An Roinn Comhshaoil, Aeráide agus Cumarsáide
Department of the Environment, Climate and Communications

INFOMAR
Integrated Mapping for the Sustainable Development of Ireland's Marine Resource

CV22_02 INFOMAR Survey Report
Area: Celtic Sea

For:
Marine Institute & Geological Survey Ireland

RV *Celtic Voyager*

May 2022

Prepared by Kevin Sheehan & INFOMAR Survey Team

Rialtas na hÉireann
Government of Ireland

Foras na Mara
Marine Institute

Geological Survey
Suirbhéireacht Gheolaíochta
Ireland | Éireann

Marine Institute Reference No:	Survey Report: CV22_02

		Signature	Date
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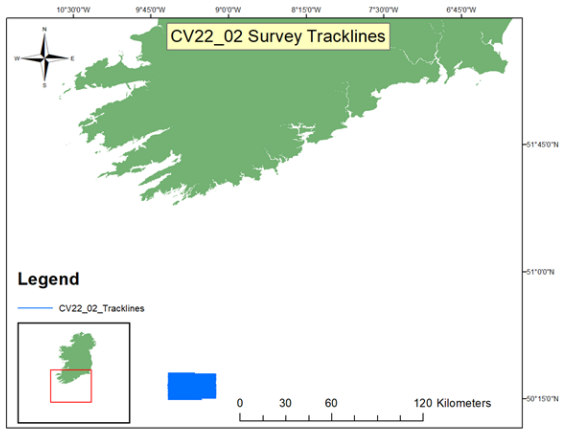
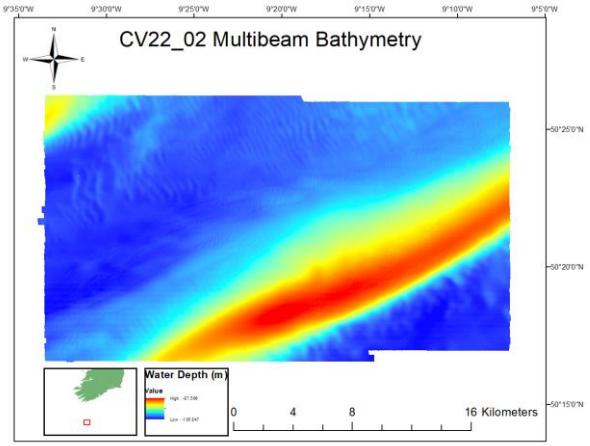
Issue	Date	Description	Author	Approved
1	10/02/2023	Draft	Kevin Sheehan	Oisín McManus
2	05/05/2023	Final	Kevin Sheehan	Oisín McManus

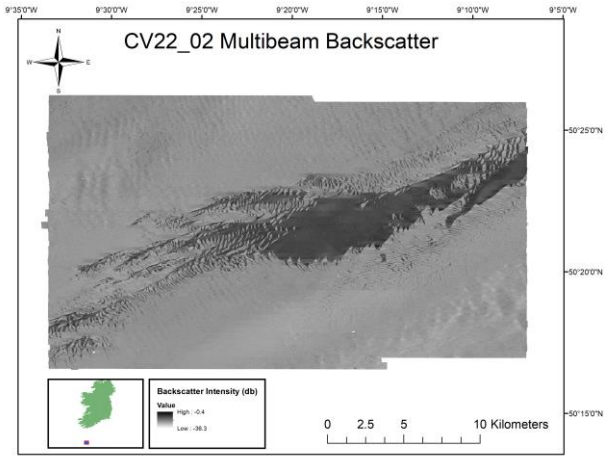
Executive Summary			
Survey Summary			
Survey Vessel:	RV *Celtic Voyager*	**Survey Leg:**	CV22_02
Mobilisation:	Cork	**Demobilisation:**	Cork
Survey Areas:	Celtic Sea	**Start Date:** **End Date:**	01/05/2022 22/05/2022
Northwest Boundary	50º 26.172 N -9º 33.449 W	**Southeast Boundary**	50º 16.964 N -9º 07.019 W
UKHO Admiralty	0002 (1:1,500,000), 1123 (1:500,000) & 2649 (1:500,000).		
Key References	CV22_02 Survey Leg Report & CV22_02 Executive Report		
Equipment Used	Kongsberg EM2040 MBES, Knudsen 3260 Chirp sub-bottom profiler, SeaSpy magnetometer, AML MVP30-350, Valeport SVP Mini, C-Nav 3050 GNSS.		

Survey Statistics			
Minimum Water Depth (LAT)	87.6 m	**Maximum Water Depth (LAT)**	136.9 m
Area Covered:	548 km^2	**Survey Line Kilometres:**	2216 km
Operational Time:	20.6%	**Weather Standby:**	40.9%
Groundtruthing Stations:	0	**Wrecks**	1
H525 forms issues (wrecks)	1	**H102 forms issued (shoals)**	0

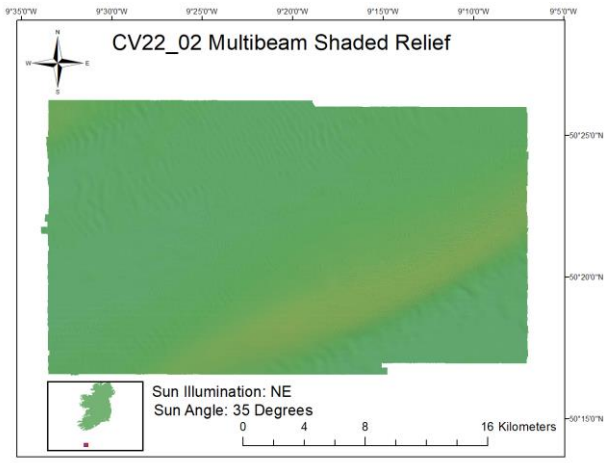
Survey Track Lines	MBES Bathymetry Overview
	

Survey Images

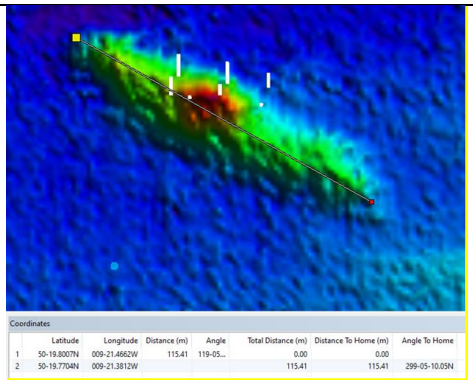
MBES Backscatter



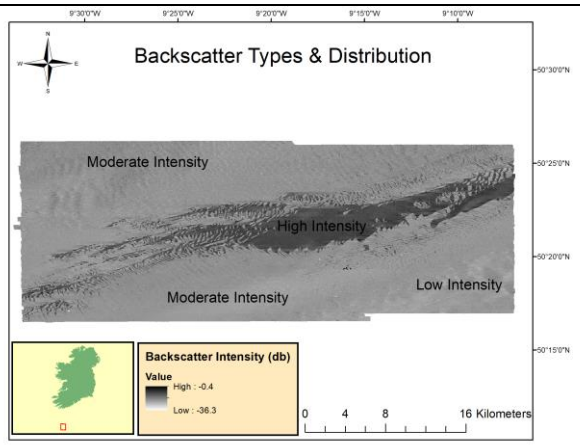
MBES Shaded Relief



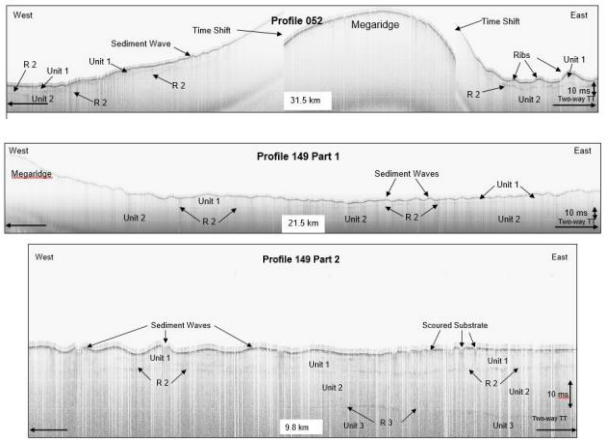
Wreck Number 1



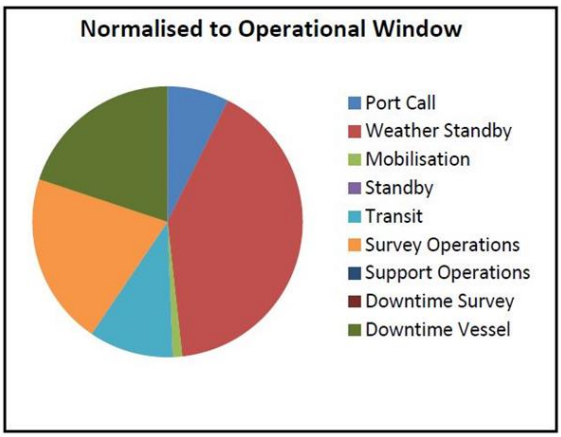
Backscatter Types



Chirp Profiles 052 & 149



Survey Statistics



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List of Acronyms Used Within This Report

Acronym	Full Name
AML	AML Oceanographic
CUBE	Combined Uncertainty and Bathymetry Estimator
DECC	Department of the Environment, Climate and Communications
DGNSS	Differential Global Navigation Satellite Systems
DPR	Daily Progress Report
FMGT	Fledermaus Geocoder Tool
GIS	Geographic Information System
GNSS	Global Navigation Satellite Systems
GSI	Geological Survey Ireland
HVF	Hips Vessel File
IHO	International Hydrographic Organisation
INFOMAR	INtegrated Mapping FOr the Sustainable Development of Irelands MArine Resource
INSS	Irish National Seabed Survey
ITRF	International Terrestrial Reference Frame 2014 (ITRF2014)
LAT	Lowest Astronomical Tide
MVP	Moving Vessel Profiler
MBES	Multibeam Echo-Sounder
MI	Marine Institute
MRU	Motion Reference Unit
NPWS	National Parks & Wildlife Service
PPE	Personal Protective Equipment
PPS	Pulse per Second
PPP	Precise Point Positioning
QINSy	Quality Integrated Navigation System
RTG	Real Time Gypsy
RV	Research Vessel
SBP	Sub Bottom Profiler
SBES	Singlebeam Echo Sounder
SIS	Seafloor Information System
SVP	Sound Velocity Profiler
TPU	Total Propagated Uncertainty
UKHO	UK Hydrographic Office
UTC	Coordinated Universal Time
VORF	Vertical Offshore Reference Frame
WGS	World Geodetic System

1. Introduction

1.1 Project Overview and Objectives

Geological Survey Ireland (GSI) and Marine Institute (MI) conducted seabed mapping between 2003 and 2005 under the auspices of the Irish National Seabed Survey (INSS) and mapping continued from 2006 to present day under the INtegrated mapping FOr the sustainable development of Irelands MArine Resource (INFOMAR) programme. INSS, which commenced in 1999 under the GSI was one of the largest marine mapping programmes ever undertaken globally, with a focus on deep water mapping. INFOMAR is a joint venture between the GSI and the MI and is funded by the Irish Government through the Department of the Environment, Climate and Communications (DECC).

INFOMAR Phase 1, 2006 to 2015 focused on mapping 26 priority bays and 3 priority areas around Ireland and creating a range of integrated mapping products of the physical, chemical and biological features of the seabed in those areas. INFOMAR Phase 2, 2016 to 2026 intends to map the remainder of Ireland's entire seabed. Figure 1 shows the extent of the continental shelf mapped area under INSS and INFOMAR and the outstanding areas as of January 2022. Grey areas have already been mapped and blue coloured areas are unmapped. Coloured hatched areas are designated for mapping in 2022

In 2018, the remaining survey area was split at the 30 nautical mile (Nm) limit. The inshore survey fleet, managed by GSI is responsible for mapping inshore of the 30 Nm limit and the MI vessels are responsible for mapping the offshore. Survey areas are defined into gridded survey units known as INFOMAR Survey Units (ISUs). ISUs are all 1000 km^2 in size and are uniquely identifiable by a letter on the x-axis and number on the y-axis. Each ISU are coloured in a shade of blue, which indicates the modal water depth within that ISU. Colour scales are used, to denote the three depth bands; 50 to 100m, 100 to 150m and 150m plus.

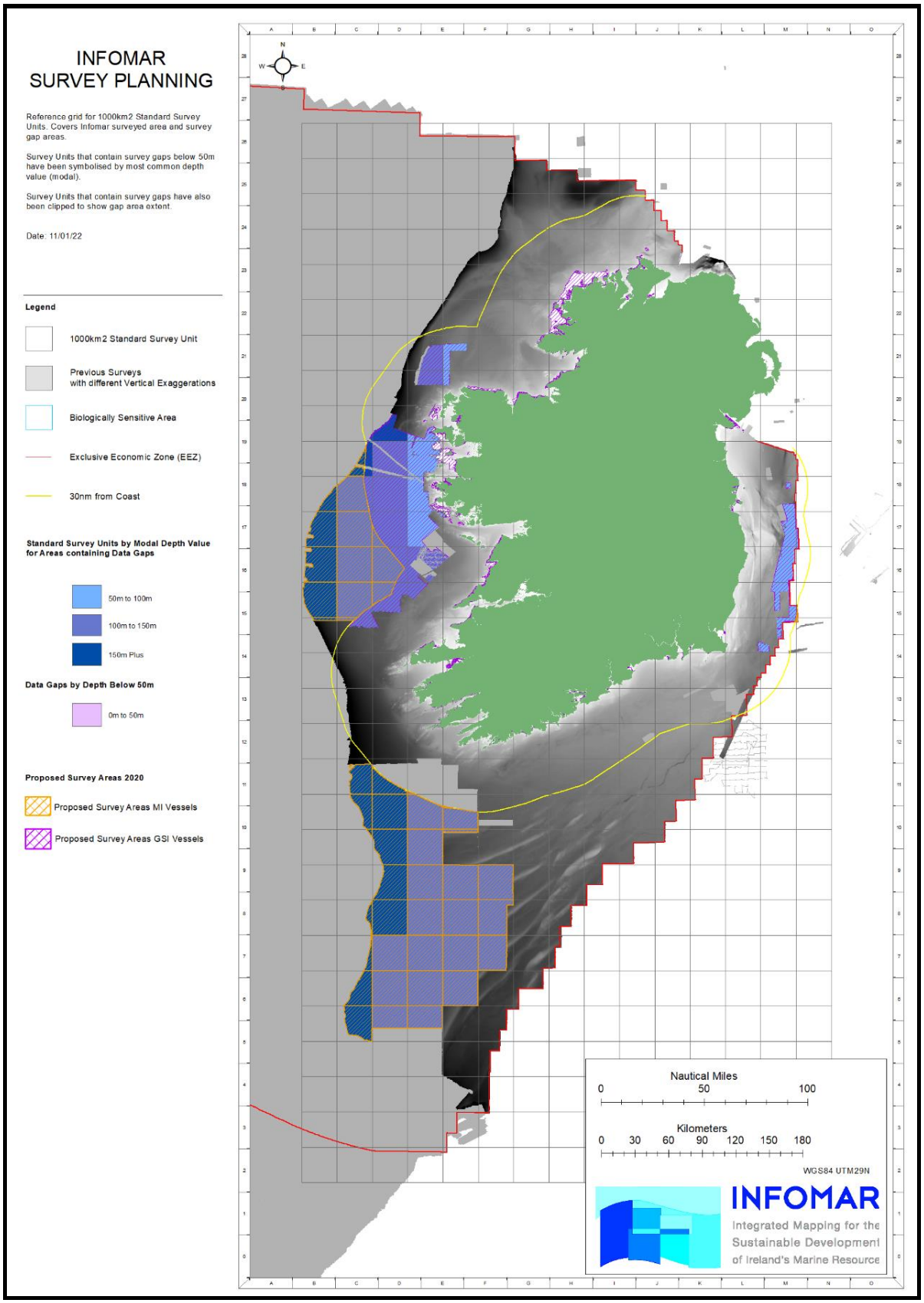


Figure 1: Survey coverage and 2022 designated operations areas.

MI supplied the research vessel RV *Celtic Voyager* and experienced personnel for the survey.

The scientific aims of the survey were to:
(i) Undertake a Multibeam Echo Sounder (MBES) hydrographic survey to a minimum standard of International Hydrographic Organisation (IHO) Order 1A in water depths less than 100 metres and Order 2 in water depths greater than 100 metres.

(ii) Produce bathymetry, shaded relief and backscatter mosaic products to provide depth, seabed features and seabed hardness/roughness information.

(iii) Acquire Sub Bottom Profiler (SBP) data of the shallow sub-seabed to determine the existence of buried objects and ascertain the sub-seabed character.

(iv) Acquire magnetometer data to investigate the sub-seabed geology and provide information on manmade seafloor debris.

(v) Map in detail and provide hydrographic wreck reports for all encountered wrecks.

1.2 Proposed Survey Area

The 2022 INFOMAR Operations Plan was agreed between MI and GSI at the start of the year, circulated to stakeholders and published online at https://www.infomar.ie.

Figure 2 shows the designated Celtic Sea mapping area, bounded to the north by the 30 Nm limit. Predicted survey coverage for the RV *Celtic Voyager* survey season was 2859 km^2 based on the number of charter days (55) and from analysis of historical survey statistics in this part of the Celtic Sea.

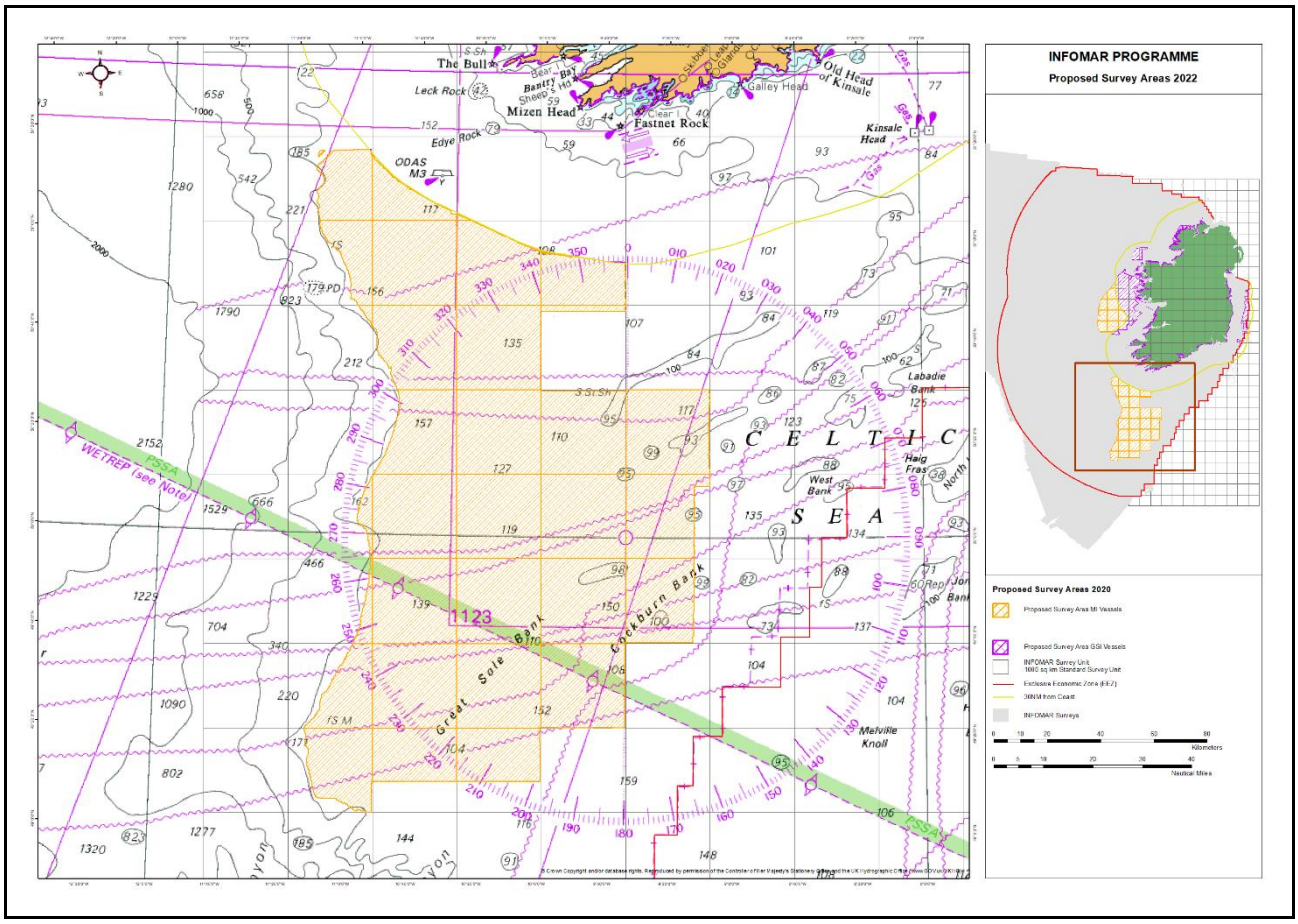


Figure 2: Proposed RV *Celtic Voyager* 2022 survey area in the Celtic Sea.

2. Operations & Survey Setup

Mobilisation took place in Cork on 1st May and survey acquisition between 2nd and 21st May. Kevin Sheehan and Fabio Sacchetti of the MI acted as Party Chiefs. The survey team comprised skilled personnel from the MI and contract staff.

2.1 Survey Track Lines

The final survey Tracklines are produced in ArcGIS software, after export of an initial shapefile from Teledyne Caris HIPS & SIPS™ software is shown in Figure 3. Data acquisition occurred in one contiguous area of the Celtic Sea. Mainlines were acquired on East-West reciprocal headings.

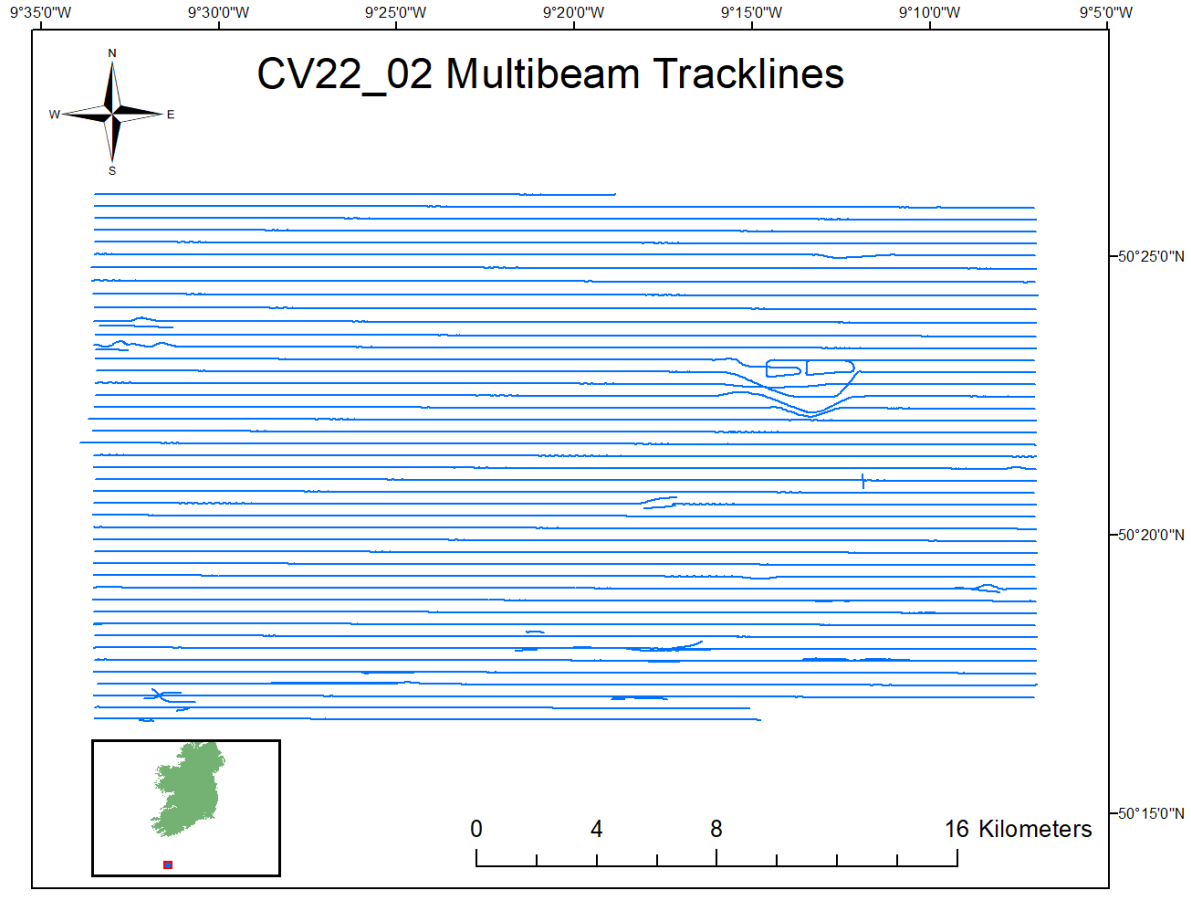


Figure 3: Survey track line plot produced in Caris and ArcGIS software.

2.2 Summary of Events

A summary of the key events is presented in Table 1. Times are in Coordinated Universal Time (UTC). Daily Progress Reports (DPRs) were distributed to management and INFOMAR personnel on a daily basis.

Date and time	Activity
01/05/2022 00:00	Port Call at Hogan's Quay, Cork City
01/05/2022 11:00	Mobilisation at Hogan's Quay, Cork City
01/05/2022 17:00	Commenced Transit to Site
02/05/2022 07:19	Commenced Survey Acquisition
03/05/2022 03:45	Downtime Vessel. MBES gaps that required infill.
03/05/2022 14:49	Resumed main survey lines acquisition
04/05/2022 01:00	Downtime vessel. Commenced passage to Howth for dry docking to investigate and solve data drop out issue.
05/05/2022 14:00	Dry Dock Howth. MBES wet cables replaced along with port side Rx and Tx.
06/05/2022 16:00	Vessel back in the water. Took on ballast. Patch test completed. Commenced transit to survey area.
07/05/2022 23:02	Verification survey performed during transit. Commenced survey acquisition late in the day.
09/05/2022 03:11	Weather Standby. Transit to Cork City.
09/05/2022 16:00	Alongside Cork City.
12/05/2022 00:00	Scheduled port call. Crew and scientists change
12/05/2022 12:00	Weather standby
13/05/2022 18:00	Transit to survey area
14/05/2022 08:00	Resumed survey acquisition
15/05/2022 21:00	Weather standby. Transit to Cork City.
16/05/2022 09:00	Alongside Cork City.
20/05/2022 18:00	Transit to survey area
21/05/2022 07:00	Resumed survey acquisition
21/05/2022 20:00	Survey acquisition finished. Transit to Cork for scheduled port call.
22/05/2022 08:00	Alongside Cork
22/05/2022 23:59	Demobilisation completed in Cork. End of Survey.

Table 1: Summary of survey events.

2.3 Survey Personnel

Survey personnel, their affiliation and roles are listed in Table 2.

Name	Affiliation	Dates	Role
Kevin Sheehan	MI	1th-12th May	Party Chief /Surveyor
Oisin McManus	MI	1th-12th May	Surveyor/DP
Fabio Sacchetti	MI	12th-22nd May	Party Chief /Surveyor
Sean Haughton	MI	12th-22nd May	Surveyor
Daniel Farrell	Contractor	12th-22nd May	Surveyor

Table 2: Survey personnel details.

2.4 Health, Safety and Environment

All personnel joining the vessel were given a safety induction tour, which was recorded by the Second Mate. Medical and Personal Sea Survival certifications for all personnel were

checked for validity prior to departure. Muster drills were held within 24 hours of departure from port each time new personnel had joined. Magnetometer, sound velocity profiler and grab sampler deck operations were performed by vessel crew and without incident, with personnel wearing correct Personal Protective Equipment (PPE).

2.5 Marine Mammal Observations

National Parks and Wildlife Service (NPWS) published a *Code of Practice for the Protection of Marine Mammals during Acoustic Seafloor Surveys in Irish Waters* in 2007. An updated document titled "Guidance to Manage the Risk to Marine Mammals from Man-made Sound Sources in Irish Waters" was published in January 2014. Full details of both documents are published on the NPWS website: https://www.npws.ie/. The code and guidance are applicable to all SBP (pinger or chirp), MBES and sidescan sonar surveys in bays, inlets or estuaries and within 1500 m of the entrance of enclosed bays/inlets/estuaries. All operations were outside of the areas covered under the above guidelines. No Sightings were observed during the survey.

2.6 General Survey Information

A summary of key survey statistics is contained in Table 3.

Total Line Length (km)	2216
Area Covered (km^2)	548
Operational (%)	20.6
Weather Standby (%)	40.9
Transit (%)	10.1

Table 3: Key survey statistics.

The pie chart in Figure 4 illustrates the cumulative survey activity statistics taken from the final DPR. Survey data acquisition accounts for approximately 21% of the time.

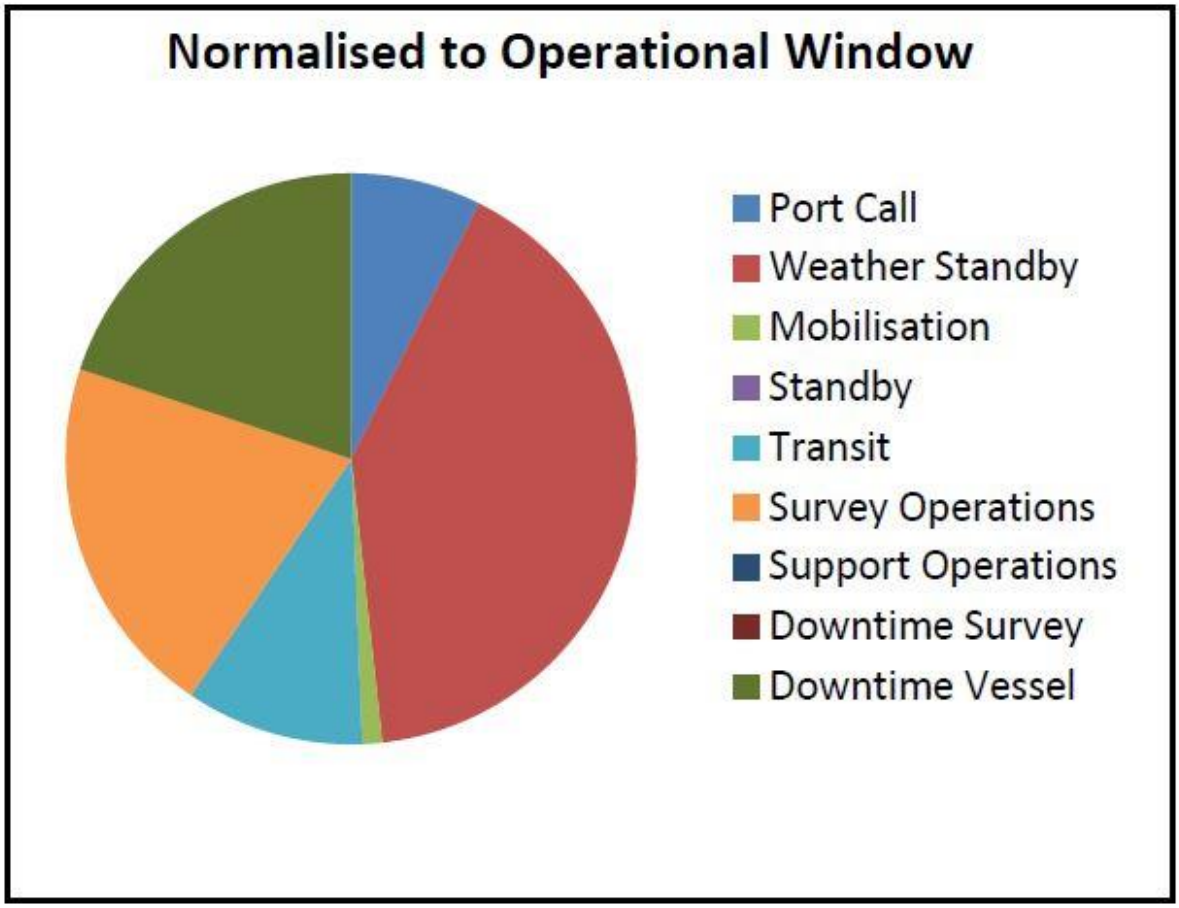


Figure 4: Survey statistics pie chart.

3 Survey Vessel Offsets, Equipment and Data Acquisition

The RV *Celtic Voyager* (Figure 5) is a multipurpose research vessel owned by MI and managed by P&O Maritime. The vessel has wet, dry and chemical laboratories, which are permanently fitted with standard scientific equipment and can accommodate 8 scientists with a maximum endurance of 14 days. It has a high resolution EM2040 MBES system fitted on a retractable pole, a Singlebeam Echo sounder (SBES), Chirp source SBP and C-NAV Differential Global Navigation Satellite Systems (DGNSS) as primary navigation and a Seatex Seapath 330+ as secondary navigation and Motion Reference Unit (MRU). All necessary geophysical and DGPS positioning equipment were pre-installed, calibrated and tested prior to commencement of survey activities.

Figure 5: The RV *Celtic Voyager*.

Detailed vessel information is contained in Table 4.

Parameter	Numeric
Length	31.4 m
Beam	8.5 m
Draught	4.0 m
Engine	1 x Baudouin 26.2 655 kW
Power Output	640 kW/1200 RPM

Speed	10 knots
Fuel	38000 Lt MGO
Generator	2 x Daewoo 1x Deutz
Max Scientists and Crew	15
Passenger Licence	P5

Table 4: RV *Celtic Voyager* vessel information.

3.1 Vessel Offsets

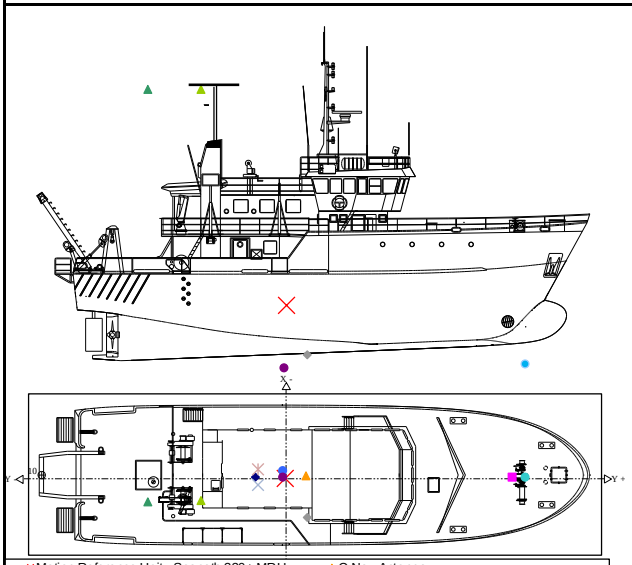
Bluepix performed an offset survey of the RV *Celtic Voyager* in August 2015 while in dry dock in Killybegs, County Donegal. An additional offset survey was conducted by Bluepix in January 2016. Current vessel offsets are presented in Table 5 below.

MARINE INSTITUTE **VESSEL OFFSET LOG**

Project Title:

Date Last Surveyed **10-11/01/2016 - Bluepix** Date: **11/01/2016**

Celtic Voyager



No'	Offset Name	X	Y	Z	Reason for change
	Common Reference Point (CRP)	0.000	0.000	0.000	
1	Motion Reference Unit - Seapath 330+ MRU	0.000	0.000	0.000	
2	C-Nav Antenna	-0.114	0.965	14.396	
3	SeaPath Fw d Antenna	0.924	-3.993	13.292	
4	SeaPath Aft Antenna	0.984	-6.491	13.299	
5	EM3002 Fully Extracted	-0.078	11.190	-3.532	New Position 2015
6	EA400-38Khz Transducer	-0.343	-0.122	-3.783	
7	EA400-200Khz Transducer	-0.036	-0.115	-3.783	
8	Knudsen Chirp	1.636	0.989	-3.004	
9	GAPs USBL Acoustic Transponder	-0.077	10.633	-4.332	
10	SSS Tow point	0.000	-13.905	1.987	
11	Maggy Tow point	-3.835	-13.905	1.987	
12	EM2040 Tx	-0.064	-1.417	-4.863	New Position
13	EM2040 RX stb	0.279	-1.287	-4.693	New Position
14	EM2040 RX port	-0.411	-1.288	-4.696	New Position

Surveyor: Fabio Sacchetti Checked: Kevin Sheehan Date: 11/01/2016

EM2040 geometry (Bluepix Report 10-11/01/2016)			
Item	**X (forward)**	**Y (starboard)**	**Z(+Down)**
Pos Com1(C-Nav)	0.965	-0.114	-14.396
EM2040 TX	-1.417	-0.064	4.863
EM2040 RX Port head	-1.288	-0.411	4.696
EM2040 RX Starboard head	-1.287	0.279	4.693
Seapath aft	-6.491	0.984	-13.299
Seapath fore	-3.993	0.924	-13.292
MRU 5+	0.000	0.000	0.000
	Yaw	**Roll**	**Pitch**
MRU 5+	0.57	0.07	0.21
EM2040 TX	-0.05	-0.37	0.74
EM2040 RX Port	-0.83	39.68	0.67
EM2040 RX Stb	0.69	-40.28	0.73
Seapath	-1.39	N/A	N/A
EM3002	0.68	-0.47	-0.14

Positive Yaw is clockwise. Positive Roll is starboard down. Positive Pitch is fore up.

CV22_02 Installation Parameters from Caris HDCS Data			
Item	**Yaw**	**Roll**	**Pitch**
MRU 5+	-0.23	0.13	-0.09
EM2040 TX	359.95	-0.33	0.74
EM2040 RX Port	179.02	-39.63	-0.67
EM2040 RX Stb	180.69	40.37	-0.73

Table 5: Vessel offsets and installation angles.

3.1.1 Multibeam Patch Test

The Tx and port side Rx were replaced in Howth mid-survey (see section 3.2.1) necessitating a new patch test. The patch test was performed on 6th May east of Howth as soon as the vessel was back in the water. An area of flat sandy seafloor with adjacent sand waves was identified from existing INFOMAR data. Figure 6 shows the angular offsets in SIS prior to the patch test. Pitch and heading angles remained the same after the patch test and verification survey were completed. The roll angles were changed after the patch test and were further refined after the verification survey.

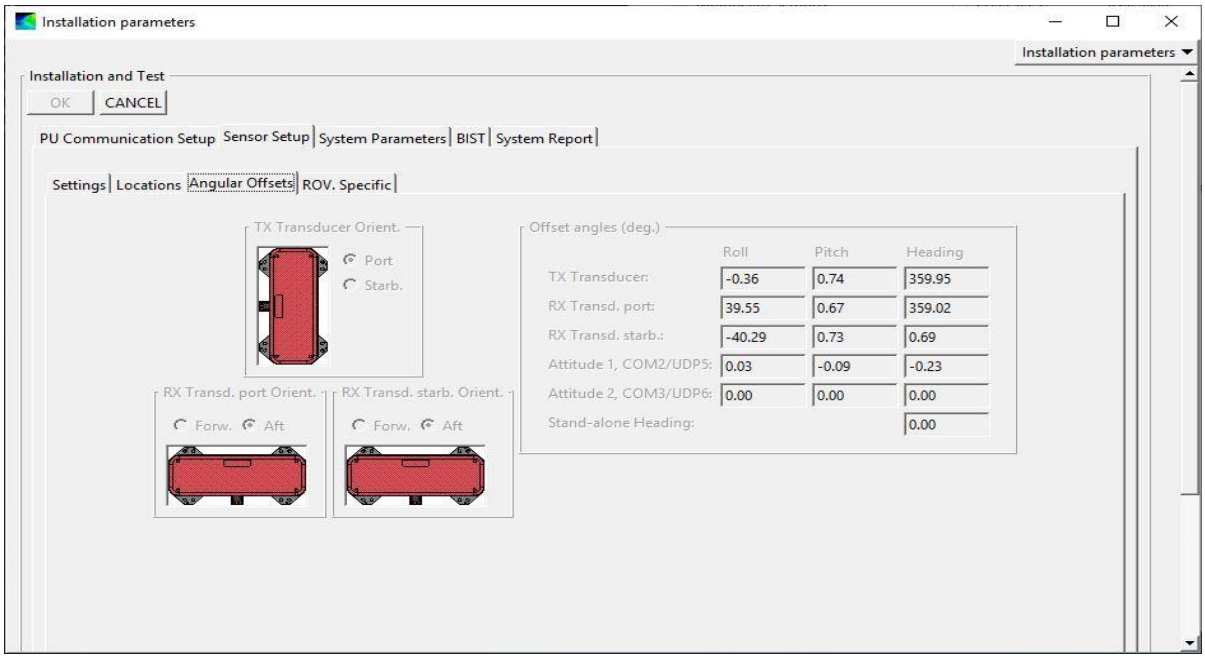


Figure 6: Angular offsets in SIS prior to patch test.

Figure 7 shows the angular offsets after patch test and verification survey.

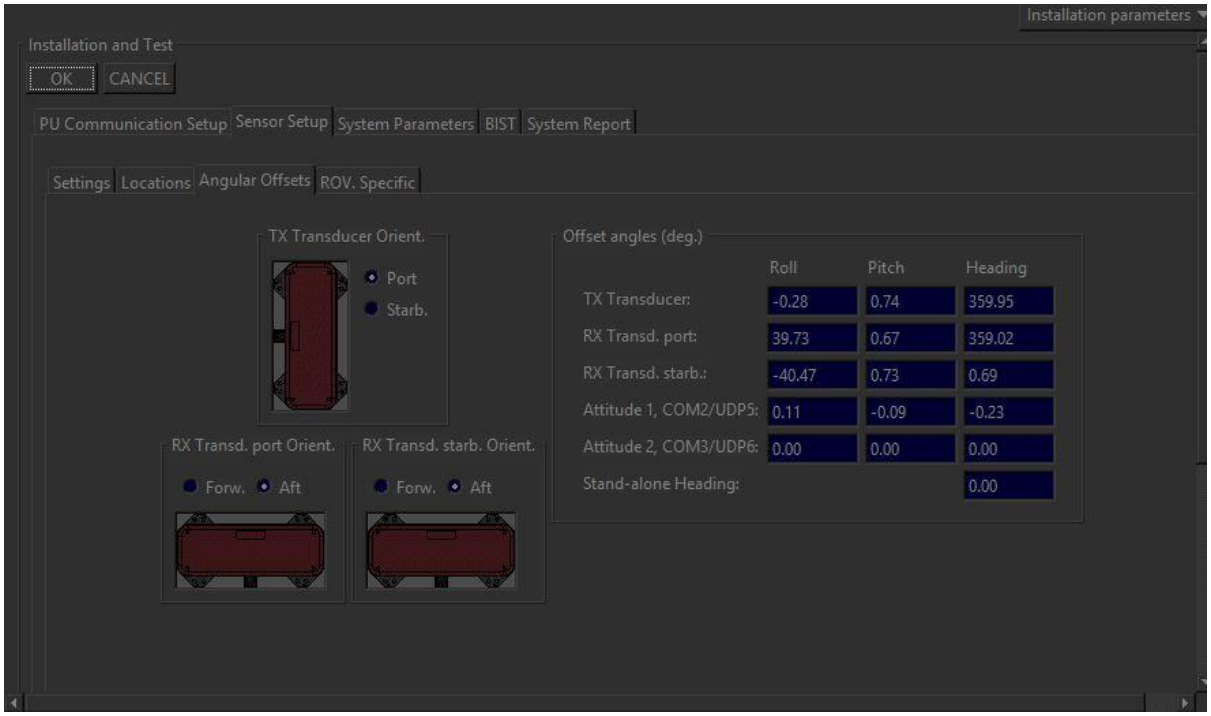


Figure 7: Angular offsets in SIS after patch test and verification survey.

3.2 Survey Equipment

Table 6 contains information on the survey equipment both permanently installed and available for mobilisation on board the RV *Celtic Voyager*.

System	Type	Comment
Multibeam Echo-Sounder	Kongsberg EM2040	200, 300 & 400 kHz
Singlebeam Echo-Sounder	Kongsberg EA400	38 and 200 kHz
Sub-Bottom Profiler	Knudsen Chirp 3260	3.5 – 9 kHz
Sidescan Sonar	Edgetech 4200	100 and 500 kHz
Positioning	C-Nav DGNSS	Seapath330+ as secondary
USBL	IXsea-Gaps	Sonardyne Scout as secondary
Sound Velocity Profiler	Valeport SVP Mini	Sound Velocity
Moving Velocity Profiler	AML MVP30-350	Sound Velocity
Realtime Sound Velocity	Valeport or AML	Sound Velocity
Magnetometers	SEASPY	Overhauser Effect

Table 6: RV *Celtic Voyager* available survey equipment.

3.2.1 Technical Issues

MBES Data Dropouts

MBES data dropouts first appeared during the 2021 survey season. They occurred again sporadically during the first survey of 2022; CV22_01. Dropouts commenced on day one of CV22_02 acquisition. Initially the issue was not bad enough to stop acquisition but the situation deteriorated and by day two it was no longer viable to map virgin ground. Dropouts originated on the port side. Figure 8 shows the SIS Geographical Window during the dropouts.

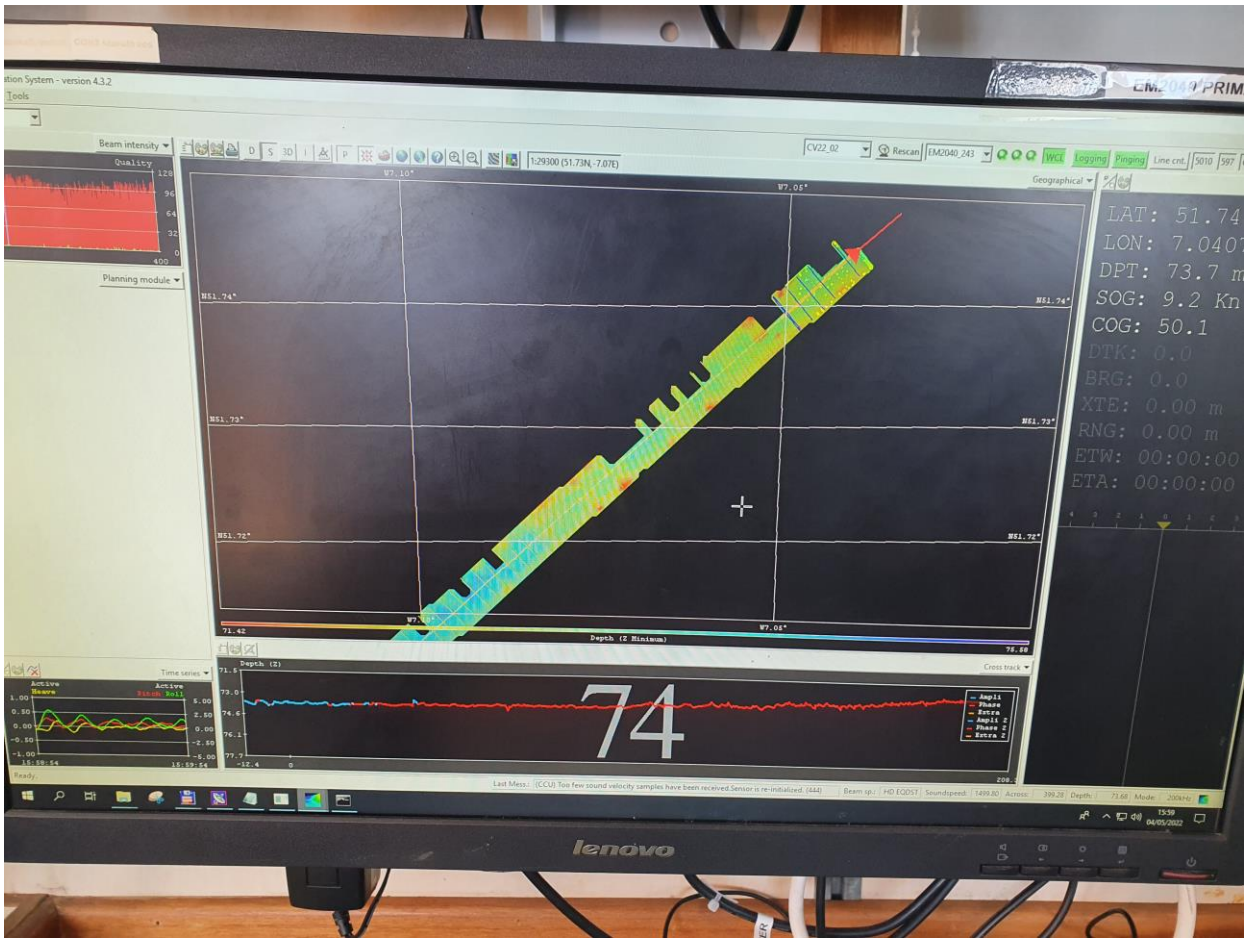


Figure 8: MBES data dropouts.

Diagnostics tests were performed using a telnet command. Kongsberg evaluated the telnet data and proposed that a cable issue was the fault source. P&O booked a dry docking in Howth, County Dublin and the vessel commenced passage on 4th May. The vessel entered dry dock on 5th May. All MBES wet cables were removed and replaced, along with the Tx Transducer and port side Rx transducer. Figure 9 shows the MBES transducer heads and cables after the heads and cables were replaced. Note starboard Rx head is the prominent head in view below and this head was not replaced as it was deemed not faulty.

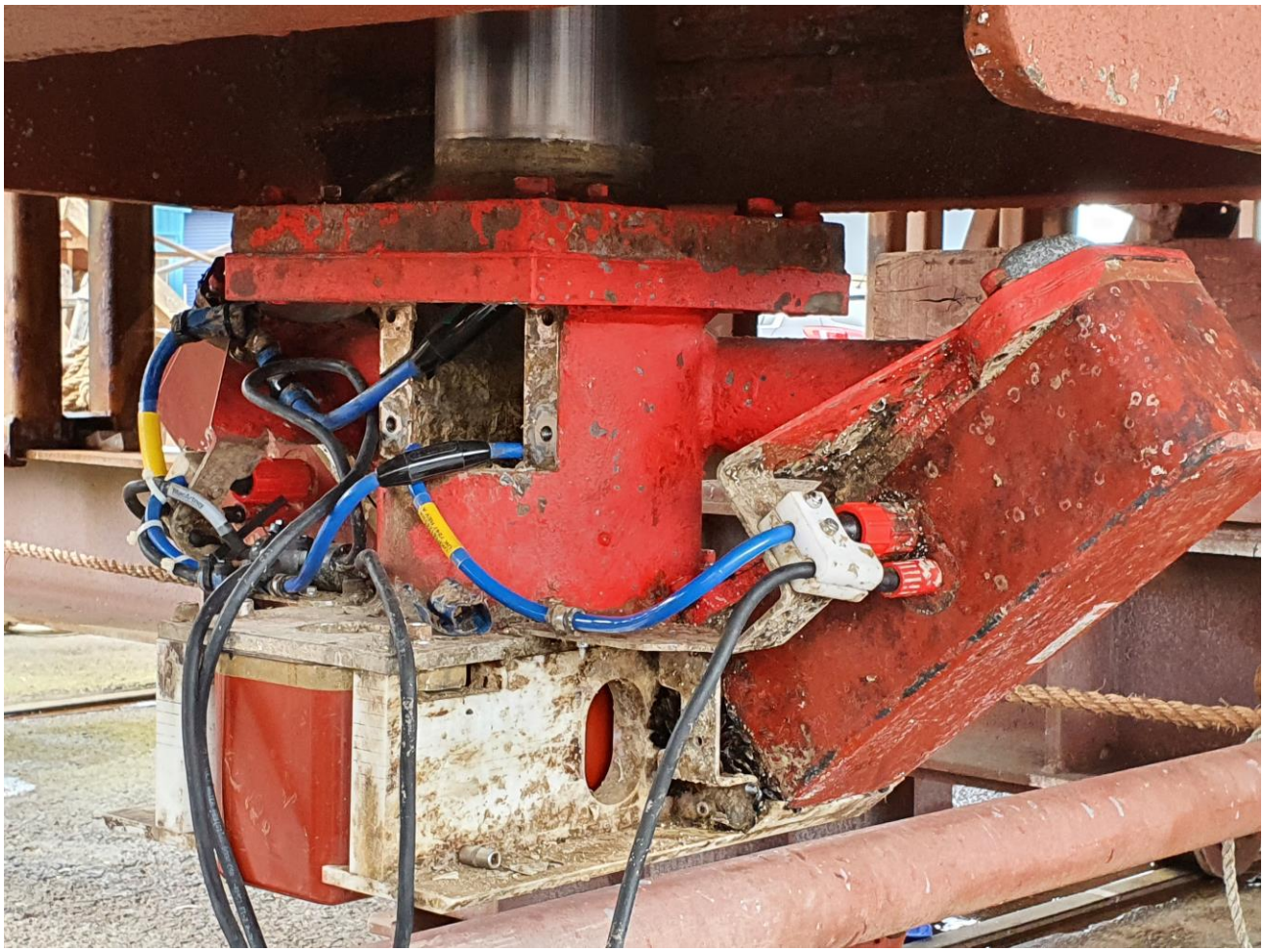


Figure 9: MBES transducers and wet cables after replacement in dry dock.

The vessel was back in the water on afternoon of the 6th. Once pinging, the MBES system was checked and no dropouts observed. A full patch test was performed outside Howth and a verification survey performed next day in the Celtic Sea during transit to site, prior to resumption of survey.

3.3 Data Acquisition

3.3.1 Geodetic Parameters

Table 7 contains the geodetic parameters used for the survey.

Local Datum Geodetic Parameters	
Datum	ITRF2014
Spheroid	World Geodetic System 1984 (WGS-84)
Semi-Major Axis (a)	6378137.000 m
Semi-Minor Axis (b)	6356752.314 m

First Eccentricity Squared (e^2)	0.0066943800
Inverse Flattening (1/f)	298.257223563
Projection Parameters	
Grid Projection	Universal Transverse Mercator
Central Meridian Zone 29 (CM)	009º West
Origin Latitude (False Lat.)	00.0°
Hemisphere	North
False Easting (FE)	500000.0 m
False Northing (FN)	0.0 m
Scale Factor on CM	0.999600
Units	M

Table 7: Geodetic parameters.

3.3.2 Survey Datum, GNSS Tides and VORF Model

Table 7 above details the vertical and horizontal datum applied during operations. Global Navigation Satellite Systems (GNSS) tides do not require us to account for vessel draft or vessel squat values, as recorded depths are related directly to the Word Geodetic System (WGS) 84 Ellipsoid. These values were reduced to Lowest Astronomical Tide (LAT) using GNSS tidal measurements and by then applying the Vertical Offshore Reference Frame (VORF) model (LAT/WGS84 separation) as illustrated in Figure 10 below.

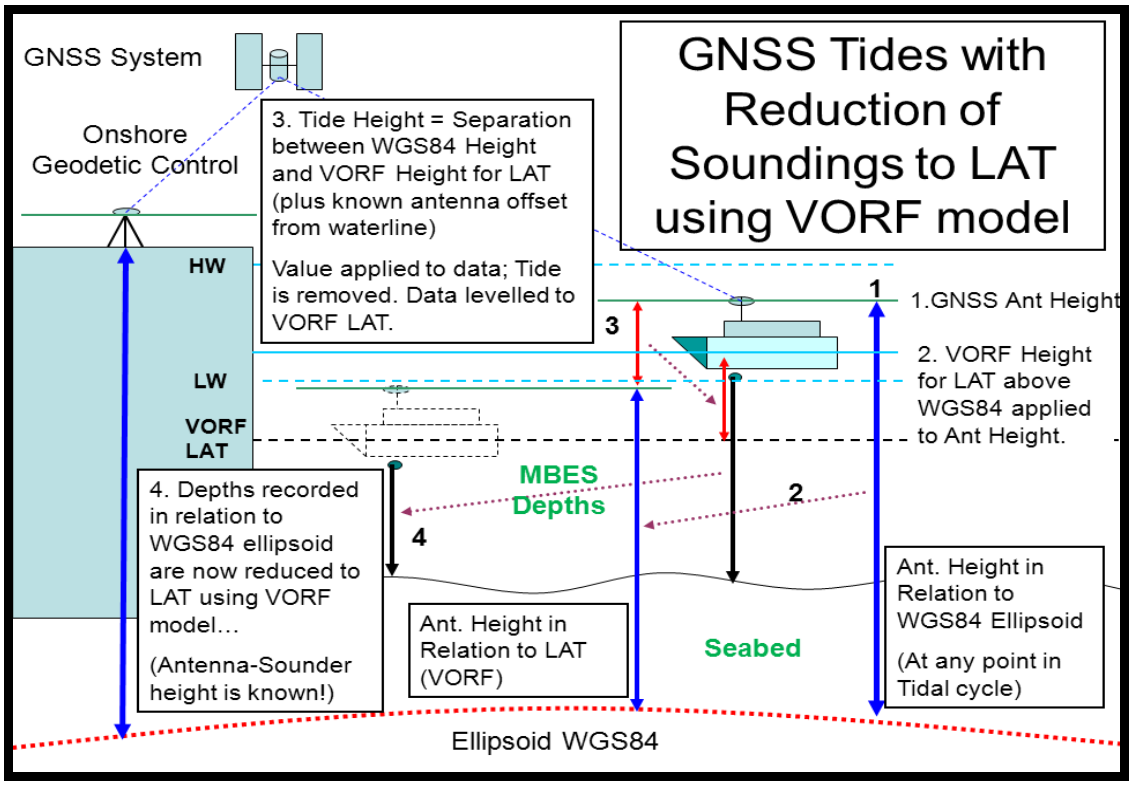


Figure 10: GNSS tides to LAT using VORF model.

3.3.3 Vessel Draft

Vessel draft was measured during mobilisation and values entered into the appropriate acquisition software's, even though strictly speaking draft values are not required when using GNSS. Distances from known draft measuring points on the vessels port and starboard sides to the water line were measured by tape once ballasting was completed. Known vertical distances at port and starboard sides between these draft measuring points and the MRU (Common Reference Point for EM2040) and EA400 transducers respectively were used along with the tape measured vertical distances to calculate draft values for the EM2040 and EA400 echosounders. Port and starboard sides were averaged to get one value for each echosounder. Table 8 lists the tape measured draft figures along with the known vertical distances.

Measurement	**Port Side**	**Starboard Side**
Tape Measurement at EA400 Draft Mark (from mark to water) 02/09/2021	4.02	3.99
Vertical distance between Starboard Side draft mark and EA400		7.4660
Vertical distance between Port Side draft mark and EA400	7.4580	
Vertical distance between Port Side EA400 draft mark and MRU	3.6746	
Vertical distance between Starboard Side EA400 draft mark and MRU		3.6824

Table 8: Draft measured and known vales.

Draft value for EM2040 = ((4.02 - 3.6746) + (3.99 - 3.6824))/2 = **0.327**
Draft value for EA400 = ((7.4580 – 4.02) + (7.4660 – 3.99))/2 = **3.46**
These draft values were entered in the respective software for both the EM2040 and EA400.

3.3.4 Acoustic Systems

A Kongsberg EM2040 high resolution MBES mounted on a retractable pole was used for swath acoustic acquisition. First bottom returns from the MBES produce highly accurate bathymetric data. Additionally, backscatter acquired by MBES sonars contains important information about the seafloor and its physical properties. Backscatter provides valuable data to aid in seafloor classification and important auxiliary information for a bathymetric survey.

The configuration consists of dual RX transducer (0.7º each) and a single TX transducer (0.7º). The system operates at frequency ranges of 200, 300 or 400 kHz with 800 soundings per ping and allows coverage of up to 10 times water depth on a flat bottom. It has a

maximum ping rate of 50 Hz. The 200 kHz frequency was used for this survey. Primary positioning was provided by C-Nav 3050 DGNSS. Seapath 330+ with integrated Seatex MRU5+ inertial unit provided secondary position and real time heading, heave, pitch, roll and velocity to the MBES system.

MBES data was recorded in raw.all format using Kongsberg's Seafloor Information Software (SIS). The raw.all files were continuously backed up on the vessel server. Table 9 contains MBES metadata. MBES water column data (.wcd) were acquired throughout and written to a separate disk.

Descriptor	**Metadata**
Survey lines	Mainlines, Crosslines and Wrecks
Data Files	171
Date Created	02-05-2022 to 21-05-2022
Dataset Size	33.5 GB
File Formats	.all & .wcd

Table 9: MBES metadata.

United Kingdom Hydrographic Office (UKHO) guidelines were implemented when carrying out wreck investigations. Three survey lines along the wreck's primary axis with high overlap and one or more lines across its secondary axis to ensure full wreck coverage along both axes were acquired. The water column logging functionality in SIS was used throughout the investigation. Beam angles, survey speed, operational frequency and pulse length were configured for maximum resolution. Wrecks were reported to the UKHO using the standard UKHO "H-Forms". A total of six wrecks were surveyed in detail.

A Knudsen hull-mounted chirp source SBP operating at 3.5 kHz was used for sub-bottom profiler data acquisition. The range and phase settings were varied appropriately with water depth to maximise ping rate and resolution. The chirp source is most effective in high resolution investigations of the top 20 or 30 m sub-seabed and where sediments are fine and medium grained. The signal does not penetrate bedrock. The Chirp 3260 is a blackbox system that interfaces to a standard PC via a USB connection. SounderSuite Windows application software controls data acquisition. Raw data were recorded in native Knudsen format along with industry standard SEGY data. Positioning data were provided from C-Nav DGNSS and MRU data were fed directly from the Seapath 330+. QC was maintained by the online surveyors, with reference to the digital display; with power, range, gains, filter parameters and transmit pulse adjusted as required for optimal imaging. All data were backed up to the vessel server. Table 10 contains SBP metadata.

Descriptor	Metadata
Survey lines	All
Data Files	174
Date Created	02-05-2022 to 21-05-2022
Dataset Size	3.58 GB
File Formats	.kea, .keb & .sgy

Table 10: SBP metadata.

3.3.5 Magnetometer

A Marine Magnetics Corporation SeaSPY towed Overhauser Magnetometer was used to acquire magnetic field data. The system comprises a towfish, tow cable, deck lead and transceiver interfaced to a standard Windows based PC. Acquisition parameters and QC were controlled via Marine Magnetics BOB™ software.

The magnetometer was towed 100 m behind the vessel at a depth of less than 5 m beneath sea surface. Magnetometer and GPS data from the towfish were input to the control PC via separate serial ports and synchronised. Initial QC was performed via real-time graphing of the magnetic field trace and by monitoring real-time GPS data. Magnetometer data were recorded in a database using BOB and output in proprietary BOB format as a .mms file. Metadata is contained in Table 11.

Descriptor	Metadata
Survey lines	NA
Data Files	2
Date Created	02-05-2022 to 21-05-2022
Dataset Size	387 MB
File Formats	.mms, .txt

Table 11: Magnetometer metadata.

3.3.6 DGPS Systems

C-Nav DGNSS provided the primary navigation. The C-Nav 3050 is a dynamic DGNSS Precise Point Positioning (PPP) system providing accuracy of <0.1 metre horizontally and 0.2 metre vertically. It provides 66 channel tracking, including multi-constellation support for GPS, GLONASS and Galileo. C-Nav provided the primary navigation feed for the MBES, SBP and magnetometer sensors. C-Nav also provided a reliable GPS tide correction.

C-Nav has a range of QC output displays that were monitored in real-time including number of satellites in use, satellite attitude and angles, vertical accuracy, vessel speed, heading and precise position. GPS signal was always very good and the system never lost the Real Time Gypsy (RTG) solution. A USB drive connected to the C-Nav receiver provided real-time data storage.

Seapath 330+ provided the secondary navigation. Seapath and C-Nav data were monitored continuously in Quality Integrated Navigation System (QINSy) software to ensure data integrity and comparison between the primary and secondary navigation systems remained within tolerance. Navigation data were recorded in .cnav3050 format using C-Nav software. One file per day was created.

3.3.7 Online Navigation

QINSy software was used for navigation acquisition and QC. QINSy performs visual and QA data-feeds from the key acquisition systems. A project template database was created containing all survey configuration parameters relevant to the project. The project template contains the datum, projections, vessel shape, administrative information, as well as vessel offsets and I/O parameters. QINSy uses a sophisticated timing routine based on the Pulse Per Second (PPS) option from the GNSS receiver. All incoming and outgoing data are accurately stamped with a UTC time label. Survey line positioning data were recorded in QINSy software in .db and .txt format. QINSy file metadata is provided in Table 12.

Descriptor	Metadata
Survey lines	All
Data Files	274
Date Created	02-05-2022 to 21-05-2022
Dataset Size	5.25 GB
File Formats	.db & .txt

Table 12: QINSy navigation metadata.

3.3.8 Sound Velocity

An AML Oceanographic Moving Vessel Profiler (MVP) 30-350 was the primary instrument for acquiring sound velocity profile data and a Valeport Mini Sound Velocity Profiler (SVP) instrument as backup. Both instruments are equipped with sound velocity sensors that directly measure sound velocity. The dual benefit of the MVP is that the vessel did not have to stop to acquire sound velocity data, allowing more casts to be acquired and without impacting MBES data acquisition rate. Fresh sound profiles were input to the echo sounders as required. A Valeport sound velocity sensor positioned at the transducer head provided a real-time sound velocity input for beam steering, directly to the EM2040.

MVP deployment was controlled from the vessel Dry Lab using Rolls Royce MVP software. The probe was continually towed in the water at between 2 and 6 metres depth and deployed to within 15 metres of the seabed during casts. Sound velocity profiles in .asvp

format were sent to SIS where they were checked and extended for import into the echo sounders. Metadata is contained in Table 13.

Descriptor	**Metadata**
Survey lines	NA
Data Files	46
Date Created	02-05-2022 to 21-05-2022
Dataset Size	368 KB
File Formats	.asvp,

Table 13: Sound velocity metadata.

4 Online QC, Data Processing, Results and Interpretation

The hydrographic survey was performed to International IHO survey standards. Rigorous standards for position, depth accuracy, feature search, feature detection and bathymetric coverage were achieved during data acquisition and processing. IHO Order 1a and Order 2 requirements are presented in Table 14.

	Order 1a (S-44)	**Order 2 (S-44)**
Description of Areas	Areas where underkeel clearance is considered not to be critical but features of concern to shipping may exist.	Areas generally where a general description of the sea floor is considered adequate.
Max THU allowable (95%C)	Total Horizontal Uncertainty (THU) 5m+5% of depth	Total Horizontal Uncertainty (THU) 20 m+10% of depth
Max TVU allowable (95%C)	Total Vertical Uncertainty (TVU) a = 0.5 metre b = 0.013 $\pm\sqrt{a^2 + (bxd)^2}$	Total Vertical Uncertainty (TVU) a = 1.0 metre b = 0.023 $\pm\sqrt{a^2 + (bxd)^2}$
Feature Search	100%	Recommended but not required
Feature Detection	Cubic Features > 2m (Depths < 40m) 10% depth > 40m	Not specified
Bathymetric Coverage	≤100%	5%

Table 14: IHO standards for hydrographic surveys

4.1 MBES Online Quality Control

4.1.1 Acquisition Parameters

Most of the important acquisition parameters are set in the Runtime Parameters module of SIS. Figure 11 shows an example of settings in the Sounder Main tab in Runtime Parameters. Max angle and max coverage parameters were adjusted to take account of depth, sea state, sound velocity conditions and seafloor character. Pulse type was maintained at FM and ping mode set to 200 kHz, which maximised swath width and maintained good signal to noise ratio. Max angle, sector mode, vessel speed and pulse type were adjusted to attain maximum resolution for wreck inspections. Water Column data were acquired for all survey lines.

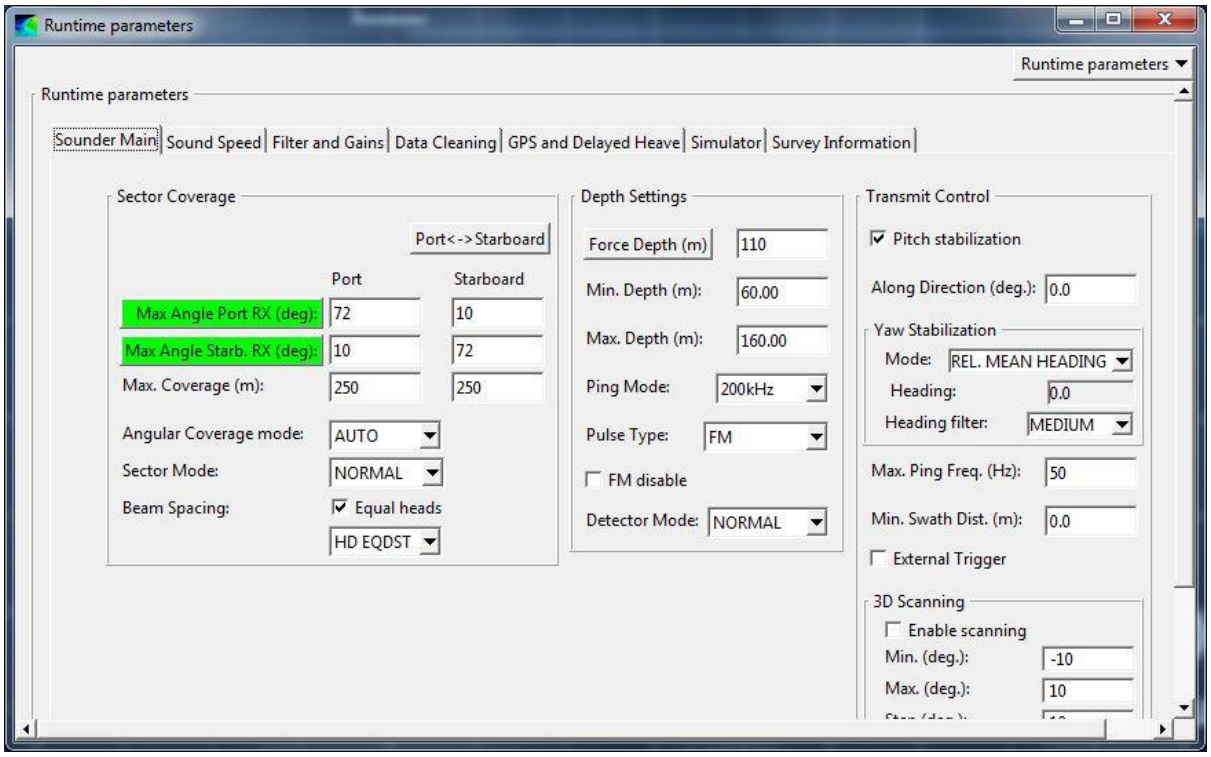


Figure 11: Runtime parameters window in SIS.

4.1.2 Crossline versus Mainline Statistics

Crossline data were acquired for QC of depth soundings. A total of 2 crosslines were acquired for statistical analysis in Caris Hips™. Crossline data were compared with mainline data. All crossline data indicated that the soundings exceeded the 95% certainty required for Order 1a specification. Results from the statistical analyses are presented in Table 15.

Line	Beam No.	Count	Max (+)	Min (-)	Mean	Std Dev	Order 1a (%)
061	1-800	952,708	71.445	8.271	1.491	10.265	95
066	1-800	1,429,198	2.036	1.615	0.041	0.250	100

Table 15: MBES crossline statistics.

4.1.3 Feature Detection

The minimum standard for feature detection for an Order 1a survey are cubic features > 2 metres in depths up to 40 metres and cubic features >10% of depth beyond 40 metres. In 40 metres water depth 9 soundings are required in a 2 m^2 bin and in 100 metres water depth 9 soundings are required in a 10 m^2 bin. Feature detection criteria are not specified in the IHO standards for Order 2 surveys. A data density traffic light plot and associated statistics were produced for the area.

Water depths range from 88 to 137 m. The minimum sized cubic features that require detection are 8.8 m, i.e. 10% of minimum water depth. A minimum of 9 soundings per 8.8 m^2 bins are required in order to attain the feature detection criteria. A bin size of 8.8 m^2 was selected to QC the data density and the results are shown in Figure 12. Green indicates where 9 soundings per bin were achieved, i.e. almost everywhere, and red where the 9 soundings were not attained. Red areas are sporadic and limited to the outer fringes of coverage where adjacent data from other surveys has not been included in the data density calculations.

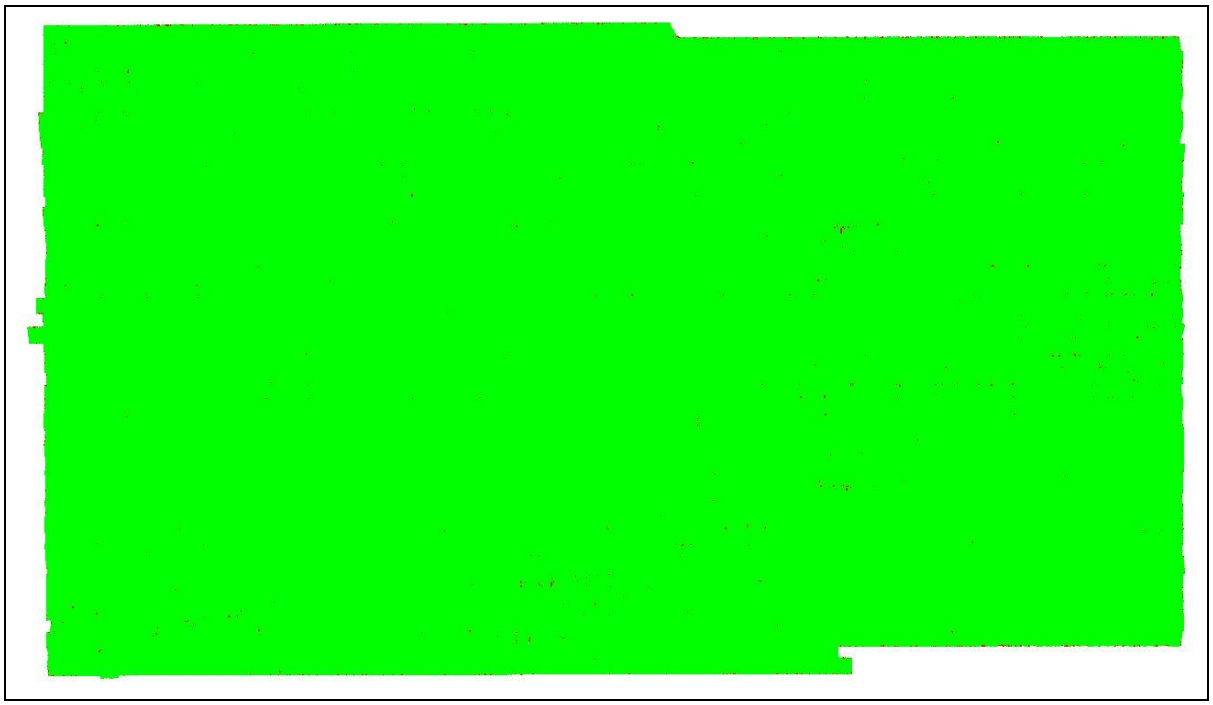


Figure 12: Sounding density traffic light plot.

The mean number of soundings per bin was computed at 52. This easily exceeded the 9 soundings required per bin. Full statistics are shown in Figure 13.

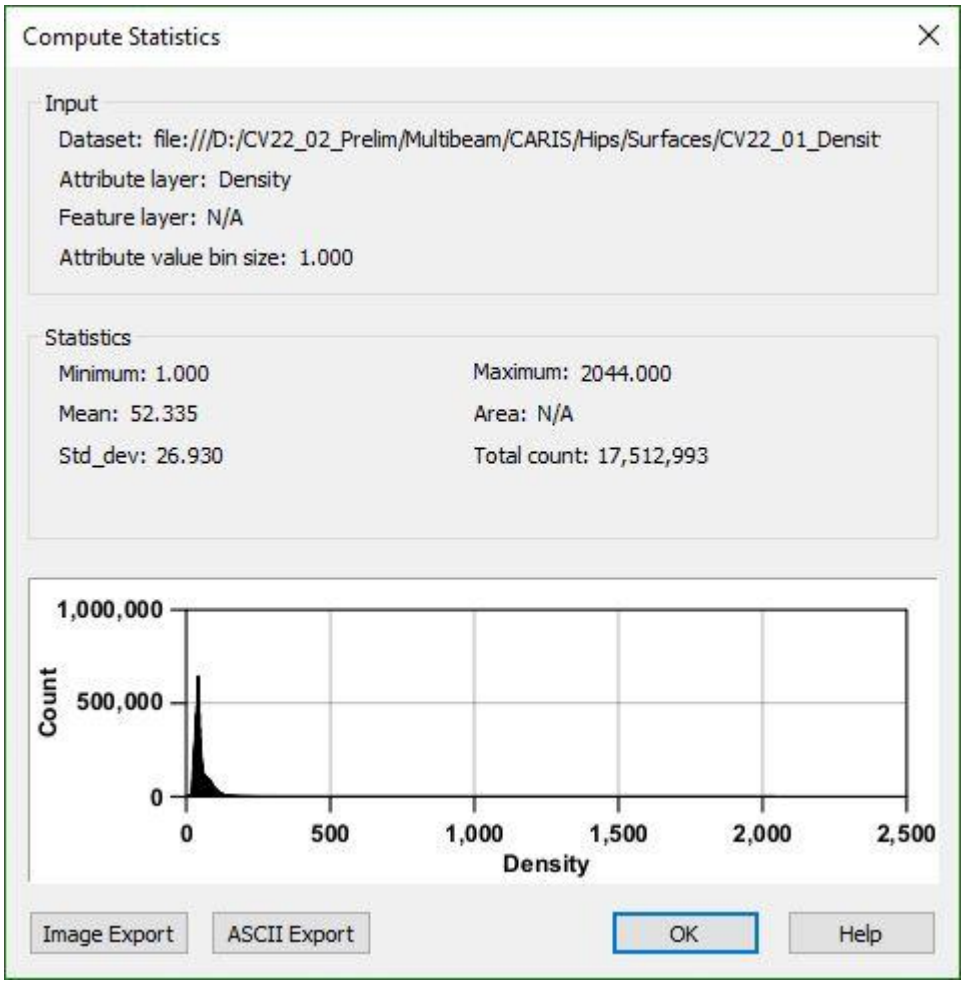


Figure 13: Sounding density statistics.

4.1.4 Error Budget and Uncertainty Model

Manufacturer values for positioning and sounding errors were factored into the vessel error budget. Vessel offsets were established through an onshore dimension control survey (see section 3.1). In addition; uncertainty levels over positions of soundings were improved through good sound velocity control while surveying. Calibration of the MBES through a standard patch test, combined with good online quality control, ensured that the vessel's error budget fell within IHO 1a specifications.

Table 16 below details standard deviation values applied in the calculation of the vessel's Total Propagated Uncertainty (TPU) model. TPU is an estimate of the uncertainty of any individual sounding, taking into account the uncertainty estimates of the component measurements (tide, sound speed, draft, range measurement, angle measurement, attitude, offsets etc). TPU is expressed as a separate value in horizontal and vertical planes. The

uncertainty of each sensor was entered in the HIPS Vessel File (HVF) and the TPU calculated.

Heading Accuracy	0.065º
Heave	5 cm or 5 % Amplitude
Roll	0.01º
Pitch	0.01º
Pitch Stabilised	0.00º
Position Navigation	0.1 m
Timing Transducer	0.00 s
Timing Navigation	0.00 s
Timing Gyro	0.00 s
Timing Heave / Pitch / Roll	0.00 / 0.00 / 0.00 s
Sound Velocity Measured	0.001 m/s
Sound Velocity Surface	0.001 m/s
Offsets X / Y /Z	X=0.01 / Y=0.01 / Z=0.01
MRU Alignment	Gyro=0.1 / Pitch=0.1 / Roll=0.1
Vessel Speed	0.03
Vessel Loading	0.00
Vessel Draft	0.00 (Use of GPS tides)
Delta Draft	0.00

Table 16: Standard deviation values used in TPU calculation.

4.1.5 Sound Velocity Control

MBES data processors continuously monitored the effect of sound velocity variations on the processed MBES data. Data processors advised on the frequency and geographical distribution of MVP casts based on this analysis. Sound velocity variations were also monitored by QC of the SIS Crosstrack window and by comparison of the sound profile versus the real-time sound velocity reading in the SIS Numerical window.

Figure 14 shows the MVP composite plot for all profiles. Sound velocity in metres per second is plotted on the x-axis and depth in metres on the y-axis. All profiles have a broadly similar trend.

Sound velocity ranges from c. 1492 m/s to c. 1504 m/s. The near surface waters down to 4 to 6 metres are very well mixed and show near constant velocity on individual profiles. There is a thermocline between those depths and down to between 30 and 50 metres where sound velocity decreases. Sound velocity starts to increase in a linear trend beneath the thermocline as the influence of pressure becomes the dominant factor controlling sound speed.

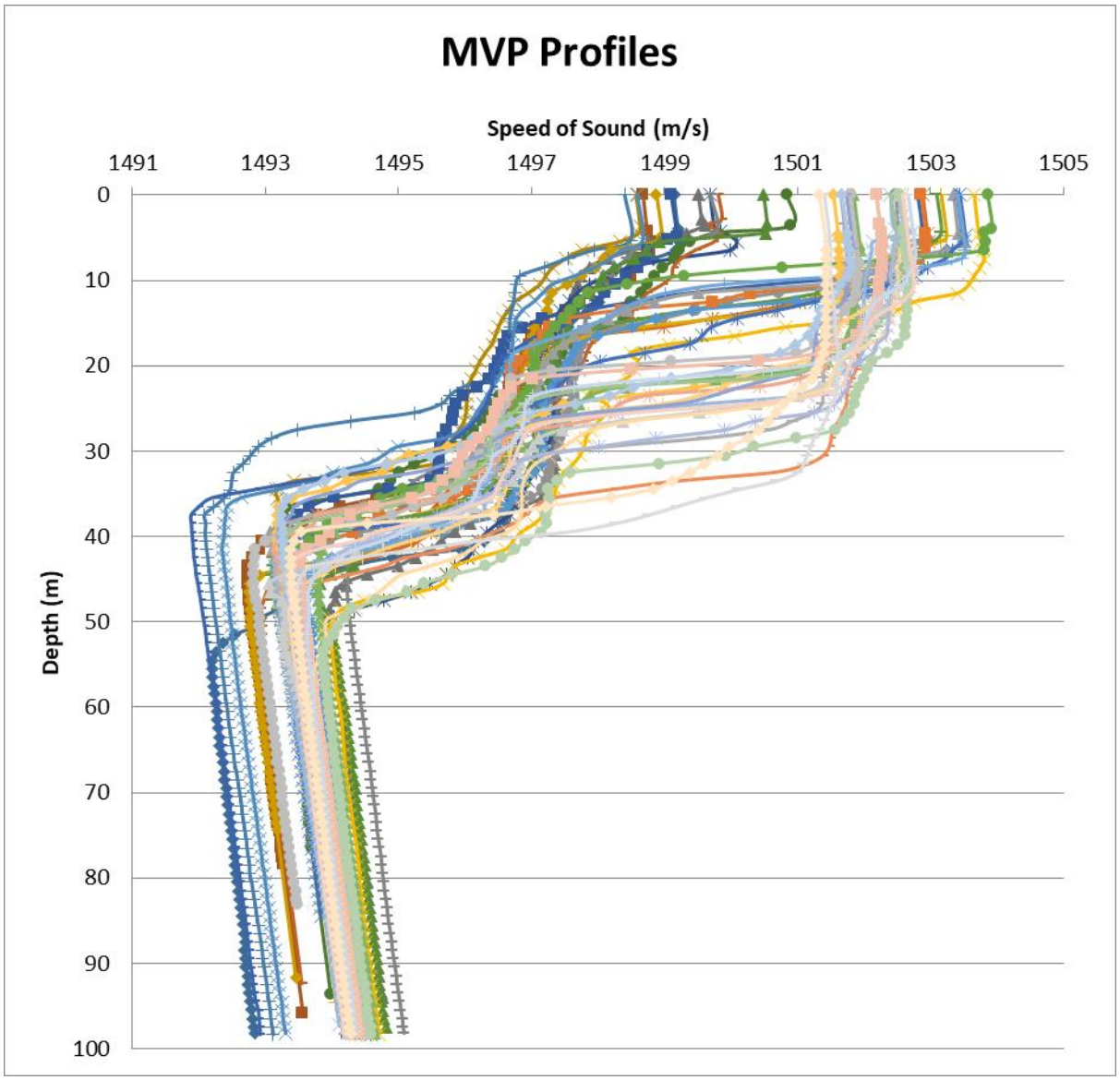


Figure 14: MVP composite plot.

4.2 Post Processing Methods

4.2.1 Navigation

Navigation data were logged in standard C-Nav format. Real-time positioning data quality from C-Nav was of sufficient quality to exceed IHO Order 1a standard requirements. Vertical errors on the GPS heights were low (+/- 20 cm) and provide a robust solution for computation of GPS tide.

Navigation data and in particular GPS heights were de-spiked and smoothed in Caris HIPS. GPS tide was computed using the separation model between International Terrestrial Reference Frame (ITRF) datum and VORF LAT.

4.2.2 Depth Soundings Data Processing

Soundings were edited in Caris HIPS software against an existing chart background. Combinations of automated and manual processing procedures were applied by experienced data processors to remove systematic errors and obvious outliers. Uncertainty results were examined to ensure soundings fell within IHO specifications for Order 1a and Order 2 surveys. Processed and cleaned data were subject to final validation by an experienced and qualified hydrographer. The following is a simplified list of steps undertaken during sounding data processing:

1. Navigation data were checked and spikes removed.
2. GPS tides were computed using the UKHO's VORF model. This reduced the MBES depth soundings to LAT. GPS tide results were then checked for quality and consistency.
3. TPU values were calculated.
4. SVP data were applied to correct for refraction errors caused by water column heterogeneity. A range of SV algorithms were used to determine the most suitable method of applying SV corrections, for example: nearest in distance versus nearest in time.
5. Qimera's "*TU Delft Sound Speed Inversion*" tool was used to correct refraction issues.
6. Subset Editing was performed in CARIS to clean large "noise" spikes from the data.
7. A CARIS Combined Uncertainty and Bathymetry Estimator (CUBE) base surface was created to allow CUBE automatic filtering.
8. Final verification of sounding consistency and absence of spikes was done using subset editing.

4.2.3 Backscatter Mosaic Generation

Backscatter is a function of the hardness and roughness of the seafloor. Raw MBES data was put through the Geocoder engine in QPS Fledermaus™ (FMGT) to produce backscatter mosaics of 2, 5 and 10 m resolutions.

4.3 Survey Results and Data Interpretation

A preliminary interpretation of MBES data was used to assess bathymetry, seabed texture and seabed features. SBP data was used to assess the shallow geology.

4.3.1 MBES Images

MBES bathymetry grids and shaded relief geotiff images at both 5 and 10 m respectively were created in Teledyne Caris HIPS & SIPS™ software and backscatter mosaic geotiffs created in QPS FMGT™. Geotiffs and grids were imported into ArcGIS™ and images (Figures 15 to 17) output for this report.

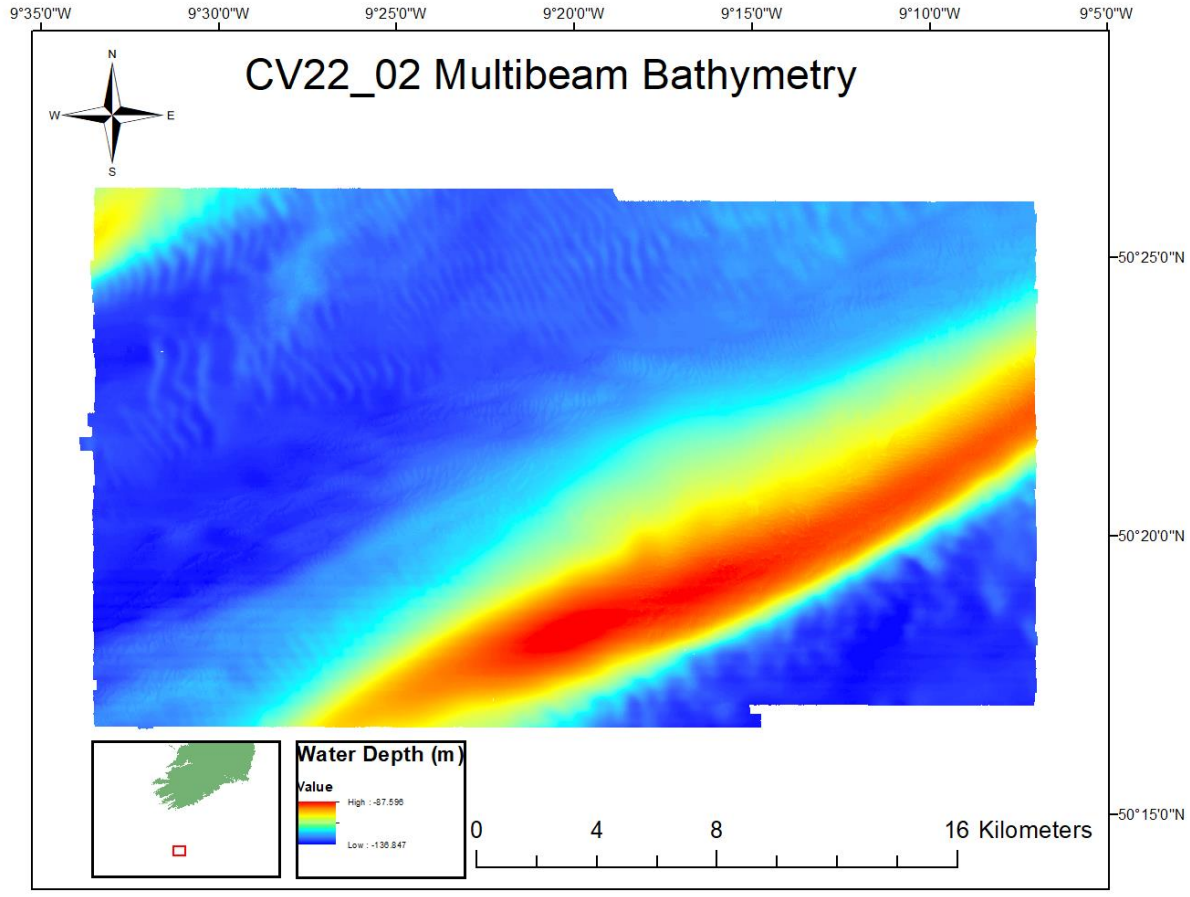


Figure 15: MBES bathymetry.

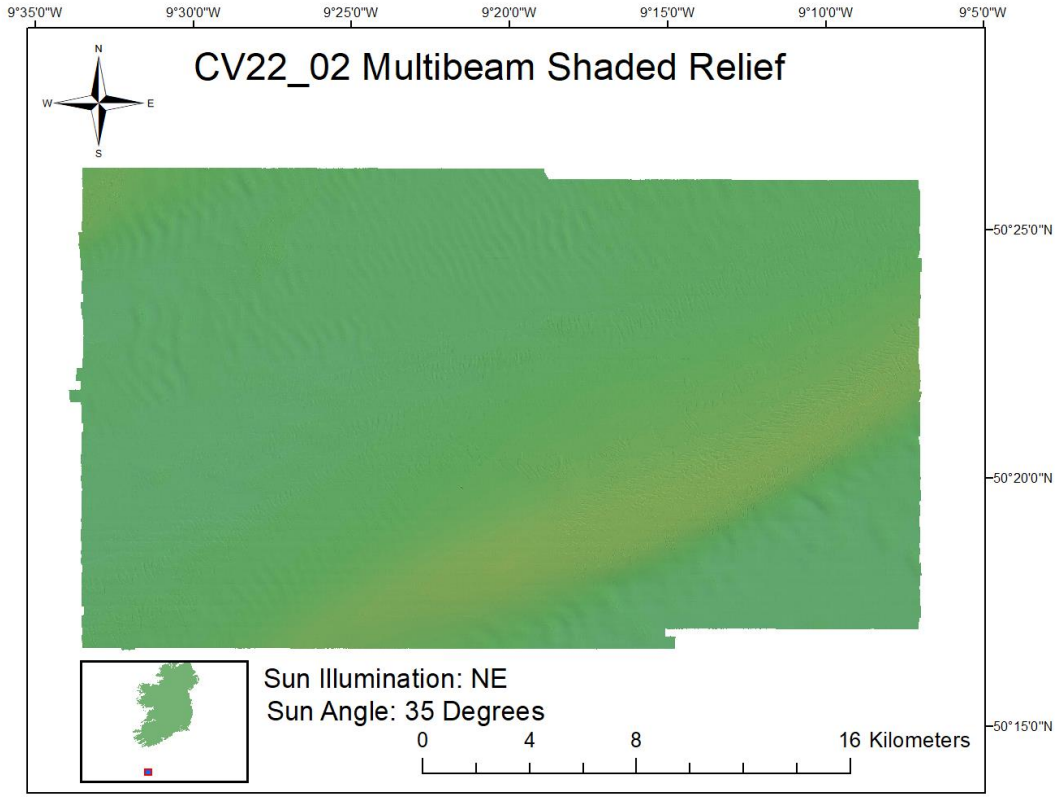


Figure 16: MBES shaded relief.

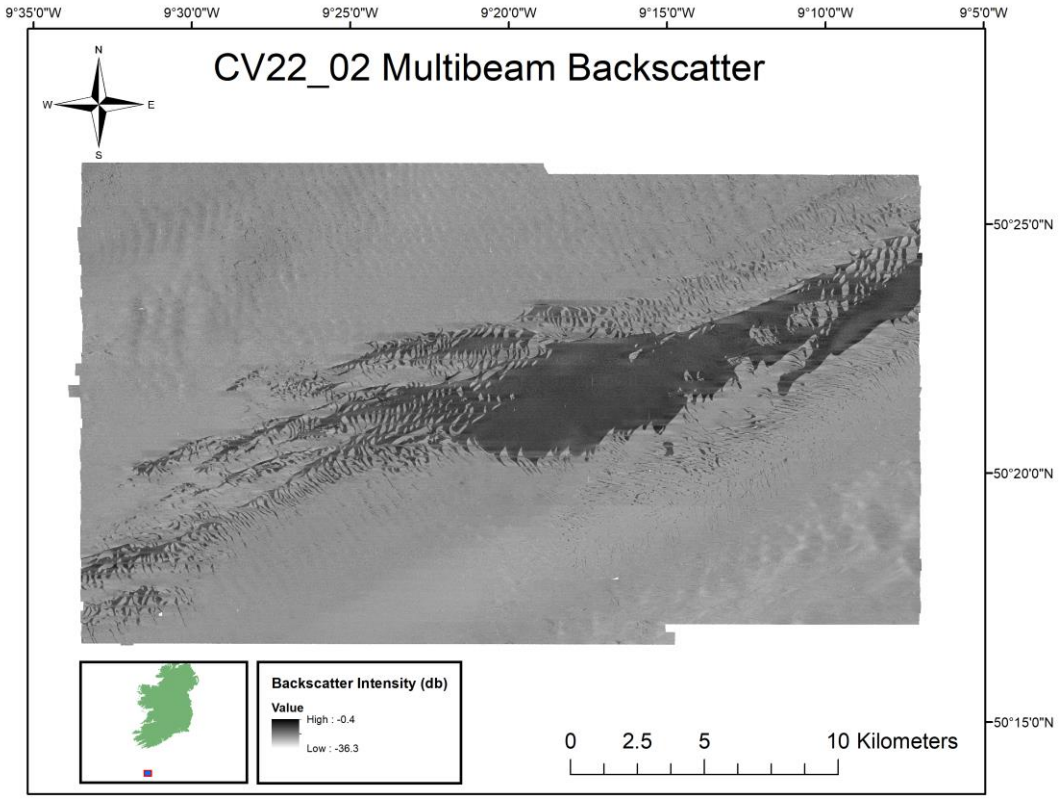


Figure 17: MBES backscatter mosaic.

4.3.2 Shallow Geology Analysis

Chirp SBP data quality varied considerably due to environmental factors relating to sea state and sub-bottom conditions. Survey speed (4-9 knots) was dictated by the ability of the MBES to meet its data density and data quality requirements. This is usually faster than the optimal maximum speed of 4 knots for SBP data acquisition. Sea state varied significantly during the survey.

Knudsen SounderSuite™ software recorded sub-bottom data in proprietary Knudsen kea and keb formats and sgy format. SGY data were converted to coda format using Coda File Utilities™ software. These Coda format files were replayed in Coda GeoSurvey™ software, where TVG and bandpass filtering were applied and tiff images created. Profile lines 052 and 149 are selected for discussion here. Their geographical locations are shown in Figure 18 where the profile extents have been overlain on the bathymetry.

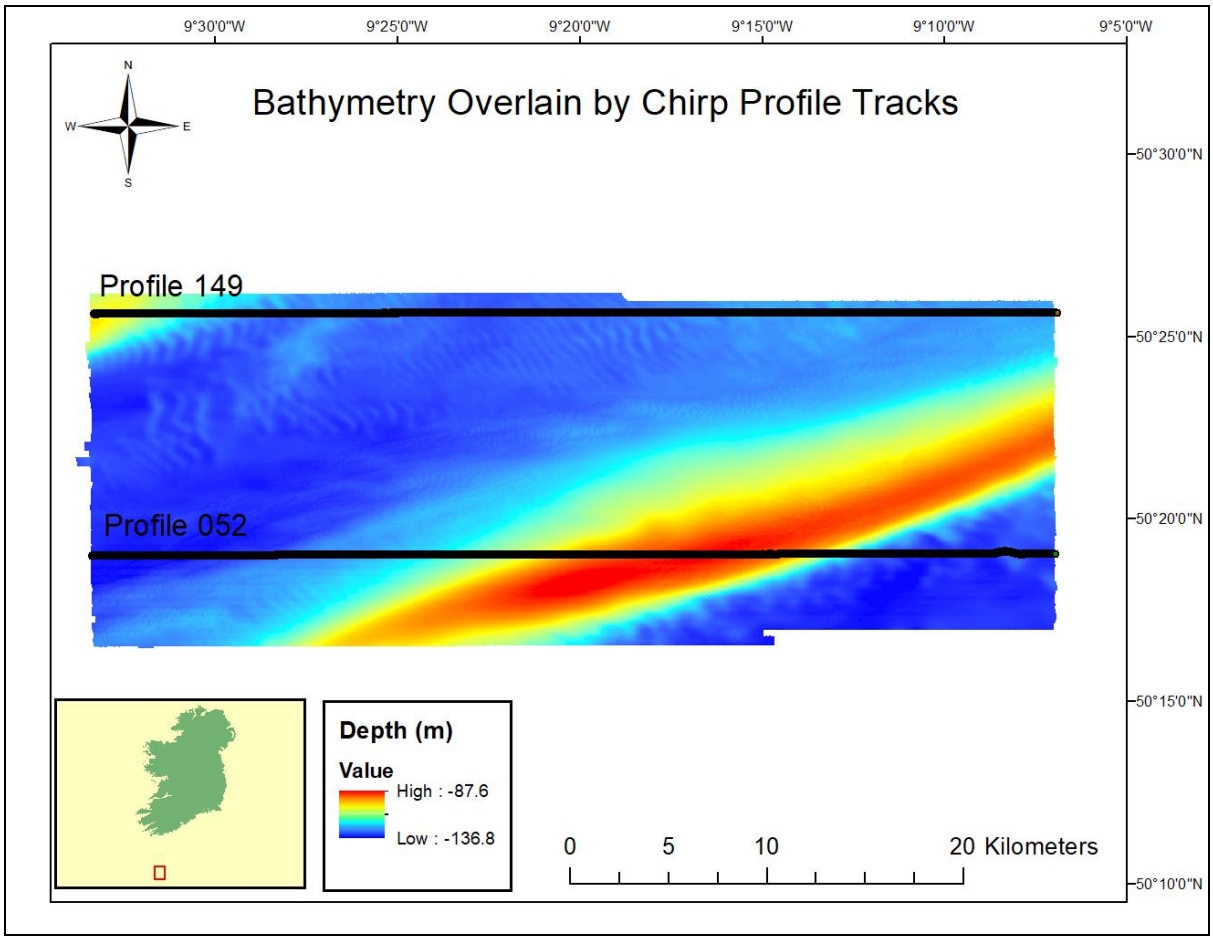


Figure 18: Profiles 052 & 149 extents overlain on bathymetry.

Interpreted SBP tiff images of profiles 052 and 149 are shown in Figures 19, 20 and 21 respectively. A bandpass filter with low cut 1.7 kHz and high cut 4.7 kHz was applied in

processing. Heave compensation is applied to the images. Horizontal scale lines are at 8 m (10 ms) intervals. Note that the vertical scale is greatly exaggerated.

Profile 052 in Figure 19 is 31.5 km in length. The profile was acquired from west to east. Data quality is good, with only minor cavitation's observed on the record. The seabed topography is dominated by a 40 m high megaridge in the centre. There is no signal penetration beneath the surface of the megaridge. The ridge is asymmetrical with a steeper eastern flank. Several ribs of various symmetry, amplitude and wavelengths are located on the eastern flank. The largest of which has an amplitude of over 4 m.

Reflector R2 is the only reflector annotated on the record. It is observed on both the east and west parts of the profile. R2 is rugged in character for the most part but it is also smooth in parts of the east. R2 denotes to the top of Unit 2, the base of which cannot be seen.

Unit 1 unconformably overlies Unit 2. Unit 1 is up to 7 m in thickness. It has several internal reflectors and is acoustically transparent. Unit 1 seems to pinch out against the megaridge but it is difficult to ascertain due to the lack of acoustic penetration beneath the ridge.

Profile 149 in Figures 20 and 21 is a combined length of 31.3 km. The profile was acquired from west to east and is north of the megaridge discussed on the interpretation of profile 052. Chirp data quality is fair, with good penetration but with frequent cavitation's.

The base unit is annotated as Unit 3. It is observed in the east of the profile. Its thickness is unknown. Unit 3 is overlain by Unit 2 with the reflector R3 marking the boundary. R3 is only observed in the eastern 6 km of the profile where acoustic penetration is best. R3 is undulating in character.

Unit 2 is observed across the entire profile. It attains its greatest thickness in the east where it is c. 15 m thick. Reflector R2 denotes the top of Unit 2. Unit 2 is overlain by Unit 1 which is also the topmost unit. Unit 1 is up to c. 8 m in thickness and it is transparent in character. Several internal reflectors are observed within Unit 1. Sediment waves and scoured substrate are observed at the seabed. The flank of a megaridge is observed on the westernmost c. 5 km of the profile where the seabed rises by c. 23 m.

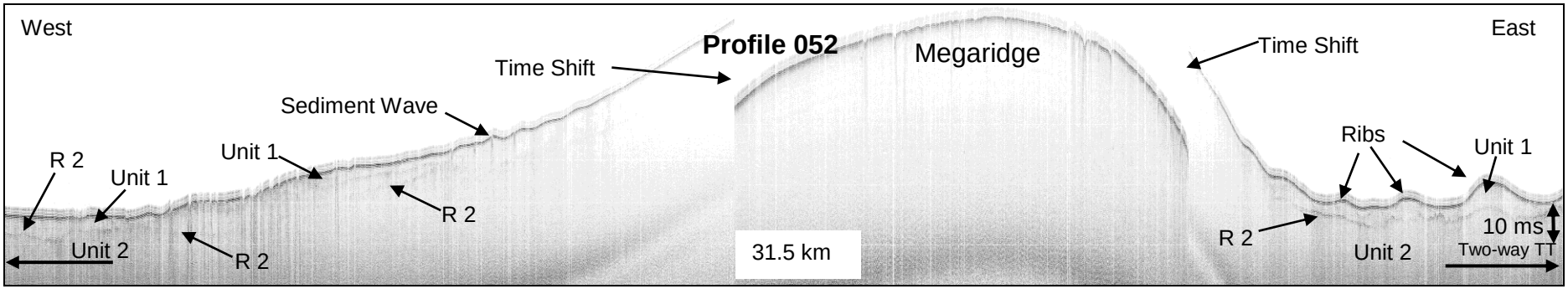


Figure 19: SBP interpreted image, line 052.

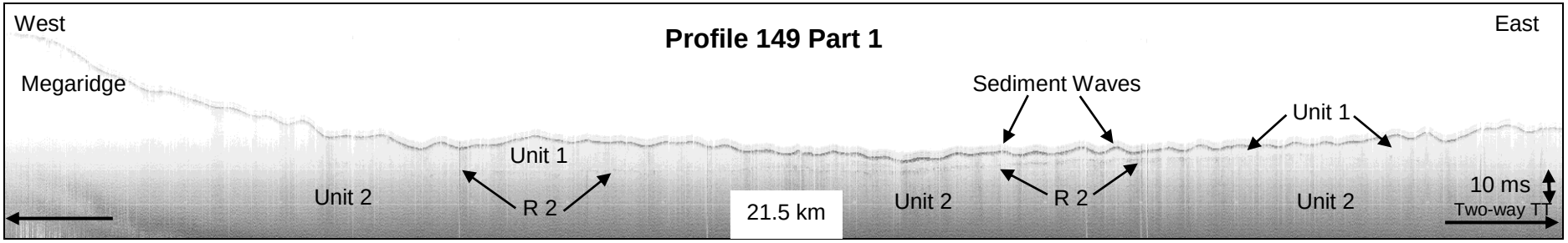


Figure 20: SBP interpreted image, line 149, part 1.

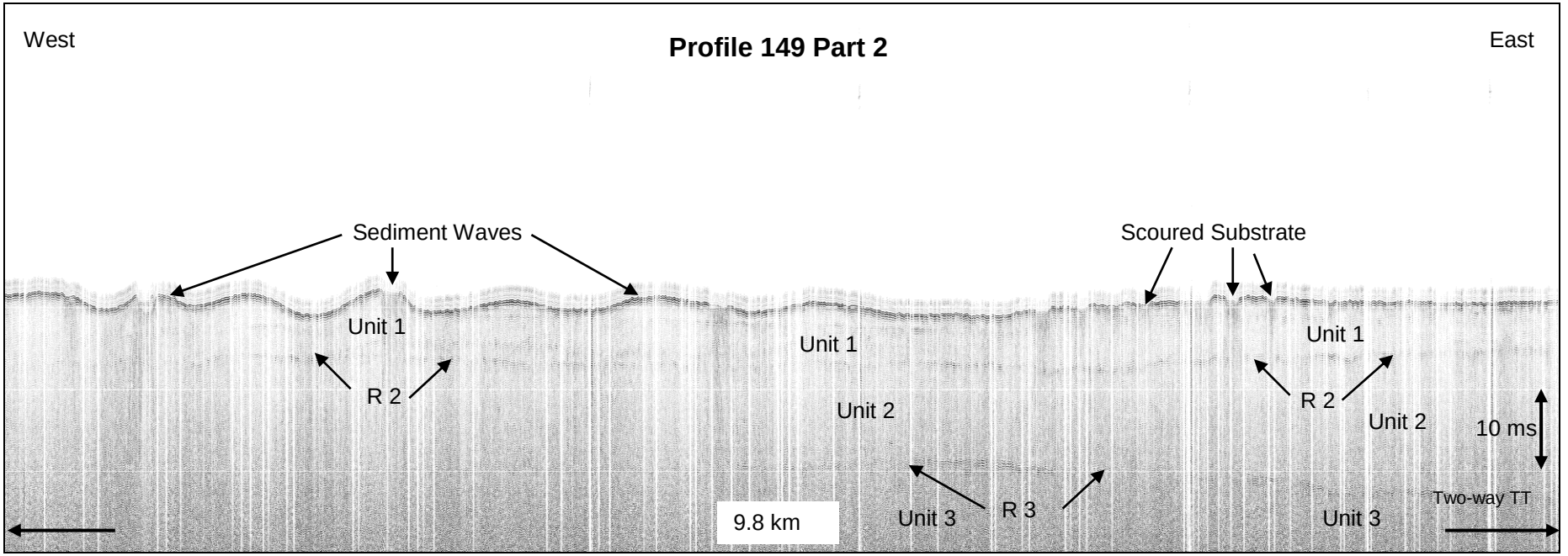


Figure 21: SBP interpreted image, line 149, part 2.

4.3.3 Bathymetry

Figure 22 is a colour coded MBES bathymetry image with the main features annotated. Water depth varies from 88 to 137 m. Least depths are located on a megaridge crest. The megaridge stretches from the eastern extent of the survey coverage to two thirds of the way across to southern extent of coverage. It is orientated along a NE–SW axis, is over 4 km in width and greater than 30 m in amplitude. Sediment waves are widely distributed north of the megaridge. They are orientated NW-SW and are both sinuous and chevron in character. Wavelengths are typically 300 to 600 m and amplitudes of less than 2 m.

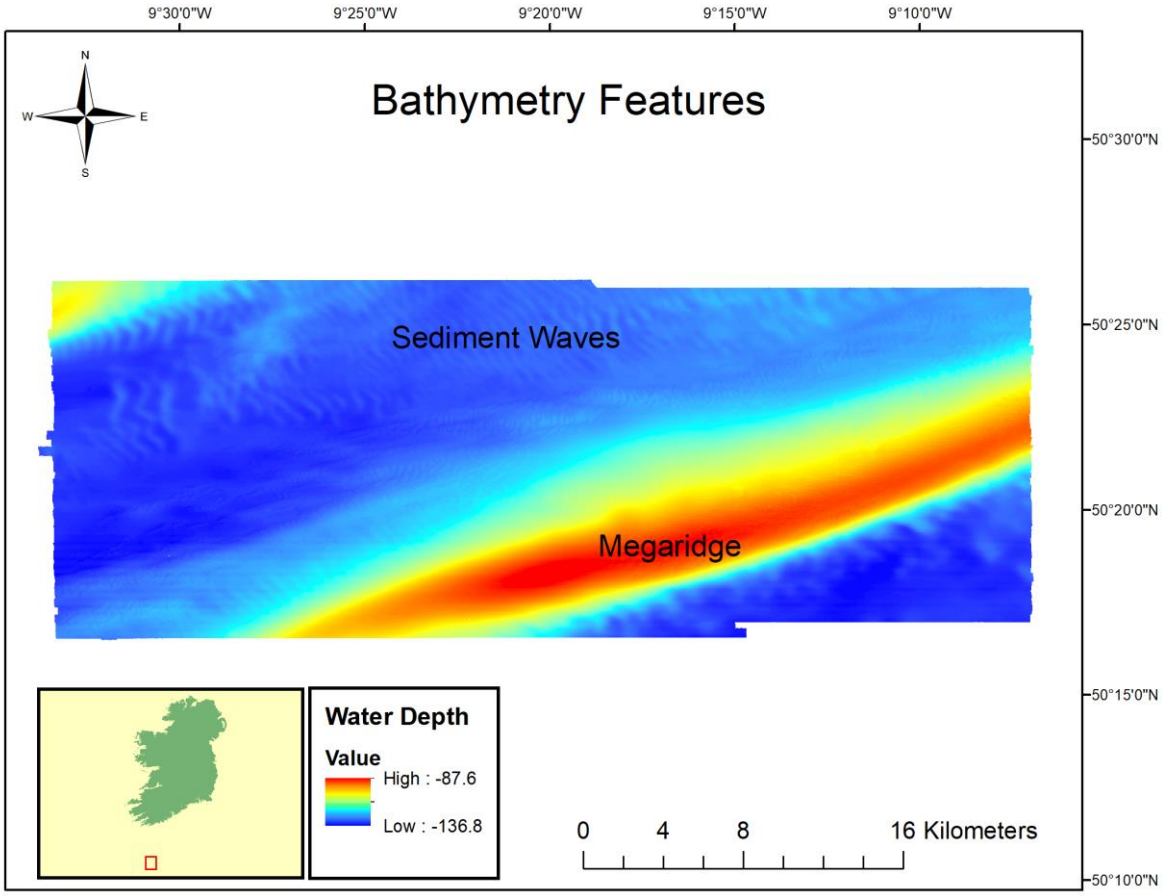


Figure 22: MBES bathymetry features.

Scoured seabed depressions are located on the megaridge crest. Scours are typically less than 1.3 m in depth and have various shapes from oval to elongated. The scours annotated in Figure 23 have long axes between 80 and 120 m and orientated NW - SE.

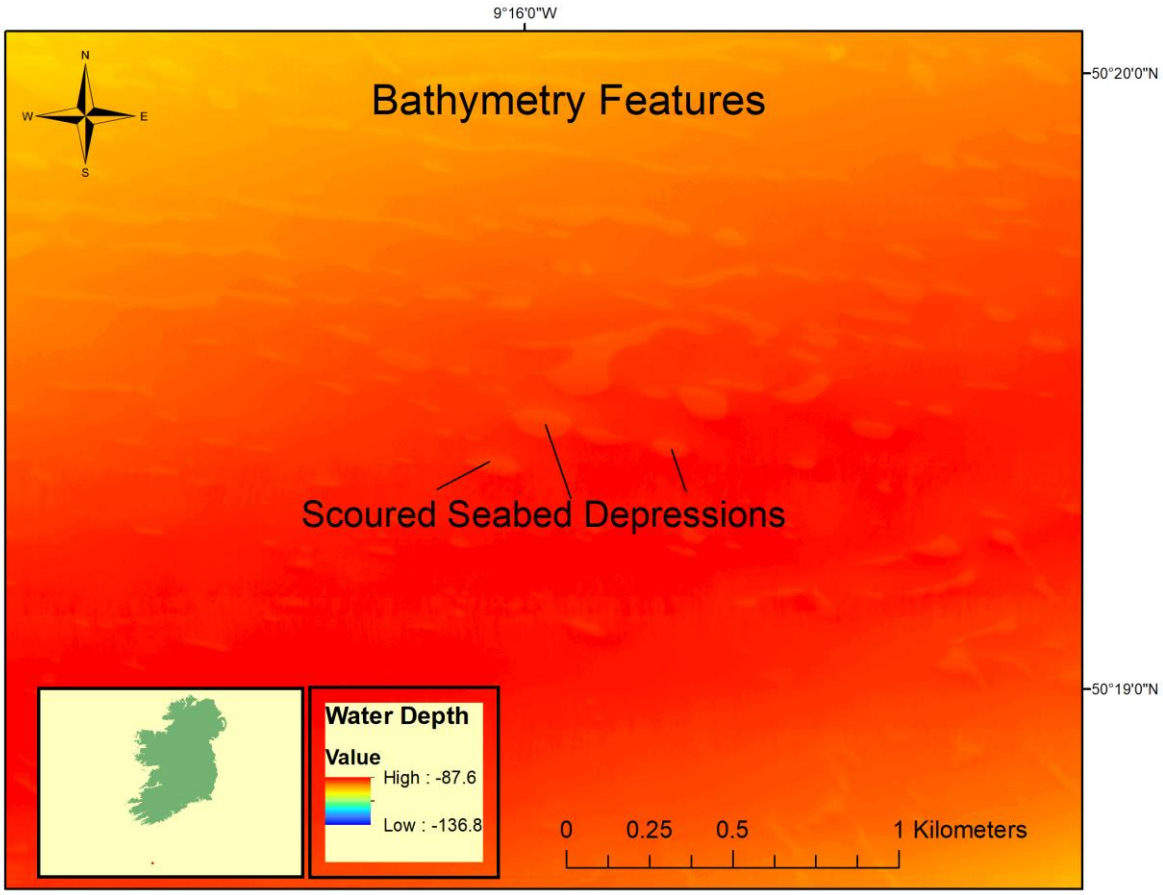


Figure 23: MBES bathymetry depressions.

4.3.4 Seabed Texture

MBES backscatter is the strength of acoustic energy received by the sonar after a complex interaction with the seafloor. By analysing the amplitude of the returning sound waves, it is possible to extract information about bottom structure and hardness, allowing for identification of bottom types. Seabed reflectivity properties depend on the hardness and roughness of the seafloor surface. In simple terms, a strong return signal indicates a hard and/or rough surface and a weak return signal indicates a soft and/or smooth surface.

Backscatter values referenced in this report are relative intensities and not absolute. The convention used in this report is that dark coloured areas represent relatively higher backscatter intensity than light coloured areas. Backscatter relative intensity values vary from -0.4 to -36.3 db.

The backscatter mosaic gridded at 2 m is shown in Figure 24. Three broad backscatter intensity categories are identified on the map. Moderate intensity backscatter is the most

widespread and is found in both the north and south. Patches of low intensity backscatter are found in the southeast. The centre of the area is dominated by high intensity backscatter. Some of the high intensity backscatter is found interspersed with slivers and lenses of moderate intensity backscatter.

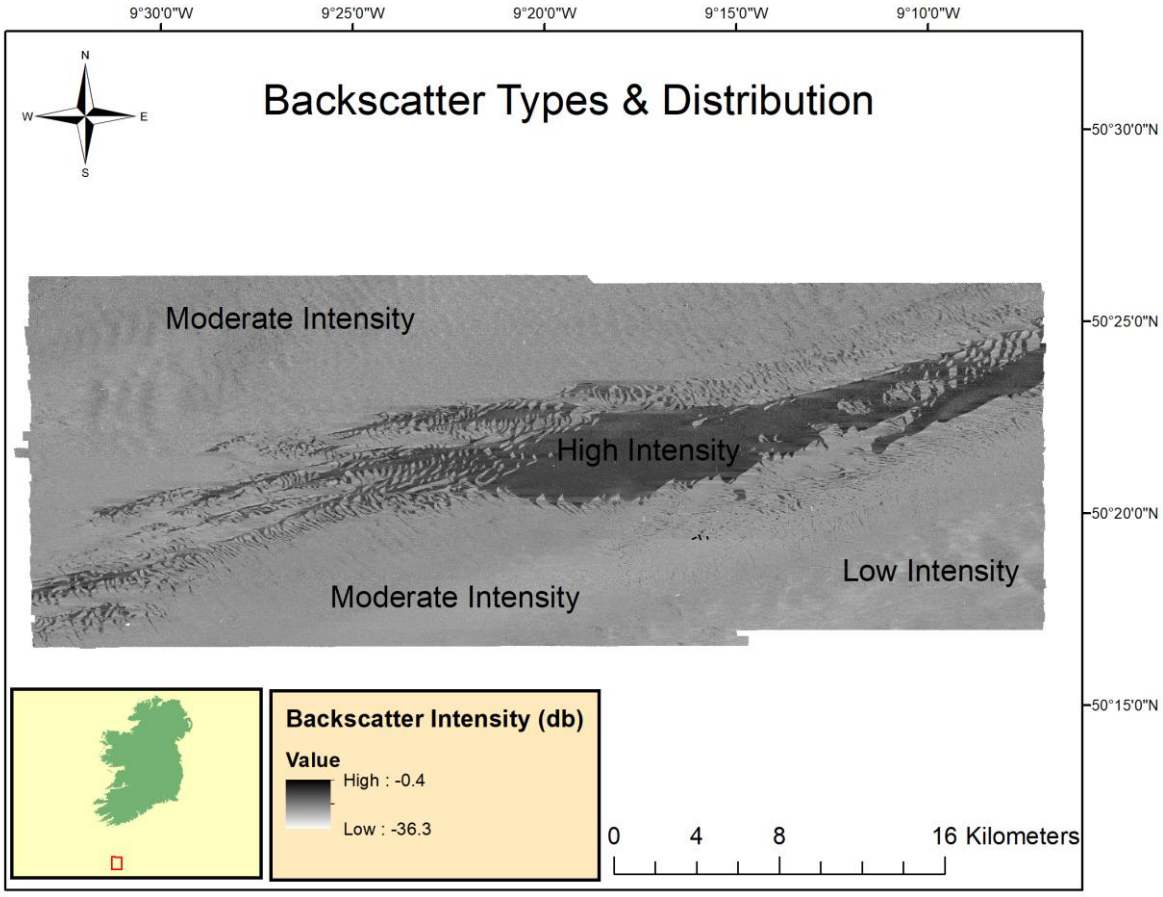


Figure 24: Backscatter data illustrating relative backscatter distribution.

Figure 25 shows backscatter data from the west central area, north of the megaridge. High and moderate backscatter types are found here. Patches of the moderate backscatter lenses are found surrounded by high backscatter substrate. Groundtruthing has not yet taken place but the morphology of the lenses coupled with their backscatter response suggests they comprise sand.

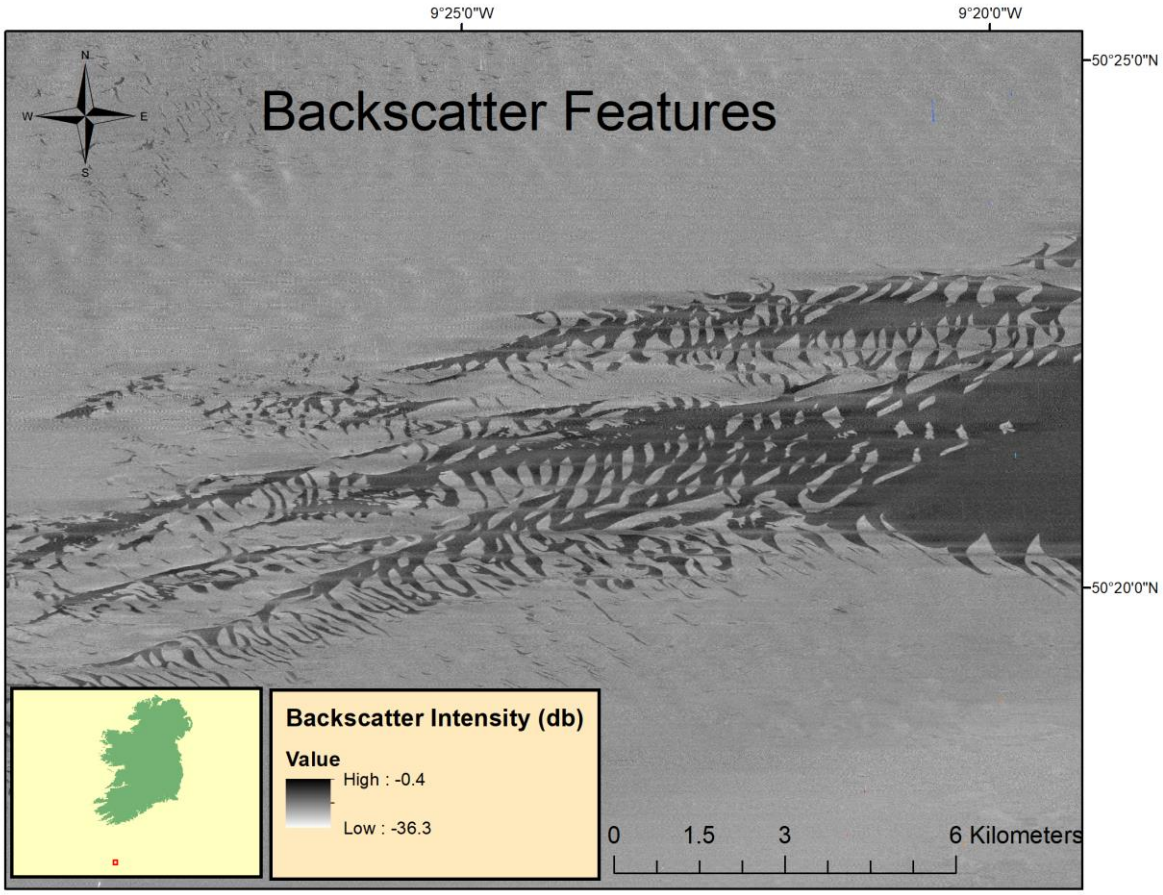


Figure 25: Backscatter features.

4.3.5 Seabed Features

Description of seabed features are based on analysis of bathymetric, shaded relief and backscatter data. It is possible to make valid inferences on seabed character and composition by correlating these datasets. Shaded relief data are used to illustrate the features discussed in this section. Shaded relief imagery is produced in Teledyne Caris HIPS & SIPS^{TM} software by shining an imaginary sun at 35º angle over the depth colour coded MBES bathymetry dataset. Data illustrated below are gridded at 5 m and with sun illumination from the NE and NW.

Figure 26 is a shaded relief image illustrating sediment waves in the northern part of the mapped area. Chevron and sinuous morphologies are evident in the image below. Axes are orientated NW-SE, indicating that the dominant current directions are NE and SW.

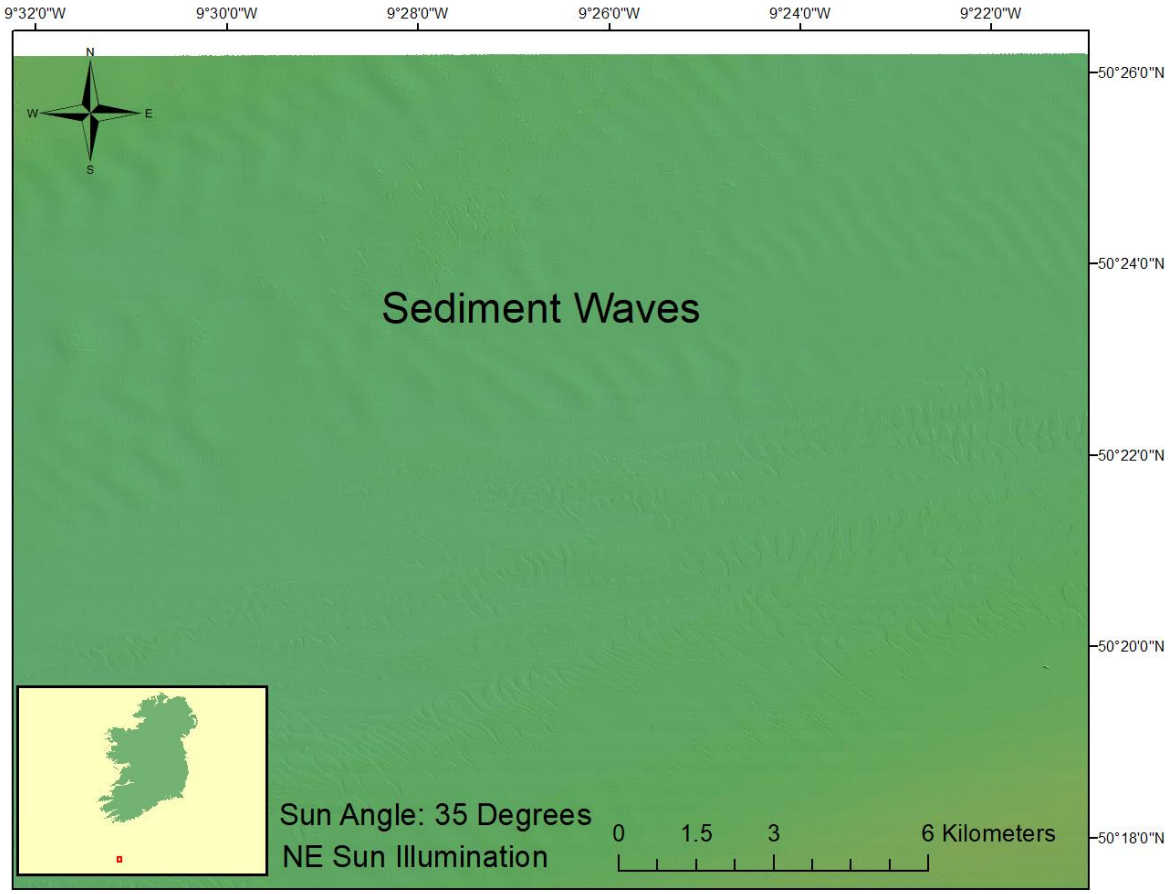


Figure 26: MBES shaded relief illustrating sediment waves.

Figure 27 is a shaded relief image of an area on the southern flank of the large megaridge. Channel features are found in this area. Channels are up to 40 m in width and c. 1 m in depth. These channels sediments have a higher backscatter intensity than surrounding sediments, indicating coarse lag material on the channel floors.

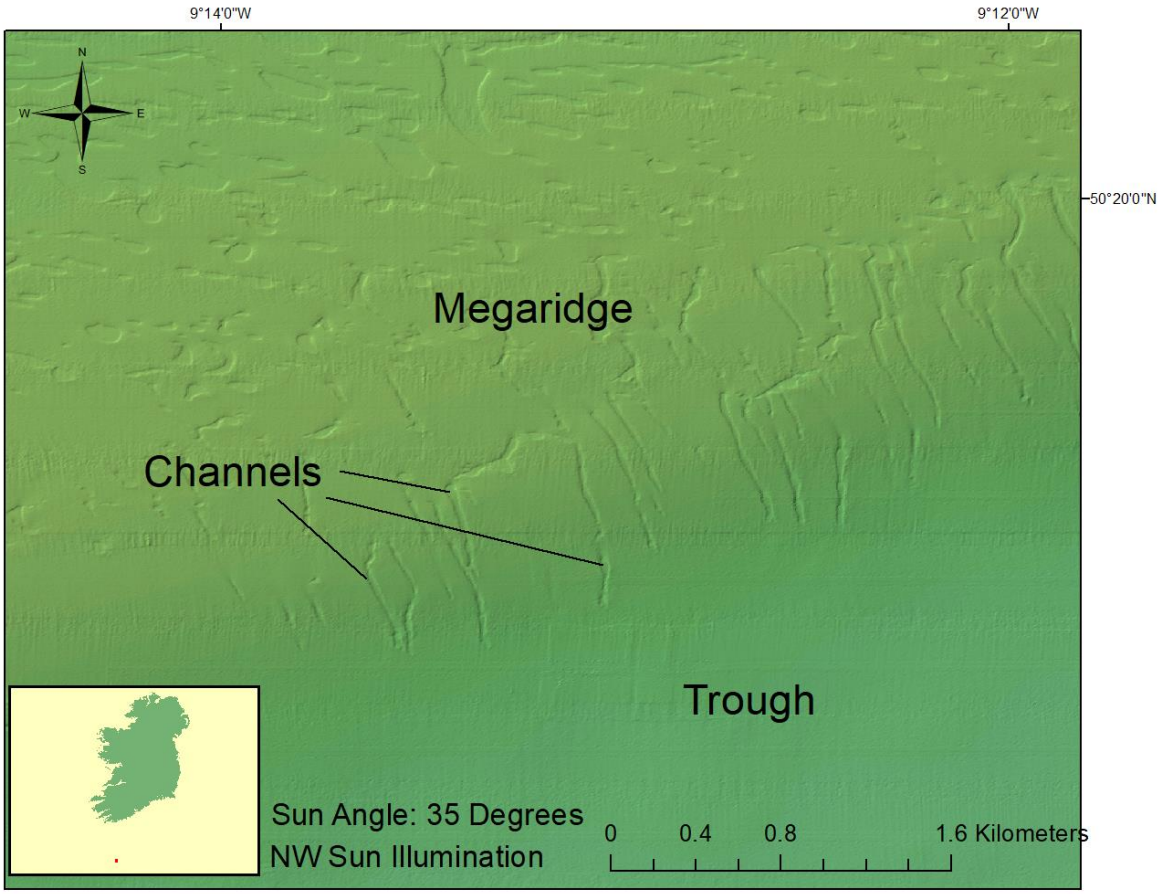


Figure 27: MBES shaded relief illustrating channel features on ridge.

4.4 Ground Truthing

Ground truthing of this area will be done in the future.

4.5 Wrecks

One wreck was located and then mapped in detail. A H525 form was completed and sent to the UKHO. Admiralty charts will be updated in due course. Table 17 provides the wreck metadata for the wreck. It is 122 m in length and previously uncharted.

Number	Latitude	Longitude	Date
1	50º 19.7870 N	-009º 21.4265 W	20/05/2022

Table 17: Wreck investigation metadata.

Figure 28 shows the mapped wreck on multibeam shaded relief data. The wreck is orientated NW-SE and is located in a flat area of seabed. An associated scour is evident around the entire wreck, most prominently in the east and SE.

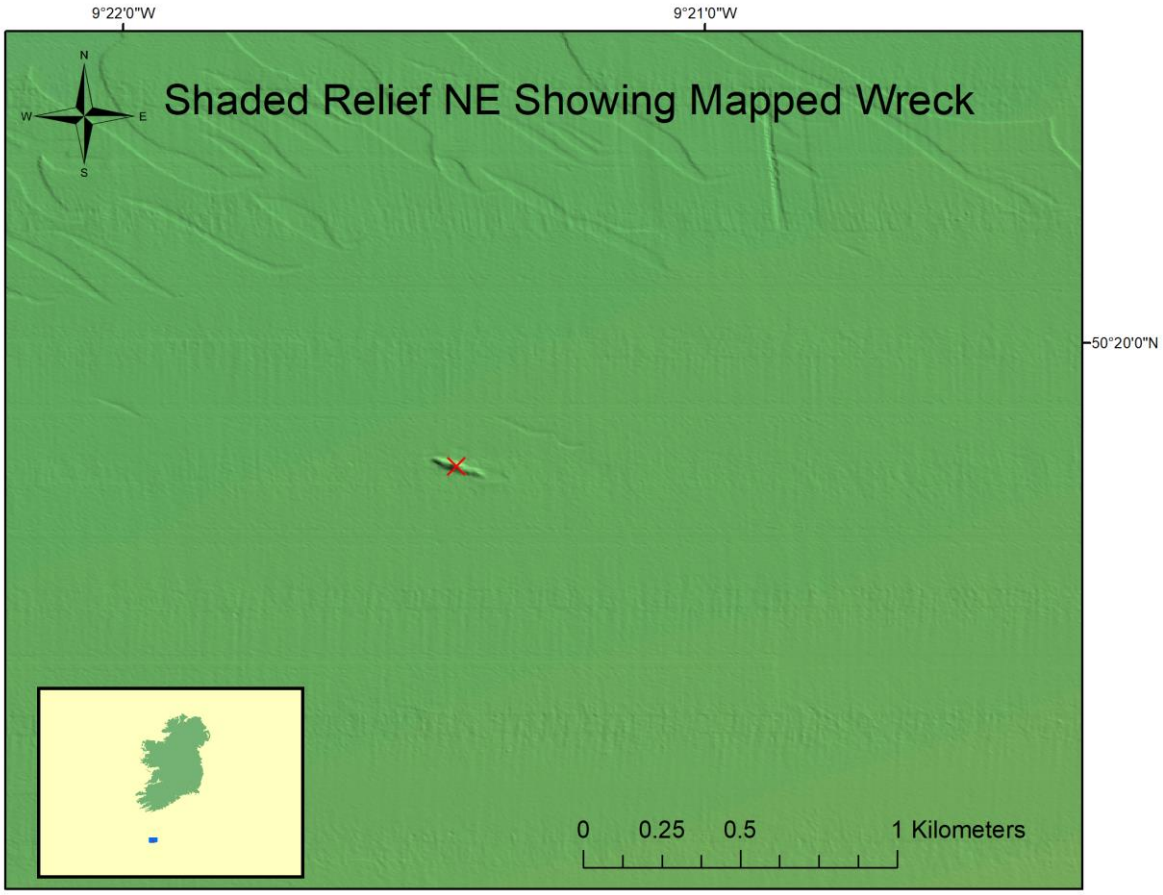


Figure 28: Mapped wreck location plot.

Table 18 contains MBES data images of the mapped wreck.

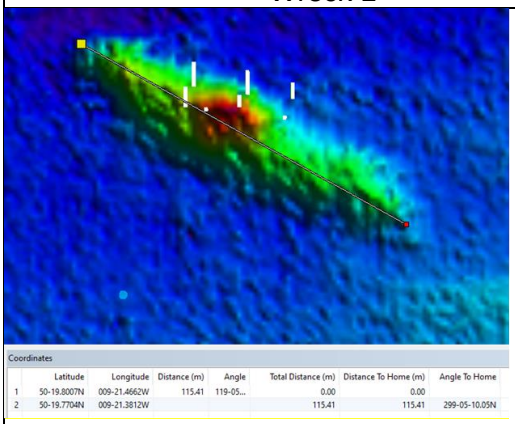
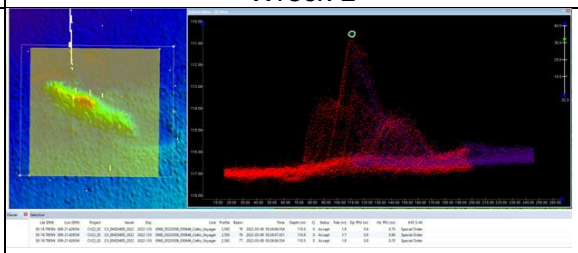
Wreck 1	Wreck 1
	

Table 18: MBES wreck images.