892027°E	0	0	0	Small point contact (<1m)
S086			10.619	-275.59	527849.5	6263775.2	3.329592°N	42.892075°E	0	0	0	Small point contact (<1m)
S087	4.866	-162.85			527878.2	6266018.6	3.328995°N	42.905805°E	0	0	0	Small point contact (<1m)
S088	4.897	-214.54			527895.8	6266076.2	3.329086°N	42.906163°E	4.4	2.3	1.7	Probable boulder
S089			10.739	-370.09	527907.7	6263916.4	3.329910°N	42.892958°E	0	0	0	Small point contact (<1m)
S090			10.741	-370.72	527909.1	6263917.9	3.329918°N	42.892968°E	0	0	0	Small point contact (<1m)
S091			10.747	-288.88	527954.6	6263849.6	3.330229°N	42.892566°E	0	0	0	Small point contact (<1m)
S092	4.826	376.13			527968.9	6265485.8	3.329751°N	42.902578°E	0	0	0	Small point contact (<1m)
S093			10.875	-350.02	528036.4	6263965.8	3.330703°N	42.893305°E	0	0	0	Small point contact (<1m)
S094			10.899	-285.48	528089.1	6263921.4	3.331051°N	42.893051°E	0	0	0	Small point contact (<1m)
S095			10.999	-439.36	528100.5	6264104.4	3.331060°N	42.894175°E	0	0	0	Small point contact (<1m)
S096			11.053	-515.63	528110.6	6264197.6	3.331091°N	42.894748°E	0	0	0	Small point contact (<1m)
S097	5.070	27.94			528122.0	6265886.4	3.330578°N	42.905081°E	0	0	0	Small point contact (<1m)
S098			11.046	-460.95	528131.3	6264146.5	3.331239°N	42.894443°E	0	0	0	Small point contact (<1m)
S099			11.049	-452.41	528137.5	6264140.2	3.331280°N	42.894406°E	0	0	0	Small point contact (<1m)
S100			10.576	407.05	528147.0	6263159.3	3.331681°N	42.888409°E	0	0	0	Small point contact (<1m)
S101			11.166	-536	528182.3	6264263.0	3.331520°N	42.895173°E	0	0	0	Small point contact (<1m)
S102	5.163	-52.81			528187.0	6265989.1	3.330951°N	42.905731°E	0	0	0	Small point contact (<1m)

	Northern Route		Southern Route									
Tag No.	KP	Offset	KP	Offset	Easting	Northing	Latitude UTM30	Longitude UTM30	Length (m)	Width (m)	Height (m)	Description
S103			10.639	379.15	528188.0	6263214.4	3.331920°N	42.888760°E	0	0	0	Small point contact (<1m)
S104	5.006	500.21			528188.8	6265414.5	3.331162°N	42.902217°E	0	0	0	Small point contact (<1m)
S105	5.167	-52.68			528191.5	6265990.4	3.330979°N	42.905740°E	0	0	0	Small point contact (<1m)
S106			11.139	-469.52	528194.3	6264192.5	3.331620°N	42.894746°E	0	0	0	Small point contact (<1m)
S107			10.990	-225.43	528197.5	6263913.5	3.331737°N	42.893040°E	0	0	0	Small point contact (<1m)
S108	5.215	-53.74			528236.7	6266005.9	3.331258°N	42.905850°E	0	0	0	Small point contact (<1m)
S109	5.068	515.55			528251.9	6265416.4	3.331559°N	42.902251°E	3.2	0.7	0.3	Probable boulder
S110			11.290	-468.39	528323.4	6264269.6	3.332407°N	42.895261°E	0	0	0	Small point contact (<1m)
S111	5.141	519.75			528323.6	6265432.3	3.332005°N	42.902373°E	2.7	1.7	0.4	Probable boulder
S112			11.289	-465.9	528323.9	6264267.0	3.332411°N	42.895246°E	0	0	0	Small point contact (<1m)
S113			11.350	-514.91	528351.0	6264340.8	3.332556°N	42.895706°E	0	0	0	Small point contact (<1m)
S114			10.845	374.93	528365.6	6263319.2	3.333003°N	42.889463°E	0	0	0	Small point contact (<1m)
S115	5.346	351.08			528490.4	6265661.9	3.332977°N	42.903834°E	0	0	0	Small point contact (<1m)
S116	5.356	364.39			528508.9	6265654.3	3.333096°N	42.903794°E	0	0	0	Small point contact (<1m)
S117			11.451	-352.6	528520.9	6264254.1	3.333657°N	42.895235°E	0	0	0	Small point contact (<1m)
S118			11.183	279.49	528620.3	6263574.9	3.334519°N	42.891114°E	5.6	10	2.3	Probable boulder
S119	5.566	255.17			528674.2	6265829.3	3.334076°N	42.904921°E	0	0	0	Small point contact (<1m)
S120	5.518	504.65			528709.0	6265576.5	3.334383°N	42.903387°E	0	0	0	Small point contact (<1m)
S121	5.764	314.05			528880.7	6265843.6	3.335373°N	42.905079°E	0	0	0	Small point contact (<1m)
S122	5.770	315.1			528886.1	6265844.5	3.335406°N	42.905086°E	0	0	0	Small point contact (<1m)
S123	5.869	283.64			528967.8	6265908.6	3.335899°N	42.905507°E	0	0	0	Small point contact (<1m)
S124	5.886	240.36			528968.6	6265955.1	3.335888°N	42.905791°E	0	0	0	Small point contact (<1m)
S125	6.043	-118.23			528990.8	6266346.2	3.335892°N	42.908191°E	3.4	0.8	1.1	Probable boulder
S126	6.145	173.28			529188.3	6266108.8	3.337219°N	42.906807°E	0	0	0	Small point contact (<1m)
S127	6.352	-285.42			529221.6	6266610.9	3.337254°N	42.909888°E	0	0	0	Small point contact (<1m)
S128	6.395	-331.76			529245.5	6266669.3	3.337384°N	42.910254°E	0	0	0	Small point contact (<1m)

	Northern Route		Southern Route									
Tag No.	KP	Offset	KP	Offset	Easting	Northing	Latitude UTM30	Longitude UTM30	Length (m)	Width (m)	Height (m)	Description
S129	6.298	75.01			529296.7	6266254.2	3.337851°N	42.907733°E	0	0	0	Small point contact (<1m)
S130	6.303	69.26			529299.8	6266261.5	3.337868°N	42.907779°E	0	0	0	Small point contact (<1m)
S131	6.316	53.25			529306.0	6266280.9	3.337901°N	42.907899°E	0	0	0	Small point contact (<1m)
S132	6.316	70			529312.1	6266265.3	3.337944°N	42.907806°E	0	0	0	Small point contact (<1m)
S133	6.447	18.18			529416.7	6266359.7	3.338571°N	42.908420°E	0	0	0	Small point contact (<1m)
S134			12.013	602.69	529513.0	6263743.4	3.340087°N	42.892452°E	30	6	0	Unknown seabed appearance
S135			12.770	-483.35	529537.7	6265059.3	3.339785°N	42.900509°E	0	0	0	Small point contact (<1m)
S136	6.732	-337.18			529559.5	6266792.4	3.339320°N	42.911114°E	0	0	0	Small point contact (<1m)
S137	6.753	-350.22			529573.9	6266811.7	3.339404°N	42.911237°E	0	0	0	Small point contact (<1m)
S138	6.469	456.03			529590.7	6265957.3	3.339807°N	42.906019°E	0	0	0	Small point contact (<1m)
S139	6.519	326.44			529592.2	6266096.2	3.339768°N	42.906868°E	0	0	0	Small point contact (<1m)
S140	6.856	-325.6			529679.3	6266824.8	3.340064°N	42.911354°E	0	0	0	Small point contact (<1m)
S141	6.577	445.96			529688.0	6266004.4	3.340404°N	42.906340°E	0	0	0	Small point contact (<1m)
S142			12.390	351.92	529690.8	6264159.3	3.341062°N	42.895057°E	3.7	1.3	0.3	Probable boulder
S143	6.719	72.96			529691.0	6266403.7	3.340284°N	42.908783°E	0	0	0	Small point contact (<1m)
S144	6.581	446.19			529692.4	6266005.8	3.340431°N	42.906350°E	0	0	0	Small point contact (<1m)
S145	6.939	-329.51			529755.4	6266857.4	3.340532°N	42.911579°E	0	0	0	Small point contact (<1m)
S146	6.775	123.91			529761.1	6266375.5	3.340735°N	42.908634°E	0	0	0	Small point contact (<1m)
S147	6.764	287.69			529807.5	6266218.0	3.341082°N	42.907688°E	0	0	0	Small point contact (<1m)
S148	6.849	122.21			529829.3	6266402.8	3.341155°N	42.908825°E	0	0	0	Small point contact (<1m)
S149	6.806	263.25			529838.3	6266255.6	3.341263°N	42.907928°E	0	0	0	Small point contact (<1m)
S150	6.818	249.71			529845.4	6266272.7	3.341302°N	42.908035°E	0	0	0	Small point contact (<1m)
S151	6.833	231.61			529853.1	6266294.9	3.341343°N	42.908174°E	0	0	0	Small point contact (<1m)
S152	6.908	44.36			529857.4	6266496.4	3.341300°N	42.909407°E	0	0	0	Small point contact (<1m)
S153	6.849	236.79			529869.5	6266295.5	3.341446°N	42.908183°E	0	0	0	Small point contact (<1m)
S154	6.866	268.31			529896.4	6266271.9	3.341624°N	42.908048°E	0	0	0	Small point contact (<1m)

	Northern Route		Southern Route									
Tag No.	KP	Offset	KP	Offset	Easting	Northing	Latitude UTM30	Longitude UTM30	Length (m)	Width (m)	Height (m)	Description
S155	6.873	268.84			529903.8	6266274.1	3.341670°N	42.908064°E	0	0	0	Small point contact (<1m)
S156			12.693	353.53	529945.6	6264324.0	3.342611°N	42.896152°E	0	0	0	Small point contact (<1m)
S157	6.925	285.97			529958.1	6266276.1	3.342011°N	42.908095°E	0	0	0	Small point contact (<1m)
S158	6.955	358.38			530011.1	6266218.6	3.342365°N	42.907761°E	0	0	0	Small point contact (<1m)
S159	6.955	359.26			530012.0	6266218.0	3.342371°N	42.907758°E	0	0	0	Small point contact (<1m)
S160			12.774	355.34	530022.9	6264375.2	3.343080°N	42.896492°E	0	0	0	Small point contact (<1m)
S161			13.143	-76.93	530075.9	6264940.7	3.343218°N	42.899969°E	0	0	0	Small point contact (<1m)
S162	7.139	122.36			530101.4	6266504.3	3.342835°N	42.909539°E	0	0	0	Small point contact (<1m)
S163	7.067	355.06			530115.1	6266261.0	3.343005°N	42.908056°E	0	0	0	Small point contact (<1m)
S164	7.250	-83.56			530133.2	6266736.0	3.342954°N	42.910967°E	3.4	2.5	0.6	Probable boulder
S165	7.095	375.94			530148.8	6266251.3	3.343221°N	42.908008°E	0	0	0	Small point contact (<1m)
S166	7.219	170.36			530192.8	6266487.2	3.343416°N	42.909466°E	0	0	0	Small point contact (<1m)
S167	7.180	293			530199.8	6266358.9	3.343505°N	42.908684°E	0	0	0	Small point contact (<1m)
S168	7.254	355.43			530290.4	6266326.1	3.344087°N	42.908515°E	0	0	0	Small point contact (<1m)
S169	7.409	164.17			530368.9	6266559.6	3.344500°N	42.909970°E	0	0	0	Small point contact (<1m)
S170			13.273	269.3	530381.7	6264732.4	3.345217°N	42.898801°E	1.2	6.4	1.7	Probable boulder
S171	7.536	-118.26			530388.7	6266868.5	3.344518°N	42.911865°E	0	0	0	Small point contact (<1m)
S172	7.717	-297.39			530495.7	6267099.7	3.345112°N	42.913316°E	0	0	0	Small point contact (<1m)
S173	7.732	-314.74			530504.2	6267121.4	3.345157°N	42.913451°E	0	0	0	Small point contact (<1m)
S174	7.620	32.01			530520.7	6266757.4	3.345388°N	42.911232°E	0	0	0	Small point contact (<1m)
S175	7.620	42.9			530523.7	6266746.9	3.345411°N	42.911168°E	0	0	0	Small point contact (<1m)
S176			13.706	-75.43	530531.6	6265267.0	3.345975°N	42.902122°E	0	0	0	Small point contact (<1m)
S177	7.773	-327.29			530537.4	6267147.2	3.345358°N	42.913621°E	0	0	0	Small point contact (<1m)
S178	7.588	238.12			530562.8	6266553.1	3.345725°N	42.909997°E	0	0	0	Small point contact (<1m)
S179	7.818	-253.57			530606.2	6267094.2	3.345809°N	42.913320°E	0	0	0	Small point contact (<1m)
S180	7.787	-131.62			530619.0	6266968.8	3.345934°N	42.912558°E	8	2	0	Probable Debris

	Northern Route		Southern Route									
Tag No.	KP	Offset	KP	Offset	Easting	Northing	Latitude UTM30	Longitude UTM30	Length (m)	Width (m)	Height (m)	Description
S181	7.881	-318.92			530641.9	6267177.3	3.346005°N	42.913840°E	0	0	0	Small point contact (<1m)
S182	7.895	-259.07			530676.4	6267126.3	3.346241°N	42.913540°E	0	0	0	Small point contact (<1m)
S183	7.821	-57.3			530676.9	6266911.1	3.346319°N	42.912225°E	0	0	0	Small point contact (<1m)
S184	7.823	-59.73			530678.0	6266914.1	3.346324°N	42.912244°E	0	0	0	Small point contact (<1m)
S185	7.822	-58.98			530678.0	6266913.3	3.346325°N	42.912239°E	3.9	2.2	0.6	Probable boulder
S186	7.898	-256.57			530679.8	6267124.9	3.346262°N	42.913533°E	0	0	0	Small point contact (<1m)
S187	7.823	-55.94			530680.0	6266910.8	3.346338°N	42.912224°E	0	0	0	Small point contact (<1m)
S188	7.862	-107.15			530698.0	6266972.2	3.346431°N	42.912606°E	19.5	9	0	Probable Debris
S189			13.871	39.15	530732.9	6265275.2	3.347241°N	42.902241°E	0	0	0	Small point contact (<1m)
S190			14.238	-435	530740.8	6265874.8	3.347082°N	42.905911°E	31	12	0	Probable Wreck
S191			14.127	-82.84	530863.6	6265526.4	3.347977°N	42.903823°E	0	0	0	Small point contact (<1m)
S192			13.944	190.65	530882.2	6265198.0	3.348209°N	42.901821°E	0	0	0	Small point contact (<1m)
S193	8.200	-388.96			530915.8	6267354.4	3.347669°N	42.915018°E	0	0	0	Small point contact (<1m)
S194	8.190	-84.13			531013.5	6267065.5	3.348386°N	42.913285°E	0	0	0	Small point contact (<1m)
S195	8.190	-84.25			531013.7	6267065.7	3.348386°N	42.913287°E	0	0	0	Small point contact (<1m)
S196	8.306	-188.47			531086.1	6267204.0	3.348795°N	42.914157°E	0	0	0	Small point contact (<1m)
S197	8.344	-139.33			531138.7	6267171.2	3.349137°N	42.913975°E	0	0	0	Small point contact (<1m)
S198			14.069	560.49	531204.3	6264977.6	3.350315°N	42.900584°E	0	0	0	Small point contact (<1m)
S199	8.458	-150.27			531241.8	6267221.4	3.349769°N	42.914317°E	0	0	0	Small point contact (<1m)
S200	8.464	-152.87			531245.9	6267225.7	3.349794°N	42.914345°E	0	0	0	Small point contact (<1m)
S201	8.554	-246.08			531297.8	6267344.6	3.350079°N	42.915090°E	0	0	0	Small point contact (<1m)
S202			14.371	546.37	531436.6	6265170.2	3.351712°N	42.901842°E	0	0	0	Small point contact (<1m)
S203	8.957	-540.76			531572.5	6267761.8	3.351664°N	42.917735°E	3.3	1.9	0.3	Probable boulder
S204	8.751	654.48	15.488	-362.52	531797.7	6266570.0	3.353499°N	42.910526°E	0	0	0	Small point contact (<1m)
S205	9.195	260.59	16.016	-632.71	532075.3	6267094.2	3.355065°N	42.913827°E	2.9	1.8	0.1	Probable boulder
S206	9.205	260.43	16.027	-630.26	532085.0	6267098.0	3.355125°N	42.913854°E	2	1.5	1.2	Probable boulder

	Northern Route		Southern Route									
Tag No.	KP	Offset	KP	Offset	Easting	Northing	Latitude UTM30	Longitude UTM30	Length (m)	Width (m)	Height (m)	Description
S207			15.619	81.11	532159.0	6266281.4	3.355876°N	42.908886°E	0	0	0	Small point contact (<1m)
S208	10.604	953.35	17.220	359.2	533637.7	6266938.4	3.364962°N	42.913416°E	0	0	0	Small point contact (<1m)
S209	12.206	135.53	18.953	-171.91	534852.8	6268265.4	3.372152°N	42.921950°E	0	0	0	Small point contact (<1m)
S210	12.832	-354.22	19.626	-575.41	535267.1	6268943.0	3.374524°N	42.926236°E	0	0	0	Small point contact (<1m)
S211	13.199	134.83	19.933	-46.44	535782.5	6268613.5	3.377886°N	42.924401°E	3.2	2	0.3	Probable boulder
S212	14.140	-592.54	20.930	-682.8	536408.9	6269624.0	3.381476°N	42.930795°E	0	0	0	Small point contact (<1m)
S213	14.336	133.87	21.064	57.59	536847.2	6269012.3	3.384452°N	42.927209°E	73.2	0	0	Possible cable
S214	14.765	-565.75	21.530	-615.4	537003.9	6269817.7	3.385155°N	42.932186°E	0	0	0	Small point contact (<1m)
S215	15.050	446.46	21.764	409.97	537625.8	6268969.5	3.389371°N	42.927219°E	0	0	0	Small point contact (<1m)
S216	15.882	-329.41	22.623	-338.36	538133.4	6269987.4	3.392209°N	42.933618°E	3.8	2.7	0.9	Probable boulder
S217	16.043	-160.58	22.780	-166.84	538342.8	6269885.4	3.393564°N	42.933067°E	0	0	0	Small point contact (<1m)
S218	16.076	304.06	22.806	298.29	538536.6	6269461.8	3.394934°N	42.930546°E	51.4	13.8	0	Possible debris
S219	17.771	-615.07	24.506	-615.07	539802.4	6270915.9	3.402392°N	42.939875°E	2.2	1.5	0.9	Probable boulder
S220	17.772	-605.29	24.507	-605.29	539806.8	6270907.1	3.402422°N	42.939823°E	2.3	1.1	0.7	Probable boulder
S221	17.712	-282.71	24.447	-282.71	539863.7	6270584.0	3.402895°N	42.937869°E	4.6	2	0.4	Probable boulder
S222	17.611	149.96	24.346	149.96	539920.4	6270143.3	3.403409°N	42.935196°E	0	0	0	Small point contact (<1m)
S223	17.643	159.38	24.378	159.38	539954.0	6270145.8	3.403619°N	42.935223°E	0	0	0	Small point contact (<1m)
S224	17.770	16.86	24.505	16.86	540023.2	6270323.8	3.403992°N	42.936335°E	3.7	0.9	0.5	Probable boulder
S225	17.900	-6.15	24.635	-6.15	540136.8	6270390.8	3.404683°N	42.936784°E	0	0	0	Small point contact (<1m)
S226	17.893	17.81	24.628	17.81	540138.6	6270365.9	3.404704°N	42.936632°E	0	0	0	Small point contact (<1m)
S227	17.894	23.97	24.629	23.97	540141.5	6270360.4	3.404724°N	42.936600°E	0	0	0	Small point contact (<1m)
S228	17.894	28.61	24.629	28.61	540143.5	6270356.2	3.404738°N	42.936575°E	0	0	0	Small point contact (<1m)
S229	17.906	6.39	24.641	6.39	540146.4	6270381.0	3.404747°N	42.936728°E	0	0	0	Small point contact (<1m)
S230	18.073	-394.57	24.808	-394.57	540162.9	6270815.2	3.404698°N	42.939387°E	0	0	0	Small point contact (<1m)
S231	17.852	213.38	24.587	213.38	540168.8	6270168.4	3.404964°N	42.935436°E	0	0	0	Small point contact (<1m)
S232	18.108	-424.26	24.843	-424.26	540185.4	6270855.3	3.404825°N	42.939639°E	0	0	0	Small point contact (<1m)

	Northern Route		Southern Route									
Tag No.	KP	Offset	KP	Offset	Easting	Northing	Latitude UTM30	Longitude UTM30	Length (m)	Width (m)	Height (m)	Description
S233	17.961	-8.52	24.696	-8.52	540193.2	6270414.4	3.405030°N	42.936948°E	2.9	2	0.8	Probable boulder
S234	17.964	-14.02	24.699	-14.02	540193.8	6270420.5	3.405032°N	42.936985°E	6.8	2	0.8	Probable boulder
S235	17.970	-13.36	24.705	-13.36	540199.7	6270422.0	3.405068°N	42.936997°E	5.9	2.8	0.6	Probable boulder
S236	18.074	-241.44	24.809	-241.44	540217.7	6270672.2	3.405094°N	42.938532°E	4.6	2.4	1.6	Probable boulder
S237	18.077	-242	24.812	-242	540220.1	6270673.7	3.405108°N	42.938542°E	2	1.9	1.2	Probable boulder
S238	18.210	-383.62	24.945	-383.62	540295.1	6270852.9	3.405517°N	42.939663°E	0	0	0	Small point contact (<1m)
S239	18.218	-382.09	24.953	-382.09	540303.5	6270854.4	3.405569°N	42.939676°E	0	0	0	Small point contact (<1m)
S240	18.243	-430.69	24.978	-430.69	540309.7	6270908.6	3.405589°N	42.940009°E	0	0	0	Small point contact (<1m)
S241	18.260	-402.89	24.995	-402.89	540334.8	6270888.3	3.405754°N	42.939894°E	0	0	0	Small point contact (<1m)
S242	18.285	-381.81	25.020	-381.81	540366.4	6270877.6	3.405957°N	42.939839°E	0	0	0	Small point contact (<1m)
S243	18.512	-306.14	25.247	-306.14	540605.1	6270886.0	3.407457°N	42.939975°E	0	0	0	Small point contact (<1m)
S244	18.365	197.33	25.100	197.33	540643.8	6270363.0	3.407886°N	42.936792°E	0	0	0	Small point contact (<1m)
S245	19.141	302.37	25.876	302.37	541407.5	6270536.2	3.412635°N	42.938118°E	0	0	0	Small point contact (<1m)
S246	19.389	-126.05	26.124	-126.05	541489.3	6271024.1	3.412976°N	42.941129°E	0	0	0	Small point contact (<1m)
S247	19.373	-84.8	26.108	-84.8	541489.4	6270980.1	3.412992°N	42.940860°E	0	0	0	Small point contact (<1m)
S248	19.439	-77.19	26.174	-77.19	541553.7	6270996.0	3.413392°N	42.940980°E	0	0	0	Small point contact (<1m)
S249	19.491	68.01	26.226	68.01	541653.0	6270878.1	3.414059°N	42.940294°E	0	0	0	Small point contact (<1m)
S250	19.511	74	26.246	74	541674.4	6270879.7	3.414193°N	42.940312°E	0	0	0	Small point contact (<1m)
S251	19.555	211.1	26.290	211.1	541763.4	6270766.6	3.414794°N	42.939652°E	0	0	0	Small point contact (<1m)
S252	19.771	34.86	26.506	34.86	541904.1	6271007.3	3.415594°N	42.941172°E	0	0	0	Small point contact (<1m)
S253	19.791	417.97	26.526	417.97	542056.6	6270655.3	3.416680°N	42.939075°E	0	0	0	Small point contact (<1m)
S254	21.289	149.92	28.024	149.92	543365.6	6271430.5	3.424647°N	42.944272°E	0	0	0	Small point contact (<1m)
S255	21.322	145.21	28.057	145.21	543395.5	6271446.7	3.424829°N	42.944382°E	0	0	0	Small point contact (<1m)
S256	21.482	-13.53	28.217	-13.53	543489.3	6271651.2	3.425347°N	42.945664°E	0	0	0	Small point contact (<1m)
S257	21.727	-329.12	28.462	-329.12	543608.4	6272032.6	3.425961°N	42.948036°E	2.1	1.5	0.1	Probable boulder
S258	21.838	-287.13	28.573	-287.13	543727.3	6272032.2	3.426710°N	42.948076°E	4	2.2	0.5	Probable boulder

	Northern Route		Southern Route									
Tag No.	KP	Offset	KP	Offset	Easting	Northing	Latitude UTM30	Longitude UTM30	Length (m)	Width (m)	Height (m)	Description
S259	21.845	-285.77	28.580	-285.77	543734.4	6272033.4	3.426754°N	42.948086°E	0	0	0	Small point contact (<1m)
S260	21.946	-523.57	28.681	-523.57	543754.2	6272293.1	3.426786°N	42.949679°E	0	0	0	Small point contact (<1m)
S261	21.932	-344.93	28.667	-344.93	543800.6	6272120.0	3.427140°N	42.948638°E	4	1.6	0.5	Probable boulder
S262	21.859	48.74	28.594	48.74	543864.2	6271724.8	3.427682°N	42.946246°E	0	0	0	Small point contact (<1m)
S263	21.965	75.63	28.700	75.63	543972.6	6271734.8	3.428360°N	42.946346°E	7.2	3.2	0.3	Probable boulder
S264	22.112	34.78	28.847	34.78	544096.5	6271817.6	3.429111°N	42.946896°E	3.1	1.4	0.5	Probable boulder
S265	22.622	-147.46	29.357	-147.46	544562.3	6272110.1	3.431939°N	42.948847°E	0	0	0	Small point contact (<1m)
S266	22.626	-162.88	29.361	-162.88	544564.3	6272126.0	3.431947°N	42.948945°E	0	0	0	Small point contact (<1m)
S267	22.562	237.11	29.297	237.11	544567.8	6271721.2	3.432113°N	42.946473°E	0	0	0	Small point contact (<1m)
S268	22.569	230.75	29.304	230.75	544574.0	6271728.8	3.432149°N	42.946521°E	0	0	0	Small point contact (<1m)
S269	22.745	46.75	29.480	46.75	544711.8	6271935.2	3.432943°N	42.947831°E	0	0	0	Small point contact (<1m)
S270	22.749	40.19	29.484	40.19	544714.3	6271942.1	3.432956°N	42.947874°E	0	0	0	Small point contact (<1m)
S271	22.767	224.55	29.502	224.55	544753.7	6271761.1	3.433269°N	42.946782°E	0	0	0	Small point contact (<1m)
S272	22.880	-283.7	29.615	-283.7	544815.7	6272278.6	3.433475°N	42.949966°E	0	0	0	Small point contact (<1m)
S273	22.890	-282.54	29.625	-282.54	544825.7	6272278.3	3.433538°N	42.949968°E	0	0	0	Small point contact (<1m)
S274	22.903	-270.22	29.638	-270.22	544840.6	6272267.2	3.433636°N	42.949905°E	0	0	0	Small point contact (<1m)
S275	22.939	-481.16	29.674	-481.16	544858.0	6272480.4	3.433669°N	42.951213°E	0	0	0	Small point contact (<1m)
S276	22.942	13.91	29.677	13.91	544903.3	6271987.4	3.434130°N	42.948218°E	0	0	0	Small point contact (<1m)
S277	22.999	-444.16	29.734	-444.16	544935.2	6272448.3	3.434166°N	42.951045°E	3.7	2.2	0.4	Probable boulder
S278	23.037	-132.8	29.772	-132.8	544989.6	6272139.4	3.434619°N	42.949177°E	0	0	0	Small point contact (<1m)
S279	23.122	121.31	29.857	121.31	545088.0	6271890.2	3.435328°N	42.947689°E	0	0	0	Small point contact (<1m)
S280	23.219	-17.75	29.954	-17.75	545176.5	6272034.6	3.435834°N	42.948603°E	8.3	1.5	0.4	Probable boulder
S281	23.223	-18.43	29.958	-18.43	545181.2	6272035.7	3.435863°N	42.948612°E	3.1	1.5	0.7	Probable boulder
S282	23.514	-5.31	30.249	-5.31	545470.9	6272055.7	3.437679°N	42.948836°E	0	0	0	Small point contact (<1m)
S283	23.506	77.17	30.241	77.17	545475.3	6271972.9	3.437737°N	42.948332°E	0	0	0	Small point contact (<1m)
S284	23.776	-627.33	30.511	-627.33	545590.2	6272710.6	3.438197°N	42.952879°E	0	0	0	Small point contact (<1m)

	Northern Route		Southern Route									
Tag No.	KP	Offset	KP	Offset	Easting	Northing	Latitude UTM30	Longitude UTM30	Length (m)	Width (m)	Height (m)	Description
S285	23.681	227.11	30.416	227.11	545678.2	6271856.0	3.439056°N	42.947689°E	0	0	0	Small point contact (<1m)
S286	23.850	423.22	30.585	423.22	545894.7	6271702.4	3.440475°N	42.946828°E	0	0	0	Small point contact (<1m)
S287	23.989	-113.22	30.724	-113.22	545903.0	6272259.2	3.440328°N	42.950232°E	0	0	0	Small point contact (<1m)
S288	23.967	36.78	30.702	36.78	545923.5	6272109.2	3.440511°N	42.949323°E	0	0	0	Small point contact (<1m)
S289	24.160	-498.75	30.895	-498.75	545940.4	6272674.3	3.440415°N	42.952781°E	0	0	0	Small point contact (<1m)
S290	23.898	387.16	30.633	387.16	545945.3	6271752.7	3.440775°N	42.947153°E	0	0	0	Small point contact (<1m)
S291	23.865	529.16	30.600	529.16	545949.5	6271607.0	3.440854°N	42.946264°E	0	0	0	Small point contact (<1m)
S292	23.900	431.38	30.635	431.38	545958.7	6271710.5	3.440874°N	42.946900°E	0	0	0	Small point contact (<1m)
S293	24.215	-584.05	30.950	-584.05	545965.2	6272772.6	3.440536°N	42.953390°E	0	0	0	Small point contact (<1m)
S294	24.162	-419.59	30.897	-419.59	545967.2	6272599.8	3.440610°N	42.952335°E	4.7	1.2	0.3	Probable boulder
S295	24.073	15.9	30.808	15.9	546020.4	6272159.5	3.441103°N	42.949665°E	0	0	0	Small point contact (<1m)
S296	23.978	381.52	30.713	381.52	546029.2	6271780.6	3.441294°N	42.947353°E	0	0	0	Small point contact (<1m)
S297	24.030	197.49	30.765	197.49	546031.5	6271973.3	3.441239°N	42.948531°E	0	0	0	Small point contact (<1m)
S298	24.081	122.6	30.816	122.6	546059.1	6272059.7	3.441382°N	42.949069°E	0	0	0	Small point contact (<1m)
S299	23.995	515.94	30.730	515.94	546088.9	6271658.1	3.441713°N	42.946626°E	0	0	0	Small point contact (<1m)
S300	24.112	120.99	30.847	120.99	546092.1	6272071.5	3.441586°N	42.949152°E	0	0	0	Small point contact (<1m)
S301	24.121	98.21	30.856	98.21	546093.5	6272096.0	3.441586°N	42.949303°E	0	0	0	Small point contact (<1m)
S302	24.114	251.98	30.849	251.98	546135.5	6271947.9	3.441903°N	42.948413°E	0	0	0	Small point contact (<1m)
S303	24.233	-87.44	30.968	-87.44	546139.9	6272307.4	3.441802°N	42.950611°E	0	0	0	Small point contact (<1m)
S304	24.341	-325.41	31.076	-325.41	546155.4	6272567.2	3.441807°N	42.952203°E	6.3	2.2	0.3	Probable boulder
S305	24.150	210.5	30.885	210.5	546155.9	6271998.5	3.442013°N	42.948729°E	0	0	0	Small point contact (<1m)
S306	24.335	-148.29	31.070	-148.29	546211.3	6272399.0	3.442219°N	42.951196°E	0	0	0	Small point contact (<1m)
S307	24.274	73.7	31.009	73.7	546232.1	6272169.8	3.442432°N	42.949803°E	0	0	0	Small point contact (<1m)
S308	24.335	-83.97	31.070	-83.97	546234.2	6272338.9	3.442385°N	42.950836°E	0	0	0	Small point contact (<1m)
S309	24.229	398.82	30.964	398.82	546290.7	6271845.1	3.442917°N	42.947840°E	0	0	0	Small point contact (<1m)
S310	24.431	-130.62	31.166	-130.62	546303.1	6272416.8	3.442790°N	42.951337°E	0	0	0	Small point contact (<1m)

	Northern Route		Southern Route									
Tag No.	KP	Offset	KP	Offset	Easting	Northing	Latitude UTM30	Longitude UTM30	Length (m)	Width (m)	Height (m)	Description
S311	24.230	463.36	30.965	463.36	546312.4	6271784.3	3.443075°N	42.947476°E	0	0	0	Small point contact (<1m)
S312	24.235	459.96	30.970	459.96	546317.5	6271789.6	3.443105°N	42.947510°E	0	0	0	Small point contact (<1m)
S313	24.324	195.44	31.059	195.44	546321.4	6272073.2	3.443028°N	42.949244°E	0	0	0	Small point contact (<1m)
S314	24.363	230.57	31.098	230.57	546377.3	6272056.7	3.443386°N	42.949164°E	0	0	0	Small point contact (<1m)
S315	24.514	29.07	31.249	29.07	546441.3	6272301.9	3.443702°N	42.950684°E	0	0	0	Small point contact (<1m)
S316	24.363	416.11	31.098	416.11	546444.4	6271883.7	3.443871°N	42.948131°E	0	0	0	Small point contact (<1m)
S317	24.413	325.56	31.148	325.56	546460.6	6271988.3	3.443936°N	42.948775°E	0	0	0	Small point contact (<1m)
S318	24.550	16.44	31.285	16.44	546469.0	6272328.3	3.443866°N	42.950855°E	0	0	0	Small point contact (<1m)
S319	24.401	386.1	31.136	386.1	546472.2	6271927.6	3.444030°N	42.948408°E	0	0	0	Small point contact (<1m)
S320	24.555	24.84	31.290	24.84	546477.0	6272322.7	3.443919°N	42.950823°E	0	0	0	Small point contact (<1m)
S321	24.556	74.03	31.291	74.03	546498.2	6272278.3	3.444068°N	42.950560°E	0	0	0	Small point contact (<1m)
S322	24.555	96.17	31.290	96.17	546505.7	6272257.4	3.444123°N	42.950435°E	0	0	0	Small point contact (<1m)
S323	24.584	56.91	31.319	56.91	546516.1	6272305.2	3.444171°N	42.950730°E	0	0	0	Small point contact (<1m)
S324	24.510	246.53	31.245	246.53	546527.0	6272102.0	3.444313°N	42.949493°E	0	0	0	Small point contact (<1m)
S325	24.609	79.52	31.344	79.52	546548.2	6272294.9	3.444377°N	42.950679°E	0	0	0	Small point contact (<1m)
S326	24.643	54.05	31.378	54.05	546570.6	6272333.9	3.444504°N	42.950925°E	0	0	0	Small point contact (<1m)
S327	24.668	33.49	31.403	33.49	546583.1	6272363.0	3.444572°N	42.951108°E	0	0	0	Small point contact (<1m)
S328	24.671	39.46	31.406	39.46	546588.9	6272359.2	3.444610°N	42.951086°E	0	0	0	Small point contact (<1m)
S329	24.651	101.37	31.386	101.37	546598.1	6272294.7	3.444692°N	42.950696°E	0	0	0	Small point contact (<1m)
S330	24.653	106.19	31.388	106.19	546602.7	6272291.6	3.444721°N	42.950678°E	4	1.3	0.3	Probable boulder
S331	24.815	-179.21	31.550	-179.21	546614.5	6272618.1	3.444679°N	42.952677°E	0	0	0	Small point contact (<1m)
S332	24.706	48.77	31.441	48.77	546624.5	6272366.4	3.444832°N	42.951143°E	0	0	0	Small point contact (<1m)
S333	24.720	22.85	31.455	22.85	546625.3	6272395.7	3.444826°N	42.951322°E	0	0	0	Small point contact (<1m)
S334	24.698	96.35	31.433	96.35	546638.4	6272320.2	3.444936°N	42.950866°E	0	0	0	Small point contact (<1m)
S335	24.803	-77.46	31.538	-77.46	546652.1	6272522.8	3.444949°N	42.952108°E	0	0	0	Small point contact (<1m)
S336	24.840	-127.57	31.575	-127.57	546661.3	6272584.6	3.444985°N	42.952489°E	0	0	0	Small point contact (<1m)

	Northern Route		Southern Route									
Tag No.	KP	Offset	KP	Offset	Easting	Northing	Latitude UTM30	Longitude UTM30	Length (m)	Width (m)	Height (m)	Description
S337	24.819	-86.78	31.554	-86.78	546662.2	6272538.8	3.445007°N	42.952209°E	0	0	0	Small point contact (<1m)
S338	24.921	-184.71	31.656	-184.71	546706.0	6272673.4	3.445235°N	42.953047°E	0	0	0	Small point contact (<1m)
S339	24.928	-185.55	31.663	-185.55	546711.5	6272677.3	3.445268°N	42.953073°E	0	0	0	Small point contact (<1m)
S340	24.860	-9.92	31.595	-9.92	546734.2	6272490.2	3.445478°N	42.951938°E	0	0	0	Small point contact (<1m)
S341	24.860	41.55	31.595	41.55	546759.2	6272445.2	3.445652°N	42.951672°E	0	0	0	Small point contact (<1m)
S342	25.176	-234.21	31.911	-234.21	546907.5	6272837.5	3.446444°N	42.954121°E	0	0	0	Small point contact (<1m)
S343	25.190	-154.75	31.925	-154.75	546959.7	6272775.3	3.446796°N	42.953759°E	0	0	0	Small point contact (<1m)
S344	25.363	-445.75	32.098	-445.75	546988.2	6273113.6	3.446854°N	42.955836°E	39	18	12	Area of unknown seabed relief
S345	25.367	-253.65	32.102	-253.65	547076.6	6272943.0	3.447472°N	42.954825°E	0	0	0	Small point contact (<1m)
S346	25.524	-549.54	32.259	-549.54	547104.7	6273285.4	3.447526°N	42.956927°E	0	0	0	Small point contact (<1m)
S347	25.324	-93.75	32.059	-93.75	547109.3	6272780.9	3.447735°N	42.953847°E	0	0	0	Small point contact (<1m)
S348	25.577	541.25	32.312	541.25	547600.0	6272312.1	3.450993°N	42.951157°E	0	0	0	Small point contact (<1m)
S349	26.132	-539.7	32.867	-539.7	547689.8	6273524.8	3.451123°N	42.958597°E	0	0	0	Small point contact (<1m)
S350	26.022	-186.59	32.757	-186.59	547716.8	6273154.5	3.451426°N	42.956345°E	0	0	0	Small point contact (<1m)
S351	26.023	-170.63	32.758	-170.63	547724.0	6273140.2	3.451476°N	42.956260°E	0	0	0	Small point contact (<1m)
S352	26.220	-284.36	32.955	-284.36	547873.3	6273320.4	3.452351°N	42.957414°E	0	0	0	Small point contact (<1m)
S353	26.249	-294.51	32.984	-294.51	547897.2	6273340.0	3.452495°N	42.957542°E	0	0	0	Small point contact (<1m)
S354	26.295	-60.54	33.030	-60.54	548020.9	6273136.2	3.453347°N	42.956341°E	4.9	2.4	0.5	Probable boulder
S355	26.401	-254.78	33.136	-254.78	548053.1	6273355.0	3.453471°N	42.957689°E	0	0	0	Small point contact (<1m)
S356	26.357	-74.93	33.092	-74.93	548074.1	6273171.1	3.453669°N	42.956573°E	3.3	1.8	1.1	Probable boulder
S357	26.514	-373.05	33.249	-373.05	548131.6	6273507.1	3.453911°N	42.958646°E	0	0	0	Small point contact (<1m)
S358	26.435	234.08	33.170	234.08	548254.5	6272908.2	3.454900°N	42.955031°E	0	0	0	Small point contact (<1m)
S359	26.431	329.14	33.166	329.14	548283.0	6272817.4	3.455112°N	42.954487°E	7.5	2.1	0.3	Probable boulder
S360	26.438	328.88	33.173	328.88	548289.6	6272820.1	3.455152°N	42.954506°E	0	0	0	Small point contact (<1m)
S361	26.488	228.71	33.223	228.71	548295.4	6272927.5	3.455151°N	42.955164°E	0	0	0	Small point contact (<1m)
S362	27.011	-233.21	33.746	-233.21	548658.0	6273523.5	3.457218°N	42.958933°E	0	0	0	Small point contact (<1m)

	Northern Route		Southern Route									
Tag No.	KP	Offset	KP	Offset	Easting	Northing	Latitude UTM30	Longitude UTM30	Length (m)	Width (m)	Height (m)	Description
S363	27.276	75.84	34.011	75.84	548997.6	6273293.0	3.459439°N	42.957647°E	29	8	0	Possible debris
S364	27.386	-395.31	34.121	-395.31	549001.6	6273779.8	3.459290°N	42.960621°E	0	0	0	Small point contact (<1m)
S365	27.550	-446.99	34.285	-446.99	549152.0	6273865.2	3.460206°N	42.961196°E	3.7	1.8	0.2	Probable boulder
S366	27.356	463.67	34.091	463.67	549170.5	6272936.7	3.460656°N	42.955532°E	0	0	0	Small point contact (<1m)
S367	27.561	-143.49	34.296	-143.49	549226.5	6273570.8	3.460781°N	42.959425°E	0	0	0	Small point contact (<1m)
S368	27.565	-138.57	34.300	-138.57	549232.2	6273567.0	3.460818°N	42.959403°E	0	0	0	Small point contact (<1m)
S369	27.523	70.21	34.258	70.21	549235.0	6273354.0	3.460912°N	42.958104°E	0	0	0	Small point contact (<1m)
S370	27.529	67.94	34.264	67.94	549240.0	6273357.4	3.460943°N	42.958126°E	5.4	2.4	0.3	Probable boulder
S371	27.664	-548.4	34.399	-548.4	549241.9	6273988.4	3.460727°N	42.961980°E	0	0	0	Small point contact (<1m)
S372	27.665	-540.93	34.400	-540.93	549244.4	6273981.3	3.460745°N	42.961938°E	0	0	0	Small point contact (<1m)
S373	27.574	-86.37	34.309	-86.37	549251.2	6273517.7	3.460955°N	42.959109°E	0	0	0	Small point contact (<1m)
S374	27.677	-540.25	34.412	-540.25	549256.4	6273983.2	3.460821°N	42.961954°E	0	0	0	Small point contact (<1m)
S375	27.485	405.3	34.220	405.3	549268.0	6273018.3	3.461241°N	42.956065°E	0	0	0	Small point contact (<1m)
S376	27.698	-565.47	34.433	-565.47	549271.2	6274012.2	3.460903°N	42.962136°E	0	0	0	Small point contact (<1m)
S377	27.689	-434.15	34.424	-434.15	549290.9	6273882.1	3.461074°N	42.961349°E	0	0	0	Small point contact (<1m)
S378	27.694	-434.02	34.429	-434.02	549295.2	6273882.9	3.461101°N	42.961355°E	0	0	0	Small point contact (<1m)
S379	27.700	-433.77	34.435	-433.77	549303.8	6273884.5	3.461154°N	42.961368°E	0	0	0	Small point contact (<1m)
S380	27.848	-428.23	34.583	-428.23	549462.4	6273907.6	3.462145°N	42.961565°E	0	0	0	Small point contact (<1m)
S381	27.780	454.66	34.515	454.66	549552.3	6273026.7	3.463028°N	42.956218°E	0	0	0	Small point contact (<1m)
S382	28.018	-533.02	34.753	-533.02	549630.3	6274043.8	3.463152°N	42.962457°E	0	0	0	Small point contact (<1m)
S383	28.114	-70.77	34.849	-70.77	549790.7	6273599.9	3.464322°N	42.959804°E	0	0	0	Small point contact (<1m)
S384	28.226	367.89	34.961	367.89	549964.0	6273181.7	3.465564°N	42.957311°E	6.6	1.7	0.6	Probable boulder
S385	28.327	-35.07	35.062	-35.07	550008.3	6273595.2	3.465693°N	42.959853°E	0	0	0	Small point contact (<1m)
S386	28.578	-5.03	35.313	-5.03	550261.2	6273592.5	3.467287°N	42.959926°E	3.9	2	0.4	Probable boulder
S387	28.581	-9.67	35.316	-9.67	550263.3	6273597.4	3.467298°N	42.959957°E	0	0	0	Small point contact (<1m)
S388	28.616	446.08	35.351	446.08	550347.3	6273148.1	3.467989°N	42.957243°E	0	0	0	Small point contact (<1m)

	Northern Route		Southern Route									
Tag No.	KP	Offset	KP	Offset	Easting	Northing	Latitude UTM30	Longitude UTM30	Length (m)	Width (m)	Height (m)	Description
S389	28.753	3.92	35.488	3.92	550436.0	6273598.6	3.468385°N	42.960026°E	0	0	0	Small point contact (<1m)
S390	29.136	-99.55	35.871	-99.55	550814.0	6273723.8	3.470719°N	42.960926°E	8.5	1.4	0.7	Probable boulder
S391	29.130	251.4	35.865	251.4	550821.9	6273372.9	3.470896°N	42.958785°E	0	0	0	Small point contact (<1m)
S392	29.171	-329.46	35.906	-329.46	550840.3	6273954.9	3.470801°N	42.962347°E	5.6	3.2	0.7	Probable boulder
S393	29.182	-333.34	35.917	-333.34	550851.0	6273959.2	3.470867°N	42.962377°E	27.3	7.1	0	Unknown seabed feature
S394	29.257	-203.45	35.992	-203.45	550930.8	6273832.3	3.471415°N	42.961630°E	21	7	0	Possible debris
S395	29.394	-77.57	36.129	-77.57	551075.9	6273707.5	3.472373°N	42.960920°E	6	2.6	0.8	Probable boulder
S396	29.529	-233.65	36.264	-233.65	551210.1	6273864.1	3.473162°N	42.961924°E	0	0	0	Small point contact (<1m)
S397	30.029	269.93	36.764	269.93	551692.8	6273342.8	3.476389°N	42.958913°E	0	0	0	Small point contact (<1m)
S398	30.148	539.91	36.883	539.91	551793.2	6273065.6	3.477121°N	42.957256°E	132	30	11	Probable Wreck and associated debris
S399	30.176	178.88	36.911	178.88	551845.0	6273424.0	3.477317°N	42.959464°E	0	0	0	Small point contact (<1m)
S400	30.201	169.06	36.936	169.06	551871.4	6273432.1	3.477481°N	42.959523°E	0	0	0	Small point contact (<1m)
S401	30.599	-284.46	37.334	-284.46	552302.7	6273851.3	3.480044°N	42.962237°E	0	0	0	Small point contact (<1m)
S402	30.604	-284.78	37.339	-284.78	552307.7	6273851.2	3.480076°N	42.962238°E	0	0	0	Small point contact (<1m)
S403	30.672	-398.9	37.407	-398.9	552384.6	6273959.3	3.480521°N	42.962926°E	0	0	0	Small point contact (<1m)
S404	31.116	241.61	37.851	241.61	552773.3	6273284.1	3.483213°N	42.958942°E	0	0	0	Small point contact (<1m)
S405	31.126	240.8	37.861	240.8	552784.2	6273284.0	3.483281°N	42.958945°E	0	0	0	Small point contact (<1m)
S406	31.120	-318.61	37.855	-318.61	552824.5	6273842.0	3.483333°N	42.962367°E	0	0	0	Small point contact (<1m)
S407	31.196	-474.99	37.931	-474.99	552913.4	6273991.5	3.483838°N	42.963312°E	5.6	2.4	0.2	Probable boulder
S408	31.210	-471.7	37.945	-471.7	552926.5	6273987.1	3.483922°N	42.963290°E	0	0	0	Small point contact (<1m)
S409	31.368	189.2	38.103	189.2	553029.5	6273315.3	3.484814°N	42.959224°E	0	0	0	Small point contact (<1m)
S410	31.352	-392.53	38.087	-392.53	553061.3	6273896.4	3.484803°N	42.962784°E	0	0	0	Small point contact (<1m)
S411	31.420	388.34	38.155	388.34	553065.0	6273112.5	3.485111°N	42.957999°E	0	0	0	Small point contact (<1m)
S412	31.361	-396.05	38.096	-396.05	553071.3	6273899.1	3.484865°N	42.962805°E	0	0	0	Small point contact (<1m)
S413	31.433	186.92	38.168	186.92	553094.1	6273312.2	3.485221°N	42.959229°E	0	0	0	Small point contact (<1m)
S414	31.473	81.52	38.208	81.52	553142.7	6273413.9	3.485491°N	42.959867°E	0	0	0	Small point contact (<1m)

	Northern Route		Southern Route									
Tag No.	KP	Offset	KP	Offset	Easting	Northing	Latitude UTM30	Longitude UTM30	Length (m)	Width (m)	Height (m)	Description
S415	31.475	81.47	38.210	81.47	553144.6	6273413.8	3.485503°N	42.959867°E	0	0	0	Small point contact (<1m)
S416	31.469	-364.31	38.204	-364.31	553176.0	6273858.5	3.485539°N	42.962594°E	0	0	0	Small point contact (<1m)
S417	31.482	-364.17	38.217	-364.17	553188.7	6273857.3	3.485620°N	42.962592°E	4.9	1.3	0.2	Probable boulder
S418	31.536	-171.92	38.271	-171.92	553226.8	6273661.2	3.485930°N	42.961408°E	0	0	0	Small point contact (<1m)
S419	31.551	-296.26	38.286	-296.26	553251.7	6273783.9	3.486043°N	42.962166°E	0	0	0	Small point contact (<1m)
S420	31.591	162.15	38.326	162.15	553254.0	6273323.7	3.486224°N	42.959357°E	0	0	0	Small point contact (<1m)
S421	31.556	-294.84	38.291	-294.84	553257.3	6273782.0	3.486079°N	42.962156°E	0	0	0	Small point contact (<1m)
S422	31.622	98.91	38.357	98.91	553289.5	6273384.2	3.486425°N	42.959739°E	0	0	0	Small point contact (<1m)
S423	31.624	100.25	38.359	100.25	553291.3	6273382.7	3.486438°N	42.959730°E	0	0	0	Small point contact (<1m)
S424	31.631	165.59	38.366	165.59	553292.9	6273317.0	3.486471°N	42.959330°E	0	0	0	Small point contact (<1m)
S425	31.636	167.41	38.371	167.41	553298.6	6273314.7	3.486508°N	42.959317°E	0	0	0	Small point contact (<1m)
S426	31.646	191.97	38.381	191.97	553306.4	6273289.4	3.486566°N	42.959166°E	0	0	0	Small point contact (<1m)
S427	31.679	133.28	38.414	133.28	553343.4	6273345.2	3.486779°N	42.959520°E	0	0	0	Small point contact (<1m)
S428	31.683	135.12	38.418	135.12	553347.7	6273343.0	3.486807°N	42.959508°E	0	0	0	Small point contact (<1m)
S429	31.707	105.63	38.442	105.63	553373.9	6273370.4	3.486962°N	42.959685°E	0	0	0	Small point contact (<1m)
S430	31.741	191.51	38.476	191.51	553400.5	6273282.0	3.487162°N	42.959154°E	0	0	0	Small point contact (<1m)
S431	31.738	93.28	38.473	93.28	553406.2	6273380.1	3.487162°N	42.959755°E	6.1	2.3	0.4	Probable boulder
S432	31.742	89.82	38.477	89.82	553410.7	6273383.2	3.487189°N	42.959776°E	0	0	0	Small point contact (<1m)
S433	31.896	273.85	38.631	273.85	553548.7	6273187.0	3.488129°N	42.958627°E	0	0	0	Small point contact (<1m)
S434	31.983	369.68	38.718	369.68	553627.0	6273084.3	3.488659°N	42.958028°E	0	0	0	Small point contact (<1m)
S435	31.937	-295.1	38.672	-295.1	553636.5	6273750.6	3.488477°N	42.962101°E	0	0	0	Small point contact (<1m)
S436	32.047	204.6	38.782	204.6	553704.3	6273243.5	3.489088°N	42.959028°E	0	0	0	Small point contact (<1m)
S437	32.059	190.3	38.794	190.3	553718.1	6273256.7	3.489170°N	42.959114°E	0	0	0	Small point contact (<1m)
S438	32.091	462.77	38.826	462.77	553727.4	6272982.5	3.489328°N	42.957442°E	0	0	0	Small point contact (<1m)
S439	32.069	129.52	38.804	129.52	553732.4	6273316.5	3.489239°N	42.959484°E	0	0	0	Small point contact (<1m)
S440	32.099	459.14	38.834	459.14	553735.2	6272985.5	3.489376°N	42.957464°E	0	0	0	Small point contact (<1m)

	Northern Route		Southern Route									
Tag No.	KP	Offset	KP	Offset	Easting	Northing	Latitude UTM30	Longitude UTM30	Length (m)	Width (m)	Height (m)	Description
S441	32.102	402.11	38.837	402.11	553742.7	6273042.1	3.489403°N	42.957812°E	0	0	0	Small point contact (<1m)
S442	32.229	554.74	38.964	554.74	553856.9	6272879.4	3.490181°N	42.956859°E	0	0	0	Small point contact (<1m)
S443	32.401	-26.36	39.136	-26.36	554076.3	6273444.2	3.491357°N	42.960388°E	0	0	0	Small point contact (<1m)
S444	32.451	-211.28	39.186	-211.28	554141.8	6273624.3	3.491704°N	42.961511°E	0	0	0	Small point contact (<1m)
S445	32.590	564.03	39.325	564.03	554215.9	6272840.1	3.492455°N	42.956748°E	0	0	0	Small point contact (<1m)
S446	32.610	586.26	39.345	586.26	554233.8	6272816.3	3.492577°N	42.956609°E	0	0	0	Small point contact (<1m)
S447	32.749	-557.67	39.484	-557.67	554467.5	6273944.7	3.493638°N	42.963585°E	0	0	0	Small point contact (<1m)
S448	32.889	-197.08	39.624	-197.08	554577.1	6273573.7	3.494462°N	42.961358°E	0	0	0	Small point contact (<1m)
S449	32.953	-266.73	39.688	-266.73	554646.4	6273637.8	3.494875°N	42.961775°E	0	0	0	Small point contact (<1m)
S450	32.981	-228.84	39.716	-228.84	554671.4	6273597.7	3.495048°N	42.961539°E	0	0	0	Small point contact (<1m)
S451	33.078	35.78	39.813	35.78	554746.3	6273325.9	3.495618°N	42.959906°E	0	0	0	Small point contact (<1m)
S452	33.078	35.26	39.813	35.26	554746.5	6273326.4	3.495619°N	42.959909°E	0	0	0	Small point contact (<1m)
S453	33.087	35.17	39.822	35.17	554754.8	6273325.8	3.495671°N	42.959909°E	4.1	2.4	0.2	Probable boulder
S454	33.109	-515.41	39.844	-515.41	554823.0	6273872.6	3.495902°N	42.963272°E	0	0	0	Small point contact (<1m)
S455	33.351	147.47	40.086	147.47	555008.8	6273191.9	3.497319°N	42.959183°E	0	0	0	Small point contact (<1m)
S456	33.656	-298.83	40.391	-298.83	555349.6	6273611.3	3.499312°N	42.961866°E	0	0	0	Small point contact (<1m)

Magnetic Anomaly Listings

	Northern Route		Southern Route									
Anomaly ID	KP	Offset	KP	Offset	Eastings	Northings	Latitude UTM30	Longitude UTM30	Width (m)	Height (nT)	Description	Comments
M001			-0.195	121.15	517727.8	6260282.6	3.266987°N	42.867264°E	12.0	7.0	Negative Monopole	
M002			-0.039	-515.93	517778.2	6260936.6	3.267083°N	42.871283°E	10.5	4.0	Asymmetric Dipole	
M003			-0.095	-86.12	517792.2	6260503.3	3.267319°N	42.868636°E	84.3	1686.4	Complex Dipole	
M004			-0.020	-542.1	517792.6	6260965.5	3.267164°N	42.871465°E	21.1	15.0	Dipole	
M005			0.002	-64.41	517891.7	6260497.7	3.267947°N	42.868635°E	29.7	193.4	Dipole	
M006			0.118	-495.56	517936.1	6260942.0	3.268076°N	42.871369°E	45.4	4.2	Positive Monopole	
M007			1.851	-105.97	519709.1	6260839.6	3.279289°N	42.871341°E	50.8	4.6	Positive Monopole	Possibly Geological
M008			2.982	-235.7	520792.7	6261171.5	3.286007°N	42.873739°E	57.8	8.5	Positive Monopole	Possibly Geological
M009			2.975	303.18	520891.4	6260641.7	3.286810°N	42.870530°E	40.8	8.2	Dipole	
M010			3.111	115.89	520987.4	6260851.8	3.287344°N	42.871848°E	17.3	3.3	Dipole	
M011			3.227	115.3	521101.8	6260875.2	3.288057°N	42.872030°E	23.1	15.3	Asymetric Dipole	
M012			3.335	302.07	521244.0	6260713.1	3.289009°N	42.871086°E	12.3	6.7	Positive Monopole	
M013			3.394	302.45	521301.6	6260724.2	3.289369°N	42.871174°E	15.1	13.5	Asymetric Dipole	
M014			3.420	416.78	521349.7	6260617.2	3.289709°N	42.870535°E	28.4	46.9	Asymetric Dipole	
M015			3.475	300.39	521380.9	6260742.1	3.289862°N	42.871310°E	21.4	10.2	Dipole	
M016			3.554	-1.29	521398.9	6261053.3	3.289870°N	42.873221°E	12.5	4.6	Positive Monopole	
M017			3.551	299.18	521455.0	6260758.1	3.290324°N	42.871434°E	27.9	3.9	Dipole	
M018			3.495	649.88	521469.0	6260403.3	3.290534°N	42.869267°E	153.7	36.3	Dipole	
M019			3.793	-495.29	521537.3	6261584.6	3.290560°N	42.876519°E	38.2	4.7	Positive Monopole	
M020			3.629	416.15	521554.7	6260658.7	3.290987°N	42.870859°E	28.6	7.0	Asymetric Dipole	
M021			3.735	-4.76	521576.3	6261092.2	3.290975°N	42.873519°E	11.3	21.6	Positive Monopole	
M022			3.860	-249.03	521651.2	6261356.2	3.291356°N	42.875160°E	59.9	3.9	Negative Monopole	Possibly Geological
M023			3.752	410.91	521673.9	6260687.8	3.291728°N	42.871077°E	19.0	4.8	Positive Monopole	
M024			3.850	-7.56	521688.4	6261117.4	3.291672°N	42.873712°E	9.0	1.2	Negative Monopole	
M025			3.933	105.67	521797.3	6261023.9	3.292391°N	42.873176°E	26.5	27.6	Dipole	

	Northern Route		Southern Route									
Anomaly ID	KP	Offset	KP	Offset	Eastings	Northings	Latitude UTM30	Longitude UTM30	Width (m)	Height (nT)	Description	Comments
M026			3.991	-5.19	521826.2	6261145.5	3.292531°N	42.873930°E	16.9	13.8	Dipole	
M027			3.930	409.46	521848.6	6260724.1	3.292817°N	42.871359°E	26.3	11.7	Dipole	
M028			4.140	-8.2	521970.4	6261184.9	3.293427°N	42.874220°E	12.7	4.4	Positive Monopole	
M029			4.268	105.93	522121.7	6261105.3	3.294408°N	42.873784°E	22.0	6.8	Positive Monopole	
M030			4.487	-420.33	522205.6	6261669.1	3.294743°N	42.877263°E	31.7	4.8	Dipole	
M031			4.287	411.58	522215.0	6260813.6	3.295097°N	42.872031°E	20.6	12.6	Positive Monopole	
M032			4.673	-242.13	522429.9	6261541.8	3.296201°N	42.876560°E	25.6	2.8	Dipole	
M033			5.351	-92.68	523115.3	6261581.5	3.300508°N	42.877036°E	60.7	8.2	Positive Monopole	Possibly Geological
M034			5.581	-398.3	523239.0	6261936.7	3.301166°N	42.879252°E	48.8	7.9	Negative Monopole	
M035			5.700	-489.93	523324.2	6262060.6	3.301661°N	42.880038°E	51.0	4.7	Dipole	
M036	0.280	577.7			523326.3	6265213.7	3.300591°N	42.899328°E	29.8	2.8	Dipole	
M037			5.428	491.98	523350.6	6261040.8	3.302177°N	42.873808°E	31.4	4.9	Positive Monopole	
M038	0.349	395.35			523402.1	6265393.4	3.301007°N	42.900453°E	33.9	1.6	Dipole	
M039			5.476	615.17	523430.9	6260935.7	3.302720°N	42.873191°E	38.5	5.1	Asymetric Dipole	
M040	0.397	399.9			523449.9	6265387.1	3.301310°N	42.900431°E	26.4	0.6	Dipole	
M041			5.475	813.48	523485.3	6260745.0	3.303129°N	42.872043°E	45.4	17.4	Negative Monopole	
M042	0.950	342.53			524005.1	6265424.2	3.304795°N	42.900847°E	30.1	1.3	Negative Monopole	
M043			6.487	-489.73	524055.4	6262302.5	3.306186°N	42.881768°E	350.0	7713.1	Complex Dipole	WRECK
M044			6.505	-299.49	524137.0	6262129.7	3.306761°N	42.880738°E	34.1	24.1	Positive Monopole	Possibly wreck-associated debris?
M045			6.473	327.95	524320.0	6261528.7	3.308121°N	42.877124°E	31.1	2.4	Positive Monopole	
M046	1.304	102.15			524367.0	6265651.5	3.306998°N	42.902360°E	18.5	1.6	Positive Monopole	
M047	1.343	-247.42			524418.9	6265999.4	3.307205°N	42.904505°E	39.7	1.9	Positive Monopole	
M048	1.620	-396.15			524701.3	6266137.9	3.308937°N	42.905448°E	28.8	1.8	Positive Monopole	
M049	1.660	-293.05			524737.8	6266033.4	3.309203°N	42.904822°E	44.9	5.1	Positive Monopole	
M050	2.178	207.54			525237.1	6265514.2	3.312528°N	42.901817°E	53.2	2.1	Negative Monopole	
M051	2.350	88.49			525412.9	6265626.9	3.313597°N	42.902566°E	4.2	16.9	Positive Monopole	

	Northern Route		Southern Route									
Anomaly ID	KP	Offset	KP	Offset	Eastings	Northings	Latitude UTM30	Longitude UTM30	Width (m)	Height (nT)	Description	Comments
M052	2.374	88.13			525436.6	6265626.4	3.313746°N	42.902571°E	4.9	18.2	Negative Monopole	
M053	2.511	-658.2			525601.4	6266367.2	3.314529°N	42.907158°E	17.7	8.4	Negative Monopole	
M054	2.514	-596.05			525601.5	6266305.0	3.314551°N	42.906777°E	15.2	19.2	Positive Monopole	
M055	2.573	-395.79			525653.5	6266102.7	3.314949°N	42.905558°E	35.6	2.1	Positive Monopole	Possibly Geological
M056	2.916	-293.67			525992.9	6265988.1	3.317127°N	42.904973°E	40.8	1.9	Dipole	
M057			8.737	412.62	526486.7	6262309.4	3.321509°N	42.882640°E	43.2	1.5	Dipole	
M058	3.508	-462.61			526567.4	6266145.3	3.320692°N	42.906131°E	114.2	28.2	Dipole	
M059	3.509	544.39			526582.1	6265138.4	3.321133°N	42.899979°E	128.5	10.3	Negative Monopole	Possibly Geological
M060			9.468	-20.89	526958.7	6263015.7	3.324240°N	42.887123°E	50.0	3.0	Negative Monopole	
M061	4.626	-500.11			527579.1	6266296.1	3.327015°N	42.907400°E	98.7	6.7	Positive Monopole	Possibly Geological
M062	4.908	-410.66			527859.3	6266269.2	3.328790°N	42.907331°E	38.2	3.3	Dipole	
M063	5.256	-410.48			528167.3	6266358.2	3.330699°N	42.907981°E	52.8	7.0	Positive Monopole	Possibly Geological
M064	5.617	-495.03			528459.4	6266549.9	3.332473°N	42.909253°E	59.3	3.9	Positive Monopole	Possibly Geological
M065	6.723	-407.58			529525.9	6266855.0	3.339086°N	42.911486°E	51.7	3.0	Negative Monopole	
M066			14.241	-443.3	530737.9	6265883.0	3.347061°N	42.905959°E	214.6	181.3	Dipole	WRECK
M067	8.263	-203.56			531040.3	6267203.0	3.348507°N	42.914135°E	195.7	4.1	Negative Monopole	
M068	8.439	406.78			531418.9	6266692.9	3.351070°N	42.911147°E	91.7	7.5	Dipole	
M069	11.157	277.27	17.901	-202.1	533919.5	6267765.4	3.366448°N	42.918569°E	87.0	2.5	Positive Monopole	
M070	15.007	43.62	21.741	5.43	537443.7	6269331.5	3.388097°N	42.929369°E	138.2	5.0	Dipole	
M071	15.012	339.79	21.731	301.51	537552.8	6269056.1	3.388881°N	42.927723°E	97.2	7.1	Positive Monopole	
M072	30.136	476.66	36.871	476.66	551785.5	6273129.5	3.477049°N	42.957643°E	643.3	688.0	Asymetric Complex Dipole	

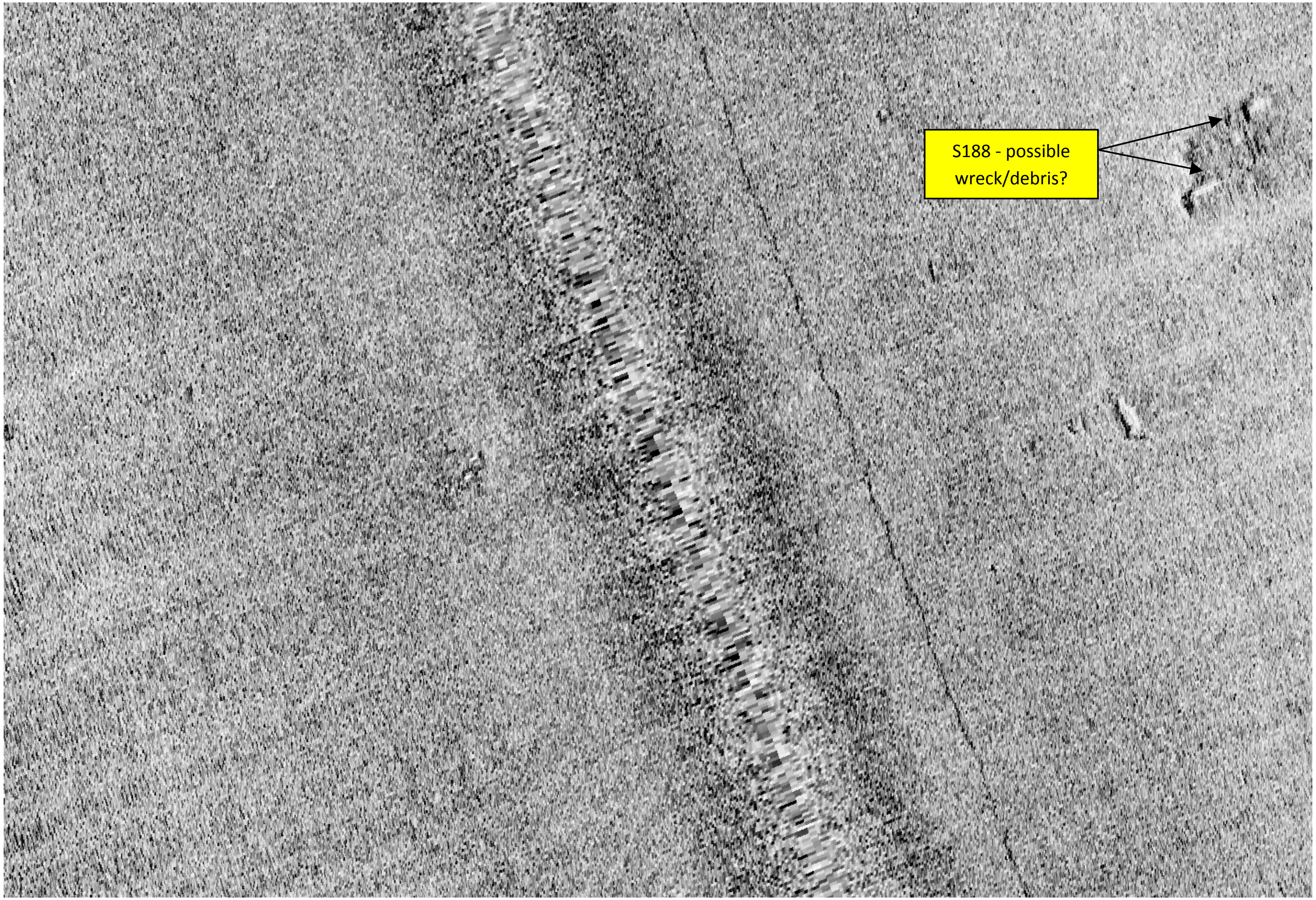
Wreck Listings (Provided by Client)

Wreck Name	Eastings (m)	Northings (m)	Vessel Type	Classification
SS Herrington	532733	6308831	Steamer	Dangerous
HMS Phineas Beard	535028	6214122	Armed Trawler	Dangerous
Unknown	534793	6273114	?	Unknown
Unknown	536892	6278809	?	Unknown
Unknown	539408	6272042	?	Unknown
SS Canginian	538984	6271370	Steamer	Non-dangerous
Margaret Rae	538631	6269697	Trawler	Non-dangerous
MFV Aurora	543306	6269297	Trawler	Non-dangerous
Primrose	546094	6272889	Unknown	Non-dangerous
Braconburn	551208	6271500	Trawler	Unknown
Unknown	551861	6273289	Unknown	Unknown
HMT Braconburn (possible)	552074	6275964	Trawler	Unknown
Unknown	553983	6270644	Unknown	Unknown
Unknown	555826	6270688	Unknown	Unknown
SS Grenmar	557073	6260221	Cargo Steamer	Non-dangerous
Queen of the Fleet	536947	6258439	Unknown	Unknown
SS Bay Fisher	541873	6258819	Steamer	Non-dangerous
Maggie Smith	535639	6260098	Sailing Vessel	Foul Ground
UC 41	524340	6254230	Submarine	Dangerous
HMT Fertile Vale	521253	6254881	Trawler	Dangerous
Clan Shaw (Part of)	521866	6255441	Steamer	Dangerous
SS Anu	524656	6256236	Steamer	Dangerous
Protector	518861	6256318	Tug	Dangerous
Uku	517559	6258093	Trawler	Unknown
Isla May	521808	6258670	Small Fishing Boat	Foul Ground
HMS Argyll	537432	6254438	Cruiser	Non-dangerous

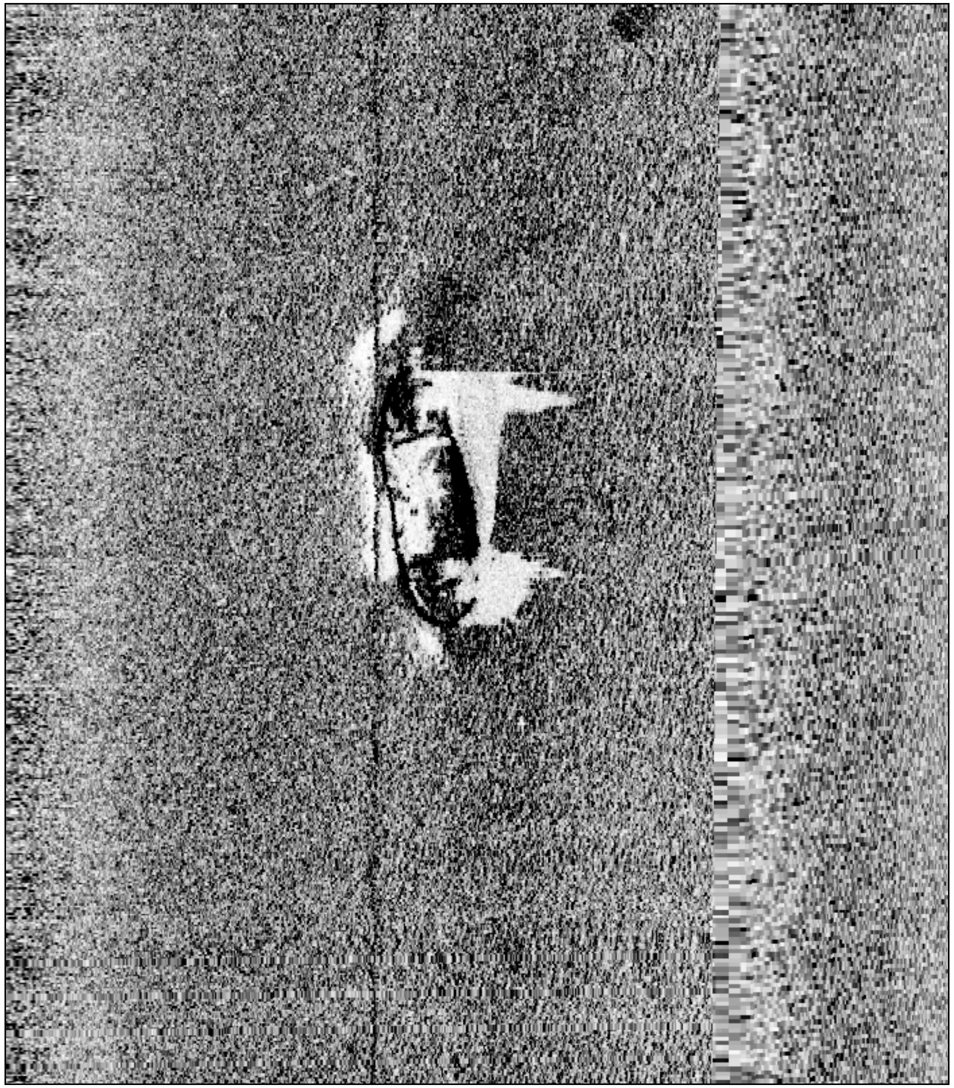
APPENDIX 3

DATA EXAMPLES

Sonar target S001 (centre of image)

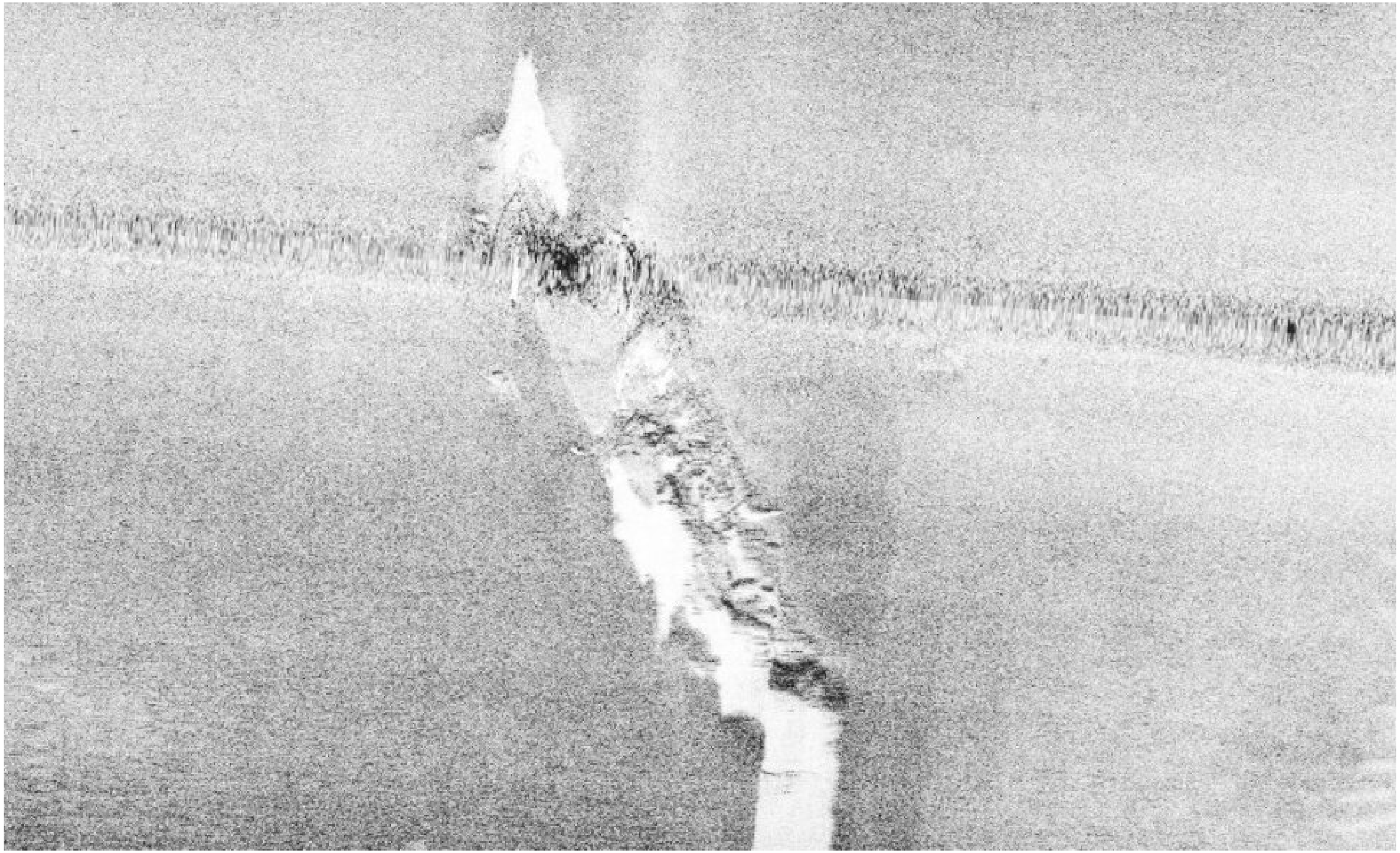


Sonar Target S188 - Wreck?



Wreck – Sonar target S190

Wreck – Sonar targets S018 & S019



Wreck – Sonar target S398

Part III

Summary of Seagreen Firth of Forth Metocean Surveys to Date

(Intertek Metoc, June 2011)

SEAGREEN WIND ENERGY

SUMMARY OF SEAGREEN FIRTH OF FORTH METOCEAN SURVEYS TO DATE

Report Reference. P1398G_R2981 Rev 0

Issued 07 June 2012

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SUMMARY

Intertek METOC prepared this metocean summary report for inclusion as a Technical Appendix to Seagreen's Environmental Statement relating to development of the UK Round 3 Offshore Wind Farm (OWF) Zone 2 Firth of Forth, which will be available for Regulator and public scrutiny. This metocean summary report aims to:

1. Describe the metocean data gathering strategy developed by Intertek METOC and Seagreen (parameters, type of instruments, number and choice of locations, planned duration and expected benefits).

2. Give an overview of data returns and timeline of valid data and present the key metocean data obtained for waves, currents and water levels and seawater quality parameters (temperature, salinity, suspended solids), discuss the key features of these and relate to the wider understanding of the hydrography of the Scottish North Sea area.

3. State the general implications for environmental aspects of the OWF development and confirm the adequacy of the Metocean survey outputs for describing the environmental characteristics of the OWF and export cable route options and informing the coastal process modelling effort.

The measurement campaign was designed to capture metocean conditions particularly in winter storms, and to examine spatial variation of their magnitude across the development area and its export cable routes to shore. It allowed for some redundancy in the event of data loss. A Datawell Waverider (DWR) buoy was deployed in the offshore side of the Zone, transmitting data ashore continuously from December 2010 to mid May 2012 when it was demobilised.

All other instruments – Acoustic Wave & Current (AWAC) devices and Acoustic Doppler Current Profilers (ADCPs) – were mounted on seabed frames and were visited periodically to recover data. They initially suffered data loss and only collected data during March to June 2011 so further measurements were made at the shore end sites over the period December 2011 to June 2012. At the time of writing their final recovery is imminent and so there is potential to include the final data – and the last portion of waverider data – in a revision of this report at a later date.

The data already in hand have been used and deemed adequate for a coastal processes study. There is potential for further study using a numerical modelling approach.

CONTENTS

TABLES

FIGURES

1 INTRODUCTION

1.1 PURPOSE OF THIS DOCUMENT

This document is prepared for inclusion as a Technical Appendix to Seagreen's Environmental Statement relating to development of the UK Round 3 Offshore Wind Farm Zone 2 Firth of Forth, which will be available for Regulator and public scrutiny.

This document provides information relating to metocean surveys that Seagreen has commissioned in the Zone during 2010-2012 insofar as they are relevant to the Environmental Statement. It includes:

- The reason why the metocean campaign was commissioned
- A concise summary of the metocean acquisition to date
- An evaluation of the relevance of the acquired data and comment on their implications for the environmental assessment of the offshore wind farm.

At the time of writing the metocean measurements are approaching completion and some of the data already collected are still in preparation; thus there is scope to update this report when the final data are available.

1.2 METOCEAN CAMPAIGN PURPOSE AND STRATEGY

The purpose of the metocean campaign was to provide sufficient detailed understanding of the oceanography of the area to be able to perform the environmental impact assessments required for its development. Existing data sources go some way towards this but were not considered to provide the level of detail required and therefore would need to be supplemented with site specific measurements.

The way to achieve this was considered and set out in an internal strategy document that Seagreen prepared in June 2010 with input from Intertek METOC. Zone 3 is being developed in a phased approach and all sites will be licensed individually but the metocean survey was designed to inform the assessment of all phases within the Zone. It also addresses the anticipated landfall areas for the two export cable routes: in the Arbroath-Carnoustie stretch of the Angus coastline (Phase 1) and near Torness in East Lothian (Phases 2 and 3).

Zone and site specific data were required for both coastal processes and engineering design purposes. The oceanography survey design took into account the following requirements:

- Provision of information to support the coastal processes assessment for Environmental Impact Assessment (EIA) and also cumulative effects studies, including providing model calibration data
- Provision of information to support development of engineering design criteria for offshore structures, infield and export cables
- Provision of information to support development of construction and subsequent Operation and Maintenance (O&M) strategies – potentially including use of data in real time for vessel and activity management

- Potential input to ecological studies linking water column mixing to productivity and preferential use of areas by marine predators (birds/cetaceans) and prey species

1.3 SURVEY REQUIREMENTS

1.3.1 Coastal processes data requirements:

The oceanography survey was required to provide sufficient data to support a modelling study of coastal processes for the project EIAs for wind farms developed in the Zone. Modelling at a regional scale was also being considered to address potential cumulative impacts arising from the development of multiple wind farms within the Zone and adjacent territorial waters. The survey data requirements included:

- Tidal heights
- Current speed and direction (minimum duration 6 weeks)
- Wave height, period and direction (minimum duration 6 months over winter)
- Seabed sediment description
- Suspended sediment information

Detailed bathymetric and seabed sediment data were available from the UK Hydrographic Office (UKHO) and from the geophysical survey output. These data are not addressed in the present review which considers just the oceanographic surveys.

Data were required at sufficient spatial resolution to adequately evaluate and describe the variability of coastal processes across the zone, with particular focus on those parts of the zone Seagreen had prioritised to take forward for development.

1.3.2 Engineering design criteria

The oceanography survey also needed to provide data to enable development of engineering design criteria. This includes:

- Tidal height and extreme water levels
- Tidal current loading and current vertical profile shape
- Wave loading and comparison with long term reference data sources
- Potential assessment of wind conditions
- Potential calibration of model hindcast data to support O&M strategy development

1.4 SURVEY CONSIDERATIONS

1.4.1 Amount of data required

At the time of designing the metocean surveys it was known that some data were being collected in neighbouring Scottish Territorial Waters (STW) offshore wind farm sites, which may have been of some value to Seagreen, but it was not known if they would ever be made available to the Project either in their own right or as part of a data exchange. Therefore all of Seagreen's metocean requirements would need to be met by its own campaign.

Furthermore, instruments would be required in enough numbers to allow redundancy in the event of data loss due to equipment malfunction or removal by trawling activity, etc.

1.4.2 Type of instruments

The range of water depths in Zone 2 partially dictated the type of metocean instruments that would be used. A favoured instrument is the Acoustic Wave and Current (AWAC) device, a seabed-mounted current profiler that also measures surface waves. However, in the deepest parts of the Zone the sea surface is beyond the acoustic sensors' range and so conventional Acoustic Doppler Current Profilers (ADCPs) were used at those sites, to collect currents without waves. AWACs and ADCPs would be upward-looking from the seabed, housed in protective frames.

A Datawell directional waverider (DWR) buoy was deployed inside the eastern limit of the Zone; this would provide real-time wave data of high quality and with a high probability of successful data recovery.

1.5 SURVEY PLAN

Instruments were positioned at eight sites A-H, six within Zone 2 and two near the candidate shore approaches, as shown in the location map Figure 1.1. The map also shows locations of measurements being collected in support of neighbouring developments.

Figure 1.1 Survey location plan

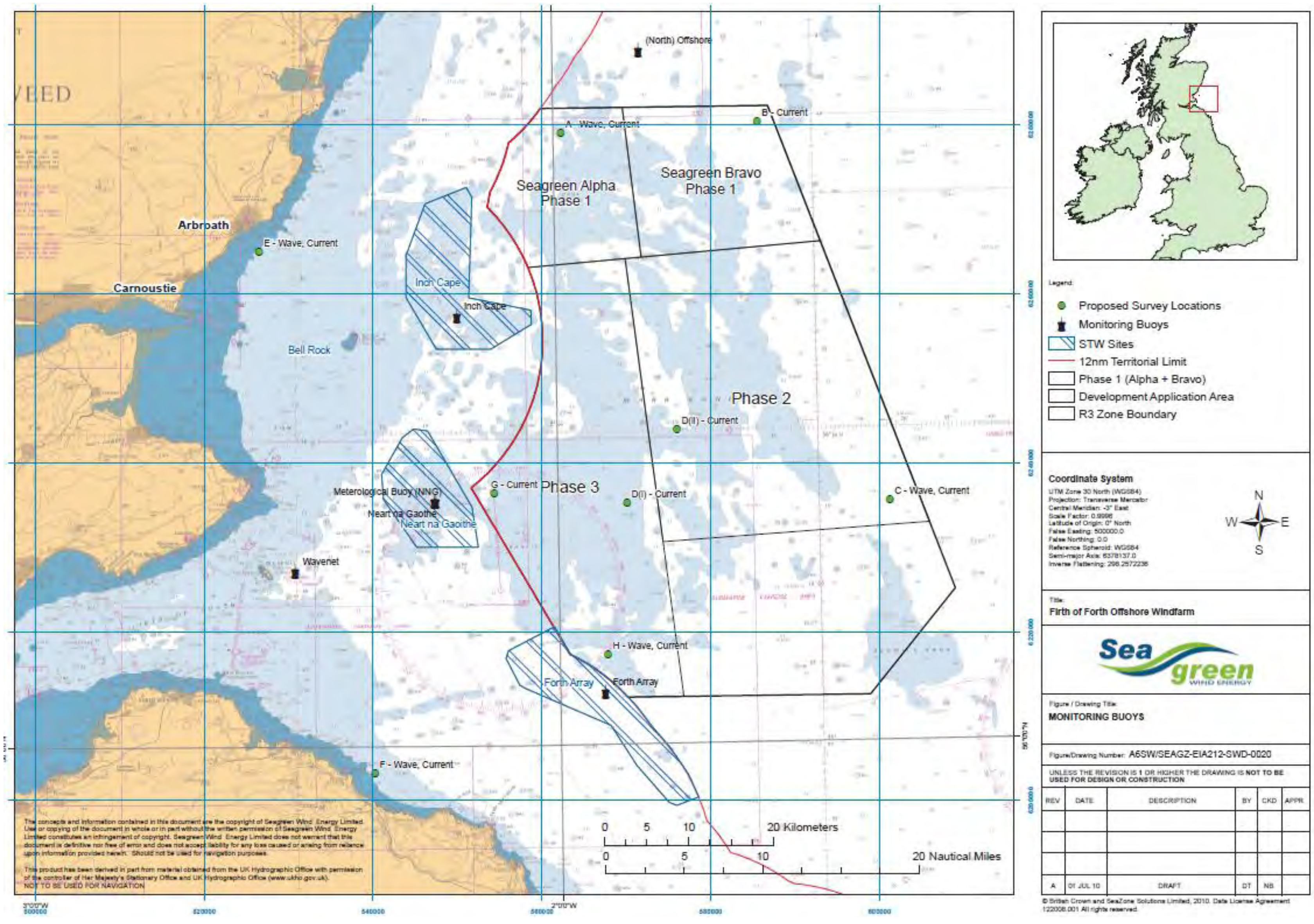


Table 1.1 Survey locations

Location	Required Parameters	Approx Depth	Easting (m)	Northing (m)	Lat° N	Long° E
A	Wave, Current	45 m	562246	6279054	56° 39.09'	-01° 59.09'
B	Current	55 m	585479	6280333	56° 39.56'	-01° 36.33'
C	Wave, Current	55 m	601204	6235642	56° 15.29'	-01° 21.99'
D	Current	50 m	575984	6243970	56° 20.06'	-01° 46.26'
E	Wave, Current	20 m	526493	6264951	56° 31.69'	-02° 34.16'
F	Wave, Current	20 m	540241	6203174	55° 58.33'	-02° 21.31'
G	Current	50 m	554356	6236342	56° 16.13'	-02° 07.34'
H	Wave, Current	50 m	567835	6217222	56° 05.72'	-01° 54.58'

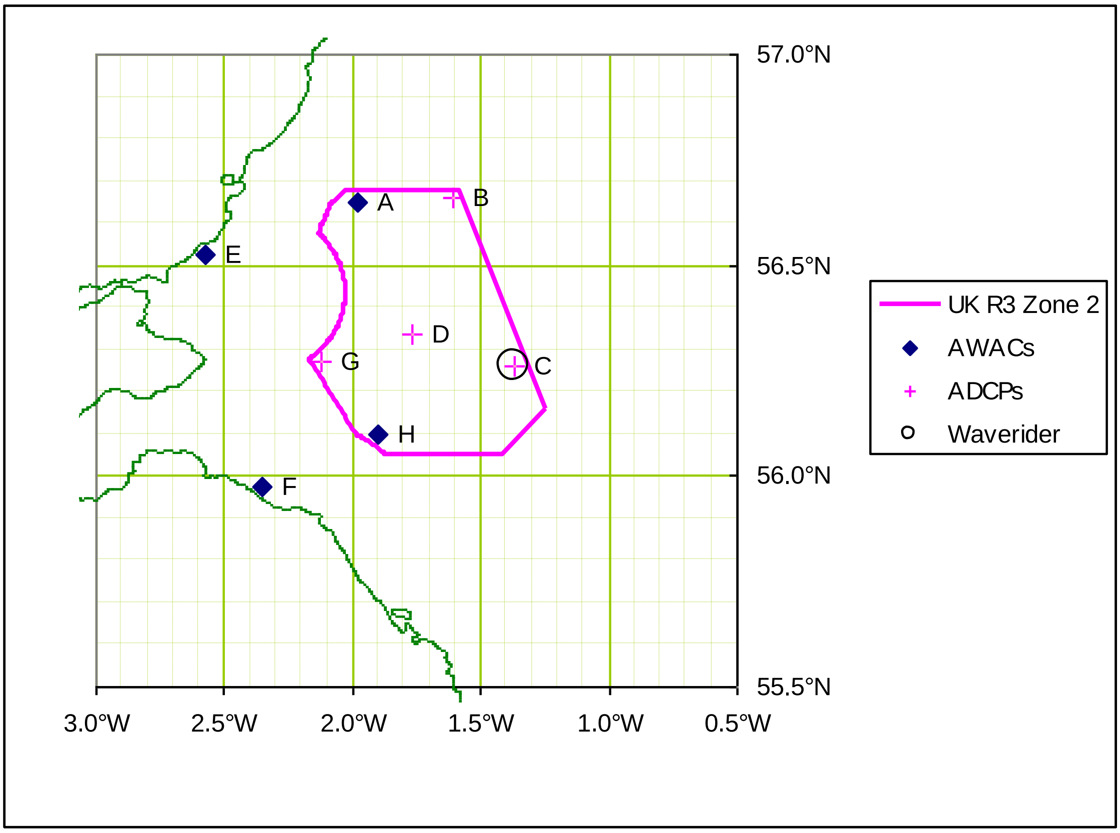
Easting and Northing are in UTM Zone 30N WGS84; latitude and longitude are in WGS84

Two instruments were deployed at site A in order to examine in more detail the near-bed current profile shape for engineering applications and to inform the coastal processes study. An ADCP was used to obtain high-resolution current profiles near the seabed, while an AWAC was deployed conventionally to sample currents throughout the greater part of the water column.

2 SUMMARY OF DATA COLLECTED

2.1 METOCEAN CAMPAIGN

Figure 2.1 Measurement locations



The plan was to capture wave data at three sites covering the Zone in a triangle CAH plus both shore ends E and F (see Figure 2.1). The Waverider buoy at C would provide a deep water benchmark; AWACs would be used at the other four sites. Currents would be measured at all of those sites plus three intermediate ones B, D, G within the Zone to better resolve the spatial variation of current strength and orientation.

This plan allowed for some redundancy in the event of data loss and was considered to be more than adequate if it achieved full data return at all sites.

The waverider was deployed continuously, and transmitted data ashore so that its status was always known with confidence. Conversely, the seabed frame-mounted instruments (AWACs and ADCPs) did not communicate but had to be visited periodically to recover their data.

2.2 DATA CAPTURED

Data returns are shown in Table 2.1 (wave) and Table 2.2 (current). The seabed-mounted instruments succeeded in capturing good quality wave and current data only in their 3rd phase of deployment (late March to early June 2011), and so further AWAC deployments were made at sites E and F to capture winter data from December 2011 through to mid-2012.

The Waverider successfully captured useful data throughout the period December 2010 to mid-May 2012.

Table 2.1 Wave data return

Site	Fugro Phase 1, 37 days 14.12.10 to 19.1.11	Fugro Phase 2, 62 days 19.1.11 to 22.3.11	Fugro Phase 3, 74 days 22.3.11 to 4.6.11	Partrac Further phases Dec 2011 to June 2012
C DWR	Yes	Yes	Yes	Yes to mid-May 2012
A AWAC			Yes	
H AWAC			Yes	
E AWAC			Yes	Yes
F AWAC			Yes (but no direction)	Yes

Table 2.2 Current data return

Site	Fugro Phase 1, 37 days 14.12.10 to 19.1.11	Fugro Phase 2, 62 days 19.1.11 to 22.3.11	Fugro Phase 3, 74 days 22.3.11 to 4.6.11	Partrac Further phases Dec 2011 to June 2012
A AWAC			Yes	
A ADCP			Part only	
B ADCP			Yes	
C ADCP			Yes	
D ADCP			Yes	
E AWAC			Yes	Yes
F AWAC			Yes	Yes
G ADCP			Yes	
H AWAC			Yes	

3 METOCEAN OVERVIEW

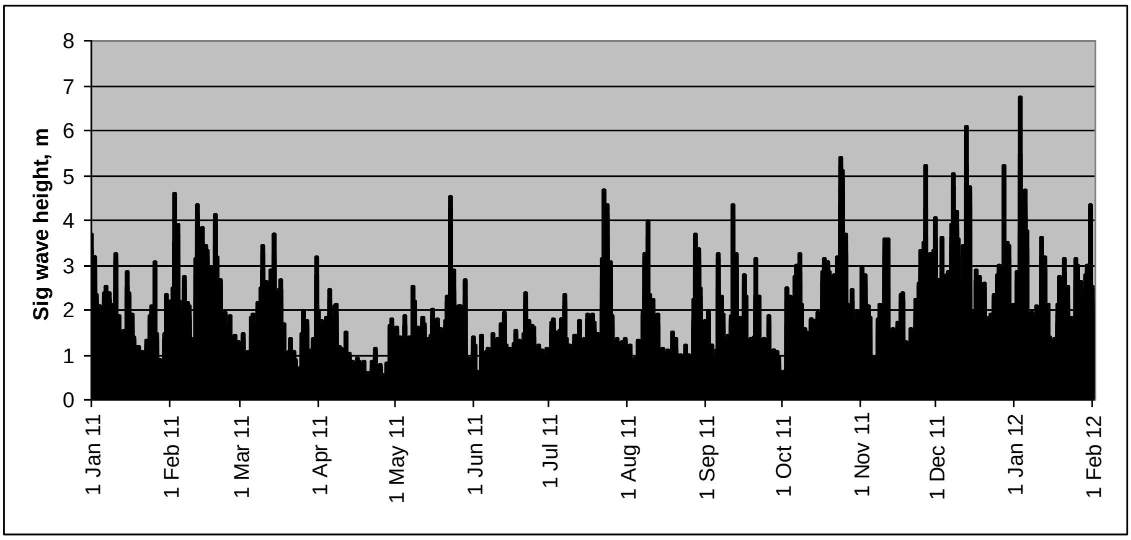
This section offers a brief and succinct summary of the metocean conditions at OWF Zone 2 Firth of Forth during the measurement campaign, with comments on how it fits with expectations for this part of the North Sea.

3.1 WAVES

3.1.1 Conditions in open water (site C)

Waverider data measured over the 13-month period Jan 2011 to Jan 2012 are presented here (Figure 3.1). Significant wave heights (Hs) reveal the seasonal signal with occasional storms in all seasons. The severity is consistent with expectations for the site as the largest Hs, around 6.7 m (measured on 3 January 2012), is equal to the one-year extreme in present use for operational applications.

Figure 3.1 Waverider site C – significant wave height time series



As the site is open to the North Sea it sometimes experiences comparatively long wave periods. The waverider data show spectral peak wave periods up to 20 seconds (Figure 3.2). These longer-period swell waves are most likely associated with storms in the Norwegian Sea. The direction plot (Figure 3.3) shows they mostly originate in the NNE (north-northeast) sector.

Such waves will generate near-bed wave orbital motions in excess of 1 m/s in the deeper parts of the Zone and therefore will be expected to contribute to sediment transport throughout the Zone.

Figure 3.2 Waverider site C – maximum wave height vs peak wave period

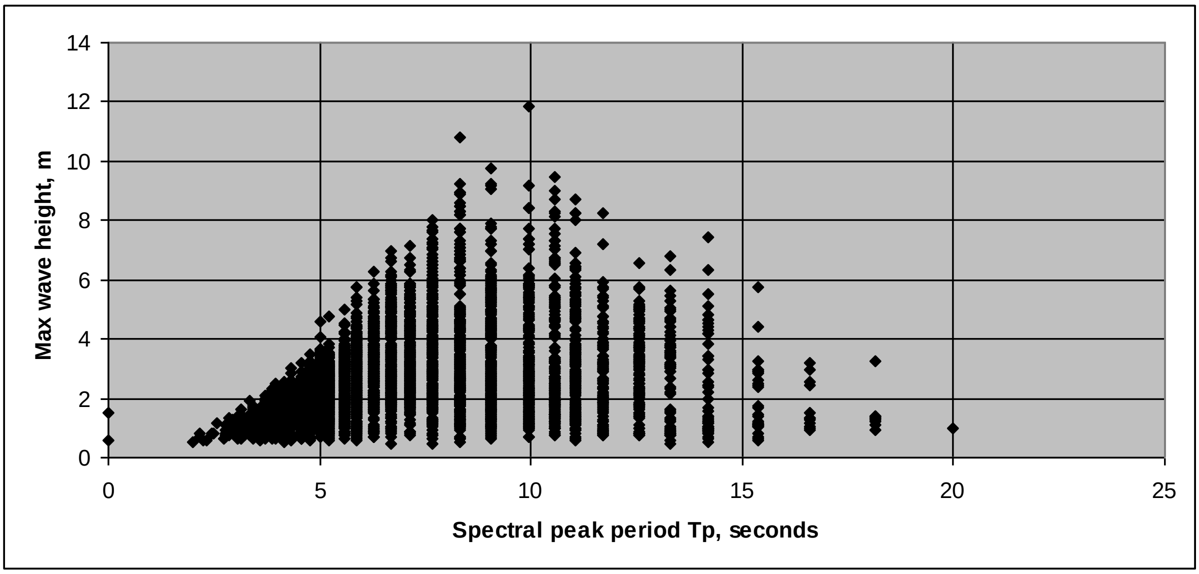
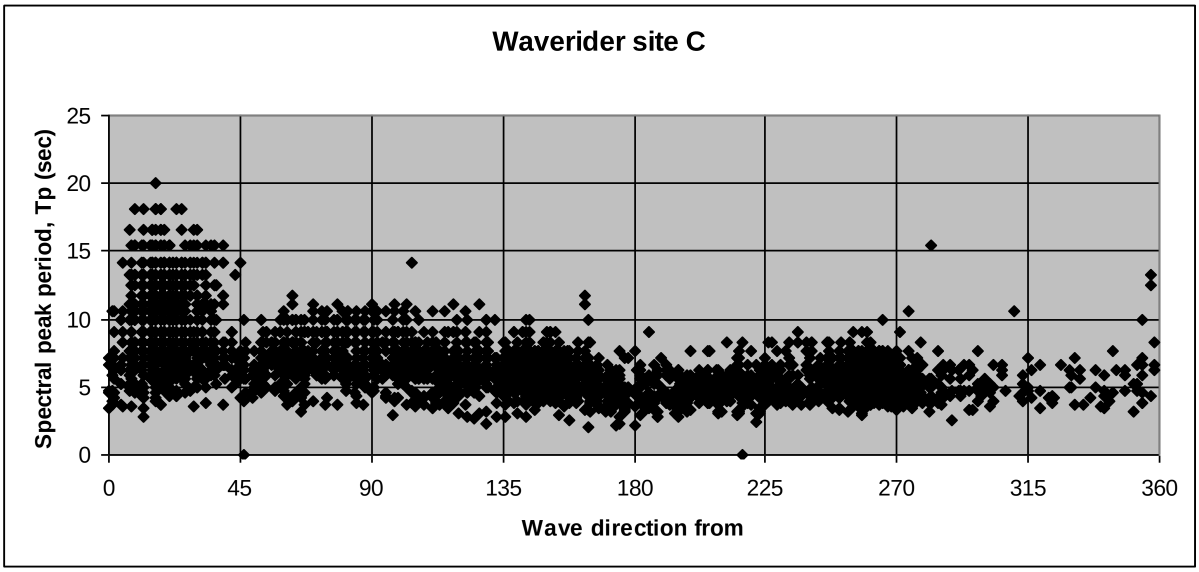
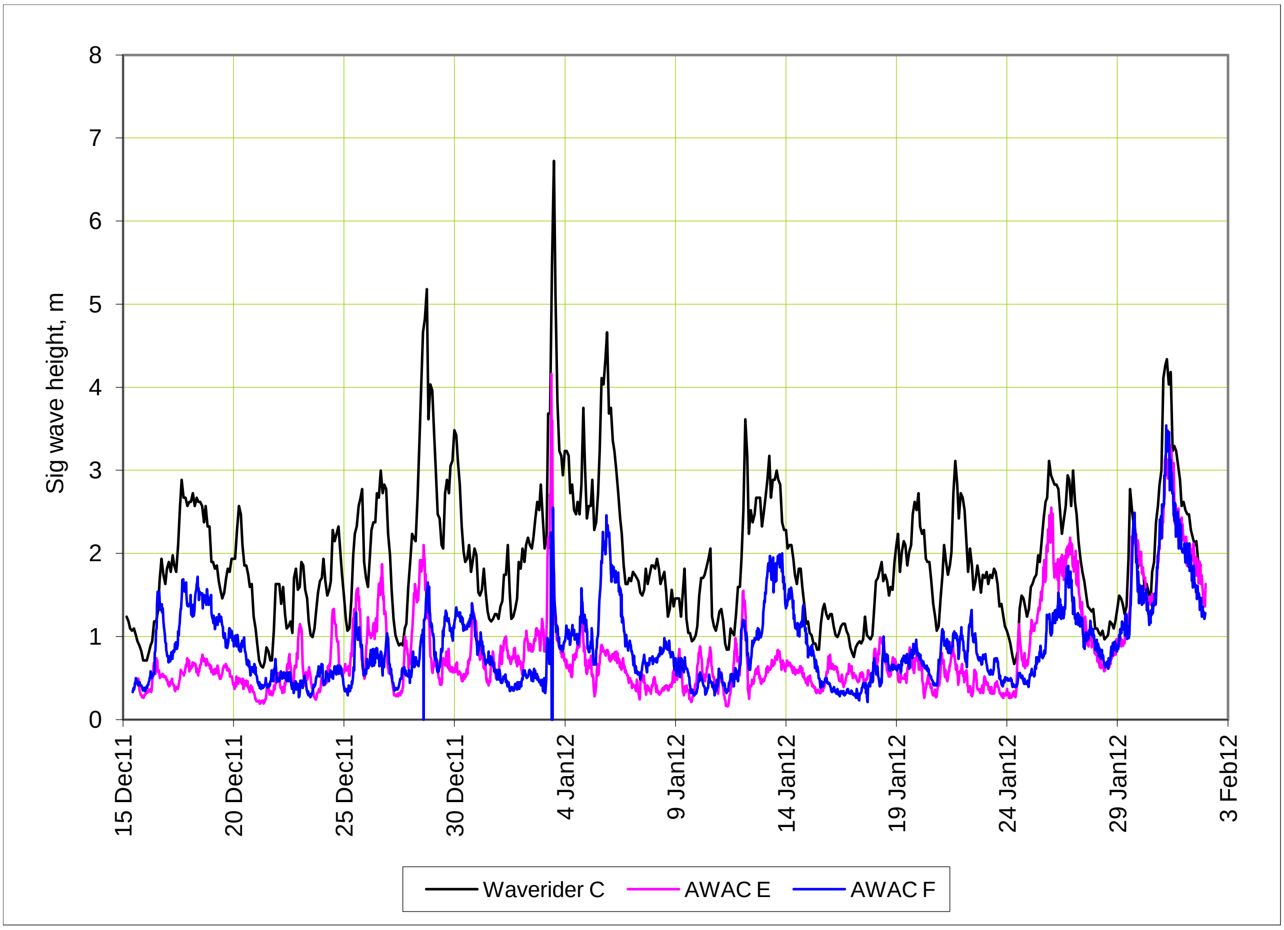


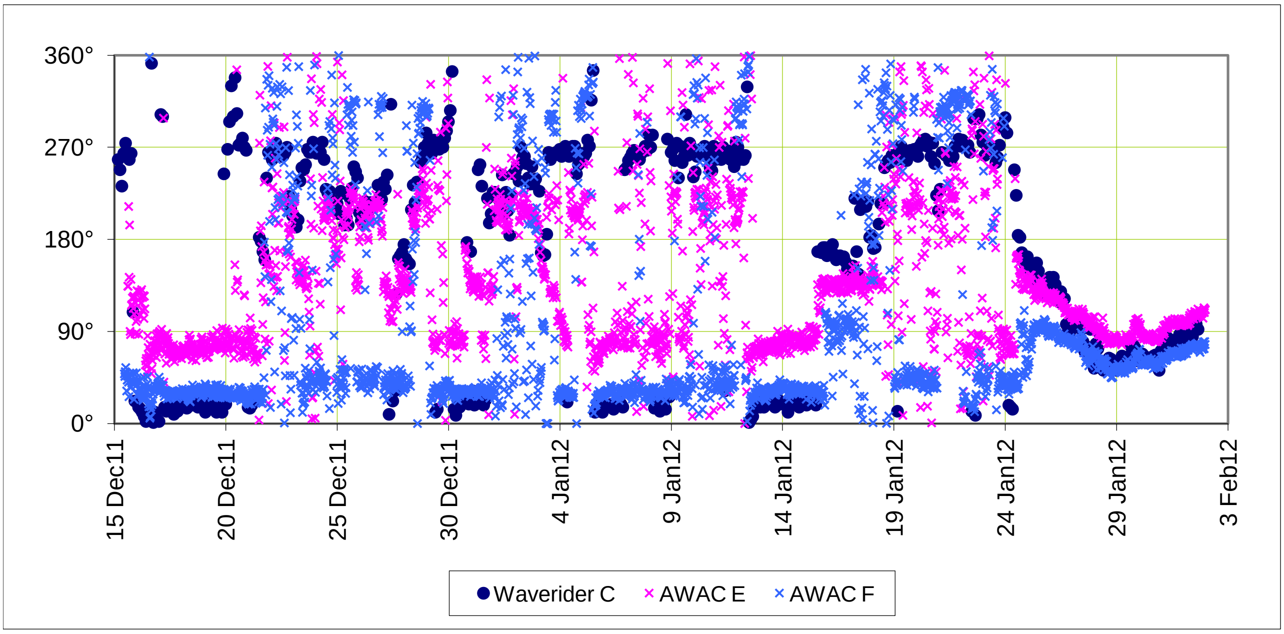
Figure 3.3 Waverider site C – wave period versus direction



3.1.2 Spatial variation

Spatial variation across the site is illustrated by comparing wave height and wave direction at the three sites C (waverider, representing open water conditions), E and F (shore approaches) over a sample period from mid December 2011 to the beginning of February 2012, which includes the storm of 3 January mentioned above. The upper panel of Figure 3.4 shows wave height and the lower panel shows wave direction; the three sites are superimposed to assist comparison. As expected, in prevailing westerly conditions the wave heights differ markedly between the sites due to their different distances from shore; however, in easterly conditions such as occurred near the end of the period, Hs is much more uniform and decreases slightly at the nearshore sites due to their reduced seafloor depth.





Round 3 Zone 2 Firth of Forth metocean campaign

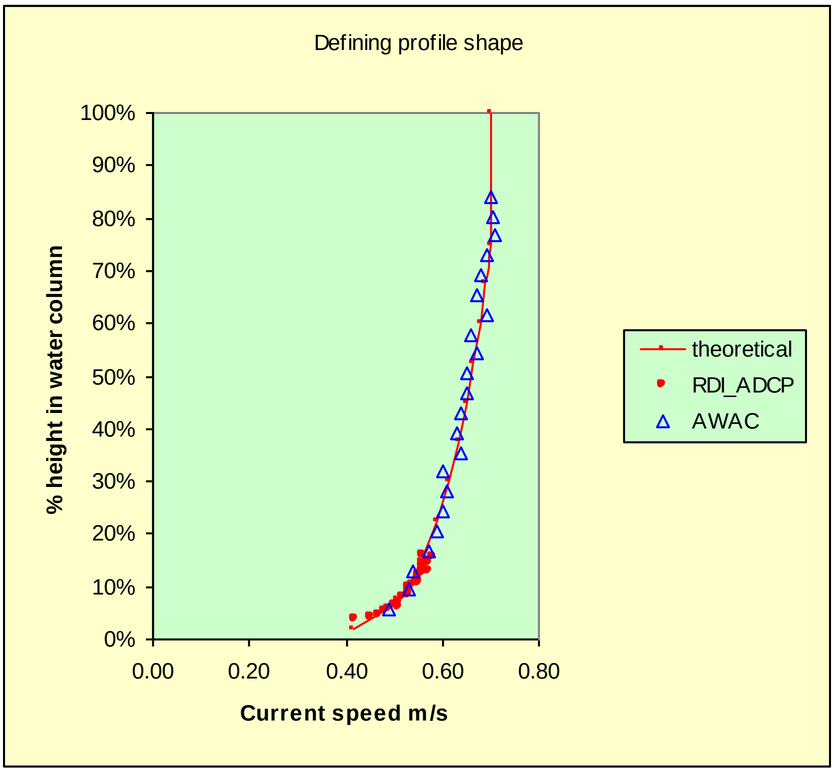
Figure 3.4 Comparison of wave conditions at sites C (waverider), E and F (AWACs)

3.2 CURRENT AND WATER LEVELS

3.2.1 Current profile shape

Current profiles have been collected at several sites. Of particular interest is the definition of profile shape near the seabed because it affects coastal processes. The survey included investigation of near-bed current profile shape using high-resolution ADCP measurements in addition to the conventional full-depth instrument; this was carried out at site A. Figure 3.5 shows the shape of the current speed profile observed over the period 24 March to 7 April 2011 at site A. The theoretical profile shape that provides the best agreement with the data follows a 1/7th power law in the lower 75% of the water column and is uniform in the upper 25%. [There is scope for further evaluation of the near-bed portion.]

Figure 3.5 Current profile at site A



3.2.2 Storm surges

A notable storm surge occurred on 4 February 2011; there were no current data at that time to identify it but it was seen in water level records as a residual that Fugro calculated to be 1.4 m above tidal predictions at the time. If their calculation is accurate, its magnitude exceeds expectations, being equivalent to a return period of 50 to 100 years.

Weather charts (see e.g. Magic Seaweed web site) show that on that date a deep depression (central pressure 956 hectopascals (millibars)) moved northeastward from the Atlantic through the Faroe Islands to the Norwegian Sea, which is a characteristic weather pattern for generating storm surges in

UK waters; however, wave heights in Zone 2 were elevated but not extreme (Hs reached around 4 m – see Figure 3.1).

Another surge is reported on 23 May 2011, which can be seen as a perturbation in the water levels and currents. Weather charts show a depression moving northeast towards the Shetland Islands at that time. Again, wave heights were elevated but not extreme; Hs reached around 4.5 m – see Figure 3.1. [This was the only notable storm in Fugro's 3rd phase of deployments.]

3.3 OTHER PARAMETERS

3.3.1 Seawater temperature

Sea temperature has been measured near the seabed throughout the metocean campaign at a number of sites. The annual minimum occurred during February and early March.

Figure 3.6 Sea temperature data collected in 2010-2011 at site A

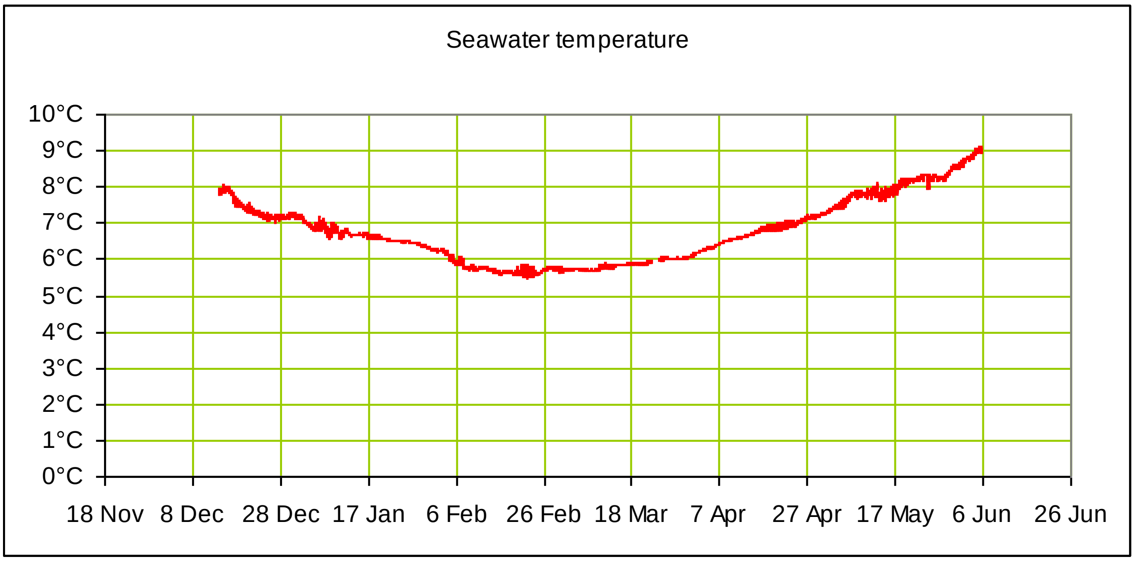
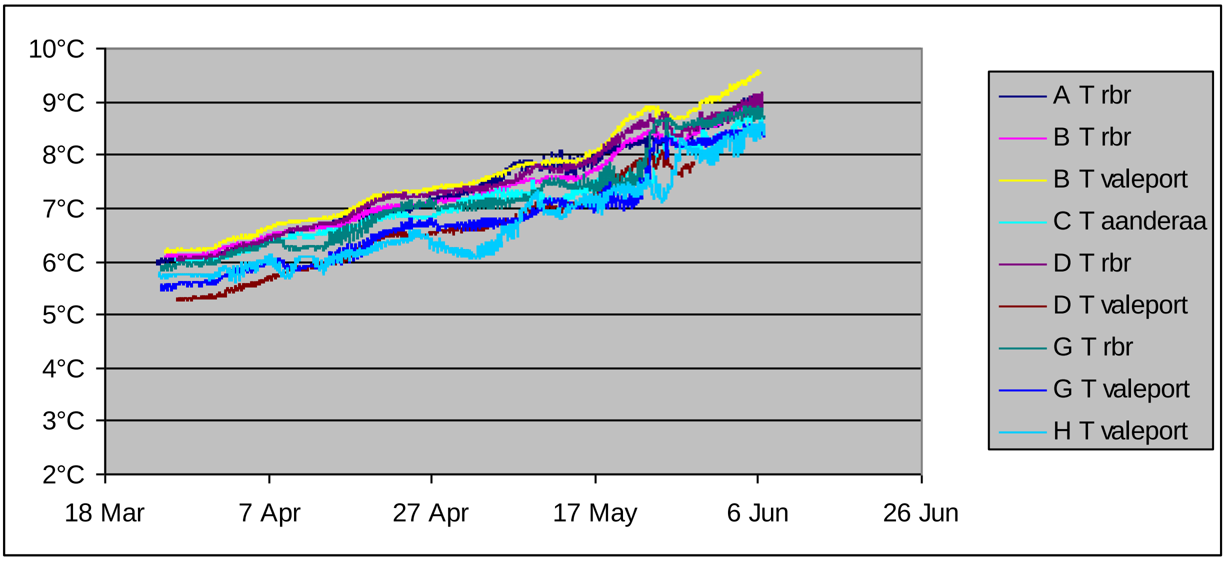


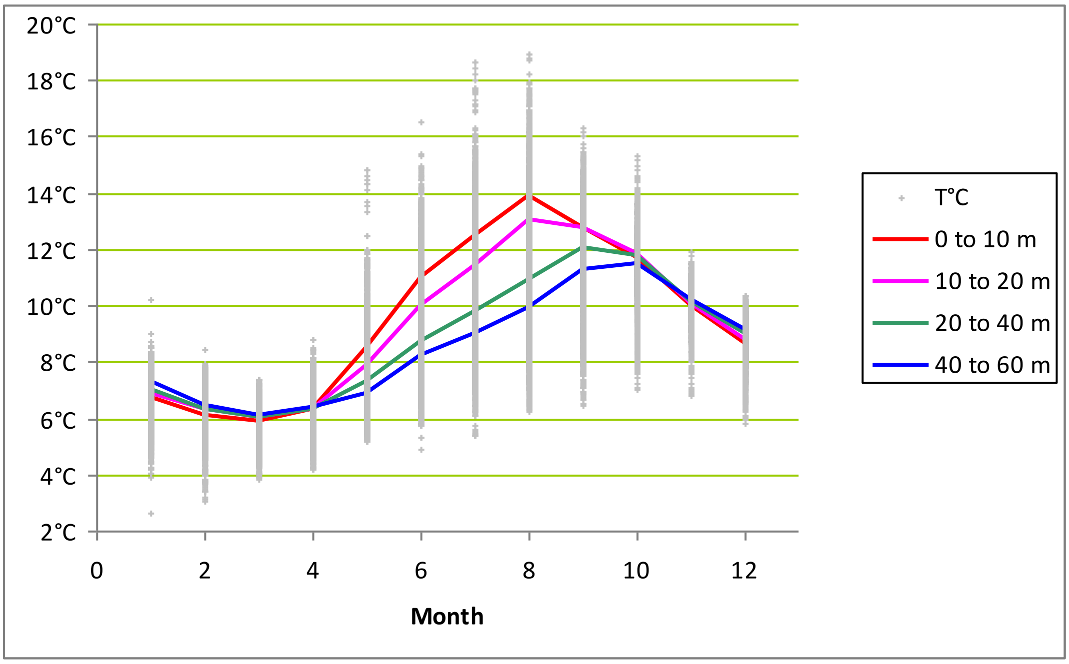
Figure 3.7 Sea temperatures – 3rd phase of deployment



[Labels denote site; T = temperature, and instrument. When two instruments were used at the same site they generally agreed within 0.5°C of each other]

The data fall within expectations based on historical measurements collected by the scientific institutions. Figure 3.8 shows the range of temperatures observed historically, and their monthly averages in specified depth layers. The annual maximum occurs first at the surface and progressively later with increasing depth.

Figure 3.8 Historical sea temperatures and monthly mean by depth



[56,000 Nansen bottle data collected in sea area 55.5°N to 57.0°N, 3.0°W to 0.0°E]

In winter the water column is well mixed but in summer a thermocline layer develops and this has been detected in Conductivity, Temperature and Depth (CTD) casts taken during service visits.

3.3.2 Turbidity

Turbidity data have been measured at sites A, E and F (the first two of these are plotted in Figure 3.9 and Figure 3.10).

Fugro notes that turbidity at site A is tidally driven; values are relatively low and fluctuate in unison with tidal diurnal and spring-neap cycles. It seems likely that this site is a good representation of conditions throughout the Zone. However, it is noted that wave conditions were not particularly severe during the period of turbidity measurements at this site and it is considered that higher turbidity is likely to occur during greater storms.

Turbidity values at the shore end sites E and F are two orders of magnitude higher because they were driven by waves; being shallower, large wave orbital motions are more able to penetrate to the seabed than at the deeper sites. Fugro notes that the higher turbidity values are seen during spells of persistent large easterly waves. Partrac's subsequent measurements at E and F are consistent with those of Fugro. Partrac has expressed its values also as suspended solids and its highest values are around 700 mg/l.

Figure 3.9 Turbidity at deep site A

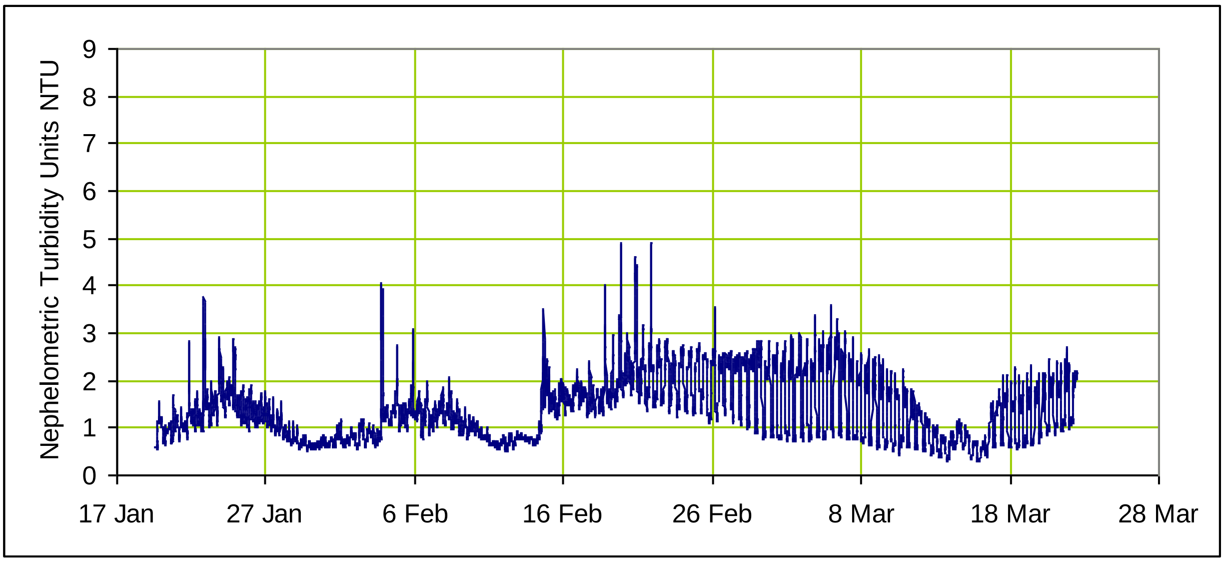
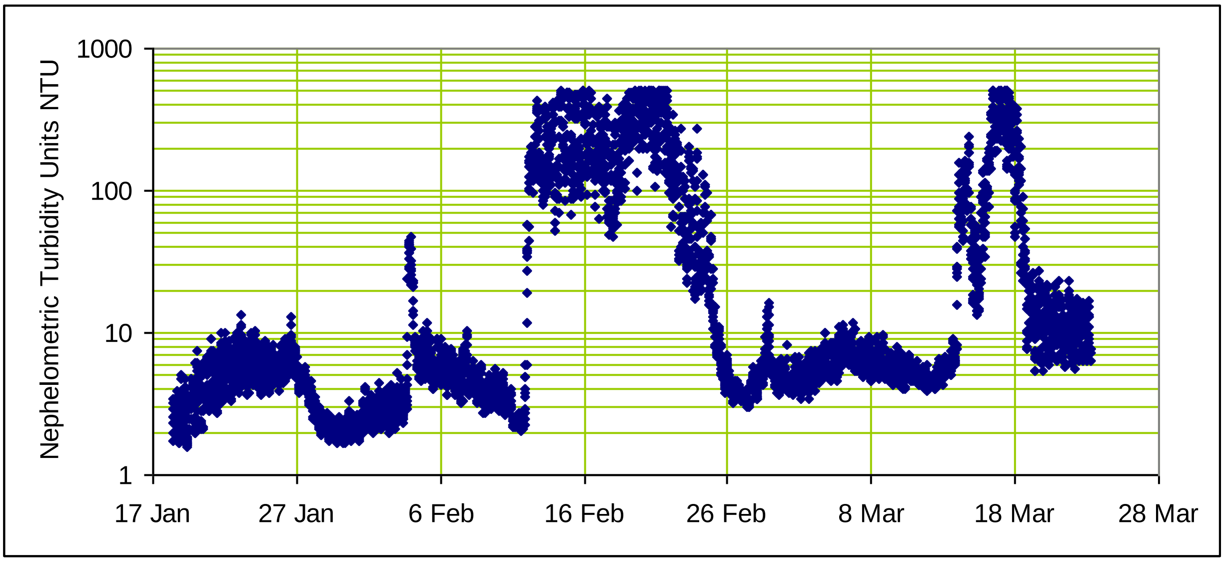


Figure 3.10 Turbidity at shallow site E



4 CONCLUDING REMARKS

4.1 DATA CAPTURED

In essence the campaign has collected the following data:

- 17 months waverider buoy from December 2010 to mid-May 2012.
- 74 days wave and current data at several other sites during Fugro's Phase 3 (22 March to 4 June 2011)
- 7 months wave and current data at the two shore end sites E and F collected by Partrac from December 2011 to June 2012 (in hand up to May 2012 at time of writing)
- Seawater properties data collected at the seabed frames including limited coverage of turbidity data.

This report has described the physical oceanography gleaned from the data, including specific examples from storms of 4 Feb and 23 May 2011 and comparison plots at sites C, E, F during the period 15 Dec 2011 to 2 Feb 2012, which included a storm with Hs exceeding 6 m.

Severe storm waves are likely to induce sediment suspension and so contribute to coastal processes even in the deeper parts of the wind farm area, where under more benign conditions they would be limited to much lower turbidity levels, driven only by tidal currents. The campaign did not capture turbidity data in a deep site during the most severe storms.

Overall the measurement campaign has yielded a good density of metocean information to inform the project. At the time of writing this review has had sight of Fugro's AWAC, ADCP and seawater properties data and the first two phases of Partrac data – a third and final phase of Partrac data is nearing completion and the instruments' recovery is scheduled for mid June 2012.

Thus there is potential to update this report with Partrac's final phase of AWAC data, and the last portion of Waverider buoy data from February to mid May 2012.

4.2 APPLICATIONS INCLUDING COASTAL PROCESSES STUDIES

As part of the ES, a coastal processes assessment is required. This will include a regional and site-specific (including the export cable route) description of the baseline metocean and sediment regime conditions (i.e. conditions experienced currently prior to any development). It will also include an assessment of the effect of the development, during construction, operation and decommissioning, on the physical environment, both in the near-field (local to the site) and far-field (regional scale). Therefore, an assessment of any changes to the metocean and sediment regimes due to the development, and how significant these changes might be to coastal processes is required. In addition, any cumulative or in-combination effects due to the Firth of Forth OWF and other developments or industry in the area is required.

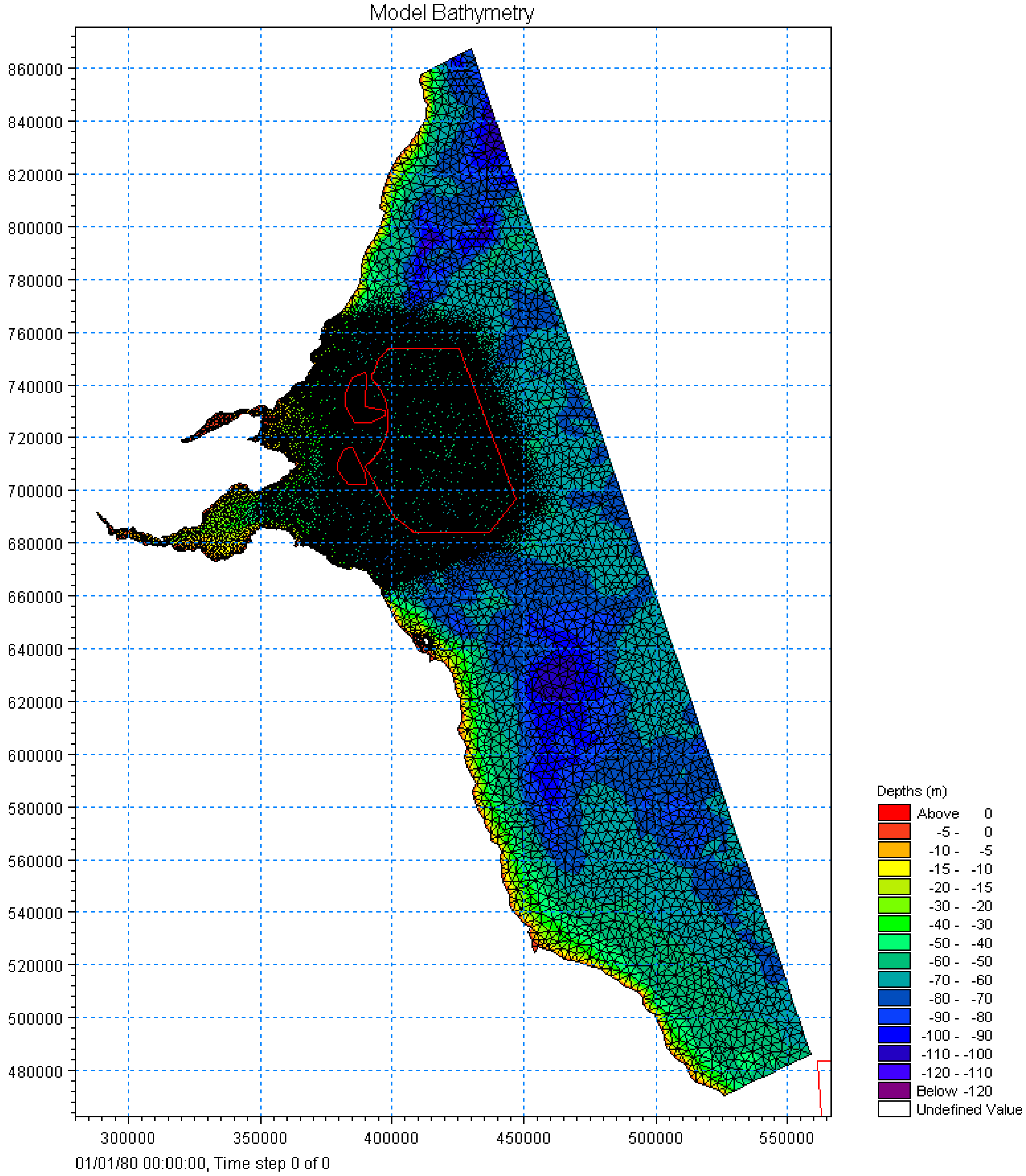
The Metocean Survey Strategy (Seagreen, 2010) specified the type of data to be collected, and the locations and durations for data collection, in order to support these assessments. These data, in conjunction with other information available from previous studies (such as Scottish Natural Heritage coastal cell assessments or Shoreline Management Plans) or third party sources, such as the Met Office or the British Geological Society, would be sufficient to enable the baseline description of conditions to be produced.

Unfortunately not all of the data were collected as specified, due to difficulties experienced in the deployment of some of the AWACs and ADCPs. However, the sub-set of data collected during the surveys should still be of use in the assessment of baseline conditions, on the basis that at least some wave and current information was collected at each site. Of particular interest are the near-bed velocities. Given that the general metocean conditions of the area do not exhibit major discontinuities across the site and are fairly well-known, and a number of sources of information, including numerical models of the area, are potentially available, the data loss experienced at some locations should not prove to be insurmountable.

It is our understanding that Seagreen is undertaking a semi-quantitative, desk-based coastal processes assessment (as opposed to utilising numerical models). The metocean data collected, together with other information and previous studies that are available, should prove sufficient for such an assessment.

However, if a full quantitative analysis of any spatially-varying impacts is required, then the benefits of the data collected can be multiplied by employing a numerical model, as was indicated in the Metocean Survey Strategy. In this case, the data collected would provide a useful, if not perfect, additional dataset for model validation. In particular, the bespoke hydrodynamic and spectral wave models of the east coast of Scotland, including the Firth of Forth OWF area, which were developed by Intertek METOC, could be utilised, subject to agreement of existing data owners (these models were developed for the purpose of undertaking coastal processes assessments as part of the EIAs for the Neart na Gaoithe and Inch Cape STW OWF developments, and have been calibrated and validated using the data collected during the STW metocean campaign). Figure 4.1 shows the model domain. The models have been used to determine spatially-varying near-bed currents and orbital wave velocities under a range of conditions, and these have then been used in conjunction with seabed characteristics of the area to determine the level and frequency of sediment movement under different conditions, both with and without the developments in place. Furthermore, the modelled wave and current climates have been utilised in the estimation of scour around the structures, using empirical equations.

Figure 4.1 Model domain for STW OWF coastal processes assessment



The metocean data collected for the Firth of Forth development site would therefore provide a means of validating these models in this area of interest, and the models could then be utilised to undertake an assessment of the baseline conditions and any changes to the coastal processes.

5 REFERENCES

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Partrac, 2012. Winter metocean survey, Phase 1 Interim Report – December 2011 to March 2012.

Partrac, 2012. Winter metocean survey, Phase 2 Interim Report – March 2012 to May 2012.

Part IV

Winter Metocean Survey: Final Report

(Partrac, July 2012)

PARTRAC

Seagreen

Winter Metocean Survey

Final Report:

15th December 2011 – 19th June 2012

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V02	Phase 3 turbidity data included in plots and stats
V03	Amendments as suggested by client made.

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EXECUTIVE SUMMARY

Seagreen Wind Energy Ltd awarded Partrac Ltd a contract in which two 600 kHz Nortek AWACs and Seapoint OBS were deployed at two locations on potential Export Cable Routes (ECR) for the Firth of Forth offshore wind farm Zone for one winter season.

The objective was to capture the inshore conditions during several storm events, with a range of wind, wave & current conditions and directions of approach. The data set will provide an understanding of the relationship between inshore conditions and those further offshore within the Firth of Forth Zone. The data will inform subsequent aspects of export cable route design and installation planning.

This report provides the analysis of the data collected through all phases between the 15th December, 2011 and 19th June, 2012.

Table 1. Summary of deployment and recovery dates.

Instrument	Site	Phase	Deployment Date	Recovery Date	Total Deployment Days	
					AWAC	TSS
AWAC & Seapoint OBS	E	1	15/12/2011	01/03/2012	77	77
	F		15/12/2011	23/02/2012	70	70
	E	2	02/03/2012	03/05/2012	62	62
	F		01/03/2012	03/05/2012	63	63
	E[1]	3	03/05/2012	19/06/2012	0	47
	F		03/05/2012	19/06/2012	47	47
Total Data Return					319 days (86%)	366 days (99%)
					91%	

1 No AWAC data due to firmware issue. See Appendix 8.7.

Table 2. Summary of principal oceanographic statistics.

Value	Hm0 (m)	Hmax (m)	Tp (s)	TM02 (s)	SprTp (°)	Velocity ($m\ s^{-1}$)	TSS ($mg\ l^{-1}$)
AWAC E (15/12/2011 – 03/05/2012)							
Min	0.09	0.11	1.68	1.66	12.69	0.01	0
	27/03/2012 22:31	31/01/2012 07:31	27/03/2012 09:31	Multiple Occurrences	31/01/2012 13:11	19/12/2011 03:10	Multiple Occurrences
Max	3.4	6.03	11.34	7.36	81.02	0.69	709
	03/01/2012 09:41	31/01/2012 05:11	12/04/2012 20:01	27/01/2012 03:41	Multiple Occurrences	26/12/2011 18:10	27/01/2012 07:10
Mean	0.76	1.15	6	3.59	48.05	0.26	27
StDev	0.49	0.76	2.48	1.08	20.73	0.14	47
AWAC F (15/12/2011 – 19/06/2012)							
Min	0.11	0.14	1.82	1.95	4.93	0.01	0
	Multiple Occurrences	27/03/2012 11:01	18/01/2012 07:01	28/03/2012 08:31	12/05/2012 16:31	03/04/2012 21:50	Multiple Occurrences
Max	4.54	8.27	13.82*	8.58	81.02	0.55	239
	03/04/2012 11:01	03/04/2012 11:01	19/02/2012 19:01	19/02/2012 18:01	18/01/2012 07:31	07/03/2012 15:00	03/04/2012 11:00
Mean	0.94	1.43	7.99	4.12	38.16	0.18	6
StDev	0.56	0.87	2.97	1.19	18.3	0.10	11

CONTENTS

Units of Measurement

All units of measurement used within this report are detailed in Table 3.

Table 3. Units of measurement.

Symbol	Description	Unit
-	Date and Time	GMT
-	Geographical Position	Degrees and Minutes WGS84
-	Distance	Metres (m)
Hm0	Significant Wave Height	Metres (m)
H10	Mean of the Top 10% of Wave Heights	Metres (m)
Hmax	Maximum Wave Height	Metres (m)
DirTp	Peak Wave Direction (From)	Degrees True (°)
SprTp	Wave Spread	Degrees (°)
MeanDir	Mean Wave Direction (From)	Degrees True (°)
Tp	Peak Wave Period	Seconds (s)
Tm02	Mean Zero-Crossing Wave Period	Seconds (s)
-	Current Speed	Metres per Second($m\ s^{-1}$)
-	Current Direction (Towards)	Degrees True (°)

1. METHODOLOGY

1.1 Background

This report summarises the instrument technical detail, provides locations for the instrumentation and presents results obtained for the entire monitoring campaign of the AWAC frames deployed between the 15th December 2011 and 19th June 2012.

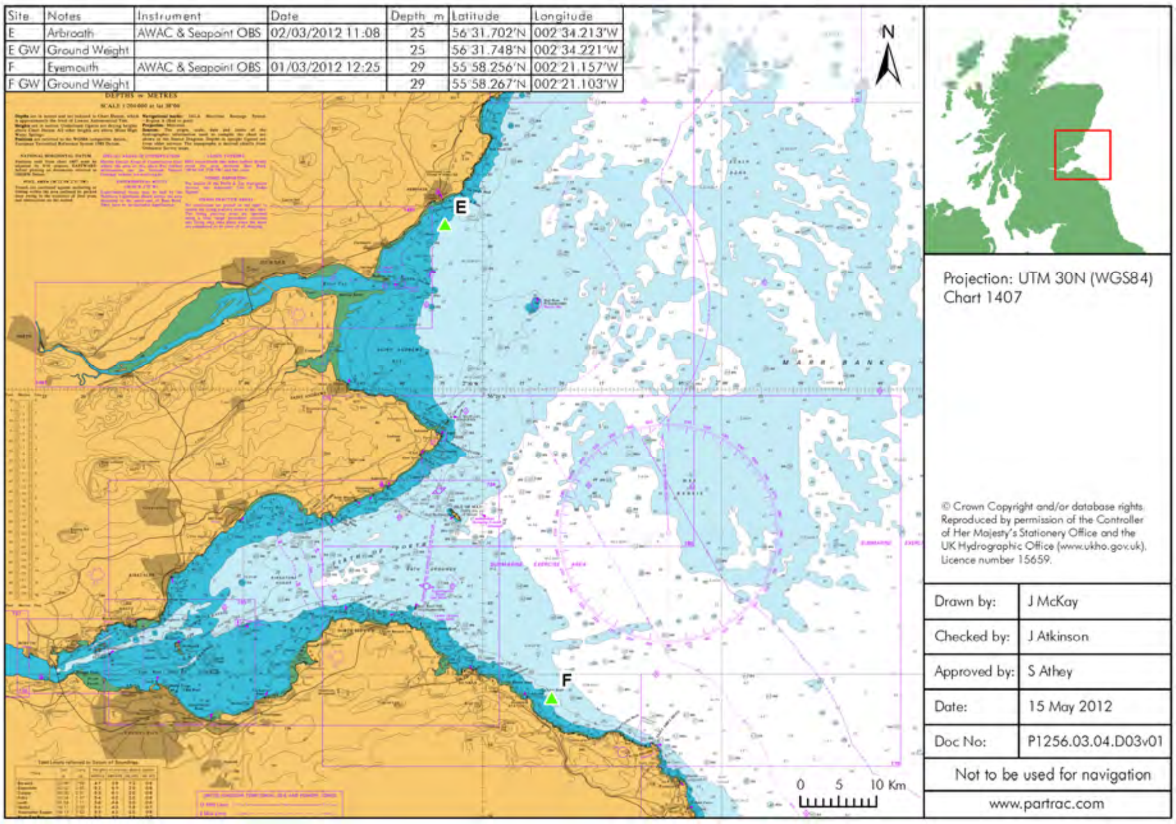

Figure 1. Proposed deployment locations of AWAC frames.

1.2 Instrumentation and Mooring

Each AWAC was housed in a marine grade stainless steel mooring frame weighing 250 kg. The AWAC was placed in a fixed level gimbal within the frame to prevent the AWAC moving. A bullseye was attached to the top of the frame so that a camera system could view the frame aspect on the seabed.

The sides of the frame were sealed with stainless steel panels in order to shield the AWAC from the tidal current. The gimbals on each frame were locked in order to securely clamp each AWAC to reduce as much vibration of the instrument as possible.

Each frame was attached to a ground line (16 mm leaded polypropylene rope) of 80 m in length and was attached directly to a 40 kg clump weight. The clump weight was attached to a Lightweight (acoustic) release transponder system (Sonardyne™ LRT) with floatation devices and sediment trap. Table 5 states instruments and associating serial numbers used throughout the monitoring period and Appendix B – Survey Log Sheets provides the survey log sheets detailing the equipment set up.

The deployment locations, distance from proposed sites and average depths are listed in Table 4 and are shown in Figure 1. Deployment location of Site F during Phase 2 was altered due to the presence of static fishing gear.

Table 4. Deployments of the AWAC and Seapoint OBS frames. PL = Proposed locations.

Instrument	Site	Phase	Deployment Date & Time	Latitude	Longitude	Distance from PL (m)	Depth (m)*
AWAC & Seapoint OBS	E	PL	-	56°31.6900'N	002°34.1600'W	-	~25.00
		1	15/12/2011 10:30	56°31.6666'N	002°34.1923'W	54.56	25.09
		2	02/03/2012 11:08	56°31.7070'N	002°34.2150'W	64.43	24.60
		3	03/05/2012 11:48	56°31.6811'N	002°34.1900'W	34.85	-
	F	PL	-	55°58.3300'N	002°21.3100'W	-	~29.00
		1	15/12/2011 14:00	55°58.3311'N	002°21.3090'W	3.70	29.62
		2	01/03/2012 12:25	55°58.2540'N	002°21.1640'W	208.41	29.39
		3	03/05/2012 15:54	55°58.3638'N	002°21.3340'W	66.70	30.44

*Average water depth over deployment

Table 5. Instrumentation used throughout monitoring period.

Phase	Site	Instrument	Serial Number
1	E	AWAC 600 kHz	6050
		Seapoint OBS	12582
		Aquatec logger	024-067
		Seapoint OBS	12577
		Frame	C
		LRT (acoustic release)	267180-002
	F	AWAC 600 kHz	6051
		Seapoint OBS	12581
		Aquatec logger	024-042
		Seapoint OBS	12529
		Frame	A
		LRT (acoustic release)	273863-003
2	E	AWAC 600 kHz	6050
		Seapoint OBS	12582
		Aquatec logger	22007
		Seapoint OBS	12654
		Frame	C
		LRT (acoustic release)	267180-002
	F	AWAC 600 kHz	6051
		Seapoint OBS	12581
		Aquatec logger	22008
		Seapoint OBS	12655
		Frame	B
		LRT (acoustic release)	273863-003

Phase	Site	Instrument	Serial Number
3	E	AWAC 600 kHz	6123
		Seapoint OBS	10976
		Aquatec logger	22009
		Seapoint OBS	12656
		Frame	4
		LRT (acoustic release)	216122-004
	F	AWAC 600 kHz	6030
		Seapoint OBS	1574
		Aquatec logger	22010
		Seapoint OBS	12657
		Frame	1
		LRT (acoustic release)	270452-004

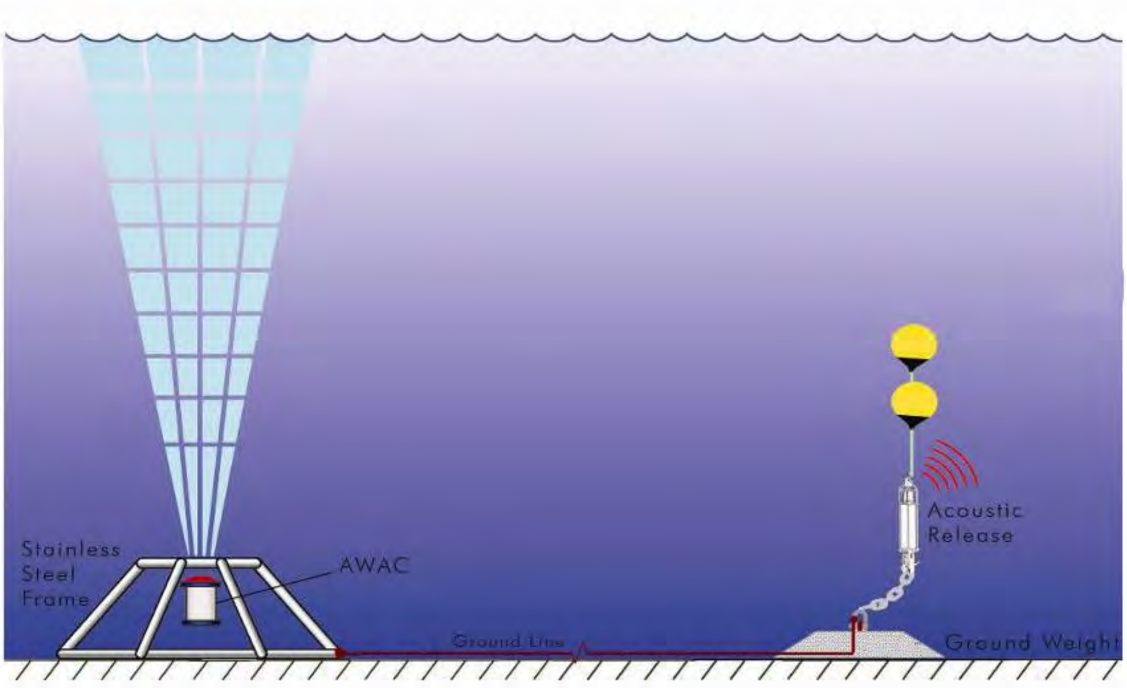

Figure 2. Example configuration of AWAC and mooring system.

Instrument	Height above seabed (m)	Blanking Distance (m)	Range (m)	Bin Height (m)
AWAC 600 kHz	0.7	0.5	50	1
Seapoint OBS sensor	0.7	0.05	Single point 0.05	-

1.3 Deployment and Recovery

The seabed frame was attached to an acoustic release system and lowered over the side of the vessel using an A frame and a drum winch until it reached the seabed. The tilt of the landed frame was assessed with the tethered camera system and the use of the bullseye levelling board.

Once the frame was level within tolerance of the bullseye (max. 7 degrees), a command was given to the frame deployment acoustic release transponder and the frame was released. On release, the vessel moved downtide deploying the groundline overboard. Just before the groundline started to come tight the acoustic release (LRT) and associated floatation devices were lowered over the side into the water. As the line became taught, the attached ground weight, which was suspended over the stern of the vessel, was lowered to the seabed with the acoustic release (LRT) and associated floatation devices attached.

At each location, position fixing was taken using a DGPS Vector system as a secondary verification of the vessel's GPS system. Distances from proposed location are shown in Figure 3 and Figure 4.

During recovery, a Sonardyne command unit was used to establish range and communication of acoustic release (LRT). Once established a release command was sent, and the LRT appeared on the surface with connected floatation devices. The slack rope from the LRT was then brought onboard allowing the vessel to back slowly toward the ground weight and groundline. Once the ground weight was on board the groundline was connected to drum winch via trawl block on the A frame and the line and AWAC frame were winched onboard.

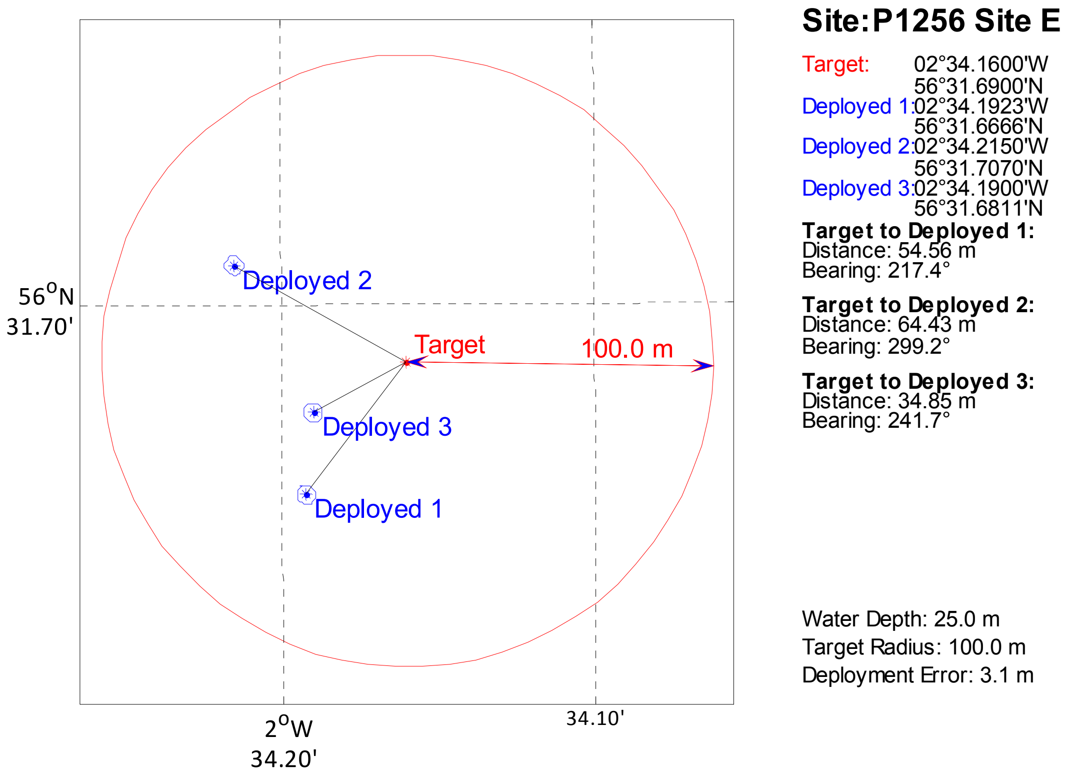

Figure 3. Summary of deployment locations for all Phases at Site E. Note; Target area is 1.5 x water depth.

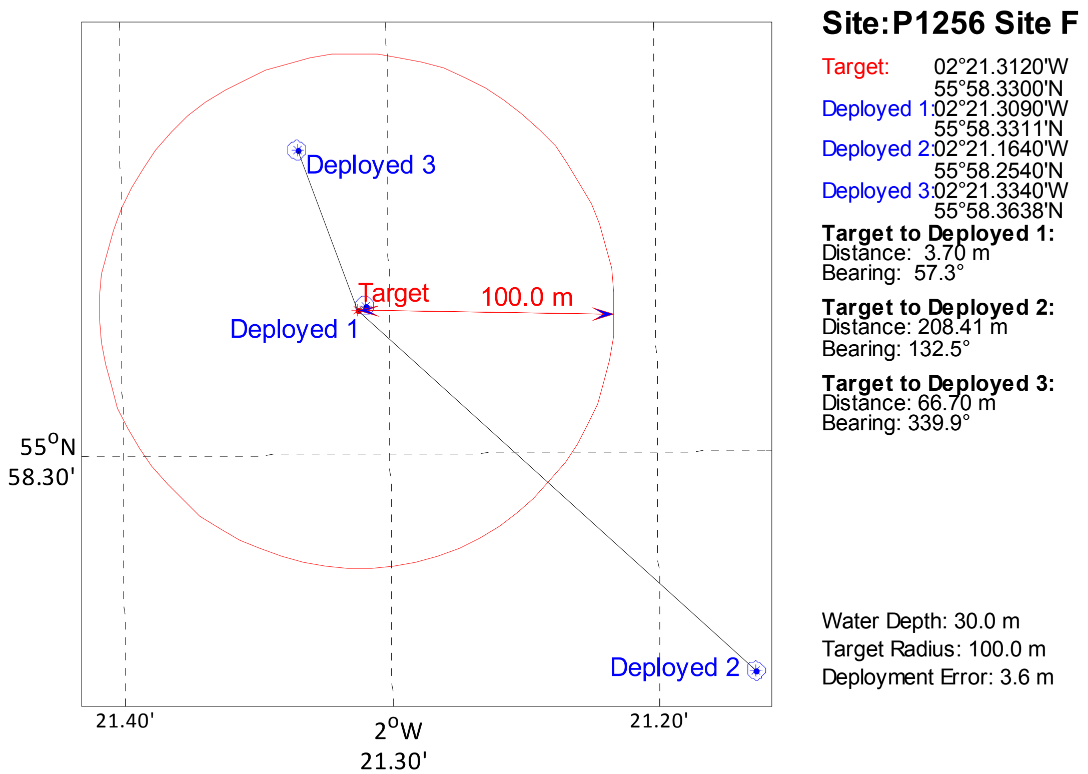

Figure 4. Summary of deployment locations for all Phases at Site F. Note; Target area is 1.5 x water depth. Deployment 2 was relocated due to static fishing gear.

1.4 Processing and Analysis

1.4.1 Quality Assurance

Wave data from the AWAC instrumentation is quality controlled through the Cefas parameters outlined in 7.3.1 as well as the integral quality control checks by the AWAC (7.3.2). Current data is quality assured through Nortek and IOC QA checks (7.3.3). All TSS data is manually quality controlled for spikes and biofouling if apparent in the data. With failed values being removed from the dataset and statistics, and flagged values (such as biofouling) removed from the statistics but highlighted within the dataset and figures.

1.4.2 Methodology

Partrac's in-house MatLab scripts are used throughout the processing of all data.

Current and wave data are processed from the raw output files obtained from AWAC-AST with a number of flags designed to highlight possible sources of error. Figure 5 and Figure 6 provide an example of the automatic checks within wave and current scripts. Figure 7 presents the Partrac user interface used within turbidity processing.

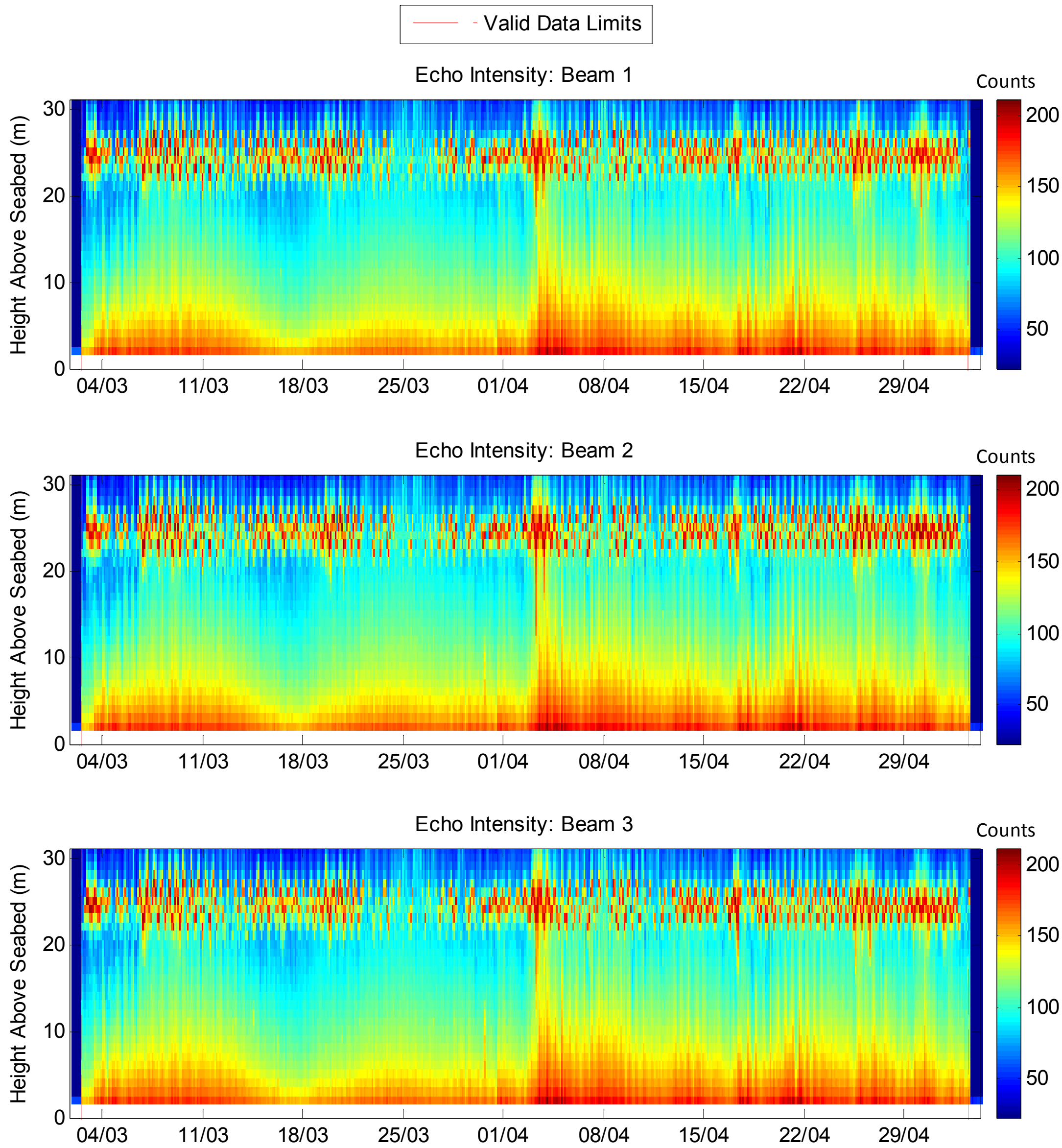

Figure 5. An example echo intensity plot, with data limits calculated.

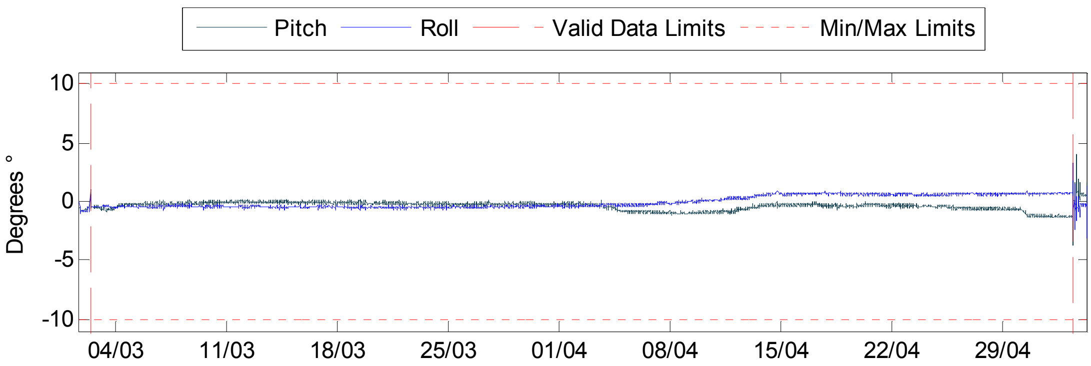

Figure 6. A pitch and roll check, with valid data limits and min/max limits of angle from the vertical.

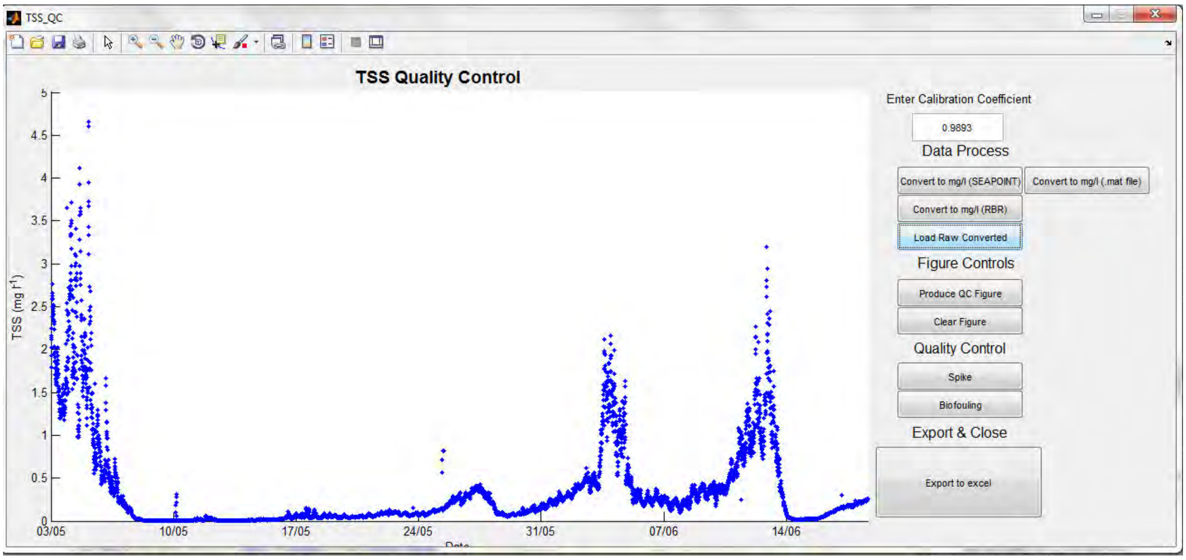

Figure 7. The Partrac developed TSS interface used to flag, fail and pass data.

2. SUMMARY OF MEASUREMENTS

Both AWAC frames were deployed over three phases between 15th December, 2012 and 19th June, 2012. Between Phases 1 and 2 each of the frames were recovered, data downloaded, serviced and redeployed. Between Phases 2 and 3 the frames were recovered and replaced immediately with a fully serviced frame.

At Site E Phases 1 and 2 were deployed and recovered successfully with full data return, upon final recovery of the frame (Phase 3) it was discovered that an inherent fault within the AWAC firmware led to no data being returned from Phase 3 (Appendix 8.7). Site F was successfully deployed, recovered and data returned through all phases. Table 6 presents the date and time of the first and last record at each site along with total data coverage.

Table 6. Data start and end times over the monitoring campaign to the nearest days.

Site	Phase	First Record Date & Time	Last Record Date & Time	Phase Data Coverage	
				AWAC	TSS
E	1	15/12/2011 14:00	01/03/2012 15:40	77 days	77 days
	2	02/03/2012 11:20	03/05/2012 10:50	62 days	62 days
	3	03/05/2012 11:52*	19/06/2012 09:00**	0 days	45 days
F	1	15/12/2011 10:20	23/02/2012 12:10	70 days	70 days
	2	01/03/2012 12:30	03/05/2012 15:00	63 days	63 days
	3	03/05/2012 16:00	19/06/2012 11:30	47 days	47 days

*Deployment and **recovery times.

3. RESULTS: WAVE DATA

The data are quality controlled and assured through the procedure outlined in Section 7.3.1. Non-Valid/Failed records are those that have been automatically rejected. Flagged records are those which have been flagged due to rate of change or error flags by the AWAC instrument, these are inspected manually and passed or rejected.

Peak period and directional noise with larger spread values (above 80°) are seen to occur at both sites during low energy multi directional sea states. This leads to directional ambiguity due to an inability for the AWAC to define a dominant peak direction. These values are flagged but not failed within the dataset as the data is seen to describe conditions in a mixed low energy sea state.

3.1 AWAC Site E

Although no data was returned during Phase 3, Phase 1 and 2 showed high quality data return. Table 7 presents the general statistics seen through the campaign with Table 8 summarising the total data return.

Table 7 Wave data statistics showing date and time of significant waves at Site E.

Parameter	Min	Date	Max	Date	Mean	StDev
Hm0 (m)	0.09	27/03/2012 22:31	3.40	03/01/2012 09:41	0.76	0.49
Hmax (m)	0.11	31/01/2012 07:31	6.03	31/01/2012 05:11	1.15	0.76
Tp (s)	1.68	27/03/2012 09:31	11.34*	12/04/2012 20:01	6.00	2.48
Tm02 (s)	1.66	Multiple Occurrences	7.36	27/01/2012 03:41	3.59	1.08
SprTp (°)	12.69	31/01/2012 13:11	81.02	Multiple Occurrences	48.05	20.73

*Max Tp is taken as the maximum observed when Hm0>1 m.

Table 8. Data return during AWAC deployment at Site E.

Parameter	Records Expected	Total Records Returned	Non-Valid/Failed Records	Valid Data Return (%)	Number of Flagged Records	QA Data Return (%)
Hm0 (m)	6675	6669	8	99.9	0	99.9
Hmax (m)			8	99.9	0	99.9
Tp (s)			8	99.9	0	99.9
Tm02 (s)			8	99.9	0	99.9
DirTp (°)			16	99.8	225	96.4
SprTp (°)			16	99.8	299	95.3
MeanDir (°)			16	99.8	26	99.4

The time series for wave height, period and direction are presented in Figure 8, Figure 9 and Figure 10 respectively. With scatter plots for significant wave height (Hm0) versus maximum wave height (Hmax) and average period (Tm02) versus peak period (Tp) as a function of significant wave height in Figure 11. Joint occurrence tables of Hm0 vs. DirTp, Hm0 vs. Tp and Hm0 vs. SprTp are presented in Table 9 to Table 11.

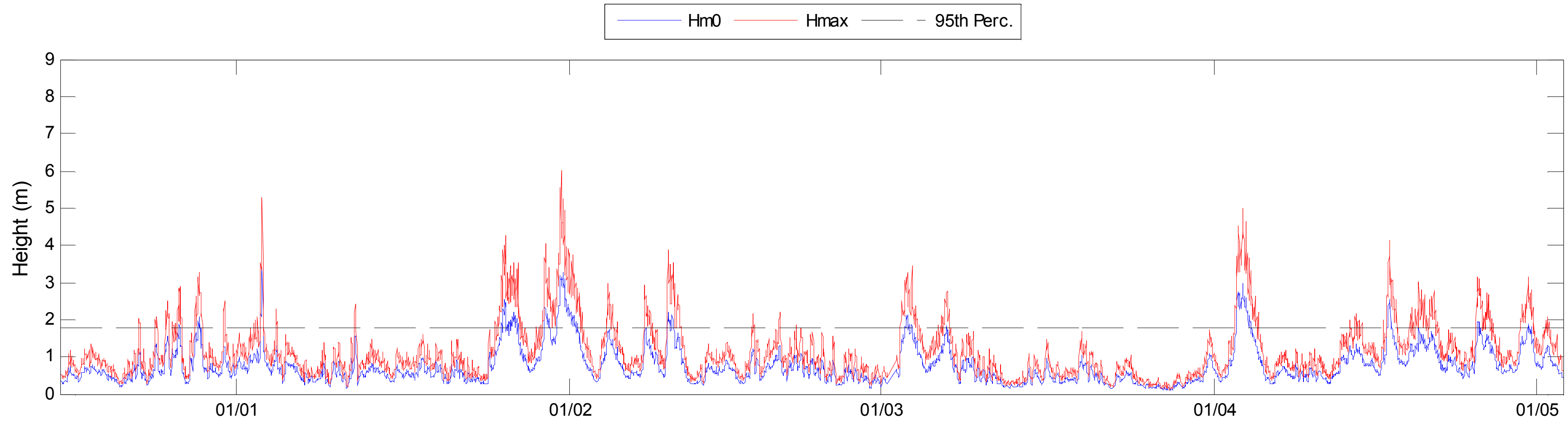

Figure 8. Wave height (Hm0 and Hmax) and the 95th percentile (Hm0) at Site E.

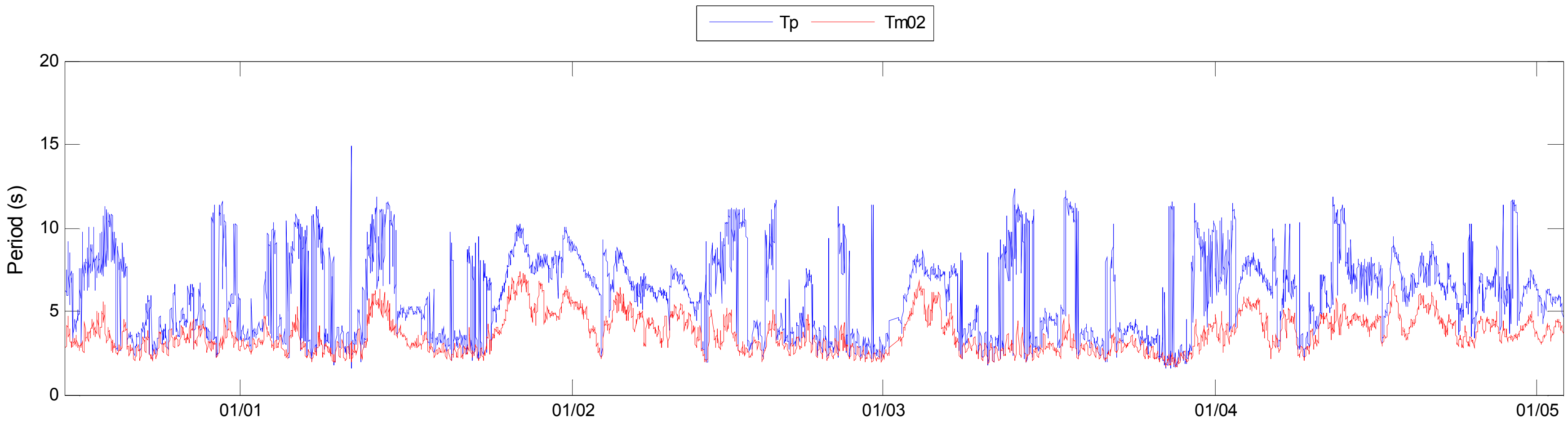

Figure 9. Wave period (Tp and Tm02) at Site E.

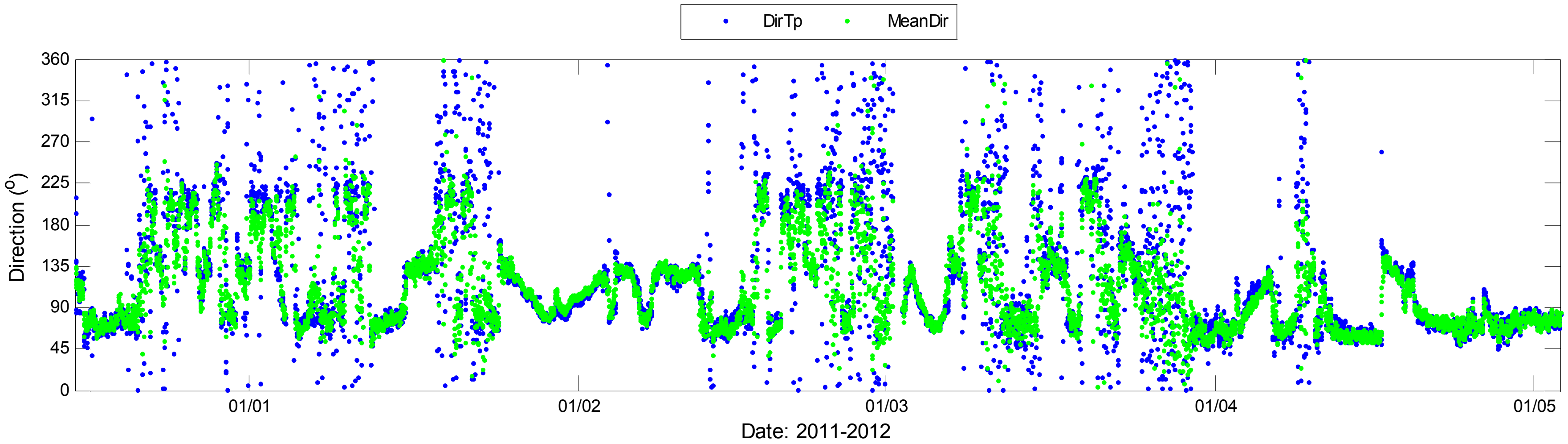

Figure 10. Wave direction (DirTp and MeanDir) at Site E.

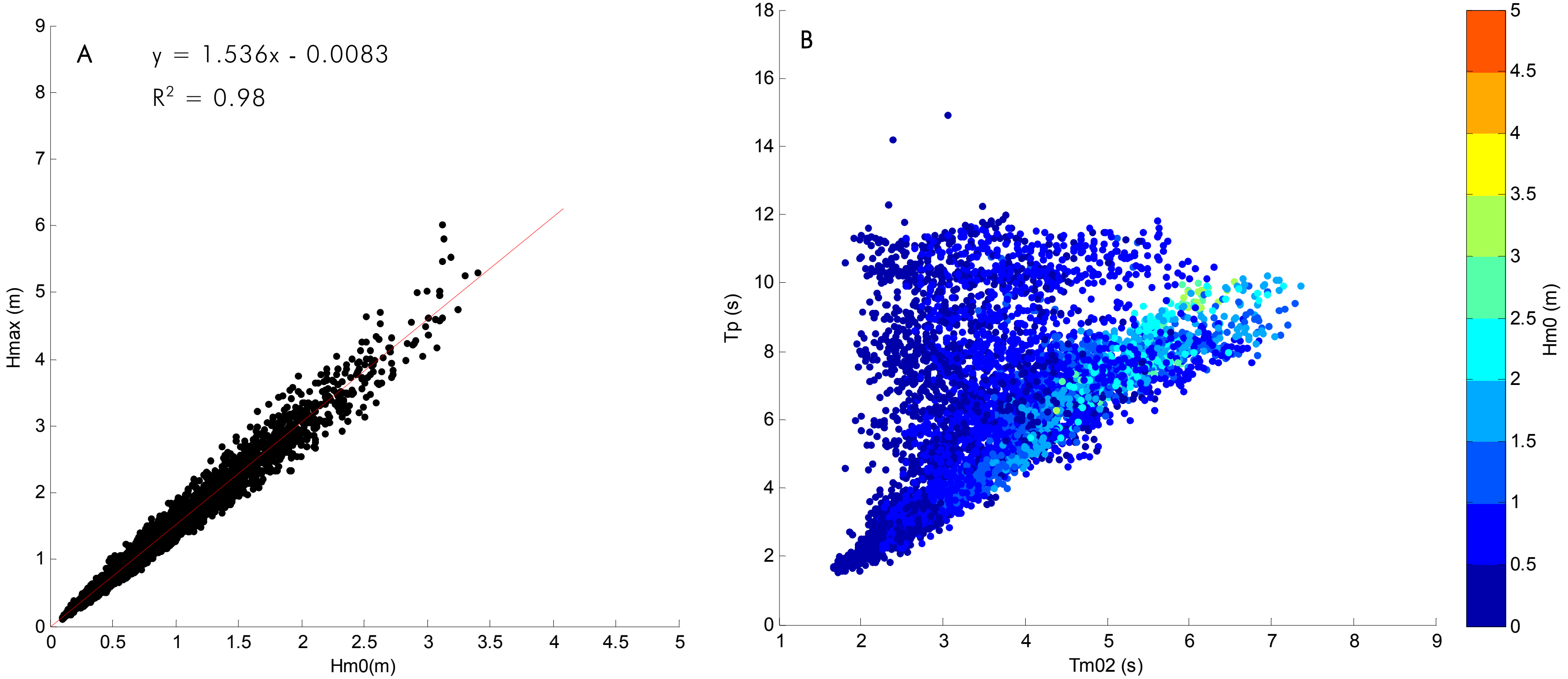

Figure 11. Scatter plots of A. Hm0 vs. Hmax (with least square line) (left) and B. Tm02 vs. Tp with a colour scale to indicate the Hm0 seen during the wave period (right) at Site E.

Table 9. Table of joint occurrence of significant wave height (Hm0) versus wave direction (DirP) for deployment at Site E.

Direction	N	NNE	NE	ENE	E	ESE	SE	SSE	S	SSW	SW	WSW	W	WNW	NW	NNW	
Direction (°) / Hm0 (m)	348.75 - 11.25	11.25 - 33.75	33.75 - 56.25	56.25 - 78.75	78.75 - 101.25	101.25 - 123.75	123.75 - 146.25	146.25 - 168.75	168.75 - 191.25	191.25 - 213.75	213.75 - 236.25	236.25 - 258.75	258.75 - 281.25	281.25 - 303.75	303.75 - 326.25	326.25 - 348.75	Total (%)
0-0.25	0.25	0.27	0.54	1.63	1.09	0.46	0.33	0.33	0.16	0.12	0.18	0.12	0.15	0.07	0.13	0.15	5.98
0.25-0.5	0.64	0.55	1.03	6.80	4.33	2.88	3.79	1.64	0.91	1.06	0.89	1.00	0.70	0.76	0.52	0.60	28.10
0.5-0.75	0.25	0.28	1.04	10.11	3.74	1.19	3.85	1.12	0.91	2.22	2.16	0.73	0.27	0.43	0.43	0.30	29.05
0.75-1	0.00	0.00	0.43	5.10	1.67	1.07	2.13	0.43	0.39	2.03	2.21	0.07	0.01	0.01	0.00	0.00	15.57
1-1.25	0.00	0.00	0.21	1.76	1.39	0.73	1.27	0.18	0.10	1.12	0.40	0.06	0.00	0.00	0.00	0.00	7.22
1.25-1.5	0.00	0.00	0.01	0.85	1.54	1.13	1.03	0.13	0.00	0.33	0.24	0.01	0.00	0.00	0.00	0.00	5.28
1.5-1.75	0.00	0.00	0.00	0.51	0.61	0.98	0.70	0.12	0.00	0.16	0.13	0.00	0.00	0.00	0.00	0.00	3.22
1.75-2	0.00	0.00	0.00	0.16	0.51	1.01	0.60	0.03	0.03	0.10	0.09	0.00	0.00	0.00	0.00	0.00	2.54
2-2.25	0.00	0.00	0.00	0.00	0.60	0.46	0.21	0.03	0.00	0.03	0.00	0.00	0.00	0.00	0.00	0.00	1.33
2.25-2.5	0.00	0.00	0.00	0.10	0.48	0.07	0.15	0.00	0.00	0.01	0.00	0.00	0.00	0.00	0.00	0.00	0.82
2.5-2.75	0.00	0.00	0.00	0.18	0.28	0.00	0.06	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.52
2.75-3	0.00	0.00	0.00	0.00	0.13	0.00	0.01	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.15
3-3.25	0.00	0.00	0.00	0.00	0.19	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.19
3.25-3.5	0.00	0.00	0.00	0.00	0.01	0.00	0.00	0.00	0.00	0.01	0.00	0.00	0.00	0.00	0.00	0.00	0.03
3.5-3.75	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
3.75-4	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
4-4.25	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
4.25-4.5	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
4.5-4.75	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
4.75-5	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Total (%)	1.15	1.10	3.27	27.20	16.57	10.01	14.12	4.01	2.51	7.20	6.31	2.00	1.13	1.28	1.09	1.04	100.00

Table 10. Table of joint occurrence of significant wave height (Hm0) versus peak period (Tp) for deployment period at Site E.

Tp (s) / Hm0 (m)	0-2	2-4	4-6	6-8	8-10	10-12	12-14	14-16	16-18	>18	Total (%)
0-0.25	0.48	2.42	0.24	1.06	0.82	0.91	0.03	0.03	0.00	0.00	5.98
0.25-0.5	0.21	12.18	4.71	5.25	2.80	2.89	0.04	0.00	0.00	0.00	28.10
0.5-0.75	0.00	10.17	6.14	7.10	2.58	3.06	0.00	0.00	0.00	0.00	29.05
0.75-1	0.00	3.85	3.88	4.97	1.80	1.07	0.00	0.00	0.00	0.00	15.57
1-1.25	0.00	0.57	2.18	3.28	1.06	0.13	0.00	0.00	0.00	0.00	7.22
1.25-1.5	0.00	0.04	1.34	3.03	0.87	0.00	0.00	0.00	0.00	0.00	5.28
1.5-1.75	0.00	0.00	0.69	1.64	0.89	0.00	0.00	0.00	0.00	0.00	3.22
1.75-2	0.00	0.00	0.39	1.07	1.01	0.06	0.00	0.00	0.00	0.00	2.54
2-2.25	0.00	0.00	0.10	0.66	0.57	0.00	0.00	0.00	0.00	0.00	1.33
2.25-2.5	0.00	0.00	0.01	0.49	0.31	0.00	0.00	0.00	0.00	0.00	0.82
2.5-2.75	0.00	0.00	0.01	0.37	0.13	0.00	0.00	0.00	0.00	0.00	0.52
2.75-3	0.00	0.00	0.00	0.06	0.07	0.01	0.00	0.00	0.00	0.00	0.15
3-3.25	0.00	0.00	0.00	0.01	0.18	0.00	0.00	0.00	0.00	0.00	0.19
3.25-3.5	0.00	0.00	0.00	0.01	0.00	0.01	0.00	0.00	0.00	0.00	0.03
3.5-3.75	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
3.75-4	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
4-4.25	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
4.25-4.5	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
4.5-4.75	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
4.75-5	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Total (%)	0.69	29.23	19.70	29.01	13.11	8.16	0.07	0.03	0.00	0.00	100.00

Table 11. Table of joint occurrence of significant wave height (Hm0) versus wave spread (SprTp) for deployment period at Site E.

Hm0 (m) \ SprTp (°)	0-10	10-20	20-30	30-40	40-50	50-60	60-70	70-80	>80	Total (%)
0-0.25	0.09	0.00	0.00	0.00	0.00	0.40	1.72	1.94	1.83	5.98
0.25-0.5	0.06	0.00	0.00	0.88	5.71	6.70	3.00	4.15	7.61	28.10
0.5-0.75	0.00	0.01	1.98	8.29	8.13	1.76	1.72	4.80	2.36	29.05
0.75-1	0.00	0.22	4.73	5.35	2.92	1.24	0.60	0.51	0.00	15.57
1-1.25	0.00	0.48	4.09	2.04	0.52	0.09	0.00	0.00	0.00	7.22
1.25-1.5	0.00	1.06	3.13	1.03	0.06	0.00	0.00	0.00	0.00	5.28
1.5-1.75	0.00	0.88	1.91	0.40	0.03	0.00	0.00	0.00	0.00	3.22
1.75-2	0.00	0.92	1.39	0.22	0.00	0.00	0.00	0.00	0.00	2.54
2-2.25	0.00	0.89	0.33	0.10	0.00	0.00	0.00	0.00	0.00	1.33
2.25-2.5	0.00	0.34	0.34	0.13	0.00	0.00	0.00	0.00	0.00	0.82
2.5-2.75	0.00	0.10	0.33	0.09	0.00	0.00	0.00	0.00	0.00	0.52
2.75-3	0.00	0.07	0.07	0.00	0.00	0.00	0.00	0.00	0.00	0.15
3-3.25	0.00	0.16	0.03	0.00	0.00	0.00	0.00	0.00	0.00	0.19
3.25-3.5	0.00	0.01	0.01	0.00	0.00	0.00	0.00	0.00	0.00	0.03
3.5-3.75	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
3.75-4	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
4-4.25	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
4.25-4.5	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
4.5-4.75	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
4.75-5	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Total (%)	0.15	5.18	18.34	18.55	17.38	10.19	7.02	11.39	11.80	100.00

3.2 AWAC Site F

Site F had successful data recovery for all phases during the campaign. Table 12 presents the general statistics for all the phases and Table 13 summarises the data return before and after quality control.

Table 12. Wave data statistics showing date and time of significant waves at Site F.

Parameter	Min	Date	Max	Date	Mean	StDev
Hm0 (m)	0.11	Multiple Occurrences	4.54	03/04/2012 11:01	0.94	0.56
Hmax (m)	0.14	27/03/2012 11:01	8.27	03/04/2012 11:01	1.43	0.87
Tp (s)	1.82	18/01/2012 07:01	13.82*	19/02/2012 19:01	7.99	2.97
Tm02 (s)	1.95	28/03/2012 08:31	8.58	19/02/2012 18:01	4.12	1.19
SprTp (°)	4.93	12/05/2012 16:31	81.02	18/01/2012 07:31	38.16	18.30

*Max Tp is taken as the maximum observed when Hm0>1 m.

Table 13. Data return during AWAC deployment at Site F.

Parameter	Records Expected	Total Records Returned	Non-Valid/Failed Records	Valid Data Return (%)	Number of Flagged Records	QA Data Return (%)
Hm0 (m)	8639	8639	7	99.9	2	99.8
Hmax (m)			7	99.9	0	99.9
Tp (s)			7	99.9	452	94.6
Tm02 (s)			7	99.9	7	99.8
DirTp (°)			7	99.9	128	98.4
SprTp (°)			7	99.9	0	99.9
MeanDir (°)			7	99.9	8	99.8

The time series for wave height, period and direction are presented in Figure 12, Figure 13 and Figure 14 respectively. Figure 15 presents scatter plots of significant wave height (Hm0) versus maximum wave height (Hmax) and also average period (Tm02) versus peak period (Tp) as a function of significant wave height. Joint occurrence tables of Hm0 vs. DirTp, Hm0 vs. Tp and Hm0 vs. SprTp are presented in Table 14 to Table 16.

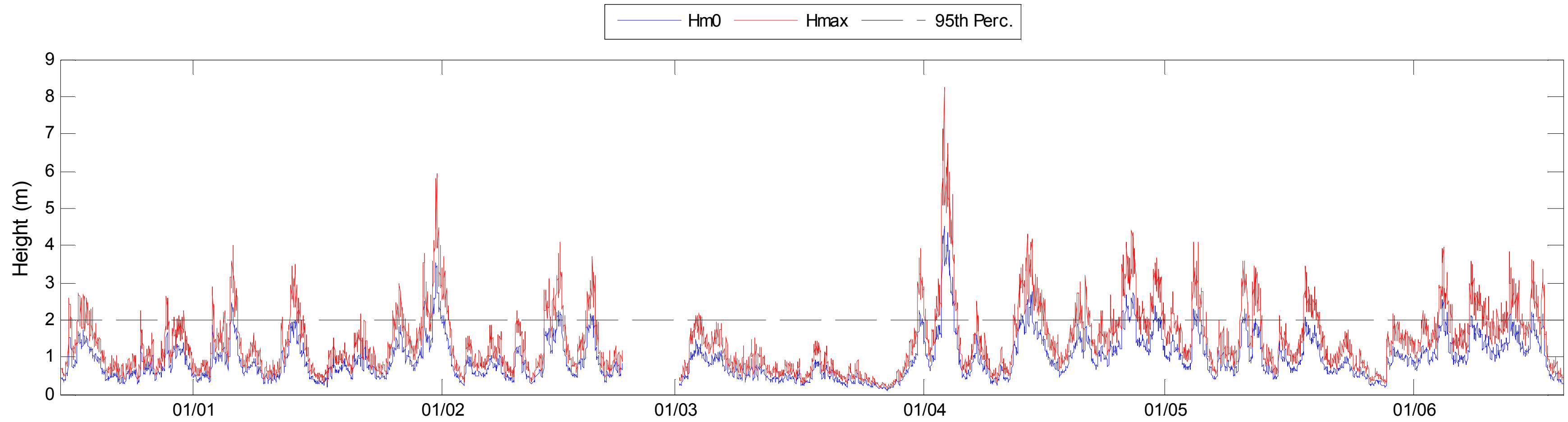

Figure 12. Wave height (Hm0 and Hmax) and 95th percentile of Hm0 at Site F.

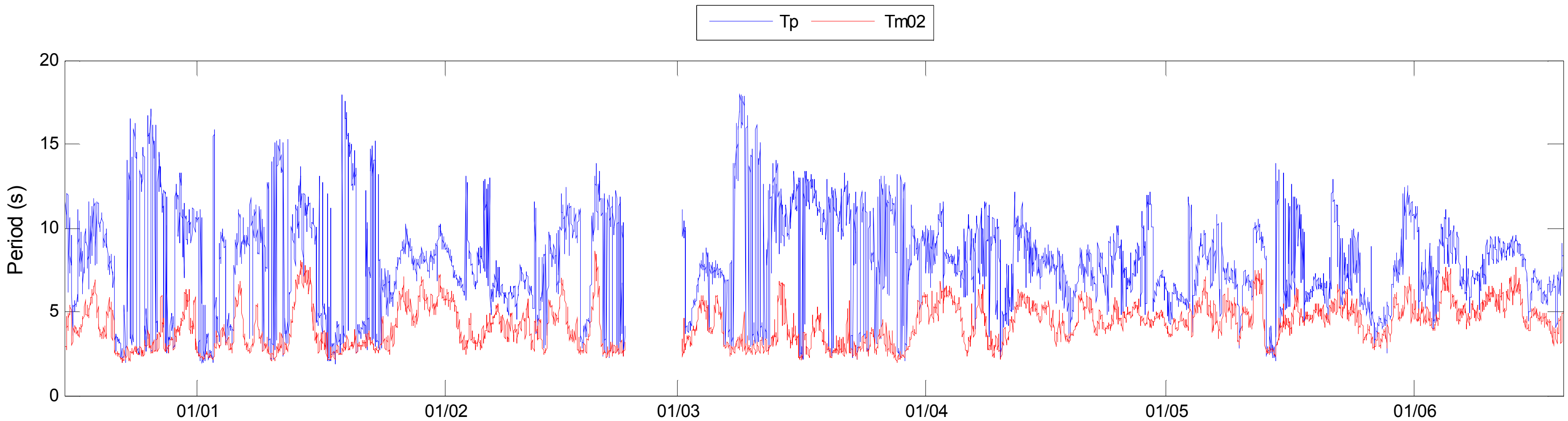

Figure 13. Wave period (Tp and Tm02) at Site F.

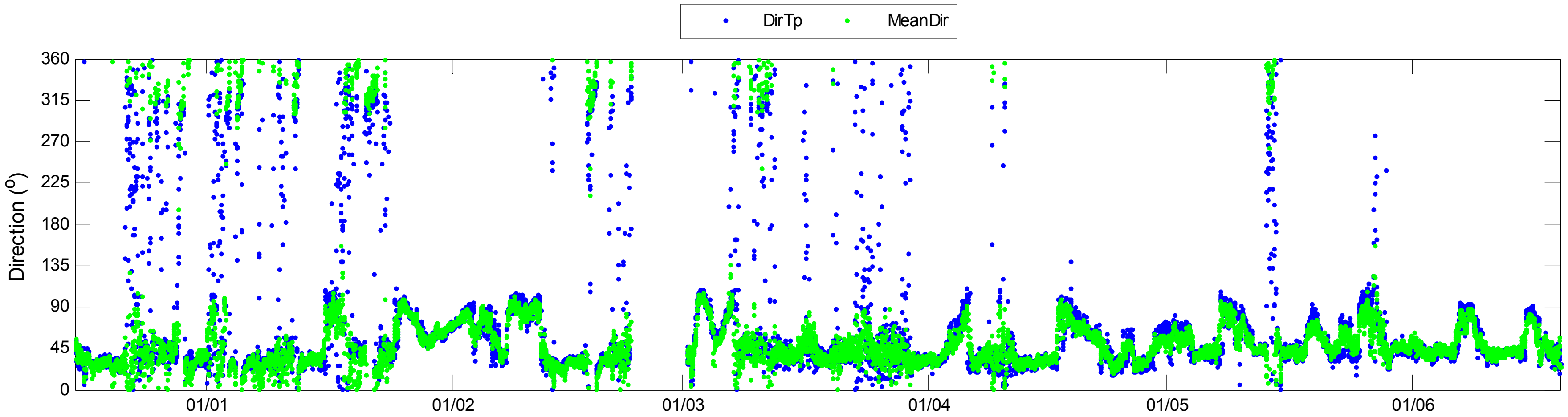

Figure 14. Wave direction (DirTp and MeanDir) at Site F.

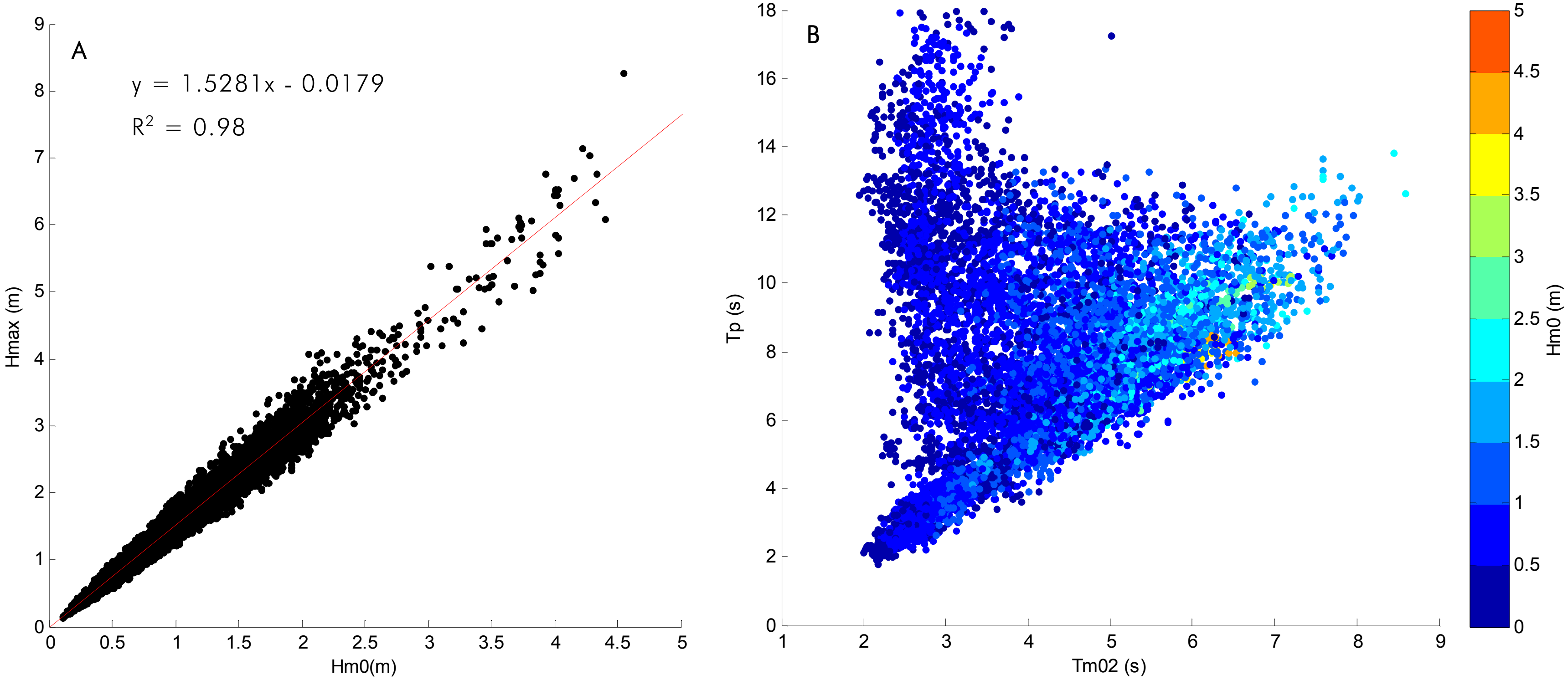

Figure 15. Scatter plots of A. Hm0 vs. Hmax (with least square line) (left) and B. Tm02 vs. Tp with a colour scale to indicate the Hm0 seen during the wave period (right) at Site F.

Table 14. Table of joint occurrence of significant wave height (Hm0) versus wave direction (DirP) for deployment at Site F.

Direction	N	NNE	NE	ENE	E	ESE	SE	SSE	S	SSW	SW	WSW	W	WNW	NW	NNW	
Direction (°) / Hm0(m)	348.75 - 11.25	11.25 - 33.75	33.75 - 56.25	56.25 - 78.75	78.75 - 101.25	101.25 - 123.75	123.75 - 146.25	146.25 - 168.75	168.75 - 191.25	191.25 - 213.75	213.75 - 236.25	236.25 - 258.75	258.75 - 281.25	281.25 - 303.75	303.75 - 326.25	326.25 - 348.75	Total (%)
0-0.25	0.02	0.60	1.10	0.45	0.09	0.01	0.02	0.00	0.00	0.02	0.00	0.00	0.00	0.00	0.01	0.01	2.34
0.25-0.5	0.28	3.97	9.12	1.63	2.48	0.80	0.08	0.27	0.14	0.18	0.28	0.20	0.18	0.17	0.14	0.21	20.13
0.5-0.75	0.24	4.49	8.34	1.82	2.94	0.39	0.21	0.21	0.25	0.21	0.32	0.31	0.39	0.59	0.88	0.47	22.08
0.75-1	0.10	4.05	6.22	2.84	2.36	0.10	0.08	0.02	0.06	0.05	0.12	0.09	0.18	0.39	1.14	0.13	17.94
1-1.25	0.03	3.36	5.28	2.24	1.65	0.25	0.01	0.01	0.01	0.00	0.02	0.03	0.07	0.24	0.54	0.10	13.87
1.25-1.5	0.03	2.68	2.24	1.82	0.87	0.03	0.00	0.00	0.00	0.00	0.01	0.00	0.01	0.07	0.08	0.05	7.90
1.5-1.75	0.03	1.91	2.03	1.67	0.58	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.03	0.05	0.00	6.30
1.75-2	0.00	1.43	1.74	0.90	0.44	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.01	0.00	0.00	4.53
2-2.25	0.00	0.85	0.99	0.62	0.23	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	2.70
2.25-2.5	0.00	0.38	0.22	0.31	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.91
2.5-2.75	0.00	0.16	0.03	0.18	0.01	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.39
2.75-3	0.00	0.01	0.03	0.16	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.21
3-3.25	0.00	0.00	0.02	0.08	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.10
3.25-3.5	0.00	0.00	0.01	0.13	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.14
3.5-3.75	0.00	0.00	0.08	0.09	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.17
3.75-4	0.00	0.00	0.08	0.02	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.10
4-4.25	0.00	0.00	0.10	0.01	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.12
4.25-4.5	0.00	0.00	0.05	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.05
4.5-4.75	0.00	0.00	0.01	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.01
4.75-5	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Total (%)	0.75	23.90	37.71	15.00	11.65	1.59	0.40	0.51	0.46	0.46	0.75	0.64	0.84	1.51	2.84	0.97	100

Table 15. Table of joint occurrence of significant wave height (Hm0) versus peak period (Tp) for deployment period at Site F.

Hm0 (m) \ Tp (s)	0-2	2-4	4-6	6-8	8-10	10-12	12-14	14-16	16-18	>18	Total (%)
0-0.25	0.00	0.07	0.37	0.48	0.27	0.83	0.32	0.00	0.00	0.00	2.34
0.25-0.5	0.07	3.19	3.41	2.88	2.61	3.93	2.71	0.97	0.36	0.01	20.13
0.5-0.75	0.00	4.76	2.75	4.78	3.05	3.87	1.39	1.03	0.46	0.00	22.08
0.75-1	0.00	1.92	2.83	6.02	4.03	2.59	0.17	0.30	0.09	0.00	17.94
1-1.25	0.00	0.51	2.16	4.99	4.25	1.69	0.28	0.00	0.00	0.00	13.87
1.25-1.5	0.00	0.05	0.90	2.62	3.41	0.83	0.09	0.00	0.00	0.00	7.90
1.5-1.75	0.00	0.00	0.66	2.17	2.53	0.87	0.08	0.00	0.00	0.00	6.30
1.75-2	0.00	0.00	0.33	1.57	1.78	0.74	0.10	0.00	0.00	0.00	4.53
2-2.25	0.00	0.00	0.07	1.29	1.02	0.27	0.06	0.00	0.00	0.00	2.70
2.25-2.5	0.00	0.00	0.00	0.46	0.44	0.01	0.00	0.00	0.00	0.00	0.91
2.5-2.75	0.00	0.00	0.00	0.17	0.22	0.00	0.00	0.00	0.00	0.00	0.39
2.75-3	0.00	0.00	0.00	0.06	0.14	0.01	0.00	0.00	0.00	0.00	0.21
3-3.25	0.00	0.00	0.00	0.02	0.05	0.03	0.00	0.00	0.00	0.00	0.10
3.25-3.5	0.00	0.00	0.00	0.01	0.08	0.05	0.00	0.00	0.00	0.00	0.14
3.5-3.75	0.00	0.00	0.00	0.06	0.12	0.00	0.00	0.00	0.00	0.00	0.17
3.75-4	0.00	0.00	0.00	0.02	0.08	0.00	0.00	0.00	0.00	0.00	0.10
4-4.25	0.00	0.00	0.00	0.02	0.09	0.00	0.00	0.00	0.00	0.00	0.12
4.25-4.5	0.00	0.00	0.00	0.02	0.02	0.00	0.00	0.00	0.00	0.00	0.05
4.5-4.75	0.00	0.00	0.00	0.00	0.01	0.00	0.00	0.00	0.00	0.00	0.01
4.75-5	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Total (%)	0.07	10.48	13.48	27.66	24.18	15.70	5.21	2.30	0.91	0.01	100

Table 16. Table of joint occurrence of significant wave height (Hm0) versus wave spread (SprTp) for deployment period at Site F.

SprTp (°) / Hm0 (m)	0-10	10-20	20-30	30-40	40-50	50-60	60-70	70-80	>80	Total (%)
0-0.25	0.00	0.00	0.00	0.00	0.05	0.52	1.26	0.47	0.05	2.34
0.25-0.5	0.00	0.00	0.05	2.02	7.08	5.64	2.01	0.96	2.38	20.13
0.5-0.75	0.00	0.01	2.24	7.53	6.41	1.09	0.24	2.51	2.06	22.08
0.75-1	0.00	0.57	8.73	5.30	1.29	0.50	0.37	0.98	0.21	17.94
1-1.25	0.01	2.17	8.28	2.36	0.61	0.10	0.07	0.25	0.01	13.87
1.25-1.5	0.00	2.21	4.54	1.02	0.09	0.01	0.01	0.01	0.01	7.90
1.5-1.75	0.02	2.85	3.01	0.30	0.12	0.00	0.00	0.00	0.00	6.30
1.75-2	0.02	2.37	1.56	0.51	0.07	0.00	0.00	0.00	0.00	4.53
2-2.25	0.01	1.20	1.03	0.38	0.08	0.00	0.00	0.00	0.00	2.70
2.25-2.5	0.00	0.35	0.33	0.16	0.07	0.00	0.00	0.00	0.00	0.91
2.5-2.75	0.00	0.15	0.13	0.07	0.05	0.00	0.00	0.00	0.00	0.39
2.75-3	0.00	0.07	0.01	0.01	0.12	0.00	0.00	0.00	0.00	0.21
3-3.25	0.00	0.06	0.00	0.02	0.02	0.00	0.00	0.00	0.00	0.10
3.25-3.5	0.00	0.06	0.00	0.03	0.05	0.00	0.00	0.00	0.00	0.14
3.5-3.75	0.00	0.01	0.02	0.13	0.01	0.00	0.00	0.00	0.00	0.17
3.75-4	0.00	0.00	0.02	0.05	0.03	0.00	0.00	0.00	0.00	0.10
4-4.25	0.00	0.00	0.01	0.08	0.02	0.00	0.00	0.00	0.00	0.12
4.25-4.5	0.00	0.00	0.01	0.03	0.00	0.00	0.00	0.00	0.00	0.05
4.5-4.75	0.00	0.00	0.00	0.01	0.00	0.00	0.00	0.00	0.00	0.01
4.75-5	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Total (%)	0.07	12.07	29.98	20.01	16.17	7.85	3.96	5.18	4.71	100.00

3.3 Summary; Waves

The two sites show a markedly different wave climate and although both have captured the similar significant events, they affect the two sites differently. A significant event is defined once waves exceed a threshold for six hours or more (Lee and Nomark, 2009). The threshold is the 95th percentile of the long-term significant wave height at each site (Table 17). Table 18 presents the dates of significant events with maximum wave height and period observed.

Table 17. 95th percentile values during campaign.

Site	95th Percentile (m)			
	Phase 1	Phase 2	Phase 3	Overall
E	1.89	1.63	N/A	1.76
F	1.87	2.16	1.93	1.99

Table 18. Significant wave events observed at both sites during campaign.

Site	Event	Max Hm0 (m)	Max Hmax (m)	Max Tm02 (s)	Max Tp (s)
E	25/01/2012	2.55	4.26	7.36	10.21
	29/01/2012	3.30	6.03	6.54	10.05
	10/02/2012	2.20	3.86	5.41	7.72
	03/03/2012	2.14	3.44	5.69	8.06
	03/04/2012	3.00	5.01	5.89	8.34
	17/04/2012	2.54	4.13	6.37	8.85
F	05/01/2012	2.46	4.00	5.86	9.66
	30/01/2012	3.54	5.95	7.2	10.24
	03/04/2012	4.54	8.27	6.53	8.69
	13/04/2012	2.75	4.32	5.92	10.04
	26/04/2012	2.74	4.41	5.59	8.76

It can be noted that both sites showed similar 95th percentiles during Phase 1, but Site F showed a significantly larger wave climate in Phase 2 which can be attributed to its larger fetch in the north direction. This can also be observed in the joint occurrence tables, where approximately 38% of waves approach from between the NE and another 24 and 15% approach from the NNE and ENE respectively. Site E shows a much larger wave spread throughout the deployment with significant values (above 10%) seen between the ENE and SE.

The scatter plots (Figure 11 and Figure 15) show a strong linear correlation between Hm0 and Hmax at both sites, the Tp and Tm02 scatter plot are coloured according to corresponding Hm0, this visualises the noise produced during low wave heights (dark blue but high Tp values) and the stronger definition as Hm0 increases (lighter blue to orange). Site F shows larger period values for both Tm02 (average period) and Tp (peak period) but also a larger spread during lower wave heights.

Figure 16 and Figure 17 present wave roses for Hm0 and Tm02 for each site over the individual phases; these show a dominant NNE-NE direction at Site F and the more mixed wave climate at Site E: between ENE, E and SE. A seasonal change between mid-winter (December to February, Phase 1) and spring (March to May, Phase 2) is noticeable at both sites, with Site E and F showing less variance in direction during Phase 2 and in the case of Site F the dominant direction changing from NNE to NE between Phases 1 and 3.

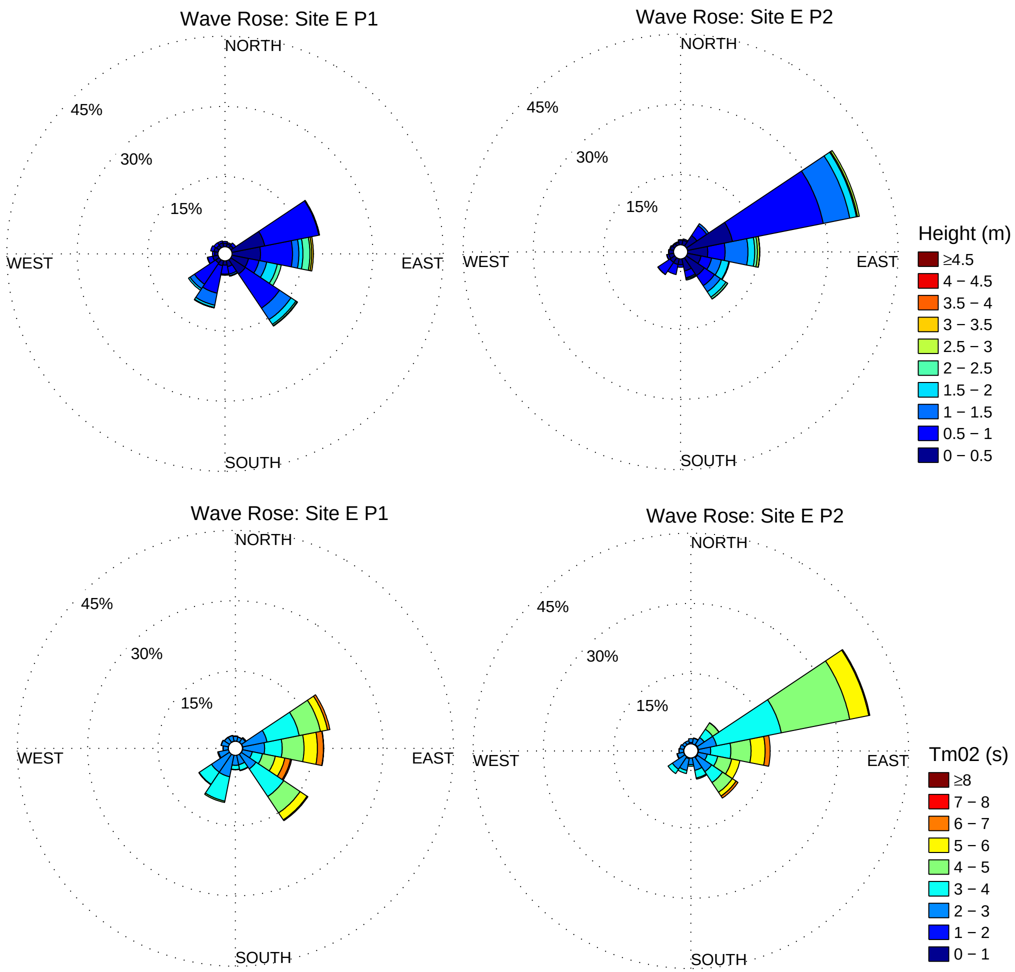

Figure 16. Wave roses of wave height (Hm0) against wave direction (DirTp) (top) and wave period (Tm02) against wave direction (DirTp) (bottom) for Site E during Phases 1 and 2.

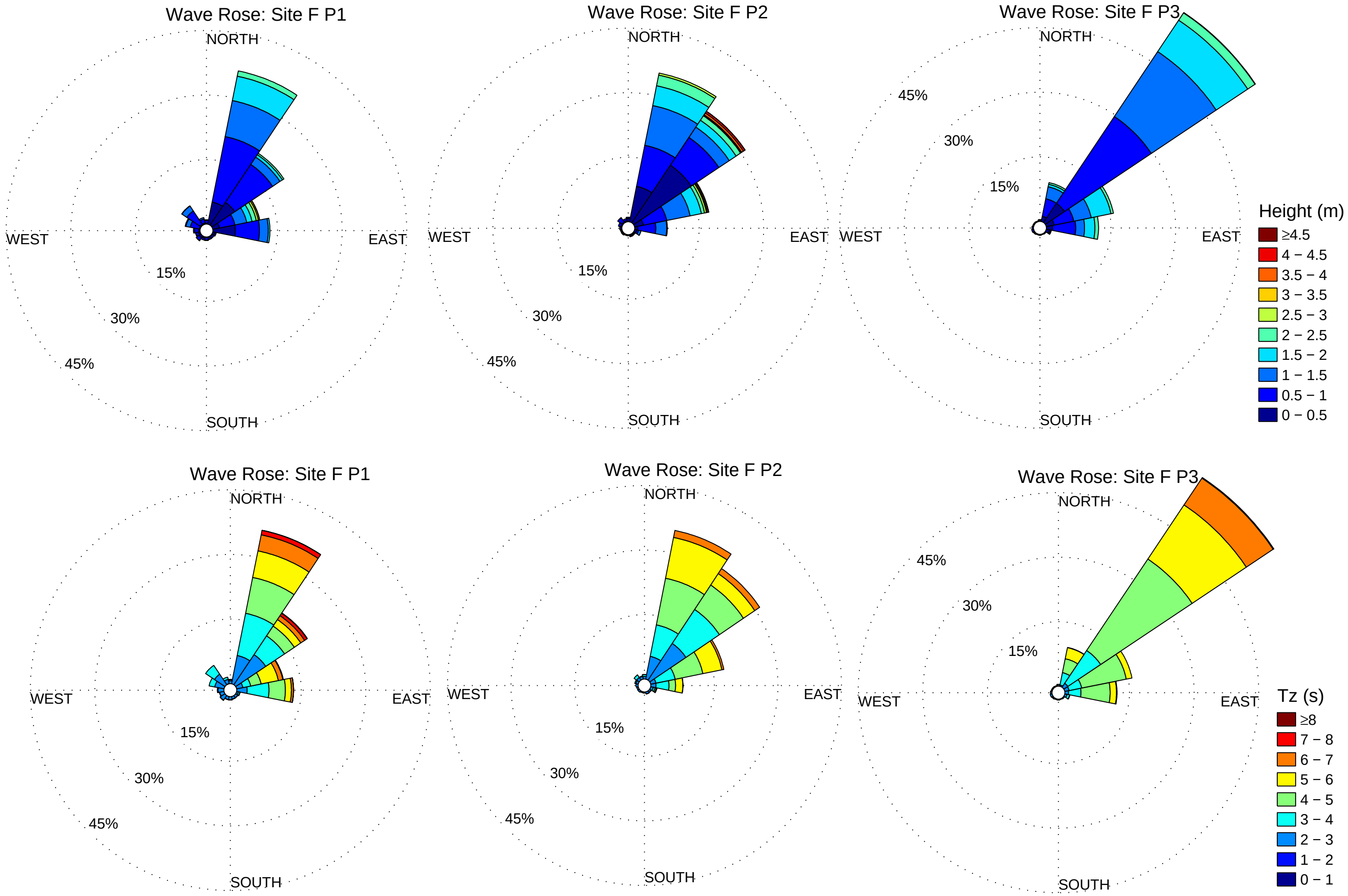

Figure 17. Wave roses of wave height (Hm0) against wave direction (DirTp) (top) and wave period (Tm02) against wave direction (DirTp) (bottom) for Site F during Phases 1, 2 and 3.

4. RESULTS: CURRENT DATA

Data return values are given for each AWAC, this is derived from the number of ensembles returned through the deployment period but does not include the data interpolated due to the current records being affected by wave measurements twice hourly. In this case the interpolated profiles are counted as a returned record (more information on the sampling regime of AWAC instruments can be seen in the AWAC User Guide).

Tidal harmonic analysis is performed at each site through Harmonic Analysis, Method of Least Squares (HAMELS) (Boon, 2004), with values of the main constituents of O_1, K_1, N_2 M_2 and S_2 derived for water level and current speed. Values for the solar annual and semi-annual (S_a and S_{sa}) for the UK were taken from the UK Hydrographic Office. To evaluate the degree of success of the astronomic model the statistical parameters of the Root Mean Square (RMS) error (difference between the observed and predicted values) and Percent Reduction in Variance (%R Variance) (the percentage of variance explained by the model) are given.

4.1 AWAC Site E

The AWAC at Site E returned high quality data for Phases 1 and 2,

Table 19 presents the basic statistics seen through the campaign with Table 20 summarising the exceedance values seen through the water column. An exceedance of 90 is the value at which 90% of the current magnitude records are greater than.

Table 21 presents the data return for the whole deployment.

Table 19. Current statistics showing date and time of significant currents at Site E.

Parameter	Min	Date	Max	Date	Mean	StDev
Depth Average (m s^{-1})	0.01	19/12/2011 03:10	0.69	26/12/2011 18:10	0.26	0.14
Current Magnitude (m s^{-1})	0.00	Multiple Occurrences	0.85	10/02/2012 20:00	0.27	0.14
Predominant Direction (°)	WSW-ENE					

Table 20 Magnitude values of exceedance for fixed percentiles at Site E.

Percentile	90	75	50	25	10	5	1	Max
Current Magnitude (m s^{-1})	0.09	0.15	0.26	0.37	0.46	0.52	0.61	0.85

Table 21. Current data return at Site E.

Expected Records	Returned Records	Data Return (%)
20031	20015	99.9

Time series of magnitude and direction are shown for a 72 hour period in Figure 18 and Figure 19, with Figure 20 and Figure 21 being a time series of the entire monitoring campaign: Note: data are removed in the top 10 % of the water column as they are susceptible to error caused by side-lobe echoes from the water surface.

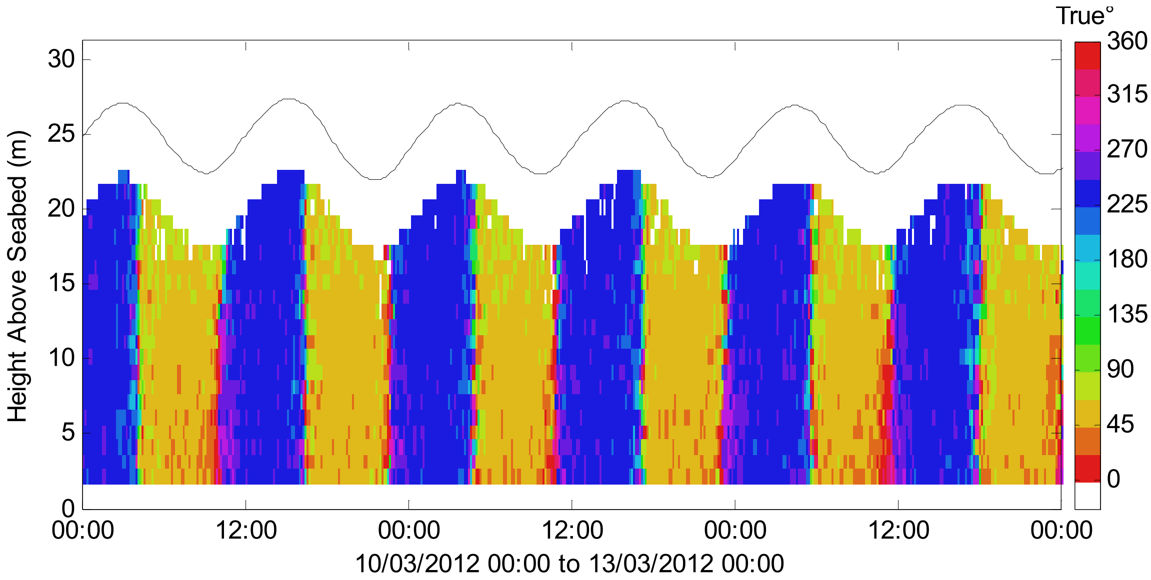

Figure 18. Current direction at Site E over a 72 hour period.

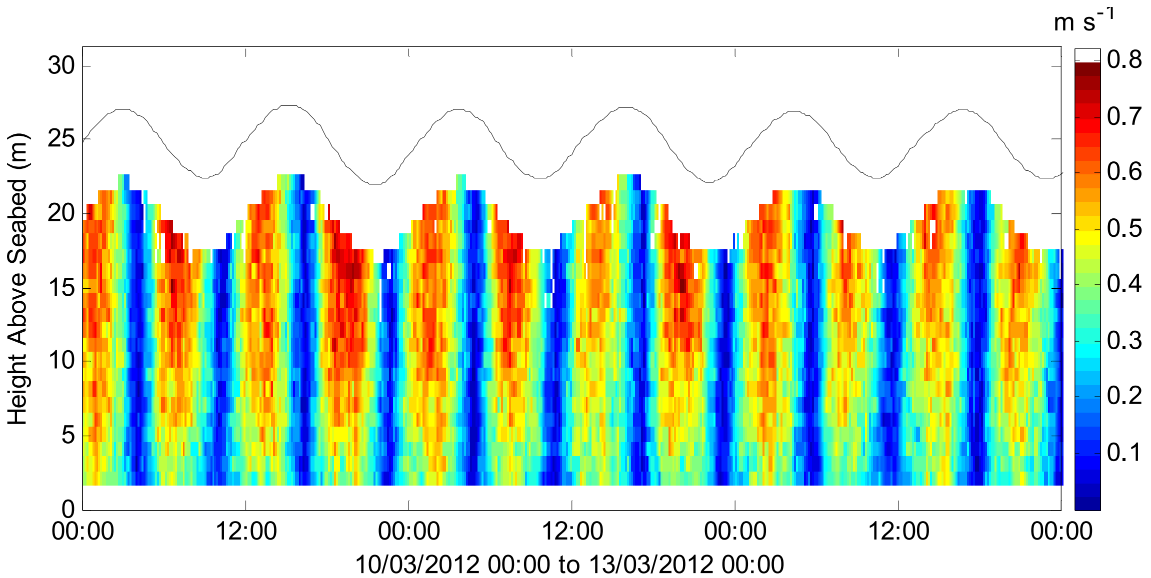

Figure 19. Current magnitude at Site E over a 72 hour period.

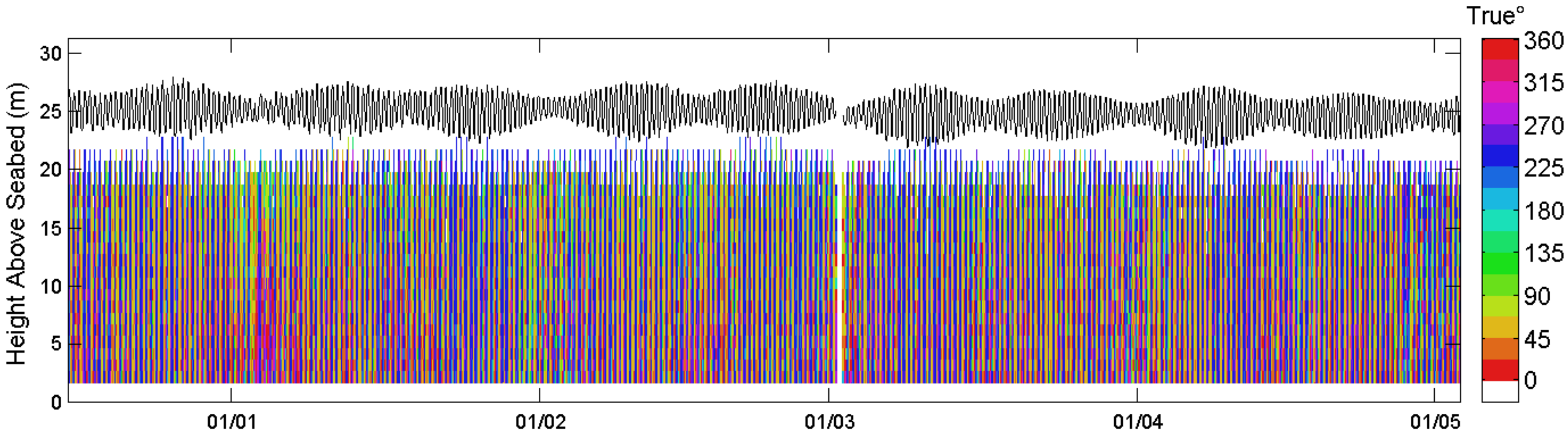

Figure 20. Current direction at Site E over monitoring campaign. Showing data gap between Phase 1 and 2 due to service visit.

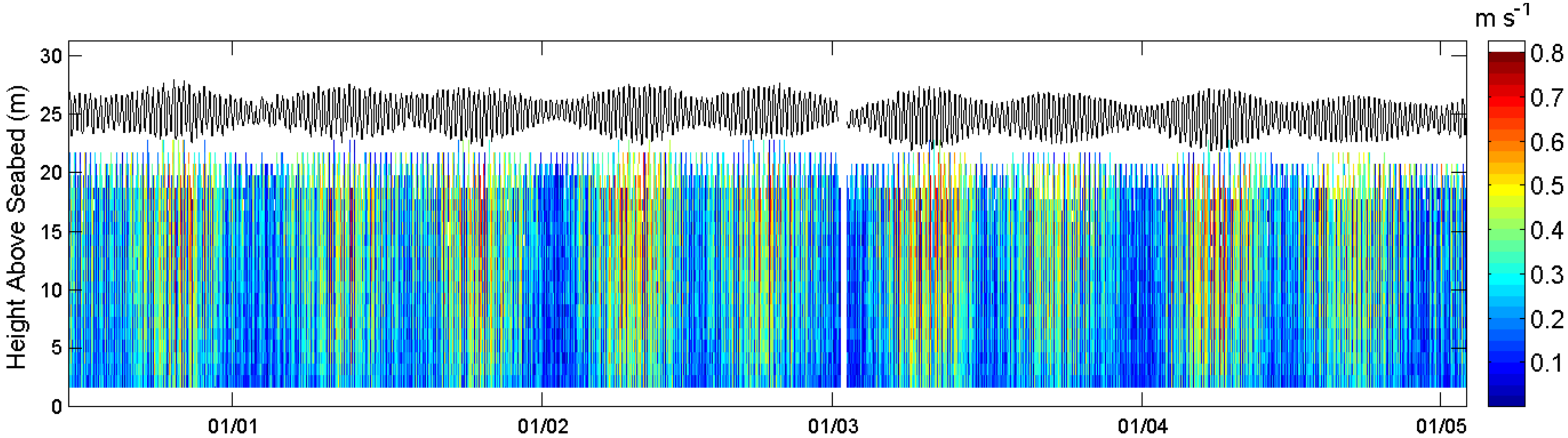

Figure 21. Current magnitude at Site E over monitoring campaign.

Table 22 summarises the deployment in a joint occurrence table of depth-averaged current speed and direction. Figure 22 presents statistical profile plots and a profile plot in which the maximum current speed was observed, current direction and magnitude as a current rose is presented in Figure 23.

Table 22. Table of joint occurrence of current speed and direction (depth-averaged) for deployment period at Site E.

Direction	N	NNE	NE	ENE	E	ESE	SE	SSE	S	SSW	SW	WSW	W	WNW	NW	NNW	
Direction (°) / Speed ($m\ s^{-1}$)	348.75 - 11.25	11.25 - 33.75	33.75 - 56.25	56.25 - 78.75	78.75 - 101.25	101.25 - 123.75	123.75 - 146.25	146.25 - 168.75	168.75 - 191.25	191.25 - 213.75	213.75 - 236.25	236.25 - 258.75	258.75 - 281.25	281.25 - 303.75	303.75 - 326.25	326.25 - 348.75	Total (%)
0 -0.1	0.78	1.24	1.90	1.80	0.83	0.44	0.29	0.34	0.38	0.93	1.83	2.00	1.48	0.73	0.51	0.55	16.09
0.1 -0.2	0.02	0.35	5.55	4.24	0.10	0.01	0.02	0.01	0.00	0.18	4.76	5.61	0.21	0.00	0.00	0.00	21.06
0.2 -0.3	0.00	0.01	5.64	5.47	0.01	0.00	0.00	0.00	0.00	0.00	5.84	6.34	0.00	0.00	0.00	0.00	23.32
0.3 -0.4	0.00	0.00	4.85	5.36	0.00	0.00	0.00	0.00	0.00	0.00	4.74	6.58	0.00	0.00	0.00	0.00	21.53
0.4 -0.5	0.00	0.00	3.31	4.17	0.00	0.00	0.00	0.00	0.00	0.00	2.11	4.18	0.00	0.00	0.00	0.00	13.77
0.5 -0.6	0.00	0.00	0.99	1.94	0.00	0.00	0.00	0.00	0.00	0.00	0.21	0.86	0.00	0.00	0.00	0.00	4.01
0.6 -0.7	0.00	0.00	0.03	0.17	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.01	0.00	0.00	0.00	0.00	0.21
0.7 -0.8	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
0.8 -0.9	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
0.9 -1	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Total (%)	0.80	1.61	22.28	23.16	0.94	0.45	0.31	0.35	0.38	1.11	19.50	25.59	1.69	0.74	0.51	0.55	100.00

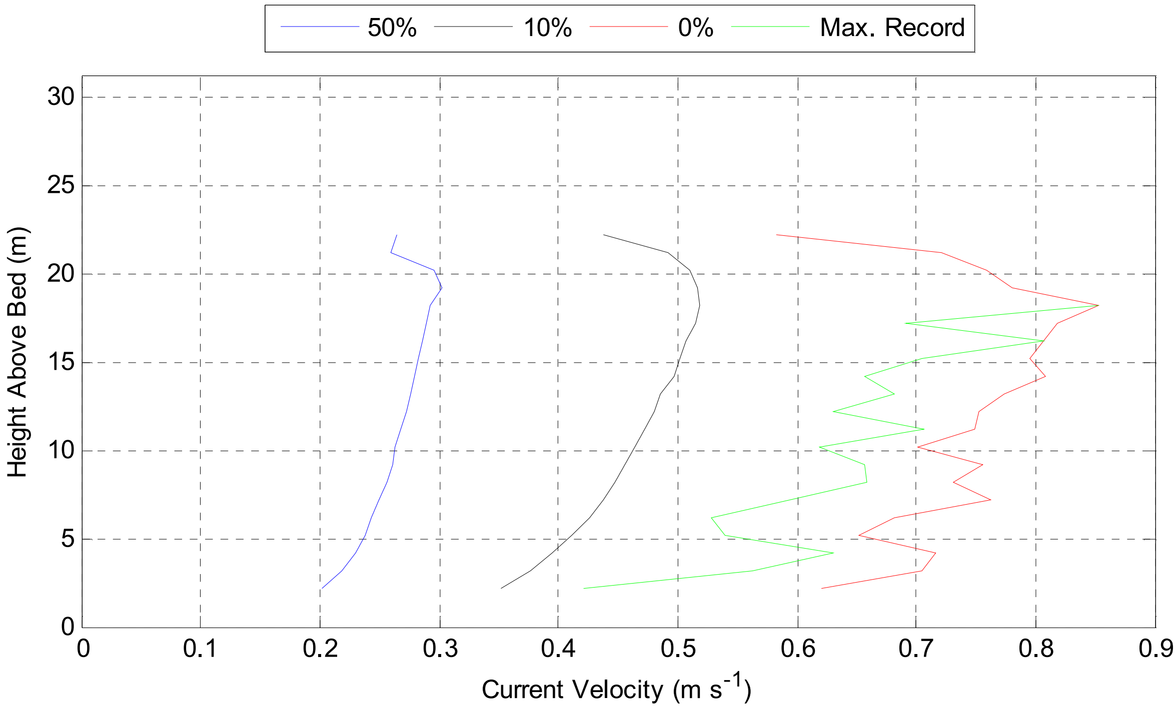

Figure 22. Statistical profile plots at 50, 10 and 0% exceedance for each measurement cell and profile plot of record with maximum current velocity during deployment (10/02/2012 20:00) at Site E.

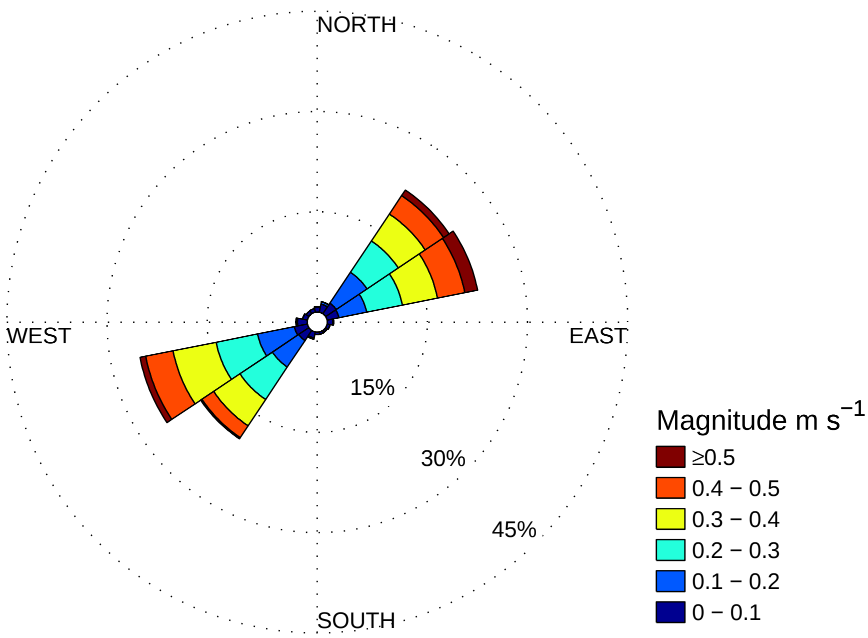

Figure 23. Current rose of depth-averaged velocity magnitude & direction at Site E.

4.1.1 Tidal Harmonics

Site E tidal harmonics were derived through a 58 day analysis between 2nd March and 29th April, 2012; this was chosen to coincide with full synodic periods (Boon, 2004) and provided the longest consecutive data period between all phases. Figure 24 and Figure 25 present the observed and modelled astronomic water level and current speeds respectively. With Table 23 providing tidal constituent values for the astronomic models along with the RMS and %R Variance.

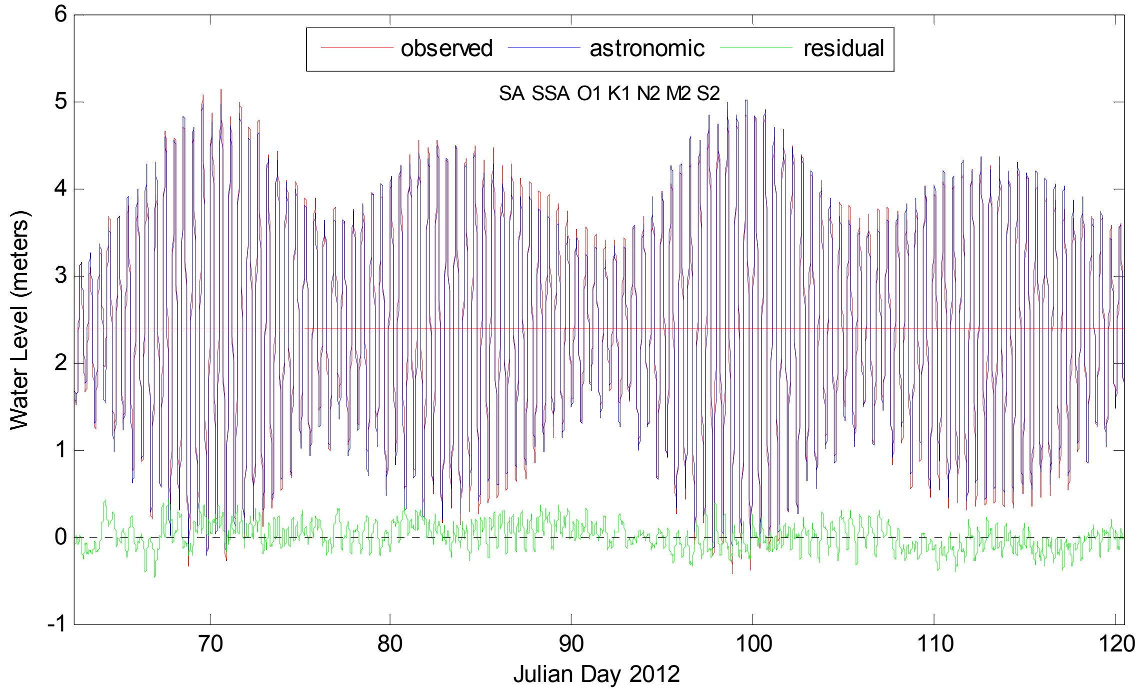

Figure 24. 58 day water level analysis of Site E. With observed against modelled height residual.

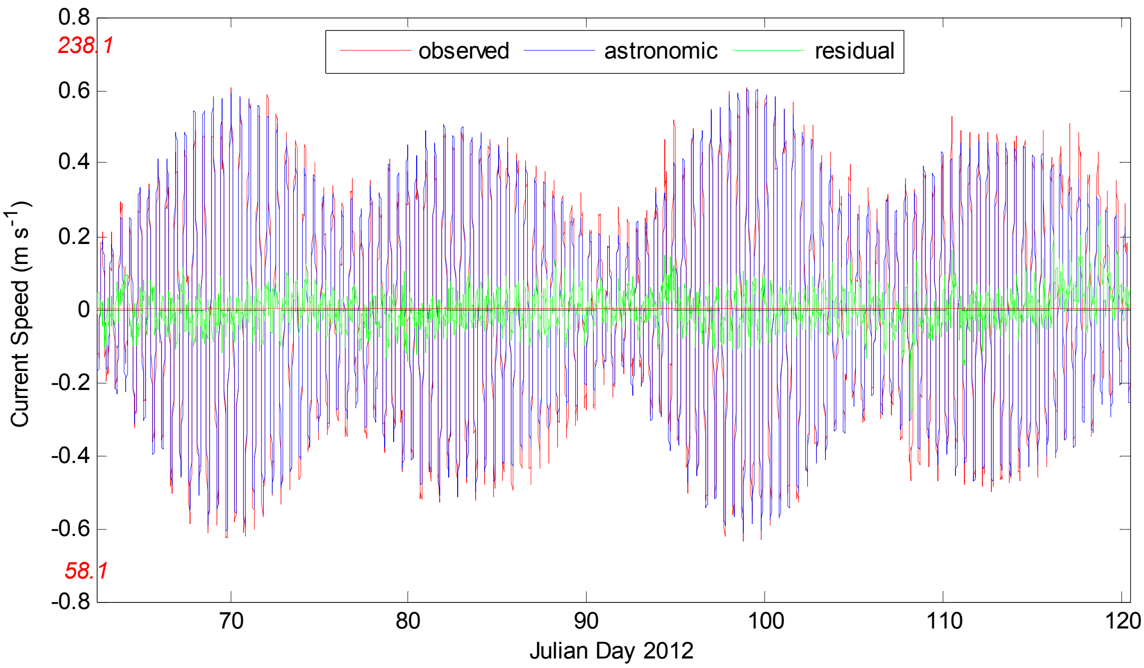

Figure 25. 58 day current analysis of Site E. With observed against modelled speed residual and direction in red. Peak current direction for ebb and flood are presented on the left in red.

Table 23. Derived tidal height and current harmonic constituents, with associated RMS error and explained variance for Site E.

	Tidal Height		Tidal Current	
Tidal Constituent	Amplitude (m)	Phase (°)	Amplitude (m)	Phase (°)
S_a	0.075	206.00	-	-
S_{sa}	0.019	350.00	-	-
O_1	0.157	13.49	0.152	19.27
K_1	0.086	193.90	0.106	200.11
N_2	0.333	250.15	0.354	255.84
M_2	1.565	350.47	1.598	2.15
S_2	0.628	80.67	0.535	92.15
RMS Error	0.15		0.16	
%R Variance	98.59		98.29	

Figure 26 presents the tidal ellipse over the 58 day analysis. With a semi-major axis of 0.342 m s^{-1} and semi-minor axis of 0.024 m s^{-1}. The major axis flood is 58.30° and ebb is 238.30°. The minor axis runs between 148.30° and 328.30°.

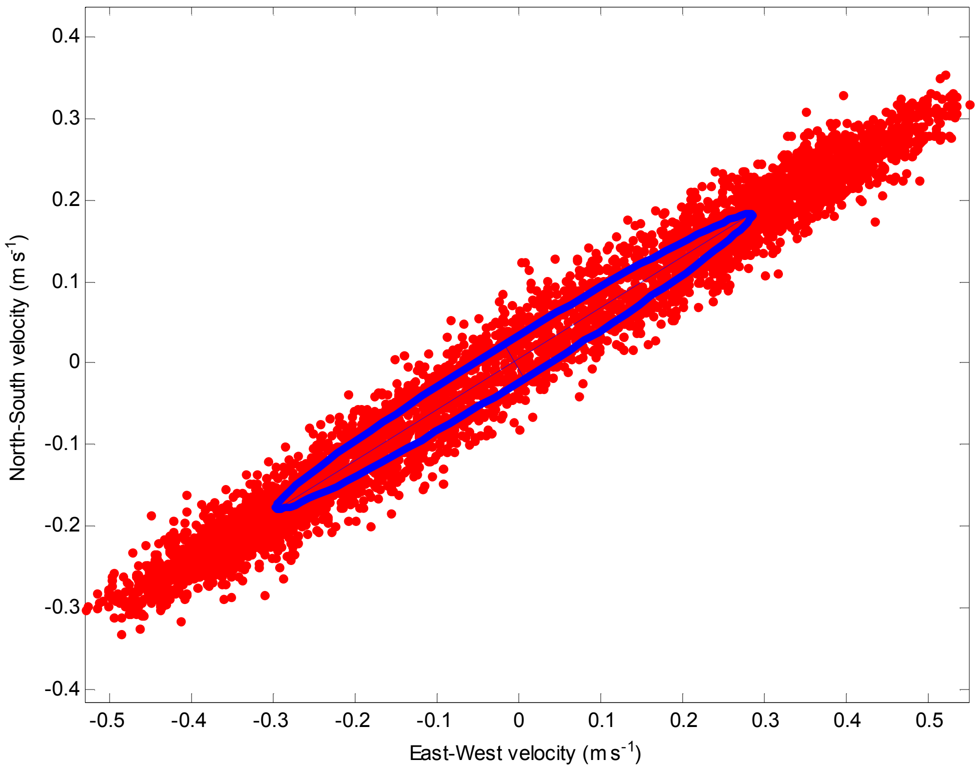

Figure 26. Mean spring tidal ellipse at Site E over 58 day analysis.

4.2 AWAC Site F

The AWAC at Site F returned high quality data for Phases 1, 2 and 3, Table 24 presents the basic statistics seen through the campaign with

Table 25 summarising the exceedance values seen through the water column, where an exceedance of 90 is the value at which 90% of the current magnitude records are greater than.

Table 26 presents the data return for the whole deployment.

Table 24. Current statistics showing date and time of significant currents at Site F.

Parameter	Min	Date	Max	Date	Mean	StDev
Depth Average ($m\ s^{-1}$)	0.01	03/04/2012 21:50	0.55	07/03/2012 15:00	0.18	0.10
Current Magnitude ($m\ s^{-1}$)	0.00	Multiple Occurrences	0.82	07/03/2012 14:50	0.19	0.11
Predominant Direction (°)	NW-SE					

Table 25. Magnitude values of exceedance for fixed percentiles at Site F.

Percentile	90	75	50	25	10	5	1	Max
Current Magnitude ($m\ s^{-1}$)	0.06	0.11	0.18	0.26	0.35	0.40	0.51	0.82

Table 26. Current data return at Site F.

Expected Records	Returned Records	Data Return (%)
25919	25916	99.99

Time series of magnitude and direction are shown for a 72 hour period in Figure 27 and Figure 28, with Figure 29 and Figure 30 being a time series of the entire monitoring campaign.

Table 22 summarises the deployment in a joint occurrence table of depth-averaged current speed and direction. Figure 31 presents statistical profile plots and the profile plot in which the maximum single bin current speed was observed, current direction and magnitude as a current rose is presented in Figure 32.

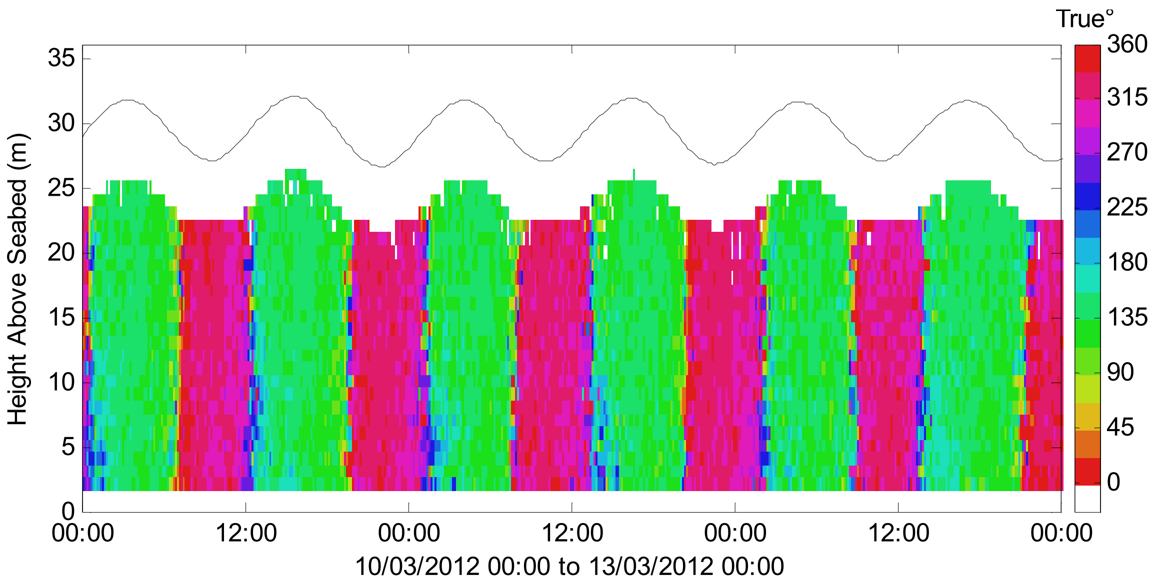

Figure 27. Current direction at Site F over a 72 hour period.

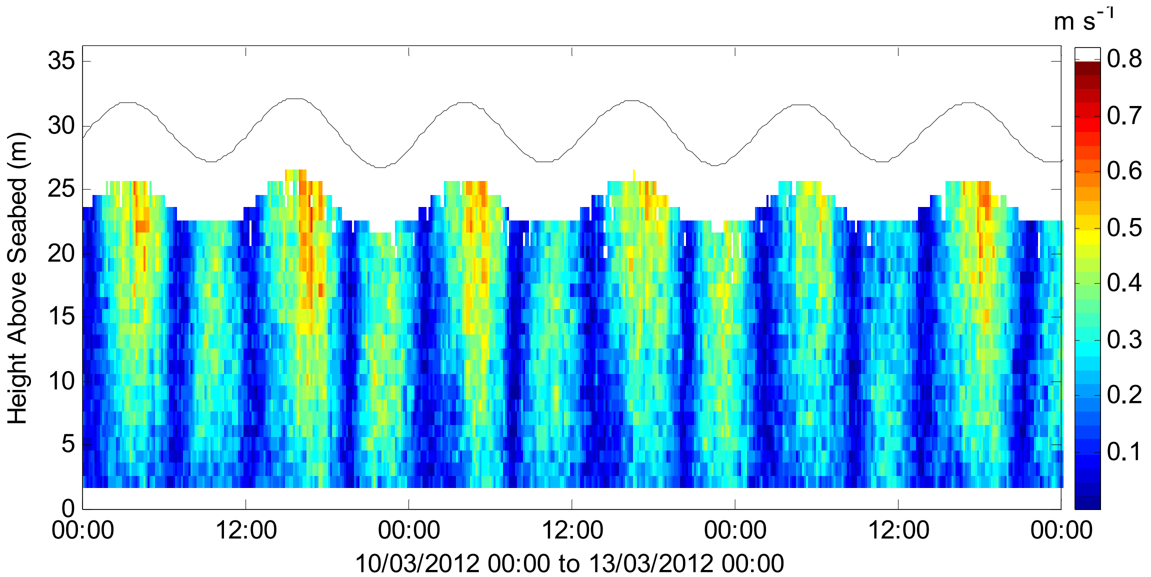

Figure 28. Current magnitude at Site F over a 72 hour period.

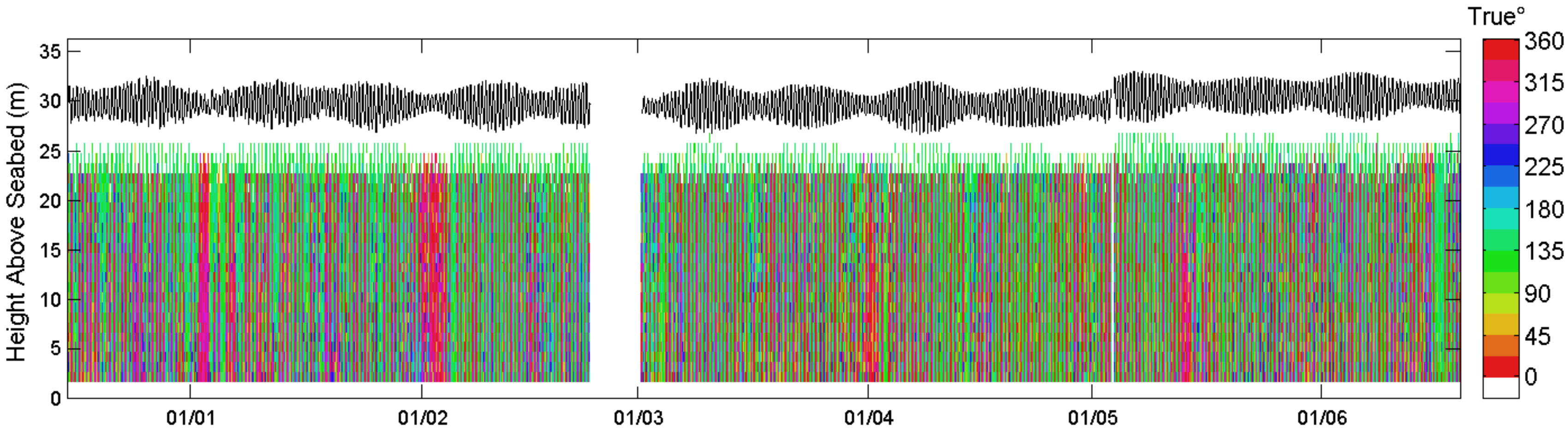

Figure 29. Current direction at Site F over monitoring campaign (missing data can be seen between phases).

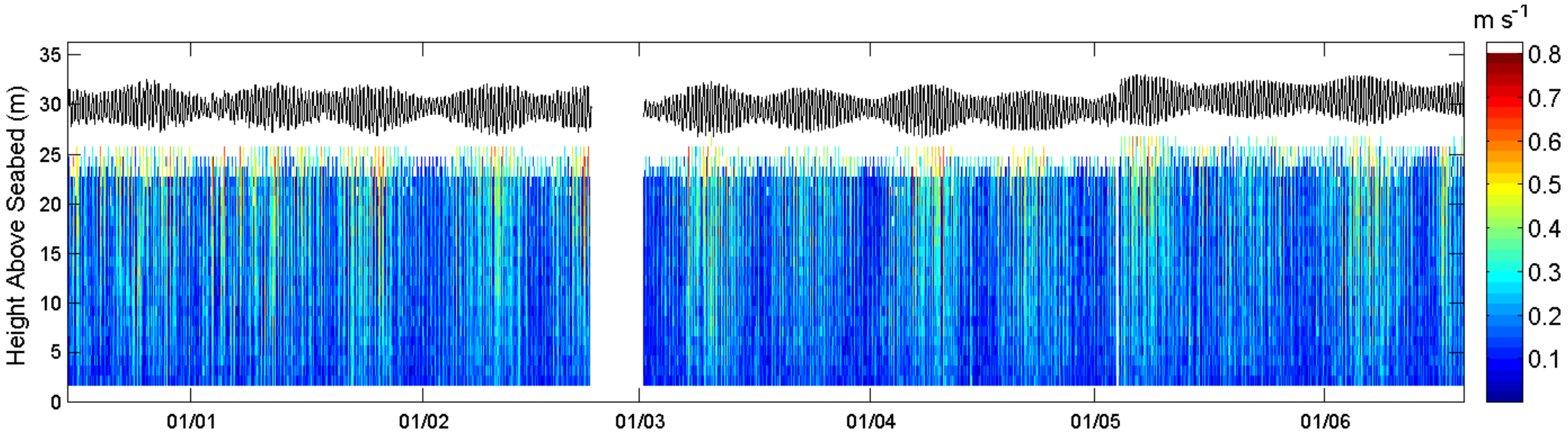

Figure 30. Current magnitude at Site F over monitoring campaign.

Table 27. Table of joint occurrence of current speed and direction (depth-averaged) for deployment period at Site F.

Direction	N	NNE	NE	ENE	E	ESE	SE	SSE	S	SSW	SW	WSW	W	WNW	NW	NNW	
Direction (°) / Speed (m s^{-1})	348.75 - 11.25	11.25 - 33.75	33.75 - 56.25	56.25 - 78.75	78.75 - 101.25	101.25 - 123.75	123.75 - 146.25	146.25 - 168.75	168.75 - 191.25	191.25 - 213.75	213.75 - 236.25	236.25 - 258.75	258.75 - 281.25	281.25 - 303.75	303.75 - 326.25	326.25 - 348.75	Total (%)
0 -0.1	1.49	0.91	0.77	1.01	1.52	2.47	3.27	2.72	1.24	0.73	0.62	0.64	1.09	2.55	3.78	3.13	27.94
0.1 -0.2	0.23	0.00	0.01	0.02	0.14	2.42	10.54	2.60	0.12	0.02	0.00	0.00	0.02	1.25	10.46	4.16	31.99
0.2 -0.3	0.00	0.00	0.00	0.00	0.00	0.44	15.51	0.76	0.00	0.00	0.00	0.00	0.00	0.11	9.38	1.35	27.55
0.3 -0.4	0.00	0.00	0.00	0.00	0.00	0.03	8.44	0.15	0.00	0.00	0.00	0.00	0.00	0.01	1.96	0.05	10.65
0.4 -0.5	0.00	0.00	0.00	0.00	0.00	0.00	1.62	0.03	0.00	0.00	0.00	0.00	0.00	0.00	0.11	0.00	1.76
0.5 -0.6	0.00	0.00	0.00	0.00	0.00	0.00	0.11	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.11
0.6 -0.7	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
0.7 -0.8	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
0.8 -0.9	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
0.9 -1	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Total (%)	1.72	0.91	0.78	1.03	1.65	5.36	39.49	6.26	1.36	0.75	0.62	0.64	1.11	3.92	25.69	8.70	100.00

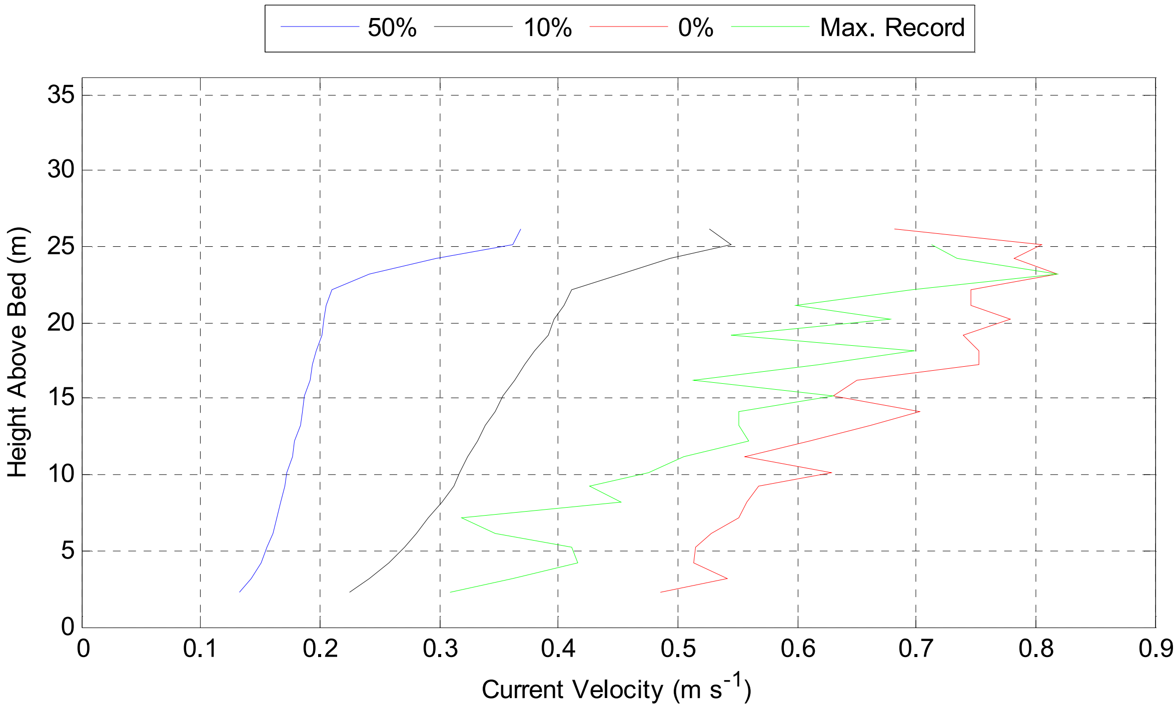

Figure 31. Statistical profile plots at 50, 10 and 0% exceedance for each measurement cell and profile plot of record with maximum current velocity during deployment (07/03/2012 14:50) at Site F.

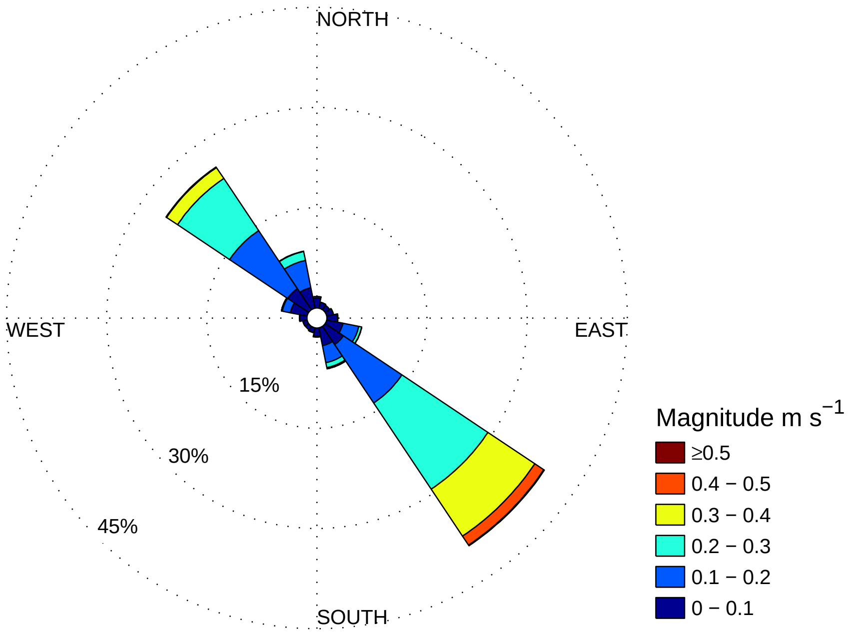

Figure 32. Current rose of depth-averaged velocity magnitude & direction at Site F.

4.2.1 Tidal Harmonics

Site E tidal harmonics were derived through a 105 day analysis between 2nd March and 15th June, 2012; this was chosen to coincide with full synodic periods (Boon, 2004) and provided the longest consecutive data period between all phases. Figure 33 and Figure 34 present the observed and modelled astronomic water level and current speeds respectively. With Table 28 providing tidal constituent values for the astronomic models along with the RMS and %R Variance.

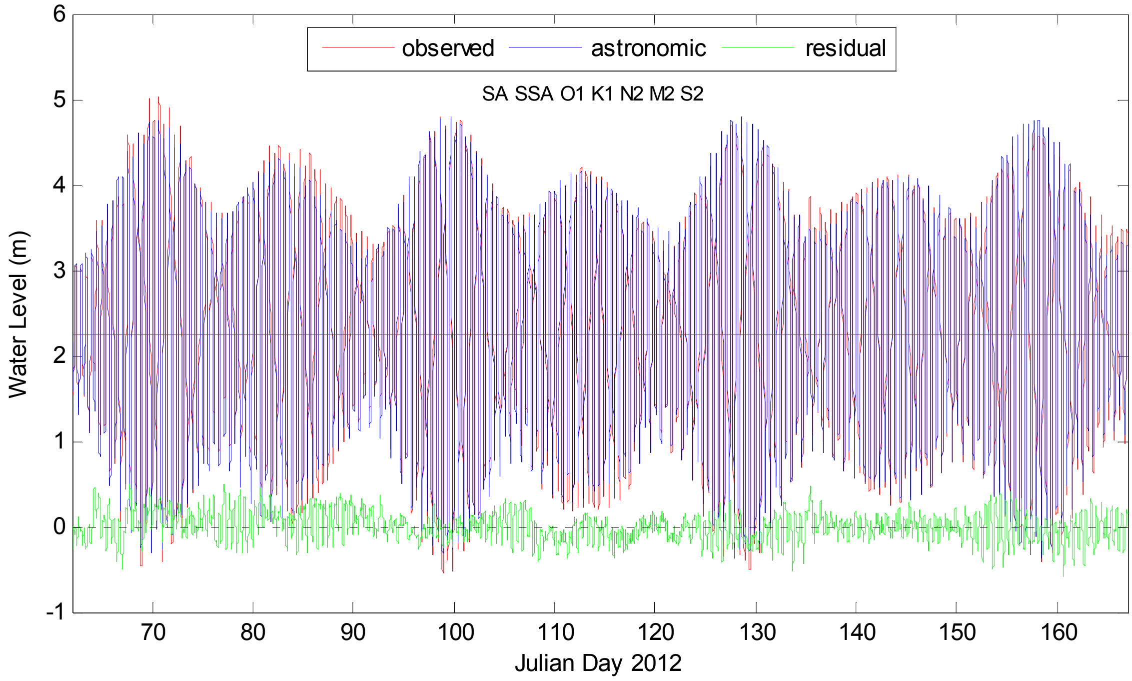

Figure 33. 105 day water level analysis at Site F. With observed against modelled height residual.

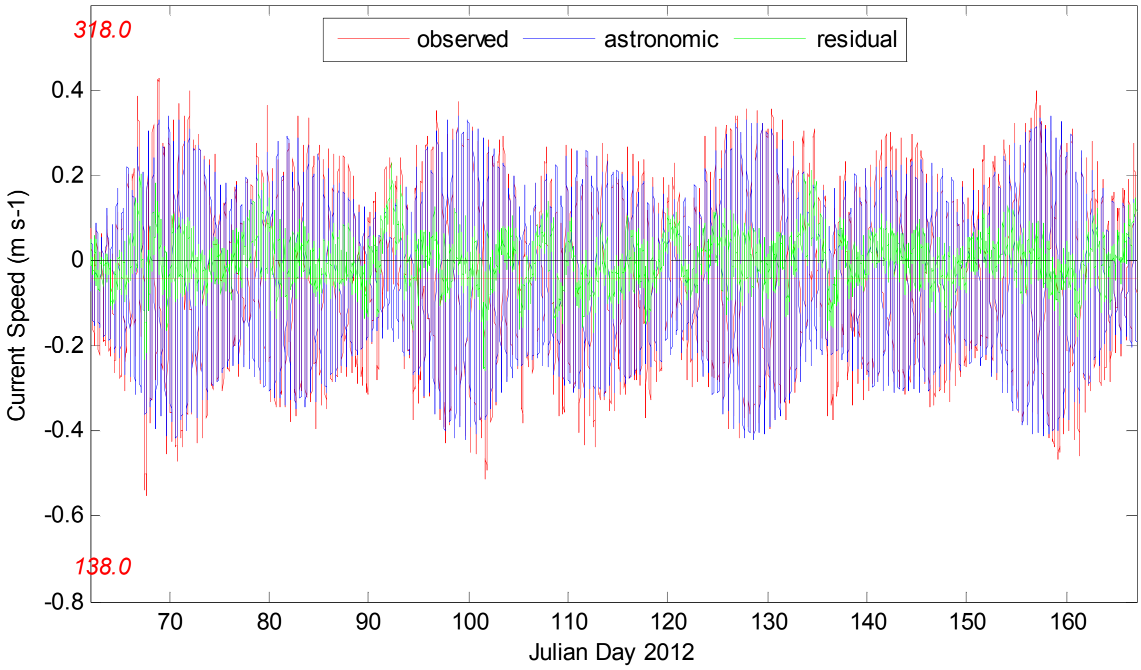

Figure 34. 105 day current speed analysis at Site F. With observed against modelled speed residual and direction in red. Peak current direction for ebb and flood are presented on the left in red.

Table 28. Derived tidal height and current harmonic constituents, with associated RMS error and explained variance for Site F.

	Tidal Height		Tidal Current	
Tidal Constituent	Amplitude (m)	Phase (°)	Amplitude (m)	Phase (°)
S_a	0.075	206.00	-	-
S_{sa}	0.019	350.00	-	-
O_1	0.152	19.27	0.027	200.18
K_1	0.106	200.11	0.020	43.09
N_2	0.354	255.84	0.053	96.54
M_2	1.598	2.15	0.231	204.71
S_2	0.535	92.15	0.080	292.93
RMS Error	0.164		0.073	
%R Variance	98.29		85.94	

Figure 35 presents the mean spring tidal ellipse over the 105 day analysis. With a semi-major axis of 0.215 m s^{-1} and semi-minor axis of 0.028 ms^{-1}. The major axis flood is 137.96° and ebb is 317.96°. The minor axis runs between 227.96° and 47.96°.

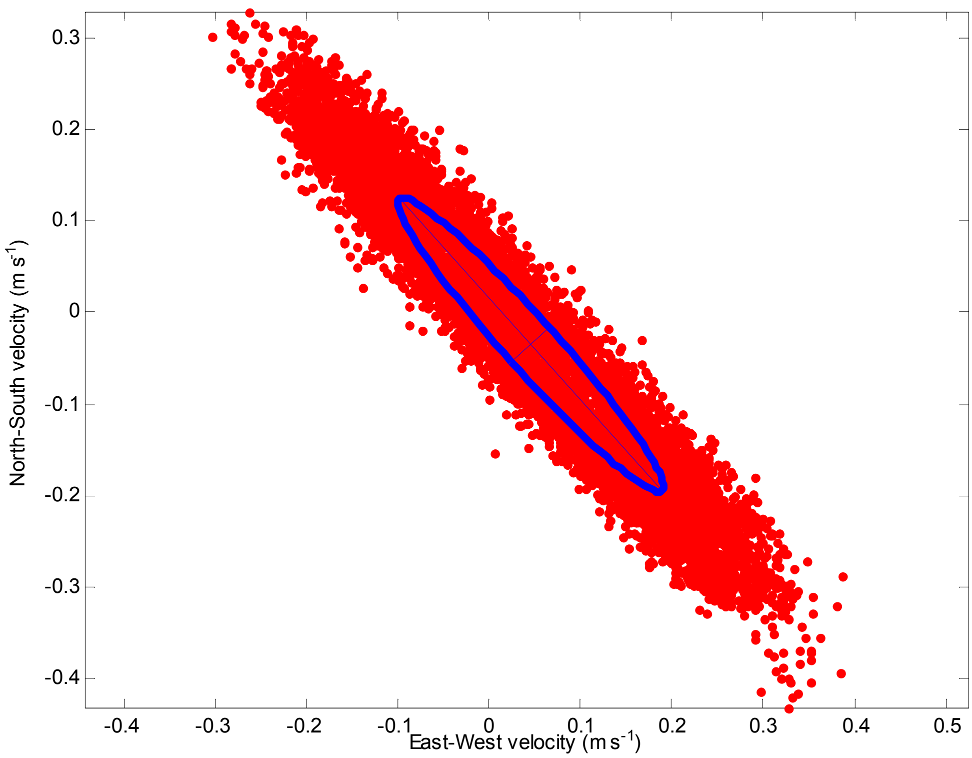

Figure 35. Mean spring tidal ellipse at Site F over 105 day analysis.

4.3 Summary; Currents

Current measurements recorded by the AWACs at both sites show variation in both magnitude and direction throughout the water column and this is correlated with the tidal phase. Overall Site E shows stronger tidal currents than those seen at Site F with higher depth-averaged and single bin values over the monitoring campaign.

The tidal currents are aligned at 180° at both sites, with Site E being aligned at WSW-SW/ENE-NE and Site F being aligned NW/SE. The sites show strong definition in direction between the ebb and flood tide (72 hour plots); however, although Site E shows no dominance between flood and ebb, Site F shows strong ebb dominance in the SE direction.

Current profiles show lower current magnitudes closer to the seabed and highest values approximately 10 m from the surface at both sites.

Both sites are dominated by M_2 (the principal lunar semidiurnal component), with it accounting for more than half of the amplitude at both sites and approximately three times larger than any other single constituents. At Site E the harmonic model has a small RMS error (0.15 and 0.16) and large %R Variance (98.59 and 98.29) for both the tidal height and currents (respectively). Suggesting the astronomical forcing at the site is much stronger than any meteorological forcing. Site F shows the same level of agreement for the tidal height (RMS error of 0.164 and %R Variance 98.29) but lower values for the tidal current (0.073 and 85.94%), this could be due to a stronger meteorological effect on the currents attributed to the north facing direction of the site.

4.4 Total Suspended Solids Seapoint OBS Data

Calibration coefficients derived from sediment traps on each of the AWAC frames for the individual phases have been used in the conversion of raw turbidity values to mg l^{-1}. These values have then been manually quality controlled for suspicious events and biofouling.

4.4.1 Site E

A Seapoint OBS at Site E recorded turbidity data during each Phase of deployment, due to the logger having a different storage format to the AWAC Phase 3 data was recovered and presented. Figure 36 presents the TSS time series during this period with Figure 37 showing the small tidal variation observed during low wave and low turbidity periods, Table 12 summarises the principal TSS statistics for the time series.

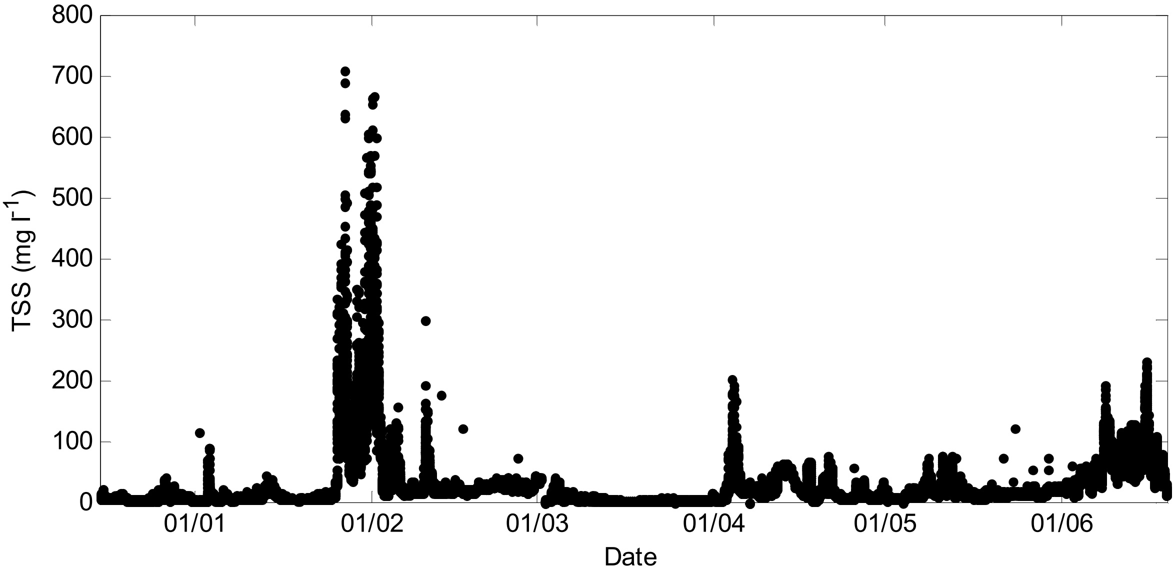

Figure 36. TSS at Site E during monitoring campaign.

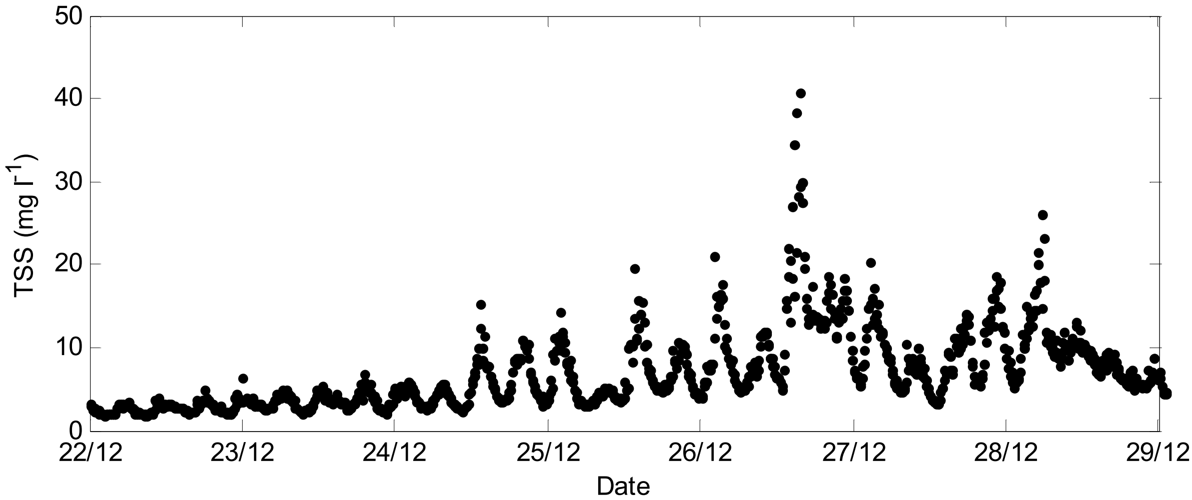

Figure 37. TSS series showing smaller tidal variation.

Table 29. TSS (mg l^{-1}) statistics for Site E.

Parameter	Min	Date	Max	Date	Mean	StDev
TSS (mg l^{-1})	0	Multiple Occurrences	709	27/01/2012 07:10	27	48

The data recorded over the deployment show a strong correlation to the wave climate with the highest TSS values coinciding with the storm events observed at the end of January. Tidal variation is also seen to have an effect on suspended solids with a cyclical variation of ~10 mg l^{-1} during times of low wave heights. Within the data a significant spike in suspended solids was manually removed on the 7th April, where TSS concentrations reached a peak 1009 mg l^{-1}. This occurred with no observable link to the metocean climate. Phase 3 showed increased background levels of TSS which may be indicative of the start of biofouling to the sensor, however these values have not been flagged due to the levels recorded being within limits seen through the earlier deployments.

4.4.2 Site F

A Seapoint OBS at Site F recorded turbidity data through all phases. Figure 38 presents the TSS time series during this period with Figure 39 illustrating the data with the same scale as figures seen at Site E. Figure 40 shows the smaller fluctuations seen during lower wave heights. Table 30 summarises the principal TSS statistics for the time series.

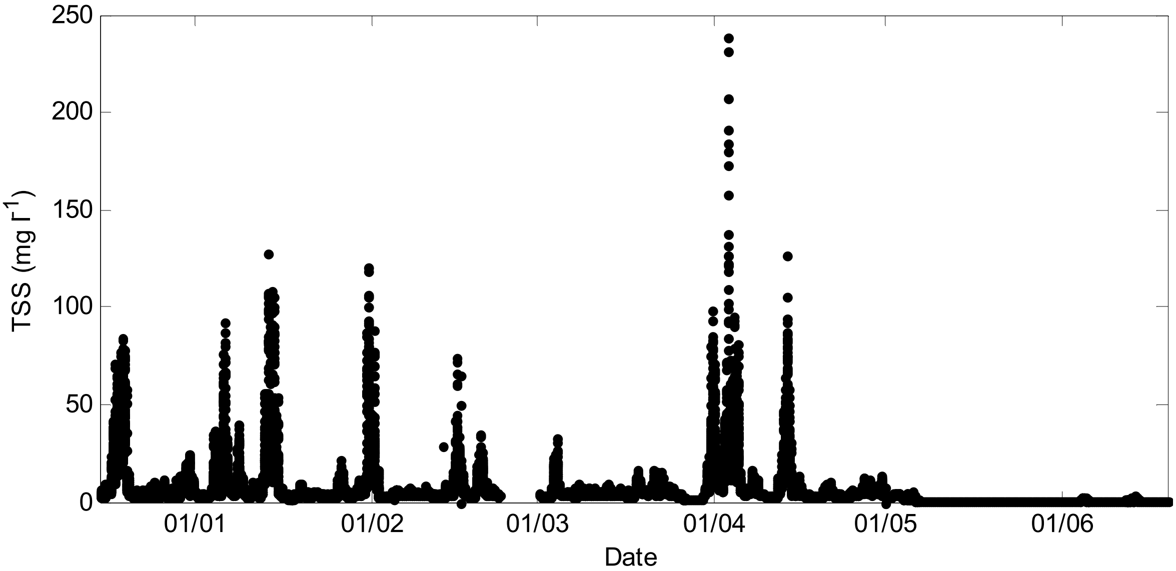

Figure 38. TSS at Site F during monitoring campaign.

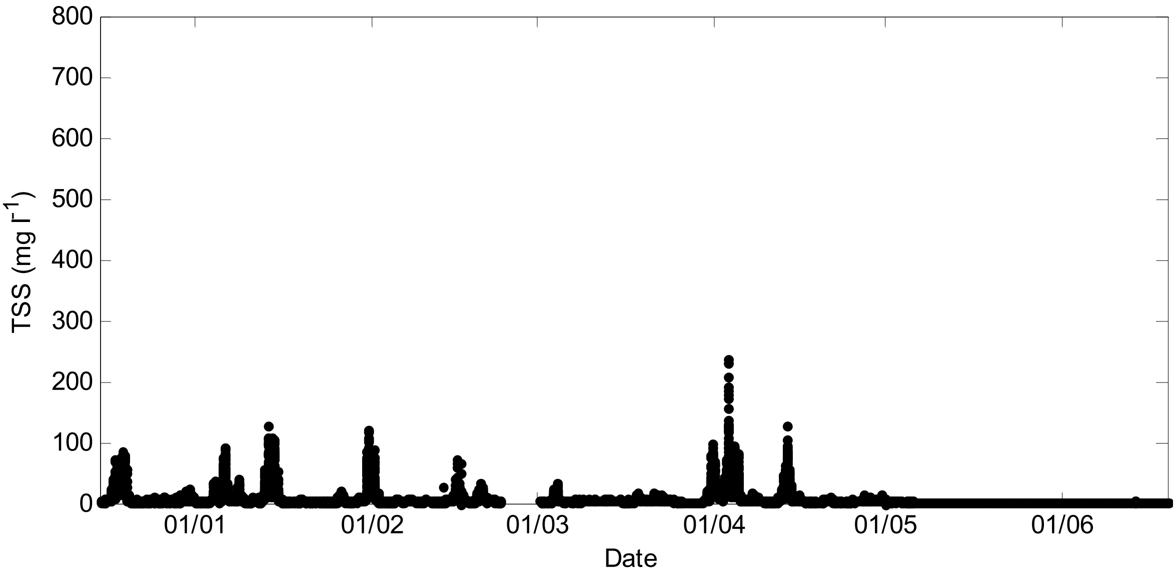

Figure 39. TSS at Site F with standardised axis between sites.

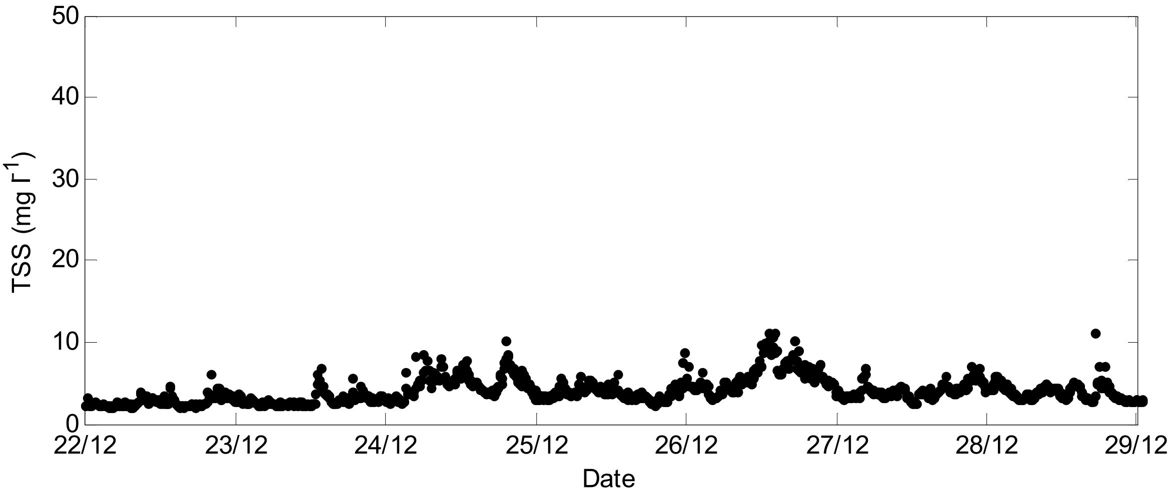

Figure 40. TSS variation at Site F during low wave heights.

Table 30. TSS (mg l^{-1}) statistics for Site F.

Parameter	Min	Date	Max	Date	Mean	StDev
TSS (mg l^{-1})	0	Multiple Occurrences	273	03/04/2012 11:00	6	11

Site F shows the same general correlation with wave height; however the TSS concentrations are lower during the wave events and through the whole deployment period, reaching maximum value of 273 mg l^{-1}. The tidal effect at the site was less pronounced during the same period when compared with Site E. Phase 3 showed much lower TSS values through the whole deployment, peaking at 6 mg l^{-1} this can be seen to be due to lower overall wave climate seen during this phase.

4.4.3 TSS summary

Through Phases 1 and 2 Site E showed consistently higher TSS values during storm events and smaller wave climates, during Phase 3 Site F showed the lowest TSS values of any deployment which can be attributed to the overall lower wave climates.

Some high values were failed at both sites where a single point was significantly larger than its surroundings. No biofouling was observed through the six month deployment at either site.

5. SUMMARY OF RESULTS

At Site E Phases 1 and 2 were deployed and recovered successfully with full data return, successfully capturing the winter metocean climate of 2011-2012. Upon final recovery of the frame (Phase 3) it was discovered that an inherent fault within the AWAC firmware led to no data being returned from Phase 3 (Appendix 8.7). Site F was successfully deployed, recovered and data returned through all phases.

Through Phases 1 and 2 a number of significant wave events were captured coinciding with increased suspended solids at Site E and F. Generally, the amount of suspended solids were affected more at Site E by the wave climate and tidal currents, with lower and higher values at Site F for TSS and wave height respectively.

Significant wave events through the period are defined by the 95th percentile of Hm0 through the monitoring campaign at site and are used to quantify sustained high energy waves. Although Site E shows more of these significant events Site F shows on average larger waves of longer periods with 95th percentiles of 1.76 and 1.99 m at Site E and F respectively.

Current data shows strong changes in magnitude over the spring-neap cycle at both sites with Site E having stronger currents on average. The currents were seen to run approximately parallel with the coastline at each site.

The tidal height and current models derived from the harmonic constituents at both sites are dominated by the M_2 component (principal lunar semidiurnal), although current velocities at Site F cannot be fully explained through the significant tidal harmonic constituents (only 85% is explained through the five applied). This suggests it maybe more susceptible to meteorological forcing. The harmonic model however, does describe the ebb dominance in current flow observed throughout the campaign.

Site F had lower TSS values during Phase 3 than for earlier deployments and no wave heights which exceeded the storm threshold for a sustained period. Low TSS values were also recorded at Site E, and whilst there was no AWAC data returned for this period, it is reasonable to assume that no significant wave events occurred at Site E.

6. REFERENCES

1. Boon, J.D., 2004. Secrets of the Tide: Tide and Tidal Current analysis and Predictions, Storm surges and Sea Level Trends. Horwood Publishing, Chichester, U.K.
2. CEFAS. (2011). QA/QC procedure. Available: http://www.cefas.defra.gov.uk/our-science/observing-and-modelling/monitoring-programmes/wavenet/qaqc-procedure.aspx. Last accessed 27/04/2012.
3. Lee, H.J., and Nomark, W.R., 2009, Earth Science in the Urban Ocean: The Southern California Continental Borderland. Special paper 454, *The Geological Society of America*, Page 174.
4. Nortek Acoustic Wave and Current User Manual (2005).

7. APPENDIX A – TECHNICAL DETAIL

7.1 AWACS

7.1.1 Sampling Regime

The AWACs and OBS sensors were set to a sampling regime shown in Table 31.

Table 31. Sample regime of AWAC E.

Currents	Sampling Regime	Waves	Sampling Regime
Profile interval (s)	600	Number of wave samples	1024
Number of cells	30	Wave interval (s)	1800
Cell size (m)	1	Wave sampling rate (Hz)	1
Average interval (s)	60		
Blanking distance (m)	0.5		
Total Suspended Solids		**Sampling Frequency**	
Analogue (OBS)		1 every 10 minutes	

Table 32. Sample regime of AWAC F.

Currents	Sampling Regime	Waves	Sampling Regime
Profile interval (s)	600	Number of wave samples	1024
Number of cells	35	Wave interval (s)	1800
Cell size (m)	1	Wave sampling rate (Hz)	1
Average interval (s)	60		
Blanking distance (m)	0.5		
Total Suspended Solids		**Sampling Frequency**	
Analogue (OBS)		1 every 10 minutes	

7.1.2 Compass Calibrations

The AWACs compasses calibrations were conducted at Partrac workshop. Figure 41 to Figure 44 show compass calibrations of each AWAC used for the monitoring period.

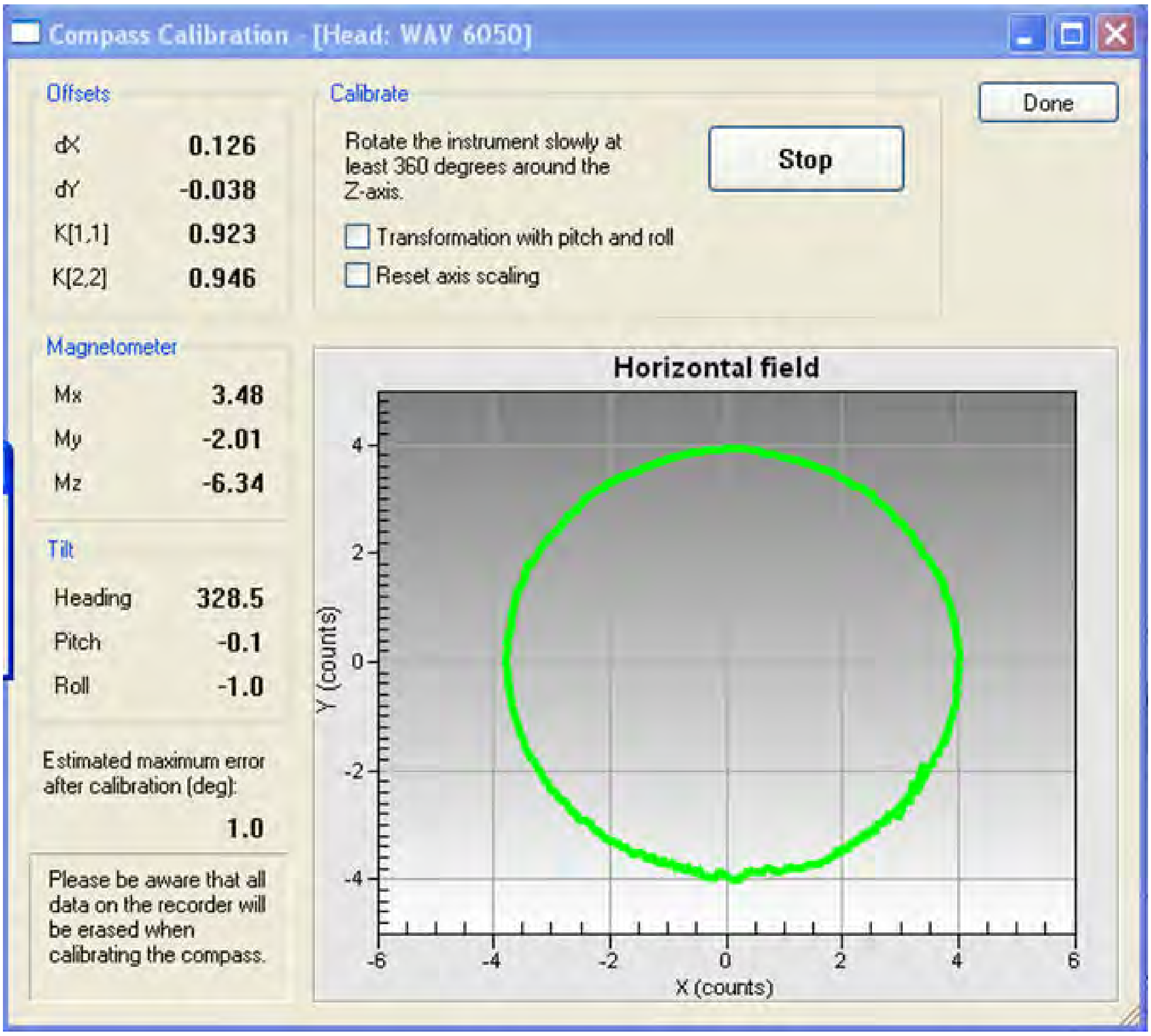

Figure 41. Screen shot of AWAC 6050 compass calibration.

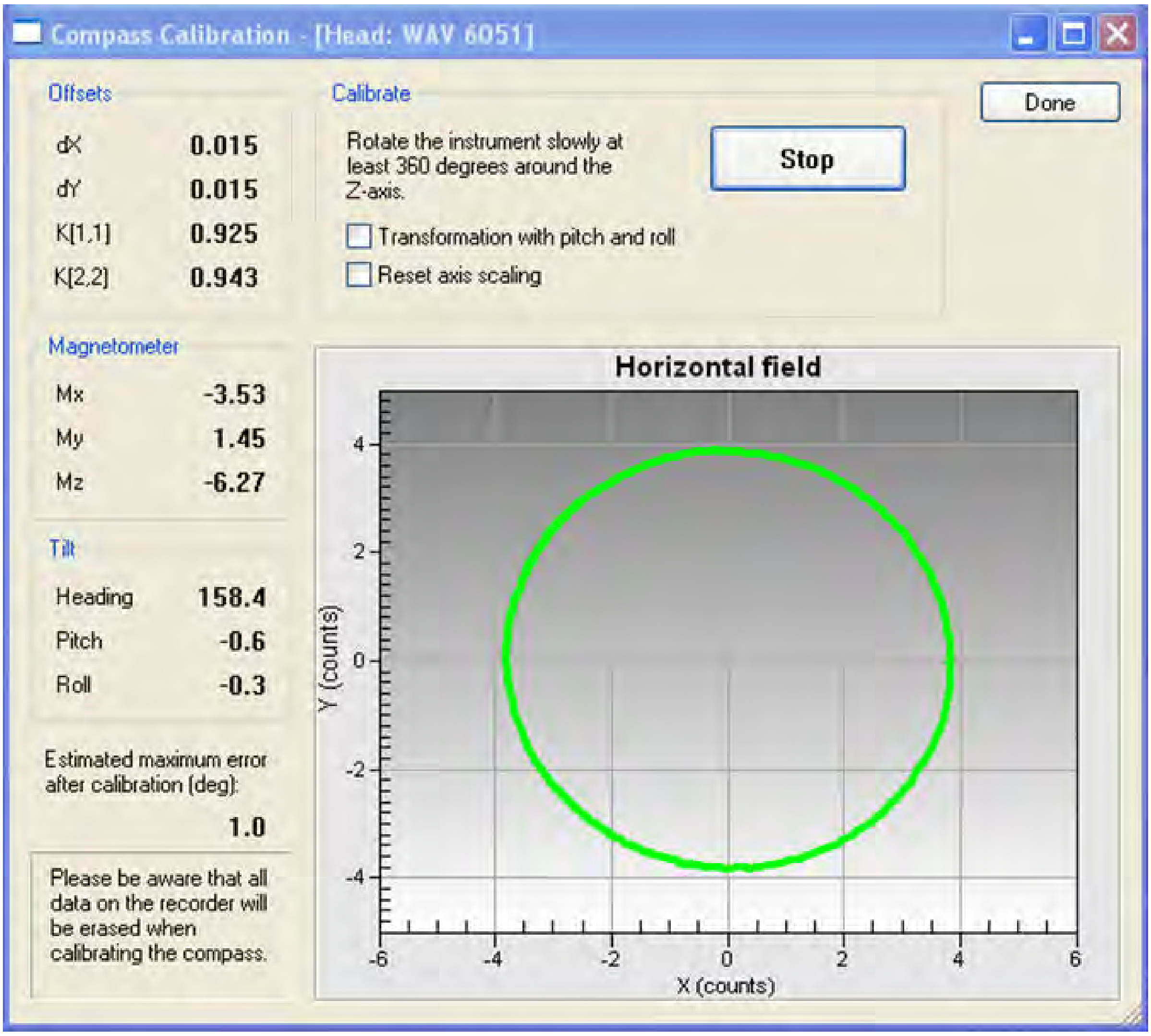

Figure 42. Screen shot of AWAC 6051 compass calibration.

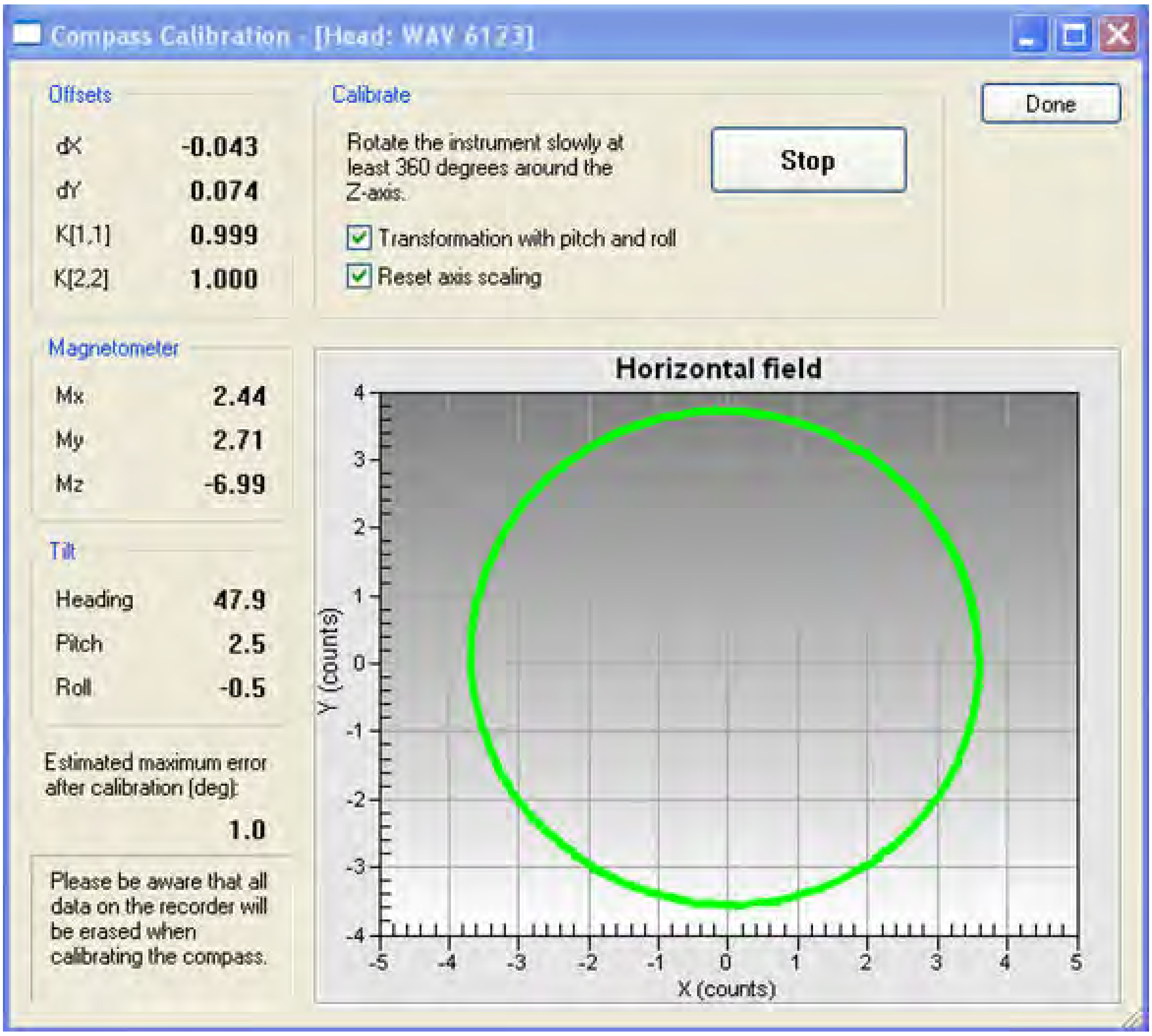

Figure 43. Screen shot of AWAC 6123 compass calibration.

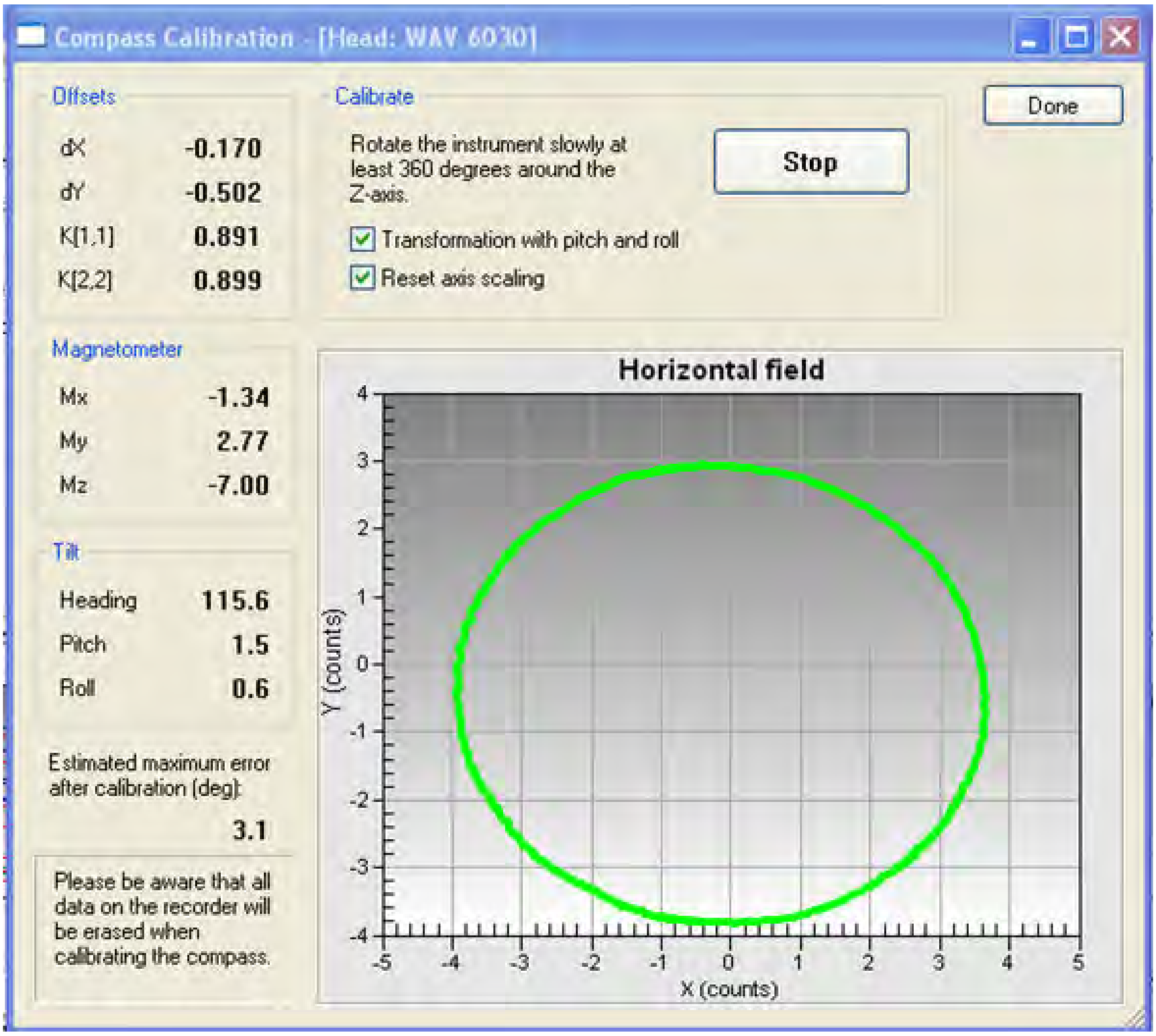

Figure 44. Screen shot of AWAC 6030 compass calibration.

7.2 Seapoint OBS Calibration

A Seapoint OBS sensor was mounted on each AWAC bedframe to acquire total suspended solids (TSS) concentration measurements. The instrument is located at the same height above the bed as the AWAC transducer, recording an average value over a period of one minute, at ten minute intervals. The OBS sensor was calibrated using sediment captured by a vertically oriented sediment trap mounted on the bedframe. The top of this sediment trap is located at the same height at the OBS sensor (± 0.05 m).

7.2.1 TSS Laboratory Analysis

Calibration of the OBS sensors was undertaken using a ten point calibration of each sensor head. Each OBS sensor was immersed in a 20 litre container filled with homogenised distilled water and programmed to sample at 1 Hz for approximately one minute. At the end of this sampling interval, 1 litre of the distilled water was sub-sampled to be sent off to a UCAS accredited laboratory for TSS analysis. Material from the sediment trap was then added to the distilled water and the process continually repeated until a ten-point calibration of varying turbidities had been sampled.

Subsequently, the water samples were filtered through pre-weighed 0.45 μm micropore filters. These filters were then oven-dried and the dry-mass (total solids) concentration (mg l^{-1}) for each sample calculated. Dry mass concentration values were plotted against observed (instrument) raw data values (Figure 45 and Figure 46) and a best-fit equation (conversion function) and calibration co-efficient determined via least squares regression analysis (Table 33). These equations were then used to calculate the Total Suspended Solids (TSS) concentration recorded during monitoring periods.

Table 33. Equations and correlation coefficient values for TSS calibration.

Site	Phase	Equation TSS (mg l^{-1}) =	Correlation Coefficient (R^2)
E	1	2.1237	0.94
F		1.2267	0.96
E	2	1.4285	0.96
F		0.9334	1.00
E	3	-	-
F		0.8466	0.99

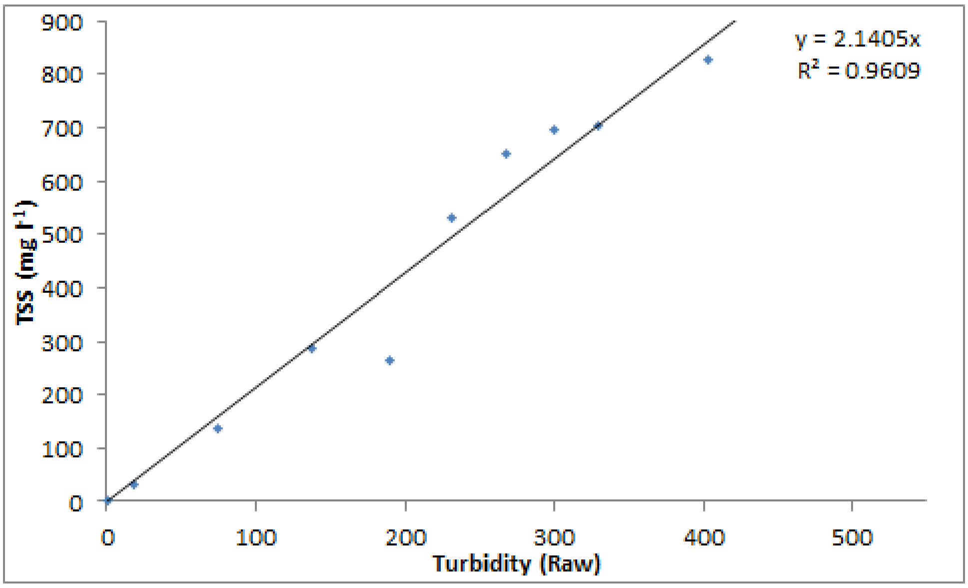

Figure 45. Calibration of OBS sensor showing dry mass concentration on y-axis (i.e. TSS concentration) versus raw turbidity values: Site E Phase 1.

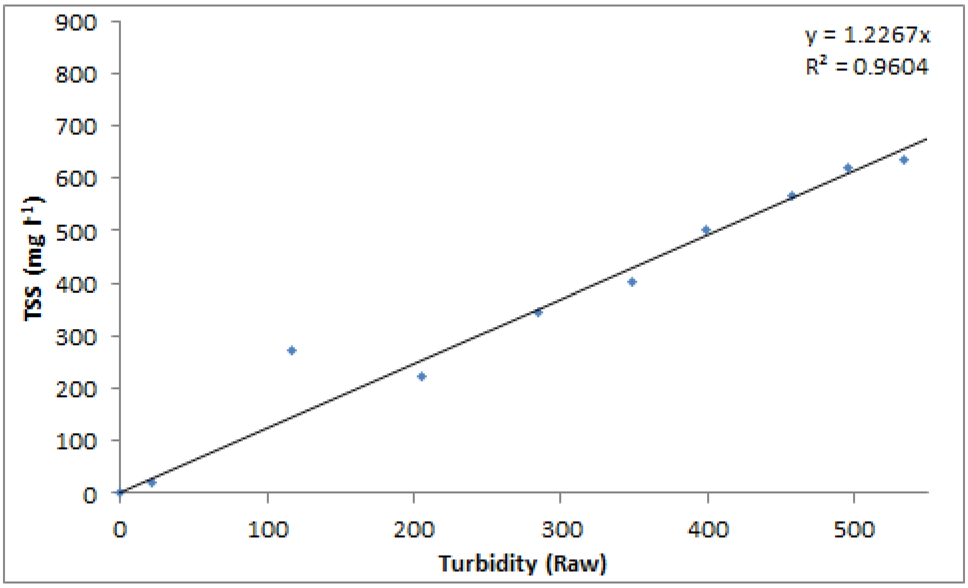

Figure 46. Calibration of OBS sensor showing dry mass concentration on y-axis (i.e. TSS concentration) versus raw turbidity values: Site F Phase 1.

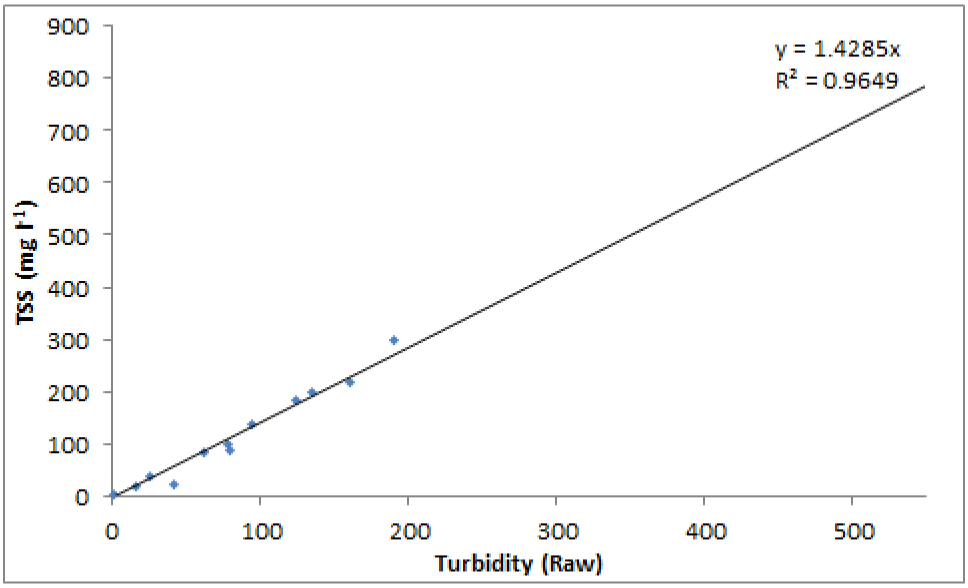

Figure 47. Calibration of OBS sensor showing dry mass concentration on y-axis (i.e. TSS concentration) versus raw turbidity values: Site E Phase 2.

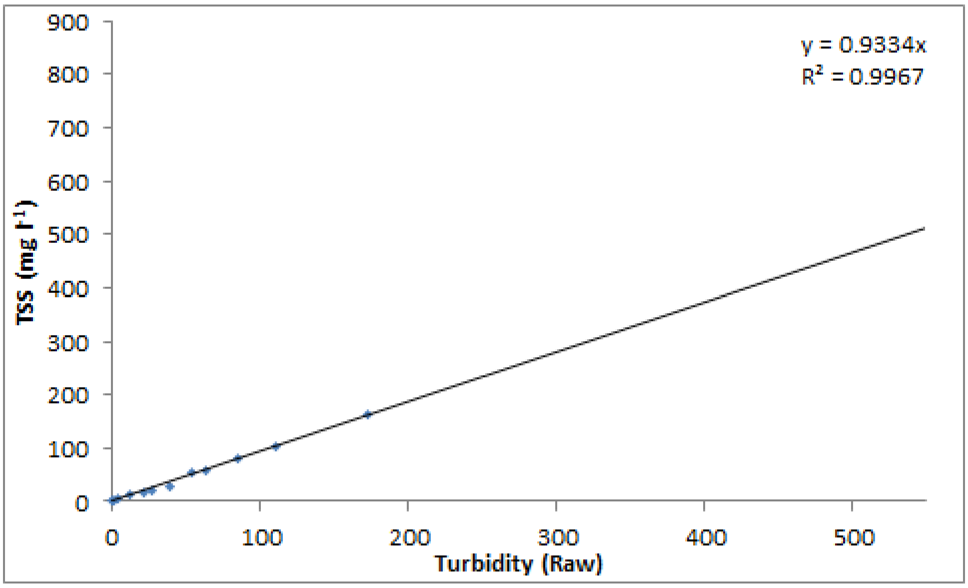

Figure 48.Calibration of OBS sensor showing dry mass concentration on y-axis (i.e. TSS concentration) versus raw turbidity values: Site F Phase 2.

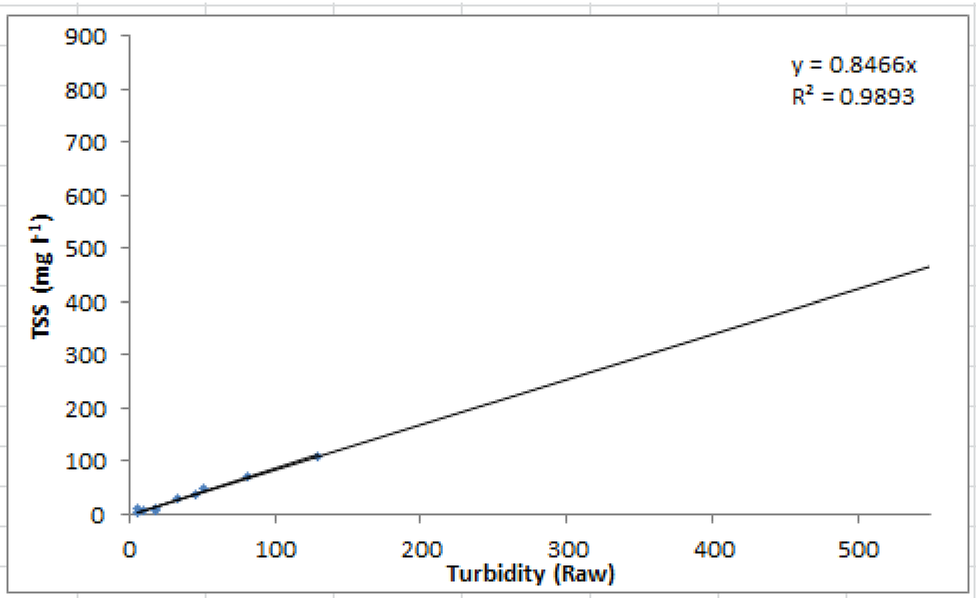

Figure 49.Calibration of OBS sensor showing dry mass concentration on y-axis (i.e. TSS concentration) versus raw turbidity values: Site F Phase 3.

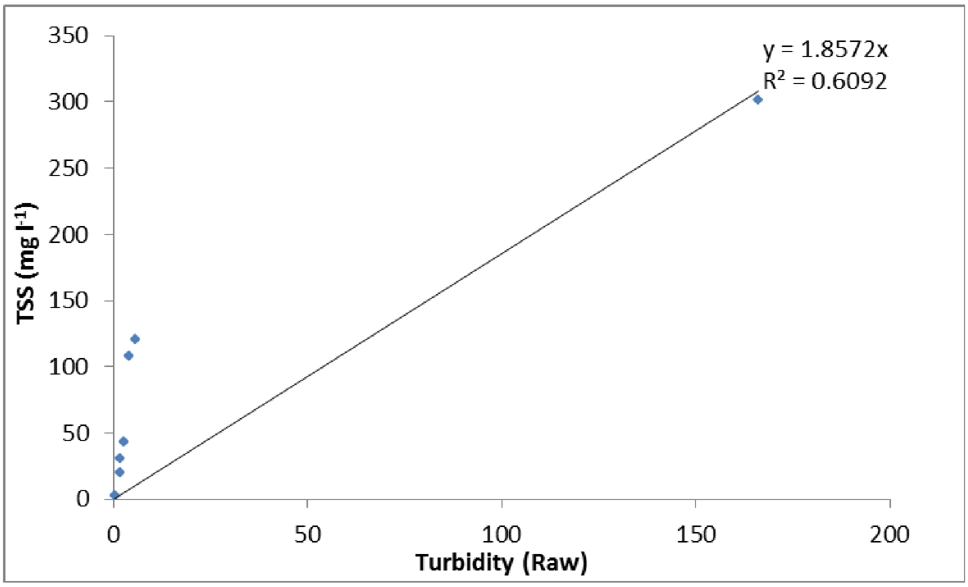

Figure 50.Calibration of OBS sensor showing dry mass concentration on y-axis (i.e. TSS concentration) versus raw turbidity values: Site E Phase 3.

7.3 Data Processing and Quality Control

7.3.1 Wave Data

Wave data have been quality controlled using Cefas (Centre for Environment, Fisheries and Aquaculture Science) WaveNet QA/QC procedures for data obtained from directional Waverider buoys via ARGOS and Orbcomm satellite telemetry.

Directional data have been converted from magnetic direction to true by applying a magnetic variation correction of 2° W obtained from the BGS model (www.geomag.bgs.ac.uk/gifs/gma_calc.html).

Quality control checks consist of range checking and removal of spikes for various parameters. These are listed in Table 34 and any data that fail are removed from the dataset. Any flagged data are inspected closely to determine their inclusion.

Table 34. Cefas data quality control range checks.

Parameter	Units	Flagged Data	Failed Data	
		Maximum Rate of Change Per Hour	Minimum	Maximum
Wave Height	Metres	1	0	20
Wave Period (Tp)	Seconds	4	1.6	20
Wave Period (Tz)	Seconds	2		
Wave Direction	Degrees	150	0	360
Wave Spread	Degrees	90		

7.3.2 AWAC Flags

The AWAC produces binary error codes during processing; these can be seen within the "Raw Data" tab of submitted data. The errors are then analysed manually by Partrac and data is deemed reliable, flagged or removed, the error descriptions can be seen in Table 35 and can contain a combination of errors. Error codes can contain a combination of errors for example an error code of 208 is a combination of errors 16, 64 and 128.

Table 35. Binary error codes in AWAC.

Error	Binary Code	Error Code
No Errors	0	0
No Pressure	0000 0001	1
Low Pressure	0000 0010	2
Low Amplitude	0000 0100	4
White Noise Test	0000 1000	8
Unreasonable Estimate	0001 0000	16
Never Processed	0010 0000	32
AST Out of Bounds	0100 0000	64
Directional Ambiguity	1000 0000	128
No Pressure Peak	1 0000 0000	256
Close to clipping	10 0000 0000	512
High AST Data Loss	100 0000 0000	1024
Excessive tilt	1000 0000 0000	2048

7.3.3 Current Data

Nortek Storm software and recommended QC settings were used in processing of the current data; these settings are shown in Table 25.

Table 36. Nortek Storm QC Parameters.

Parameter	Purpose	Units	Value
Signal to Noise Ratio (SNR) Threshold Limit	Low SNR values have high variability: specifies when estimates are invalid.	dB	3
SNR Spike Rejection level	Removes current spikes caused by fish.	dB	70
Statistical Threshold	Rejects data outside of specified number of standard deviations. Used for fish and anomaly rejection.	#StDev	5

Current magnitude and direction rate of change were calculated using the IOC Manual of Quality Control procedures shown below.

The theoretical difference between two consecutive current speed samples u1 and u2 for various sampling intervals (Δt) assuming a smooth sinusoidal semi-diurnal tidal current with a period of 12.24 hours are given in Table 37. Where *u* is the orthogonal tidal current amplitude.

Table 37. IOC theoretical differences.

Δt (min)	Theoretical	Factor	Allowable
	$u_1 - u_2$		$u_1 - u_2$
5	0.0422 u	2.0	0.08 m s^{-1}
10	0.0843 u	1.8	0.15 m s^{-1}
15	0.1264 u	1.6	0.20 m s^{-1}
20	0.1685 u	1.5	0.25 m s^{-1}
30	0.2523 u	1.4	0.35 m s^{-1}
60	0.5001 u	1.2	0.60 m s^{-1}

In order to allow for some inherent variability in current speed and direction signal and for asymmetric tidal current speed curves, these difference have been increased by the above factors whilst *u* has been set at 1.0 m s^{-1} since the variability will increase with decreasing *u*.

The resulting allowable maximum difference between samples for particular sampling intervals are provided above.

7.4 Water Level

Figure 51 and Figure 52 present the measured water level at each site through all phases.

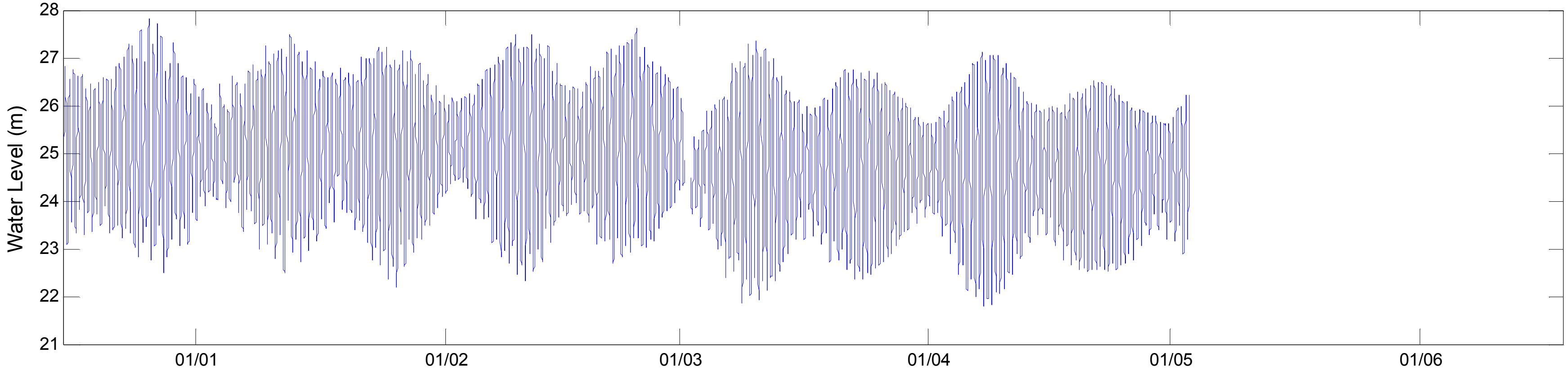

Figure 51. Water level at Site E during deployment.

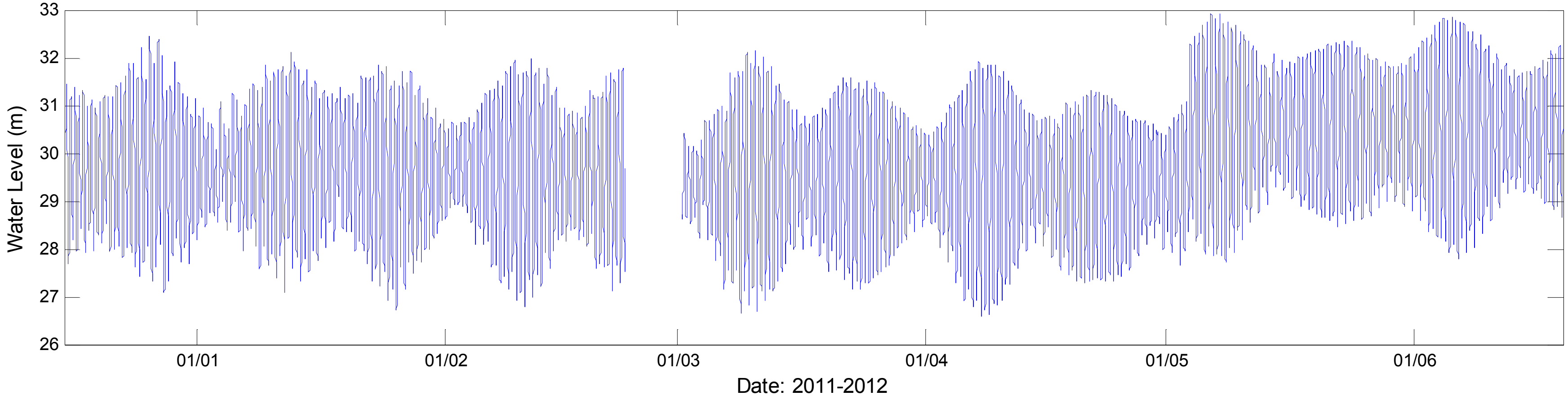

Figure 52. Water level at Site F during deployment.

8. APPENDIX B – SURVEY LOG SHEETS

8.1 Site E – Phase 1

Survey Log Sheet FRAMEC SITE (E)

Moorings

1. PROJECT No. P1256
Site Name: Site E
Phase (mobilisation / ~~service visit / demobilisation~~)
Deployment Date & Time (GMT): 15, Dec 2011
Water Depth (m): 25

LAT: 56° 31.6571'N
LONG: 002° 34.1923'W
Check transducer height off seabed
~~Latitude 56° 31 6571 N~~
~~Longitude 002° 34. 2002~~

2. FRAME DETAILS
Size Frame: GSE hexagonal 1.6 x 1.6m
Type Material Frame: stainless
Total Weight of Frame: ~250kg
Instrument type in frame: AWAC 600kHz
Sonardyne pinger #7 75kHz 4-8-8 930ms
Height of instrument
Instrument type in frame: AQUATECH LOGGER
Height of instrument: AWAC = 70cm

3. STANDARD DEPLOYMENT PLANNING
No. Ground lines: 1
Ground line length: 80m
Diameter of rope: 16mm
Leaded rope: Yes
Condition of rope: Good
Ground weight material: Large Link Anchor Chain bundle
Total weight ballast: ~30kg
Ground weight attached to: HC3 chain -> LRT + Rope Connector + sediment trap

4. ADVANCED DEPLOYMENT PLANNING

Acoustic release
Acoustic release: LRT
Type of acoustic release
Acoustic release serial no: 267180-002
Acoustic release address: 2-2-2-2

Buoys
Buoys: x3
Type of Buoys: Vinny
Diameter of Buoys: 8"
Lift of Buoys

5. Deployment Planning Notes
Duration of survey
Ground Weight Location:

6. RECOVER
Physical condition? GOOD.
Data inspected: YES.

NOTES

Ground Weight Position
56° 31.6565'N
002° 34.2018'W

Presurvey Check (Director)　　　Date

Survey Log Sheet

AWAC NORTEK

1.PROJECT No.

Project Name P1256 Site E Phase Phase 1 Deployment

2. INSTRUMENT DETAILS

Serial no. 23603-5 Bottom track fitted Memory fitted (MB) 4GB
Frequency (kHz) 600 Housing depth rating (m): Planned orientation upward
CPU Firmware version: ~~1.42~~ 3.33 Height of transducer
Frame number Frame C
Compass Calibration file **DEPLOYMENT FILENAME**
AWAC AST Version 1.42

3. DEPLOYMENT PLANNING

Current profile
Profile interval (s) 600
Number of cells 30
Cell size (m) 1
(adv) Average interval (s) 60
(adv) Blanking distance (m) 0.5
(adv) Measurement load (%) 50

Waves
Number of samples 1024
Sampling rate (Hz) 1Hz
Interval (s) 1800
(adv) Velocity cell size (m) 3.6
(adv) AST window start (m) 22.9
(adv) AST window size (m) 14.2
(adv) AST threshold 100

Instrument
Frequ 600 kHz
Extended SD data logger

Speed of sound
Measured Salinity (ppt)
Fixed (m/s) 1482
File wrapping

4. FURTHER DEPLOYMENT PLANNING

Assumed duration (days) 75
Estimated depth (m) 30
Battery Utilization 99%
Memory required (MB) 90.6
Vertical vel. Prec. (cm/s) 1.5
Horizont. Vel. Prec. (cm/s) 4.5
Compass update rate (s) 600
Power level High

Analogue -OBS turbidity sensor
Enable Power to Sensor Yes
Enable Logging to AWAC Yes
Gain of cable x 5
OBS serial No. 12582
Pre-calibrated Yes

5. BATTERIES AND SERVICE

Battery type alk
Battery supplier AIM
No. of battery packs 2
Measured voltage 14.6/14.6
New battery capacity (Wh)
New batteries fitted YES
Comms switch RS422
Silica decesent installed ✓
Battery connected ✓
Instrument sealed ✓

6. DEPLOYMENT

In water test? NO ✓
Computer clock set to GMT ✓
TESTAWAC filename
Memory erased YES
DEPLOY to send CMD file to AWAC
Start date and time (GMT) 13 Dec 2011 13:40
Deployment log filename ~~DEC~~ SteE
.CMD and log files backed up
Dummy plug greased & replaced ✓
Dummy plug tied in ✓
AWAC pinging audible ✓
Chilli applied to Tx NO
Initials Date

7. RECOVERY

Still pinging (RADIO CHECK)? ✓
Physical condition? GOOD.
Do NOT stop data collection when recovered instead go to 'stop recorder deployment'
Clock error
Switch off date and time 01 MAR 12 16:10
Battery Voltage after recovery
Data filename (IF DIFFERENT)

Quality Control
Pitch/roll/heading consistant? ✓
Complete dataset over time? ✓
Complete dataset over depth? ✓

Initials [illegible] Date 01/03/12

* Coordinates System = ENU

Survey Log Sheet
OBS Aquatech 200/210TY   frame C   SITE E

1.PROJECT No.

Project Name P1256   Site G   Phase 1

2. INSTRUMENT DETAILS

Serial no. 2467
Logger:
OBS : 12577

Mounting
Moving Buoy
Mooring line
Fixed structure: FRAME

Environment
Coastal water ✓
River
Deep water (>300m)
Open Ocean

3.STANDARD DEPLOYMENT PLANNING

Deployment Planning

Enable burst mode (Yes) No
Burst/sample interval 10 min
Burst sample rate 1hz @ 10 samples
Turbidity gain: (Auto) x100 x20 x5 x1
Start time 10.30 15 DEC 11

6. BATTERIES AND SERVICE

Battery type (alk) / lith
Measured voltage
New battery capacity (Wh)
New batteries fitted ✓
Silica decesent installed ☐
Battery connected ☑
Instrument sealed ☑
Initials MM Date 15 DEC 11

7. DEPLOYMENT

DEPLOY to send CMD file to Aquadopp
Computer clock set to GMT ☑ Start date and time (GMT) 1030 15DEC11
TESTOBS filename Deployment log filename
Memory erased ☑ .CMD and log files backed up
Initials MM Date 15DEC11

8. RECOVER

Switch off date and time 01.MAR.12 16:10
Data recovered YES
Data filename SITE E
Physical condition? GOOD
Clock error NONE
Data inspected ☑
Data backed up Y ☐ N ☐
Initials BH Date 01/03/12

NOTES

Checked By: Date

8.2 Site F – Phase 1

Survey Log Sheet FRAMEA SITE F

Moorings

1.PROJECT No. P1256

Site Name: Site F

Phase (mobilisation / ~~service / demobilisation~~)

Deployment Date & Time (GMT): 15/12/11

Water Depth (m): 23.9m

Lat 55° 58.3276'N

Long 002° 21.3147'W

Check transducer height off seabed

Latitude: ~~55°58.3311'N~~

Longitude: ~~002°21.3090'W~~

2. FRAME DETAILS

Size Frame: GSE hexagonal 1.6m x 1.2m

Type Material Frame: Stainless Steel

Total Weight of Frame: ~250kg

Instrument type in frame: AWAC 600kHz

Sonardyne Ranger #5 73kH, 4-4-7# 910ms

Height of instrument:

Instrument type in frame: Aquatech logger

Height of instrument: 70cm

3.STANDARD DEPLOYMENT PLANNING

No. Ground lines: 1

Ground line length: 80m

Diameter of rope: 16mm

Leaded rope: Yes

Condition of rope: Good

Ground weight material: Large link anchor bundle

Total weight ballast: 30Kg

Ground weight attached to: HL3 chain → LRT + rope Canister + Sediment trap

4. ADVANCED DEPLOYMENT PLANNING

Acoustic release

Acoustic release: LRT

Type of acoustic release:

Acoustic release serial no: 27386 3-03

Acoustic release address: 1-1-1-1

Buoys

Buoys: X3

Type of Buoys: Vinyl 8"

Diameter of Buoys: 8"

Lift of Buoys:

5. Deployment Planning Notes

Duration of survey: ~ 70 days

Ground Weight Location:

6. RECOVER

Physical condition? GOOD

Data inspected: YES FULL DATA SET

NOTES

CORRECT DEPTH TO WATER LEVEL

GROUND WEIGHT

55 58.370' N

002 21.317' W

Presurvey Check (Director) Date

Survey Log Sheet

AWAC NORTEK

1.PROJECT No.

Project Name P1256 Site F Phase Phase 1 Deployment

2. INSTRUMENT DETAILS

Serial no.	23603-4	Bottom track fitted		Memory fitted (~~MB~~)	4GB
Frequency (kHz)	600	Housing depth rating (m):		Planned orientation	upward
CPU Firmware version:	~~1.12~~ 4.06/3.33			Height of transducer	70cm
Frame number	Frame A				
Compass Calibration file	see attached document	DEPLOYMENT FILENAME			
AWAC AST Version	1.42				

3. DEPLOYMENT PLANNING

Current profile		**Waves**		**Instrument**	
Profile interval (s)	600	Number of samples	1024	Freq. 600 kHz	
Number of cells	35	Sampling rate (Hz)	1Hz	Extended SD data logger	
Cell size (m)	1	Interval (s)	1800		
(adv) Average interval (s)	60	(adv) Velocity cell size (m)	4.2	**Speed of sound**	
(adv) Blanking distance (m)	0.5	(adv) AST window start (m)	26.8	Measured Salinity (ppt)	1485
(adv) Measurement load (%)	50	(adv) AST window size (m)	16.4	Fixed (m/s)	
		(adv) AST threshold	100	File wrapping	NO

4. FURTHER DEPLOYMENT PLANNING

		Analogue -OBS turbidity sensor	
Assumed duration (days)	66		
Estimated depth (m)	35		
Battery Utilization	100%	Enable Power to Sensor	Yes
Memory required (MB)	80.6	Enable Logging to AWAC	Yes
Vertical vel. Prec. (cm/s)	1.5	Gain of cable	x 5
Horizont. Vel. Prec. (cm/s)	4.5	OBS serial No.	12581
Compass update rate (s)	600	Pre-calibrated	Yes
Power level	High		

5. BATTERIES AND SERVICE

Battery type	alk	Measured voltage	14.6/14.6	Silica decesent installed	✓
Battery supplier	AIM	New battery capacity (Wh)		Battery connected	✓
No. of battery packs	2	New batteries fitted	YES	Instrument sealed	✓
		Comms switch	RS422		

6. DEPLOYMENT

In water test?	NO	DEPLOY to send CMD file to AWAC		Dummy plug greased & replaced	✓
Computer clock set to GMT	Yes	Start date and time (GMT)	09:30 15/12/11	Dummy plug tied in	✓
TESTAWAC filename	1256PA	Deployment log filename	DLG	AWAC pinging audible	✓
Memory erased	Yes	.CMD and log files backed up	✓	Chilli applied to Tx	NO
				Initials ML	Date 15 DEC 11

7. RECOVERY

Still pinging (RADIO CHECK)?	✓	**Quality Control**	
Physical condition?	Good	Pitch/roll/heading consistant?	✓
Do NOT stop data collection when recovered instead go to 'stop recorder deployment'		Complete dataset over time?	✓
		Complete dataset over depth?	✓
Clock error			
Switch off date and time	10:00 24FEB12		
Battery Voltage after recovery	TBC 12V		
Data filename (IF DIFFERENT)		Initials ML	Date 24 FEB 2012

Survey Log Sheet
OBS Aquatech 200/210TY

FRAME A SITE F

1.PROJECT No. P1256
Project Name seagreen | Site F | Phase Deployment Dec 2011

2. INSTRUMENT DETAILS	Mounting	Environment
Serial no. 24-42	Moving Buoy	Coastal water
Logger:	Mooring line	River
OBS: 12529	Fixed structure:	Deep water (>300m)
		(Open Ocean) circled

3.STANDARD DEPLOYMENT PLANNING
Deployment Planning

Enable burst mode	(Yes) No	Turbidity gain:	(Auto) x100 x20 x5 x1
Burst/sample interval	10 min	Start time	08:30 15/12/11
Burst sample rate	1		
Samples Per burst 10			

6. BATTERIES AND SERVICE

Battery type	(alk) / lith		Silica decesent installed	☐
Measured voltage		New batteries fitted ✓	Battery connected	☑
New battery capacity (Wh)			Instrument sealed	☑
			Initials ML Date 15 DEC 11	

7. DEPLOYMENT

		DEPLOY to send CMD file to Aquadopp	✓
Computer clock set to GMT	☑	Start date and time (GMT)	0830 15 DEC 11
TESTOBS filename	SITE F	Deployment log filename	SITE F
Memory erased	☑	.CMD and log files backed up	✓
		Initials ML	Date 15 DEC 11

8. RECOVER

		Physical condition?	GOOD
		Clock error	NONE
Switch off date and time	23 FEB 12 13:50	Data inspected	☑
Data recovered	YES	Data backed up	Y ☑ N ☐
Data filename	P1256-SiteF-23 Feb 2012	Initials MC	Date 23/02/12

NOTES

Start Pinging at 0830.

Checked By: | Date

8.3 Site E – Phase 2

Survey Log Sheet — Site: E
Moorings — Frame: C

1.PROJECT No. P1256
Site Name: SITE E
Phase (mobilisation / service visit / demobilisation)
Deployment Date & Time (GMT): 02 MAR 12 11 08
Water Depth (m): 21.23 m
Check transducer height off seabed
Latitude: 56° 31.70712 N
Longitude: 002° 34.21547 W

2. FRAME DETAILS
Size Frame: GSE HEX 1.6 x 1.6
Type Material Frame: S/S
Total Weight of Frame: ~250 kg
Instrument type in frame: AWAC — Height of instrument: 0.7
Instrument type in frame: RBR — Height of instrument: 0.7

3.STANDARD DEPLOYMENT PLANNING
No. Ground lines: 1
Ground line length: 80 m
Diameter of rope: 16 mm
Leaded rope: YES
Condition of rope: GOOD
Ground weight material: LARGE LINK ANCHOR CHAIN BUNDLE
Total weight ballast: ~30 kg
Ground weight attached to: HLZ CHAIN → LRT + ROPE (ANT + SEDIMENT TRAP

4. ADVANCED DEPLOYMENT PLANNING
Acoustic release
Acoustic release
Type of acoustic release: LRT
Acoustic release serial no: 267180.002
Acoustic release address: 2222
Buoys
Buoys: 3
Type of Buoys: VINNY
Diameter of Buoys: 9"
Lift of Buoys

5. Deployment Planning Notes
Duration of survey
Ground Weight Location: 56° 31.74406 N
002° 34.22040 W

6. RECOVER
Physical condition? GOOD.
Data inspected

NOTES
VESSEL GPS.
56° 31.702 N
002° 34.213 W FRAME
56° 31.748 N
002° 34.221 W GROUND WEIGHT

SONARDYNE PINGER
#7
75 kHz
4-8-8
930 ms

AWAC 6050
RBR 22001

Presurvey Check (Director) Date

Survey Log Sheet — SITE E FRAME C

AWAC NORTEK

1. PROJECT No. P1256
Project Name: Seagreen | Site: E | Phase: 2

2. INSTRUMENT DETAILS

Serial no.	6050	Bottom track fitted		Memory fitted (MB)	
Frequency (kHz)	600	Housing depth rating (m):		Planned orientation	upward (circled) / downward
CPU Firmware version:	3.33			Height of transducer	0.70m
Frame number	C				
Compass Calibration file		DEPLOYMENT FILENAME	P1256E		
AWAC AST Version	1.42				

3. DEPLOYMENT PLANNING

Current profile		Waves		Instrument	
Profile interval (s)	600	Number of samples	1024	Frequ 1 MHz / 600 kHz (circled)	
Number of cells	30	Sampling rate (Hz)	1	Extended SD data logger	
Cell size (m)	1	Interval (s)	1800	Speed of sound	
(adv) Average interval (s)	60	(adv) Velocity cell size (m)	1	Measured Salinity (ppt)	N/A
(adv) Blanking distance (m)	0.52	(adv) AST window start (m)		Fixed (m/s)	1482
(adv) Measurement load (%)	50	(adv) AST window size (m)		File wrapping	NO
		(adv) AST threshold			

4. FURTHER DEPLOYMENT PLANNING

Assumed duration (days)	75	SUV mode (sub-surface buoy)		Analogue -OBS turbidity sensor	
Estimated depth (m)	30			Enable Power to Sensor	YES
Battery Utilization	99			Enable Logging to AWAC	YES P
Memory required (MB)	90.8			Gain of cable	5
Vertical vel. Prec. (cm/s)	1.5			OBS serial No.	12582
Horizont. Vel. Prec. (cm/s)	4.5			Pre-calibrated	Yes / No (circled)
Compass update rate (s)	600				
Power level	HIGH				

5. BATTERIES AND SERVICE

Battery type	alk (circled) / lith	Measured voltage	14.55 / 14.58	Silica decesant installed	YES
Battery supplier	ATM (circled) / Consolidated	New battery capacity (Wh)		Battery connected	YES
No. of battery packs	2	New batteries fitted	YES	Instrument sealed	YES
		Comms switch	RS232 / RS422 (circled)		

6. DEPLOYMENT

In water test?	NO	DEPLOY to send CMD file to AWAC		Dummy plug greased & replaced	YES
Computer clock set to GMT	YES	Start date and time (GMT)	01 MAR 12 18:30	Dummy plug tied in	YES
TESTAWAC filename		Deployment log filename	DLG	AWAC pinging audible	YES
Memory erased	YES	.CMD and log files backed up		Chilli applied to Tx	NO
				Initials	[illegible] Date 01/03/12

7. RECOVERY

Still pinging (RADIO CHECK)?	✓	Quality Control	
Physical condition?	GOOD	Pitch/roll/heading consistant?	✓
Do NOT stop data collection when recovered instead go to 'stop recorder deployment'		Complete dataset over time?	✓
		Complete dataset over depth?	✓
Clock error	8 sec Fast		
Switch off date and time	~~1200~~ 04 MAY 12		
Battery Voltage after recovery			
Data filename (IF DIFFERENT)	0948	Initials [illegible]	Date 04 MAY 12

14.12 GMT OBS + RBR Sensors cleaned

Survey Log Sheet
OBS Aquatech 200/210TY — FRAME C

1.PROJECT No. P1256
Project Name SEAGREEN Site E Phase 2

2. INSTRUMENT DETAILS
Serial no.
Logger: 22007
OBS : 12654

Mounting
Moving Buoy
Mooring line
Fixed structure: FRAME

Environment
Coastal water (circled)
River
Deep water (>300m)
Open Ocean

3.STANDARD DEPLOYMENT PLANNING
Deployment Planning
Enable burst mode Yes No
Burst/sample interval 00:10:00
Burst sample rate 00:01:00
Turbidity gain: Auto (circled) x100 x20 x5 x1
Start time 01 MAR 12 17:20

6. BATTERIES AND SERVICE
Battery type alk (circled) / lith
Measured voltage
New battery capacity (Wh)
New batteries fitted
Silica decesent installed ☐
Battery connected ☑
Instrument sealed ☑
Initials SH Date 01 MAR 12

7. DEPLOYMENT
Computer clock set to GMT ☑
TESTOBS filename
Memory erased ☑
DEPLOY to send CMD file to Aquadopp
Start date and time (GMT) 01 MAR 12 17:20.
Deployment log filename
.CMD and log files backed up
Initials SH Date 01/03/12

8. RECOVER
Switch off date and time 1150 04 MAY 12
Data recovered
Data filename 22007_20120504_1152.HEX Initials ML
Physical condition? GOOD
Clock error ZERO
Data inspected ☑
Data backed up Y ☑ N ☐
Date 04 MAY 12

NOTES

Checked By: Date

8.4 Site F – Phase 2

Survey Log Sheet — Site: F

Moorings — Frame: B

1.PROJECT No. P1256.
Site Name SITE F
Phase (mobilisation / (service visit) / demobilisation)
Deployment Date & Time (GMT) 01 MAR 12 12:25
Water Depth (m) 26.63m (WATER LEVEL)
Check transducer height off seabed 0.70 m
Latitude 55°58.25367 N
Longitude 002°21.16408 W

2. FRAME DETAILS
Size Frame. GSE HEX 1.6mx1.2
Type Material Frame S/S
Total Weight of Frame: ~250 kg
Instrument type in frame AWAC 600 kHz — Height of instrument 0.7 m.
Instrument type in frame RBR — Height of instrument 0.7 m

3.STANDARD DEPLOYMENT PLANNING
No. Ground lines 1
Ground line length 20 m
Diameter of rope 16 mm
Leaded rope YES
Condition of rope GOOD
Ground weight material STAGE WEIGHTS
Total weight ballast 30 kg.
Ground weight attached to HLZ → WEIGHT → GROUND LINE → RUE → LRT

4. ADVANCED DEPLOYMENT PLANNING
Acoustic release
Acoustic release
Type of acoustic release LRT
Acoustic release serial no 273863-003
Acoustic release address 1111
Buoys
Buoys ~~YES~~ 3
Type of Buoys VINNY
Diameter of Buoys 9"
Lift of Buoys

5. Deployment Planning Notes
Duration of survey
Ground Weight Location: 55°58.26570 N
002°21.10515 W

6. RECOVER
Physical condition? GOOD
Data inspected
FRAME FIX 55°58.358'N
002°21.310'W

NOTES
* FRAME MOVED FROM PROPOSED POSITION DUE TO FISHING GEAR.
215 m FROM PROPOSED SITE.

VESSEL GPS.
FRAME 55°58.256
002°21.157
GW: 55°58.267
002°21.103

AWAC 6051
RBR 22008

~~AWAC SN 6050~~
~~RBR SN 22007~~

Presurvey Check (Director) — Date

Survey Log Sheet — Site: F

AWAC NORTEK — Frame: AB

1.PROJECT No. P1256
Project Name Seagreen — Phase 2 — Notes

2. INSTRUMENT DETAILS
Serial no. 23603-4/ 6051 ✓ — Bottom track fitted — Memory fitted (MB) 4 GB
Frequency (kHz) 600 — Housing depth rating (m): — Planned orientation (upward) downward
CPU Firmware version: 3.33 — Height of transducer 0.7
Frame number AB
Compass Calibration file — DEPLOYMENT FILENAME SGrFP2
AWAC AST Version 1.42

3. DEPLOYMENT PLANNING

Current profile
Profile interval (s) 600
Number of cells 35
Cell size (m) 1
(adv) Average interval (s) 60
(adv) Blanking distance (m) 0.52
(adv) Measurement load (%) 50
Coordinate System (ENU) XYZ Beam

Waves
Number of samples 1024
Sampling rate (Hz) 1
Interval (s) 1800
(adv) Velocity cell size (m)
(adv) AST window start (m)
(adv) AST window size (m)
(adv) AST threshold

Instrument
Frequ 1 MHz / (600 kHz)
Extended SD data logger

Speed of sound
Measured Salinity (ppt) 35
Fixed (m/s) 8
File wrapping NO

4. FURTHER DEPLOYMENT PLANNING
Assumed duration (days) 66
Estimated depth (m) 35
Battery Utilization 100
Memory required (MB) 80.6
Vertical vel. Prec. (cm/s) 1.5
Horizont. Vel. Prec. (cm/s) 4.5
Compass update rate (s) 600
Power level HIGH
SUV mode (sub-surface buoy)

Analogue -OBS turbidity sensor
Enable Power to Sensor YES
Enable Logging to AWAC YES
Gain of cable x5
OBS serial No. 12581
Pre-calibrated Yes (No)

5. BATTERIES AND SERVICE
Battery type (alk) / lith
Battery supplier (ATM) Consolidated
No. of battery packs 2
Measured voltage 14
New battery capacity (Wh)
New batteries fitted YES
Comms switch RS232 (RS422)
Silica decesent installed YES
Battery connected YES
Instrument sealed YES.

6. COMPASS CALIBRATION
Caliration file name
Estimated Maximum Error (degrees)

7. DEPLOYMENT
In water test? NO
Computer clock set to GMT YES
TESTAWAC filename
Memory erased YES.
DEPLOY to send CMD file to AWAC
Start date and time (GMT) 01|03|12 10:30
Deployment log filename DLG
.CMD and log files backed up
Dummy plug greased & replaced YES
Dummy plug tied in YES
AWAC pinging audible YES
Chilli applied to Tx NO
Initials [illegible] Date 01/03/12

8. RECOVERY
Still pinging (RADIO CHECK)? ✓
Physical condition? Good, Light BioFouling
Do NOT stop data collection when recovered instead go to 'stop recorder deployment'
Clock error 6 sec fast
Switch off date and time ~~1200~~ 04 MAY 12
Battery Voltage after recovery
Data filename (IF DIFFERENT)

Quality Control
Pitch/roll/heading consistant? ✓
Complete dataset over time? ✓
Complete dataset over depth? ✓

Initials [illegible] Date 04 MAY 12

0930 04 MAY 12 COMMENCE OBS CAL
1025 OBS CLEANED FACES.

Survey Log Sheet RBR
~~OBS Aquatech 200/210TY~~ FRAME B

1.PROJECT No. P1256
Project Name SEAGREEN Site F Phase 2

2. INSTRUMENT DETAILS	Mounting	Environment
Serial no. RBR	Moving Buoy	Coastal water (circled)
Logger: 22008 ✓	Mooring line	River
OBS: 12655	Fixed structure: ATTACHED TO FRAME	Deep water (>300m)
		Open Ocean

3.STANDARD DEPLOYMENT PLANNING
Deployment Planning

Enable burst mode	Yes No	Turbidity gain:	(Auto) x100 x20 x5 x1
Burst/sample interval	00:10:00	Start time	01 MAR 12 09:30
Burst sample rate	00:01:00	END	15 MAY 12 12:00

6. BATTERIES AND SERVICE

Battery type	(alk) / lith	Silica decesent installed	☐
Measured voltage		Battery connected	☑
New batteries fitted	YES	Instrument sealed	☑
New battery capacity (Wh)		Initials BH	Date 01/03/12

7. DEPLOYMENT

		DEPLOY to send CMD file to Aquadopp	
Computer clock set to GMT	☑	Start date and time (GMT)	01/03/12 09:30
TESTOBS filename		Deployment log filename	
Memory erased	☑	.CMD and log files backed up	
		Initials	Date

8. RECOVER

		Physical condition?	GOOD
		Clock error	NONE
Switch off date and time	1313 04MAY12	Data inspected	☑
Data recovered		Data backed up	Y ☑ N ☐
Data filename	022008_20120504_1313.HEX	Initials [signature]	Date 04-MAY 12

NOTES

Checked By: Date

8.5 Site E – Phase 3

Survey Log Sheet — Site: E

Moorings — Frame: 4

1.PROJECT No. P1256
Site Name E
Phase (mobilisation / service visit / demobilisation)
Deployment Date & Time (GMT)
Water Depth (m) 30
Check transducer height off seabed 0.75
Latitude 56°31.6832'N
Longitude 002°34.1797'W

2. FRAME DETAILS
Size Frame. 1.4 x 1.4 x 0.75
Type Material Frame SS
Total Weight of Frame: 230KG
Instrument type in frame AWAC + RBR + OBS
Height of instrument 0.75
Instrument type in frame
Height of instrument

3.STANDARD DEPLOYMENT PLANNING
No. Ground lines 1
Ground line length 80m
Diameter of rope 16mm
Leaded rope ✓
Condition of rope VERY GOOD
Ground weight material STAGE WEIGHTS
Total weight ballast 40KG
Pos. 56°31.6809'N 002°34.2658'W
Ground weight attached to LRT

4. ADVANCED DEPLOYMENT PLANNING

Acoustic release
Acoustic release SONARDYNE
Type of acoustic release LRT
Acoustic release serial no 216122-004
Acoustic release address 0077

Buoys
Buoys x3 VINNY
Type of Buoys
Diameter of Buoys 8"
Lift of Buoys 25KN

5. Deployment Planning Notes
Duration of survey
Ground Weight Location:

6. RECOVER
Physical condition? GOOD
Data inspected UNABLE TO DOWNLOAD.

NOTES
Pinger: #7
75KHZ
4-8-8
930ms
Sonotronics
EMT-01-1

AWAC SN 6123
RBR SN 22009

Presurvey Check (Director) Date

Survey Log Sheet — Site: E

AWAC NORTEK — Frame: 4

1. PROJECT No.
Project Name P1256 Phase 3 Notes

2. INSTRUMENT DETAILS
Serial no. 6123
Frequency (kHz) 600
CPU Firmware version: 4.06
Frame number 4
Compass Calibration file
AWAC AST Version 1.42
Bottom track fitted N/A
Housing depth rating (m): 200
DEPLOYMENT FILENAME Site_e.dep
Memory fitted (MB) 4GB
Planned orientation (upward) downward
Height of transducer 0.75m

3. DEPLOYMENT PLANNING

Current profile
Profile interval (s) 600
Number of cells 30
Cell size (m) 1
(adv) Average interval (s) 60
(adv) Blanking distance (m) 0.5
(adv) Measurement load (%) 50
Coordinate System (ENU) XYZ Beam

Waves
Number of samples 1024
Sampling rate (Hz) 1
Interval (s) 1800
(adv) Velocity cell size (m) 3.6
(adv) AST window start (m) 22.9
(adv) AST window size (m) 14.2
(adv) AST threshold 100

Instrument
Frequ 1 MHz / (600 kHz)
Extended SD data logger ✓

Speed of sound
Measured Salinity (ppt) 35
Fixed (m/s) 1482
File wrapping

4. FURTHER DEPLOYMENT PLANNING
Assumed duration (days) 75
Estimated depth (m) 30
Battery Utilization 991
Memory required (MB) 49.8
Vertical vel. Prec. (cm/s) 1.5
Horizont. Vel. Prec. (cm/s) 4.5
Compass update rate (s) 600
Power level High
SUV mode (sub-surface buoy)

Analogue -OBS turbidity sensor
Enable Power to Sensor yes
Enable Logging to AWAC yes
Gain of cable x5
OBS serial No. 10976
Pre-calibrated (Yes) No

5. BATTERIES AND SERVICE
Battery type (alk) / lith
Battery supplier (A1M) Consolidated
No. of battery packs 2
Measured voltage 14.4 / 14.4
New battery capacity (Wh) 1080
New batteries fitted yes
Comms switch RS232 (RS422)
Silica decesent installed ✓
Battery connected ✓
Instrument sealed ✓

6. COMPASS CALIBRATION
Caliration file name Serial no 6123.docx
Estimated Maximum Error (degrees)

7. DEPLOYMENT
In water test? No
Computer clock set to GMT ✓
TESTAWAC filename 6123-4.wpr
Memory erased ✓
DEPLOY to send CMD file to AWAC
Start date and time (GMT) 03/05/12 9.00
Deployment log filename Site_EDLG
.CMD and log files backed up ✓
Dummy plug greased & replaced ✓
Dummy plug tied in ✓
AWAC pinging audible ✓
Chilli applied to Tx No
Initials GM Date 03/05/12

8. RECOVERY
Still pinging (RADIO CHECK)? NO
Physical condition? GOOD.
Do NOT stop data collection when recovered instead go to 'stop recorder deployment'
Clock error
Switch off date and time
Battery Voltage after recovery
Data filename (IF DIFFERENT)
Quality Control - UNABLE TO DOWNLOAD
Pitch/roll/heading consistant? ✗
Complete dataset over time? ✗
Complete dataset over depth? ✗
Initials [illegible] Date 21 Jun 2012

Analogue input 1+2 Profile
Output power ✓

Survey Log Sheet
~~OBS Aquatech 200/210TY~~ RBR XR420

1.PROJECT No.
Project Name P1256 | Site E | Phase 3

2. INSTRUMENT DETAILS

Serial no. 22009	**Mounting**	**Environment**	
Logger:	Moving Buoy	Coastal water (circled)	
OBS : 22009	Mooring line	River	
12656	Fixed structure: ATTACHED TO FRAME	Deep water (>300m)	
		Open Ocean	

3.STANDARD DEPLOYMENT PLANNING
Deployment Planning
Enable burst mode Yes No | Turbidity gain: (Auto) x100 x20 x5 x1
Burst/sample interval 00:10:00 | Start time
Burst sample rate 00:01:00

6. BATTERIES AND SERVICE
Battery type alk / (lith) | Silica decesent installed ☐
Measured voltage 12.41 | New batteries fitted YES | Battery connected ☑
New battery capacity (Wh) | Instrument sealed ☑
Initials ML Date 03MAY12

7. DEPLOYMENT
☑ DEPLOY to send CMD file to Aquadopp
Computer clock set to GMT ☑ Start date and time (GMT) 08:00 03MAY12
TESTOBS filename ______ Deployment log filename
Memory erased ☑ CMD and log files backed up 20 JULY 12
Initials ML Date 03MAY12

8. RECOVER
Physical condition? GOOD
Clock error 40SEC SLOW
Switch off date and time 1425 21JUN2012 | Data inspected ☑
Data recovered | Data backed up Y ☑ N ☐
Data filename | Initials ML | Date 21JUN2012

NOTES
NO of samples : 7025
FIRMWARE 6.78

Checked By: | Date

8.6 Site F – Phase 3

Survey Log Sheet — Site: F

Moorings — Frame: 1

1.PROJECT No. P1256
Site Name F
Phase (mobilisation / service visit / demobilisation)
Deployment Date & Time (GMT) 03MAY12 09.00
Water Depth (m) 35
Check transducer height off seabed 0.75
Latitude 55°58.3702'N
Longitude 002°21.3214'W

2. FRAME DETAILS
Size Frame. 1.4x1.4mx0.75m
Type Material Frame SS
Total Weight of Frame: 280kg
Instrument type in frame AWAC +RBR +OBS
Height of instrument 0.75m
Instrument type in frame
Height of instrument

3.STANDARD DEPLOYMENT PLANNING
No. Ground lines 1
Ground line length 80m
Diameter of rope 16mm
Leaded rope ✓
Condition of rope VG
Ground weight material Stage weights
Total weight ballast 40kg
Ground weight attached to LRT
Pos: 55°58.3880N 002°21.3848'W

4. ADVANCED DEPLOYMENT PLANNING

Acoustic release
Acoustic release SONARDYNE
Type of acoustic release LRT
Acoustic release serial no 270452-004
Acoustic release address 3333

Buoys
Buoys x 3 vinny
Type of Buoys Vinny
Diameter of Buoys 8"
Lift of Buoys 25 KN

5. Deployment Planning Notes
Duration of survey 60 days
Ground Weight Location: 55°58.383'N 002°21.384'W

6. RECOVER
Physical condition? Good
Data inspected
Frame Fix 55°58.358'N 002°21.310'W
1250 19JUN2012

NOTES
Pinger #5
73 khz
4-4-7
910ms
Sonotronics EMT-01-1
AWAC 6030
RBR 22010

Presurvey Check (Director)
Date

Survey Log Sheet — Site: F

AWAC NORTEK — Frame: 1

1. PROJECT No.

Project Name Seagreen | Phase 3 | Notes S1

2. INSTRUMENT DETAILS

Serial no. 6030 | Bottom track fitted N/A | Memory fitted (MB) 4GB
Frequency (kHz) 600 | Housing depth rating (m): 200 | Planned orientation (upward) downward
CPU Firmware version: 4.07 | Height of transducer 0.75m
Frame number Site F frame 1
Compass Calibration file | DEPLOYMENT FILENAME Site_F
AWAC AST Version 1.42

3. DEPLOYMENT PLANNING

Current profile	Waves	Instrument
Profile interval (s) 600	Number of samples 1024	Frequ 1 MHz / (600 kHz)
Number of cells 35	Sampling rate (Hz) 1	Extended SD data logger ✓
Cell size (m) 1	Interval (s) 1800	
(adv) Average interval (s) 60	(adv) Velocity cell size (m) 4.2	Speed of sound
(adv) Blanking distance (m) 0.5	(adv) AST window start (m) 26.8	Measured Salinity (ppt) 35
(adv) Measurement load (%) 50	(adv) AST window size (m) 16.4	Fixed (m/s) 1485
Coordinate System (ENU) XYZ Beam	(adv) AST threshold 100	File wrapping

4. FURTHER DEPLOYMENT PLANNING

Assumed duration (days) 66 | SUV mode (sub-surface buoy) | Analogue -OBS turbidity sensor
Estimated depth (m) 35
Battery Utilization 100%
Memory required (MB) 80.6
Vertical vel. Prec. (cm/s) 1.5
Horizont. Vel. Prec. (cm/s) 4.5
Compass update rate (s) 600
Power level HIGH

Enable Power to Sensor YES
Enable Logging to AWAC YES
Gain of cable x5
OBS serial No. 1574
Pre-calibrated Yes (No)

5. BATTERIES AND SERVICE

Battery type (alk) / lith | Measured voltage 14.4/14.4 | Silica decesent installed ✓
Battery supplier (ATM) Consolidated | New battery capacity (Wh) 1080 | Battery connected ✓
No. of battery packs 2 | New batteries fitted yes | Instrument sealed ✓
Comms switch RS232 (RS422)

6. COMPASS CALIBRATION

Calibration file name Serial number 6030 frame 1.docx | Estimated Maximum Error (degrees)

7. DEPLOYMENT

In water test? No | DEPLOY to send CMD file to AWAC | Dummy plug greased & replaced ✓
Computer clock set to GMT ✓ | Start date and time (GMT) 03/05/12 09:00 | Dummy plug tied in ✓
TESTAWAC filename 6030-303.wpr | Deployment log filename SiteF DLG | AWAC pinging audible ✓
Memory erased ✓ | .CMD and log files backed up ✓ | Chilli applied to Tx No
Initials CM | Date 03MAY12

8. RECOVERY

Still pinging (RADIO CHECK)? ✓
Physical condition? Good
Do NOT stop data collection when recovered instead go to 'stop recorder deployment'
Clock error 15 sec slow
Switch off date and time 1200 19JUN2012
Battery Voltage after recovery 12.17V/12.17V
Data filename (IF DIFFERENT)

Quality Control
Pitch/roll/heading consistent? ✓
Complete dataset over time? ✓
Complete dataset over depth? ✓

Initials [signature] Date 19Jun2012

Analogue input 1:2 Profile
Output power: ✓

Survey Log Sheet
~~OBS Aquatech 200/210TY~~ RBR

1. PROJECT No.
Project Name P1256 Site F Phase 3

2. INSTRUMENT DETAILS

Serial no. 22010	Mounting	Environment	
Logger: -	Moving Buoy	Coastal water (circled)	
OBS: 22010	Mooring line	~~River~~	
12657	Fixed structure: ATTACHED TO FRAME	Deep water (>300m)	
		Open Ocean	

3. STANDARD DEPLOYMENT PLANNING
Deployment Planning

Enable burst mode Yes No
Burst/sample interval 00:10:00
Burst sample rate 00:01:00
Turbidity gain: (Auto) x100 x20 x5 x1
Start time

6. BATTERIES AND SERVICE

Battery type alk / (lith)
Measured voltage 6.13
New battery capacity (Wh)
New batteries fitted YES
Silica decesent installed ☐
Battery connected ☑
Instrument sealed ☑
Initials [signature] Date 05MAY12

7. DEPLOYMENT

Computer clock set to GMT ☐
TESTOBS filename
Memory erased ☑
DEPLOY to send CMD file to Aquadopp
Start date and time (GMT) 08:00pm 05MAY12
Deployment log filename
.CMD and log files backed up 20 JULY 12
Initials [signature] Date 05MAY12

8. RECOVER

Switch off date and time 1330 19Jun2012
Data recovered
Data filename 022010_20120619.HEX
Initials [signature]
Physical condition? Good
Clock error 30sec fast
Data inspected ☑
Data backed up Y ☑ N ☐
Date 19Jun2012

NOTES

Checked By: Date

8.7 AWAC Site E Phase 3 Data Loss

Dear Pete,

Norway had a go at trying to get data off the card, but unfortunately were unsuccessful.

The reason for problem, is thought to have been due to an intermittent bug which was related to the AWAC when operating the Prolog. When it happens, if can lead to data loss as we have seen here. The matter has now been solved and Nortek are advising all customers having AWACs with ProLog, that they should update their firmware to AWAC v3.36/AWAC-AST v3.37/AWAC-WPC v3.37.

My apologies for the inconvenience caused by this issue.

--
Regards
Gordon

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