



ORMONDE OFFSHORE WINDFARM

POST-CONSTRUCTION SURVEY

(JUNE 2013)

SURVEY REPORT

REVISION 1 - FINAL

SEPTEMBER 2013

Client:

Vattenfall Wind Power Ltd.
1st Floor
1 Tudor Street
London
EC4Y 0AH



Contractor:

EGS (International) Ltd
27 Woolmer Way
Bordon
GU35 9QE



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INTERPRETIVE REPORT – REV 1 FINAL

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Document prepared by:

Peter Watchorn
Geoscience Team Leader

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Checked & Approved by:

Dr. Walter Colautti
Senior Project Manager/ Principal
Geoscientist

Date 13th September 2013

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DRAWINGS

Chart Type	Scale	Chart Content	Chart Title
Panel Charts at WTG locations (x30)	1:1000	4 Panels containing: 1) Bathymetric Image 2) Difference Plot 3) SSS Mosaic 4) 4x SSS screenshots	5137_OR_A1-A7 5137_OR_B1-B8 5137_OR_C1-C7 5137_OR_D1-D8
Alignment Charts of the Export Cable Route (x10)	1:2500	5 x Bathymetric and SBF 5 x Difference Plots	5137_EC_01-05 5137_EC_01-05_DIFF
OWF Overview Chart (x1)	1:5000	Bathymetric image Seabed features	5137_AC_01

ABBREVIATIONS

Abbreviation	Meaning
CD	(Admiralty) Chart Datum
CRP	Common Reference Point
DGPS	Differential Global Positioning System
DPR	Daily Progress Report
GPS	Global Positioning System
HIRA	Hazard Identification and Risk Assessment
HSE	Health, Safety & Environmental
kHz	Kilohertz
km	Kilometre
KP	Kilometre Point
Lat	Latitude
Long	Longitude
m	Metre
MBES	Multibeam Echo Sounder
MRU	Motion Reference Unit
ODN	Ordnance Chart Datum
nmh	No measurable height
NA	Not Applicable
OWF	Offshore Wind Farm
QC	Quality Control
RPL	Route Position List
SSS	Side-Scan Sonar
SVP	Sound Velocity Profile
UTM	Universal Transverse Mercator
WGS84	World Geodetic System 1984
WTG	Wind Turbine Generator

EXECUTIVE SUMMARY

The Ormonde Offshore Wind Farm (OWF) is located approximately 10km west of Walney Island, UK. Vattenfall Wind Power, as developer, has installed 30 Wind Turbine Generators (WTG) and one substation at the site along with one export cable (Figure 1). The survey site has three main components: the wind farm site, the export cable route and the inter array cables.

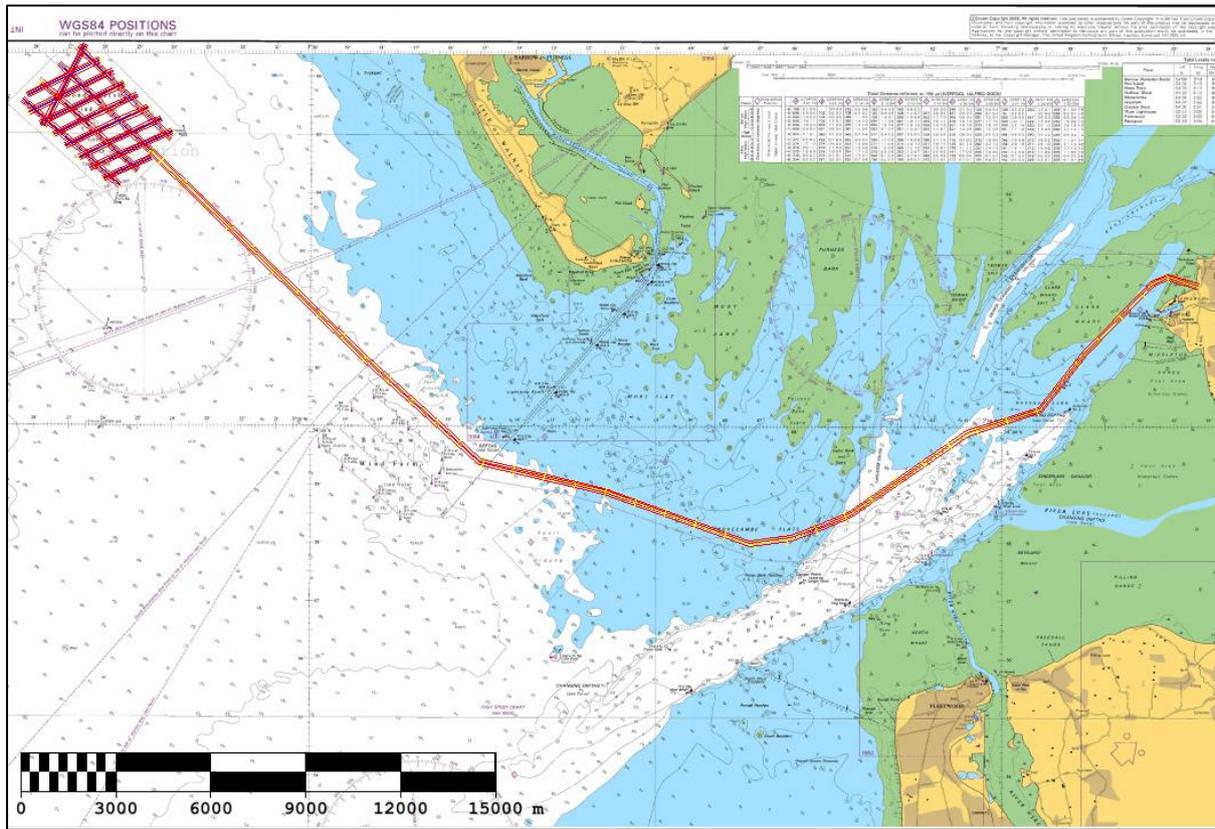


FIGURE 1: ORMONDE OFFSHORE WIND FARM EXPORT CABLE.

EGSi have been contracted to conduct a detailed bathymetric and geophysical survey of the Ormonde OWF and export cable route that can be compared with the data collected from previous surveys in order to meet the Marine Licence requirements. These require an assessment of the changes of both the bathymetry and the seabed morphology to be made at various time intervals across the site and along the cable route. Specific attention is to be paid to the differences in seabed depth and any identifiable areas of scour.

The survey vessel “Otarie”, operating on a 12 hour basis, was mobilised between the 1st and 4th June, 2013 in Fleetwood, with kickoff meetings held in Barrow-in-Furness, UK on 3rd June, 2013. Equipment wet tests and MBES calibrations were carried out on 3rd and 4th June

respectively. Survey operations commenced later on 4th June and were completed on 11th June, 2013. During survey operations the vessel was based in Fleetwood Docks.

The equipment spread consisted primarily of a Kongsberg EM3002D MBES, a Klein 3000 dual frequency SSS, a G882 Geometrics Marine Magnetometer and a Seatex Seapath 330+ inertial positioning, heading and attitude system, with all positions transformed to the UTM-30N projection.

Fixed offset measurements were used to position the SSS and MAG towfish towpoints on the stern of the vessel. Added to this were layback figures that enabled the towfish to be positioned relative to the CRP (itself referenced to the GPS), which were interfaced into the QPS QINSy navigation package.

Vertical levels were reduced to CD defined as being 4.9m below Ordnance Datum Newlyn at Heysham. Levels were derived by post processing raw GPS data acquired by the C&C Technologies C-Nav 3050 unit.

In order to acquire sufficient coverage of the turbine and cable locations over a corridor of 300m (150m either side of the centreline), survey lines were run at a distance of 30m and 90m offset either side of the turbine rows, array cables and export cable.

341km of survey lines were run over the Ormonde OWF survey area out of a planned total of 344km. The remaining 3km of export cable route crosslines were cancelled onsite at the instruction of the client.

Survey results are presented primarily as three sets of charts that accompany this report. The first set of charts consists of 30 panel charts (1 for each WTG) comprising of 4 panels illustrating bathymetric and SSS datasets surrounding the turbine locations. The second series of charts consists of 10 alignment charts; five displaying the bathymetry and seabed features and five bathymetric difference plots along the export cable route; the difference plots have been created using data from the EGS 2013 survey and a previous survey conducted in 2008. The third set is a single bathymetric and seabed features overview chart of the OWF site including the array cables.

The bathymetric survey difference plot indicates that in general the site seems to be experiencing limited sediment erosion/deposition with the exception of landward of approximately KP3.5. Here the entire site experiences both the largest amounts of erosion and deposition, changing by up to 4.8m and 2.5m respectively. No evidence of scour has been identified surrounding either the 30 turbine bases or the substation.

The export and array cables appear buried throughout the site with only two exposures interpreted; a 5.8m array cable exposure within a limited depression in the OWF site and a 77m exposure of the export cable located at approximately KP1.5.

A total of 45 sonar contacts were identified within the survey area. 43 of the contacts have been interpreted as debris or linear debris whilst the remaining 2 contacts have been listed as wrecks. 13 magnetic anomalies, excluding the export and array cables, were identified from the survey with 10 interpreted as being ferrous debris and the remaining 3 being associated with the gas pipelines connecting the North and South Morecambe gas fields.

When plotted against the survey data the client supplied RPL (EOS1174) shows divergence away from features that have been interpreted as cable protection, in some cases up to 60m of separation exists.

1. PROJECT OVERVIEW

1.1. PROJECT INFORMATION

Client:	Vattenfall Wind Power Ltd
Project:	Ormonde Offshore Wind Farm
Contractor:	EGS (International) Ltd
Contractor Reference:	5137
Contract Purpose:	Post-Construction survey
Survey Area:	NE Irish Sea, UK
Survey Type:	Hydrographic and Geophysical Survey
Survey Period:	June 2013
Survey Vessel:	Otarie
Survey Equipment:	Multibeam echo sounder, vessel positioning system, side scan sonar and magnetometer
Client Project Manager:	Kirsty Godwin Kirsty.godwin@vattenfall.com
Contractor Project Manager:	Dr Walter Colautti wcolautti@egssurvey.co.uk

1.2. PROJECT DESCRIPTION

The Ormonde Offshore Wind Farm (OWF) is located approximately 10km west of Walney Island, UK. Vattenfall Wind Power, as developer, has installed 30 Wind Turbine Generators (WTG) and one substation and at the site along with one export cable (Figure 1 and Figure 3). The survey site has three main components: the wind farm site, the export cable route and the inter array cables.

EGSi have been contracted to conduct a detailed bathymetric and geophysical survey of the Ormonde OWF and export cable route that can be compared with the data collected from previous surveys in order to meet the Marine Licence requirements. These require an assessment of the changes of both the bathymetry and the seabed morphology to be made at various time intervals across the site and along the cable route. Specific attention is to be paid to the differences in seabed depth and any identifiable areas of scour.

This report details the post-construction survey carried out by EGSi in June 2013.

1.3. KEY PERSONNEL

1.3.1. PROJECT MANAGEMENT

The following table details the personnel involved in the project management:

Name	Position
Stephen Hayes	Project Director
Dr Walter Colautti	Project Manager

TABLE 1: PROJECT MANAGEMENT PERSONNEL

1.3.2. SURVEY OPERATIONS

The following table details the personnel involved in the survey operations:

Name	Position
Daniele Novello	Party Chief / Hydrographic Surveyor
Thomas Smethurst	Geophysicist
Norman MacDonald	Survey Engineer
William Rand	Boat Skipper
David Richards	Client Representative

TABLE 2: SURVEY OPERATIONS KEY PERSONNEL

1.3.3. REPORTING

The following table details the personnel involved in the data processing and reporting:

Name	Position
Peter Watchorn	Reporting Manager
William Elliott	SSS Processor
Robert Cousins	Magnetometer Processor
Owen Thomas	Bathymetric Processor
Callum Tait	CAD/GIS

TABLE 3: KEY DATA PROCESSING AND REPORTING PERSONNEL

1.4. SURVEY OPERATIONS

The survey vessel “Otarie”, operating on a 12 hour basis, was mobilised between the 1st and 4th June, 2013 in Fleetwood, with kickoff meetings held in Barrow-in-Furness, UK on 3rd June, 2013. Equipment wet tests and MBES calibrations were carried out on 3rd and 4th June respectively. Survey operations commenced later on 4th June and were completed on 11th June, 2013. During survey operations the vessel was based at Fleetwood docks. Details of the calibration and verification procedures and results are presented in the Calibration-Verification Report (Appendix D).

A breakdown of survey operations are summarised in Table 4 and illustrated as a pie chart in Figure 2; Daily Progress Reports (DPRs), submitted during operations, are provided in Appendix A.

Activity	Total (hh:mm)	Total (%)
Mob/Demob	36:35	15.2
Operational	71:10	29.1
Standby (Port 12h ops)	122:05	50.9
Any Other	08:45	3.6
Transit (Weather)	00:00	0
Weather (Port)	00:40	0.3
Weather (Site)	00:45	0.3
Downtime	00:00	0
Sum Totals	240:00	100.0

TABLE 4: BREAKDOWN OF SURVEY OPERATIONS ON THE SV OTARIE.

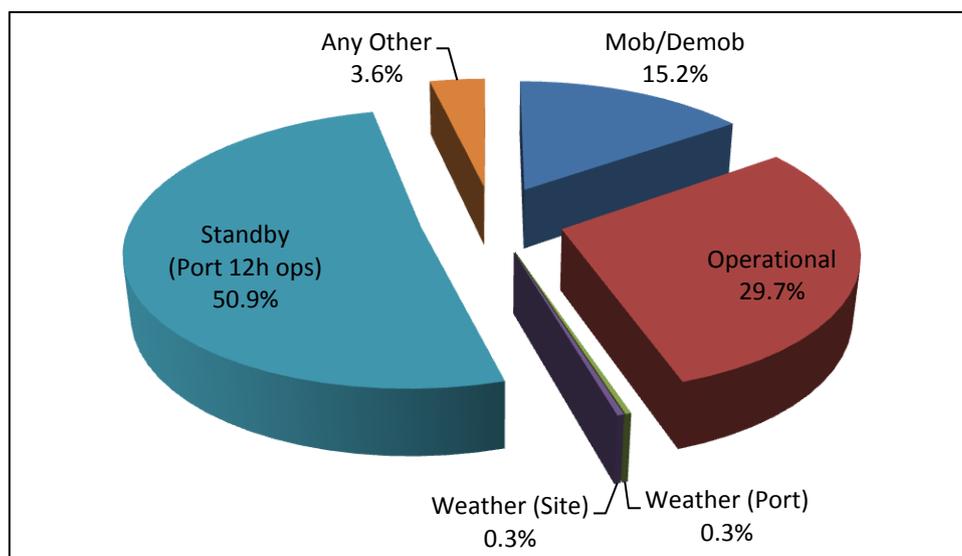


FIGURE 2: BREAKDOWN OF SURVEY OPERATIONS ON THE SV OTARIE

1.5. HSE

Prior to the start of survey operations a full project briefing including a HSE and safety meeting was undertaken whilst the vessel was alongside in Fleetwood Docks on 3rd and 4th June 2013. During this meeting the HIRA document, prepared for the Ormonde survey, was presented to the survey personnel by the EGSi Party Chief. Before sailing all survey personnel and vessel crew were given a vessel safety induction by the vessel skipper.

Prior to deployment of any equipment a relevant toolbox talk was held between the survey personnel and vessel crew involved in that particular operation. During the talks the procedures for equipment deployment were outlined and any hazards involved in the operations were discussed. Full PPE was worn at all times by all personnel working on the vessel's back deck. A list of tool-box talks performed has been included in the DPRs located in Appendix A.

No HSE incidents occurred during the mobilisation or the survey operations.

2. METHODOLOGY

2.1. SCOPE OF WORK

The objective of the survey was to determine whether there have been any changes to the seabed morphology at the wind farm site including along the inter array cables and export cable route, of particular interest was the identification of any seabed scouring and cable exposures. To meet this objective EGS conducted a high-resolution MBES bathymetric and SSS survey across each of the WTGs, substation locations and the export cable route.

2.2. SURVEY LINE PLAN

To meet the survey requirements, EGSi operated a SSS tow fish with a 'piggy-backed' magnetometer in conjunction with a MBES system over planned survey lines at each of the 30 WTG structures, the substation and along the cable routes. In order to obtain data coverage over a 300m corridor two lines were run parallel to and either side of the WTG arrays and export cable route at 30m and 90m spacing from the centreline. Figure 3 shows the survey lines parallel to the WTGs and along the export cable route. To increase the efficiency of the survey and to reduce operational time, the line plan linked together multiple WTG locations rather than surveying each WTG individually, thereby reducing the number of line turns required to complete the survey.

Figure 3 below illustrates the layout of the Ormonde site; WTGs are divided into 4 'arrays' orientated approximately NW-SE. Arrays are labelled alphabetically from southwest to northeast so that the southwestern-most Array is labelled 'A' and the northeastern-most is labelled 'D'; Array 'A' consisting of 7 WTGs; Array 'B' 8 WTGs; Array 'C' 7 WTGs; Array 'D' 8 WTGs. Within each array WTGs are numbered from 01 up to 08 from the southeast to the northwest. The substation is located between Arrays B and D in the southeast side of the OWF site where it joins the export cable route (yellow line in Figure 3).

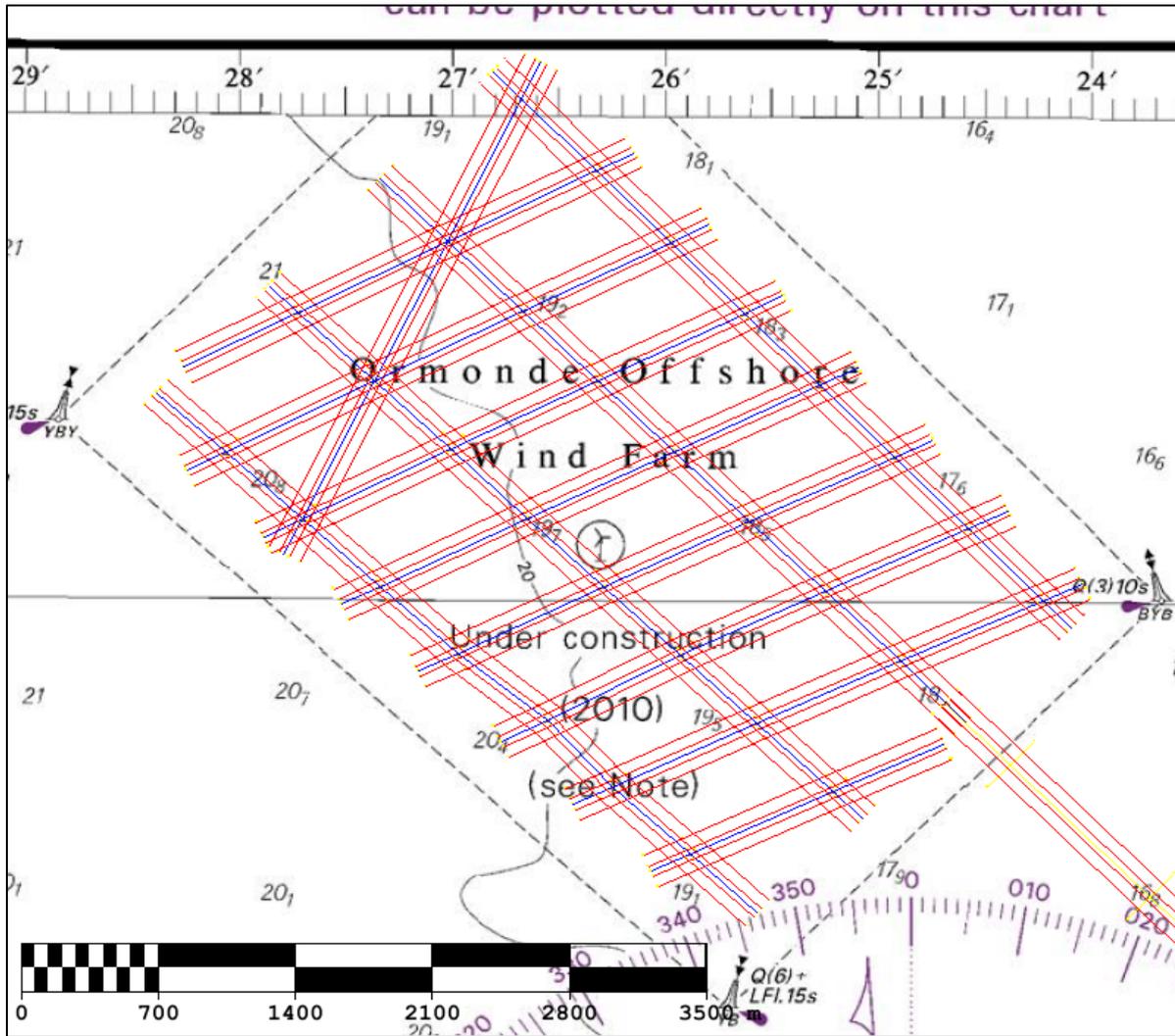


FIGURE 3: OVERVIEW OF ORMONDE OWF LINE PLAN (30M AND 60M OFFSET SURVEY LINES IN RED, CENTRE LINE IN BLUE, WTG'S ARE LOCATED AT THE CROSSING POINT)

Wind farm infrastructure including WTG and substation locations and the export cable RPL (EOS1174) were provided by Vattenfall Wind Power Ltd prior to the commencement of survey activities. The location of the infrastructure and the RPL were used to create the line plan used for survey operations.

The pattern of the survey lines was the same as a survey carried out in the same area in 2008, as indicated by the client. The survey line plan included crosslines every 1km along the export cable route in accordance with the scope of work. All crosslines were surveyed except a 10km section between KP4 and KP14 as instructed onsite by the client.

2.3. VESSEL SUMMARY

All the survey work was carried out using the SV Otarie; a 10m long survey vessel equipped to undertake coastal survey work (Figure 4). The vessel operates under the UK Workboat Code (category 2) for work up to 60 nautical miles from a safe haven. The vessel operated on a 12 hour working day and returned to Fleetwood harbour during the night. Further information regarding the survey vessel is provided in Appendix B – Vessel Specifications.



FIGURE 4: SV OTARIE – SURVEY VESSEL

Summary of Vessel Specifications	
Length overall	10.1m
Breadth	3.7m
Maximum draft	1.1m
Tonnage	8.6Tons
Cruising speed	18 knots

TABLE 5: SUMMARY OF SV OTARIE SPECIFICATIONS

2.4. SURVEY EQUIPMENT

A summary of the equipment mobilised on the SV Otarie and a list of the software used for the processing of each dataset is presented below (Table 6). Further information about the survey systems used during the survey is provided in Appendix C – Equipment Specifications:

SV OTARIE – EQUIPMENT LIST	
SURVEY EQUIPMENT REQUIRED	NO., MAKE & MODEL
POSITIONING:	
Positioning system (primary)	1 x Seapath 330+
positioning system (Secondary)	1 x C&C Technologies C-Nav 3050 DGPS
Heading sensor	1 x Seapath 330+
BATHYMETRIC:	
Multibeam echo-sounder	1 x Kongsberg EM3002 Dual Head Multibeam System (pole mounted)
Motion reference unit	1 x Kongsberg Seatex MRU-5
Sound velocity profiler	2 x Valeport Soundbar 2 SVP (one spare) 1 x Valeport Mini SVS
GEOPHYSICAL:	
Side-Scan Sonar system	2 x Klein 3000 System (one spare)
Magnetometer system	2 X Geometrics G882 caesium-vapour marine magnetometers with depth sensors and altimeters (one spare)
DATA ACQUISITION & PROCESSING SOFTWARE:	
Navigation acquisition	QPS QINSy v8.0
MBES acquisition	Kongsberg SIS v3.6.4
MBES processing	Caris HIPS and SIPS v7.1
SSS acquisition	Klein SonarPro v12.1
SSS processing	IXSEA Delph Sonar v2.9.2
MAG acquisition	Geometrics MagLog v3.20
MAG processing	Geosoft Oasis Montaj v7.3

TABLE 6: GEOPHYSICAL SURVEY EQUIPMENT AND SOFTWARE

2.5. HORIZONTAL POSITIONING

2.5.1. HORIZONTAL DATUM & PROJECTION

All marine survey operations and subsequent reporting were based on the WGS84 Datum and UTM Grid, Zone 30N. Full geodetic parameters are given in Table 7 below:

Datum Parameters	
Datum	WGS-84
Spheroid	WGS-84
Semi-Major Axis (a)	6,378,137.000m
Inverse Flattening (1/f)	298.257 223 563
Projection Parameters	
System Name	Universal Transverse Mercator (UTM)
Projection Method	Transverse Mercator
UTM Zone	30N
Latitude of Origin of Projection	0° (Equator)
Longitude of Origin of Projection	3° W
False Easting (m)	500,000
False Northing (m)	0
Scale Factor	0.9996 at Central Meridian

TABLE 7: GEODETIC PARAMETERS FOR CHARTING AND MAPPING

2.5.2. POSITIONING

The SV Otarie was mobilised with a temporary suite of survey equipment including:

- 2 x positioning systems: a Seapath 330+ was used as the primary source of positioning and a C-Nav 3050 was used as the secondary horizontal control. This ensured redundancy and a back-up system in case of differential corrections lost in the primary positioning system.
- 1 x heading system: the Seapath 300+ was used as primary source for the heading and a CSI Hemisphere GPS Vector Sensor was used as a secondary source.

All positioning systems, heading sensors and the MRU were interfaced using QPS QINSy which determines the best source for positioning and heading in real time, monitors the quality of the signal received from the sensors and warns the user/navigator in the case of poor data quality or data-flow interruptions. The QINSy software package supplied the survey acquisition systems and software with a navigation stream (heading and position).

QINSy supplied the MBES with accurate positioning relative to the vessel’s CRP, and the SSS acquisition system with the position of the towfish tow point during the survey.

With this set-up, the SSS system directly received the position of the tow point of the system without having to calculate the lever arm offsets when deriving a layback position. Cable out values were recorded in the geophysical logsheet and then input to the data during post-processing.

QINSy applied the offsets from the CRP to the centre of the transducers of the SSS towfish, smoothing out any navigation spikes using standard deviation coefficients as well as a 2D Kalman Filter and saving the absolute positions (WGS84 and UTM30N) into an ASCII file.

2.6. VERTICAL POSITIONING

2.6.1. VERTICAL DATUM

The Scope of Work required that “All soundings shall be reduced to Chart Datum which is defined as being 4.9m below Ordnance Datum Newlyn at Heysham”.

The table below details the parameters used in deriving Admiralty Chart Datum.

Separation Values	
Ellipsoid / ODN	52.28m
ODN / Chart Datum	4.9m
The position used to derive the separation value at Heysham was 54° 02’ N, 002° 55’ W. The Ellipsoid separation value has been derived using the Ordnance Survey’s Geoid separation model (OSGM02), for the given position	

TABLE 8: PARAMETERS USED IN DERIVING ADMIRALTY CHART DATUM

2.6.2. TIDAL ELEVATION

The C&C Technologies C-Nav 3050 DGPS was used for primary vertical control with the Seapath 330+ used for redundancy purposes. Throughout survey operations both systems were set to constantly record raw GPS data at one-second intervals. The vertical distance between the antennas and the vessel CRP was measured onsite and input to the positioning system. The water level relative to the CRP was measured during survey operations, but all MBES vertical levels were recorded directly with reference to the CRP.

During final processing, the raw C-Nav 3050 GPS data were post-processed in Leica Geo Office (using GPS reference station data from the nearest Ordnance Survey Active station), to provide vertical positions relative to the ETRS89 ellipsoid (WGS84).

Using the antenna/CRP offset and the separation values, detailed in the table above, heights were reduced to Admiralty Chart Datum.

3. DATA PROCESSING AND PRESENTATION

3.1. BATHYMETRIC SURVEY

The SV Otarie was mobilised with a temporary suite of survey equipment including a fully-integrated, over-the-side pole-mounted Kongsberg EM3002D (Dual-Head) MBES system, operated by Kongsberg SIS 3.8.4 acquisition software. The EM3002D is a high-resolution system working nominally at 300 kHz and capable of a ping rate of 40 pings per second, providing 508 soundings per ping in high density mode. The high-density mode was utilised for this survey.

In shallow water (i.e. less than 50m), such as encountered during this survey, the theoretically-calculated mean uncertainty of the EM3002D MBES is 0.05m RMS relative to the transducer. This value may vary depending on the quality of the external instruments (i.e. MRU, heading sensor and SVP). For more information regarding data quality please refer to Appendix D – Calibration-Verification Report.

3.1.1. ONSITE DATA PROCESSING AND REDUCTION

The preliminary bathymetric dataset was processed on site using Caris HIPS and SIPS bathymetric processing software. The data were imported to the software and tidally reduced to Admiralty Chart Datum, using preliminary post-processed raw GPS data.

Following tidal reduction a 1m gridded swath angle base surface was then created for data QC and coverage assessment.

Figure 5 below illustrates the Caris HIPs and SIPs workflow used as a guideline for MBES data-processing during on-site processing and QC.

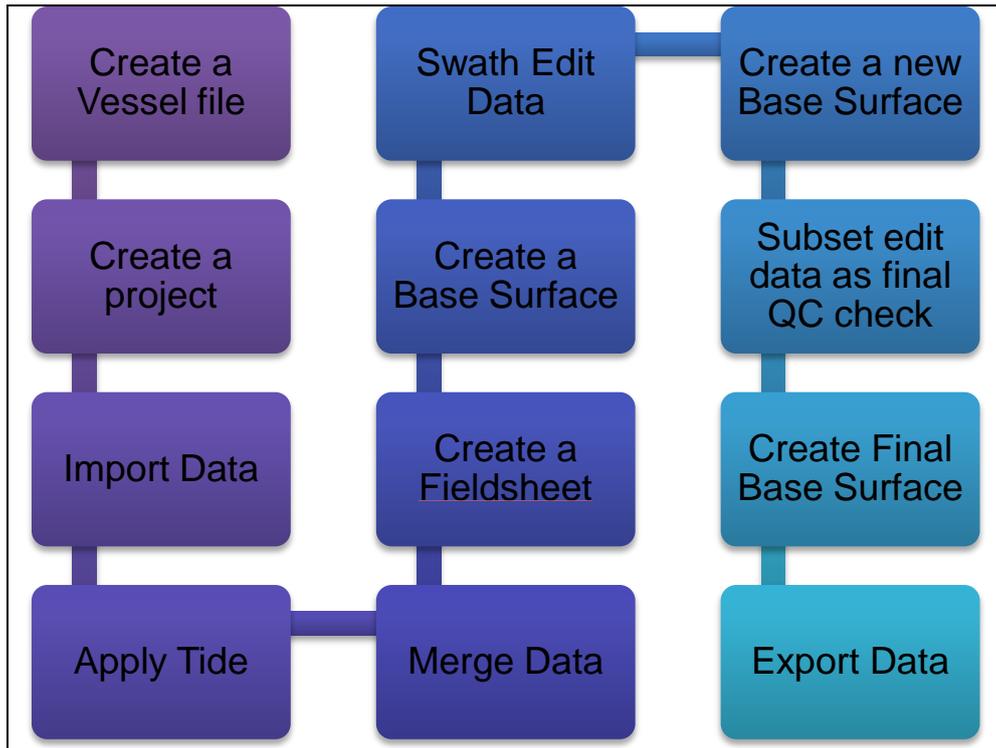


FIGURE 5: CARIS HIPS AND SIPS PROCESSING WORKFLOW

3.1.2. DATA PROCESSING AND REDUCTION

The multibeam bathymetry data were processed in stages, firstly around each individual turbine and substation and secondly by assessing any features appearing in the wind farm site or along the cable routes. The main focus on each of the turbines was to identify evidence of scouring.

The preliminary bathymetric dataset was processed on site using Caris HIPS and SIPS bathymetric processing software. The raw data were imported and a predicted tide file was used for preliminary onsite tidal reduction. Following tidal reduction, a swath angle derived base surface at 1m cell size was created in order to assess data coverage and quality at the base of the turbine stations. This preliminary processing was used to assess any need for additional infill lines.

Final bathymetric data processing was carried out following the completion of survey operations. The GPS data logged by the C-Nav 3050 system were post-processed in Leica Geo-Office software and reduced to Admiralty Chart datum. The post-processed GPS data were input to Caris HIPS and SIPS to tidally reduce the final dataset to Admiralty Chart Datum. Subsequently, the MBES data were de-spiked and vertical soundings identified as part of the turbine bases were removed to highlight any scouring at the base of the turbines.

The final bathymetric datasets have been produced at a horizontal resolution of 0.2m for the area surrounding each of the turbines and the substation and 1m for the array and export cables. The vertical resolution for all datasets is 0.01m.

It should be noted that the degree of uncertainty to which seabed levels can be derived is dependent upon various factors and therefore the accuracy achieved will be less than the resolution. These factors include:

- Depth of water
- Sea state at time of survey
- Uniformity of velocity of sound in water (affected by gradients in density (temperature and salinity))
- Uncertainty of seabed bottom detection
- Uncertainty of tidal measurements
- Suitability of tidal data to survey area

The requirements for this survey are that bathymetric values are to be within the IHO Order 1a. The Order 1a uncertainties were calculated using the formula below. The formula is used to compute the TVU (Total Vertical Uncertainty), a component of TPU, at a 95% (2σ) confidence level, which is the maximum allowed for TVU:

$$TVU = \pm \sqrt{a^2 + (b \times d)^2}$$

- a** Represents the portion of the uncertainty that does not vary with depth (m)
- b** Is a coefficient which represents the portion of the uncertainty that varies with depth (m)
- d** Is the depth (m)
- b x d** Represents the portion of the uncertainty that varies with depth (m)

The following examples have been calculated using values derived from the IHO standards for hydrographic surveys where a= 0.5m and b= 0.013, the TVU is stated at 2σ:

- 1m water depth: ± 0.50m
- 20m water depth: ± 0.56m

3.1.3. ERROR MODEL

An error model which takes into account all the previously mentioned factors has been created for the SV Otarie, in order to quantify the theoretical error budget associated with the bathymetric data collected during the survey. The Error budget model includes all the ancillary systems' inaccuracies and environment induced errors for vertical, horizontal and target detection capability.

The following table (

Coverage summary			
Sounding speed	4	<i>knots</i>	
Swath overlap	100%		
Ping rate	11.3	<i>Hz</i>	
Maximum swath width	116	<i>m</i>	
Number of beams having 100% coverage	508	<i>of</i>	508
Limiting seafloor coverage	178%		

TABLE 9) SHOWS A SUMMARY OF THE ENVIRONMENTAL SETTINGS INPUT TO THE MODEL AND A SUMMARY OF THE RESULTS CALCULATED FROM THE MODEL (

Coverage summary			
Sounding speed	4	<i>knots</i>	
Swath overlap	100%		
Ping rate	11.3	<i>Hz</i>	
Maximum swath width	116	<i>m</i>	
Number of beams having 100% coverage	508	<i>of</i>	508
Limiting seafloor coverage	178%		

Table 9); the model also indicates whether or not the bathymetric data (with the set-up used during the Ormonde OWF survey) is capable of meeting the IHO Order 1a in terms of horizontal and vertical target detection.

Environment			
Water depth	30	<i>m</i>	
Sea state	1	<i>m</i>	
Vessel roll	0	<i>deg</i>	
Vessel pitch	0	<i>deg</i>	
Seafloor slope	0	<i>deg</i>	
Sound speed	1500	<i>m/s</i>	
Maximum sound speed uncertainty	2	<i>m/s</i>	
Depth error summary			
Maximum sounder error	0.13	<i>m</i>	
Maximum refraction error	0.08	<i>m</i>	
Maximum roll error	0.11	<i>m</i>	
Heave error	0.14	<i>m</i>	
Draft error	0.09	<i>m</i>	
Tide error	0.04	<i>m</i>	
Maximum depth error	0.23	<i>m</i>	
Number of beams meeting Special Order	508	<i>of</i>	508
Number of beams meeting Order 1	508	<i>of</i>	508
Positioning error summary			

Maximum positioning system error	0.5	<i>m</i>	
Maximum depth measurement error	0.7	<i>m</i>	
Maximum refraction error	0.1	<i>m</i>	
Maximum roll error	0.1	<i>m</i>	
Maximum pitch error	0.0	<i>m</i>	
Maximum heading error	0.2	<i>m</i>	
Maximum positioning error	0.9	<i>m</i>	
Number of beams meeting Special Order	508	<i>of</i>	508
Number of beams meeting Order 1	508	<i>of</i>	508
Target detection summary			
Absorption coefficient	79.6	<i>dB/km</i>	
Number of detected beams	508	<i>of</i>	508
Minimum detectable target	0.5	<i>m</i>	
Number of beams meeting Special Order	484	<i>of</i>	508
Number of beams meeting Order 1	508	<i>of</i>	508

Coverage summary			
Sounding speed	4	<i>knots</i>	
Swath overlap	100%		
Ping rate	11.3	<i>Hz</i>	
Maximum swath width	116	<i>m</i>	
Number of beams having 100% coverage	508	<i>of</i>	508
Limiting seafloor coverage	178%		

TABLE 9: ERROR BUDGET MODEL RESULTS

IHO summary	Special Order	Order 1a
Accuracy	508 of 508 beams pass	508 of 508 beams pass
Target detect	484 of 508 beams pass	508 of 508 beams pass
Coverage	178% Passes	

TABLE 10: SUMMARY OF MBES ERROR BUDGET MODEL RESULTS

The output from the error budget model shows that theoretically, as expected, the system is capable of meeting not-only IHO Order 1a, but also the more rigorous IHO Special Order requirements with the exception of target detection in the outer beams.

3.2. SIDE-SCAN SONAR SURVEY

SSS data were acquired using a dual-frequency (445 KHz and 125 KHz operating) Klein 3000 system towed via a soft-tow cable. Klein software SonarPro v12.1 was used onboard to acquire the SSS data in XTF-format with files automatically split at 45 minute intervals to

make them more manageable for data processing. Both operational frequencies of the Klein 3000 were recorded simultaneously and were available for display during acquisition and for use during processing.

Sonar data were acquired with a range setting of 75m, using a low-frequency pulse length of 25 μ s and high-frequency pulse length of 50 μ s. SSS cable-out figures ranged from 10 - 80m during survey operations. In the shallowest section of the site, i.e. approaching the landfall, the SSS was mounted from the bow of the vessel. In this case a fixed offset from the CRP to the SSS was applied within QINSy and exported to SonarPro so that no cable-out figure was required to position the SSS towfish.

A positioning string offset to the SSS towpoint was sent from QPS QINSy to SonarPro to ensure that the XTFs were recorded using GPS time and to remove any potential timing offsets.

3.2.1. DATA PROCESSING

SSS data were processed using IXSEA Delph Sonar processing software. ASCII format navigation data logged in QPS QINSy was smoothed in Delph using a combination of linear interpolation, moving average and Kalman filters. Once the smoothed navigation had been applied to the XTF data, generation of mosaics, target picking and production of seabed features was performed in Delph using the following processing procedures:

- The altitude of the towfish was corrected and seabed bottom tracked, in order to apply the slant range correction. In addition speed correction, Time-Variied Gain and Beam Angle Compensation were applied to enhance signal quality and to harmonise backscatter intensity throughout the SSS swath.
- Backscatter patterns and all the relevant seabed features observed in the data set were mapped and displayed up using mosaics generated by the RoadMap module within Delph.
- Sonar contacts (debris etc) were identified and marked up on a line-by-line basis; length, width and height of targets were measured using the automatic slant-range correction formula applied within Delph.
- Linear features such as interpreted cable exposures or remnant cable trenches are also marked up on a line-by-line basis and subsequently checked against the bathymetric dataset in order to improve positioning.
- The details of all marked targets were manually entered into a C-View Tools generated database (*.mdb). This software also allowed the targets to be plotted on the SBF charts.

- The interpreted contacts and features were exported from Delph into AutoCAD. A list of all the relevant targets identified has also been produced and are found in Appendix E: Sonar Contacts Listing.

A threshold for picking potentially significant targets was set at 0.5m (length) by 0.5m (width) by 0.5m (height). All identifiable targets (excluding boulders) on the sonar record above this threshold have been included in target lists. A contact has been interpreted as debris (and therefore included on the charts and within the database), i.e. a potentially man-made object, if it had a distinctively regular or linear shape.

3.3. MAGNETOMETER SURVEY

Total magnetic field data were collected using a Geometrics G882 caesium-vapour magnetometer, soft-towed via a 10.1m 'piggy-back' interface cable from the SSS towfish, itself being soft towed. In shallow water near the landfall the magnetometer was separately soft-towed using a Kevlar cable suspended from a pellet buoy at a distance of between 10m and 60m. Due to the shallow water encountered vessel manoeuvrability was prioritised over maintaining a long magnetometer tow cable lengths in these areas and this resulted in shorter than desired cable lengths being employed. Quality control checks showed that no magnetic influence from the vessel was identified within the magnetometer dataset.

Magnetic data were acquired using two software packages; QPS QINSy and Geometrics MagLog Lite acquisition software. The reason for having two MAG acquisition software packages was for quality control and backup purposes. MagLog Lite applies layback dynamically (to account for any cable out changes and catenary effect) however, as with any equipment towed from the stern positional errors are increased by uncertainties in the layback distance and in the degree to which the towed fish fails to follow the vessel's track. This potential error will increase with increased layback. See Figure 6 below for the MAG acquisition workflow.

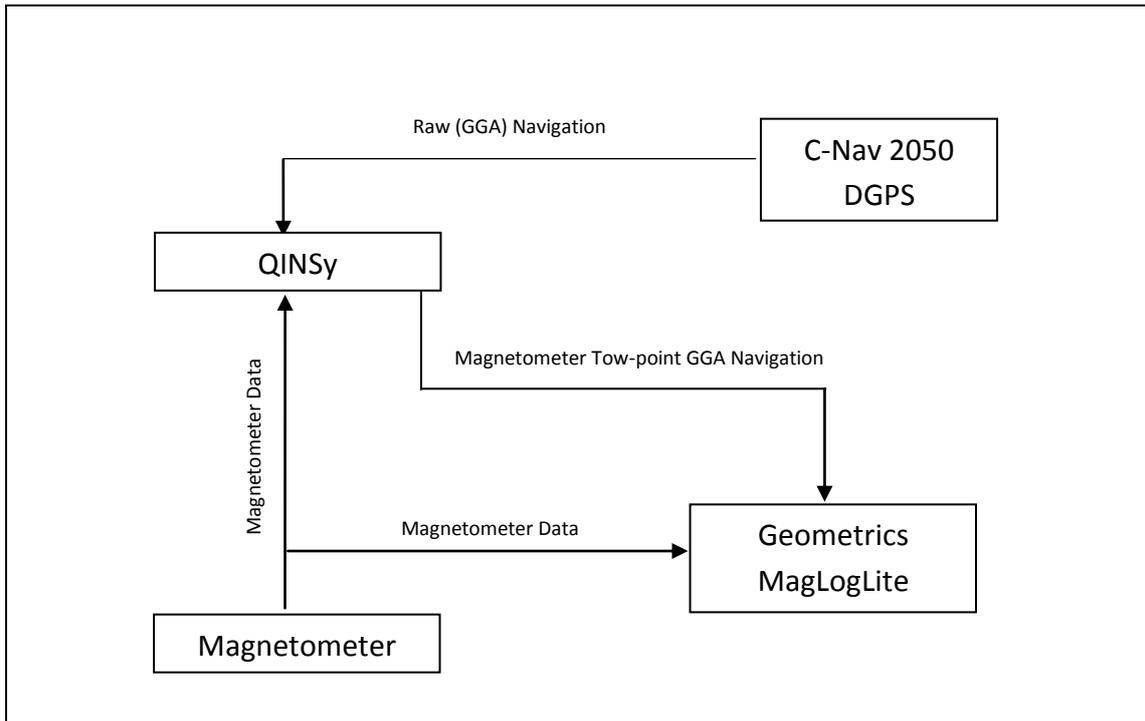


FIGURE 6: MAGNETOMETER ACQUISITION FLOW CHART

The magnetometers used during the survey were fitted with depth sensors and altimeters. In order to obtain accurate depth/altitude readings the sensors required calibration. To carry out the calibration, towfish were lowered into the water and sensor readings were compared to known depths and altitudes. From comparison, bias and linearity adjustments could be derived to empirically calibrate the sensors readings to convert these into depth and altitude values.

A similar process was carried out for altimeter calibrations, but altimeter values were averaged above the seabed with altimeter scaling and bias values derived from results. A lead line was used to determine known altitudes of the MAG.

3.3.1. DATA PROCESSING

In order to increase efficiency MAG data processing was divided into 2 stages; separating out and smoothing of navigation data (Figure 7) and then recombining back the navigation into the original MAG dataset (Figure 8) for gridding and target picking.

For navigation smoothing ASCII data files recorded in QPS QINSy were first imported into Oasis Montaj software and navigation data were separated from their corresponding MAG readings. The navigation data were then smoothed before being re-inserted back into the MAG data files ready for further processing.

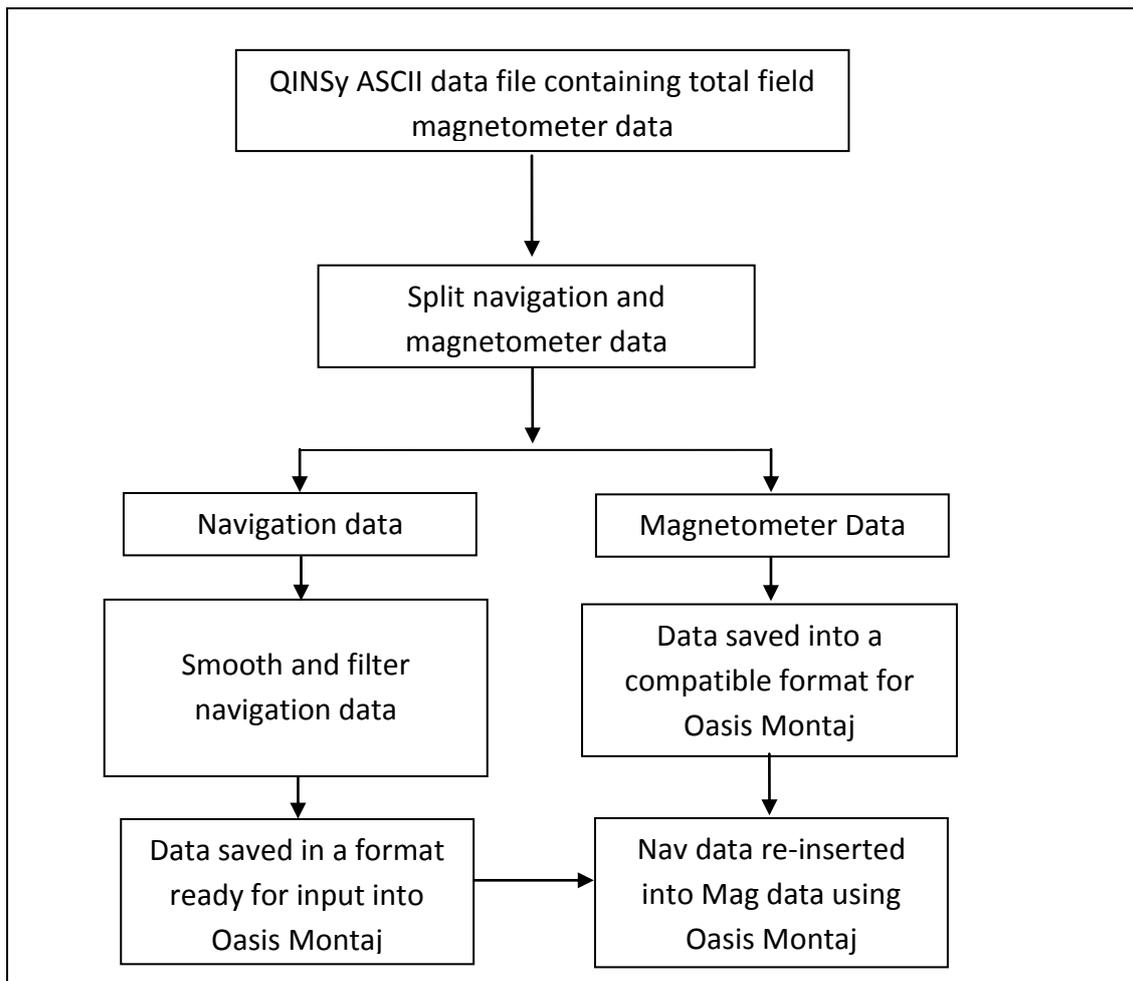


FIGURE 7: STAGE 1 MAG DATA PROCESSING FLOW CHART

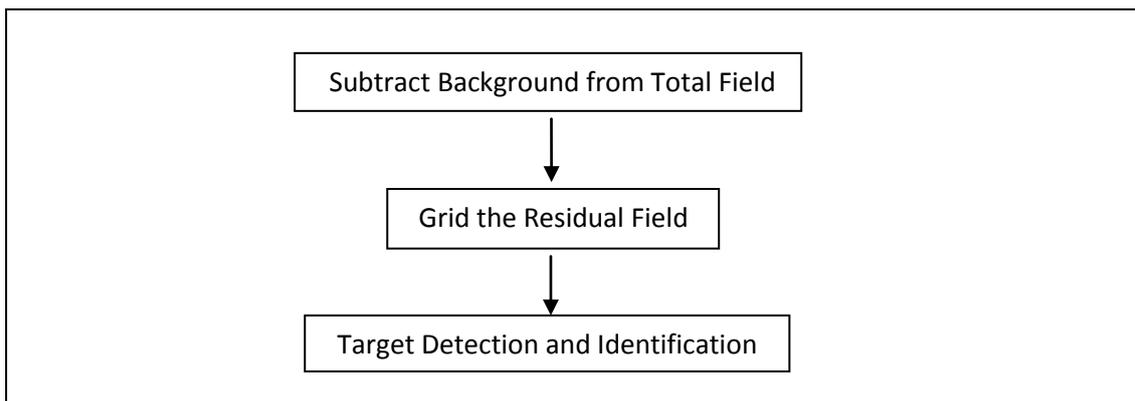


FIGURE 8: STAGE 2 MAG DATA PROCESSING FLOW CHART

The residual grid was created by subtracting the background field of each line from the total field. This enables any geological influence and noise to be ‘filtered’ out of the dataset enabling ‘true’ anomalies to be more clearly defined and therefore easier to interpret and more accurately position. The background field was defined by removing spikes, anomalies

and noise from the total field and then using a rolling statistical smoothing filter to interpolate the gaps. It is essential to remove the 'genuine' anomalies from the total field before smoothing as this will preserve their shape and avoid their signatures being distorted. After smoothing the 'genuine' anomalies are reintegrated back into the data. Cross-referencing with MBES and SSS data can show some magnetic anomalies to be attributable to seabed features and aid in magnetic contact picking.

3.4. DATA PRESENTATION

Accompanying this report three series of charts have been produced to display the acquired hydrographic and geophysical data within the Ormonde OWF and along the export cable route.

The first set of charts consists of 30 panel charts (1 for each WTG). The charts each comprise of 4 panels illustrating:

- Top left: Bathymetry data gridded at 0.2m cell size
- Top right: Bathymetric difference plot, gridded at 0.2m cell size
- Bottom left: SSS Mosaic
- Top right: SSS target display screenshots, showing the turbine base from four different aspects

Charts centred over the WTG locations were produced at a scale of 1:1000.

The second series of charts consists of 10 alignment charts; five displaying the bathymetry and seabed features and five bathymetric difference plots along the export cable route, both at a scale of 1:2500. The difference plots have been created using data from the EGS 2013 survey and a previous survey conducted in 2008.

The third set is a single bathymetric and seabed features overview chart of the OWF including the Array Cables. The scale of this chart is 1:5000 and it is orientated for maximum coverage over the OWF.

4. DATA INTERPRETATION RESULTS

Results from the survey are presented in this section. Reference is made to supporting information presented in the appendices and in the drawings. All water depths are referenced to CD.

Full data coverage was achieved except for crosslines located between KP4 and KP14 of the export cable route; at the instruction of the client onsite these survey lines were not run.

In general, all of the recorded data were considered to be of good quality throughout the survey, exceeding the survey specification in many areas such as data coverage and overlap. The seabed mapping systems used (MBES and SSS) made it possible to interpret and quantify areas of sediment scour or deposition as well as interpret any potential debris. The magnetometer was able to identify the export cable during crosslines, although as expected any survey lines run parallel to the cable suffered from a distorted total magnetic field. Within the OWF the magnetometer was saturated by the presence of so much ferrous material and so it was impossible to accurately and precisely map the alignment of the cables using the magnetometer.

4.1. BATHYMETRY

The required line spacing was used during data acquisition to provide in excess of 120% coverage of the WTGs, substation, export cable route and inter array cables. The depth of the seabed within the OWF varies from approximately 16.7m (below CD) in the east and 23.6m (below CD) in the west. The seabed bathymetry surveyed over the export cable route decreases in depth towards the landfall in the east to a minimum of approximately -3.8m (below CD). A bathymetric overview of the OWF is presented in Figure 9.

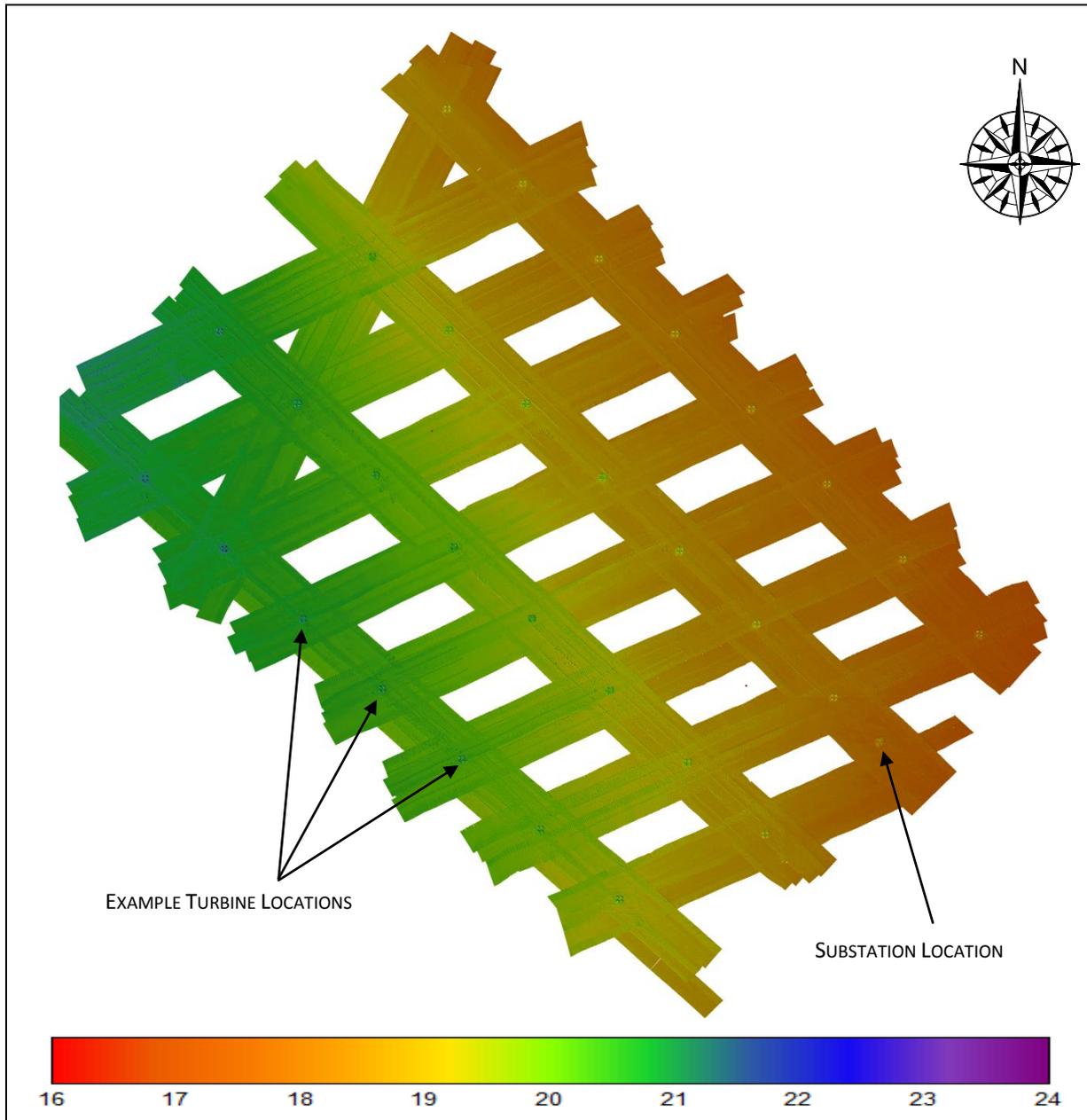


FIGURE 9: BATHYMETRIC OVERVIEW OF THE ORMONDE OWF (M BELOW CD)

4.1.1. SEABED SCOUR

As part of the requirement to identify areas of sediment scour, particularly around turbine bases, the EGS 2013 bathymetric dataset has been compared against another bathymetric dataset, surveyed in 2008. Whilst five years is a considerable amount of time, especially in such a dynamic environment as Morecambe Bay it has still been possible to make an accurate comparison, with the exception of between approximately KP16.5 and KP25.7 where the 2008 survey data does not appear to follow the current client supplied RPL

(EOS1174). Since the data here does not overlap then a seabed level comparison has not been possible in this area.

Where bathymetric data overlap exists minor sediment scour and deposition has occurred with less than +/- 1m of seabed level change along the cable route except landward of approximately KP3.5, where a maximum of 4.8m (northwest of KP1.5) of sediment erosion has occurred, this coincides with one of drainage channels of Morecambe Bay, and as such is extremely dynamic. These drainage channels can migrate over many years and will continually alter their course, illustrated by the fact that the site of greatest sediment deposition is located nearby at approximately KP1.3 where almost 2.5m of sediment has accumulated.

4.2. SEABED FEATURES

All seabed features have been appropriately marked up on the charts, whilst sonar and magnetic contact information have also been included in Appendices E and F respectively.

4.2.1. TURBINE BASE SCOUR

Within the OWF site itself, i.e. not including the export cable route, little sediment erosion or deposition has occurred, particularly concerning the array cable routes. In general there has been less than +/- 0.3m of seabed level change since the previous survey five years earlier.

No evidence of significant scour around the base of any of the 30 turbines or the substation can be found within the bathymetric or SSS datasets and there is also no evidence of any cable exposures entering/exiting the turbine bases.

4.2.2. INSTALLATION FEATURES

Two small sections of cable have been interpreted to be exposed at the seabed:

- 5.8m of Array Cable between turbines OR_C4 (471665E, 5993705N) and OR_C5 (471661E, 5993710N).
- 77m of Export Cable between KP1.507 (504750E, 5988086N) and KP1.580 (504678E, 5988059N). As presented below in Figure 10.

The short exposure between the turbines exists due to a small area of scour along the cable route, whereas the export cable exposure appears to be at the level of the surrounding seabed, potentially indicating an 'area wide' patch of erosion. This interpreted exposure is located next to the area of the export cable route that experiences the most dynamic sedimentary environment within the entire site.

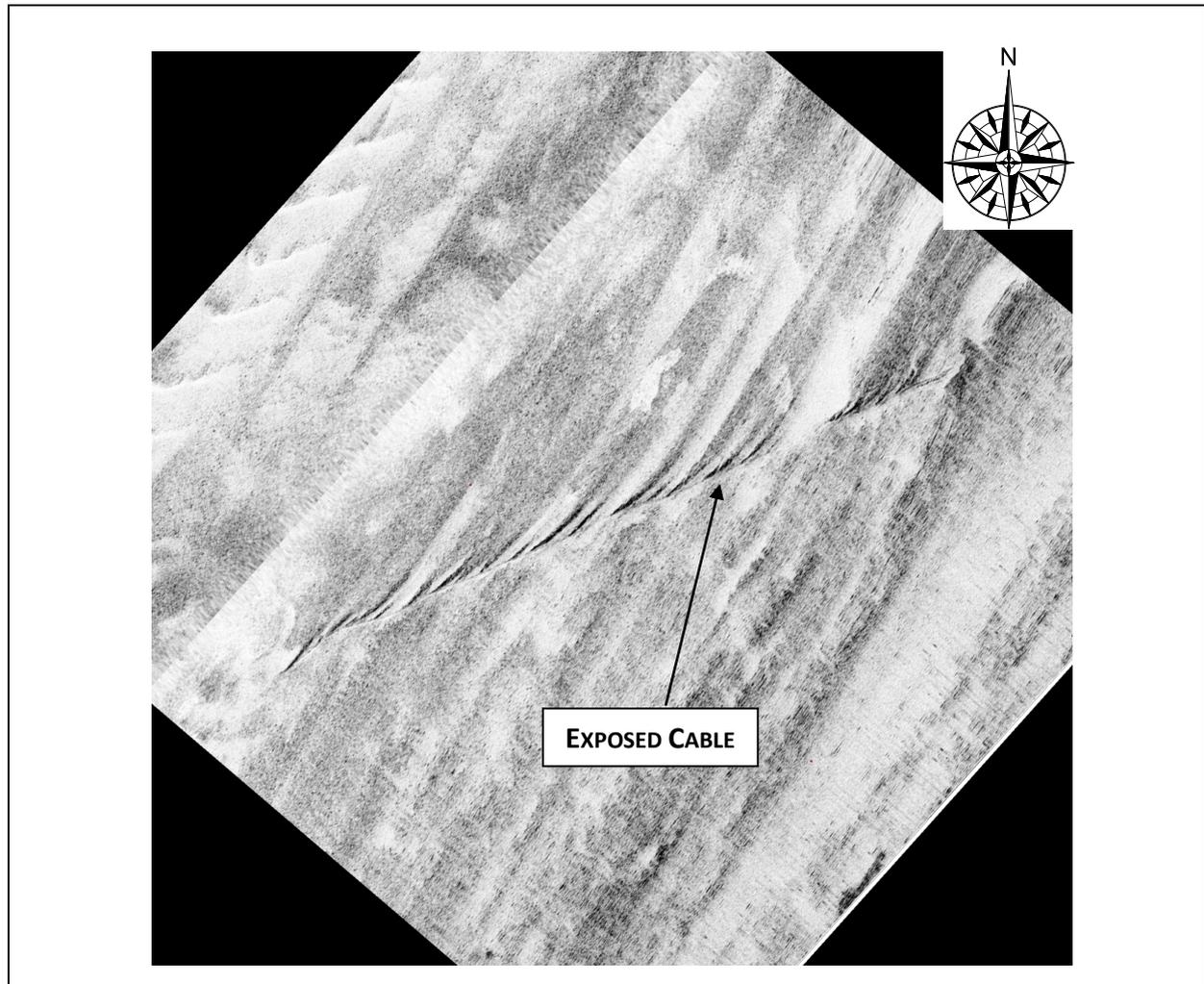


FIGURE 10: PROCESSED NORTH-UP SSS IMAGE OF INTERPRETED EXPOSED CABLE (EXPOSURE = 77M)

Several sections of remnant array cable trench have been interpreted within the OWF area using a combination of bathymetric and SSS data. They follow a logical route internally between the turbines and also to the substation thereby adding confidence to the interpretation.

Along the export cable route several sections of cable protection have been identified from the bathymetric and SSS datasets. These are often significantly offset from the supplied RPL as can be seen in the following figure (Figure 11). A tighter crossline spacing, potentially also including shallow seismic equipment, could yield a more accurate cable route alignment.

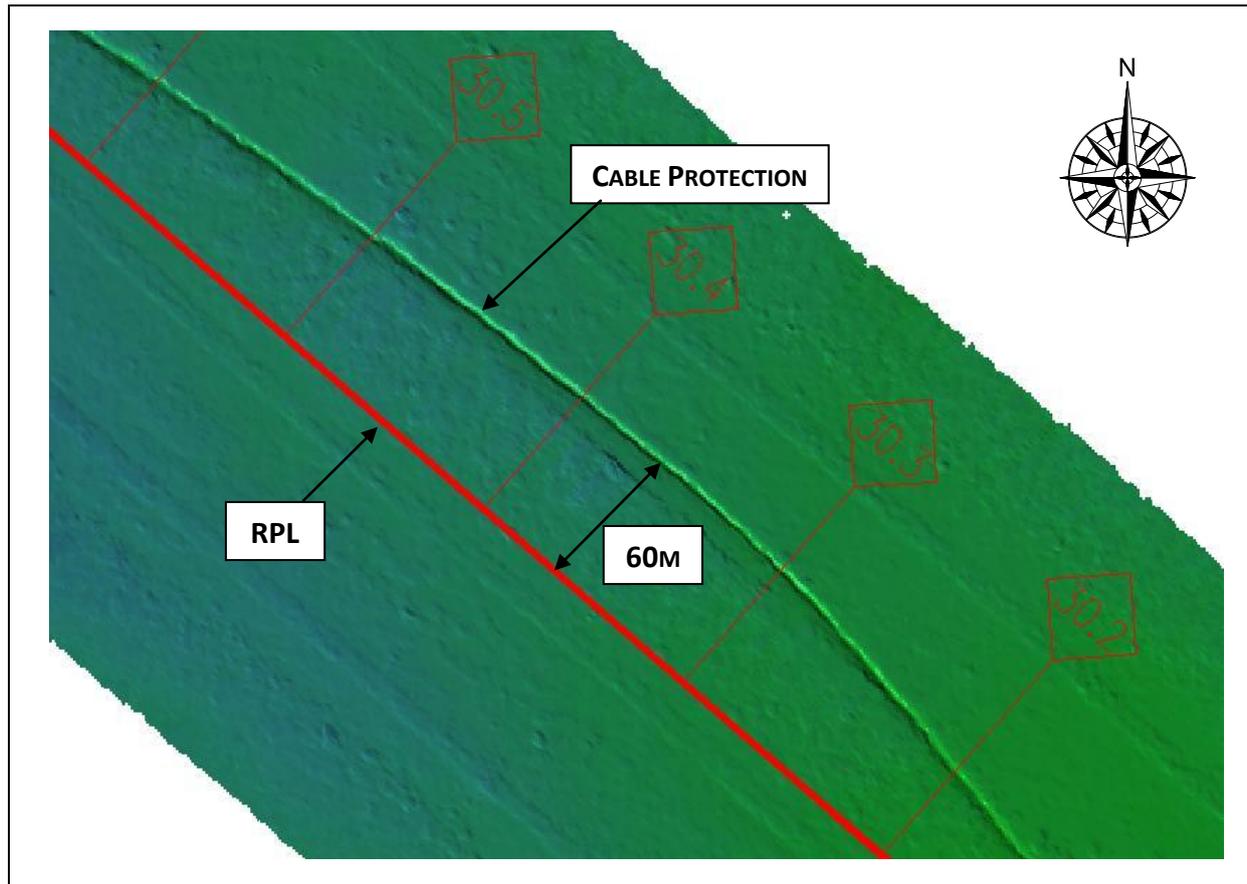


FIGURE 11: BATHYMETRIC IMAGE SHOWING THE OFFSET BETWEEN CABLE PROTECTION AND THE SUPPLIED CABLE RPL

The bathymetric survey has also identified areas where seabed depressions caused by jack-up rig footprints are still present within the OWF area. These are most prevalent along the A and B arrays as well as the northwestern end of the C array, they are absent from the D array.

4.2.3. SONAR CONTACTS

SSS data were processed on a line-by-line basis to identify any evidence of scouring around the turbine foundations and along the inter-array and export cables and to identify any seabed features and targets of interest such as cable exposure and debris. The sonar contacts list includes information such as a contact identifier, position of the contact, contact dimensions (length, width and height), KP and RPL offset and an interpretation of the contact. A contact has been identified as debris (and therefore included on the charts and within the database), i.e. a potentially man-made object, if it had a distinctively regular or linear shape or shadow. A total of 45 sonar contacts were identified within the survey area of which 43 were interpreted as either debris or linear debris, the remaining two have been interpreted as wrecks. Full details regarding sonar contact information can be found in Appendix E – Sonar Contacts Listings.

4.2.4. MAGNETIC CONTACTS

Excluding the Ormonde export cable 13 anomalies were interpreted from the magnetic dataset, this includes three that are associated with gas pipelines connecting the North and South Morecambe gas fields to the Isle of Walney, the remaining 10 are interpreted to be caused by debris. The magnetic contacts list includes information such as a contact identifier, position of the contact, anomaly amplitude, KP and RPL offset, magnetic signature description and an interpretation of the causative body. Full details regarding magnetic contact information can be found in Appendix F – Magnetic Contacts Listings.

5. CONCLUSIONS

EGS (International) Ltd was contracted to undertake a geophysical and hydrographic survey with the primary aim of determining whether there have been any changes to the seabed morphology at the wind farm site including along the inter array cables and export cable route, of particular interest was the identification of any seabed scouring around WTGs and cable exposures.

Vessel mobilisation and survey operations were conducted in a safe and timely manner with no HSE incidents. No equipment downtime was experienced and the only time lost to weather was 85 minutes on the final day of survey. At the clients' instruction onsite the survey vessel was demobilised with only several crosslines outstanding, this resulted in 341km (99.1%) of the planned 344km of survey lines being complete.

Survey results are presented primarily as three sets of charts that accompany this report. The first set of charts consists of 30 panel charts (1 for each WTG) comprising of 4 panels illustrating bathymetric and SSS datasets surrounding the turbine locations. The second series of charts consists of 10 alignment charts; five displaying the bathymetry and seabed features and five bathymetric difference plots along the export cable route; the difference plots have been created using data from the EGS 2013 survey and a previous survey conducted in 2008. The third set is a single bathymetric and seabed features overview chart of the OWF including the Array Cables.

The bathymetric survey difference plot indicates that in general the site seems to be experiencing limited sediment erosion/deposition with the exception of landward of approximately KP3.5. Here the entire site experiences both the largest amounts of erosion and deposition, changing by up to 4.8m and 2.5m respectively. No evidence of scour has been identified surrounding either the 30 turbine bases or the substation. It should however be noted that with the two different surveys of the difference plot being conducted five years apart caution should be employed when interpreting whether the site is experiencing net sediment erosion, deposition or is not experiencing either. More regular survey could be undertaken in order to build up a trend analysis in which a higher degree of confidence can be placed.

The export and array cables appear buried throughout the site with only two exposures interpreted; a 5.8m exposure within a limited depression in the OWF site and a 77m exposure of the export cable located at approximately KP1.5.

When plotted against the survey data the client supplied RPL (EOS1174) shows divergence away from features that have been interpreted as cable protection, in some cases up to

60m of separation exists. A tighter crossline spacing, potentially also including shallow seismic equipment, could yield a more accurate cable route alignment.

A total of 45 sonar contacts have been identified within the survey area. Of the contacts, 43 have been interpreted as being debris or linear debris (potentially man-made with a distinctive linear or regular shape); whilst two have been categorised as wrecks. 13 magnetic anomalies, excluding the export and array cables, were identified from the survey with 10 interpreted as being ferrous debris and the remaining 3 being associated with gas pipelines connected to the North and South Morecambe gas fields.

Within the OWF site itself the magnetometer data clarity suffered by becoming saturated due to the sheer presence of so much ferrous material, i.e. from the WTGs. This made the task of trying to define alignments for the array cables impossible. If it is critical to know the cable alignments then a high-resolution shallow seismic system such as a pinger could be employed. This would also be applicable for the export cable, but of course there is far less magnetic interference on the route away from the OWF.