LLŶR FLOATING OFFSHORE WIND PROJECT

Llŷr 1 Floating Offshore Wind Farm

Environmental Statement

Volume 6: Appendix 17A – SEA Geophysical Survey Report

August 2024

Prepared by: Llŷr Floating Wind Ltd

Document Status

Version	Authored by	Reviewed by	Approved by	Date
FINAL	AECOM	AECOM	AECOM	August 2024

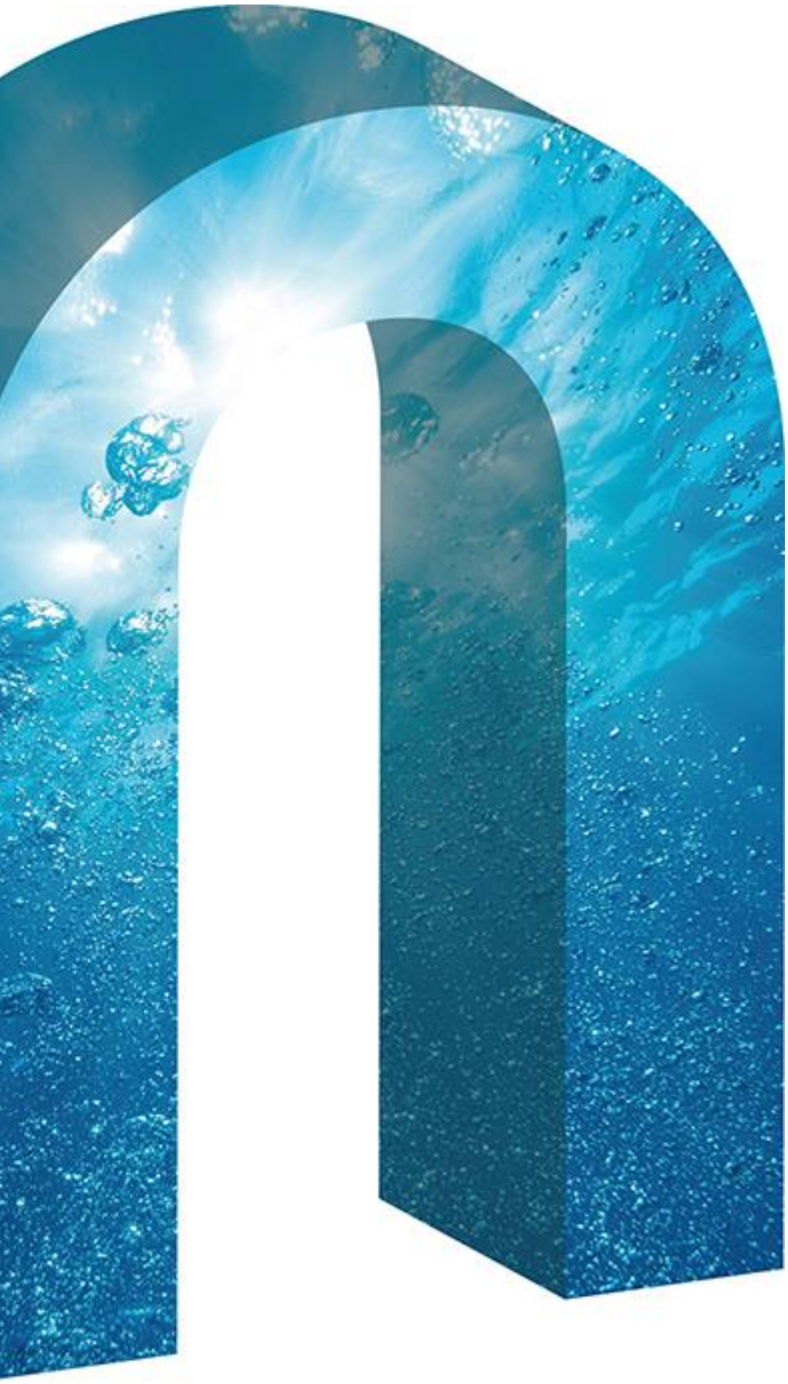
Approval for Issue

Prepared by	AECOM
Prepared for	Llŷr Floating Wind Limited
Approved by	Jay Hilton-Miller

This report has been prepared by AECOM on behalf of Llŷr Floating Wind Ltd. Llŷr Floating Wind Ltd has made reasonable efforts to ensure that the content is accurate, up to date and complete for the purpose of the Environmental Statement. Llŷr Floating Wind Ltd shall have no liability for any loss, damage, injury, claim, expense, cost or other consequence arising as a result of use or reliance upon any information contained in or omitted from this document.

Glossary of project terms

Term	Definition
The Applicant	The developer of the Project, Llŷr Floating Wind Limited.
Array	All wind turbine generators, inter array cables, mooring lines, floating sub-structures and supporting subsea infrastructure within the Array Area, as defined, when considered collectively, excluding the offshore export cable(s).
Array Area	The area within which the wind turbine generators, inter array cables, mooring lines, floating sub-structures and supporting subsea infrastructure will be located.
Floventis Energy	A joint venture company between Cierco Ltd and SBM Offshore Ltd of which Llŷr Floating Wind Limited is a wholly owned subsidiary.
Landfall	The location where the offshore export cable(s) from the Array Area, as defined, are brought onshore and connected to the onshore export cables (as defined) via the transition joint bays.
Llŷr 1	The proposed Project, for which the Applicant is applying for Section 36 and Marine Licence consents. Including all offshore and onshore infrastructure and activities, and all project phases.
Marine Licence	A licence required under the Marine and Coastal Access Act 2009 for marine works which is administered by Natural Resources Wales (NRW) Marine Licensing Team on behalf of the Welsh Ministers.
Offshore Development Area	The footprint of the offshore infrastructure and associated temporary works, comprised of the Array Area and the Offshore Export Cable Corridor, as defined, that forms the offshore boundary for the S36 Consent and Marine Licence application.
Offshore Export Cable	The cable(s) that transmit electricity produced by the WTGs to landfall.
Offshore Export Cable Corridor (OfECC)	The area within which the offshore export cable circuit(s) will be located, from the Array Area to the Landfall.
Onshore Development Area	The footprint of the onshore infrastructure and associated temporary works, comprised of the Onshore Export Cable Corridor and the Onshore Substation, as defined, and including new access routes and visibility splays, that forms the onshore boundary for the planning application.
Onshore Export Cable(s)	The cable(s) that transmit electricity from the landfall to the onshore substation.
Onshore Export Cable Corridor (OnECC)	The area within which the onshore export cable circuit(s) will be located.
proposed Project	All aspects of the Llŷr 1 development (i.e. the onshore and offshore components).
Onshore Substation	Located within the Onshore Development Area, converts high voltage generated electricity into low voltage electricity that can be used for the grid and domestic consumption.
Section 36 consent	Consent to construct and operate an offshore generating station, under Section 36 (S.36) of the Electricity Act 1989. This includes deemed planning permission for onshore works.



FLOVENTIS ENERGY LIMITED

LLŶR FLOATING OFFSHORE WINDFARM - MARINE SURVEY

GEOPHYSICAL RESULTS REPORT

DOC NO: NSW-PJ00301-RR-DC-SUR-001

WE LISTEN THEN DELIVER

Rev	Date	Originator	Reviewed	Approved	Client Approved
1.1	14-03-2023	D. Ollivier	S. Frederiks	M. Gerhards	E. Marciszewska
Signature	n/a				

This is an electronically generated document, which has been reviewed and approved in accordance with the N-Sea Management System.

The screen version of this document is the CONTROLLED COPY at all times. When printed, it is considered a FOR INFORMATION ONLY copy, and it is the holder's responsibility that they hold the latest valid version. Copying and/or disclosure of the confidential information contained herein is prohibited without written permission of N-Sea.

Revision Index		Abbreviation
1.x	Issued for Review	IFR
2.x	Approved / As Built	APR / ASB

REVISION HISTORY

Revision	Date	Chapters	Description of Changes
1.0	08-02-2023	All	First issue to Client – excluding nearshore vessel data
1.1	14-03-2023	All	Client's comments addressed; Nearshore results integrated

EXECUTIVE SUMMARY

WORK SCOPE

Objectives
The objective of the surveys is the acquisition of geophysical and benthic ecology data to underpin the Environmental Impact Assessments (EIA) and Habitat Regulations Assessments (HRA) which will support consent applications and to inform the concept design for the projects are: • Geophysical Survey consisting of: - Bathymetric survey; - Side scan survey with magnetometer piggybacked; - Sub bottom profiling (data recorded only, no processing required) • Environmental survey including investigation of occurring habitat types and benthos (benthos shall be investigated through bottom sampling)

OPERATION SUMMARY

Operations	Offshore Vessel – *Braveheart Spirit*		Nearshore Vessel – *Coastal Observer*	
	Start	End	Start	End
Mobilisation	17-09-2022	22-09-2022	05-12-2022	08-12-2022
Operations	23-09-2022	16-12-2022	08-08-2022	[hold]
Demobilisation	19-12-2022	19-12-2022	[hold]	[hold]

MAIN SURVEY EQUIPMENT SUMMARY

Item	Offshore Vessel – *Braveheart Spirit*	Nearshore Vessel - *Coastal Observer*
DGNSS (primary)	Starpack Omnistar (XP2 PPP)	Applanix PosMV Wavemaster 2
Gyro (primary)	iXBlue Hydrins	Applanix PosMV Wavemaster 2
Motion sensor (primary)	iXBlue Hydrins	Applanix PosMV Wavemaster 2
USBL	HiPAP 501	Sonardyne Mini Ranger 2
Sound velocity profiler	AML-3 LGR CTD	Valeport Swift SVP
MBES (Bathymetry)	Kongsberg EM2040-04 MK II	Norbit B41 Winghead MBES
MBES (Backscatter)	R2Sonic 2024	Norbit B41 Winghead MBES
SSS	Klein MA-X VIEW 600	EdgeTech 4125
SBP	EdgeTech 2050-DSS (also used for SSS low frequency)	Geo-pulse 5430A
Magnetometer	Geometrics G-882	Geometrics G-882

RESULTS SUMMARY

Bathymetry Summary

Area	Max depth (m LAT)	Min depth (m LAT)	Average depth (m LAT)
Nearshore - ECR	52.7	-3.1	36.3
Nearshore - extra	47.6	-2.9	25.1
ECR - North	53.2	27.0	45.4
ECR - Centre	62.2	36.5	55.9
ECR - South	69.0	52.0	64.0
OWF	72.8	65.5	68.9

Seabed Summary

The sediment classification within the survey area was performed based on the side scan sonar data and sediments reflectivity and appearance. Analysis was done in line with SSDM / IOGP standard classification.

Table 1-1: Seabed sediments classification and distribution

Class	Area in km^2	% of the surveyed area
Sediment		
Muddy SAND	114.8	42.3%
Sandy MUD	85.4	31.5%
SAND	37.2	13.7%
Gravelly Muddy SAND	10.0	3.7%
Outcrop	10.0	3.7%
Gravelly Sandy MUD	4.3	1.6%
MUD	4.0	1.5%
Gravelly SAND	3.3	1.2%
Subcrop	1.7	0.6%
GRAVEL	0.3	0.1%
Seabed Features		
Megaripples	247.0	91.1%
Rocky	10.0	3.7%
Hummocky	7.2	2.7%
Flat	4.8	1.8%
Sand Waves	3.6	1.3%
Subcrop	3.0	1.1%
Long Wavelength Sand Waves	0.2	0.1%
Ripples	<0.1	<0.1%

Side Scan Sonar Contact Summary

Contact Type	Nearshore Extension	Nearshore ECR	ECR	OWF	Total
Isolated Boulders	180	39	390	6360	6969
Debris	4	46	31	77	158
Wreck	0	3	1	1	5
Linear Debris	2	21	0	3	26
Trawl scars	0	0	6	3213	3219
Cables	0	0	0	0	0*
Total	186	109	428	9654	10377

Magnetic Anomalies Summary

Anomaly Classification	Nearshore	ECR	OWF	Total
Other/Geology	639	205	224	1068
Linear Feature	11	16	61	88
Wreck	4 (3 wrecks)	2 (1 wreck)	1	7
Total	654	223	286	1163

TABLE OF CONTENTS

TABLE OF TABLES

TABLE OF FIGURES

DEFINITIONS AND ABBREVIATIONS

Throughout this report the following terminology is used:

Floventis	Floventis Energy Limited	(Client)
N-Sea	N-Sea Offshore Wind B.V.	(Contractor)
OEL	Ocean Ecology Limited	(Environmental / MMO subcontractor)
Ultrabeam	Ultrabeam Limited	(Nearshore sub-contractor)

AGC	Automatic Gain Control
BS	Backscatter
BSP	Braveheart Spirit
CTD	Conductivity, Temperature, Density
DGNSS	Differential Global Navigation Satellite System
DTM	Digital Terrain Model
E	East / Easting
ECR	Export Cable Route
EGN	Empirical Gain Normalization
EIA	Environmental Impact Assessment
EPSG	European Petroleum Survey Group
FMGT	Fledermouse Geocoder Toolbox
GIS	Geographic Information System
HRA	Habitat Regulation Assessment
INNS	Invasive Non-Native Species
IOGP	International Association of Oil & Gas Producers
LAT	Lowest Astronomical Tide
MAG	Magnetic Data
MBES	Multibeam Echo Sounder
N	North / Northing
OWF	Offshore Wind Farm
PPP	Precise Point Positioning
QC	Quality Control
S	South
SBP	Sub bottom Profiler
SSDM	Seabed Survey Data Model
SSS	Side Scan Sonar
SVP	Sound Velocity Profile
UB	Ultrabeam
UK	United Kingdom
USBL	Ultra-Short Baseline
UTM	Universal Transverse Mercator
VORF	Vertical Offshore Reference Frame
W	West
WGS	World Geodetic System

Where abbreviations used in this document are neither part of the International System of Units nor included in this list, it may be assumed that they are either equipment brand names or company names.

1 INTRODUCTION

Floventis Energy is planning to develop two Offshore Windfarms (OWF), Llŷr 1 and Llŷr 2, in the southern part of the Celtic Sea. The OWF comprises of two separate 100 MW sites located south of Pembroke, on the UK's Welsh coast. The Llŷr projects are located in the approaches to the Bristol Channel in the Celtic Sea approximately 40 km offshore at water depths averaging 60 m to 70 m. The Export Cable Route (ECR) is located in water depths ranging between 10 m to 60 m and will run north towards Pembroke. Figure 1-1 shows an overview of the project site.

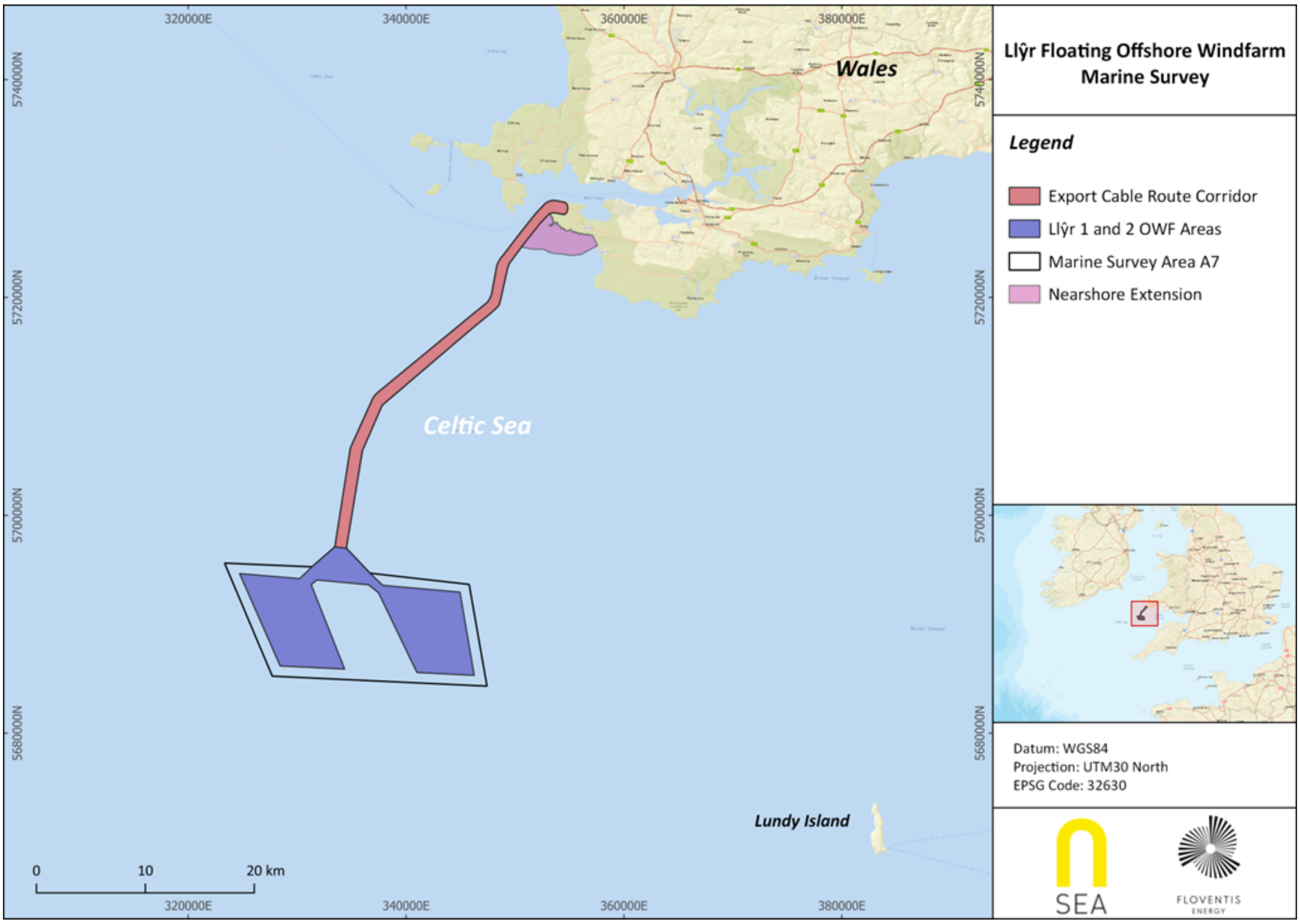


Figure 1-1: Project location

1.1 SCOPE OF DOCUMENT

This document presents the results from geophysical survey conducted between 17 September and 19 December 2022 on the *Braveheart Spirit*. Results from the nearshore campaign are to be delivered at a later stage.

A *Field Operations Report* and *Mobilisation and Calibrations Report* were issued separately [Ref. 2 and 4].

This results report focuses on the geophysical campaign. Details about the environmental survey are compiled in a separated report [Ref. 6].

1.2 REFERENCE DOCUMENT

1.2.1 N-Sea

Table 1-1: N-Sea reference documents

#	Document number / filename	Title
1.	NSW-PJ00301-PEP-001	Project Execution Plan – Survey
2.	NSW-PJ00301-MCR- BSP-SUR-001	Mobilisation and Calibration Report
3.	NSW-PJ00301-MDR-01	Master Document Register
4.	NSW-PJ00301-FOR-BSP-SUR-001	Field Operations Report
5.	NSW-PJ00301-RR-DC-SUR-001	Geophysical Results Report
6.	NSW-PJ00301-RR-DC-SUR-002	Environmental Results Report
7.	BMS-OP-0510-PR-001	MBES Processing
8.	BMS-OP-0510-PR-002	Magnetometer and Gradiometer processing
9.	BMS-OP-0510-PR-003	Side Scan Sonar processing
10.	BMS-OP-0510-PR-004	Sub-Bottom Profiler processing

1.2.2 Client

Table 1-2: Client reference documents

#	Document number / filename	Title
11.	Marine Survey - Final Revised ITT Scope August 2022	Scope of Work
12.	Marine Survey - Annex 1	Llyr survey technical specifications
13.	Marine Survey - Annex 3	GIS data specifications
14.	220307 Llyr Seabed Survey Area B2	Site Area

1.3 SCOPE OF WORK

The objective of the surveys is the acquisition of geophysical and benthic ecology data to underpin the Environmental Impact Assessments (EIA) and Habitat Regulations Assessments (HRA) which will support consent applications and to inform the concept design for the projects are:

- Geophysical survey consisting of:
  - Bathymetric survey;
  - Side scan survey with magnetometer piggybacked;
  - Sub bottom profiling (data recorded only, no processing required).
- Environmental survey including investigation of occurring habitat types and benthos (investigated through bottom sampling).

1.3.1 Survey Areas

For the offshore section, the two OWF locations, Llŷr 1 and Llŷr 2, are treated as one survey area (OWF) whilst the ECR is treated as the second survey area. The project survey area was partitioned into 12 acquisition survey blocks (7 in the OWF, 4 along the ECR, and 1 nearshore extension ECR-X) as shown on Figure 1-2. All areas were surveyed with 100% coverage for all datasets (MBES, SSS and MAG).

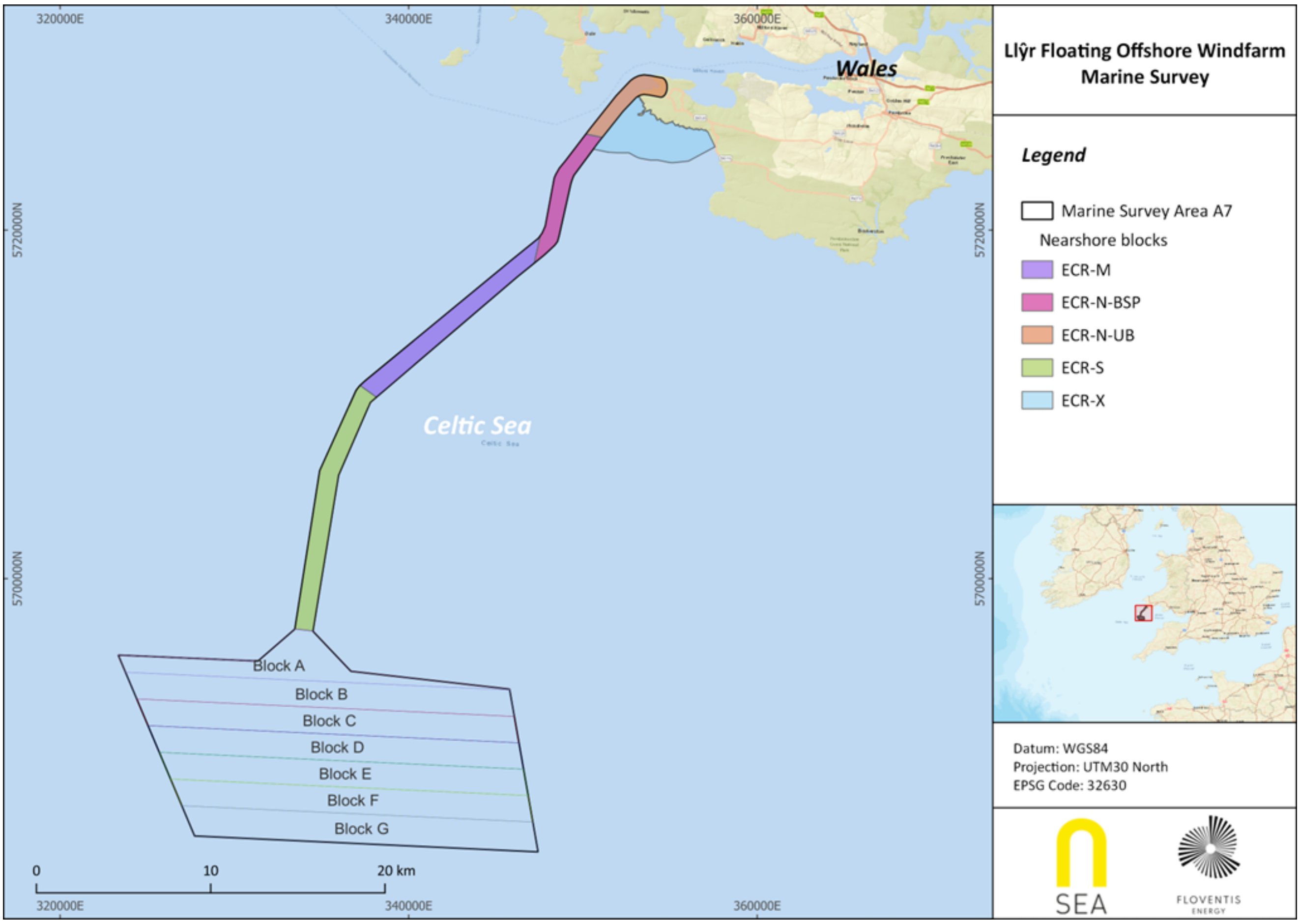


Figure 1-2: Survey block definition of the OWF and ECR areas

1.3.2 Geophysical Survey

The geophysical survey consisted of vessel mounted multibeam echo sounder (MBES), providing both bathymetric and backscatter data, towed side scan sonar (SSS) combined with sub-bottom profiler (SBP) and a single magnetometer (MAG), piggybacked to SSS. The same setup was used for the OWF array and ECR areas.

Table 1-3: Geophysical survey overview

Area	Blocks	Geophysical
OWF Array	Block A	MBES (bathymetry and backscatter) SSS (LF and HF) MAG (single magnetometer) SBP (acquisition only)
	Block B	
	Block C	
	Block D	
	Block E	
	Block F	
	Block G	
ECR	ECR-S (ECR South)	MBES (bathymetry and backscatter) SSS (LF and HF) MAG (single magnetometer) SBP (acquisition only)
	ECR-M (ECR Centre)	
	ECR-N-BSP (ECR North, surveyed by *Braveheart Spirit*)	
	ECR-N-UB (ECR North, surveyed by *Coastal Explorer*)	
	ECR-X (ECR Nearshore Extension)	

Each system was utilised to achieve a specific goal.

Side Scan Sonar

The SSS data were used to identify seabed features such as:

- Archaeological artefacts;
- Boulders and other natural objects;
- Debris and other non-natural objects;
- Classification of habitats;
- Seabed sediments.

Multibeam Echo Sounder

The MBES was used to record both bathymetry and backscatter data. These data were used to achieve following goals:

- Gather accurate bathymetric data;
- Aide the identification of seabed features in combination with SSS data (bathymetry and backscatter);
- Provide acoustic ground definition data to inform benthic assessment (backscatter).

Magnetometer

The MAG data were used to:

- Identify magnetic anomalies on the surface and below the seabed and correlate with SSS objects where possible;
- Identify buried infrastructure.

Sub-bottom Profiler

SBP data were collected at Client request, however no processing or interpretation was done as part of this scope of work.

1.3.3 Environmental Survey

Environmental survey was conducted to provide baseline information about the biological and physio-chemical nature of the seabed across the project area. The specific objectives were as follows:

- Describe the benthic communities present within the project's areas, including description of biotopes, covering biodiversity, function, abundance, extent, species richness, representativeness, rarity and sensitivity;
- Identify and assess the status of species and habitats;
- Confirm the presence/absence of any invasive non-native species (INNS), species non-native to UK waters and species non-native to the local habitat types.

The environmental survey consisted of 30 benthic samples spread out over the survey areas, as per Table 1-4, including image/video capture at each location. Additionally, seven video transects were planned within the ECR corridor.

Table 1-4: Environmental survey overview

Area	Number of grab stations	Spacing rationale
OWF Array	22	Initial 5 km grid, adjusted after review of SSS and MBES data
ECR	8	Initial 5 km spacing, adjusted after review of SSS and MBES data

2 SURVEY PARAMETERS

2.1 HORIZONTAL DATUM

The following horizontal datum parameters were used throughout survey operations:

Table 2-1: Datum parameters

Parameter	Details
Name	World Geodetic System 1984 (WGS84)
Ellipsoid	WGS 84
Semi-Major Axis (a)	6 378 137.000 m
Semi-Minor Axis (b)	6 356 752.314 m
Inverse Flattening	298.257 223 563
Geodetic parameters EPSG Code	4326

Table 2-2: Projection parameters

Parameter	Details
Projection	Universal Transverse Mercator (UTM)
Zone	30 North
Central Meridian	3° West
Latitude of Origin	0°
False Easting	500 000.00 m
False Northing	0.00 m
Scale Factor at Central Meridian	0.9996
Projected coordinate system EPSG code	32630
Units	metres

2.2 VERTICAL DATUM

All elevations and depths used for vertical referencing in this project are relative to Lowest Astronomical Tide [LAT]. Data were reduced online using VORF Ellipsoid to LAT separation.

2.3 STANDARD NOMENCLATURE & UNITS

Throughout this report the following nomenclature and units apply unless otherwise stated:

- Linear units are expressed in international meters [m]
- Angular units are expressed in degrees (°)
- Frequency units are expressed in hertz (Hz)
- Magnetic field induction is expressed in nanoteslas (nT)

3 SURVEY EQUIPMENT

3.1.1 Vessel Equipment

For the geophysical acquisition, the systems listed in Table 3-1 were used.

Table 3-1: Vessel survey equipment

Item	Offshore Vessel – *Braveheart Spirit*	Nearshore Vessel - *Coastal Observer*
DGNSS 1 (primary)	Starpack Omnistar (XP2 PPP)	Applanix PosMV Wavemaster 2
DGNSS 2 (secondary)	Starpack Omnistar (G2+ PPP)	
Gyrocompass (primary)	iXBlue Hydrins	Applanix PosMV Wavemaster 2
Gyrocompass (secondary)	Starpack Omnistar (G2+ PPP) dual Antenna	
Motion sensor (primary)	iXBlue Hydrins	Applanix PosMV Wavemaster 2
Motion sensor (secondary)	Kongsberg Seatex MRU-5	
USBL	HiPAP 501	Sonardyne Mini Ranger 2
Sound velocity profiler	AML-3 LGR CTD	Valeport Swift SVP
MBES (Bathymetry)	Kongsberg EM2040-04 MK II	Norbit B41 Winghead MBES
MBES (Backscatter)	R2Sonic 2024	Norbit B41 Winghead MBES
SSS	Klein MA-X VIEW 600	EdgeTech 4125
SBP	EdgeTech 2050-DSS (also used for SSS low frequency)	Geo-pulse 5430A
Magnetometer	Geometrics G-882	Geometrics G-882
Transponders	3 cNode MiniS 34-180, 2 cNode Maxi 34-180-R	Sonardyne WSM 6+ x2

3.1.2 Software

Table 3-2 shows the main software utilised for the interpretation.

Table 3-2: Software list

Use	Manufacturer / Model
MBES processing	QPS / Qimera
SSS processing	Chesapeake / SonarWiz
Magnetometer processing	Seequent / Oasis Montaj
MBES backscatter processing	QPS / FMGT
GIS – Data QC	Open source qgis.org / QGIS
GIS – Data presentation	ESRI / ArcGIS Pro

4 PROCESSING AND INTERPRETATION METHOD STATEMENT

4.1 MBES

4.1.1 Processing

Data acquired by the offshore vessel were quality checked on board by the Data Liaison Officer. The raw data was sent to shore and received by the onshore processing team and subsequently processed with in-house processing and coverage checked. The N-Sea MBES Processing Procedure document [Ref. 7], which contained detailed, step-by-step processing sequence, was used by project data processors as a guide. This document was always adhered to in respect of the bathymetric data processing. General overview of the processing workflow is summarised by diagram in Figure 4-1.

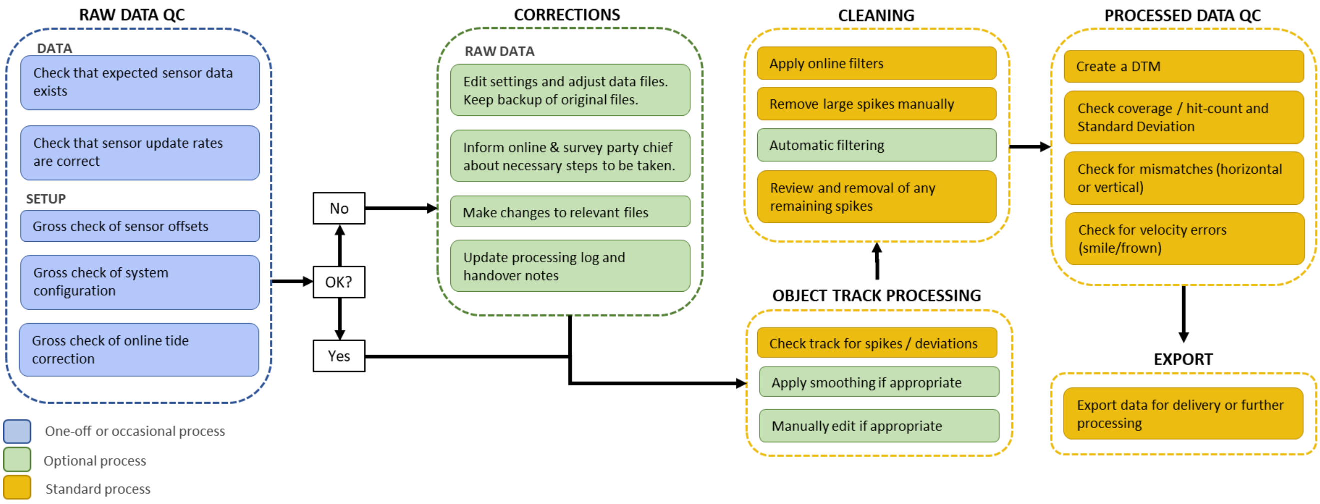


Figure 4-1: MBES processing flow

4.1.2 Interpretation

The MBES bathymetry dataset was used in conjunction with the MBES backscatter and SSS data in order to complete the seabed feature interpretation. MBES datasets were useful to accurately delineate large features such as sand megaripples, sand waves, or large man-made features. The MBES dataset was also used to quality check the SSS data positioning accuracy.

4.2 MBES BACKSCATTER

4.2.1 Processing

Data was exported from the online navigation software and converted in QPS's Fledermouse Geocoder Toolbox (FMGT) software to backscatter grids. General overview of the processing workflow is summarised by diagram in Figure 4-2. Mosaic was then produced at 0.25m resolution, exported as geotiff, and provided as part of the deliverable package.

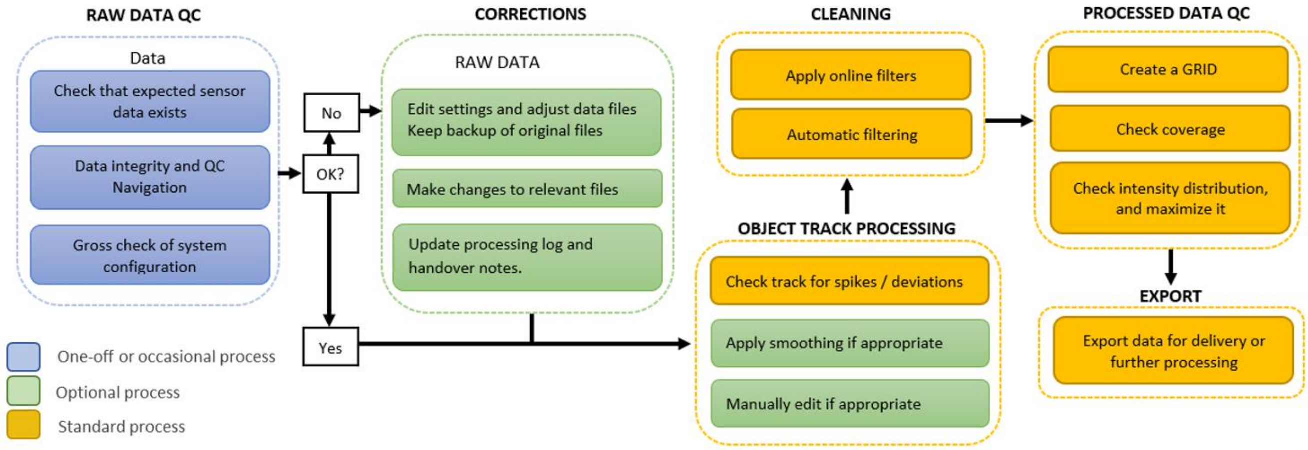


Figure 4-2: MBES backscatter processing flow

4.2.2 Interpretation

The MBES backscatter dataset was used in conjunction with the MBES bathymetric and SSS data in order to complete the seabed feature interpretation.

4.3 SIDE SCAN SONAR

4.3.1 Processing

The Side Scan Sonar survey was used to identify items of debris and any significant seabed features and to draw surficial sediment unit boundaries. The N-Sea *Side Scan Sonar Processing Procedure* document [Ref. 8] was used by project geophysicists as a processing guide. This document was always adhered to in respect of the side scan sonar data processing and interpretation.

The processing of the data consisted of the following steps:

- Copied data from online to the vessel network and then transferred the data ashore to N-Sea’s office network;
- QC the data and filled in the offline log sheet;
- Tracked the seabed;
- Applied gain (AGC or EGN);
- Applied corrected navigation provided by Data Processor;
- Picked targets in line with picking criteria outlined in job specific documentation;
- Aligned SSS to MBES /BS;
- Exported target lists;
- Exported mosaic images, imported them in GIS suite and interpreted seabed features.

General overview of the processing workflow is summarised by diagram in Figure 4-3.

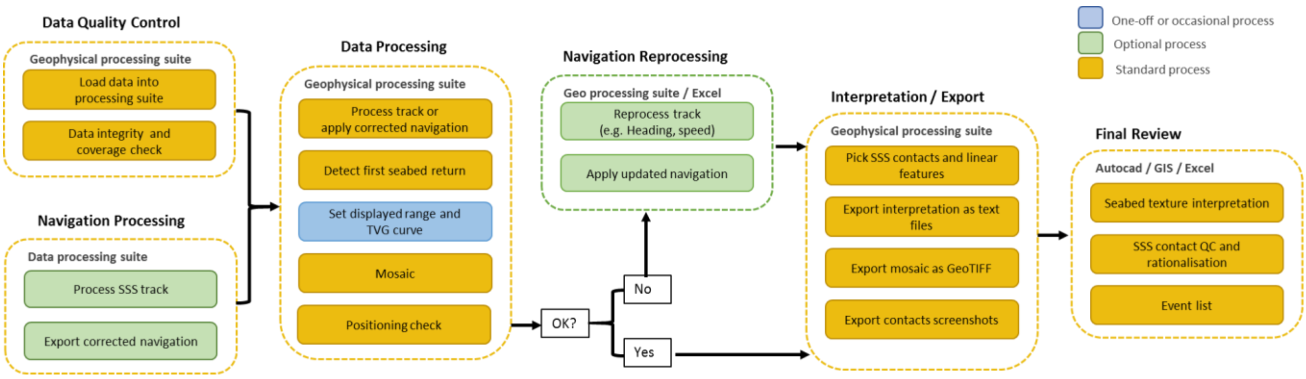


Figure 4-3: Side Scan Sonar processing workflow

4.3.2 Interpretation

Discrete Anomalies

The SSS imagery was interpreted for any seabed surface objects greater than 1 m in size. A side scan sonar contact listing was derived from the High Frequency SSS dataset. All side scan sonar lines were reviewed, and items classified as per SSDM / IOGP classification (Table 4-1).

Table 4-1: SSS contact classification with IOGP equivalent code

Class	IOGP Code
Debris	IOGP1021 Debris
Wreck	IOGP1022 Wreck
Linear Debris	IOGP2002 Linear Debris
Trawl scar	IOGP2004 Trawl Scars
Cable or wire	IOGP2078 Cable

Seabed Sediments Classification and Morphology

The sediment classification within the survey area was interpreted from the seabed reflectivity and appearance in the MBES Backscatter dataset. Where possible, the results from the grab sampling program were also used as ground truthing. Classification was done in line with SSDM / IOGP standards and the Folk's Classification system of sediments, see Table 4-2 and Table 4-3.

For the purposes of interpretation and reporting, the ECR has been split into blocks North (N), Centre (C), South (S).

Table 4-2: Seabed sediments classification with IOGP equivalent code

Class	IOGP Code - Primary	IOGP Code - Secondary
MUD	IOGP3104 Clay	
Sandy MUD	IOGP3204 Sandy-clay	
Gravelly Sandy MUD	IOGP3204 Sandy-clay	IOGP3101 Gravel
Muddy SAND	IOGP3202 Clayey-Sand	
SAND	IOGP3102 Sand	
Gravelly Muddy SAND	IOGP3202 Clayey-Sand	IOGP3101 Gravel
Gravelly SAND	IOGP3102 Sand	IOGP3101 Gravel
GRAVEL	IOGP3101 Gravel	

Class	IOGP Code - Primary	IOGP Code - Secondary
Rock Outcrop	IOGP3205 Rocky	
Subcrop	Depending on surficial sediment	IOGP3205 Rocky

Table 4-3: Seabed morphology classification with IOGP equivalent code

Class	IOGP Code	Comment
Flat	IOGP3073 Boundary - Others	Flat Seabed
Hummocky	IOGP3013 Hillock/Hummocky Seafloor	
Ripples	IOGP3004 Sand Ripples	
Megaripples	IOGP3052 Mega Ripples	
Sand Waves	IOGP3015 Sediment Waveform	Sand Waves
Long Wavelength Sand Waves	IOGP3015 Sediment Waveform	Long Wavelength Sand Waves
Subcrop	IOGP3079 Area of Bedrock	Subcrop
Rock	IOGP3079 Area of Bedrock	
Fault Scarp	IOGP2051 Fault Scarp	Linear feature
Sand Ridge	IOGP2059 Ridge	Linear feature
Sand Wave Crest	IOGP2069 Sand Wave Crest	Linear feature

Interpretation and Reporting of Boulders

The area comprises thousands of boulders, irregularly spread across the entire site. Instead of reporting all of them individually it was decided to report them, in line with IOGP classification, as areas of occasional and numerous boulders:

- IOGP3075 – Numerous boulders (Polygons): more than 10 boulders > 1 m in a 50 m radius
- IOGP3076 – Occasional boulders (Polygons): more than 2 boulders > 1 m in a 50 m radius
- IOGP1007 – Isolated boulders (Points)

Figure 4-4 to Figure 4-6 provide an example of the boulder classification approach followed during the interpretation process.

Regardless of boulder field classification, all side scan sonar contacts deemed to be of man-made origin were kept in the listing. Manmade objects could be discriminated from boulders by their sharp edges, sharp shadows. They could also be correlated to other datasets (wreck database, magnetometer data…).

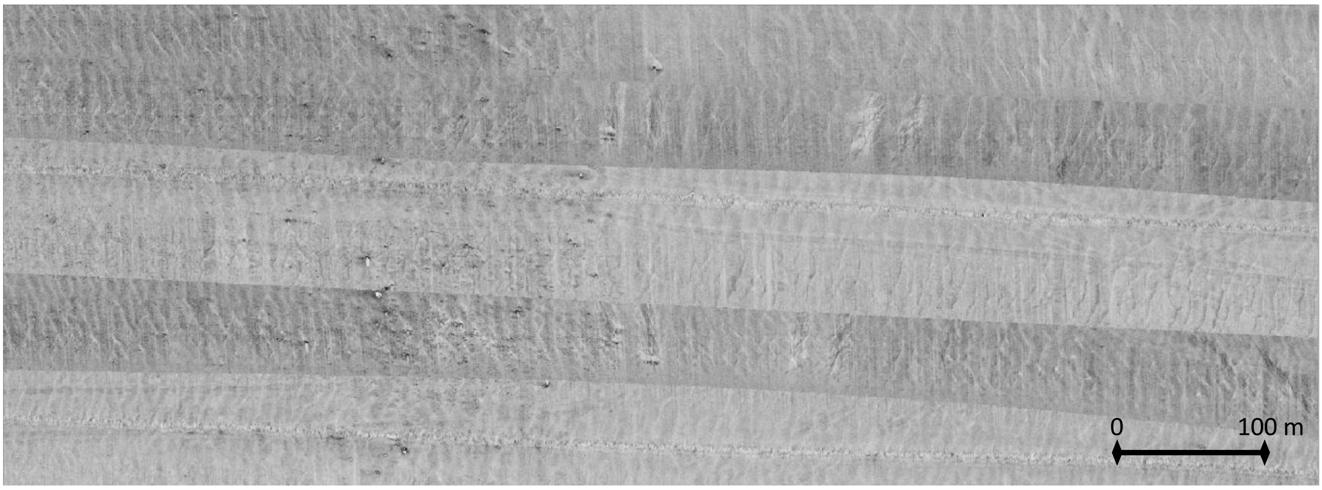


Figure 4-4: SSS mosaic showing multiple boulders on the western half of the mosaic

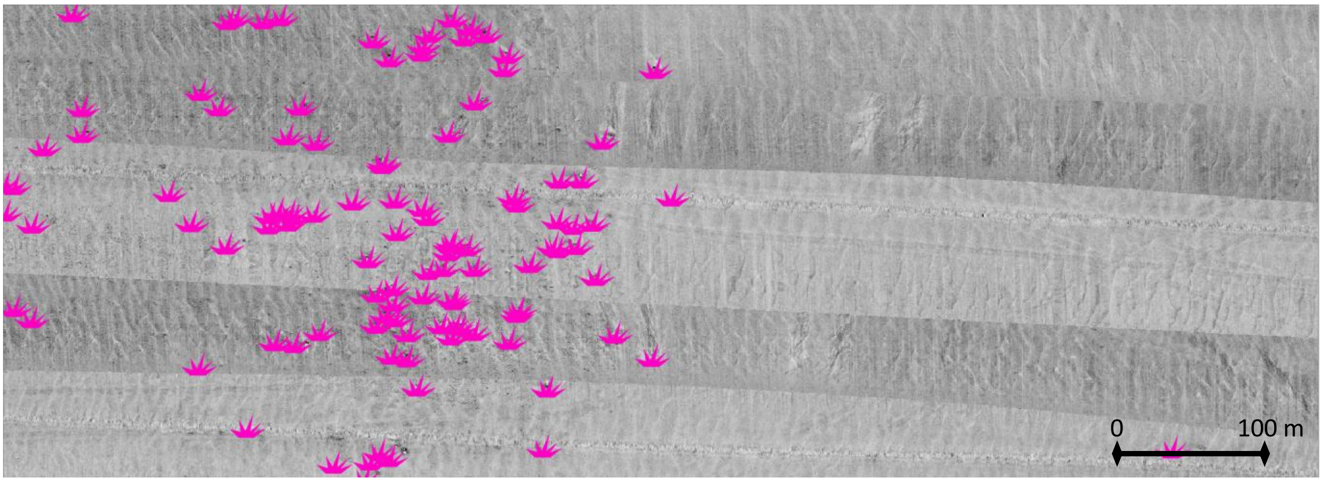


Figure 4-5: Preliminary interpretation - single boulder eventing

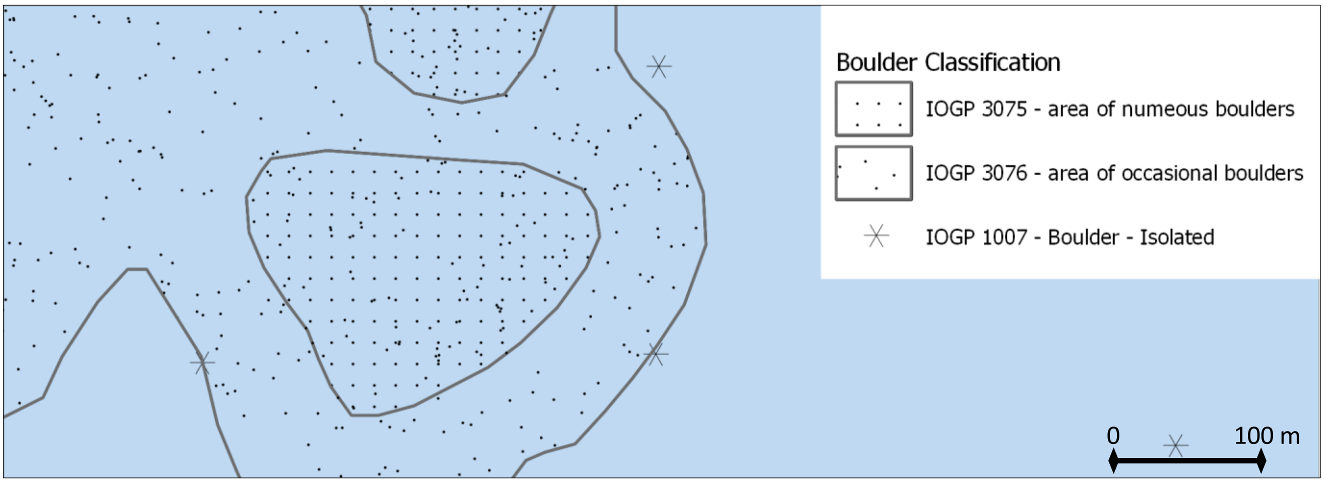


Figure 4-6: Final classification based on boulder density

4.4 MAGNETOMETER

A Geometrics G-882 magnetometer was soft-towed behind the SSS to map the location of cables/pipelines and potential buried archaeological sites such as wrecks. The planned survey line separation was 100 m, so ferrous items on or beneath the seabed midway between survey lines are not expected to generate a magnetic response within the magnetometer data.

Table 4-4: Summary of magnetic survey

Area	Total lines processed	Mean mag altitude (m)	Mean data separation (m)
OWF	147	6.3 ± 1.4	0.20 ± 0.04
ECR	81	6.2 ± 0.9	0.18 ± 0.02

4.4.1 Processing and Interpretation

The magnetometer data processing was undertaken using the using the N-Sea Magnetometer and Gradiometer Processing Procedure document [Ref. 9].

Processing sequence is summarised below and in Figure 4-7.

- Despiked, interpolated and smoothed the raw navigation data.
- Despiked, interpolated and smoothed the raw altitude data.
- Fitted a magnetic background to the raw total magnetic field data using a combination of non-linear and rolling statistics filters. Subtracted background from raw data to derive a residual magnetic field that primarily contained the magnetic response of debris/cables/shallow geology.
- Gridded data using a cell size of 0.5 m and extrapolated/clipped to 7.5 m either side of line track to help visualise the data and recognise linear features.
- Calculated a horizontal derivative and total magnetic gradient (analytic signal) to assist interpretation.
- Target picking (manual process). All significant anomalies with a peak-to-peak of 5 nT (-2.5 nT to +2.5 nT) were reported, subsequently the anomaly characteristics were determined. One exception should be noted, in the nearshore extension and far north of the ECR corridor where the geology affects the magnetometry data. Then the target picking threshold was increased to 20 nT peak-to-peak.
- Anomaly characteristics were determined i.e., wavelength and amplitude. Where possible the anomalies have been correlated to known subsea infrastructure (i.e., subsea cables, wreck).

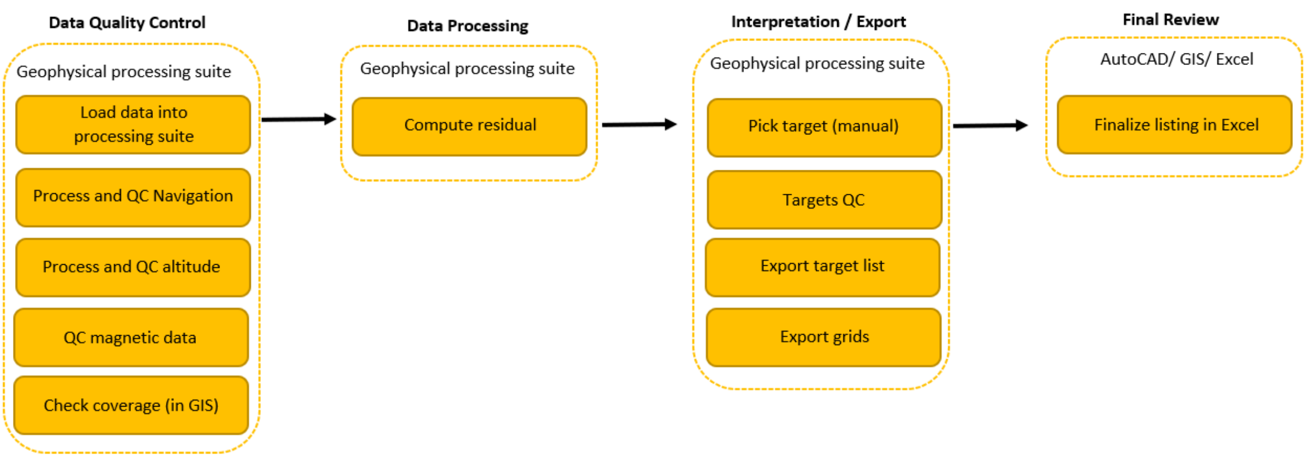


Figure 4-7: Magnetometer processing flow

4.5 DELIVERABLES

This *Results Report* is part of a bundle of documents and data which may be considered to constitute the full *Survey Report*. The structure of this bundle is presented in Table 4-5 . The content of the deliverables package is as per the *Project Execution Plan* [Ref. 1] unless otherwise requested by, or agreed with the Client.

Table 4-5: Deliverables structure

Item	Vessel / Phase	Description	Format
Operational Report	BSP (Offshore) Coastal Observer (nearshore)	Mobilisation and Calibration Report	PDF
		Daily Progress Report	PDF
		Field Operation Report	PDF
Draft Report	Report	Geophysical Survey Report	PDF
		Benthic Survey Report	PDF / XLSX
Final Report	Report	Geophysical Survey Report	PDF
		Benthic Survey Report	PDF / XLSX
Data Deliverables	100. SBP	101 - Raw data	SEGY
	200. MBES	201 - Bathy Raw files	DB files
		202 - Bathy XYZ Ungridded	XYZ
		203 - Bathy XYZ Gridded – 0.25m x 0.25m	XYZ
		204 - Bathy Esri TIN	TIN
		205 - Bathymetric DTM Raster	GeoTiff
		206 - Bathy GeoTiff shaded relief	GeoTiff
		207 - MBES backscatter mosaic 0.25m x 0.25m	GeoTiff
		208 - Backscatter Raw	GSF
		209 - Bathy Contours	Shapefile
		210 - Bathy Coverage	Shapefile
		211 - Bathy Trackplots	Shapefile
	300. SSS	300 - SSS native files	SDF and XTF
		301 - SSS Mosaics (HF) (0.1 x 0.1 m Resolution)	GeoTiff
		302 - Contact List	XLSX
		303 - SSS Contact Images	Tiff
		304 - SSS Trackplot	Shapefile
		305 - SSS Seabed interpretation	Shapefile
		306 - SSS Coverage	Shapefile / XLSX
	400. MAG	401 - Raw data	TXT
		402 - Contact List	XLSX
		403 - Linear Features	Shapefile
	500. GIS	ESRI ArcGIS Geodatabase (Compatible ARCGIS 9.x) conforming to SSDM format	Geodatabase

5 RESULTS

5.1 BATHYMETRY

5.1.1 Summary

Figure 5-1 summarises the 2022 survey findings. The seabed levels range from -3.1 m (above LAT) recorded in the nearshore area of the ECR, to 72.8 m, recorded in the southern section of the OWF area. The seabed morphology in the survey area is dominated by mobile sediment bedforms ranging from ripples to sand waves. The overall ECR bathymetric trend shows a slight relatively regular slope resulting in increasing depth towards the south while in the OWF, the seabed is generally flat with water depths ranging around 69 m LAT +/- 4 m.

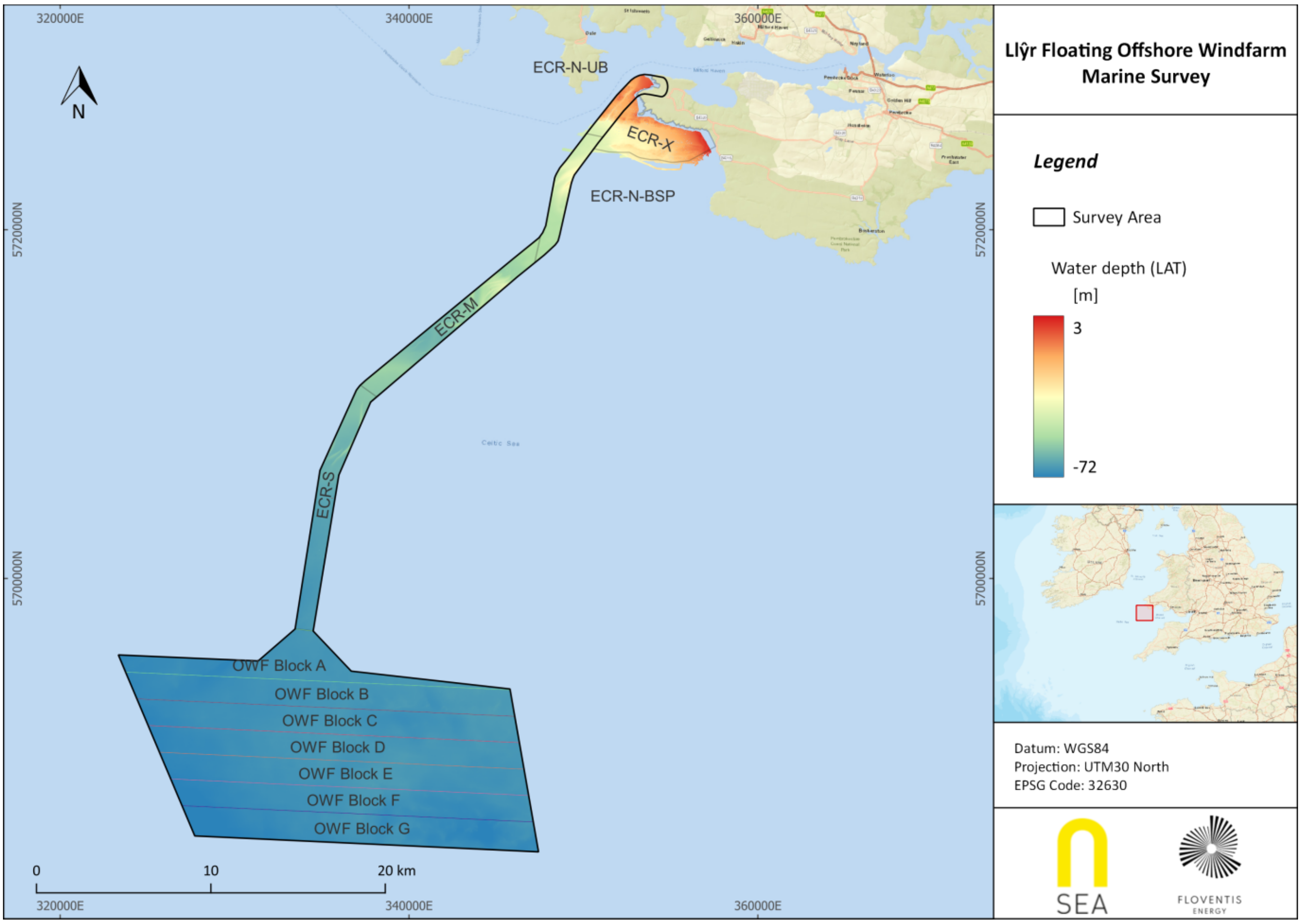


Figure 5-1: Bathymetry overview

Table 5-1: Bathymetry summary

Area	Max depth (m LAT)	Min depth (m LAT)	Average depth (m LAT)
Nearshore - ECR	52.7	-3.1	36.3
Nearshore - extra	47.6	-2.9	25.1
ECR - North	53.2	27.0	45.4
ECR - Centre	62.2	36.5	55.9
ECR - South	69.0	52.0	64.0
OWF	72.8	65.5	68.9

5.1.2 Nearshore Extension

The depths at Nearshore Extension area range between -2.9 and 47.6 m; with an average depth of 25.1 m.

The water generally deepens from shoreline towards south and west. An exemption from this rule is the section of seabed at the southernmost edge of the area. Here, extensive rock exposures create a raised platform, clearly visible on bathymetry DTM (Figure 5-2).

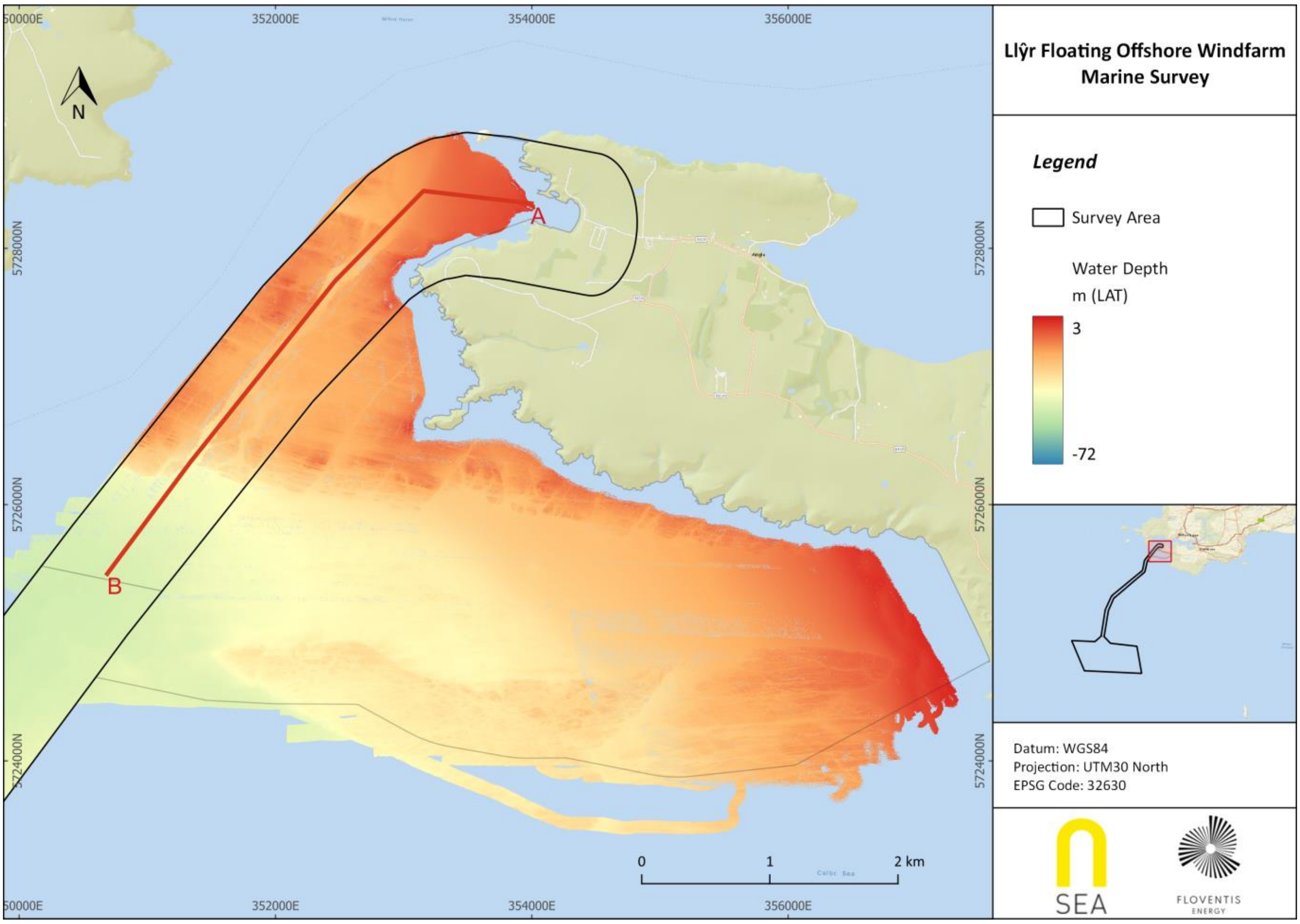


Figure 5-2: Bathymetry overview of ECR North Nearshore and extension areas

5.1.3 ECR Nearshore

The depths at ECR - North Nearshore area range between -3.1 and 52.7 m; with an average depth of 36.3.4 m (Figure 5-2).

Figure 5-3 presents bathymetry profile along the ECR North Nearshore area, while the slope gradients along the route are displayed in Figure 5-4. The light blue series displays the gradients computed at 2 m intervals while the dark blue series shows the gradients calculated at 10 m intervals. The seabed profile generally follows the channel feature visible cutting through the band of rock dominating shore approaches within the nearshore section of the route. It shows gently deepening water depths (towards south), with a slightly shallowing area in the middle of the profile, likely caused by localised accumulation of surface sediments within the channel.

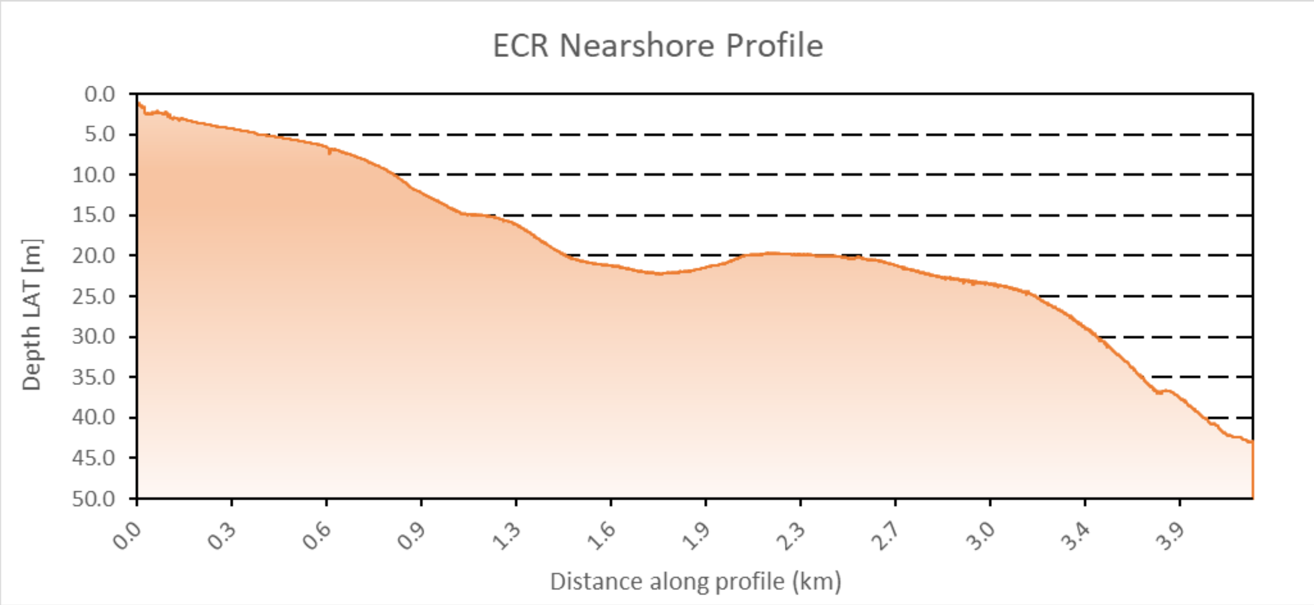


Figure 5-3: Bathymetry profile along ECR North Nearshore area

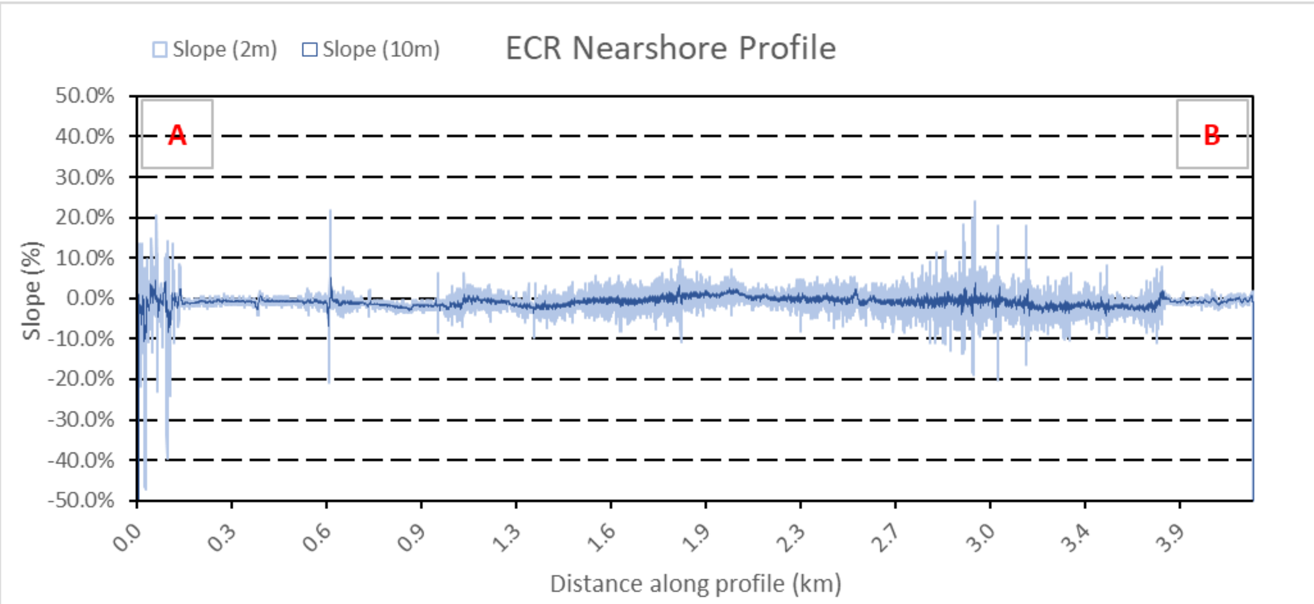


Figure 5-4: Slope gradient along ECR North Nearshore area

5.1.4 ECR North

The depths at ECR - North area range between 27.0 and 53.2 m; with an average depth of 45.4 m (Figure 5-5).

Figure 5-6 presents bathymetry profile along the ECR North area, while the slope gradients along the route are displayed in Figure 5-7. The light blue series displays the gradients computed at 2 m intervals while the dark blue series shows the gradients calculated at 10 m intervals. The seabed profile shows two large sand waves (up to 4 m in height) in the middle of the block. From the sand waves, the slope gradient increases until the seabed reaches a depth of 51 m to the southern end of the block.

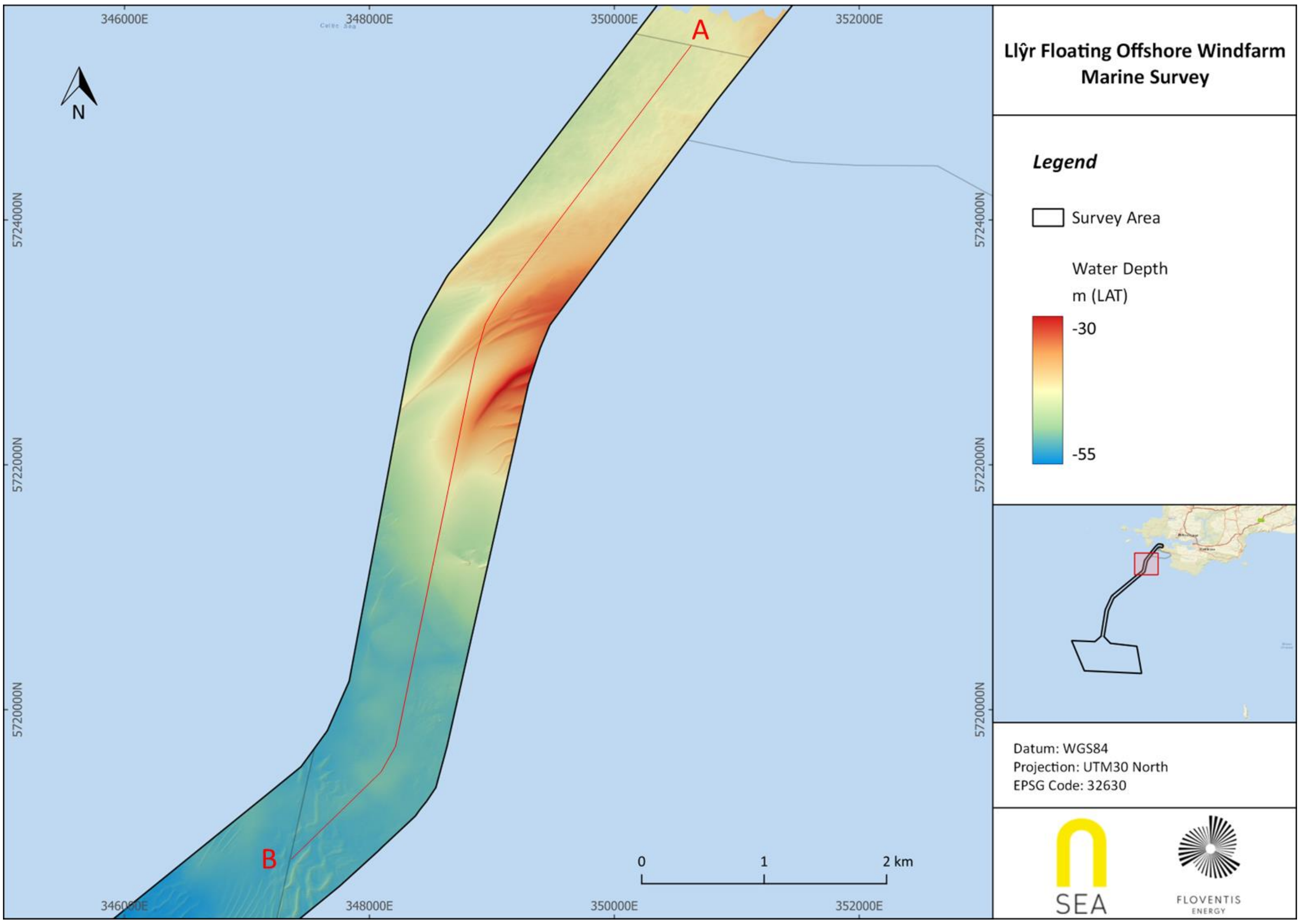


Figure 5-5: Bathymetry overview of ECR North area

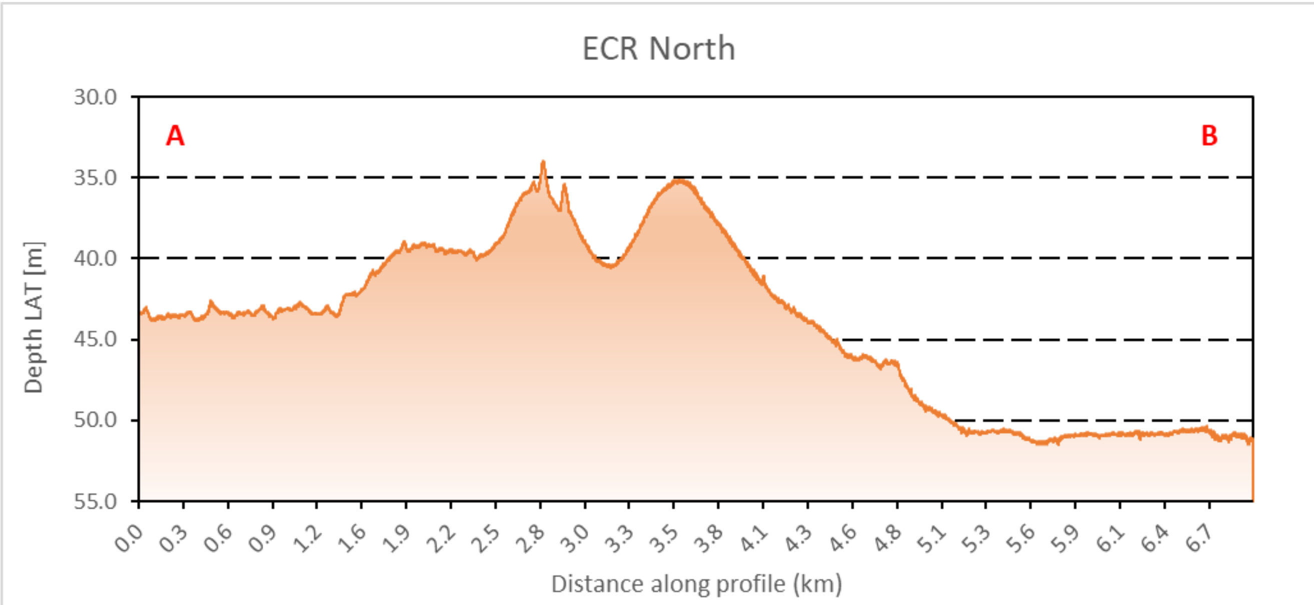


Figure 5-6: Bathymetry profile along ECR North area

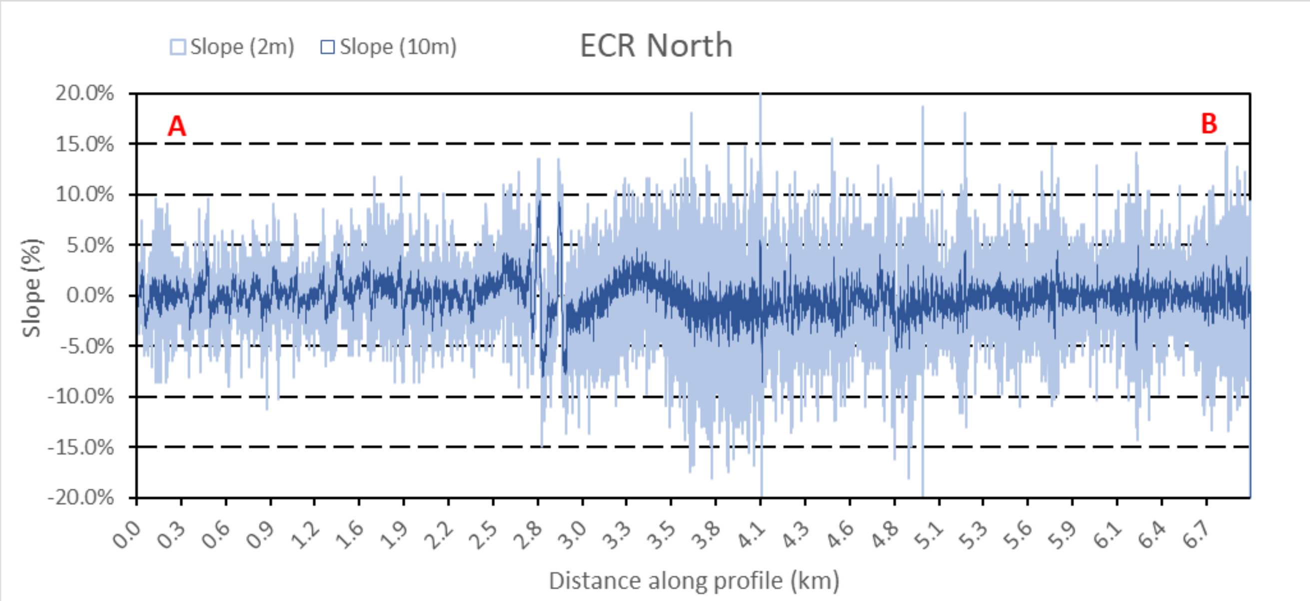


Figure 5-7: Slope gradient along ECR North area

5.1.5 ECR Centre

The depths across ECR Centre range between 36.5 m and 62.2 m; with an average depth of 55.9 m.

The seabed profile shows a general slope with increasing depths towards south-west. The route crosses an area of sand for about 2 km. From the sand waves, the depth profile drops off to 61 m over 4 km and then rises steadily over 2 km to a plateau at a depth of 55 m.

Figure 5-9 presents bathymetry profile along the ECR Centre area, while the slope gradients along the route are displayed in Figure 5-10. The light blue series displays the gradients computed at 2 m intervals while the dark blue series shows the gradients calculated at 10 m intervals.

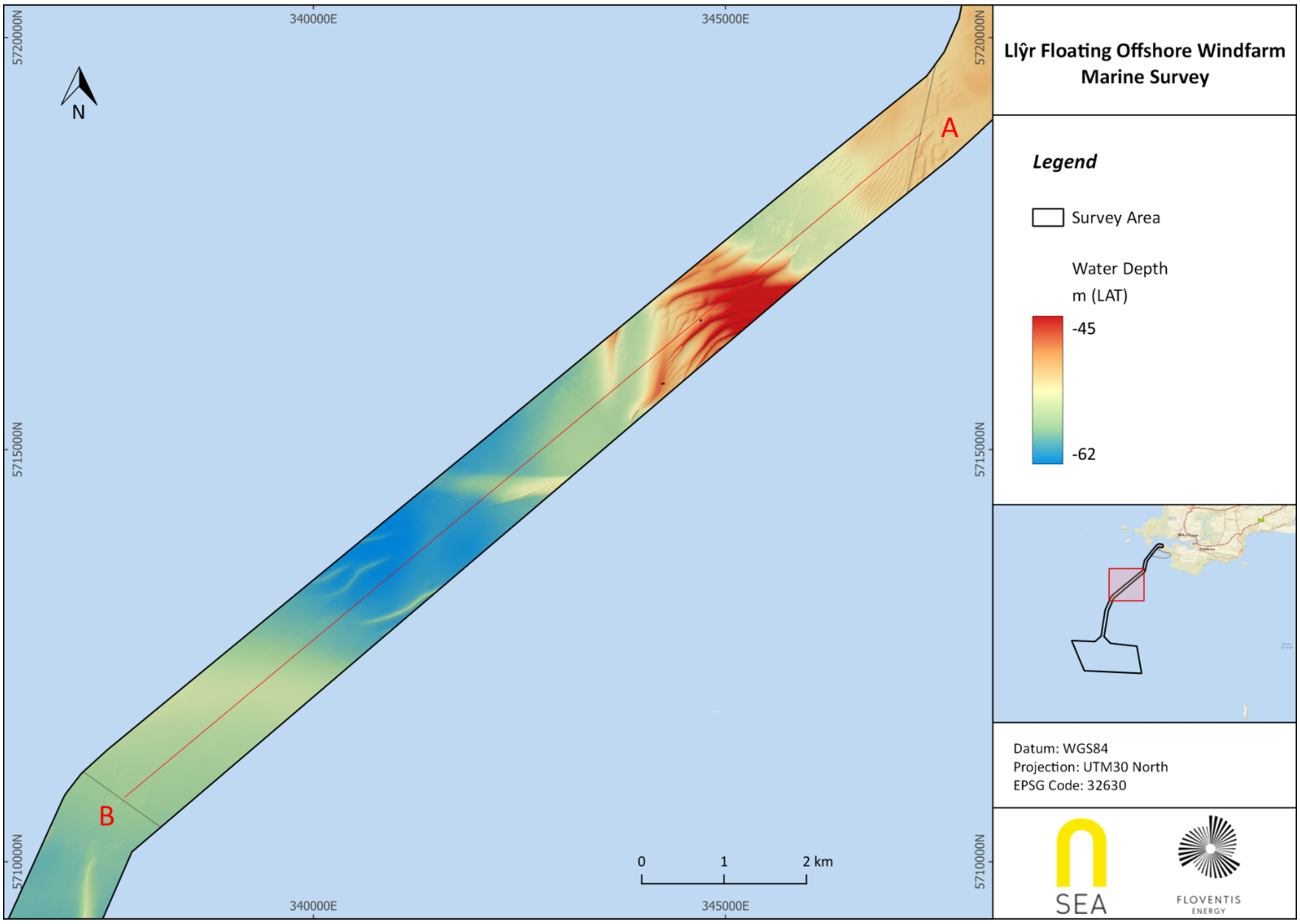


Figure 5-8: Bathymetry overview of ECR Centre area

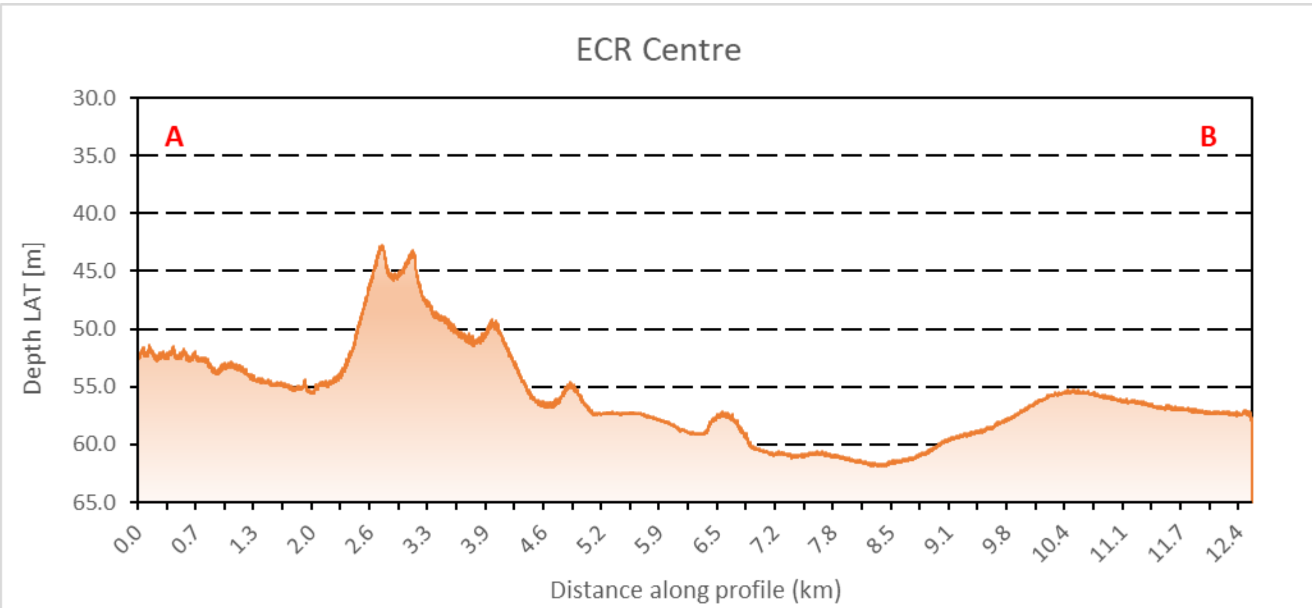


Figure 5-9: Bathymetry profile along ECR Centre area

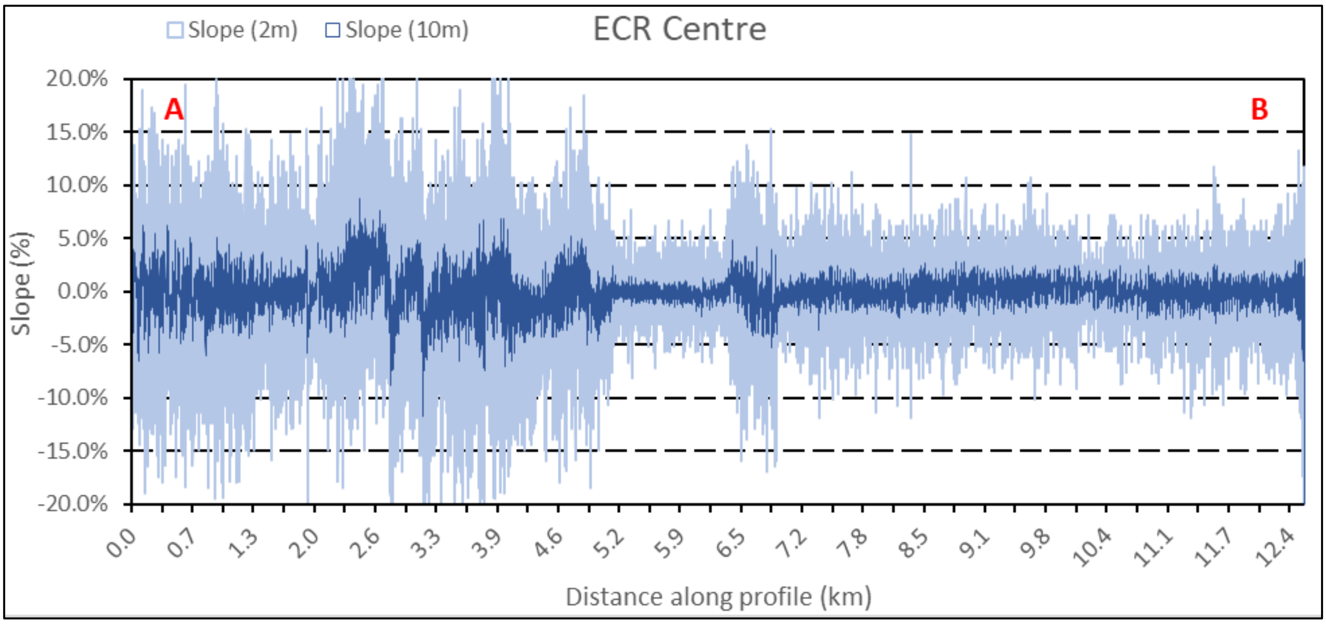


Figure 5-10: Slope gradient along ECR Centre area

5.1.6 ECR South

The water depths at ECR South range between 52.0 m and 69.0 m; with an average depth of 64.0 m. The north section of this block attributes to few sand waves/megaripples following a slight and regular increase in depth as the ECR reach the OWF area. South of the sand waves area, the seabed is relatively featureless outside the regular megaripple observed. A wreck is situated around 125 m off the centre of the ECR corridor.

Figure 5-12 presents bathymetry profile along the ECR North area, while the slope gradients along the route are displayed in Figure 5-13. The light blue series displays the gradients computed at 2 m intervals while the dark blue series shows the gradients calculated at 10 m intervals.

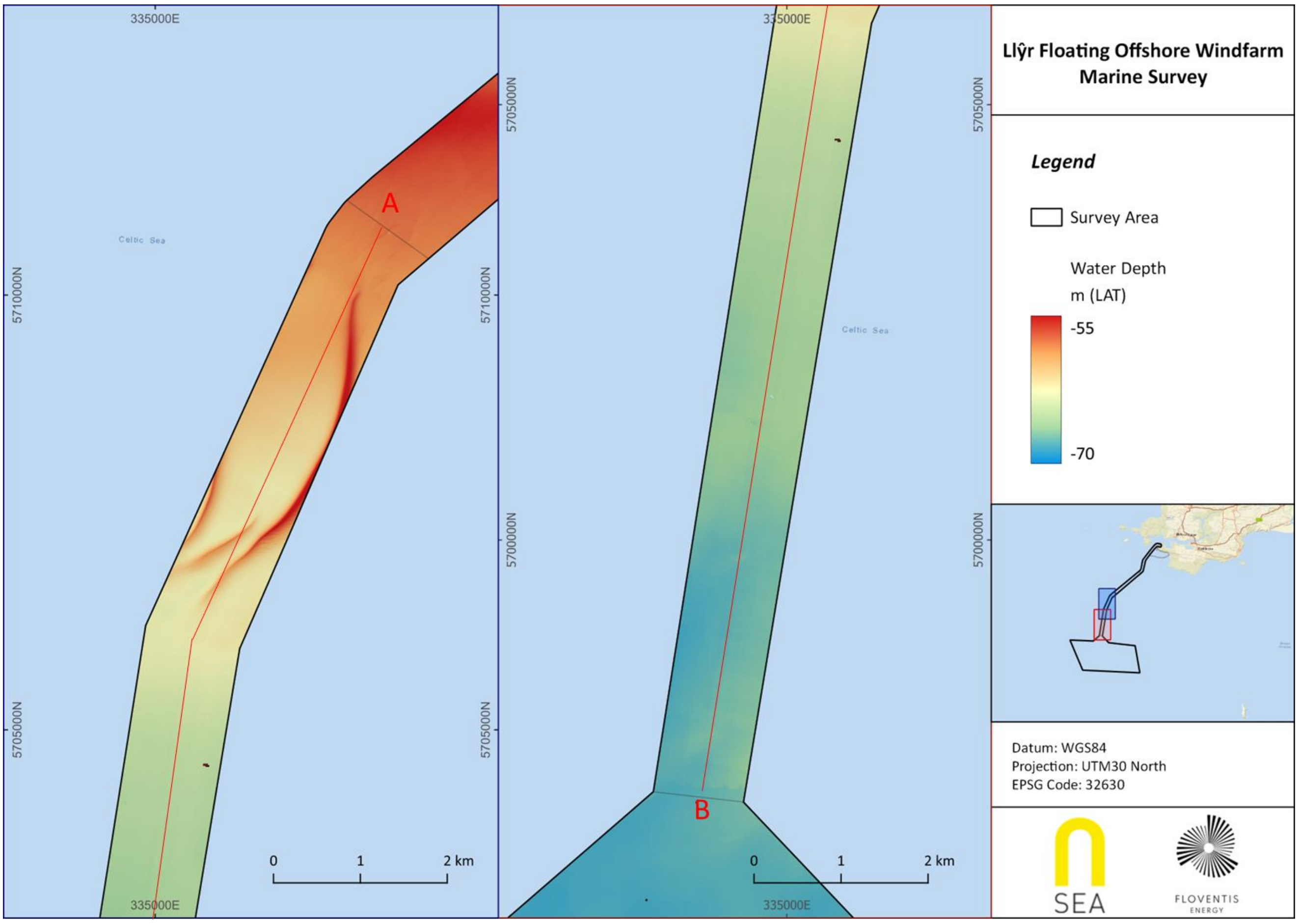


Figure 5-11: Bathymetry overview of ECR South area

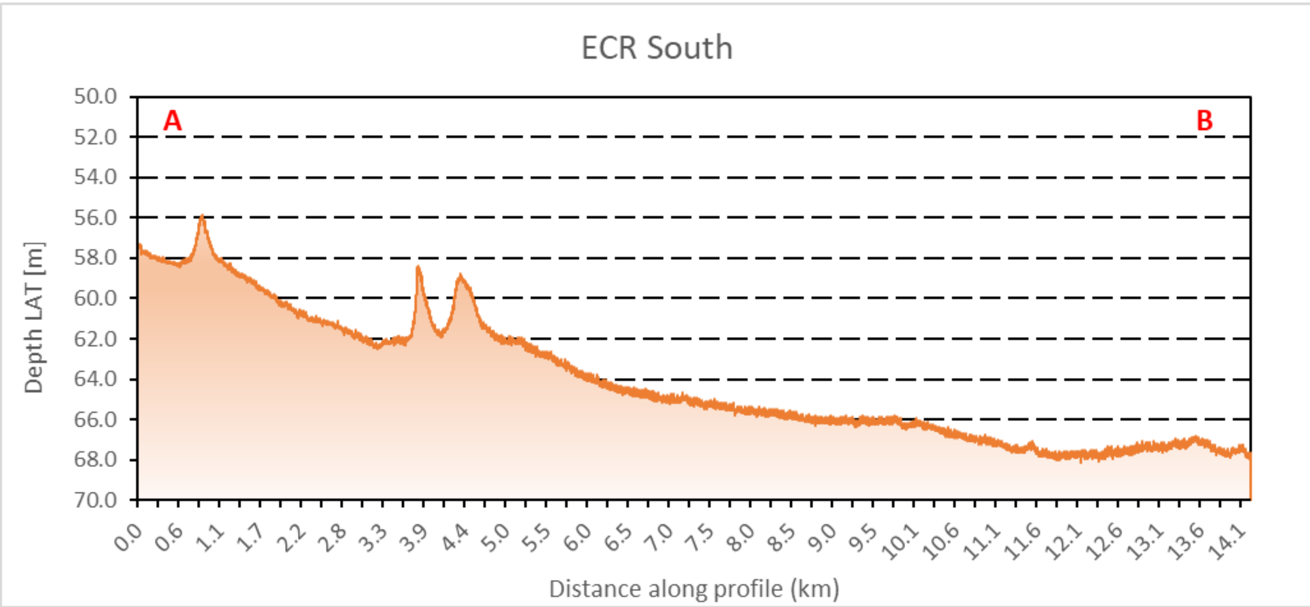


Figure 5-12: Bathymetry profile along ECR South area

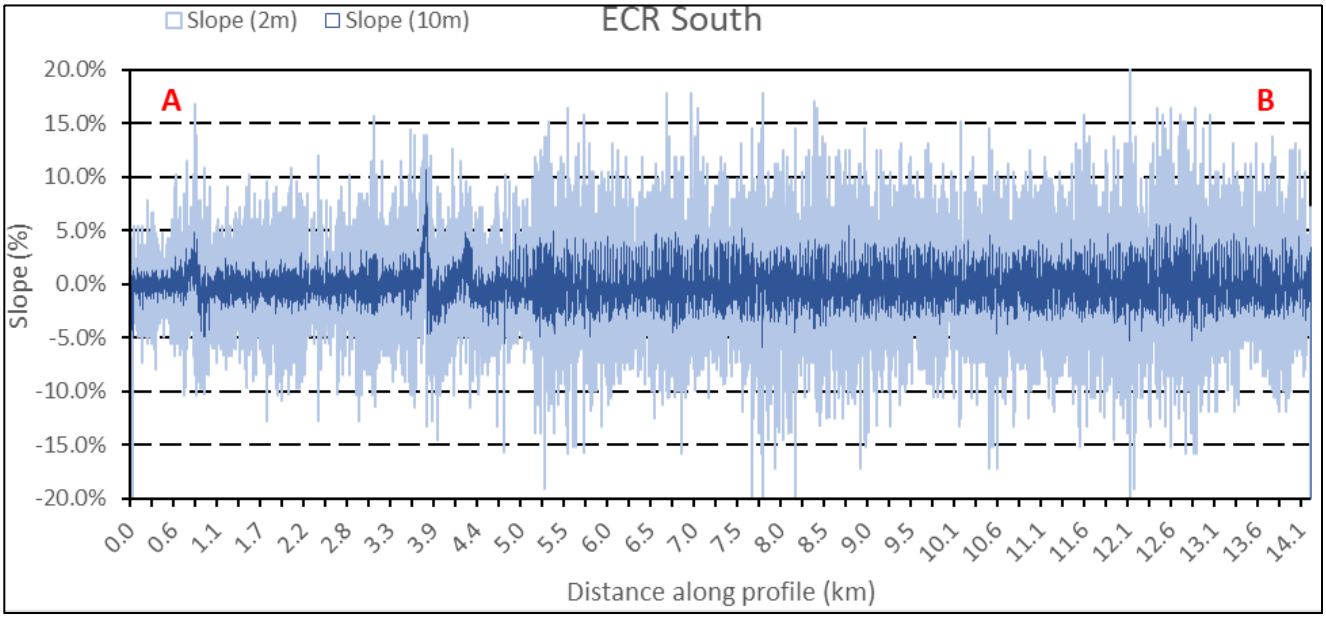


Figure 5-13: Slope gradient along ECR South area

5.1.7 OWF

The water depths at the OWF range between 65.5 m and 72.8 m; with an average depth of 68.9 m. The slope tends to run from the north-east to the south-west. Two profiles were drawn at perpendicular directions and can be seen in Figure 5-15 and Figure 5-17. Sand ripples can be seen throughout the area with a high concentration of boulders in the south and east of the area. The slope gradients along the two profiles are displayed in Figure 5-16 and Figure 5-18.

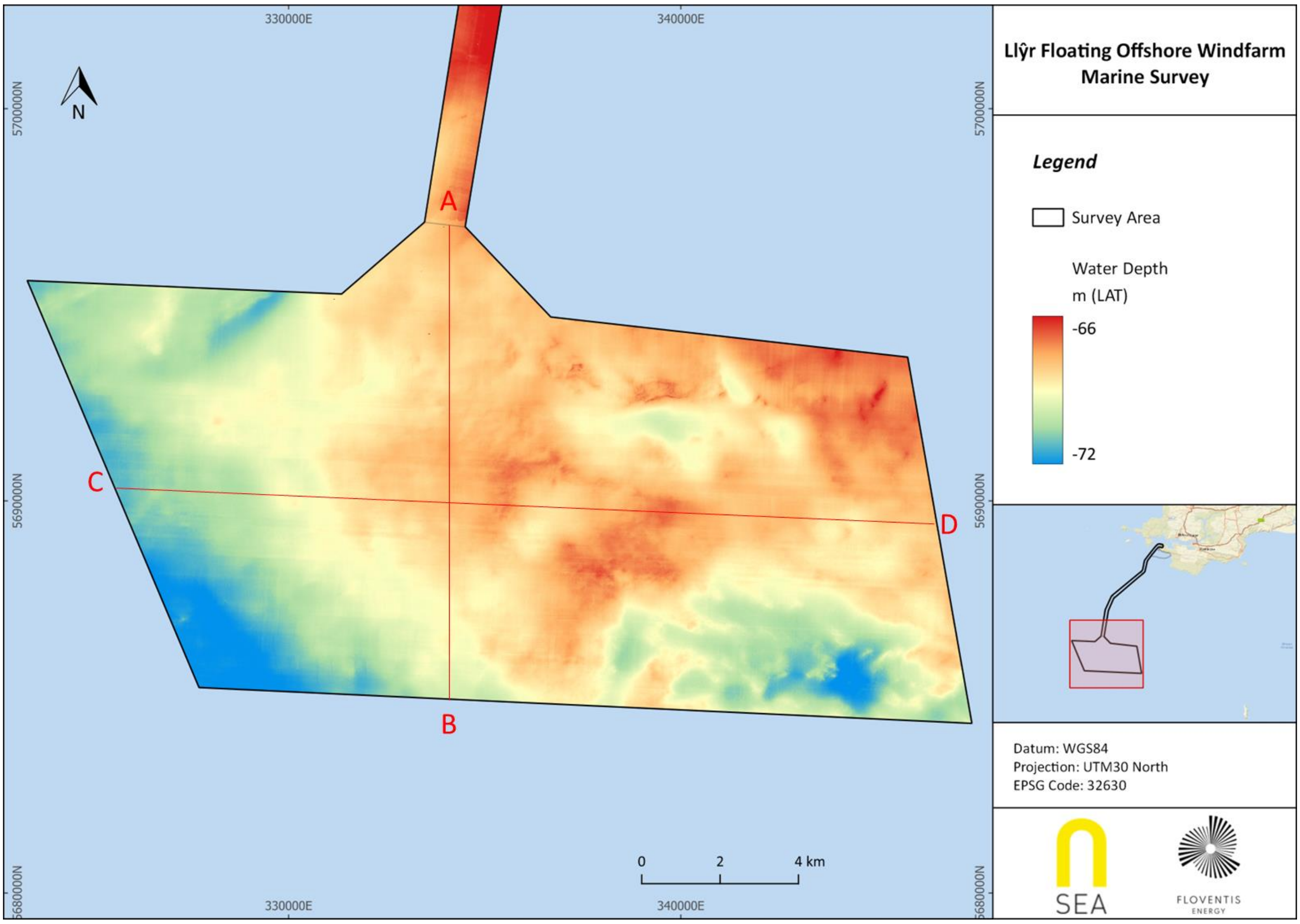


Figure 5-14: Bathymetry overview of the OWF

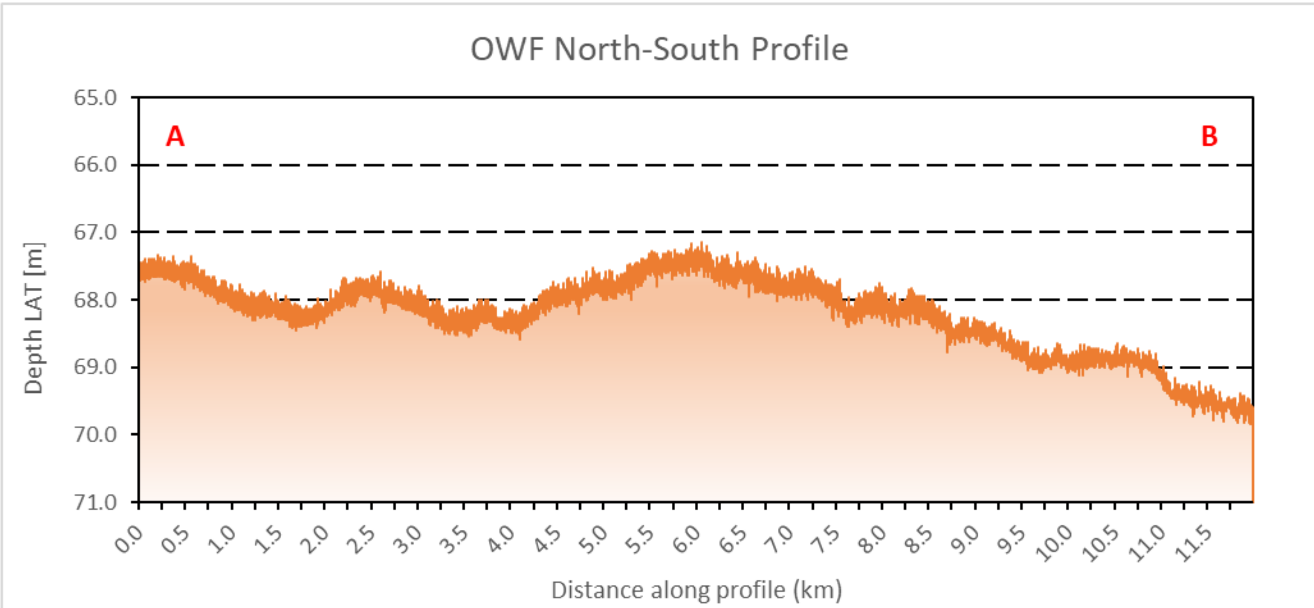


Figure 5-15: Bathymetry profile across OWF (North-South profile)

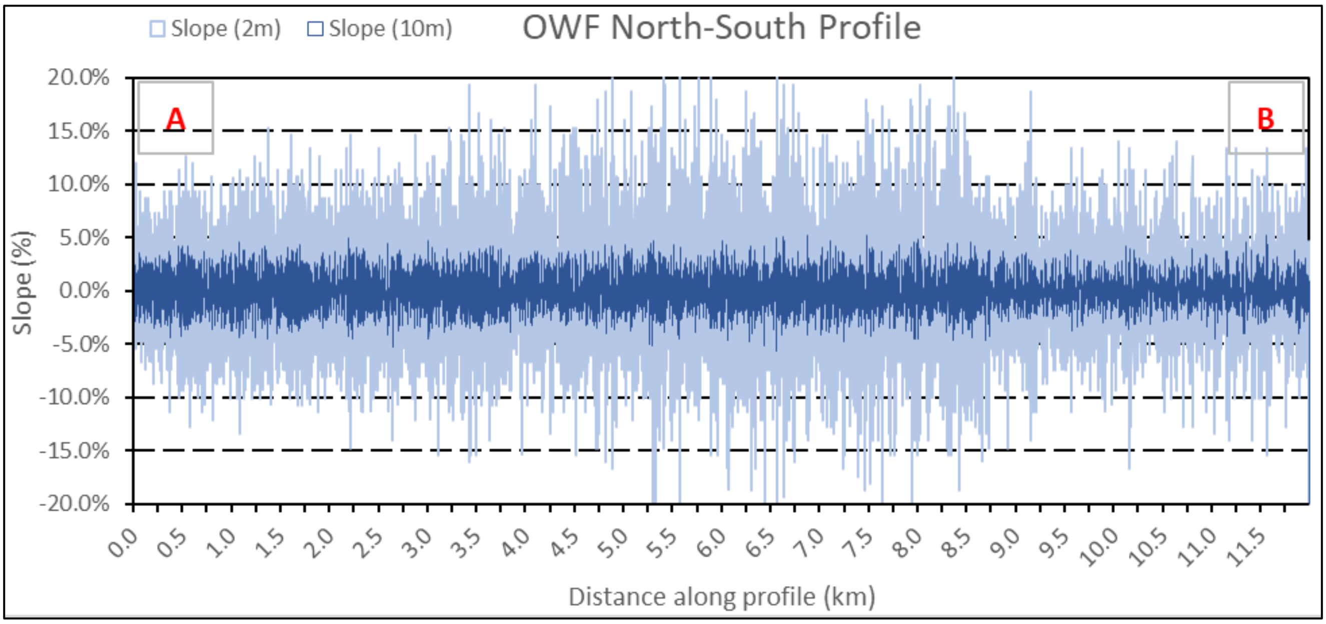


Figure 5-16: Slope gradient across OWF (North-South profile)

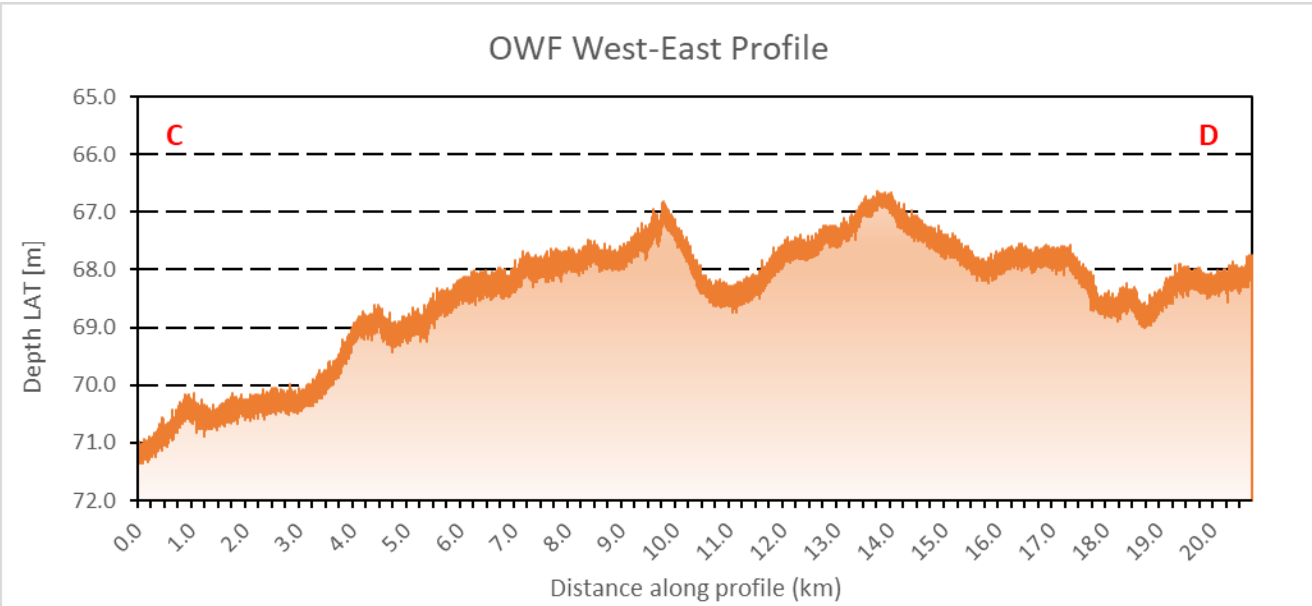


Figure 5-17: Bathymetry profile across OWF (West-East profile)

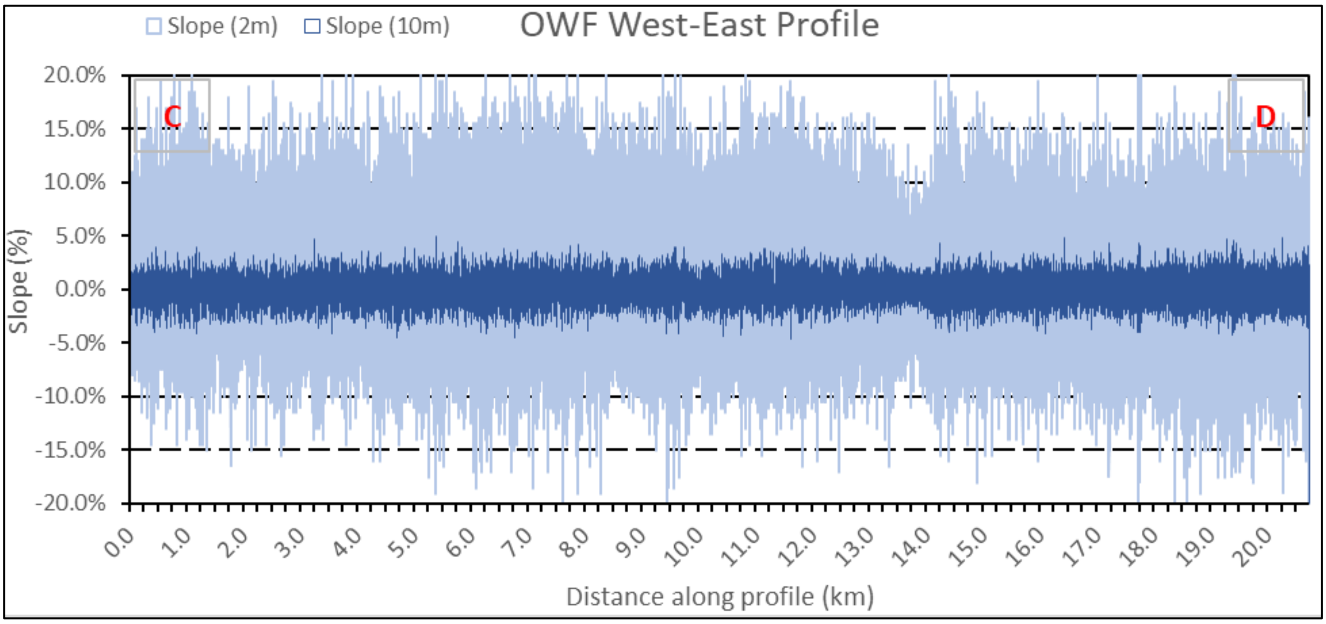


Figure 5-18: Slope gradient across OWF (West-East profile)

5.2 SEABED SEDIMENTS CLASSIFICATION AND MORPHOLOGY

5.2.1 Nearshore Extension

The Nearshore extension area stretches along the southern coast of Pembrokeshire, in an approximately 2 km wide (N-S) and 6 km long (E-W) band, adjacent to the eastern edge of the ECR area (Figure 5-19). The area is characterised by presence of bedrock exposed on the seabed, mainly in two wide bands, one running along the coastline (200 to 1200 m wide) and second one running parallel to the southern boundary of the survey area (400 to 900 m wide). The middle section of the Nearshore extension can be seen split into generally two major sections: eastern part, exhibiting mostly flat and featureless seabed morphology, and western part, mostly displaying hummocky character, with sections of shallow lying (sub-cropping) bedrock adjacent to the northern and southern bands of rock exposures. Narrow section between the eastern and western parts is covered by megarippled sediments and hummocky sections. Megaripples are generally straight with crests running NWN-SES. Wavelengths are generally uniform, in the 1 to 2 m range, with amplitudes up to 0.2 m. Another area of megaripples was observed at the eastern edge of the nearshore extension. The megaripples here are mostly linguoid in type, with crests running NW-SE and wavelengths up to 4 m. Heights vary from 0.1 to 0.3 m. Small patches of megarippled sediments were also noted along some edges of the bedrock exposures, where the forms are generally smaller than the ones described previously.

Linear structures (internal fractures/joints) were observed within the exposed bedrock. Most of the main ones were mapped as *Fault Scarp* feature. These show a general bi-directional tendency: NNE-SSW and WNW-ESE.

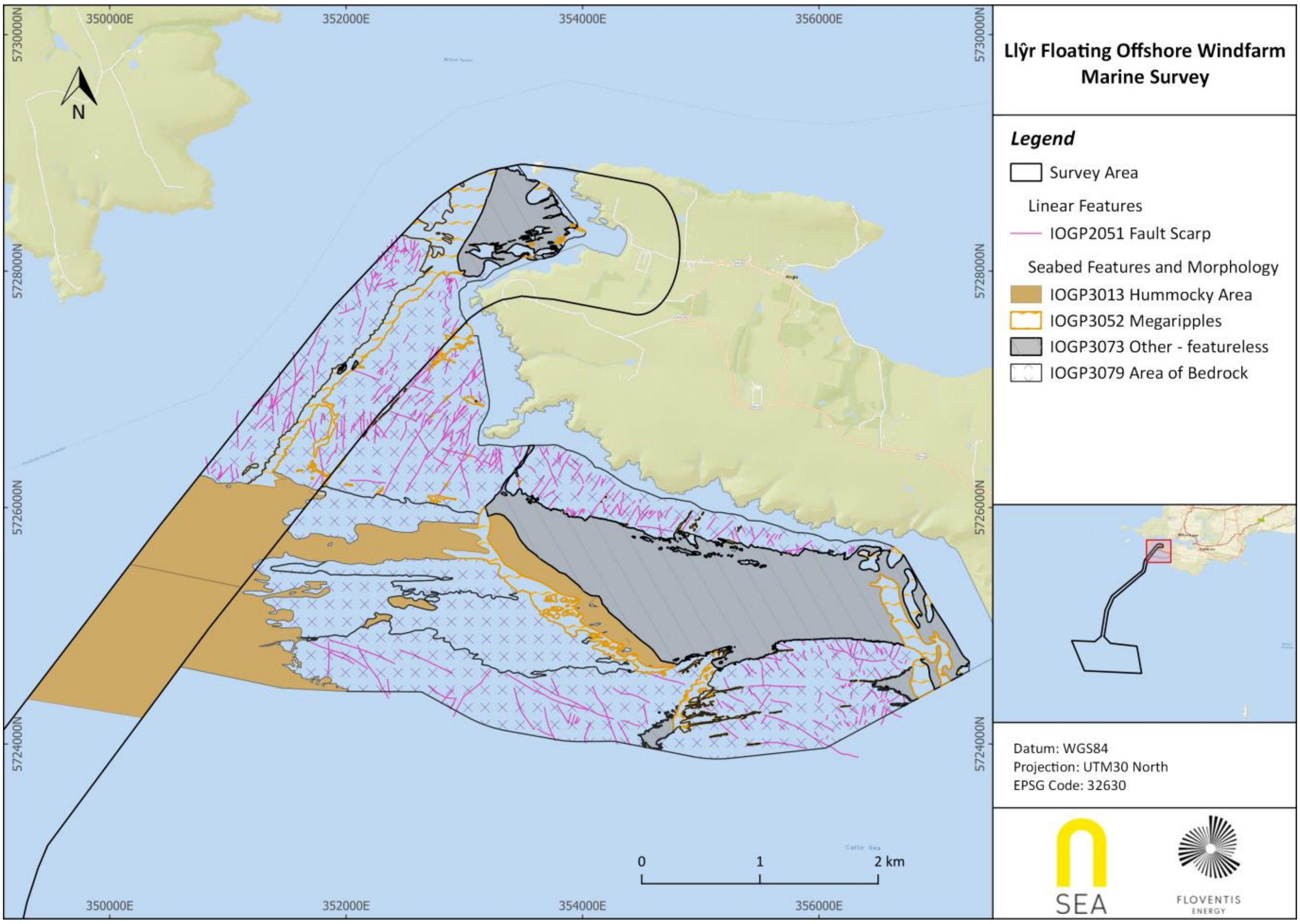


Figure 5-19: ECR North Nearshore and extension areas - seabed features interpretation overview

Figure 5-20 shows the overview of the seabed sediments interpretation within the nearshore sections. The majority of the area is covered by exposed bedrock (as described in the seabed features section). The featureless seabed in the east of the area was interpreted as comprising mostly MUD with localised presence of SAND (megaripples). The middle section with megaripple features was recorded as consisting of Gravelly SAND, while the hummocky seabed in the west is likely covered with Gravelly Muddy SAND. This is likely also the major type of sediment comprising the veneer overlaying the areas of sub-cropping bedrock (western part of the survey area).

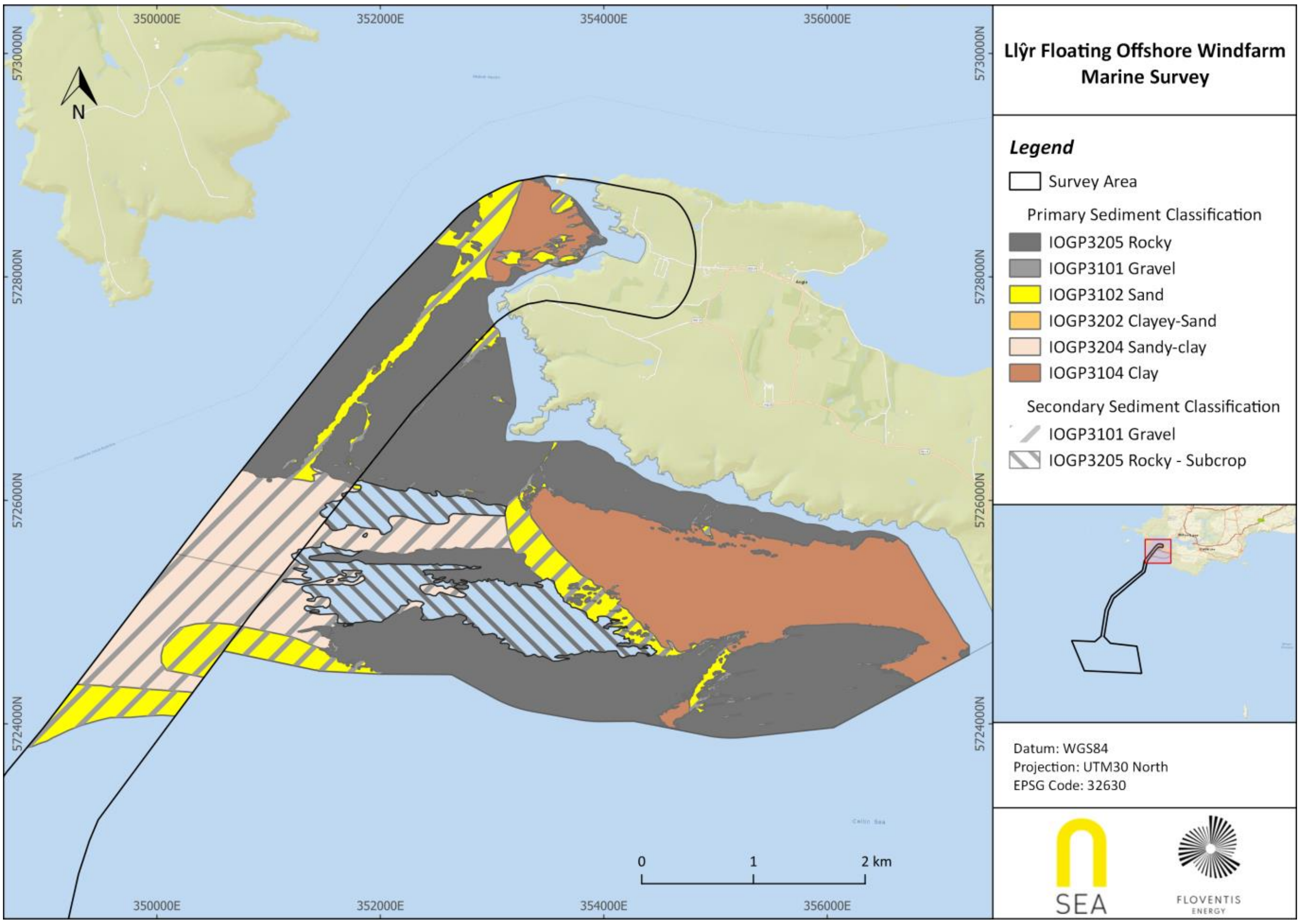


Figure 5-20: ECR North Nearshore and extension areas - seabed sediments interpretation overview

5.2.2 ECR Nearshore

The nearshore section of the ECR (Figure 5-19) has similar morphology types to the Extension area. At the start of the ECR, close to the shore, the seabed is flat and featureless, with occasional patches of megarippled sediments. These megaripples are mostly uniform, sinuous in type, with crests oriented N-S. Wavelengths are approximately 1 m and amplitudes are low, maximum 0.1 m. The megaripples become more frequent to south and west of this section. The most characteristic feature of the nearshore ECR section is the presence of bedrock exposures. These cover entire width of the survey corridor from appoint approximately 1200 m from the shoreline, for another 2.5 km. There is a characteristic trough or gully feature, cutting through the exposed bedrock, generally along the centre of the ECR corridor. From the edge of the rock outcrops, for next 2.6 km, to the boundary of the nearshore section, the seabed has hummocky appearance.

Figure 5-20 shows the overview of the seabed sediments interpretation within the nearshore ECR section. The sediments interpreted along the route have close correlation with the seabed morphology. The featureless areas at the shore approaches are most likely covered with MUD. The megarippled sections coincide with the presence of Gravelly SAND and the hummocky terrain is comprised of Gravelly Sandy MUD. These is likely becoming coarser (Gravelly SAND) towards the southern boundary of the area. The exposed bedrock is likely to be devoid of any sediment cover.

Boulders are present throughout both nearshore sections, which are mostly classified as occasional boulder areas. Localised patches of numerous boulders were also mapped, mostly in the Extension area.

5.2.3 ECR North

The ECR North is situated at the north-eastern edge of the offshore section of the ECR, adjacent to the nearshore area. Figure 5-22, shows an overview of the interpretation of the seabed features in this area.

The seabed features are characterised by a predominately hummocky topography (Figure 5-21) in the northeast of the ECR North adjacent to the nearshore region. The distinct lack of ripples and sand waves in this section indicates a relatively lower energy environment. Hummocky textures are possibly attributable to a thin veneer of sediments overlying the bedrock, which outcrops extensively further east, in the nearshore extension region.

Approximately 2 km from the northern boundary of the ECR North, sand waves trending E-W are present. The largest scale wave features of the ECR North are two sandbanks with crests trending WSW to ENE, with a wavelength of over 400 m and heights up to 5 m (Figure 5-24). Overlying these, are a sand waves with wavelengths of approximately 45 - 80 m and heights up to 2 m. These large-scale features in the ECR North are consistently superimposed by megaripples. The megaripples, throughout most of this section are sinuous to straight in type (Figure 5-23), with crests orientated SW-NE, wavelengths between 1 to 2 m and heights up to 0.4 m. South of the sand waves, the ECR North transitions into a region of predominantly megaripples. The crests of these megaripples run SSW to NNE, with heights varying between 0.1 to 0.4 m and wavelengths ranging from 3.0 to 4.5 m. Crests orientation indicates current direction towards west-north-west.

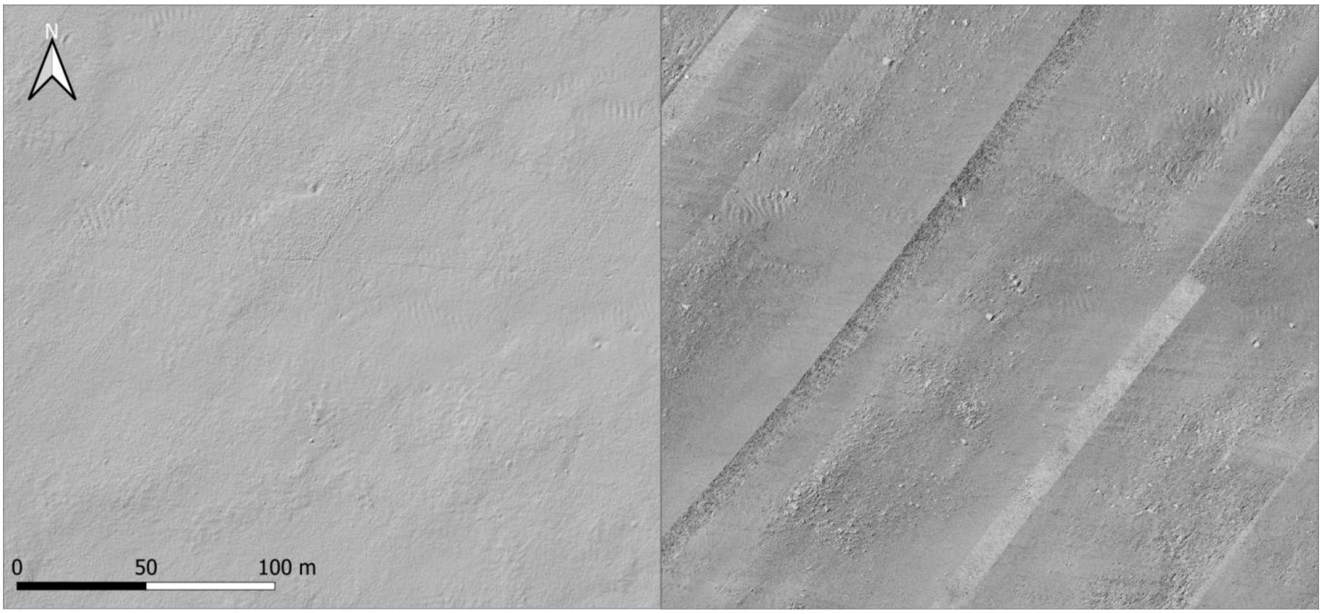


Figure 5-21: ECR North – hummocky seabed IOGP3013 (MBES left, SSS right)

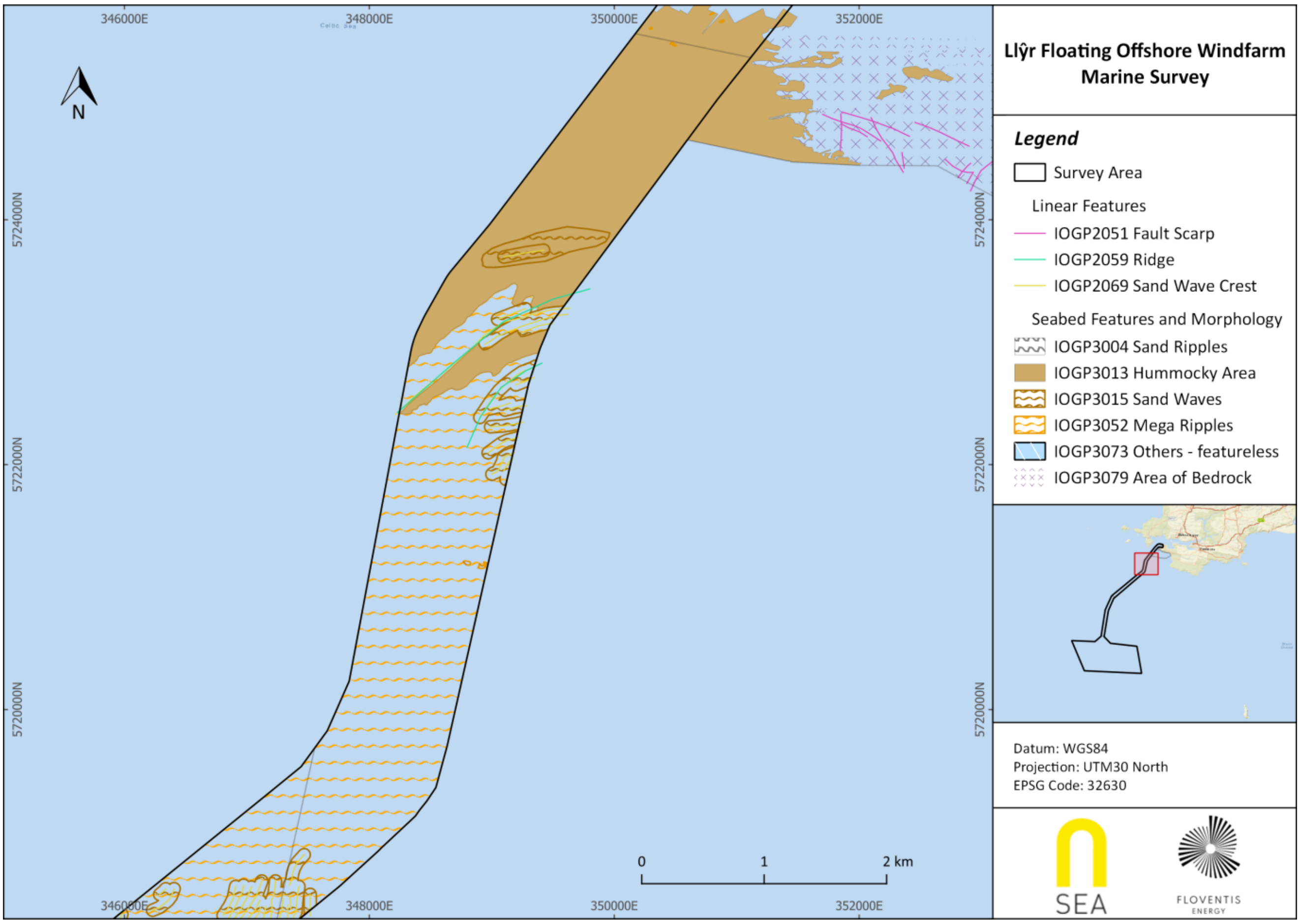


Figure 5-22: ECR North - seabed features interpretation overview

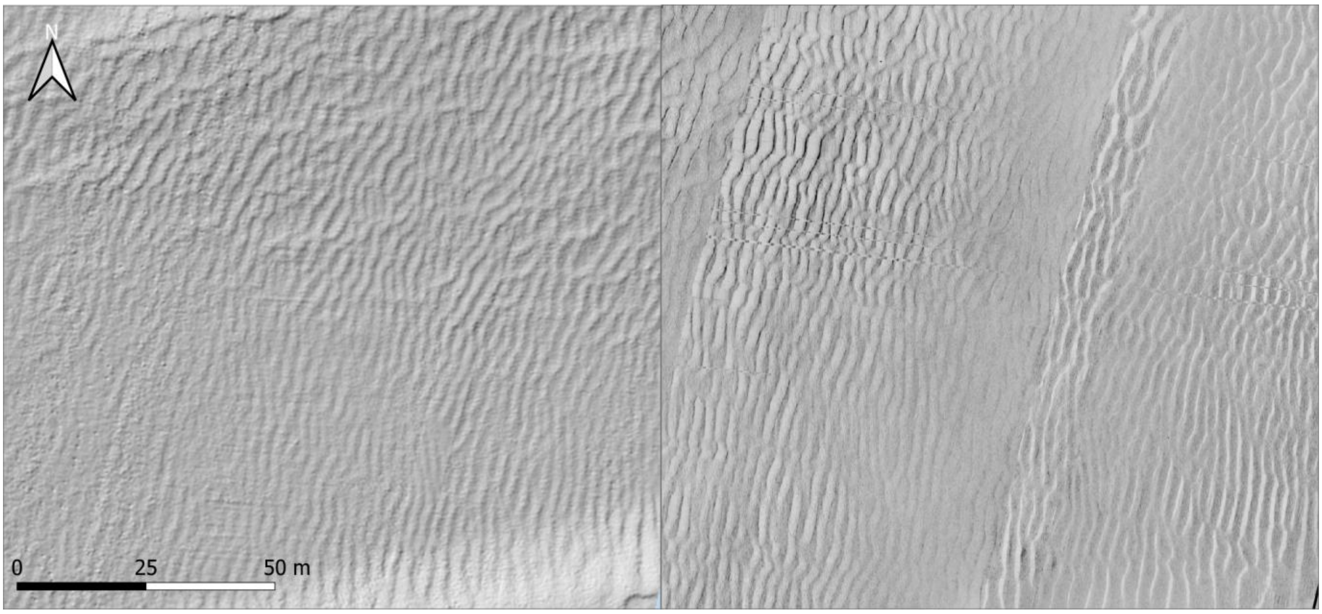


Figure 5-23: ECR North – straight to sinuous megaripples IOGP3013 (MBES left, SSS right)

Figure 5-25 shows the majority of the ECR North region covered with uniform medium to medium-high reflectivity sediments, interpreted as Gravelly Muddy SAND, with thin regions of SAND that sometimes coincide with the sand waves cutting through the ECR. However, for the first 1.5 km of the ECR North block, the seabed has been interpreted to have a composition of Gravelly muddy SAND. This region also contains a large boulder field (IOGP3075), within which 18 contacts have been interpreted as debris. The next 2 km alternate between bands of gravelly sandy MUD, and Gravelly SAND. Further south, the seabed composition interchanges between gravelly muddy SAND and portions of SAND.

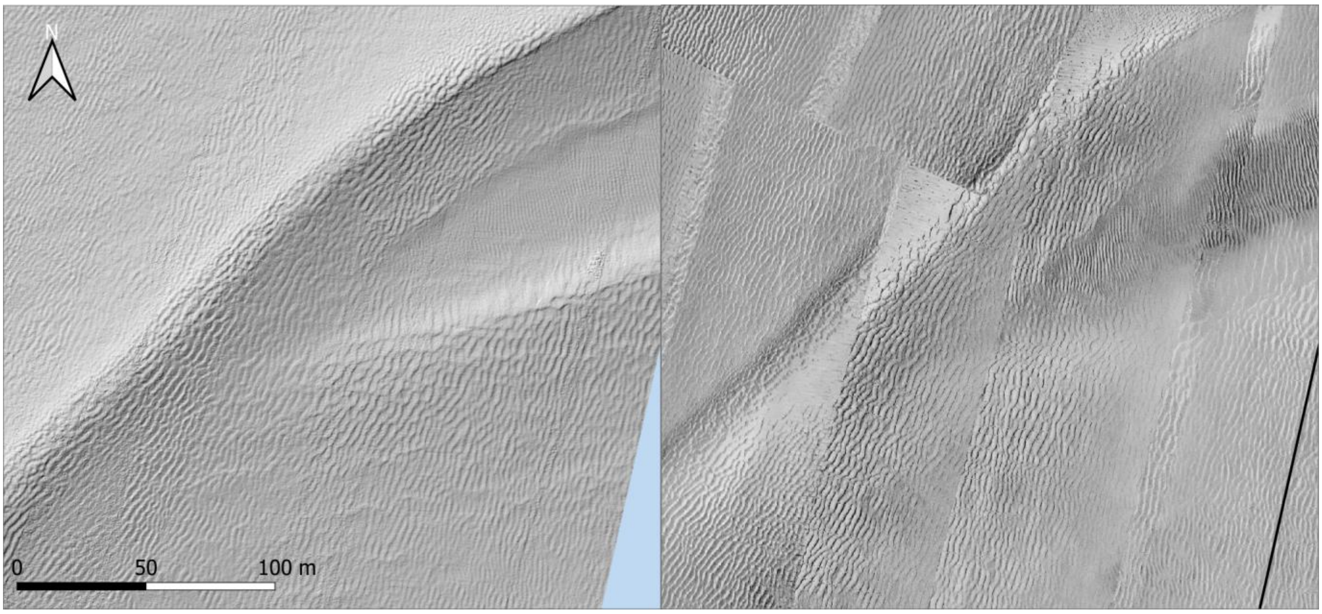


Figure 5-24: ECR North – sandbank (MBES left, SSS right)

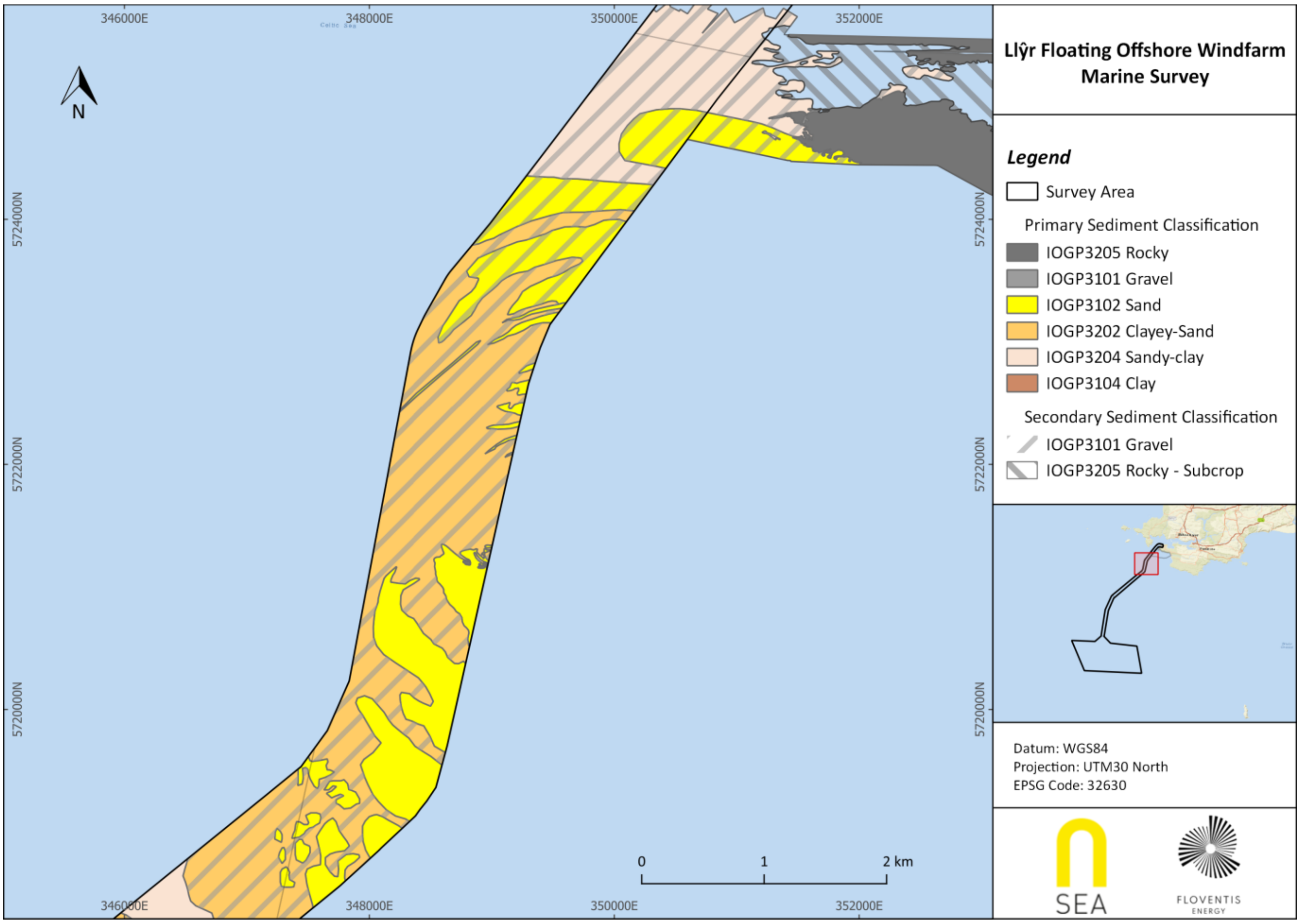


Figure 5-25: ECR North – seabed sediment interpretation overview

5.2.4 ECR Centre

ECR Centre is situated to the southwest of the ECR North. Figure 5-26, shows an overview of the interpretation of the seabed features in this area.

The features of the ECR Centre are predominantly characterised by megaripples. The crests of these megaripples run SW to NE with wavelengths ranging between 3 and 4 m and heights up to 0.5 m, indicating a SE to NW current direction. The first 3 km of the ECR Centre are classified as large sand waves (up to 1.2 m in height, with wavelengths between 20 and 200 m) with superimposed megaripples. Sand wave crests in the ECR Centre area display variable directions (SSW-NNE to W-E) that are non-conforming with overlying megaripples' crests. Bifurcation of these sand waves is also apparent at their southern extents (Figure 5-27), possibly indicating a turbulent flow regime. There are small sections (6 to 100 m wide, 7 to 170 m long) of isolated outcropping bedrock in this region (Figure 5-28), with a possible anticline hinge and associated internal bedding visible. The features of the ECR Centre then transition into a flat area roughly 1 km in length, which extends into a sandbank, up to 5 m heigh, with slopes not exceeding 3°. This sandbank crosses the route corridor E-W, immediately to the south of the featureless area. South of this sandbank, the ECR Centre changes to an area of sand waves with superimposed megaripples for another 2 km. The megaripples in this section have crests orientated SW-NE, wavelengths 3 to 4 m and heights up to 0.3 m, while the sand waves are sparsely spaced, with wavelengths between 300 to 600 m, crests running WSW-ENE and heights up to 4 m. The last 2 km of the ECR Centre are once more characterised by megaripples, here with larger wavelengths (7 to 15 m), crests orientated SW-NE and heights between 0.1 and 0.2 m (Figure 5-26).

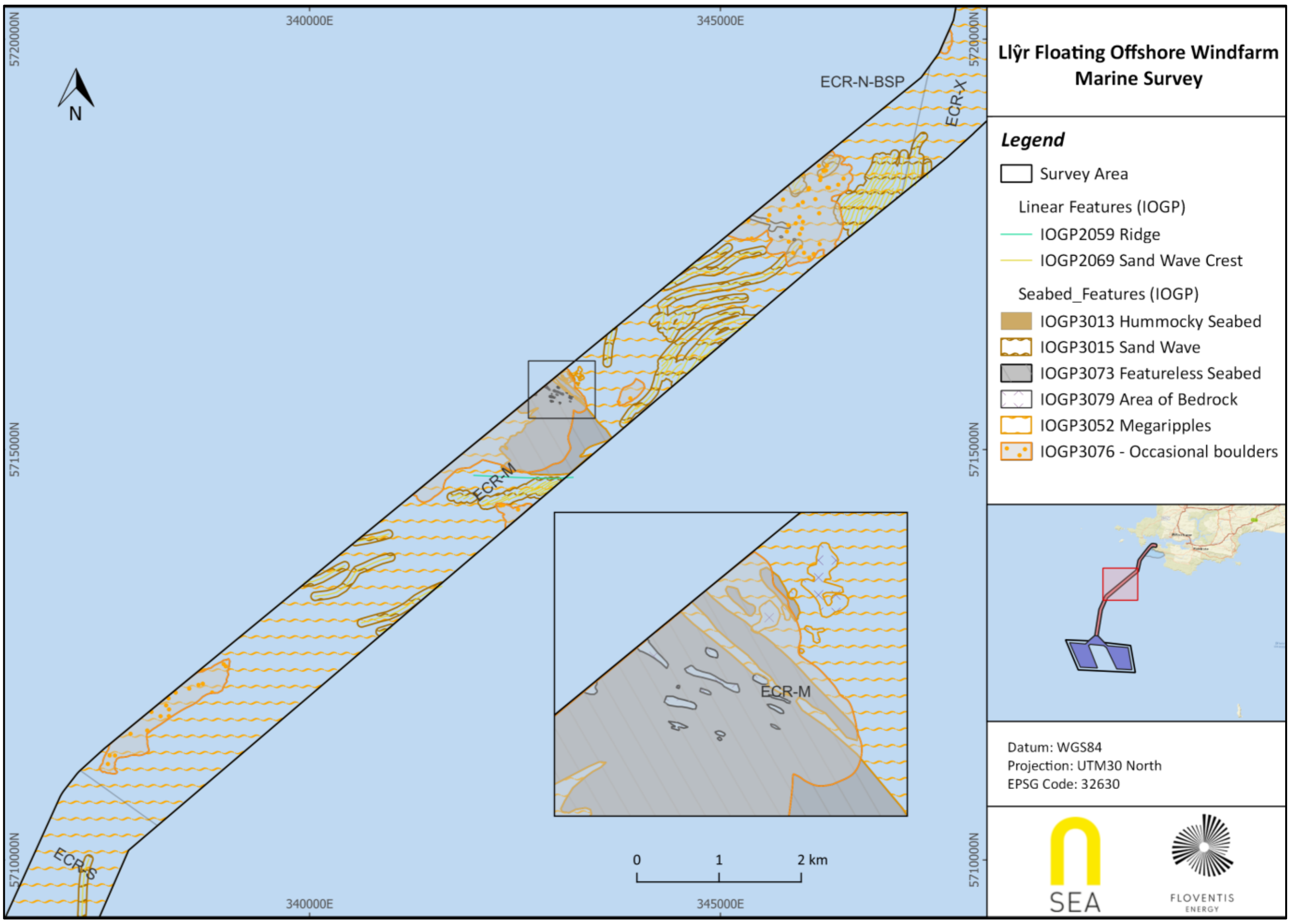


Figure 5-26: ECR Centre – seabed features interpretation overview

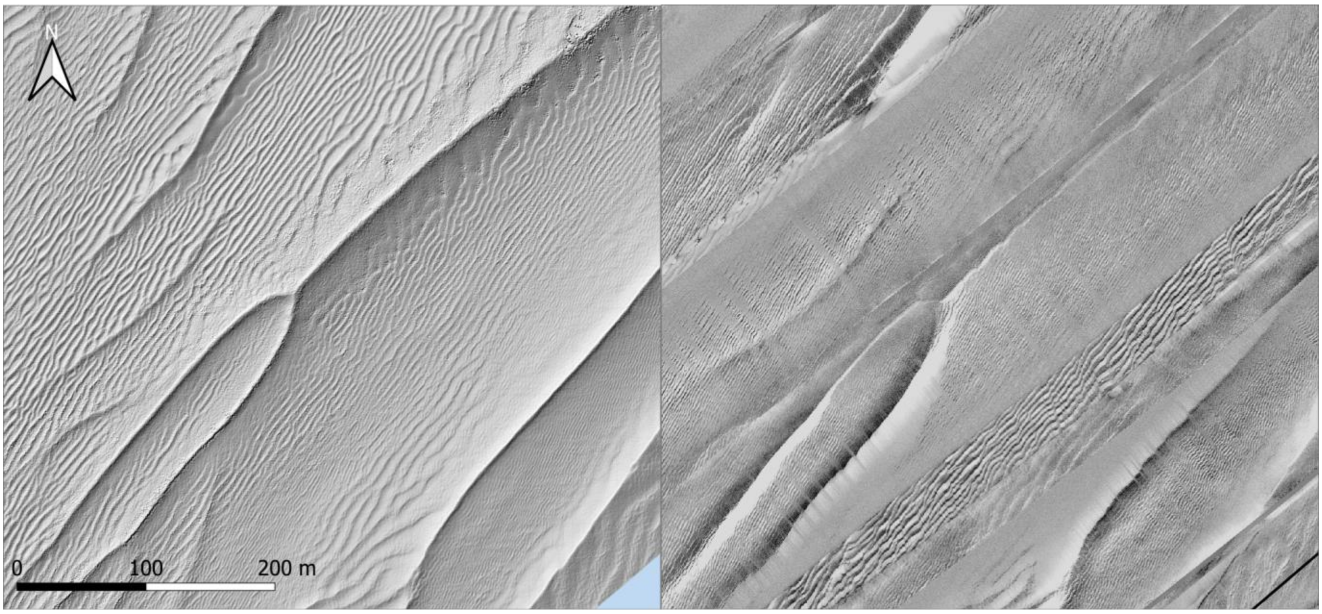


Figure 5-27: ECR Centre – sand waves bifurcation (MBES left, SSS right)

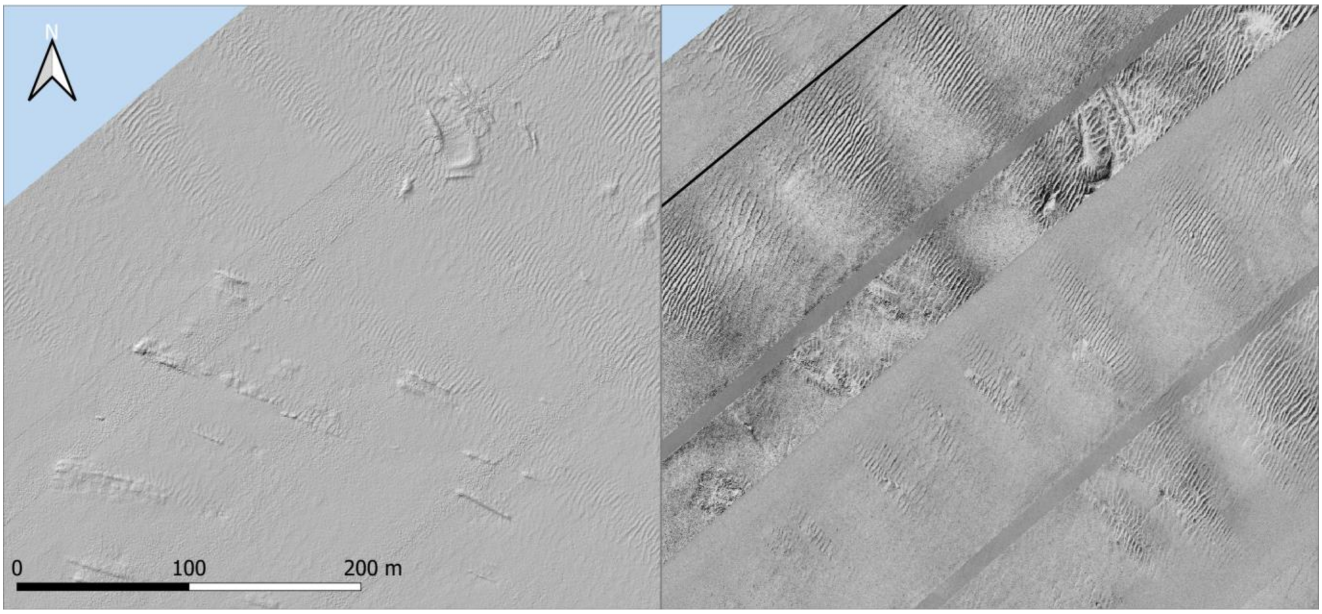


Figure 5-28: ECR Centre – bedrock outcrops (MBES left, SSS right)

Figure 5-29: ECR Centre – seabed sediment interpretation overview

Uniform, medium to medium-high reflectivity sediments are visible throughout the block. The first 2 km of the ECR Centre region is interpreted to be composed of Sandy MUD and Gravelly Muddy SAND. The following two 2 km are uniquely Muddy SAND. Moving south of this point, a transition back into Gravelly Muddy SAND is apparent, with areas of rock outcrop. Finally, the seabed composition appears to change into Muddy SAND until the end of the ECR Centre block (Figure 5-29).

5.2.5 ECR South

The ECR South is situated to the southwest of the ECR Centre. Figure 5-30 shows an overview of the interpretation of the seabed in this area.

The first 4 km of the ECR South area are dominated by megaripples, superimposing occasional sand waves (Figure 5-31). Megaripples have crests orientated SW-NE, wavelengths ranging from 7 to 15 m and heights reaching up to 0.3 m. The sand waves have crests running SSW to NNE, with wavelengths between 250 to 400 m and heights of 4 to 5 m. The rest of the ECR is covered in megaripples, generally straight in shape (Figure 5-32), with wavelengths on average between 8 and 10 m, heights up to 0.2 m and crests orientated SSW to NNE, indicative of a dominant current towards WNW direction.

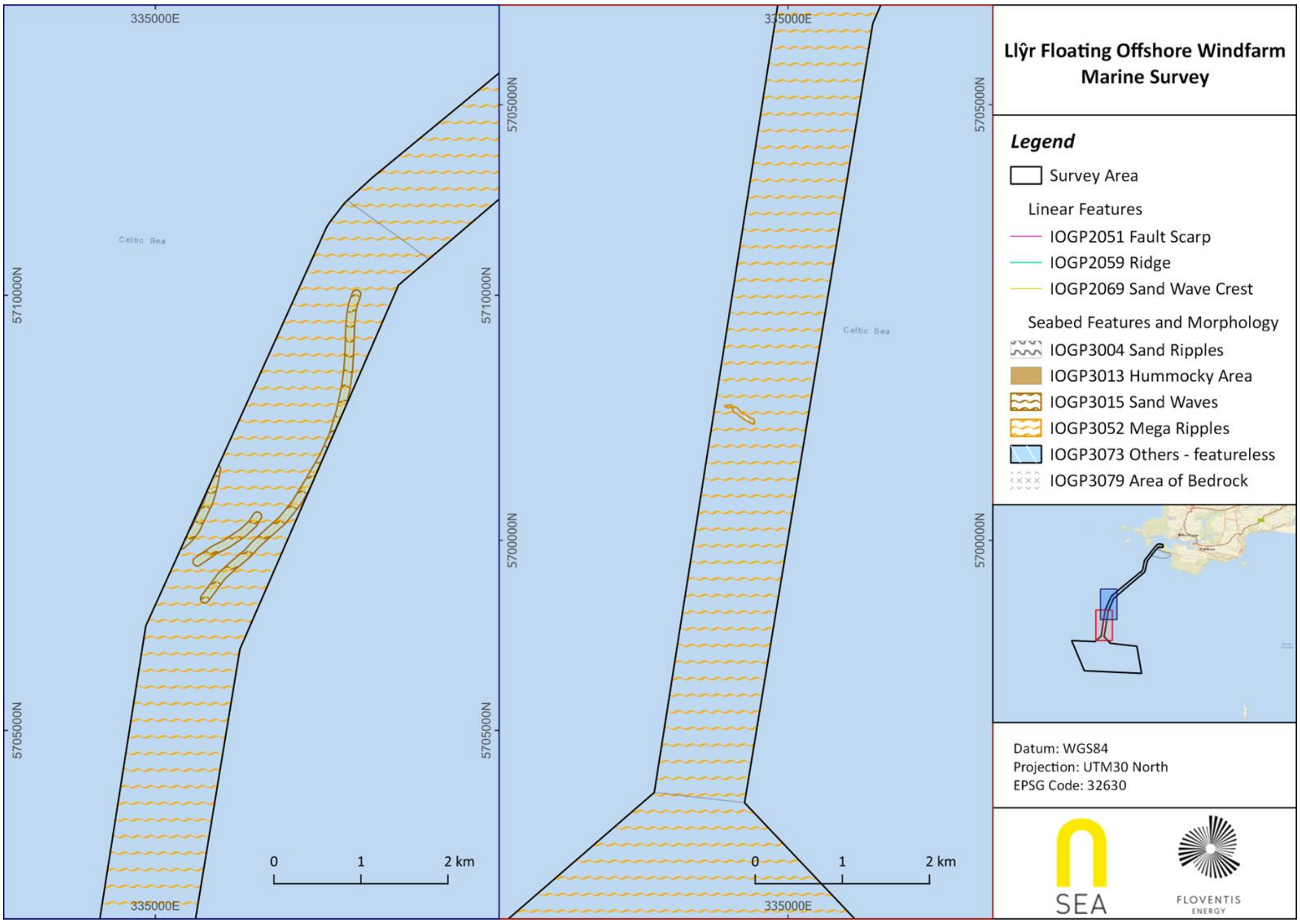


Figure 5-30: ECR South – seabed feature interpretation overview

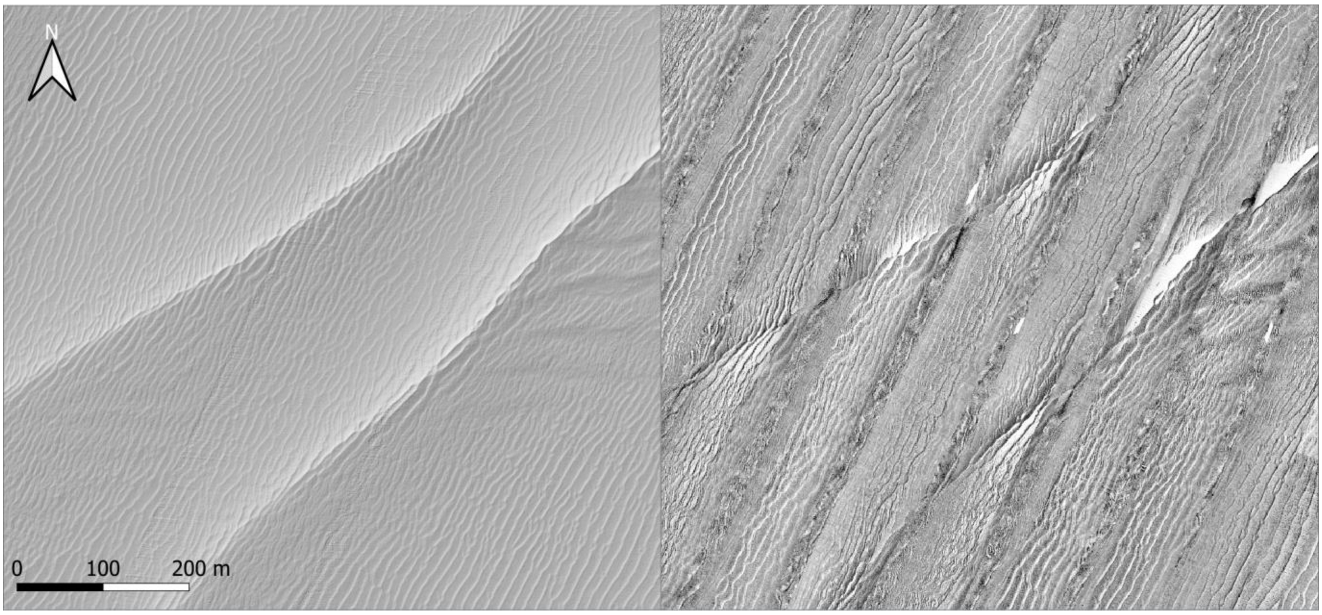


Figure 5-31: ECR South – sand waves (MBES left, SSS right)

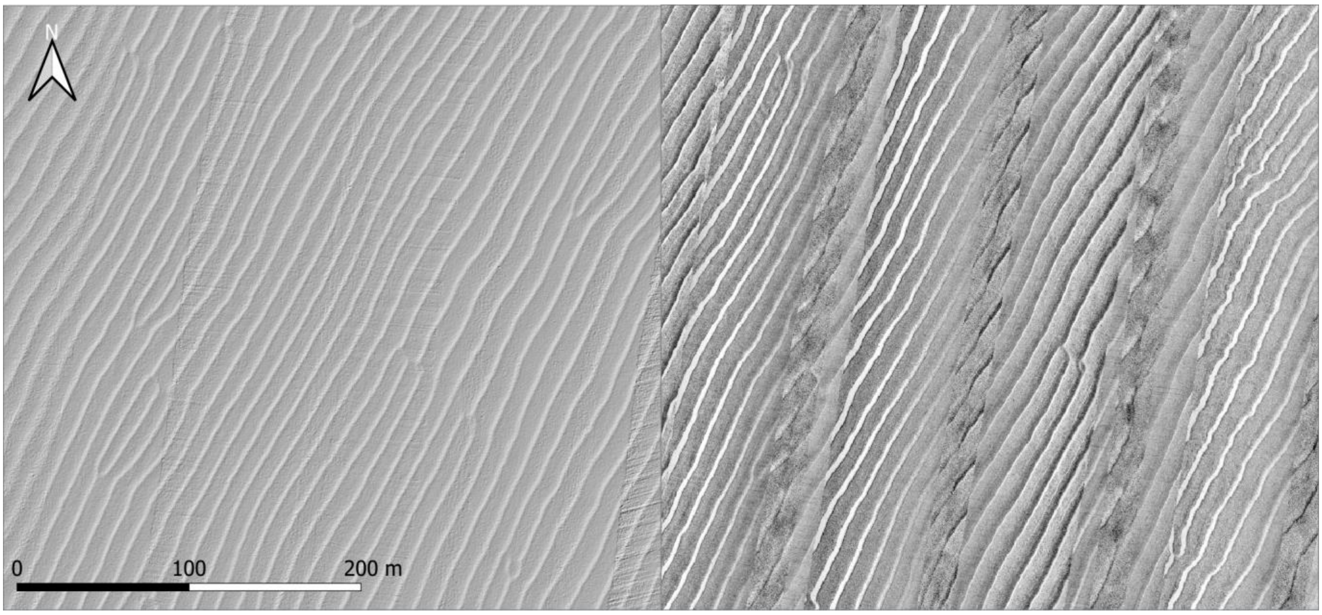


Figure 5-32: ECR South – straight megaripples (MBES left, SSS right)

Most of the ECR South is relatively uniform in comparison to the ECR North and the ECR Centre. Figure 5-33 shows the ECR South covered with medium-high reflectivity sediments which have been classified as Muddy SAND, with occasional intersections of Sandy MUD. Grab samples from the environmental survey were used to ground truth the sediment reflectivity contrasts.

Figure 5-33: ECR South - seabed sediment interpretation overview

5.2.6 Offshore Wind Farm Area

The OWF Area is situated south of the ECR. Multiple trawl scars were detected across the OWF (Figure 5-44). The frequency of trawl scars increases to the south of the OWF survey area. Especially prolific in the southeast, evidence of recent fishing activity in the area.

Seabed features such as megaripples are present throughout the survey area. Their wavelengths range from 7 to 12 m. The crests of these features are broadly perpendicular to the current direction, running in an approximate NNE to SSW direction (Figure 5-35). Heights of the megaripples range from 0.2 to 0.3 m on average. Ripples are generally asymmetrical with their lee side on the WNW side (Figure 5-37), indicating a prevailing current direction toward this direction. In the northeast of the OWF, sand wave are visible, with crests running in an approximate ENE to WSW direction and reaching height of 0.6 m maximum.

Located in the northwest region of the OWF there is a thin elongated region of flat seabed (Figure 5-34), potentially indicating a lower energy environment there. Interpretation overview is shown in Figure 5-36.

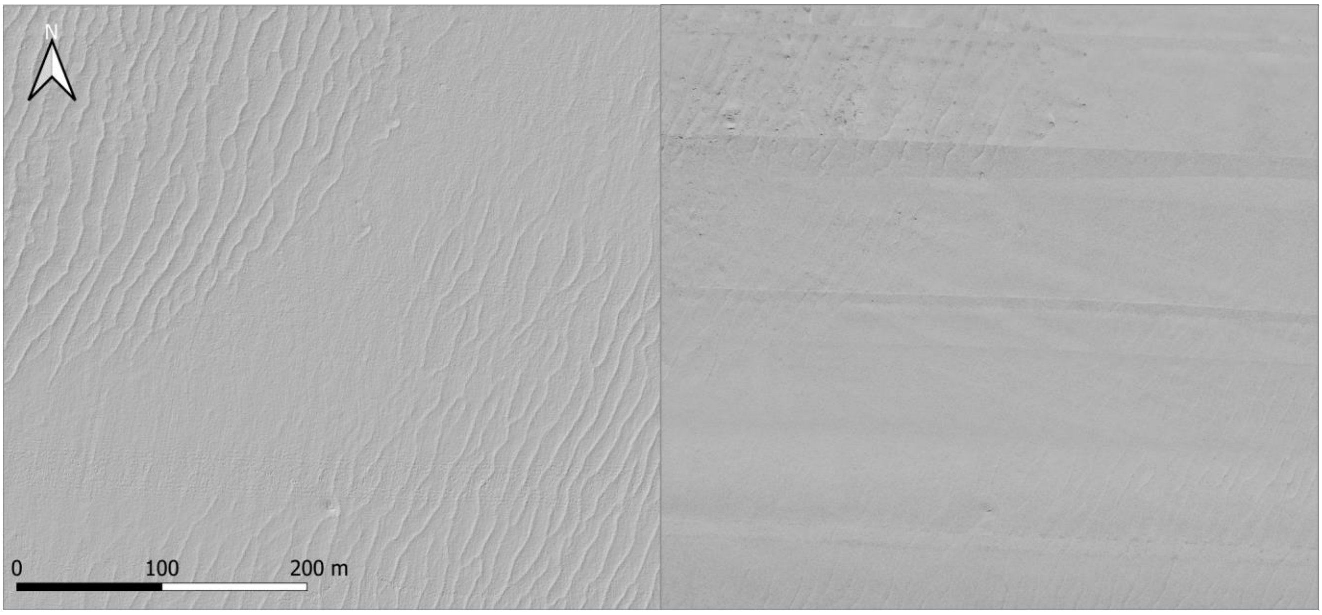


Figure 5-34: OWF – patch of featureless seabed (MBES left, SSS right)

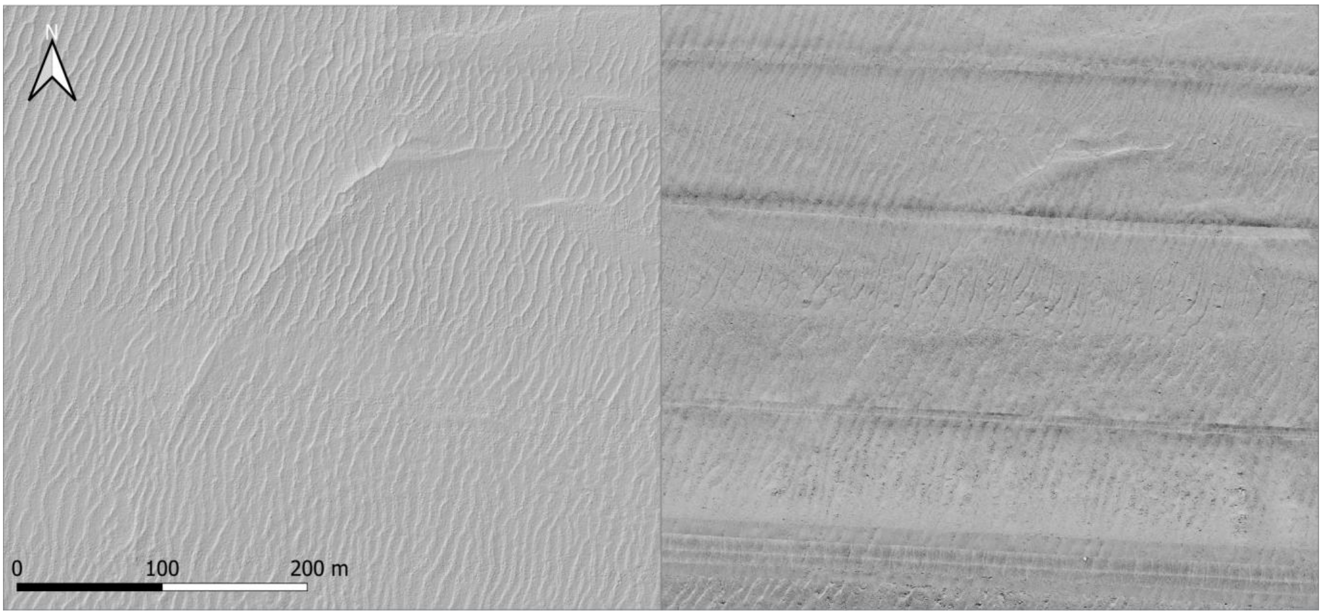


Figure 5-35: OWF –sand wave and megaripples (MBES left, SSS right)

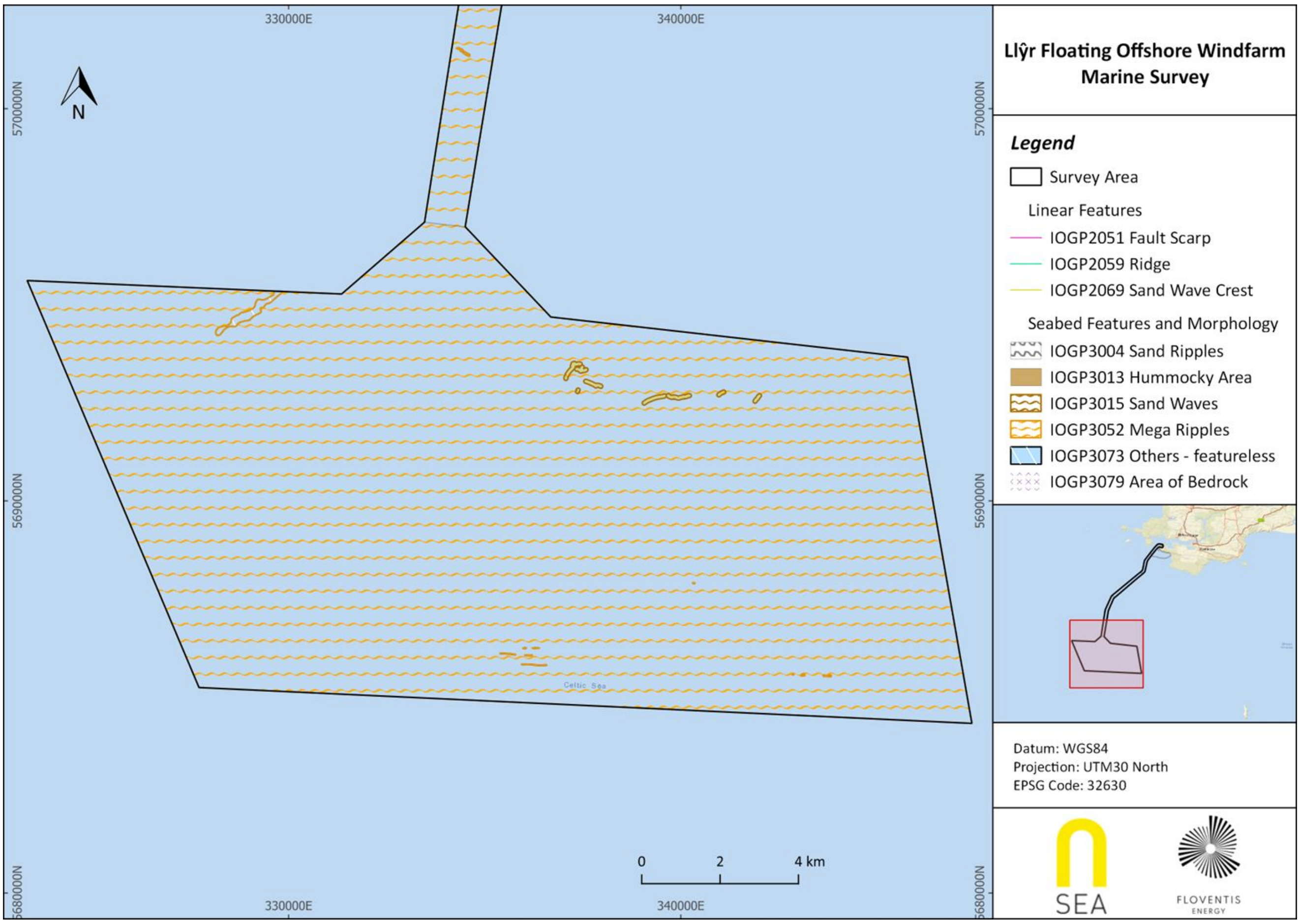


Figure 5-36: OWF – seabed feature interpretation overview

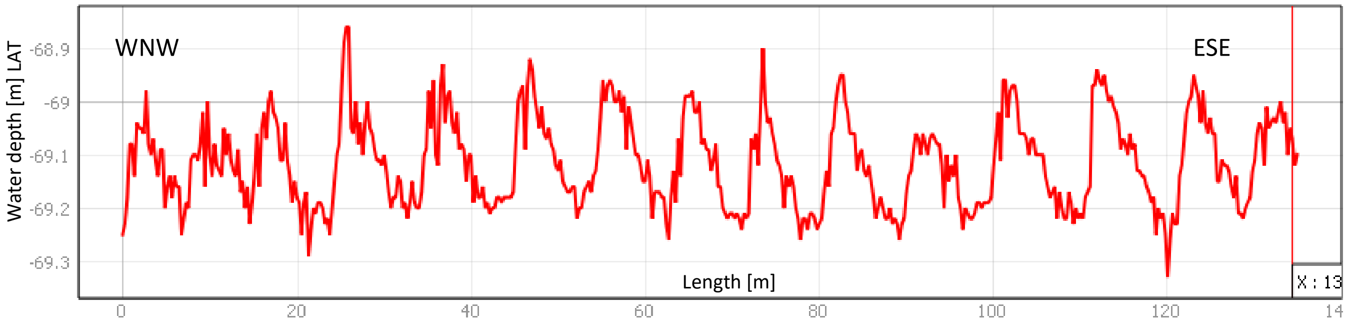


Figure 5-37: Megaripples cross-section showing the asymmetry in shape, wavelengths and heights

Figure 5-38 shows an overview of the sediment composition within the OWF survey area. SAND, Muddy SAND and Sandy MUD make up the entirety of the region. Muddy SANDs and Sandy MUDs are interpreted to be interwoven throughout the northern two thirds of the OWF, the sediment then transitions into predominately SAND in the south.

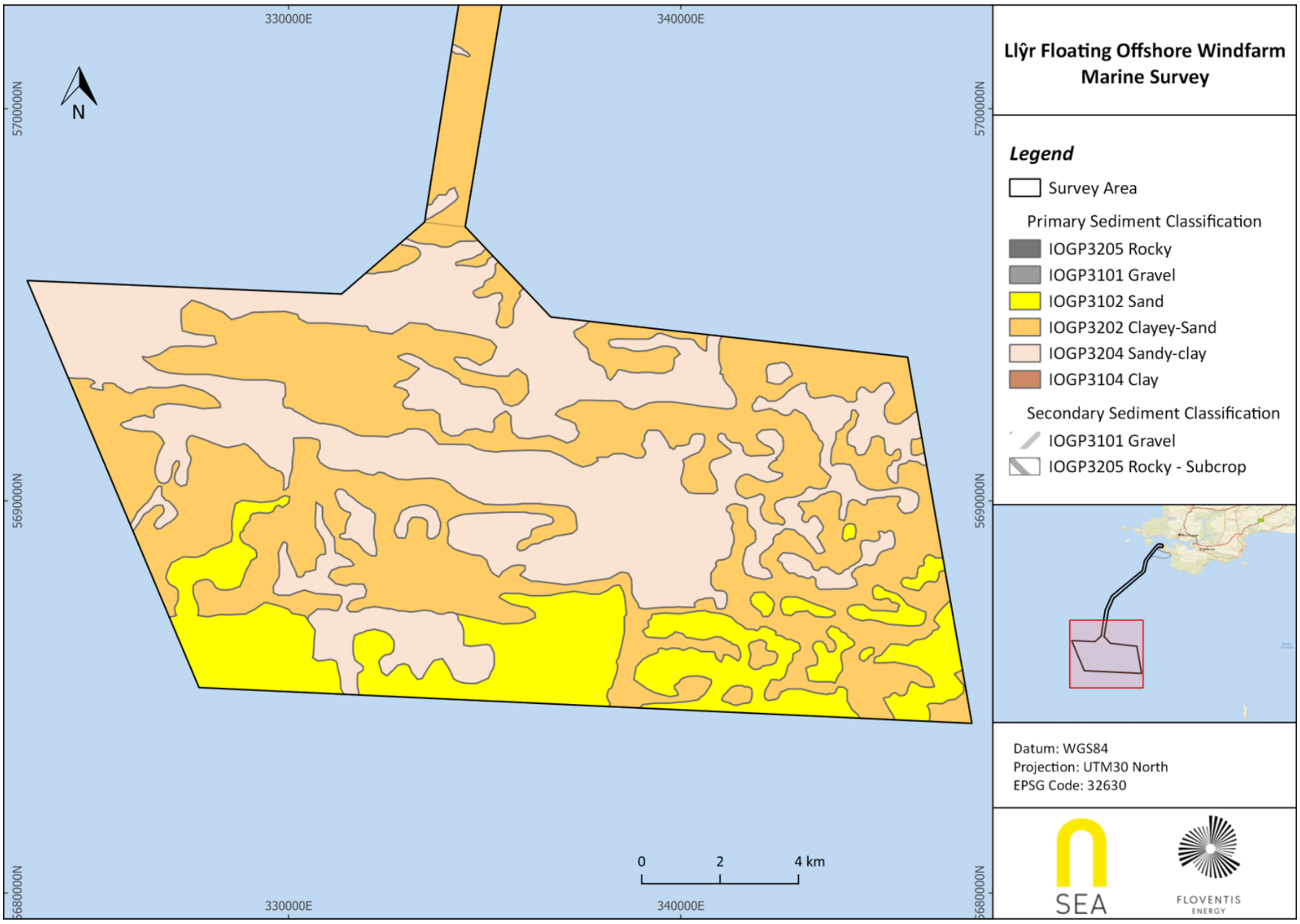


Figure 5-38: OWF – seabed sediment interpretation overview

5.2.7 Sediment Migration

As mentioned in the previous sections, a vast majority of the survey area is covered by mobile sediments. Figure 5-39 provides an overview of the expected sediment migration directions, based on the megaripples shape across the site. The arrows point towards the expected prevailing current direction while the arrow size is proportional to the megaripples wavelength. It reveals an expected sediment migration towards WNW.

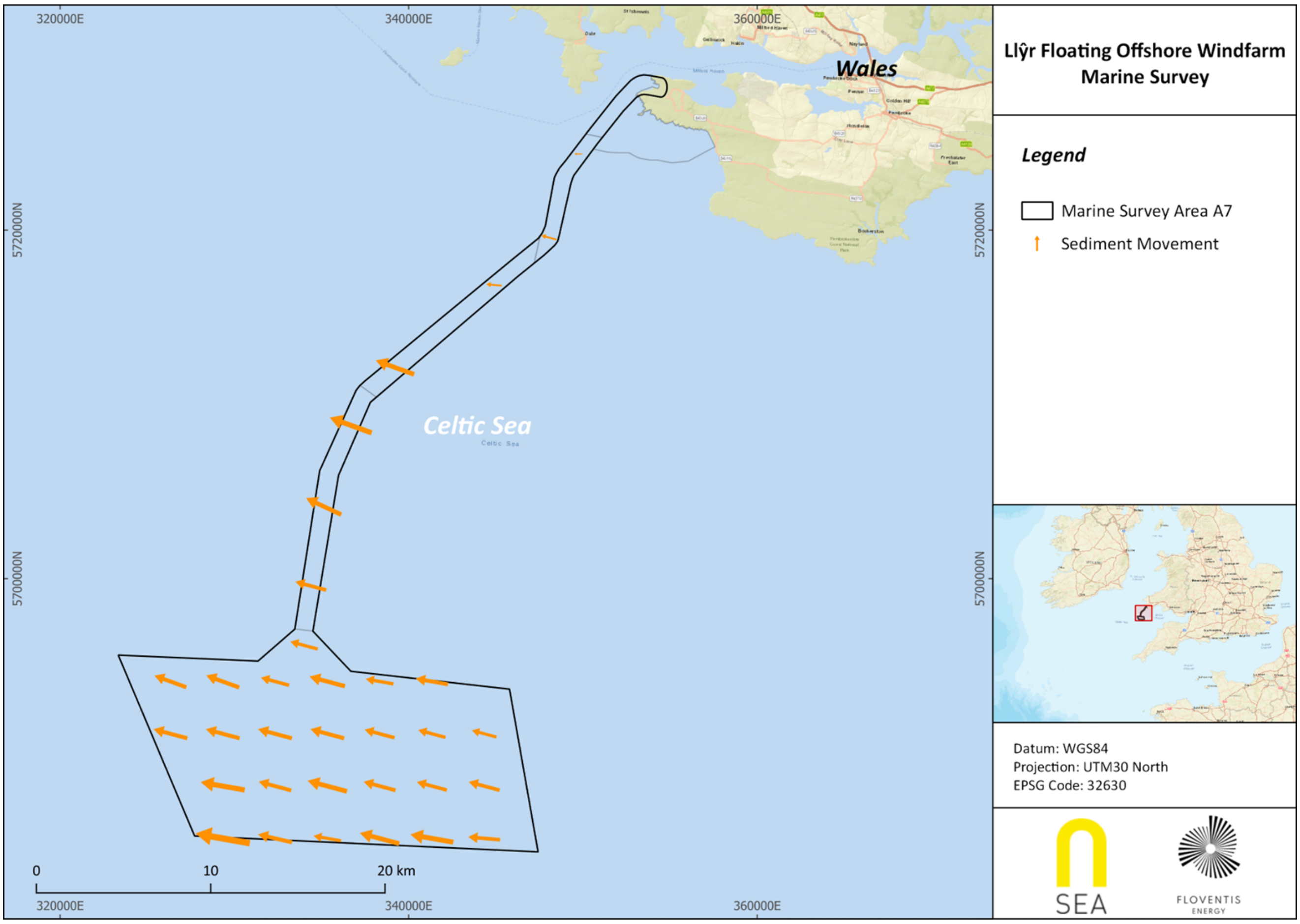


Figure 5-39: Sediment movement based on megaripples characteristics

5.3 SIDE SCAN SONAR CONTACTS

Table 5-2 summarises the results of the seabed contact picking.

Table 5-2: SSS discrete target summary

Contact Type	Nearshore Extension	Nearshore ECR	ECR	OWF	Total
Isolated Boulders	180	39	390	6360	6969
Debris	4	46	31	77	158
Wreck	0	3	1	1	5
Linear Debris	2	21	0	3	26
Trawl scars	0	0	6	3213	3219
Cables	0	0	0	0	0*
Total	186	109	428	9654	10377
* *Cables were detected on magnetometer data. See section 5.5.2 for further details*					

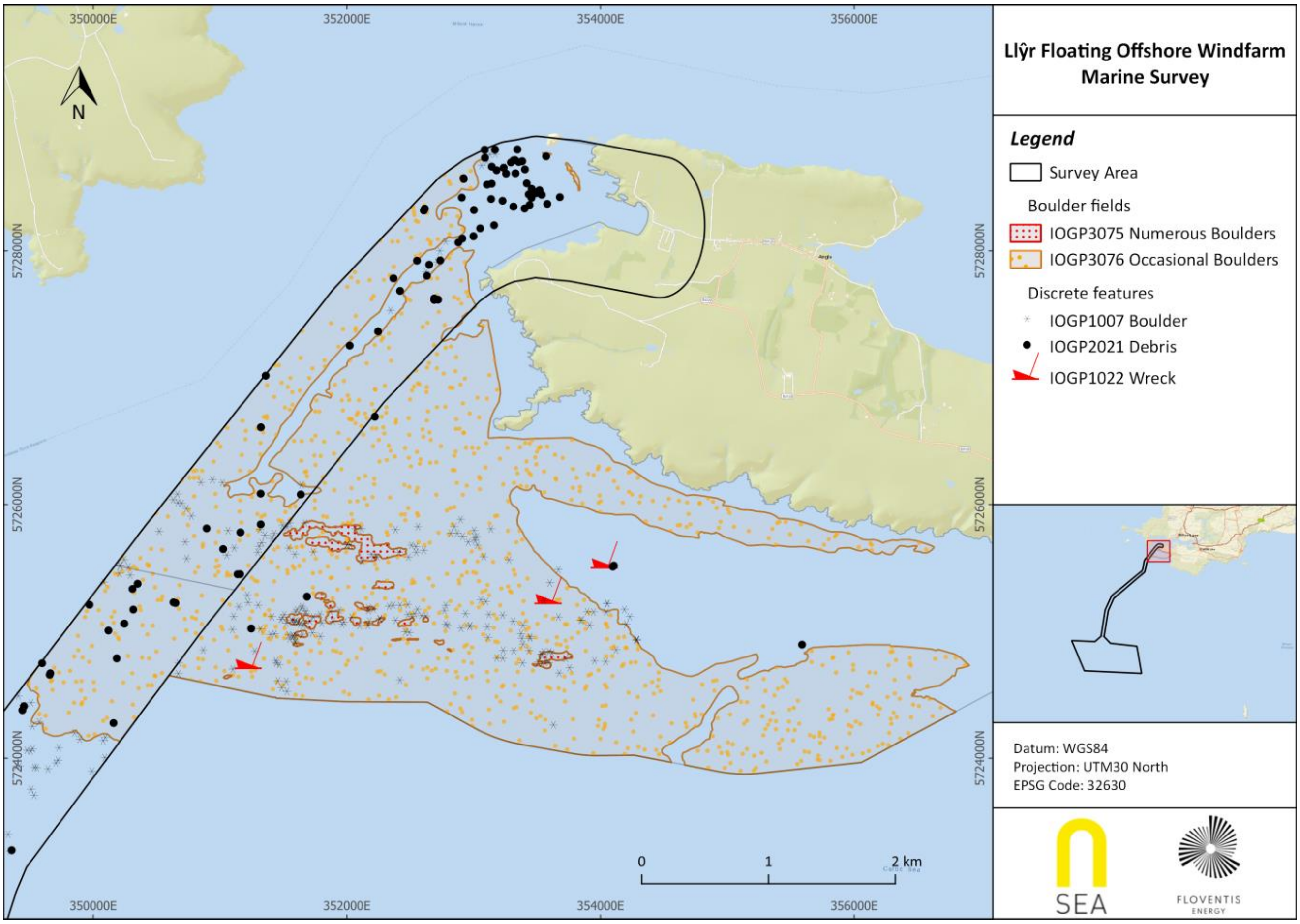


Figure 5-40: ECR North Nearshore and extension - boulders and SSS contacts overview

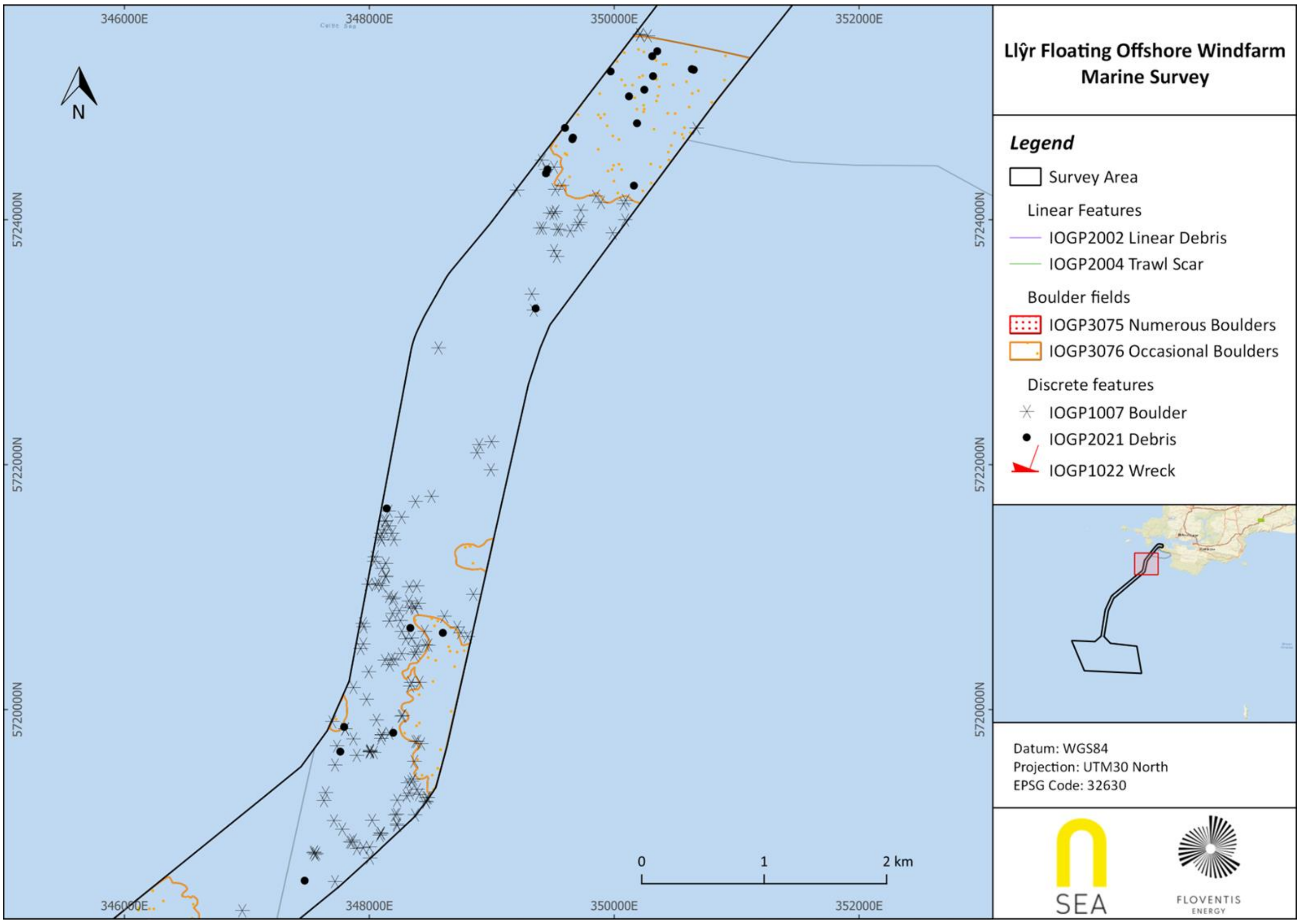


Figure 5-41: ECR North - boulders and SSS contacts overview

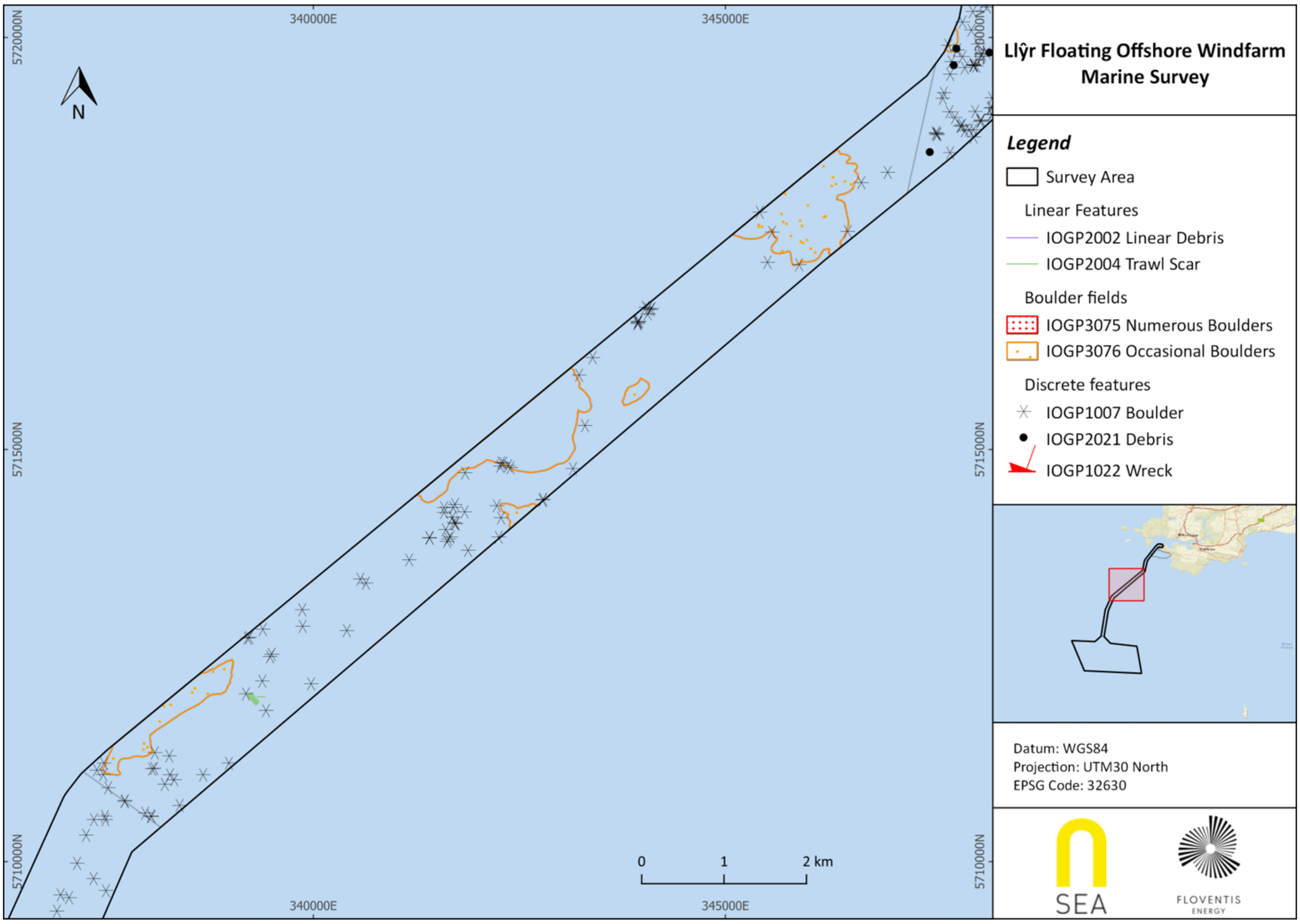


Figure 5-42: ECR Centre - boulders and SSS contacts overview

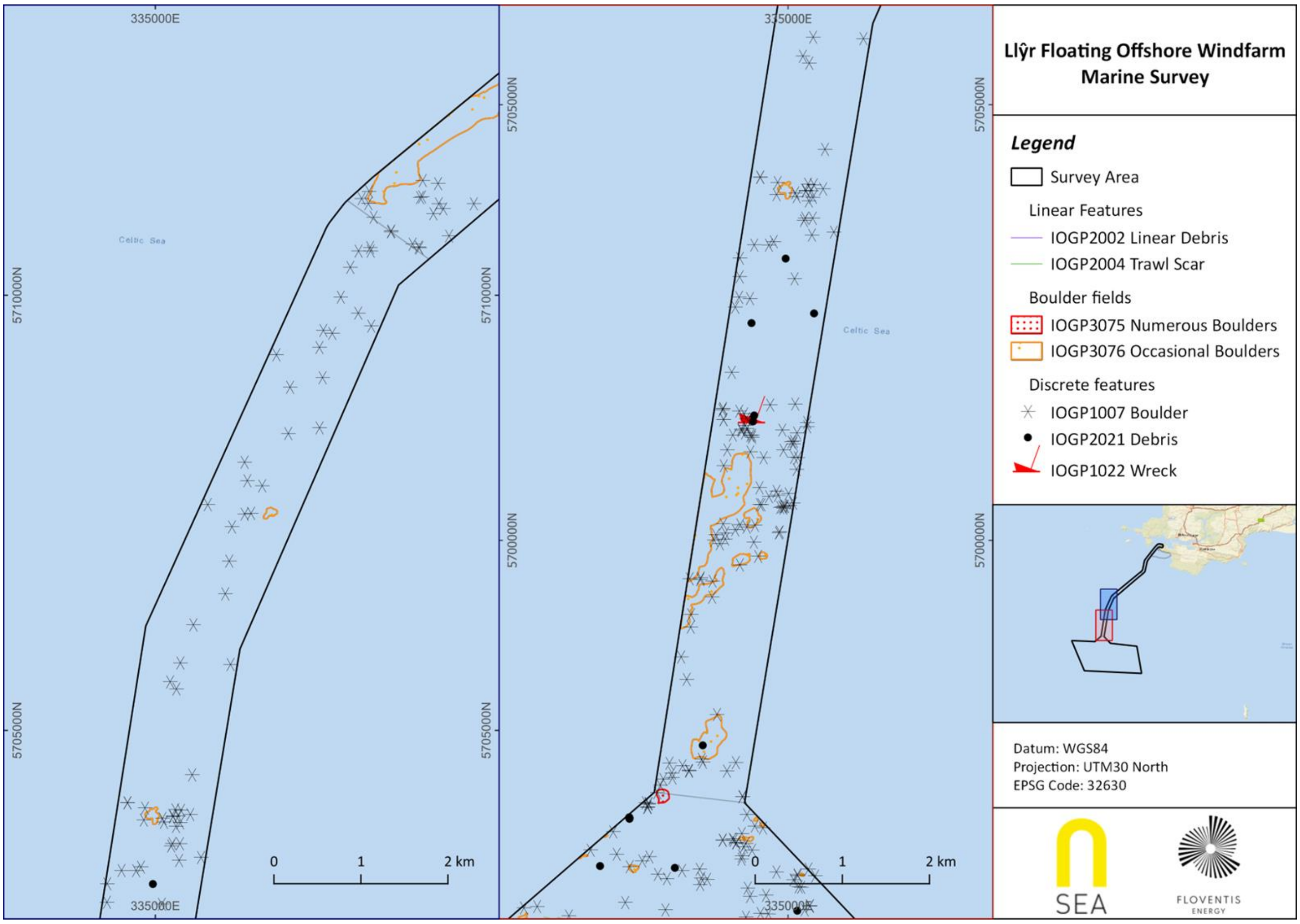


Figure 5-43: ECR South - boulders and SSS contacts overview

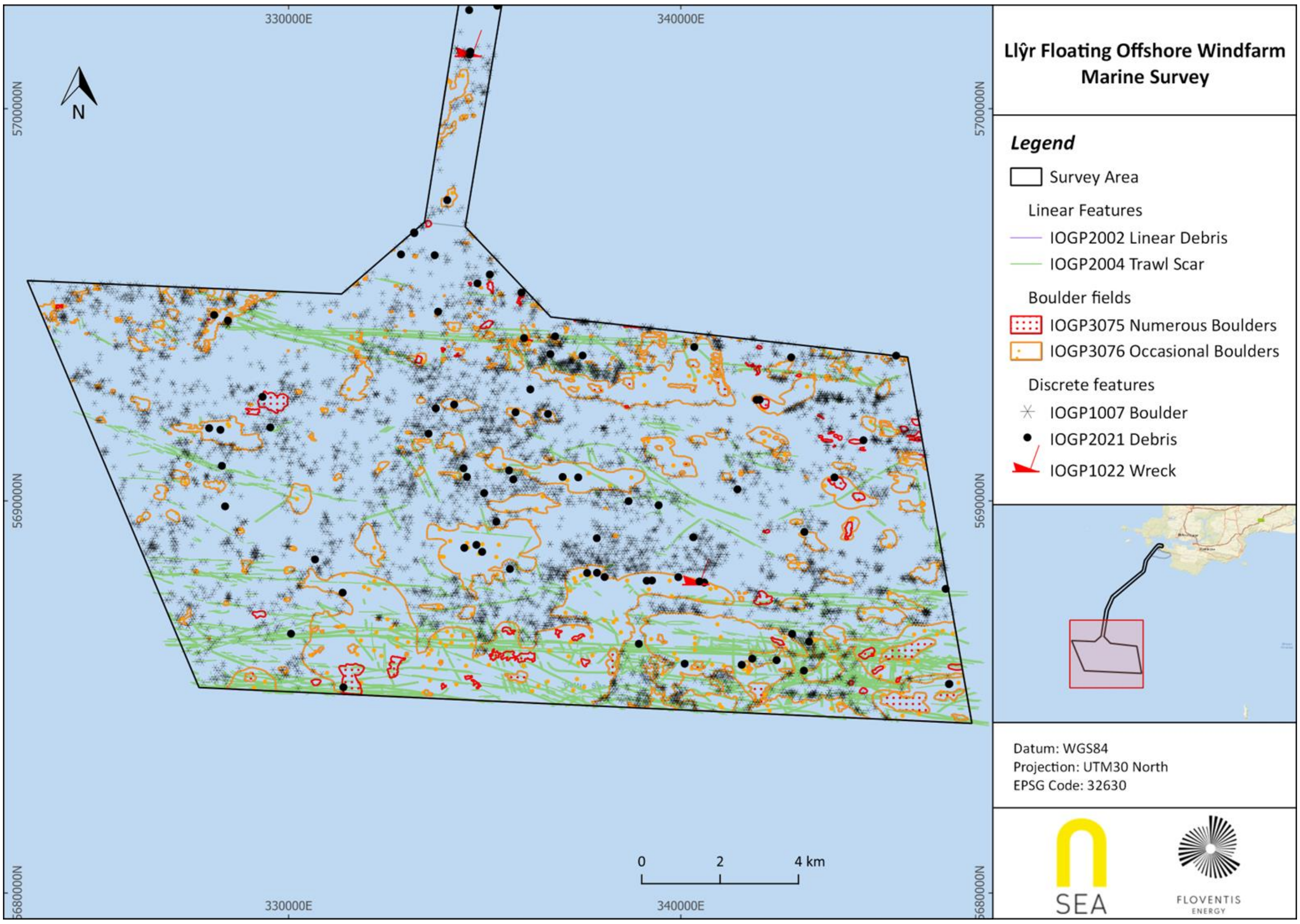


Figure 5-44: OWF - boulders and SSS contacts overview

5.4 MAGNETOMETER

5.4.1 Summary

A total of 1163 magnetic anomalies above 5 nT peak-to-peak amplitude threshold have been picked from the magnetic residual field profiles, 286 in the OWF block, 223 in the ECR blocks and 654 in the nearshore section. Of these, 88 are associated with linear features and interpreted as either cables/chains/steel wire ropes or geology.

Three E-W orientated linear anomalies confirm the location of the following cables (from north to south): GEMINI NORTH – Seg 2, TATA ATLANTIC NORTH and an unknown cable. Unfortunately, the E-W orientation of the survey lines within the OWF area was not favourable for accurately defining the location of several sections of these cables. Further details are provided in section 5.5.2.

Numerous unidentified targets were difficult to interpret with any certainty due to the wide survey line spacing. Some are likely related to the geology of the survey area, perhaps magnetic boulders. The five wrecks interpreted from the SSS data were also detected by the magnetometer survey. However, the interpretation of many of the magnetic anomalies could not be made with a high level of confidence. A detailed magnetometry survey, ideally utilising a gradiometer array, would be recommended to ascertain UXO risk and any existing buried infrastructure (e.g. cables).

Table 5-3: Summary of magnetic anomalies (> 5nT)

Anomaly Classification	Nearshore	ECR	OWF	Total
Other/Geology	639	205	224	1068
Linear Feature	11	16	61	88
Wreck	4 (3 wrecks)	2 (1 wreck)	1	7
Total	654	223	286	1163

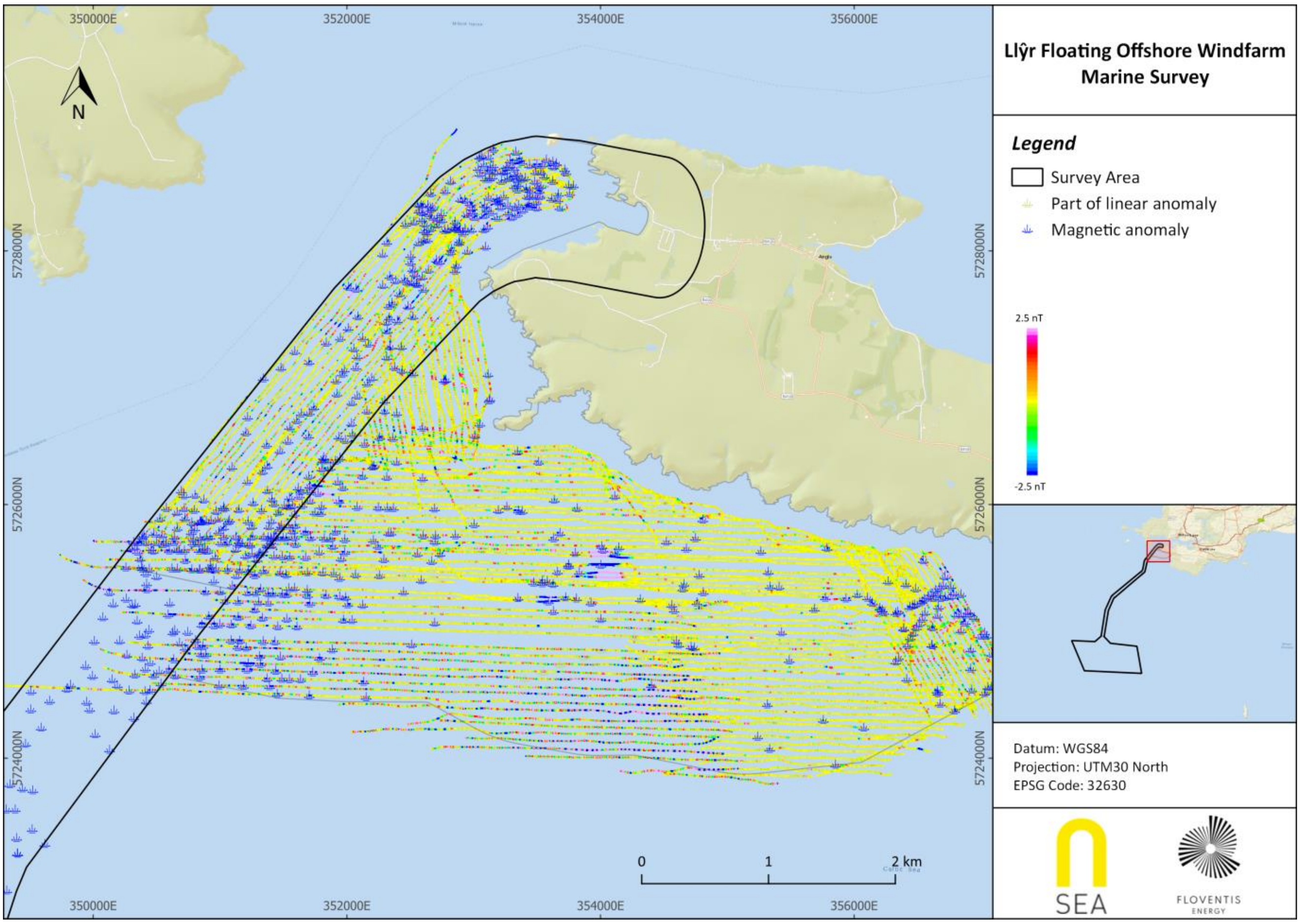


Figure 5-45: Overview of magnetic survey results – Nearshore

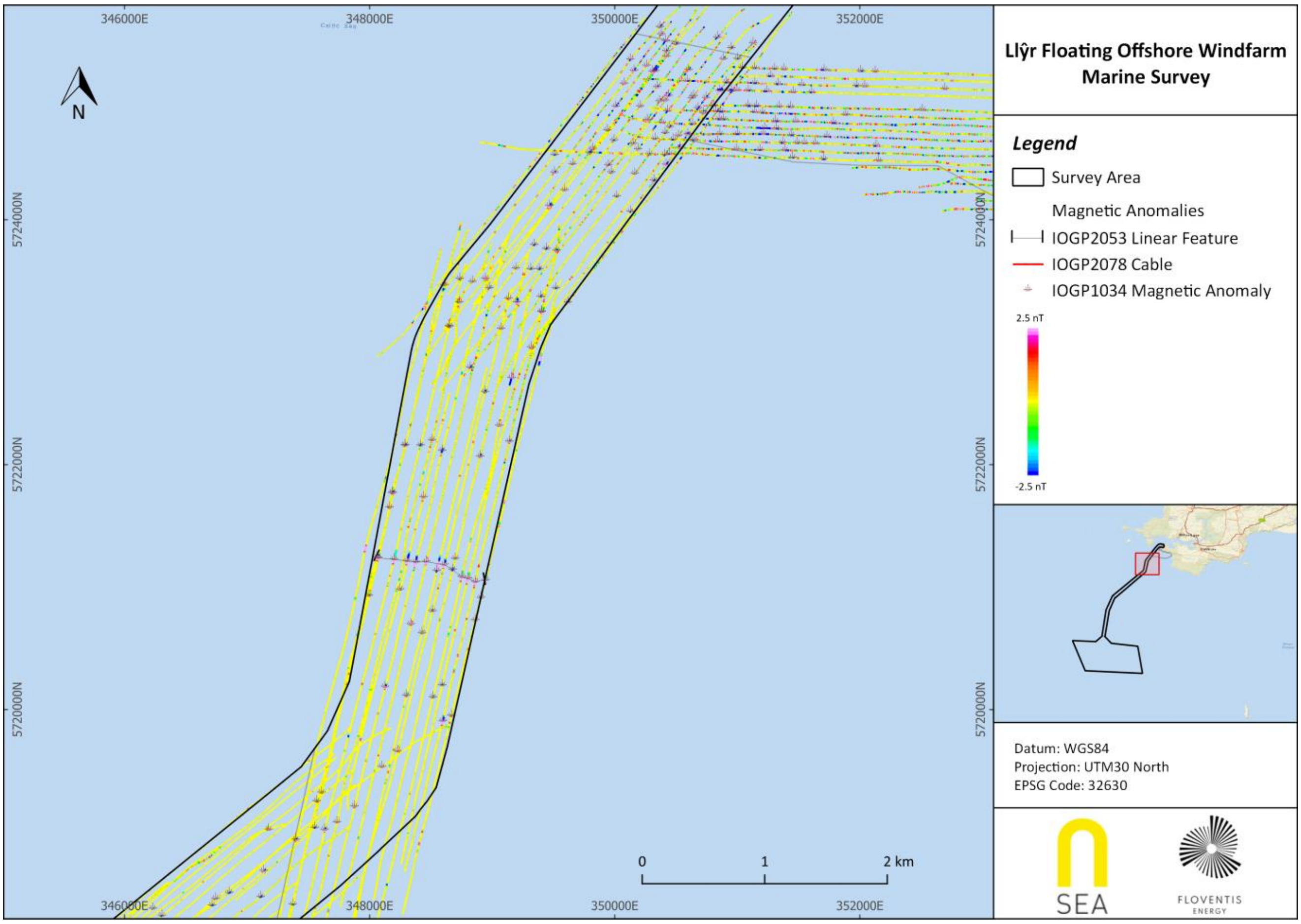


Figure 5-46: Overview of magnetic survey results – ECR North

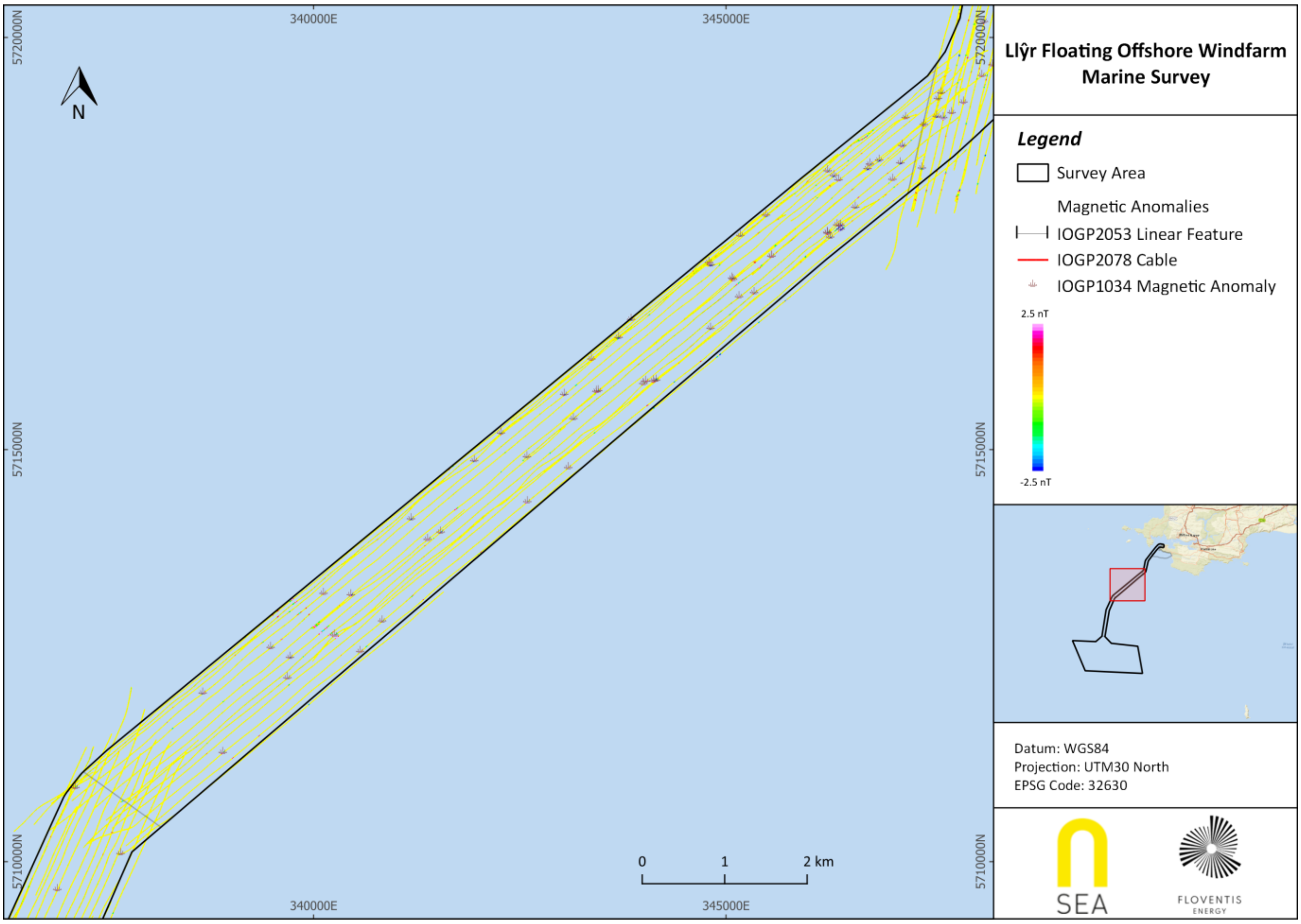


Figure 5-47: Overview of magnetic survey results – ECR Centre

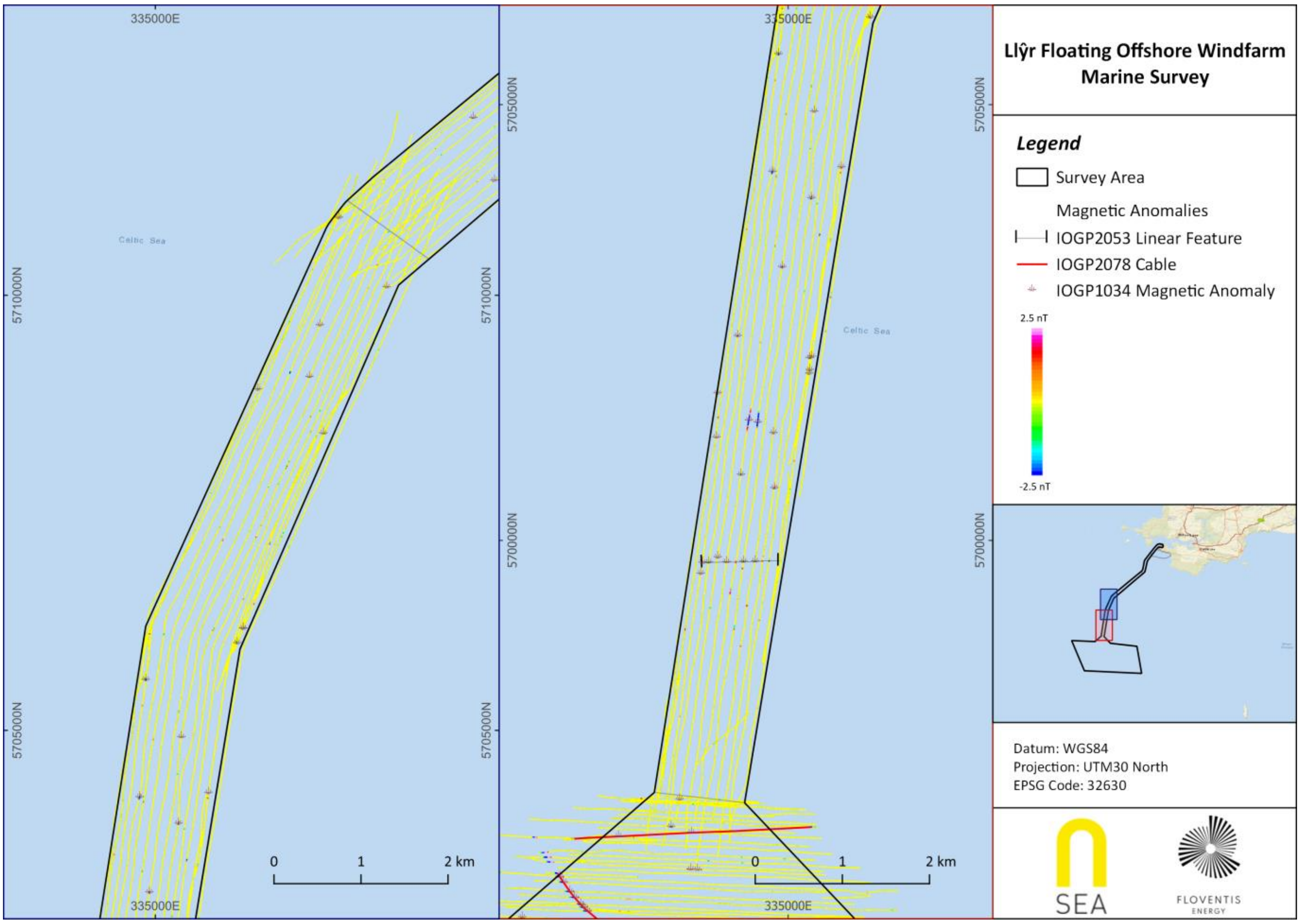


Figure 5-48: Overview of magnetic survey results – ECR South

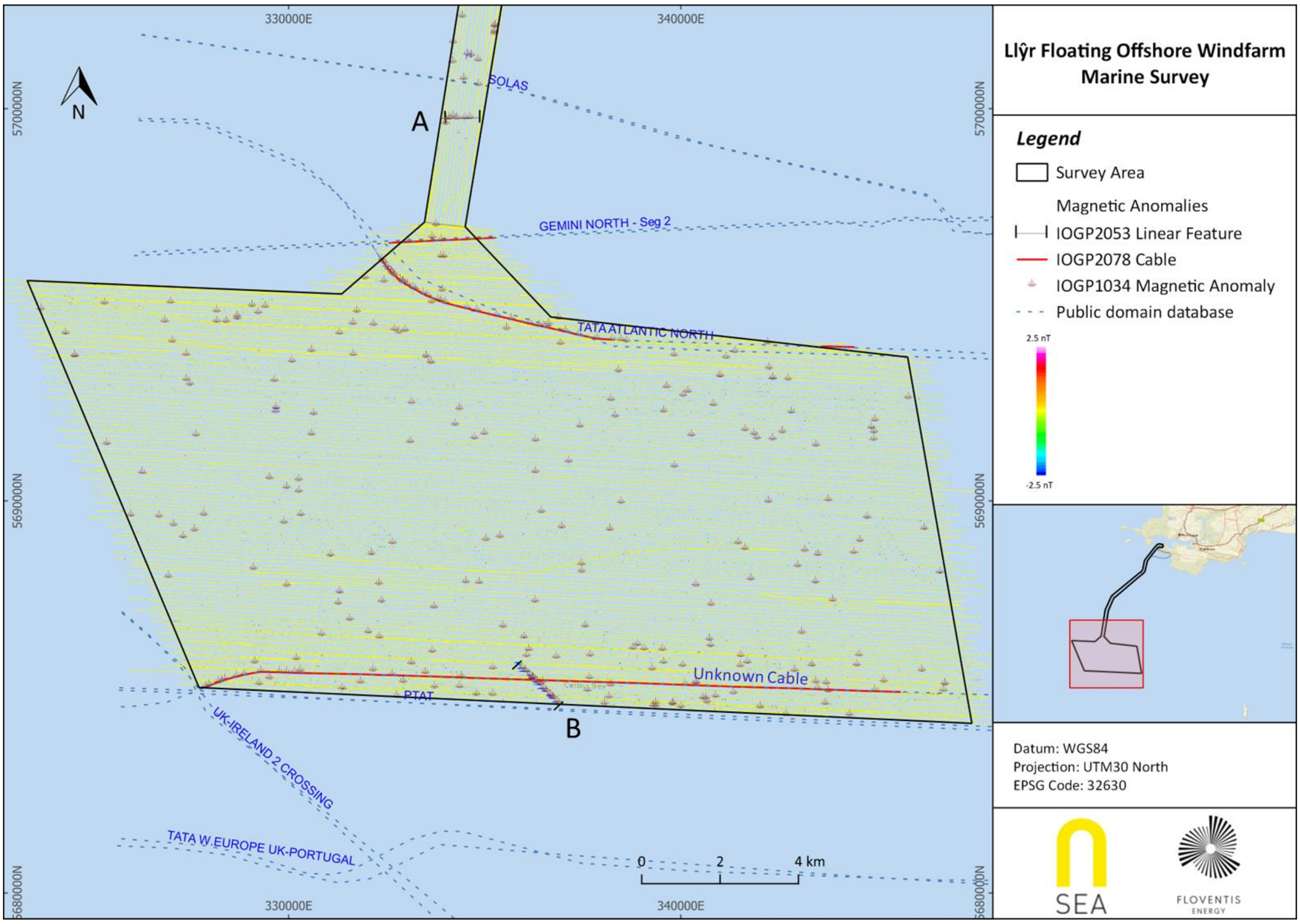


Figure 5-49: Overview of magnetic survey results - OWF

5.4.2 Debris

Figure 5-50 compares the magnetic target repartition to the location of trawl scars and boulder fields as digitised from the SSS data in the OWF area. Trawl marks and boulder fields are concentrated in the sandy sediment areas in the southern third of the OWF, and to a lower extent in the northern part of the site. The correlation suggests that some of the magnetic targets could be related to trawling activities and/or magnetic boulders.

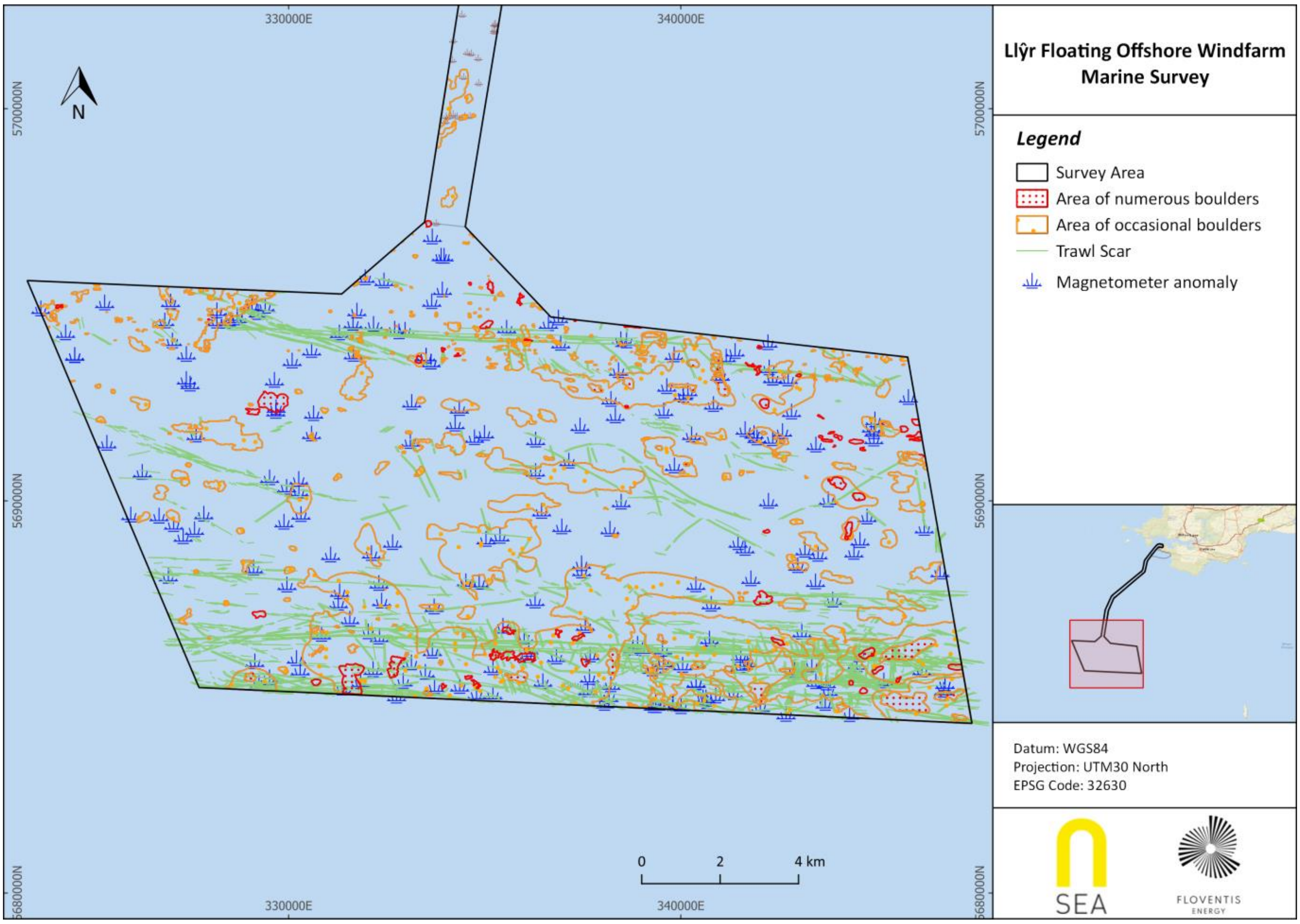


Figure 5-50: Magnetometer anomaly repartition correlated to boulder and trawl scars repartition in the OWF

Some magnetic anomalies appear to be caused by ferrous objects that are buried. An example may be seen in Figure 5-51 where a large amplitude, broad dipole anomaly is unlikely to be caused by the pieces of surface debris imaged in the SSS data. Such a large anomaly is comparable to the two wreck examples, or geology (unlikely).

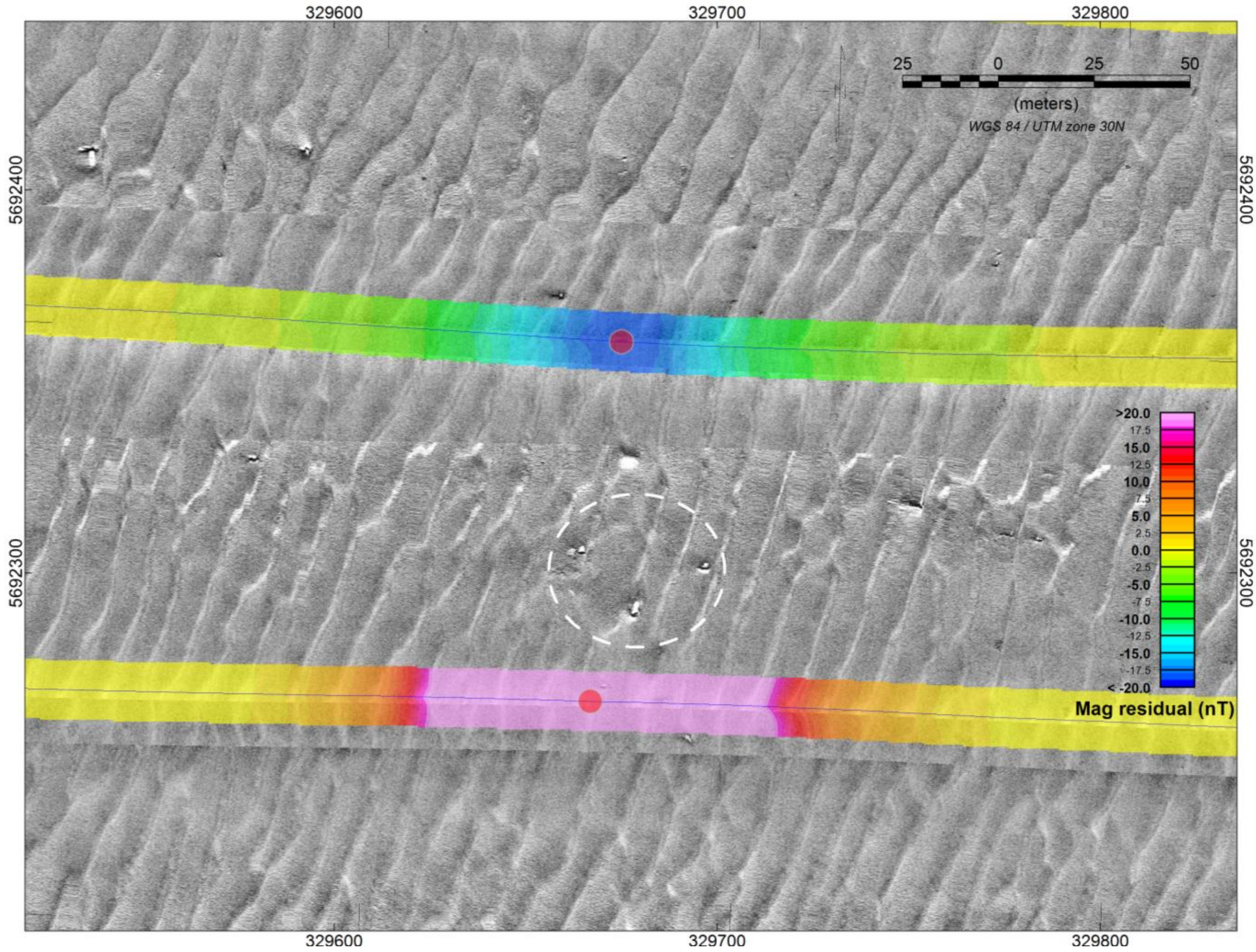


Figure 5-51: Broad dipole suggesting a possible larger object buried below the surface debris items

5.4.3 Geology

The surface sediment particle size within the ECR becomes coarser towards the north, so that gravelly sands and gravels are encountered. The magnetic residual data becomes noisier, as can be seen in Figure 5-52. Some discrete anomalies are debris-related (a wreck with a 235 nT dipole anomaly recorded on two survey lines is well imaged on the SSS). However, most of the magnetic signal appears to originate from the outcropping bedrock and possibly also from the gravels/boulders. Note that the magnetic residual grids in Figure 5-52 are displayed with a larger colour range (-10nT to 10nT) to help visualise the debris within the noisier magnetic data. The magnetic anomaly picking criteria was increased up to 20nT peak-to-peak, but target picking also considered the anomaly shape and wavelength.

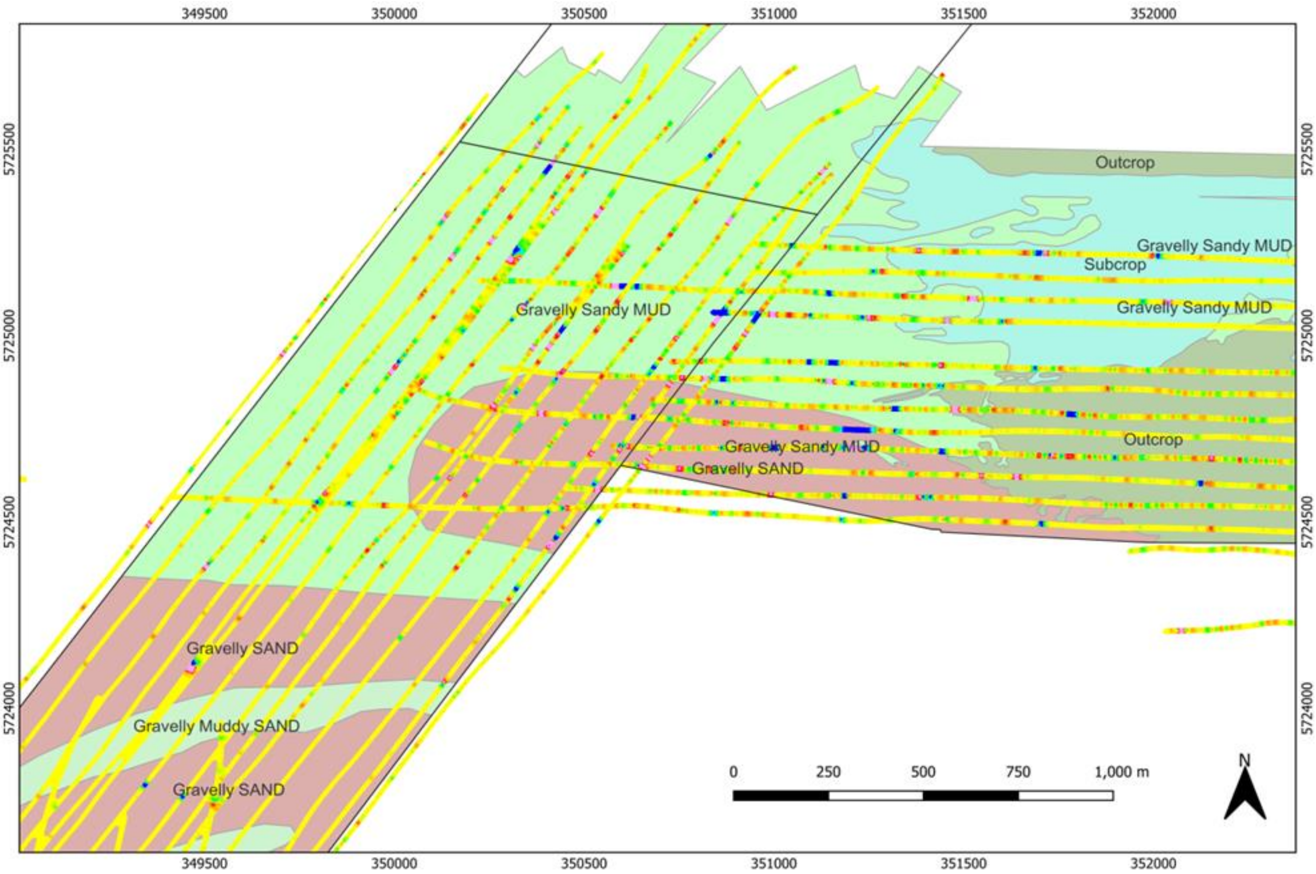


Figure 5-52: Presumed shallow bedrock and gravel contaminating the magnetic residual grids

5.5 ITEMS OF INTEREST

5.5.1 Wrecks

Five wrecks were recorded on survey datasets, three within the nearshore extended area (Freshwater West), one within the ECR and one in the OWF area. Details are presented in Table 5-4 and sections below.

Table 5-4: Summary of detected wrecks

Wreck	Location	Position		Dimensions		
		Easting	Northing	Length	Width	Height
Highland Home	Nearshore extension	354028.61	5725512.07	82.8	46.0	2.8
LCG15		353586.18	5725231.09	56.1	30.3	3.0
Unidentified		351220.96	5724718.84	27.3	6.3	4.0
Christian Borum	OWF Block F	340381.58	5687893.08	26.3	6.5	1.42
Unidentified	ECR South	334581.39	5701369.82	42.8	7.5	3.38

Nearshore Extended Area – "possibly Highland Home"

The wreck recorded in the central section of the extended nearshore area, lying at 354028.61 E, 5725512.07 N, is described within the Admiralty's wreck database as "possibly *Highland Home*", an iron barque documented as having sunk whilst under tow in 1895 (Figure 5-56).

The wreck was detected on six magnetometer survey lines (centre of wreck was directly under two of the magnetometer line tracks) and overall has an appearance of complex anomaly centred around a dipole response with a peak-to-peak amplitude of 7364.9 nT at sensor altitude = 5.3 m above seabed (Figure 5-53).

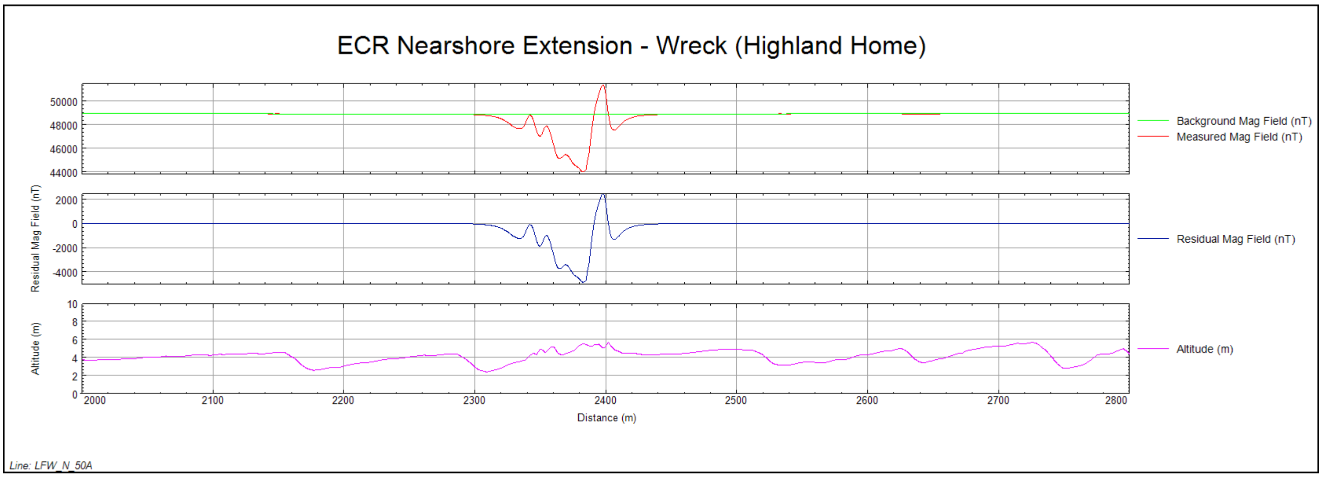


Figure 5-53: Profile of the magnetic anomaly associated with the wreck "Highland Home"

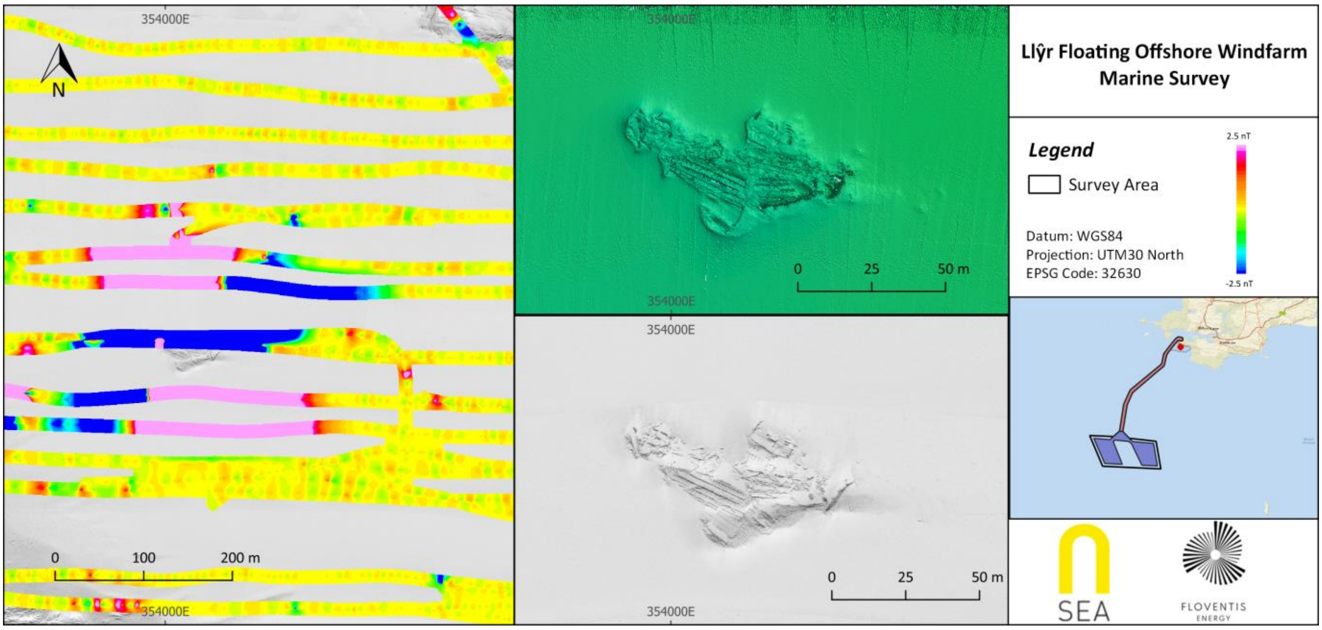


Figure 5-54: Gridded magnetic response (left), MBES (right-top) and SSS mosaic (right-bottom) of the wreck "Highland Home"

Nearshore Extended Area – "LCG15"

The second wreck in the central section of the extended nearshore area, was recorded approximately 500 m to the south-west of the "*Highland Home",* lying at 353586.18 E, 5725231.09 N. It is described within the Admiralty's wreck database as "*LCG15"*, a landing craft designated for the D-Day landings, documented as having sunk during a storm in 1943 (Figure 5-54).

The wreck was clearly detected on two magnetometer survey lines (centre of wreck was directly under one of the magnetometer line tracks), with another two lines showing a lower response, one to the north and one to the south of the wreck. The wreck's magnetic response was recorded as a complex anomaly, centred around a negative monopole with an amplitude of 3346.5 nT at sensor altitude = 3.8 m (Figure 5-53).

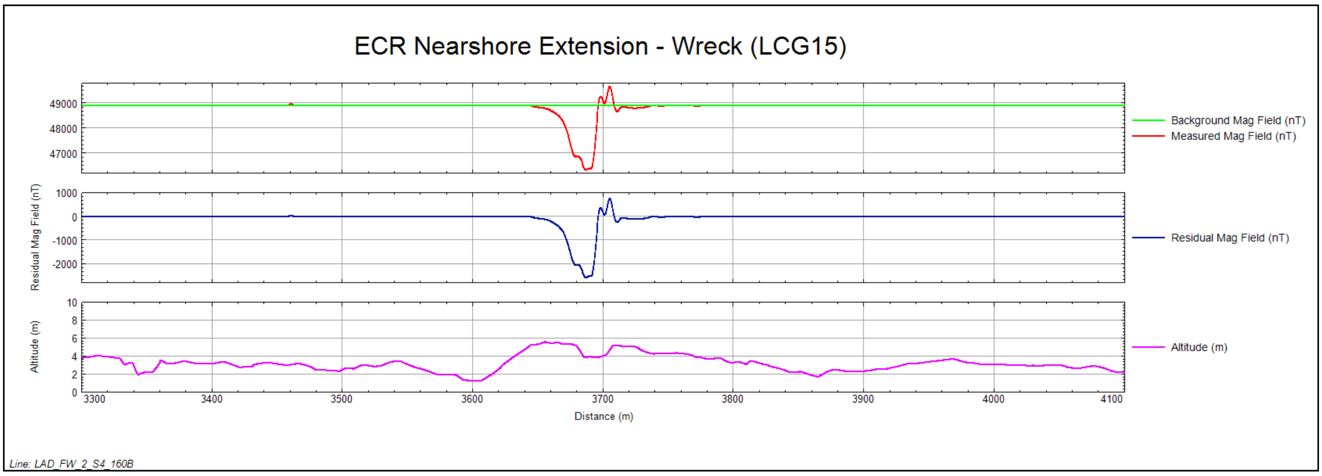


Figure 5-55: Profile of the magnetic anomaly associated with the wreck "LCG15"

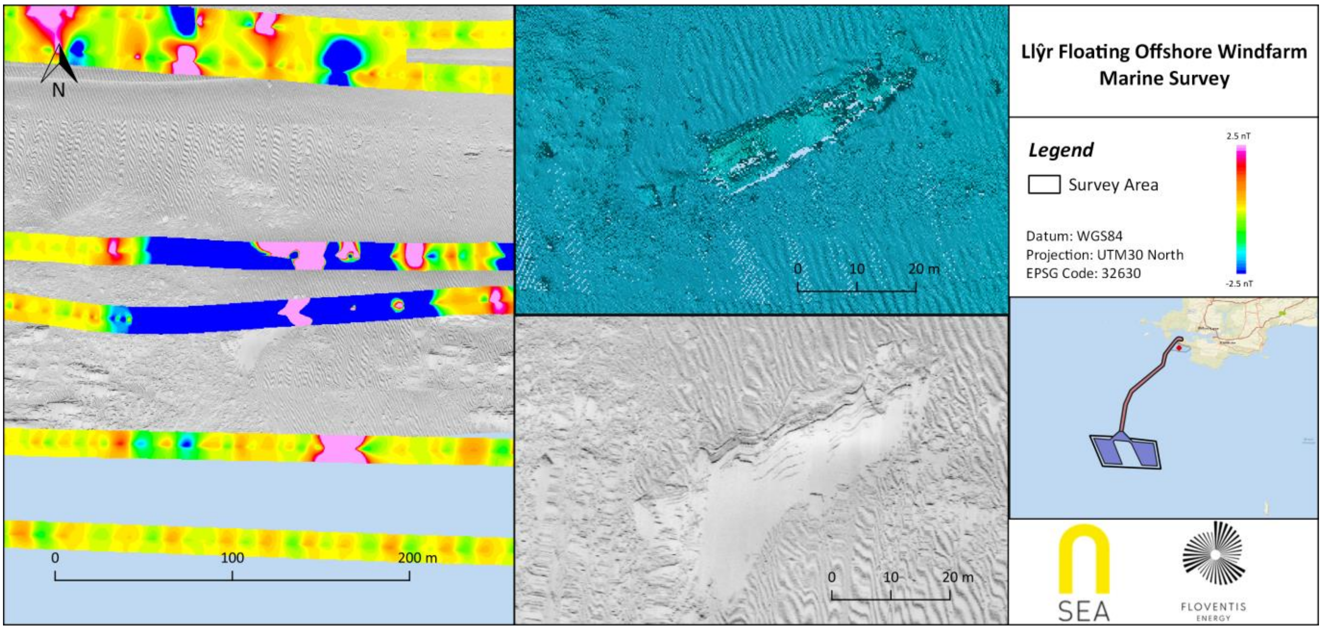


Figure 5-56: Gridded magnetic response (left), MBES (right-top) and SSS mosaic (right-bottom) of the wreck " LCG15"

Nearshore Extended Area – Unidentified wreck

The third wreck in the nearshore area was recorded in the south-western corner of the extended area, lying at 351220.96 E, 5724718.84 N. It is described within the Admiralty's wreck database as unidentified barge (Figure 5-57).

The wreck was clearly detected on only one magnetometer survey line (centre of wreck was approximately 10 m north of the magnetometer line track). The wreck's magnetic response was recorded as a complex anomaly, centred around a positive monopole with an amplitude of 208.2 nT at sensor altitude = 3.9 m.

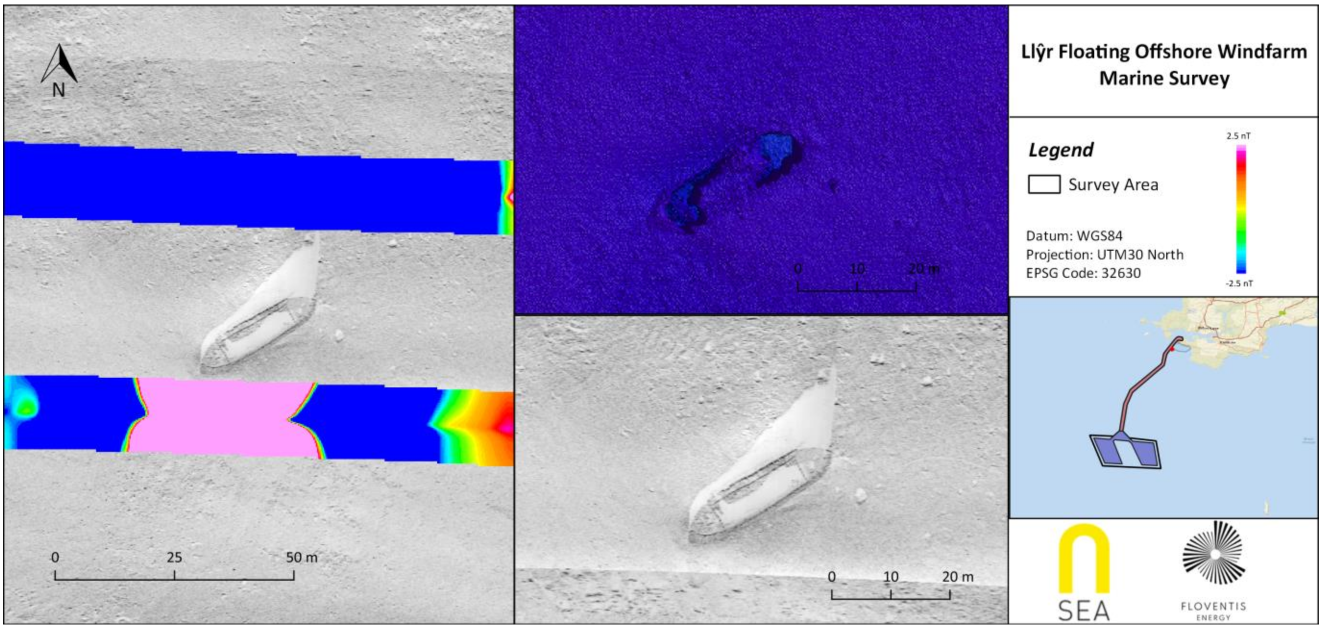


Figure 5-57: Gridded magnetic response (left), MBES (right-top) and SSS mosaic (right-bottom) of the unidentified wreck

OWF – "Christian Borum"

The "*Christian Borum*" trawler is documented as having sunk whilst under tow in 2003. The SSS data shows it lying north-south on the seabed in the OWF at 340381.58 E, 5687893.08 N (Figure 5-59). This is approximately 135 m north of the Admiralty database position.

The wreck was only detected on one magnetometer survey line (centre of wreck is offset 50 m from the magnetometer line track) and gives a positive monopole response with an amplitude of 17.6 nT (sensor altitude = 9 m), with a half-wavelength (inflection to inflection) of 41 m (Figure 5-58). No magnetic response was detected on the survey line that was offset 85 m to the north. No magnetic response was detected from the debris imaged on the SSS data and located 175 m to the east of the wreck.

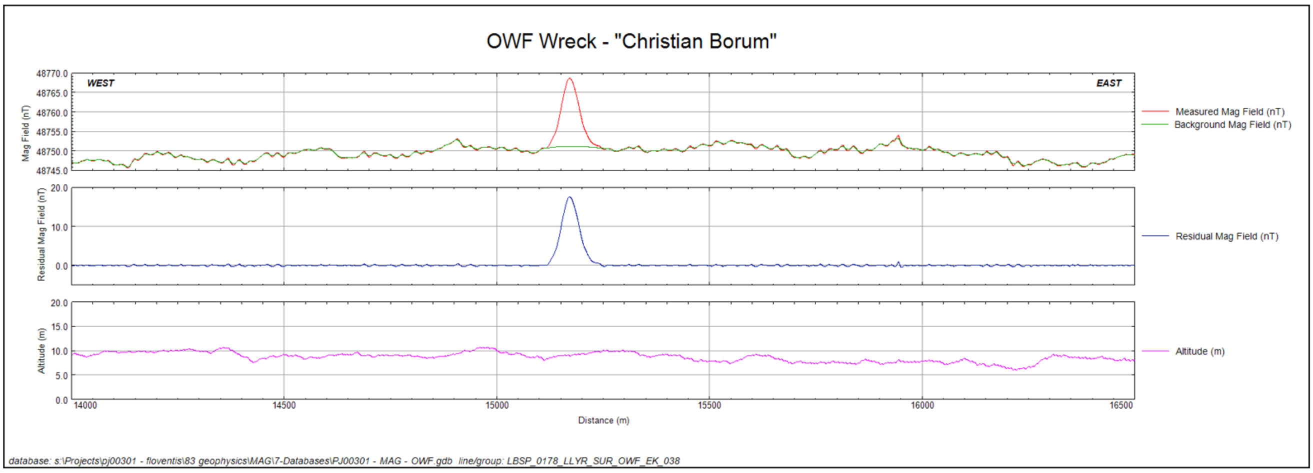


Figure 5-58: Profile of the magnetic anomaly associated with the wreck "Christian Borum"

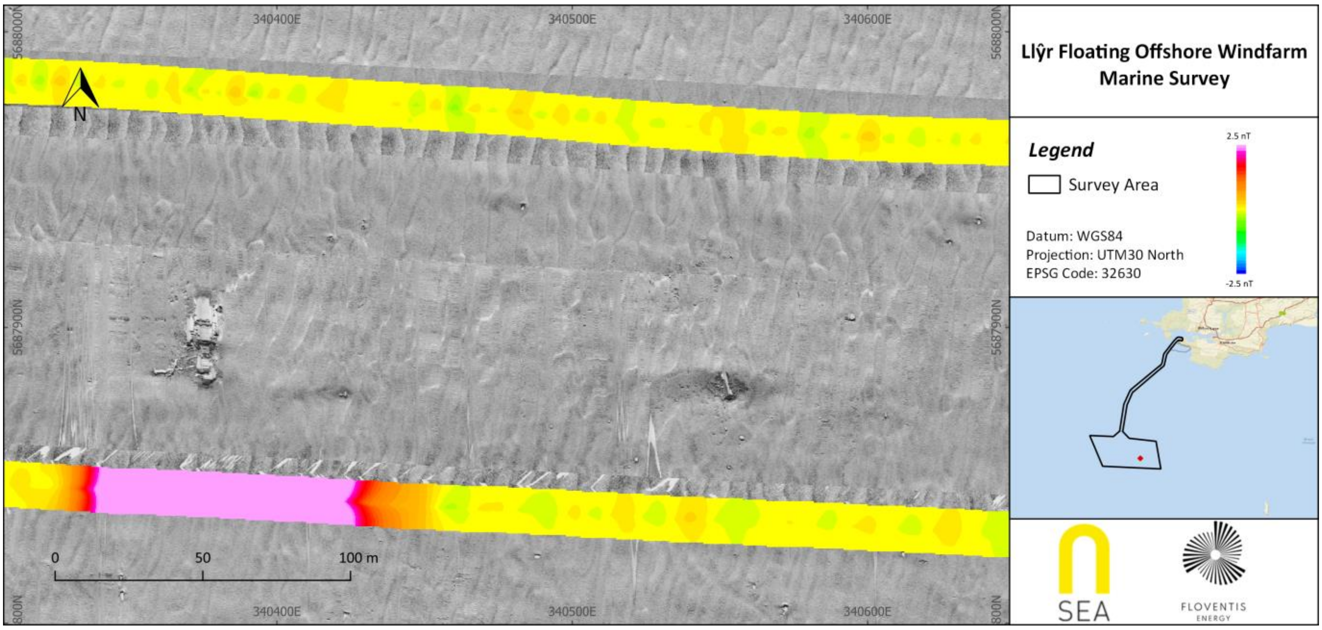


Figure 5-59: SSS mosaic and gridded magnetic response of the wreck "Christian Borum"

ECR – Unidentified wreck

A wreck, included in Admiralty database as unidentified (Figure 5-61), was recorded at 334581.39 E, 5701369.82 N, in an upright position and in apparently good condition. The SSS data provided excellent imaging of the structure, as well as two large pieces of debris on the seabed, near the vessel port side, to the aft and stern, and a third one 50 m at 014°. The MBES DTM revealed extensive scouring at the bow and stern.

The unidentified wreck produced a significant magnetic response on two adjacent survey lines: a 278.5 nT negative anomaly on the westerly 005 line (half-wavelength of 3 m) and a 42.9 nT negative anomaly on the easterly 006 line. The wreck lies approximately 30 m from survey line 005 and 70 m from survey line 006. The magnetometer was flying at 6 m altitude on both lines. The large magnetic response suggests it has a large ferrous mass, with shorter wavelength dipoles on line 006 likely caused by debris (Figure 5-60).

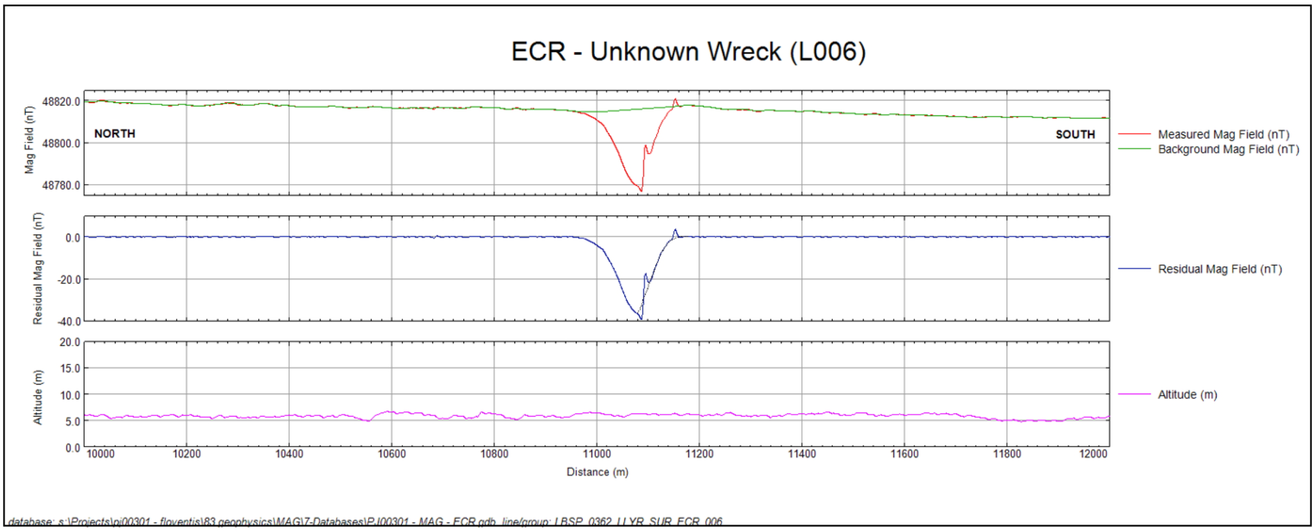


Figure 5-60: Profile of the magnetic anomaly associated with the unknown ECR wreck (easterly 006 line)

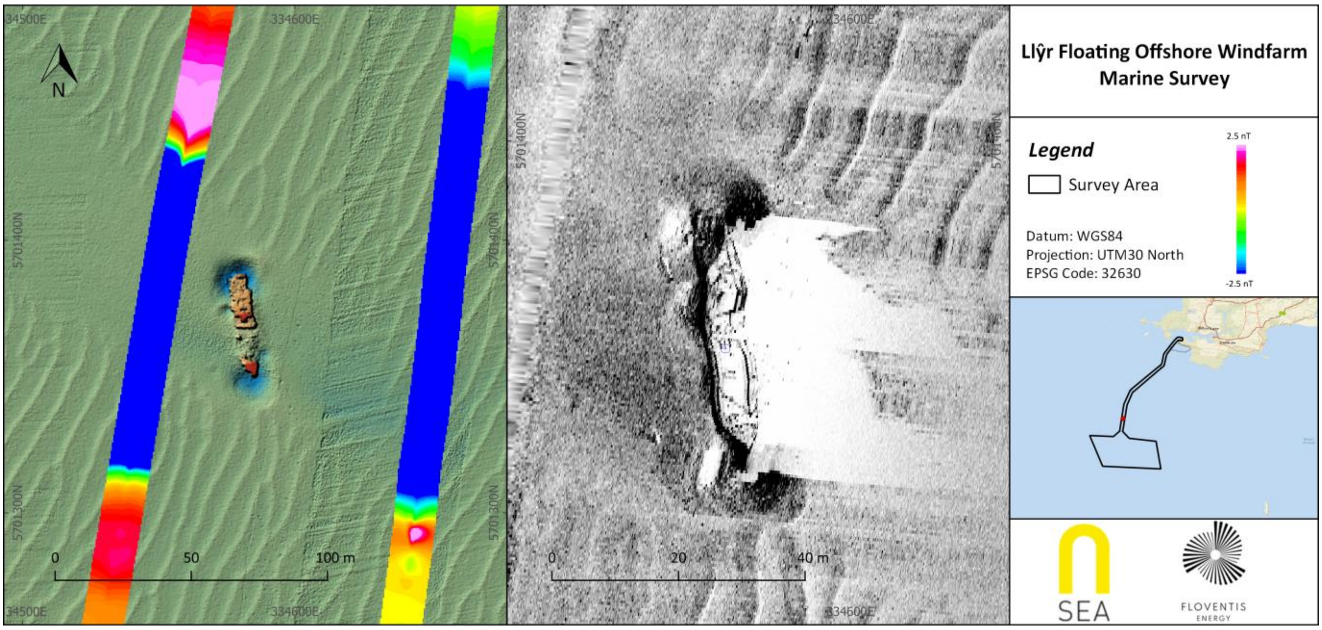


Figure 5-61: Geophysical data of the unknown wreck within the ECR (MBES and MAG to the left, SSS to the right)

5.5.2 Cable Crossings and Linear Features

SOLAS

The linear mag anomaly labelled A in Figure 5-49 within the ECR could indicate the location of the SOLAS cable but could also be due to geology. This feature is 850-950 m to the south of the expected SOLAS location. Alternatively, a single dipole anomaly (8.4 nT peak-to-peak) does coincide with the expected SOLAS cable location, although this may just be coincidence. Further investigation would be needed to confidently ascertain the origin of this linear magnetic anomaly. No evidence of cable exposures was detected on the SSS data.

Gemini North - Seg 2

A linear magnetic anomaly corresponds to the expected GEMINI NORTH – Seg 2 cable location and is characterised by a high-frequency "live cable" magnetic signature (Figure 5-49). No evidence of cable exposures was detected on the SSS data.

TATA Atlantic North

A curved linear anomaly correlates with one of the expected TATA ATLANTIC NORTH locations. The magnetic signature is typically a broad dipole of ~20 nT peak-to-peak amplitude. A second linear magnetic located outside of the OWF block is presumed to be the continuation of this cable (Figure 5-49). No evidence of cable exposures was detected on the SSS data.

Unknown Cable (South of OWF)

The almost parallel survey lines to the majority of this cable prompted several rerun/infill survey lines as the magnetic data appeared to be contaminated with high-frequency noise. The cable response is only seen in short sections, and its position is linearly extrapolated between these sections (Figure 5-49). No evidence of cable exposures was detected on the SSS data.

UK-Ireland 2 Crossing

This cable is approximately 100 m outside of the OWF area, however magnetic anomalies coincident with its location were visible in the data acquired during the run-in for several survey lines. No evidence of cable exposures was detected on the SSS data.

Other Magnetic Linear Anomalies

The linear magnetic feature marked as B on Figure 5-49 is characterised by the highest magnetic anomaly amplitudes (up to 324 nT) within the OWF, with the amplitudes increasing towards the south-east. Asymmetric dipole anomalies are recorded on every line crossing this feature, which extends > 1.5 km in length. It is straight (i.e., not meandering) as might be expected from a buried channel, so it is interpreted as of geological origin. The orientation corresponds with the one of several orientations of bedrock faults visible in the nearshore SSS data. There is no surface expression with the seabed being classified as rippled SAND.

Figure 5-62 shows the contrasting magnetic response of linear feature B to a section of the interpreted "unknown cable" where a survey line runs over it for a short distance. Note the characteristic high-frequency magnetic anomalies caused by the cable.

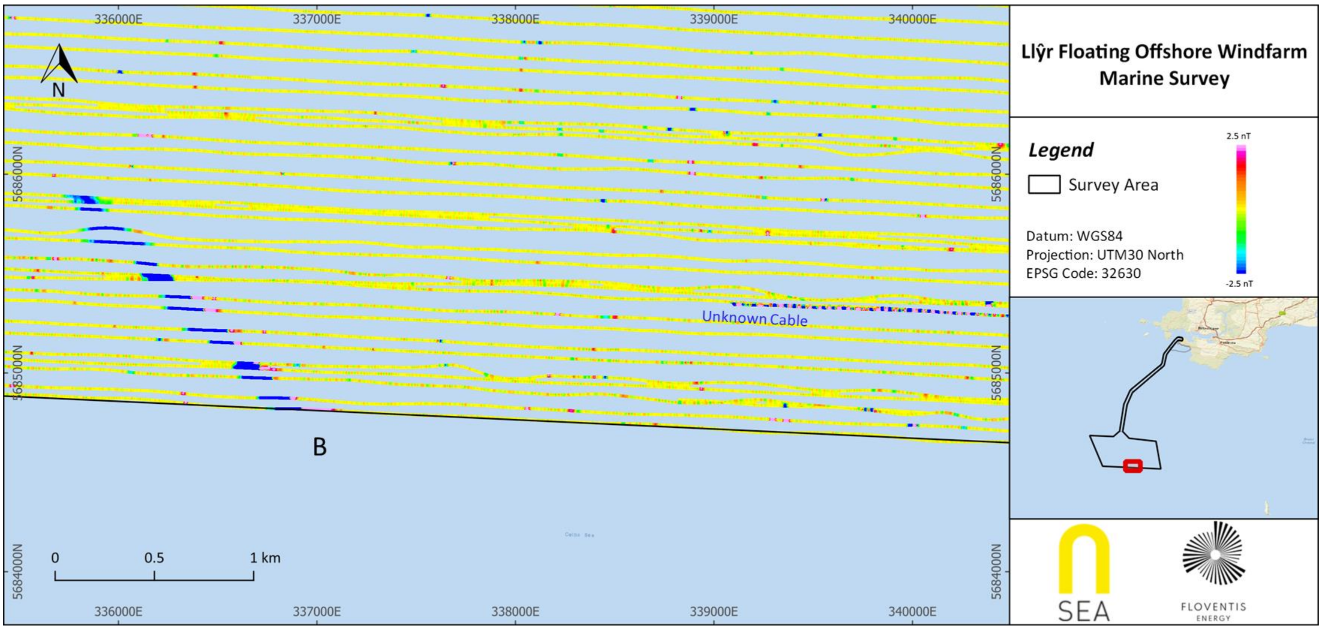


Figure 5-62: Close-up of the linear features B interpreted as geology (West) and unknown cable (East)

The ECR has one additional magnetic lineament (Figure 5-63) that is attributed to geology due to its consistent dipole response (amplitude & wavelength) and slightly irregular shape. The peak-to-peak amplitude is typically 25 – 35 nT for magnetometer altitudes of 6 – 7 m.

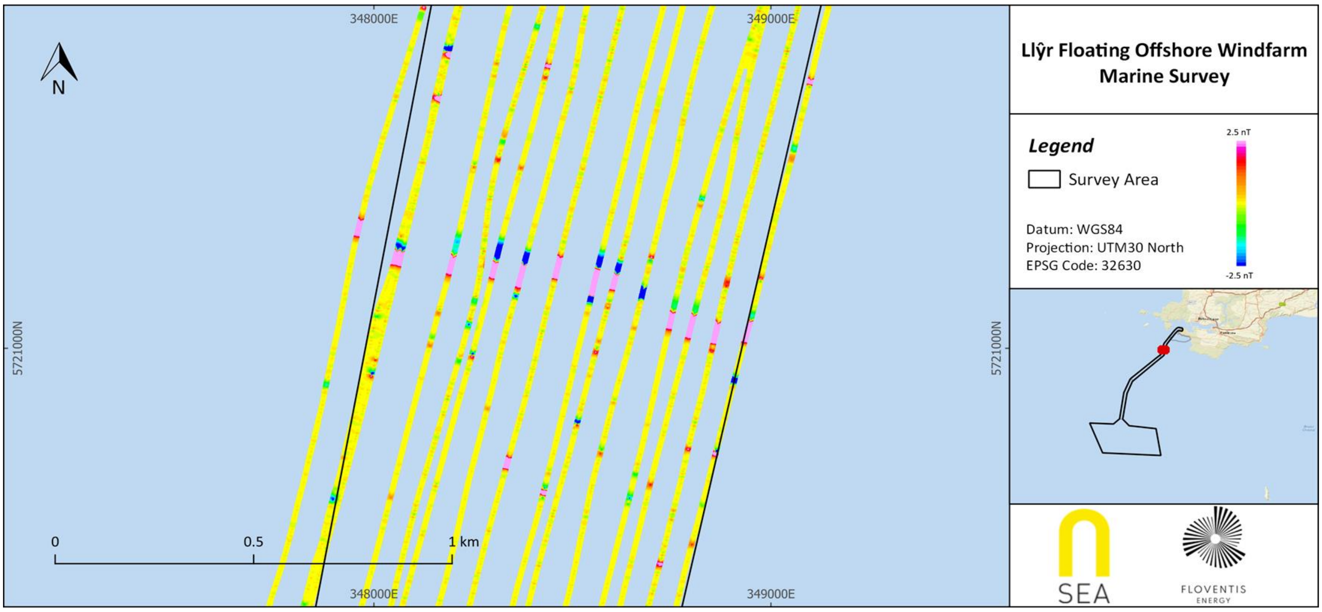


Figure 5-63: Magnetic lineament within the ECR attributed to geology