Roinn Cumarsáide, Gníomhaithe ar son na hAeráide & Comhshaoil
Department of Communications, Climate Action & Environment

INFOMAR Survey Report: CV19_02
Area: Celtic Sea

For:
Marine Institute & Geological Survey Ireland

RV *Celtic Voyager*

May & June 2019

Prepared by Kevin Sheehan

Rialtas na hÉireann Government of Ireland | Marine Institute Foras na Mara | Geological Survey Suirbhéireacht Gheolaíochta Ireland | Éireann | INFOMAR Integrated Mapping for the Sustainable Development of Ireland's Marine Resource

Marine Institute Reference No:	Survey Report: CV19_02

		Signature	Date
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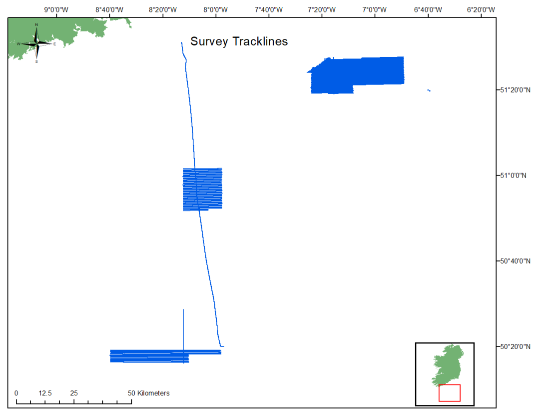
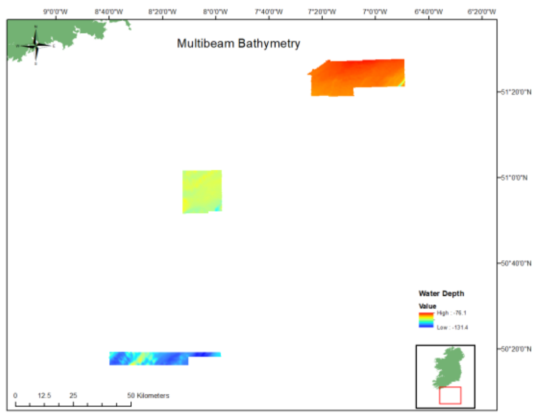
Issue	Change	Date	Description	By	Approved
1		27/01/2020	Draft	K. Sheehan	
2		03/02/2020	Final	K. Sheehan	F.Sacchetti

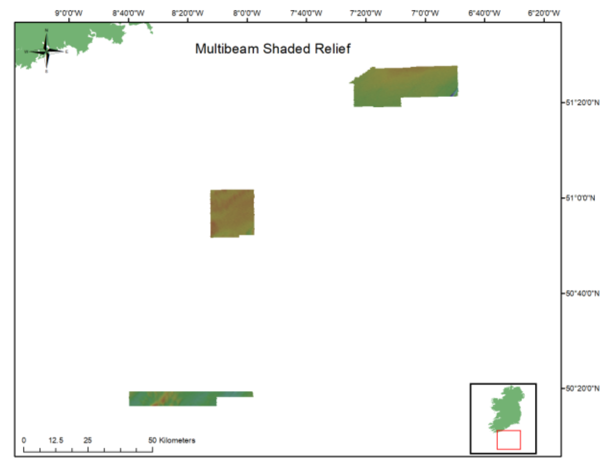
Executive Summary			
Survey Summary			
Survey Vessel:	RV *Celtic Voyager*	**Survey Leg:**	CV19_02
Mobilisation:	Cork	**Demobilisation:**	Cork
Survey Areas:	Celtic Sea	**Start Date:** **End Date:**	18/05/2019 06/06/2019
Northeast Boundary	51º 28.509N -6º 49.765W	**Southwest Boundary**	50º 18.150N -8º 40.411W
UKHO Admiralty	1121 (1:500,000) and 1123 (1:500.000)		
Key References	CV19_02 Survey Leg Report		
Equipment Used	EM2040 multibeam, Pinger sub-bottom profiler, EA400 single beam, SeaSpy magnetometer, AML MVP200, Valeport SVP Mini, C-Nav 3050 GNSS, Seapath 330+.		
Survey Statistics			
Minimum Water Depth (VORF LAT):	76 m	**Maximum Water Depth (VORF LAT):**	131 m
Area Covered:	1057 km^2	**Survey Line Kilometres:**	2817 km
Approximate Operational:	48%	**Approximate Downtime :**	28%
Groundtruthing Stations:	34	**Wrecks**	1
H525 forms issues (wrecks)	4	**H102 forms issued (shoals)**	0
Survey Tracklines		**Bathymetry**	



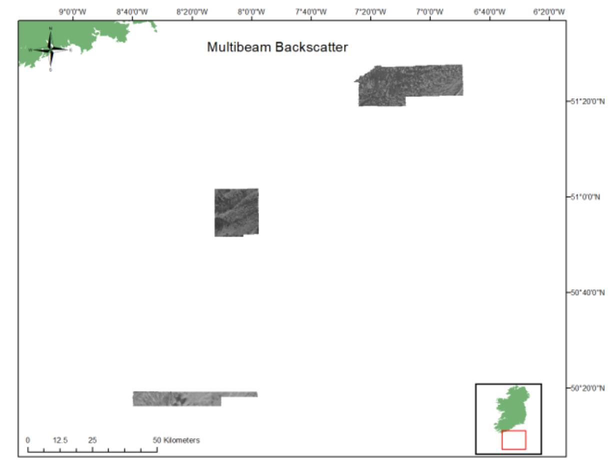


Survey Images

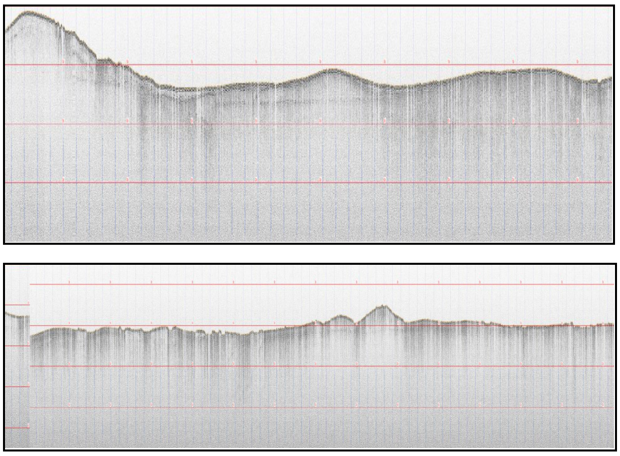
Multibeam Shaded Relief



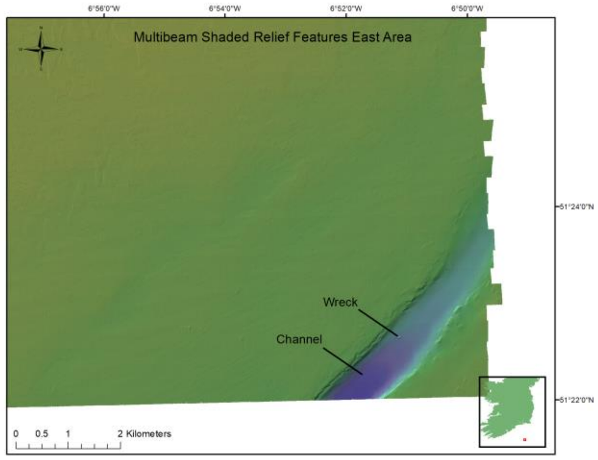
Multibeam Backscatter



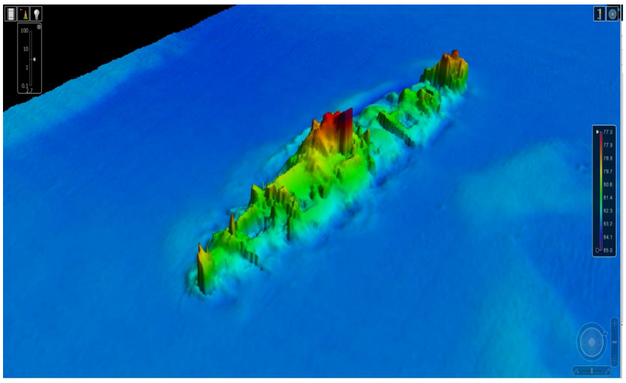
Sub Bottom Profiler Lines 360 & 285



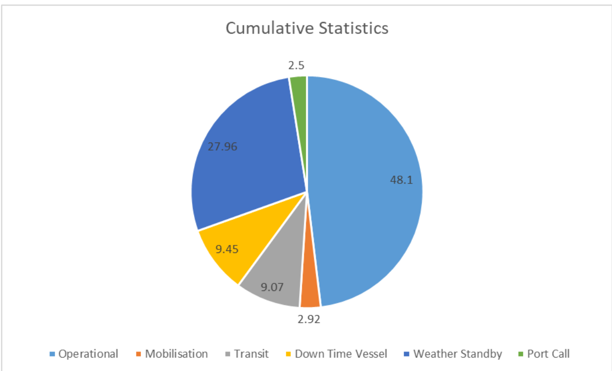
Shaded Relief Illustrating Channel & Wreck



Wreck Number 3 (11473)



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
DCCAE	Department of Communications, Climate Action & Environment
DGNSS	Differential Global Navigation Satellite Systems
DPR	Daily Progress Report
GIS	Geographic Information System
GNSS	Global Navigation Satellite Systems
GSI	Geological Survey Ireland
HSE	Health Safety & Environment
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 Profile
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 this continued from 2006 to present day under the INtegrated mapping FOr the sustainable development of Irelands MArine Resource (INFOMAR) programme. INSS 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 Communications, Climate Action and Environment (DCCAE).

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 2019. Grey have already been mapped, blue, white and coloured hatched areas are unmapped.

As of 2018 the remaining survey area has been split at the 30 nautical mile limit (Nm). The inshore survey fleet, managed by GSI is responsible for mapping inshore of the 30Nm 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 is coloured in a shade of blue which indicates the modal water depth in that ISU. Colour scales are used, to denote the three depth bands; 50 to 100m, 100 to 150m and 150m plus.

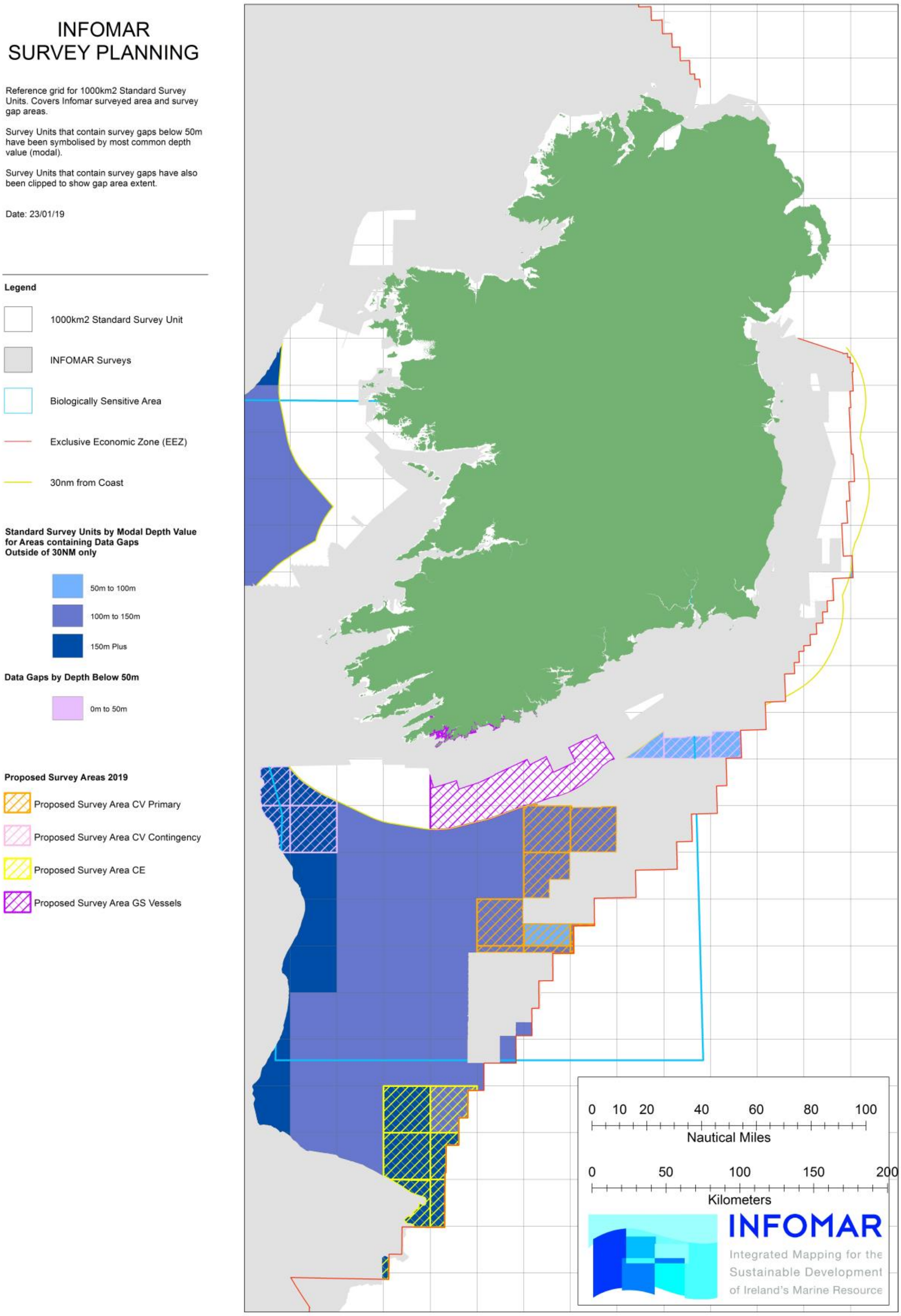


Figure 1: Survey coverage status January 2019.

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 International Hydrographic Organisation (IHO) Order 1A standard in depths less than 100 m and Order 2 in areas deeper than 100 m.

(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 (up to 30 m) 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 on any wrecks.

(vi) Groundtruth the acoustic data with grab samples.

1.2 Proposed Survey Area

Figure 2 shows the area designated for mapping by the RV *Celtic Voyager* in 2019. The entire area is in the Celtic Sea in water depths ranging from 70 to 130 m. Predicted survey coverage for the RV *Celtic Voyager* 2019 survey season is 4169 km^2 based on annual survey statistics since 2016 and modal depth of ISUs to be surveyed. The primary target area, hatched in orange in figure 2 is 4640 km^2 as hatched boundaries were drawn along existing ISU boundaries. Approximately 10% of the area lies in the 50 to 100 m depth zone and 80% in the 100 to 150 m depth zone. Survey coverage rates for these two zones are estimated at 80 km^2 and 113 km^2 per day respectively.

A bad weather contingency area located to the north east of the primary area is hatched in pink. It is 480 km^2 and it resides within the 50 to 100 m depth zone.

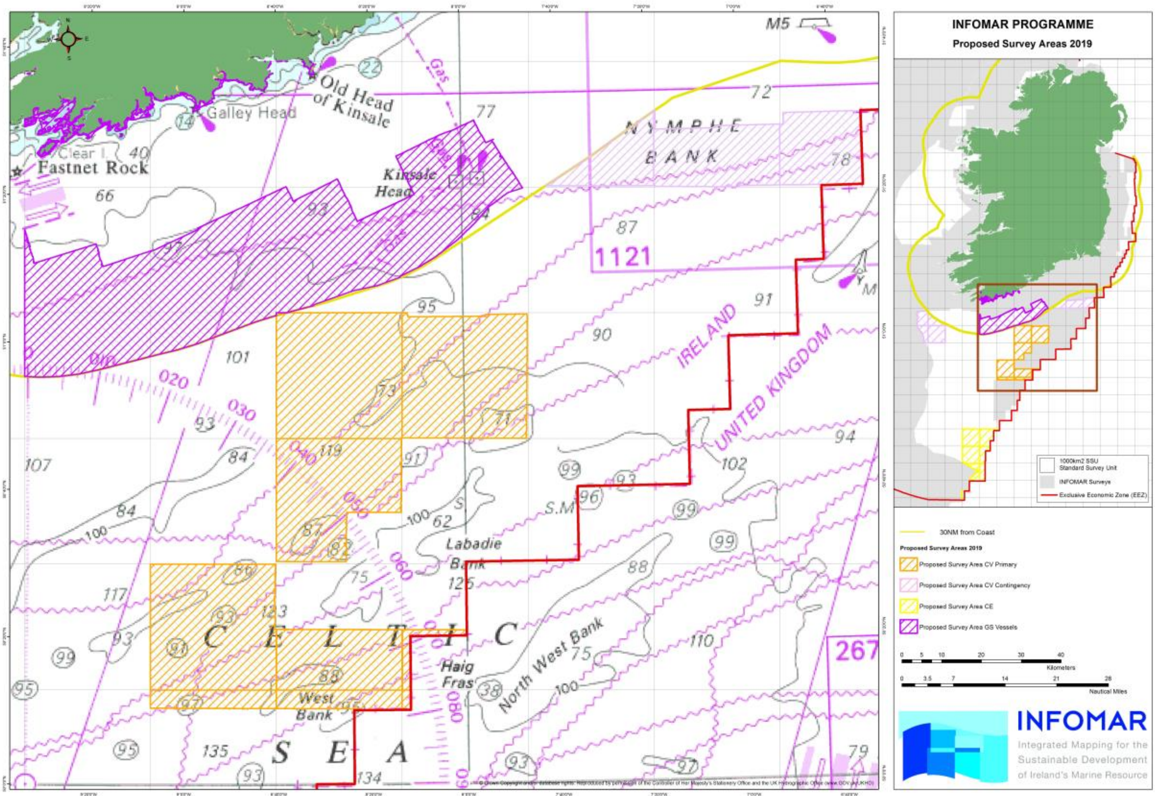


Figure 2: Proposed survey area for 2019.

2. Operations & Survey Setup

Mobilisation took place in Cork on 18th May. Survey acquisition took place between 19th May and 6th June. Kevin Sheehan and Fabio Sacchetti of the MI acted as Party Chiefs. The survey team comprised skilled personnel from the MI and a freelance contractor.

2.1 Survey Tracklines

The final survey trackline plot is contained in figure 3. Mainlines were acquired on east – west and northeast – southwest reciprocal headings. Three separate survey polygons were mapped, denoted in this report as the East, Central and South areas respectively.

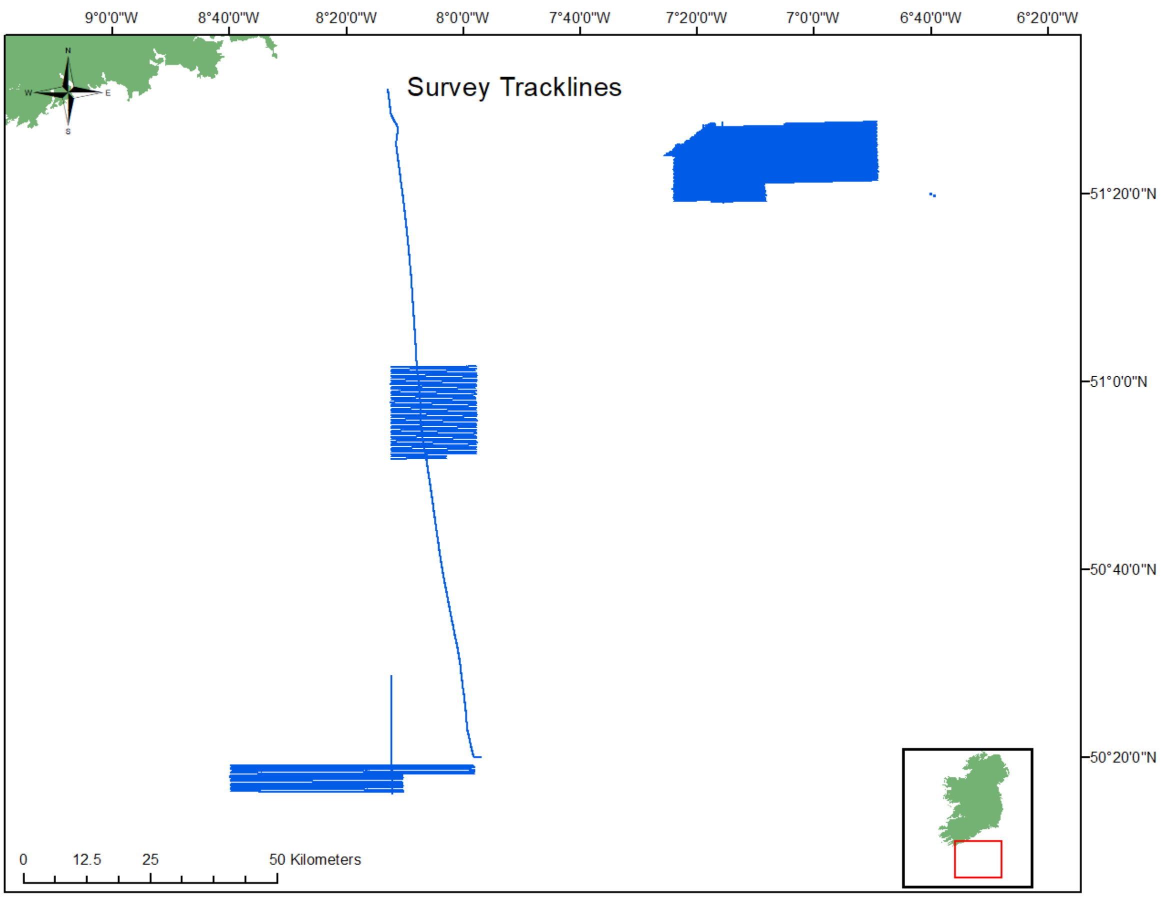


Figure 3: Survey trackline plot produced in Caris and ArcGIS software.

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

18/05/2019 00:00	Mobilised in Cork City
18/05/2019 14:00	Departed Cork
19/05/2019 03:18	Commenced operations
20/05/2019 21:31	Transit to Cork for personal situation
21/05/2019 22:06	Resumed operations
25/05/2019 22:00	Transit to Cork for personal situation
26/05/2019 18:47	Resumed operations
27/05/2019 10:43	Weather Standby. Transit to Cork
28/05/2019 06:00	Scheduled port call in Cork. Change of scientific personnel
28/05/2019 18:00	Weather Standby
31/05/2019 12:00	Transit to survey site
31/05/2019 20:49	Commenced operations
01/06/2019 18:07	Weather Standby in Cork
03/06/2019 19:01	Commenced survey operations
06/06/2019 05:36	Acquisition completed. Transit for Galway

Table 1: Summary of survey events.

2.3 Survey Personnel

Survey personnel, their affiliation and role are listed in table 2.

Name	Affiliation	Role
Kevin Sheehan	MI	Party Chief /Surveyor
Fabio Sacchetti	MI	Party Chief /Surveyor
Nicola O' Brien	MI	Surveyor
Oisin McManus	MI	Surveyor
Slava Sobolev	Contractor	Data Processor

Table 2: Survey personnel details.

2.4 Health, Safety and Environment (HSE)

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. A muster drill was held within 24 hours of departure from port. Magnetometer and sound velocity profiler deployments were performed by vessel crew and without incident, with personnel wearing correct Personal Protective Equipment (PPE). There were no near misses or safety incidents to report.

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. The code and guidance are applicable to all seismic, 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 marine mammals were observed during the course of the survey.

2.6 General Survey Information

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

Total Line Length (km)	2817
Area Covered (km^2)	1057
Operational (%)	48
Weather Standby (%)	28
Transit (%)	9
Port Call (%)	3

Table 3: Key survey statistics.

The pie chart in figure 4 presents the cumulative statistics from the final DPR. Survey data acquisition accounts for approximately 48% of the time.

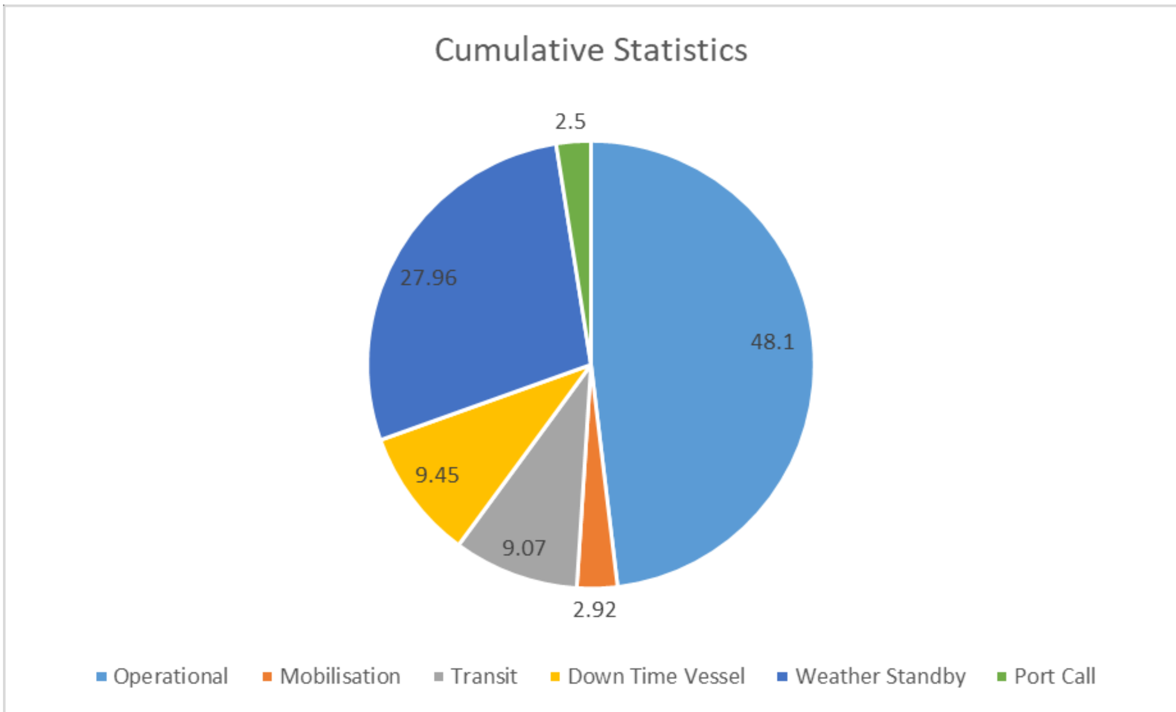


Figure 4: Survey statistics pie chart.

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 hull mounted high-resolution EM2040 MBES system, a Singlebeam Echo sounder (SBES), pinger 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.

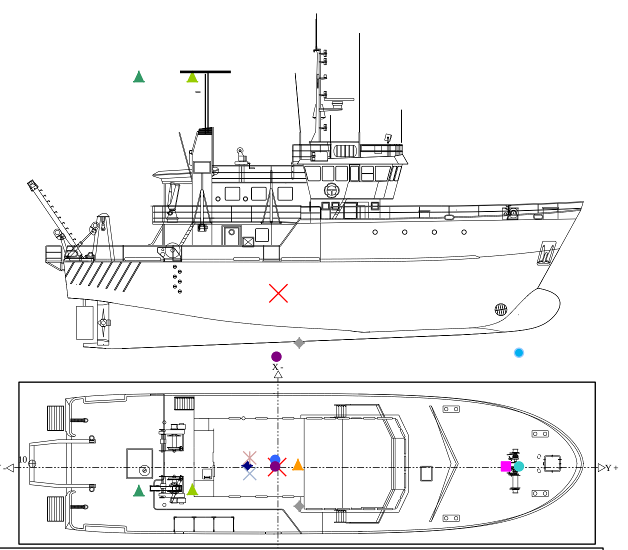
3.1 Vessel Offsets

Bluepix performed an offset survey of the RV *Celtic Voyager* in August 2015 while in dry dock Killybegs. 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: **INFOMAR**
Client: **MI & GSI**
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 Fwd 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	Probe500 Pinger	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	10-11/01/2016		
	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

Bluepix Report 10&11/01/2016 Killybegs			
Item	**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.

Table 5: Vessel offsets and installation angles.

3.2 Survey Equipment

Table 6 contains information on the survey equipment both permanently installed and available for mobilisation onboard 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	Sonar Equipment Services Pinger source	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 Profilers	Valeport SVX2	SV & Conductivity
Moving Velocity Profiler	AML MVP200	SV
Realtime Sound Velocity	Valeport / AML	SV
Magnetometers	SEASPY	Overhauser Effect

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

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 6 below.

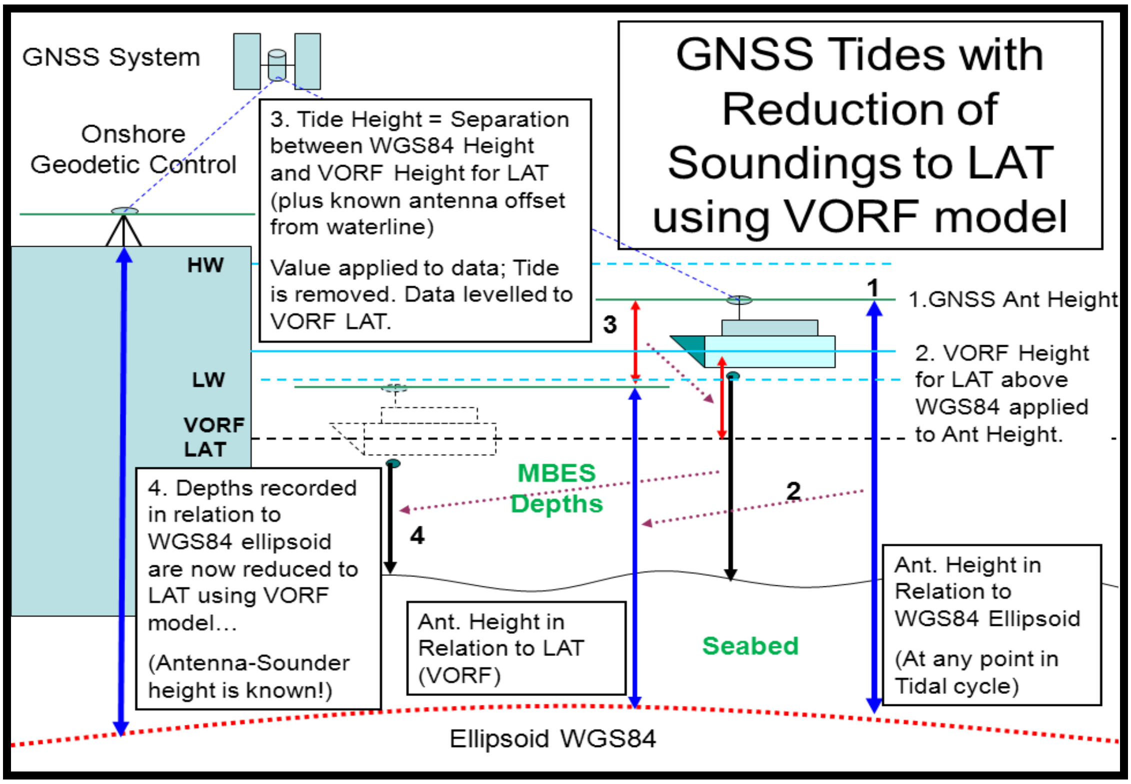


Figure 6: GNSS tides to LAT using VORF model.

3.3.3 Acoustic Systems

A Kongsberg EM2040 high resolution multibeam 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. This information 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 8 contains

MBES metadata. Mutilbeam water column data was also acquired throughout the survey and the data stored on a separate backup disk.

Descriptor	Metadata
Survey lines	NA
Data Files	323
Date Created	16-04-2019 to 29-04-2019
Dataset Size	75.2 GB
File Formats	.all

Table 8: 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 one wreck was surveyed in detail.

A hull mounted pinger source 2x2 transducer array SBP operating at 3.5 kHz was used for sub-bottom data acquisition. The sweep time was varied appropriately with water depth to maximise ping rate and resolution. The pinger source is most effective in investigations of the top 20 or 30 m sub-seabed and where sediments are fine to medium grained. The signal does not penetrate bedrock. A CodaOctopus DA4G acted as the topside trigger and acquisition system. Raw data was recorded in native coda format through CodaOctopus GeoSurvey™ software along with tiff images of each survey line. Positioning data was provided from C-Nav DGNSS and MRU data was fed directly from the Seapath 330+. QC was maintained by the online engineers, with reference to the digital display; with sweep time, gains, filter parameters and transmit energy adjusted as required for optimal imaging. All data were backed up to the vessel server. Table 9 contains SBP metadata.

Descriptor	Metadata
Survey lines	NA
Data Files	298
Date Created	16-04-2019 to 29-04-2019
Dataset Size	28.2 GB
File Formats	.cod & .tiff

Table 9: SBP metadata.

3.3.4 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 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 10.

Descriptor	Metadata
Survey lines	NA
Data Files	2
Date Created	16-04-2019 to 29-04-2019
Dataset Size	728 MB
File Formats	.mms, .txt

Table 10: Magnetometer metadata.

3.3.5 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, SBES, 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 hard disk 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. Metadata is contained in table 11.

Descriptor	Metadata
Survey lines	All
Data Files	16
Date Created	13-04-2019 to 29-04-2019
Dataset Size	3.13 GB
File Formats	.cnav3050

Table 11: C-Nav navigation metadata.

3.3.6 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 is accurately stamped with a UTC time label.

Survey line and groundtruthing positioning data were recorded in QINSy software in .db and .txt format. The QINSy navigation .txt file was input to the Multilog database for metadata recording of each survey system. QINSy metadata is provided in table 12.

Descriptor	Metadata
Survey lines	NA
Data Files	619
Date Created	16-04-2019 to 29-04-2019
Dataset Size	22.6 GB
File Formats	.db & .txt

Table 12: QINSy navigation metadata.

3.3.7 Sound Velocity

An AML Moving Vessel Profiler (MVP) 200 was the primary instrument for acquiring sound velocity profile data. A Valeport Mini Sound Velocity Profiler (SVP) instrument was used 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 slow down or stop to acquire sound velocity data and more casts were acquired to better constrain the sound velocity regime. Fresh sound profiles were input to the echosounders as required. A Valeport sound velocity sensor positioned at the transducer head provided a real time sound velocity input 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 4 and 8 metres depth off the starboard aft side and deployed to within 15 metres of the seabed during casts. Sound velocity profiles in .asvp format were automatically sent to SIS where they were checked and extended for import into the echo sounders.

SVP profiles were acquired at times when the MVP was inoperable due to technical issues. Sound velocity profile data were recorded in asvp format and downloaded with DataLog X2 software. Metadata is contained in table 13.

Descriptor	**Metadata**
Survey lines	NA
Data Files	150
Date Created	16-04-2019 to 29-04-2019
Dataset Size	0.57 MB
File Formats	.asvp

Table 13: Sound velocity metadata.

3.3.8 Multilog

A Microsoft Access database was used for logging survey metadata. Data acquisition parameters, data QC, sound velocity and daily progress report information were input and recorded. A backup of the database was made regularly. DPRs were created using this database.

4 Online QC, Data Processing, Results and Interpretation

The hydrographic survey was performed to International Hydrographic Organization (IHO) survey standard Order 1a for areas of 100 m depth or less and Order 2 for areas exceeding 100 m. The survey order represents the minimum standard for position, depth accuracy and feature detection achieved during data acquisition and processing. Order 1a and Order 2 requirements are presented in table 14.

	Order 1a (S-44)	**Order 2 (S-44)**
Description of Areas	Shallower than 100m, features of concern to shipping.	Areas generally deeper than 100 m 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 $\pm\sqrt{a^2 + (bxd)^2}$
Full Seafloor Search	Required	Not Required
Feature Detection	Cubic Features > 2m (Depths < 40m) 10% depth > 40m	Not Applicable
Recommended Max line spacing	Full Seafloor search	4 x average depth

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 7 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 for survey mainlines and crosslines was maintained at FM and ping mode set to 200 kHz, which maximised swath width in the depths encountered. Wreck surveys were performed at Medium CW or Long CW and at 300 kHz to provide maximum resolution.

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 and stored directly to external disk.

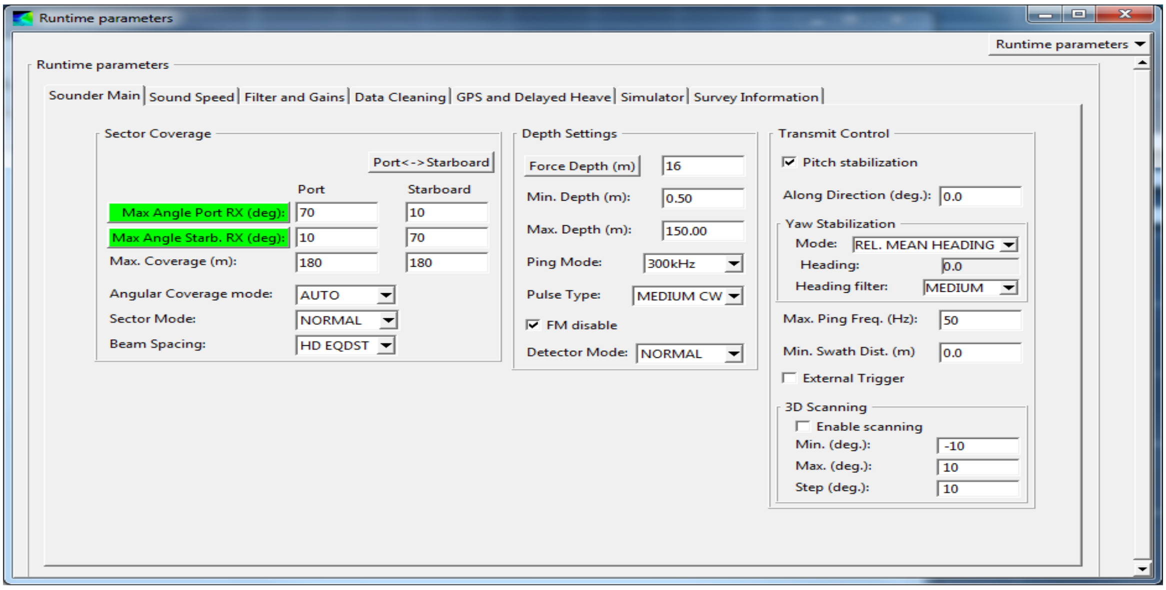


Figure 7: Runtime parameters window in SIS.

4.1.2 Crossline versus Mainline Statistics

Crossline data were acquired for QC of depth soundings. A total of 4 crosslines were acquired for statistical analysis in Caris Hips; lines 61, 126, 193 and 194. Crossline data were compared with mainline data and all crossline data indicated that the soundings exceeded the 95% certainty required for Order 1a specification. QC data statistics are presented in table 15.

Beam	Count	Max (+)	Min (-)	Mean	Std Dev	Special Order (%)	Order 1a (%)	Order 1b (%)
1-800	2,154,219	0.778	0.580	0.085	0.123	100	100	100
1-800	2,202,125	0.679	0.592	-0.006	0.128	100	100	100
1-800	5,405,537	0.696	1.008	-0.043	0.124	99.986	100	100
1-800	2,076,156	0.779	0.754	-0.017	0.134	99.987	100	100

Table 15: Crossline QC statistics.

4.1.3 Feature Detection

The minimum standard for feature detection for an Order 1a survey are cubic features > 2 m in depths up to 40 m and 10% of depth beyond 40 m. Feature detection is not relevant for water depths greater than 100 m where a general description of the seafloor is deemed adequate for Order 2 survey specification. Water depths range from 76 to 109 m in the East area. The minimum sized cubic features that require detection are 7.6 m, i.e. 10% of water depth. A minimum of 9 soundings per 7.6 m bins are required in order to attain the feature detection criteria. A bin size of 7.6 m was selected to QC the data density and the results are shown in figure 8.

The mean number of soundings per bin was computed at 78. This easily exceeded the 9 soundings required per bin. Green indicates where 9 soundings per bin were achieved and red where the 9 soundings requirement was not attained.

Figure 8: Sounding density traffic light plot, East area.

Water depths range from 95 to 113 m in the Central area. The minimum sized cubic features that require detection are 9.5 m, i.e. 10% of water depth. A minimum of 9 soundings per 9.5 m bins are required in order to attain the feature detection criteria. A bin size of 9.4 m was selected to QC the data density and the results are shown in figure 9.

The mean number of soundings per bin was computed at 71. This easily exceeded the 9 soundings required per bin. Green indicates where 9 soundings per bin were achieved and red where the 9 soundings requirement was not attained. The vast majority of the dataset exceeds 9 soundings per bin.

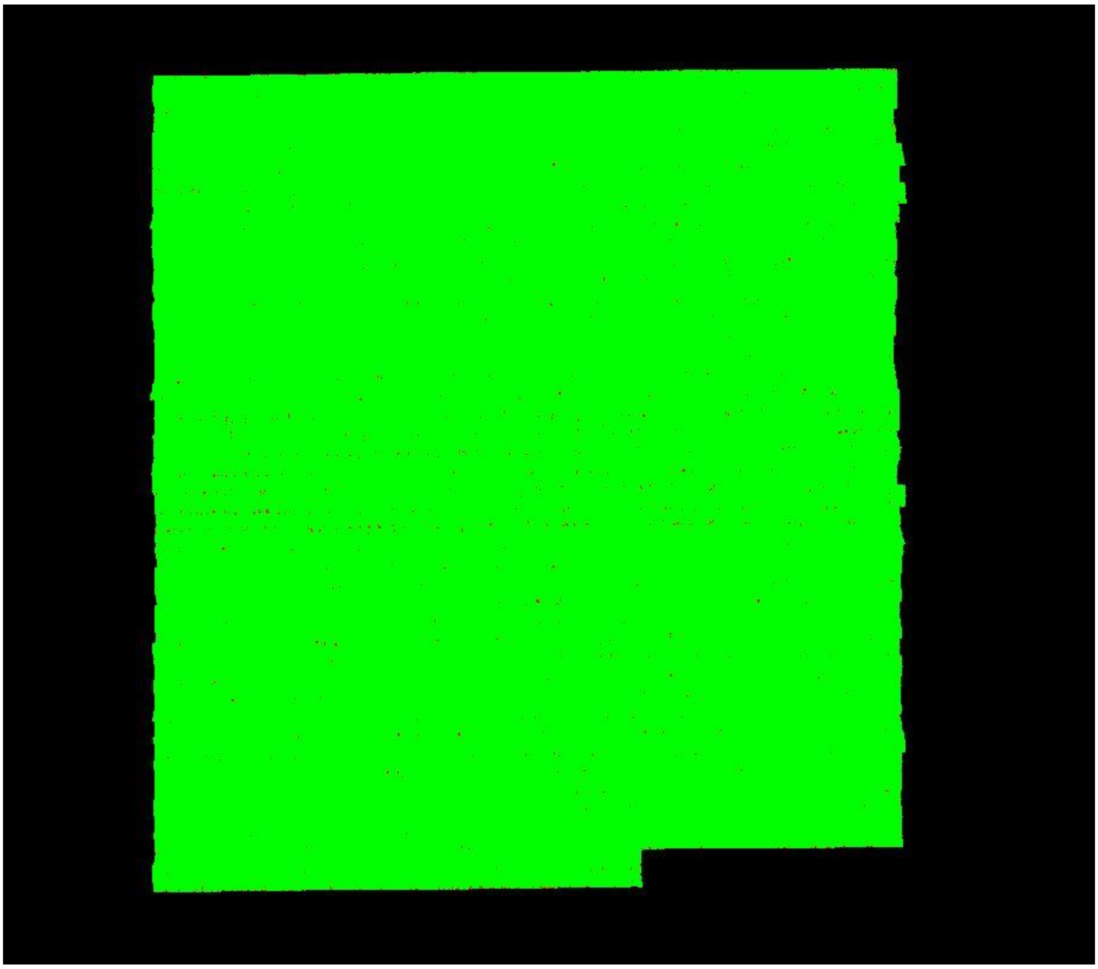


Figure 9: Sounding density traffic light plot, Central area.

Water depths range from 93 to 131 m in the South area. The minimum sized cubic features that require detection are 9.3 m, i.e. 10% of water depth. A minimum of 9 soundings per 9.3 m bins are required in order to attain the feature detection criteria. A bin size of 9.2 m was selected to QC the data density and the results are shown in figure 10.

The mean number of soundings per bin was computed at 113. This easily exceeded the 9 soundings required per bin. Green indicates where 9 soundings per bin were achieved.

Figure 10: Sounding density statistics, South area.

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

Multibeam data processors continuously monitored the effect of sound velocity variations on the processed multibeam data. The processors advised on the frequency and geographical distribution of MVP casts based on this analysis. Sound velocity issues were also monitored

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by QC of the Crosstrack window and by comparison of the sound profile versus the realtime sound velocity reading in the Numerical window of SIS.

Composite MVP plots were made for the three survey areas and are shown in Figures 11 (East area), 12 (Central area) and 13 (South area). Sound velocity in metres per second is plotted on the x-axes and depth in metres on the y-axes.

Profiles from the East area show a stratified water column above 30 metres depth with sound velocity decreasing with depth from surface to approximately 32 metres. Sound velocity then increases with pressure beneath these depths.

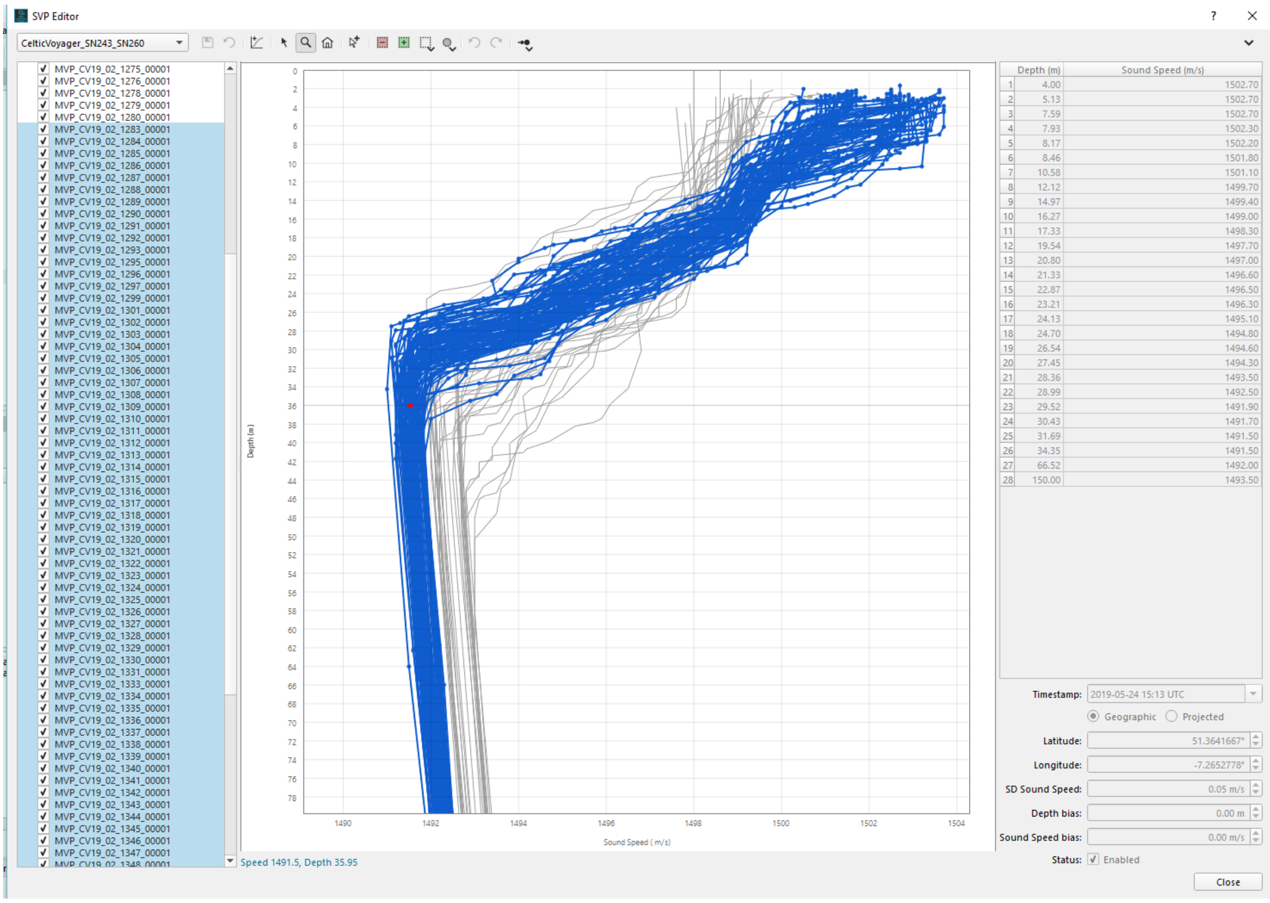

Figure 11: MVP composite plot for East area.

Profiles from the Central area show a well-mixed water column above 18 metres depth, then a thermocline from 18 metres to 35 metres depth where sound velocity rapidly decreases. Sound velocity then increases with pressure beneath 35 metres.

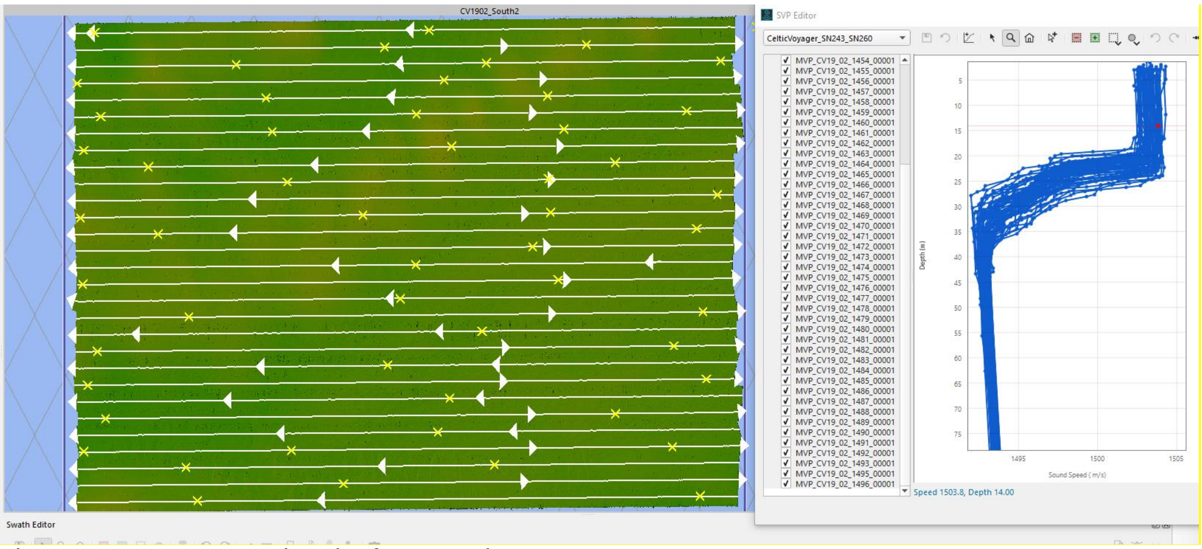

Figure 12: MVP composite plot for Central area.

Profiles from the South area show a well-mixed water column above 15 metres depth, then a thermocline from 15 metres to 35 metres depth where sound velocity rapidly decreases. Sound velocity then increases with pressure beneath 35 metres.

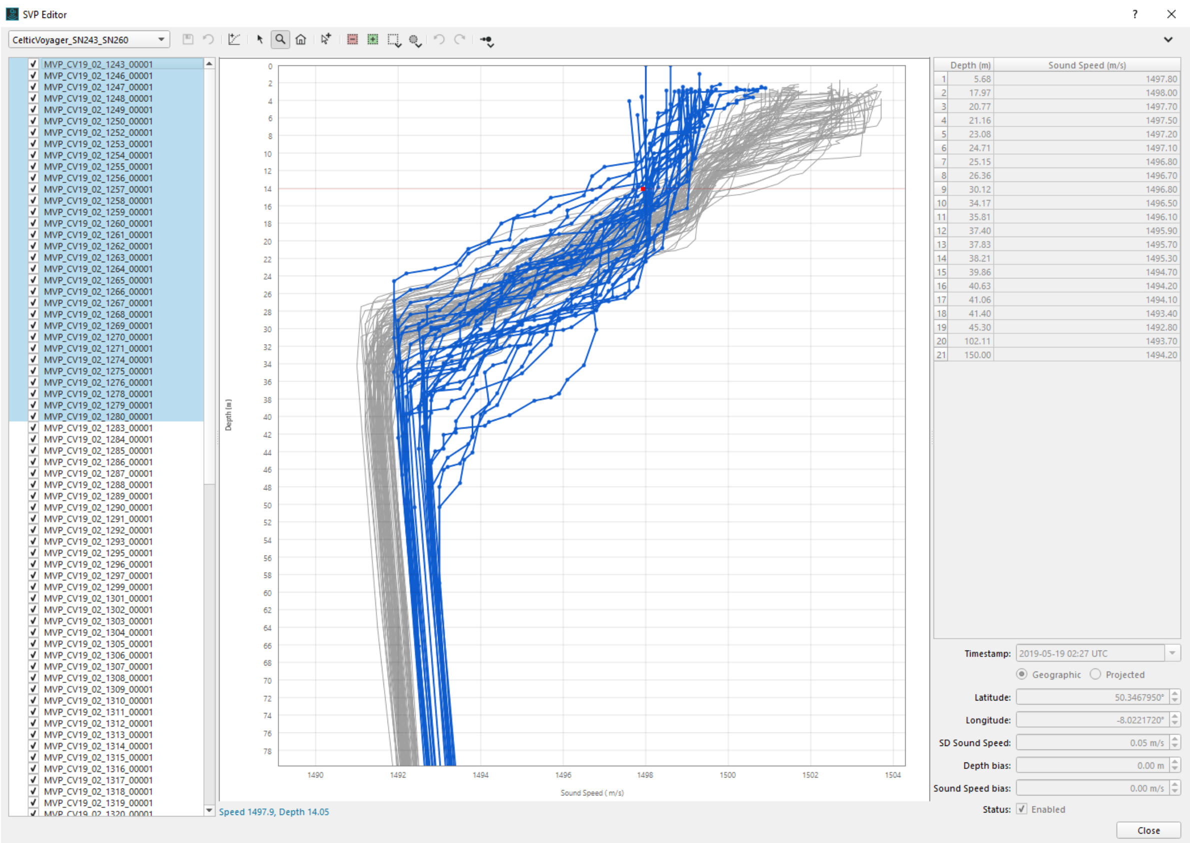

Figure 13: MVP composite plot for South area.

4.2 Post Processing Methods

4.2.1 Navigation

Navigation data was 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 despiked 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 subjected 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. Swath Editing was performed in CARIS to clean large “noise” spikes from the data.
5. 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. (Example: nearest in distance verses nearest in time).
6. A CARIS Combined Uncertainty and Bathymetry Estimator (CUBE) base surface was then created to allow CUBE automatic filtering.
7. Final verification of sounding consistency and absence of spikes was carried out using subset editing.
8. Export of final products from Caris: Multibeam Bathymetry grids, Shaded Relief grids, and Backscatter Mosaics. XYZ and trackline grids were also output.

4.2.3 Backscatter Mosaic Generation

Backscatter is a function of the hardness and roughness of the seafloor. Multibeam backscatter mosaics were produced using QPS FlederMaus Geocoder Tool (FMGT), backscatter analysis software with advanced functionalities capable of providing an enhanced backscatter mosaic.

4.3 Survey Results and Data Interpretation

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

4.3.1 Multibeam Images

Grids and geotiff images were created in Teledyne Caris HIPS & SIPS™ software of MBES bathymetry and shaded relief. Backscatter mosaics were created in QPS FMGT™. Geotiffs and grids were imported into ArcGIS™ and images (figures 14 to 22) output for this report.

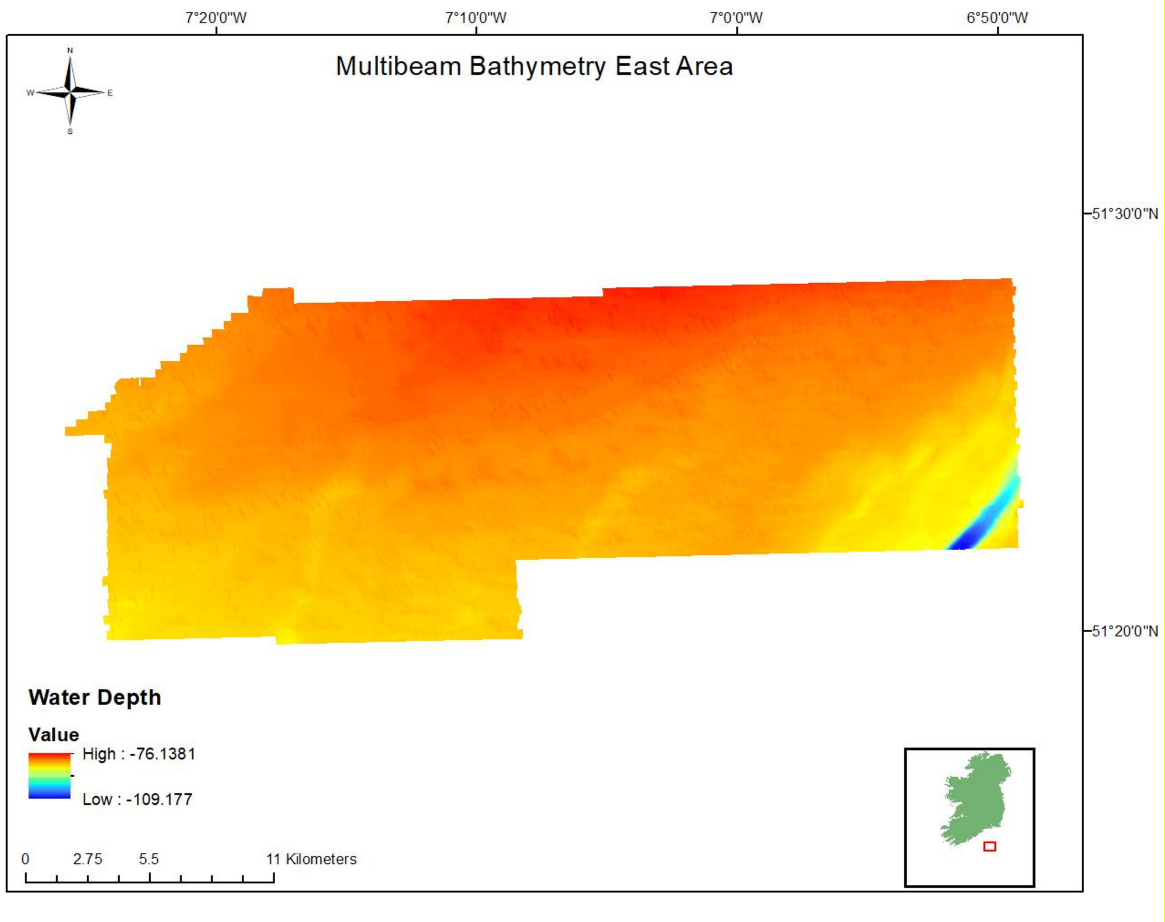

Figure 14: Multibeam bathymetry East area.

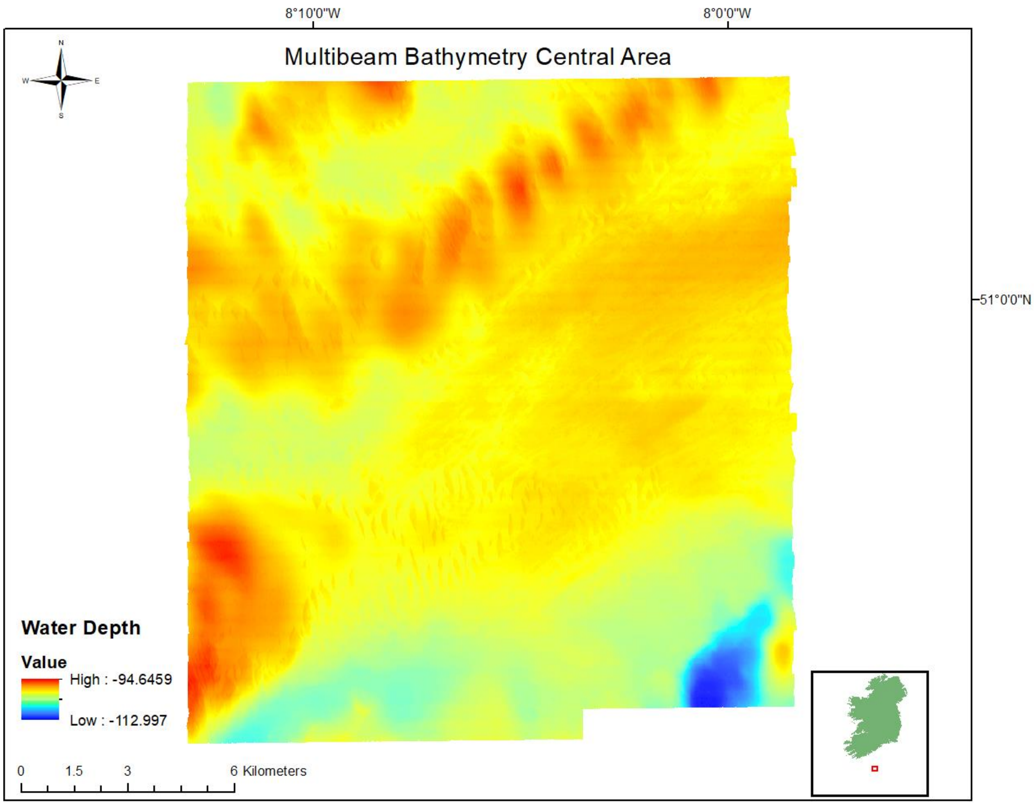

Figure 15: Multibeam bathymetry Central area.

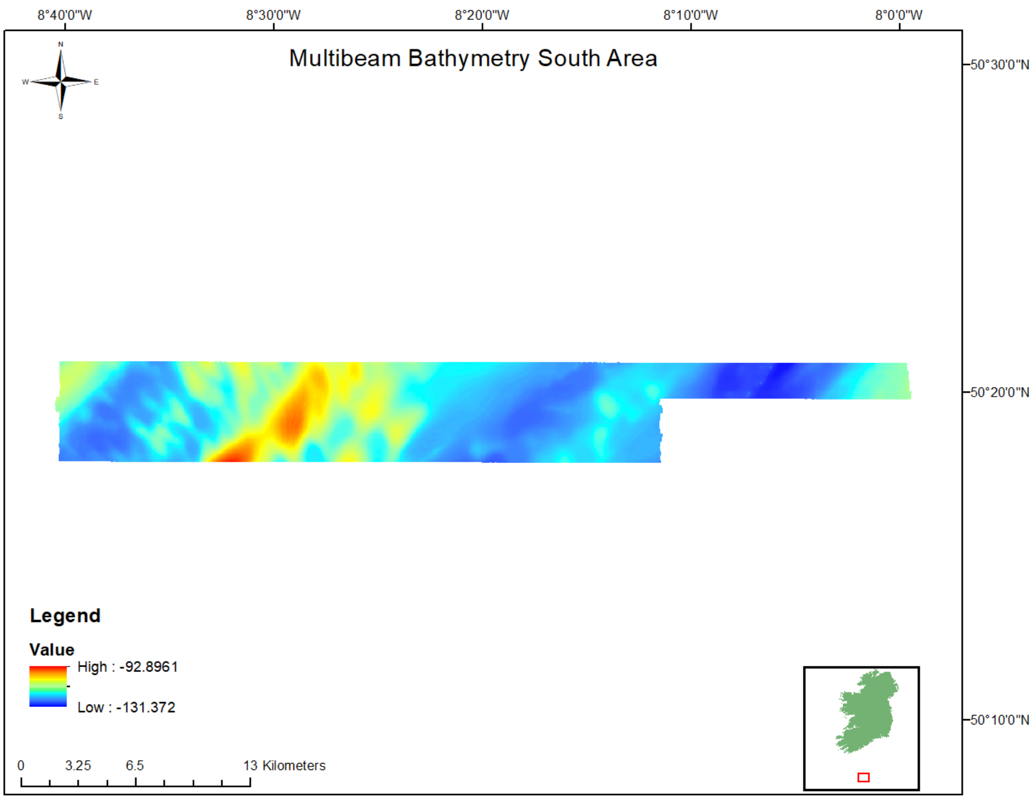

Figure 16: Multibeam bathymetry South area.

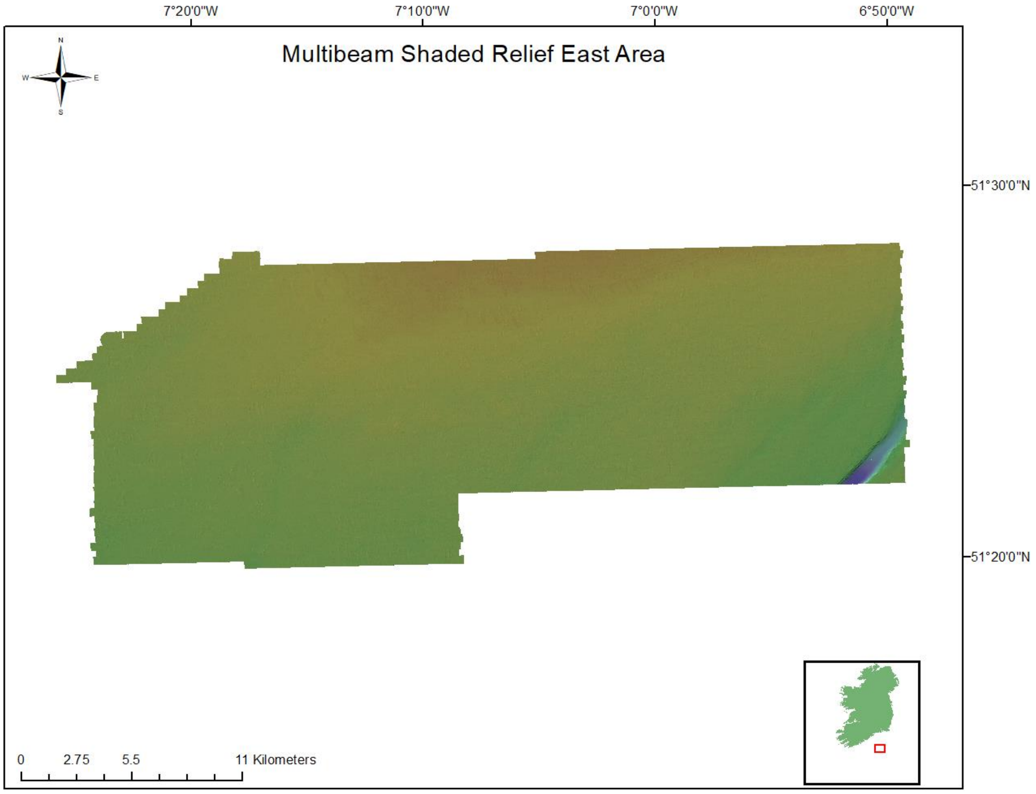

Figure 17: Multibeam shaded relief East area.

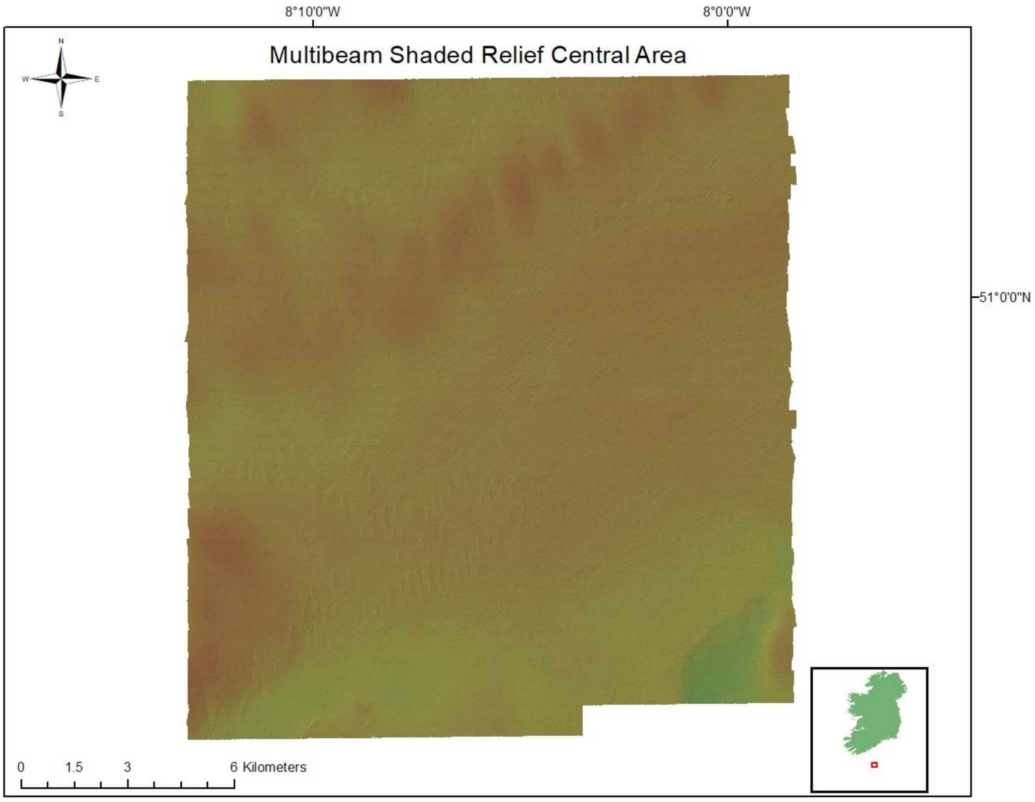

Figure 18: Multibeam shaded relief Central area.

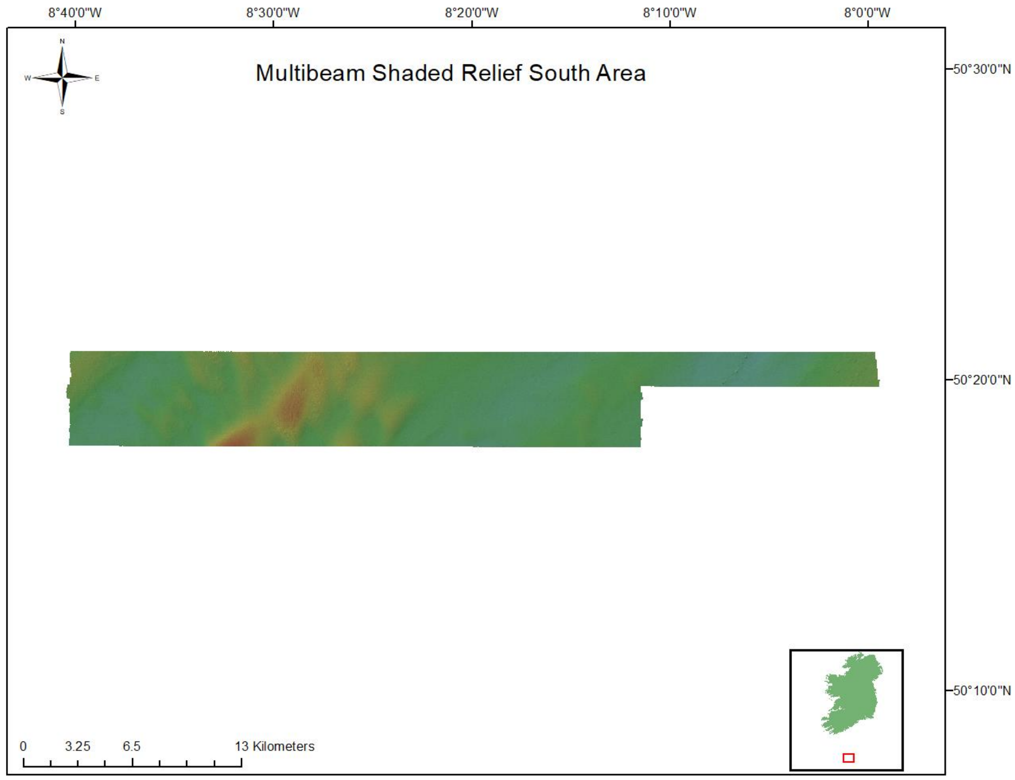

Figure 19: Multibeam shaded relief South area.

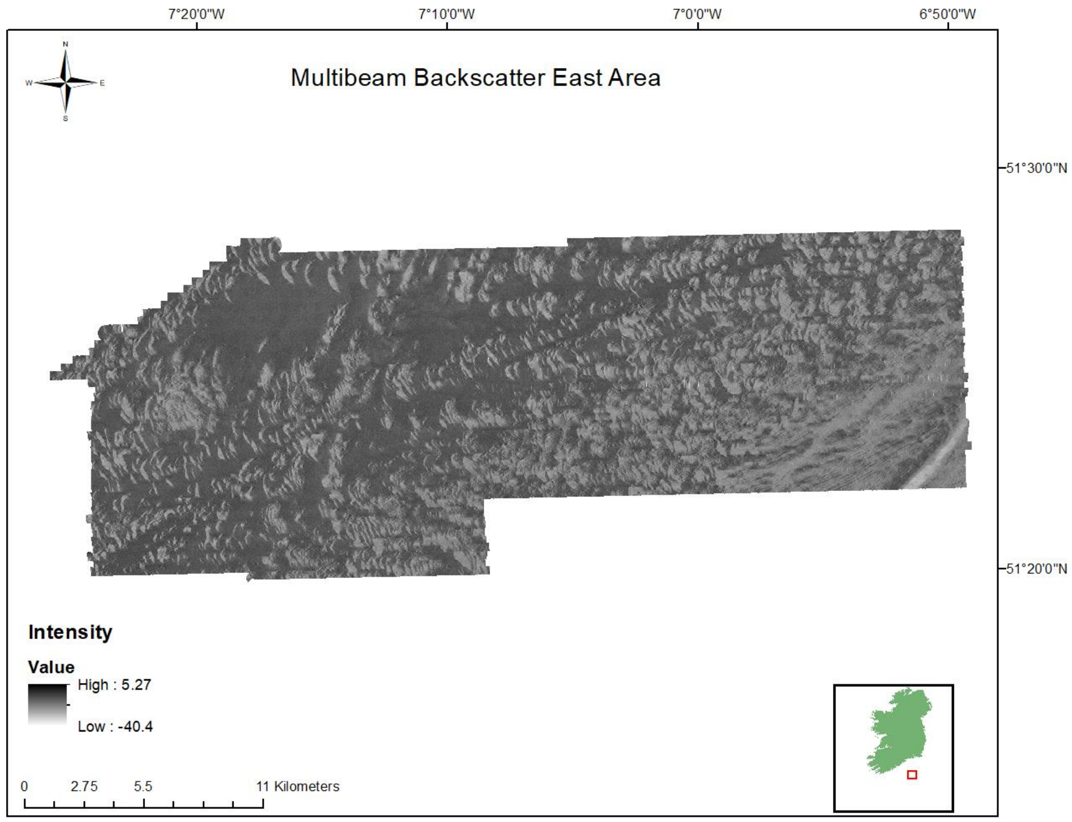

Figure 20: Multibeam backscatter mosaic East area.

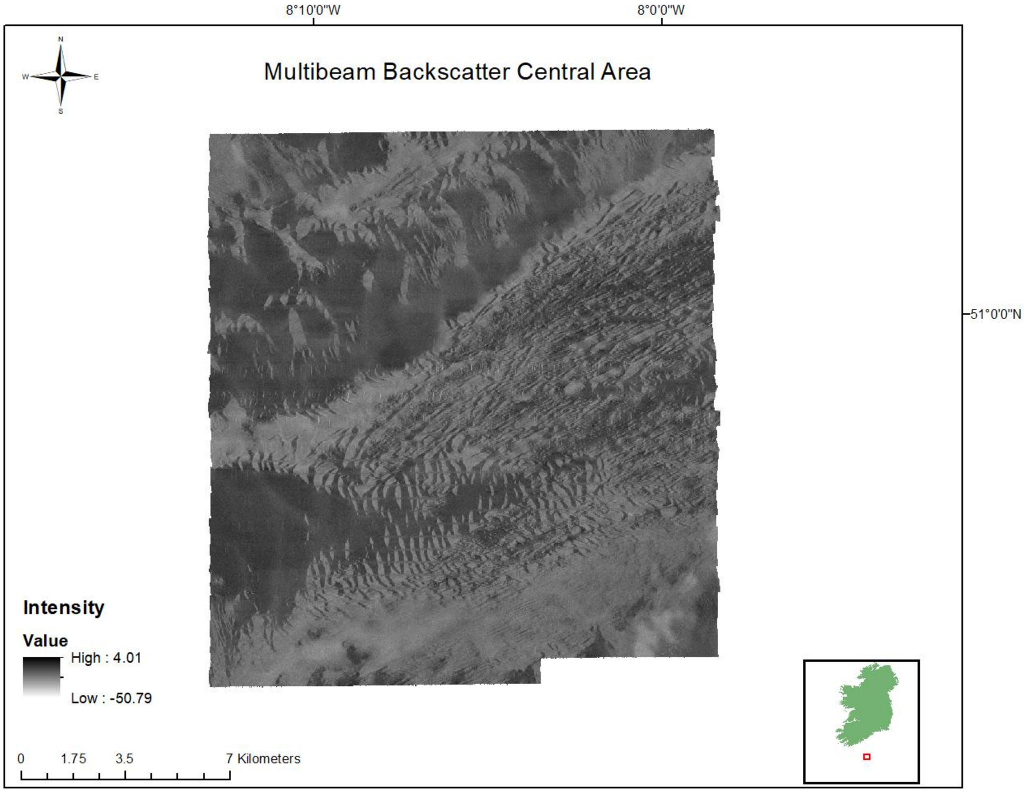

Figure 21: Multibeam backscatter mosaic Central area.

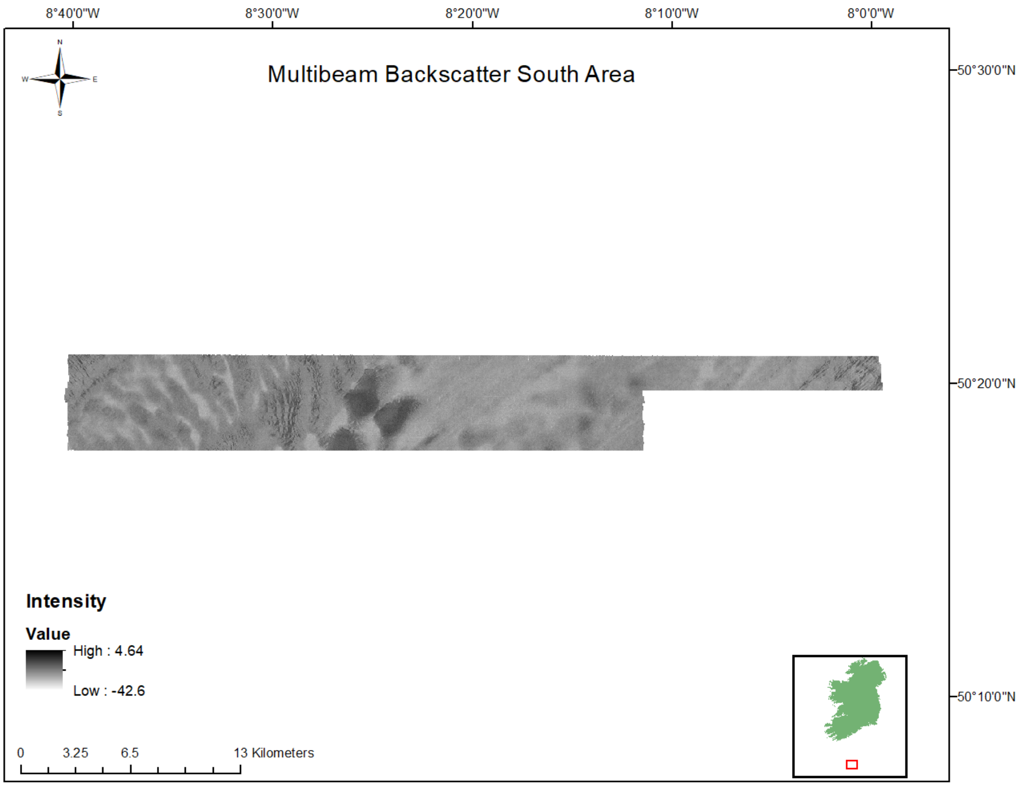

Figure 22: Multibeam backscatter mosaic South area.

4.3.2 Shallow Geology Analysis

Data quality and penetration varied depending on prevailing sea state, survey direction and sub-bottom hardness. Survey speed (4-9 knots) was dictated by the ability of the MBES to meet its data density and data quality requirement. This is faster than the optimal maximum speed of 4 knots for sub bottom data integrity. Sea state varied significantly during the survey and in general the seabed is hard apart from channels and sand ribbons. This combination resulted in limited sub bottom penetration and sub-surface horizon delineation.

Tiff images and CodaOctopus™ format seismic files were recorded for all SBP lines. Profile lines 285 and 360 are selected for discussion here. Their geographical locations are shown in figure 23 where the profile extents have been overlain on shaded relief data. Both profiles were acquired in the Central survey area and on easterly headings

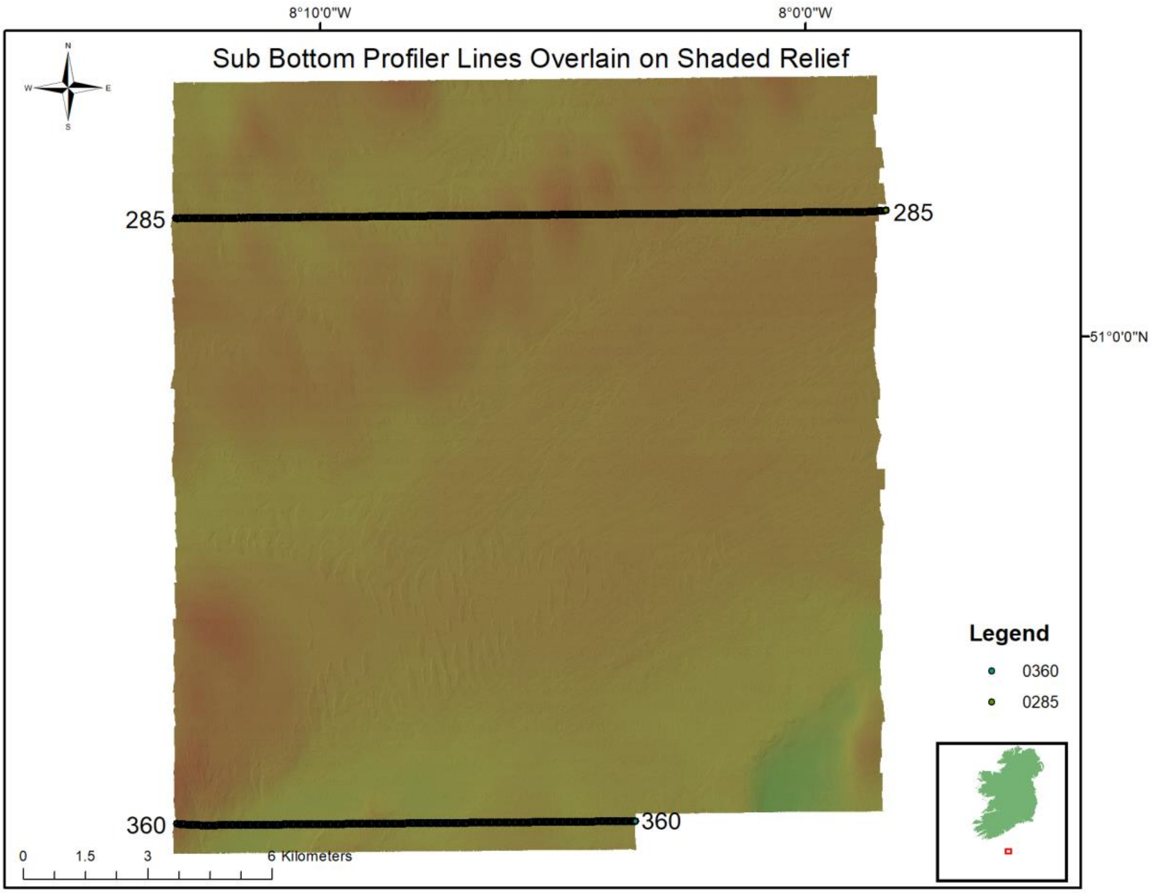

Figure 23: Sub bottom profile lines 285 & 360 overlain on shaded relief data.

Interpreted sub bottom profiler tiff images of survey lines 285 and 360 are shown in figures 24 and 25 respectively. A bandpass filter with low cut 2.2 kHz and high cut 4.7 kHz was applied in processing, along with a suitable gain. Heave compensation is applied to the images displayed. Horizontal scale lines are at 10 metre intervals for all sub bottom images below.

Profile 285 in figure 24 is 17.2 km in length. The profile is dominated by hard ground with the result that signal penetration is limited. Unit 1 is the basal unit throughout. It is characterised by having no internal reflectors. The top of Unit 1 is marked by horizontal reflector, named Horizon 1. Horizon 1 is most pronounced in the centre of the profile where it is overlain by Unit 2. The horizon dies out laterally away from the ridges. Unit 2 varies in thickness up to a maximum of 5 metres. It forms the sediment ridges that outcrop in the centre of the profile. No internal reflectors are evident. Unit 1 is overlain by a thin recent unit of sand ribbons in parts of the west of the section. These ribbons are less than 1 m in thickness and approximately 200 m width. They are interspersed with a coarse unit whose thickness cannot be ascertained.

Profile 360 in figure 25 is 11.2 km in length. Unit 1 is the base unit throughout the profile extent. It is characterised by an absence of internal reflectors. The top of Unit 1 is marked by Horizon 1. Horizon 1 is best identified in the western 8 km of the profile. It is sub-horizontal in character and laterally discontinuous. Unit 1 is overlain by Unit 2. Unit 2 has maximum thickness of over 6 m. The unit is characterised by hyperbolae, indicating coarse sediments and/or shells. Horizon 2 marks the top of Unit 2. Horizon 2 is overlain by Unit 3. Unit 3 has a maximum thickness of up to 4 m. It comprises recent sediments with cross-stratification evident under the ridge on the western end of the profile. Further east Unit 3 comprises a mix of unconsolidated sediments alternating between sands and coarse material. The coarse material has an abundance of hyperbolae.

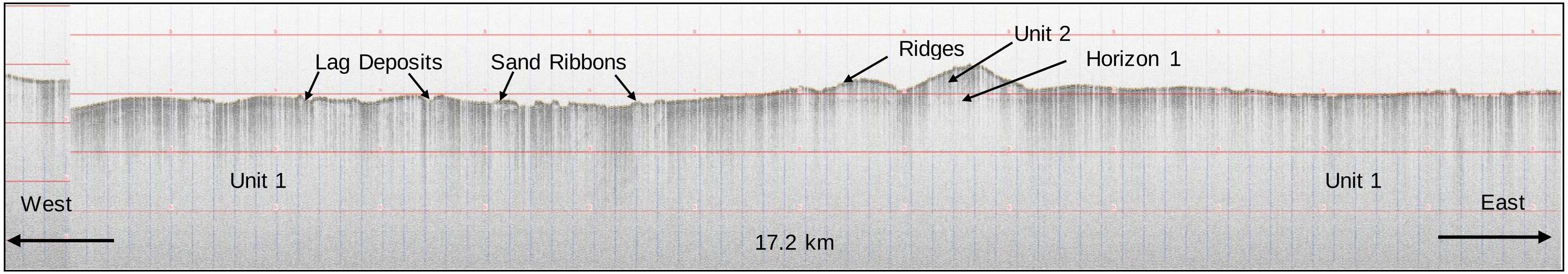

Figure 24: Sub bottom profile interpreted image, line 285.

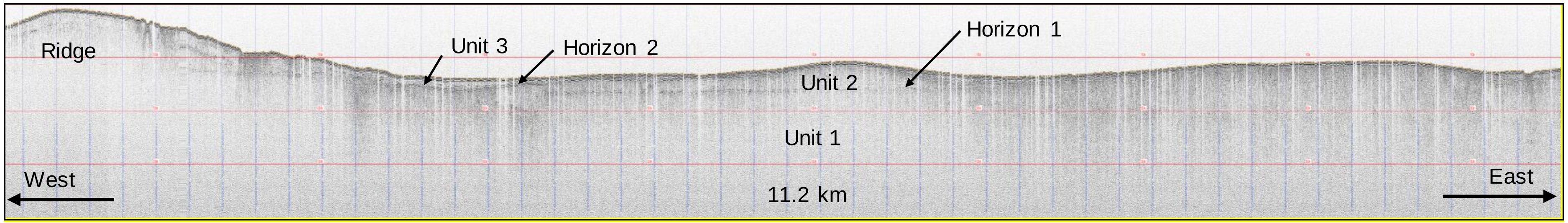

Figure 25: Sub bottom profile interpreted image, line 360.

4.3.3 Bathymetry

Figure 26 shows the colour coded multibeam bathymetry image for the east area. Water depth varies from 76 to 109 m. Greatest depths are located in the south-east and coincide with a channel feature. Least depths are found in the north. Very gentle seafloor gradients are common apart from the channel margins where moderate gradients are found.

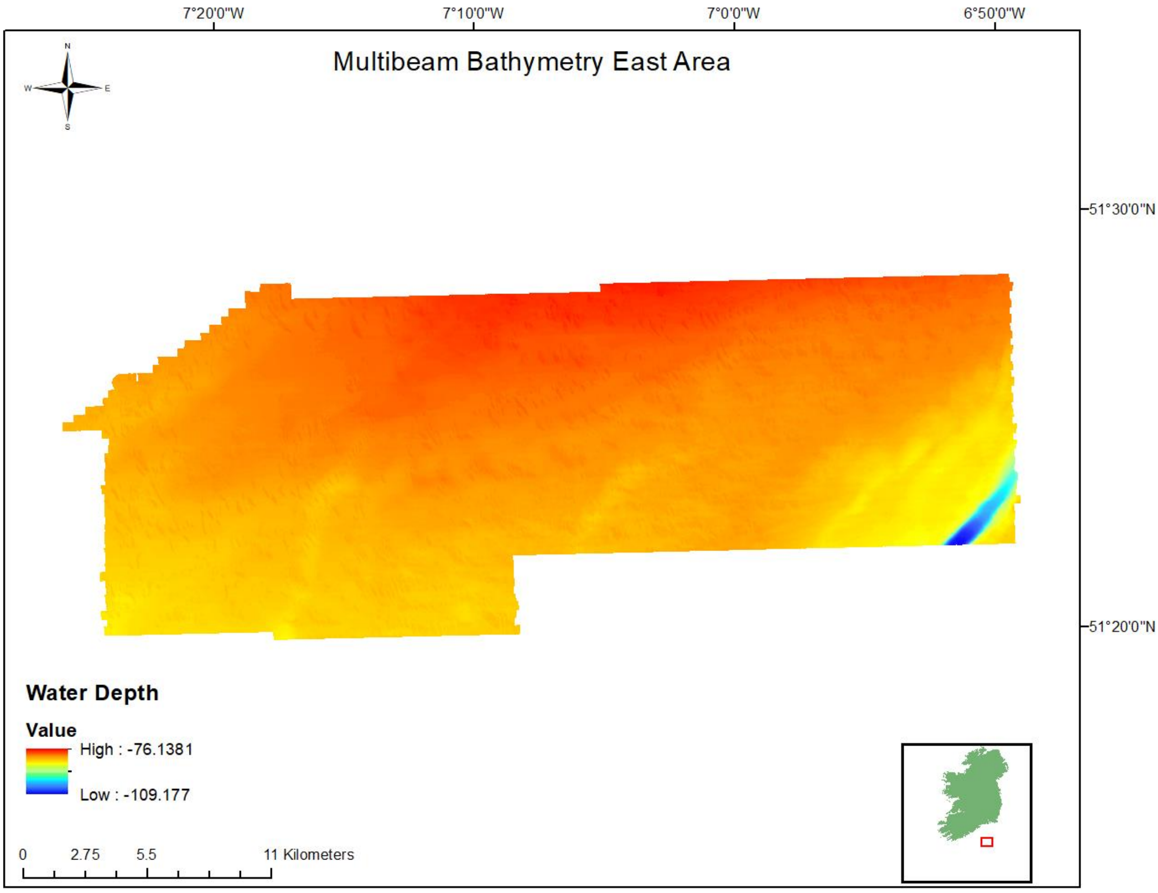

Figure 26: Multibeam bathymetry image East area.

Figure 27 shows the colour coded multibeam bathymetry image for the central area. Water depth varies from 95 to 113 m. Water depth generally increases from north to south although local depth changes are also found and are associated with small ridges. The least depth is found in the south-west, associated with a ridge and the greatest depth is found in the south-east. A gentle seafloor gradient is found throughout.

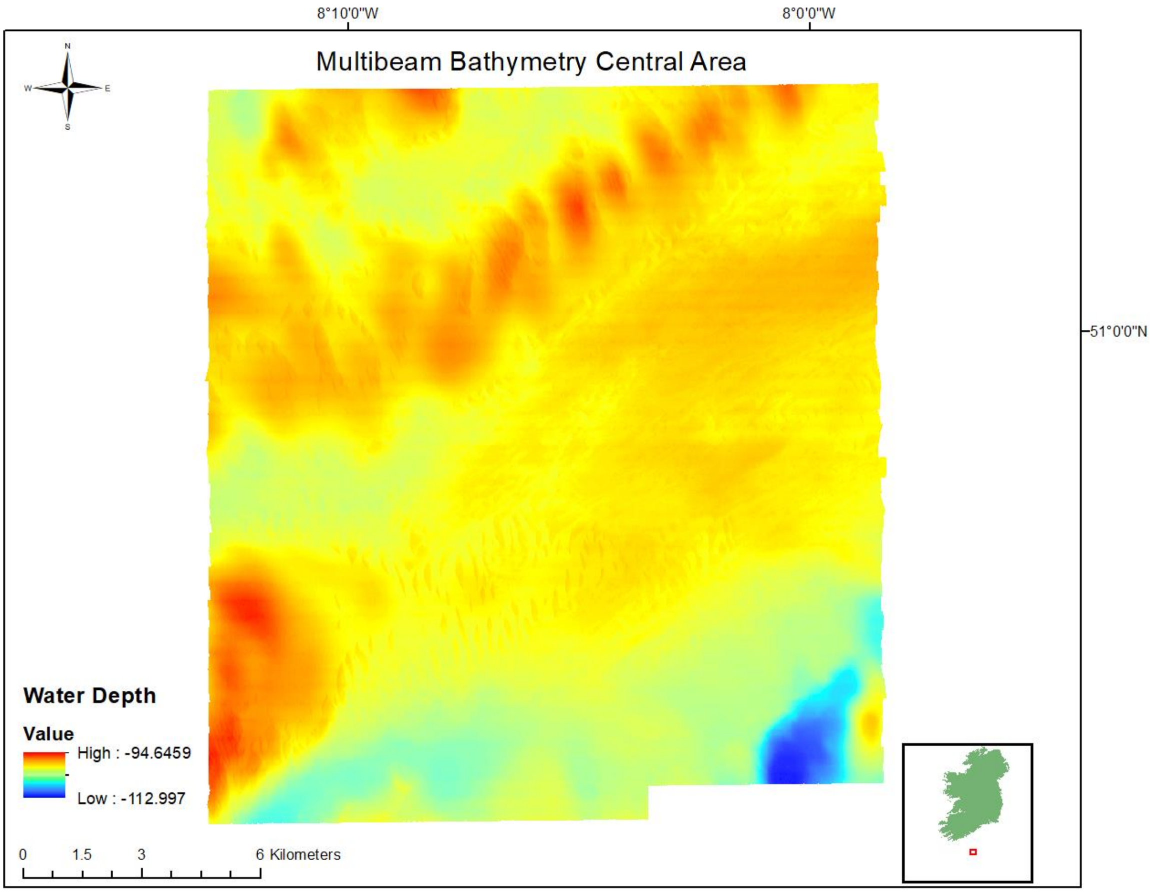

Figure 27: Multibeam bathymetry image Central area.

Figure 28 shows the annotated bathymetry image for the south area. Water depth ranges from 93 to 131 m. Water depth correlates with ridge features. Seafloor gradient is very gentle although some localised moderate gradients are found associated with ridges. Greatest depth is located in the east and the least depth is associated with a ridge crest.

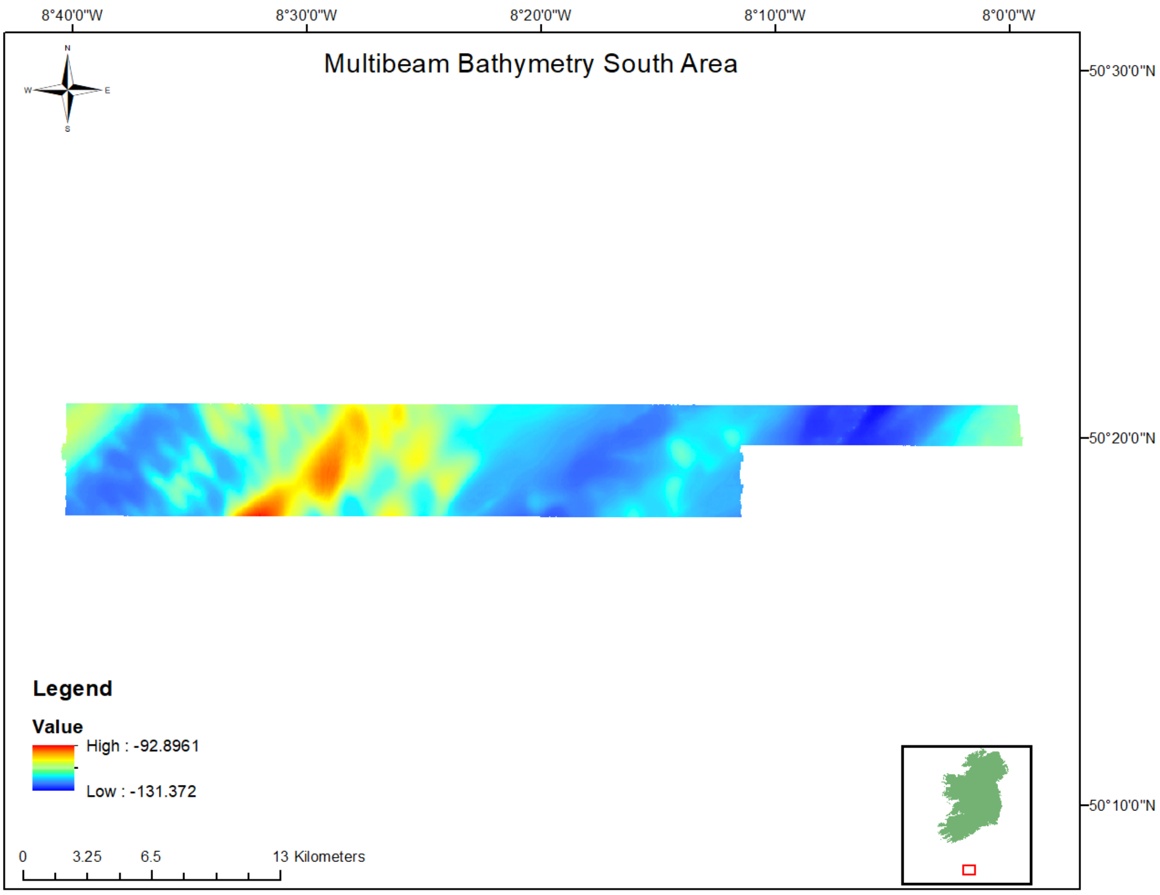

Figure 28: Multibeam bathymetry image South area.

4.3.4 Seabed Texture

Multibeam backscatter is the amount 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.

Figure 29 shows the substrate interpreted backscatter mosaic for the central area. The convention used in this report is that dark coloured areas represent relatively higher backscatter intensity than light coloured areas. A wide variety of backscatter responses are found with intensities ranging from 4 to -51 db. Lowest backscatter intensities are located in the southeast and are associated with a bathymetric low.

Other low backscatter intensity areas correlate with sand ribbons, which are widespread. High intensity backscatter in the west of the image correlates with a bathymetric high, where currents have eroded soft sediment from the seafloor. High intensity backscatter returns are also found between sediment ribbons and are believed to be associated with coarse lag deposits such as gravel and shell.

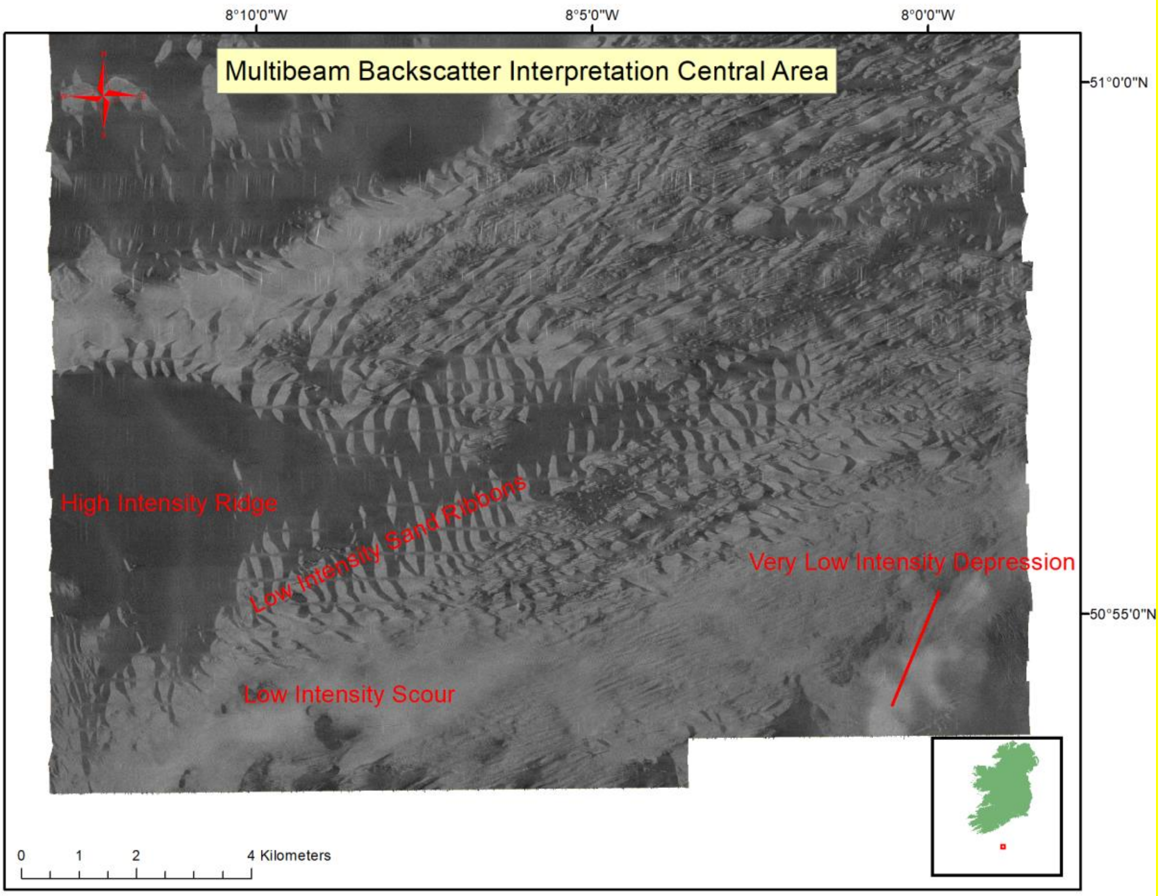

Figure 29: Interpreted multibeam backscatter, west area.

Figure 30 shows the substrate interpreted backscatter mosaic for the south area. The convention used in this image is that dark coloured areas represent relatively higher backscatter intensity than light coloured areas. Backscatter intensities range from 5 to -43 db. Lowest backscatter intensities are associated with bathymetric lows, i.e. depressions. Depressions are both elongated, in the west and more circular in the east. High intensity backscatter values are associated with mounds in the east of the area and with scours in the central part. The mounds are circular and up to 1.5 km in diameter. Scours are elongated in a north-south orientation. Low intensity backscatter areas are located adjacent to the scours. These correlate with bathymetric highs and are interpreted as sand ribbons.

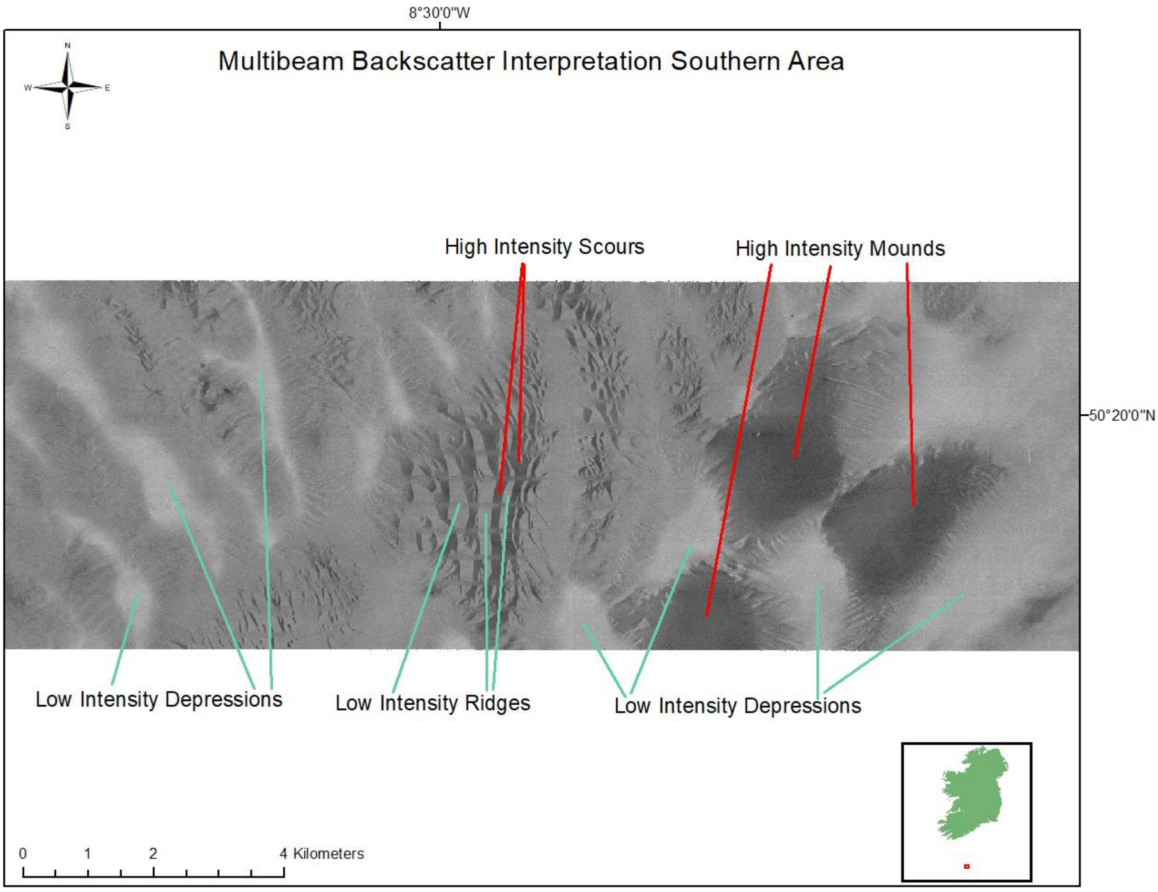

Figure 30: Interpreted multibeam backscatter, east area.

4.3.5 Seabed Features

Description of seabed features is 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 Caris by shining an imaginary sun at 35º angle over the depth colour coded multibeam bathymetry dataset. Images presented in this report are illuminated from a northwest azimuth.

Figure 31 is a shaded relief image of part of the east area illustrating a channel feature. This is part of a much larger channel which was mapped previously on other INFOMAR surveys. Relief between the surrounding plateau and channel floor is approximately 20 m. The channel is approximately 900 m wide. Mapped wreck number 4 is located within the channel and is annotated on the image.

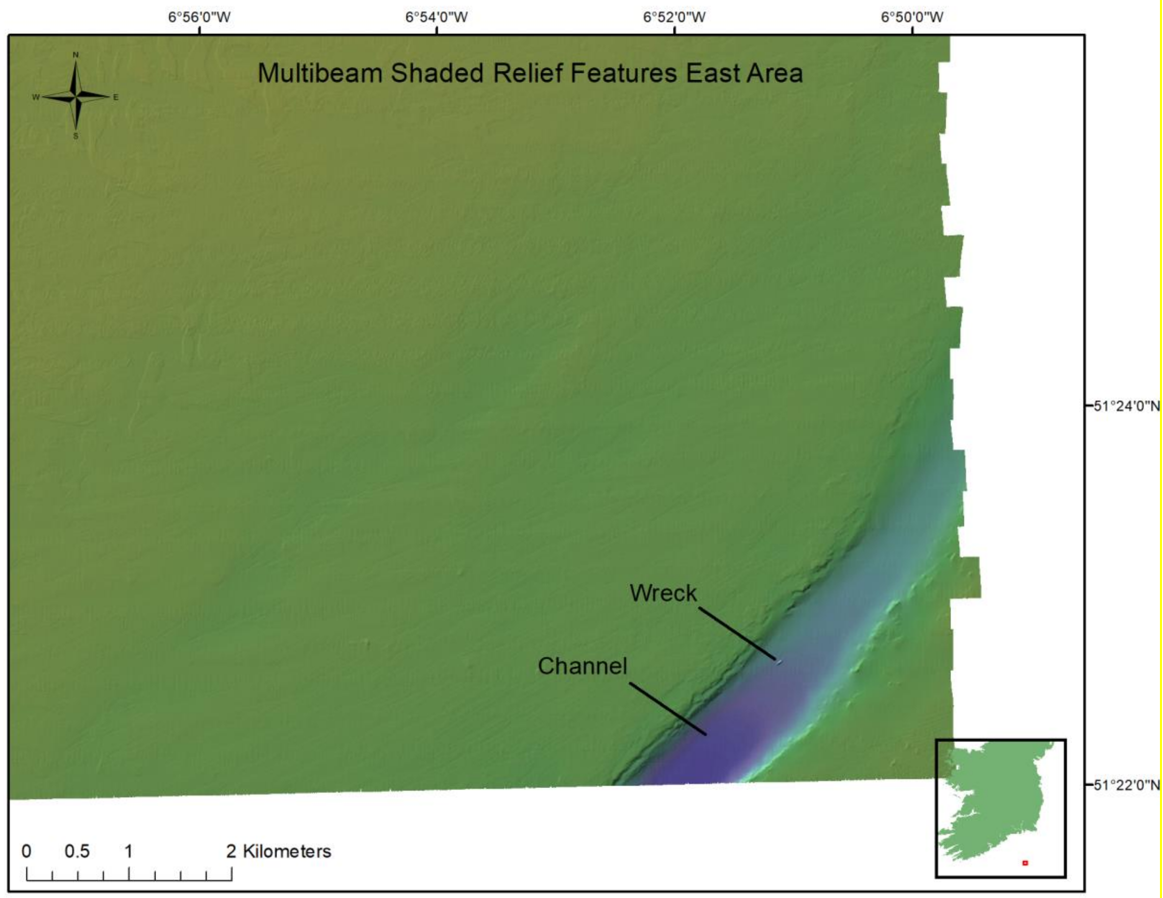

Figure 31: Multibeam shaded relief illustrating channel feature in east area.

Figure 32 is a shaded relief illustrating a ridge and mounds in the south area. The ridge is orientated north-east to south-west. It has an amplitude of up to 26 m and a maximum width of 2 km. The mounds are up to 1.5km in diameter and have amplitudes of approximately 12 m.

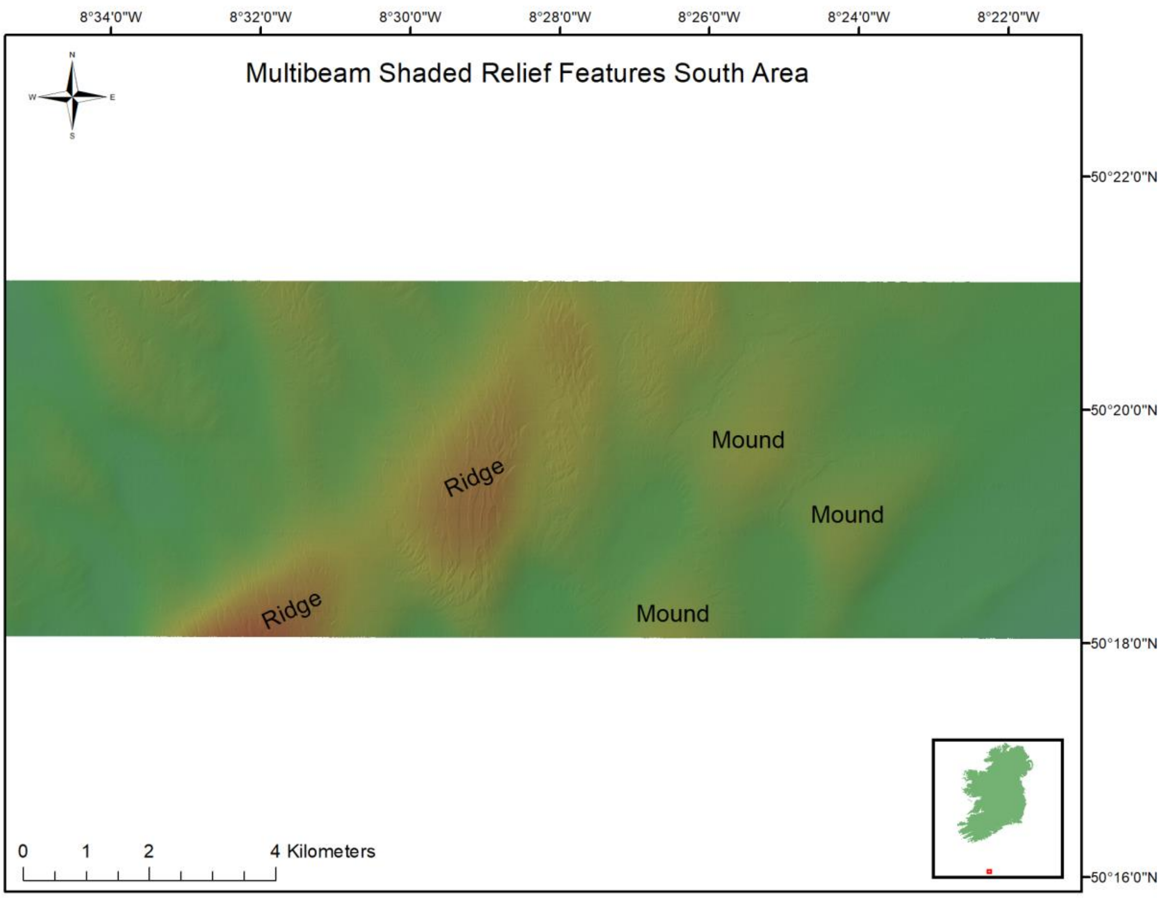

Figure 32: Multibeam shaded relief illustrating ridge & mounds in south area.

4.4 Groundtruthing

Groundtruthing was undertaken using a Day Grab. Thirty-four stations were acquired with the data listed in table 17. All samples will be sent for particle size analysis in a specialised lab and results will be used in the creation of substrate maps.

Station	Latitude	Longitude	Sediment
001	51.45317	-7.16255	**Sand**
002	51.45318	-7.16276	**Sand**
003	51.45328	-7.15867	**Shelly Sand**
004	52.44735	-7.12916	**Muddy Sand**
005	52.45308	-7.12829	**Gravel**
006	51.46031	-7.08403	**Sand**
007	51.47295	-7.05118	**Sand**
008	51.47227	-7.04152	**Gravelly Sand**
009	51.44808	-6.86136	**Sandy Gravel**
010	51.44874	-6.82079	**Sand**
011	51.44045	-6.81954	**Sandy Gravel**

012	51.46139	-6.75287	**Sandy Gravel**
013	51.45764	-6.74603	**Sand**
014	51.45093	-6.73234	**Muddy Sand**
015	51.44909	-6.72709	**Gravelly Muddy Sand**
016	51.44458	-6.72071	**Shelly Gravel**
017	51.4476	-6.70706	**Muddy Gravel**
018	51.4502	-6.70168	**Shelly Sand**
019	51.42623	-6.74405	**Sand**
020	51.42394	-6.74897	**Muddy Sand**
021	51.41957	-6.75667	**Sandy Mud**
022	51.41413	-6.76289	**Muddy Sand**
023	51.40832	-6.76056	**Sand**
024	51.40342	-6.76078	**Sand**
025	51.38913	-6.71924	**Sand**
026	51.38616	-6.71752	**Muddy Sand**
027	51.362	-6.70446	**Gravelly Mud**
028	51.36306	-6.66627	**Sandy Mud**
029	51.37279	-6.65664	**Gravelly Mud**
030	51.37012	-6.61458	**Sandy Mud**
031	51.36131	-6.63751	**Sandy Mud**
032	51.35278	-6.65177	**Gravelly Mud**
033	51.34264	-6.67428	**Sandy Mud**
034	51.34668	-6.69059	**Sandy Mud**

Table 17: Groundtruthing metadata.

Figure 33 is a plot of the groundtruthing stations overlain on tracklines.

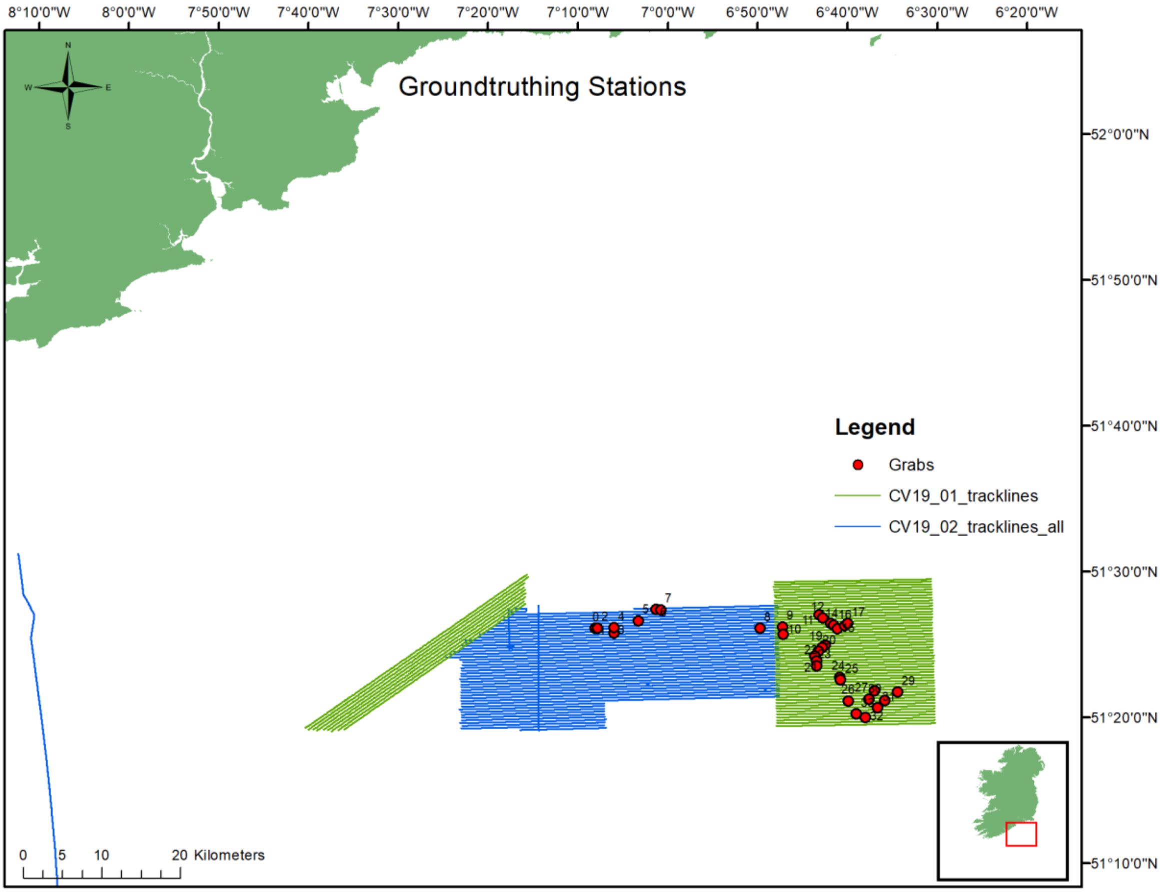

Figure 33: Grab stations locations in relation to survey track lines.

4.5 Wrecks

A total of four wrecks were mapped in detail. H525 forms were filled out for each wreck and reports sent to UKHO. Two of these wrecks were originally discovered during the previous INFOMAR survey but poor weather at the time prevented their detailed mapping. Table 18 provides the wreck metadata for this wreck.

Number	Wreck DB No	Latitude	Longitude
1	11821	51º 20.373 N	-006º 40.275 W
2	11820	51º 20.577 N	-006º 40.854 W
3	11473	51º 23.229 N	-007º 04.154 W
4	11823	51º 22.694 N	-006º 51.273 W

Table 18: Wreck investigation metadata.

Figure 34 shows the locations of mapped wrecks.

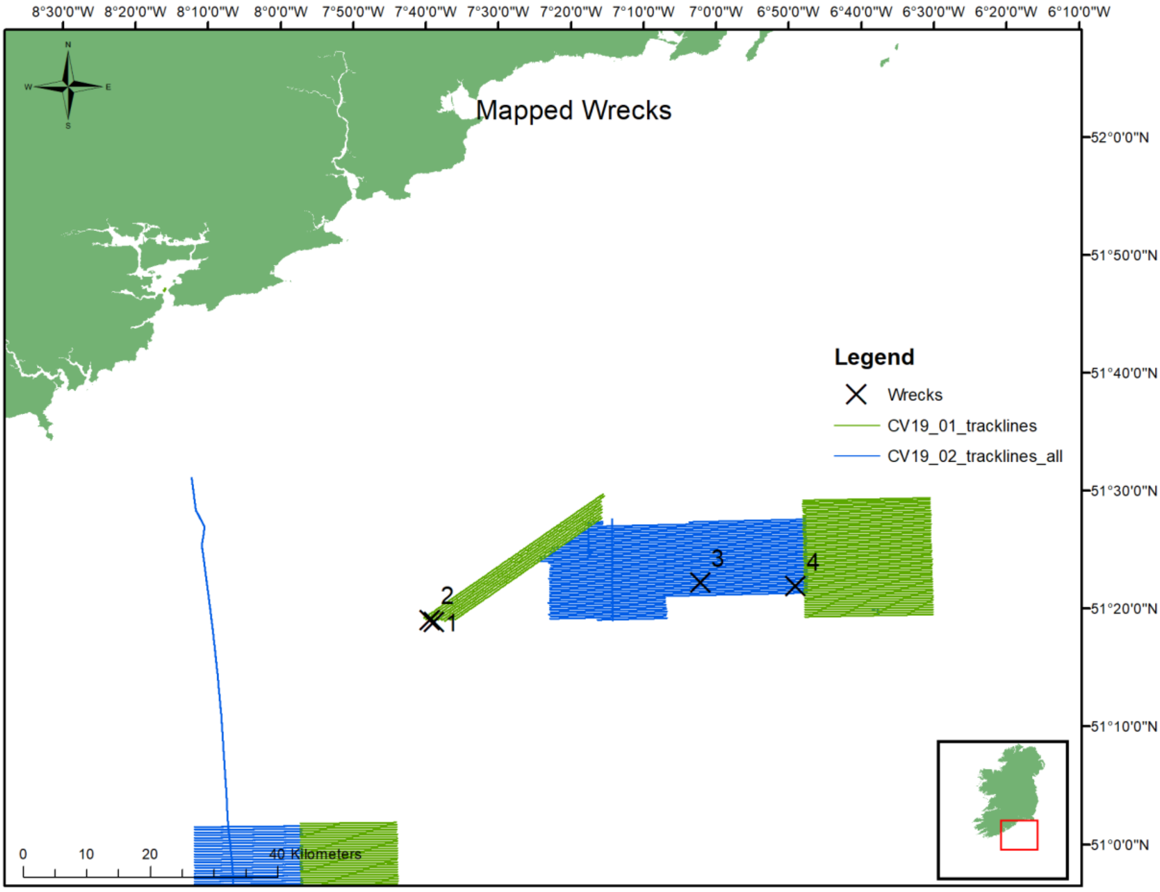

Figure 34: Wreck locations in relation to survey track lines.

Figures 35 to 38 are multibeam images of the mapped wrecks.

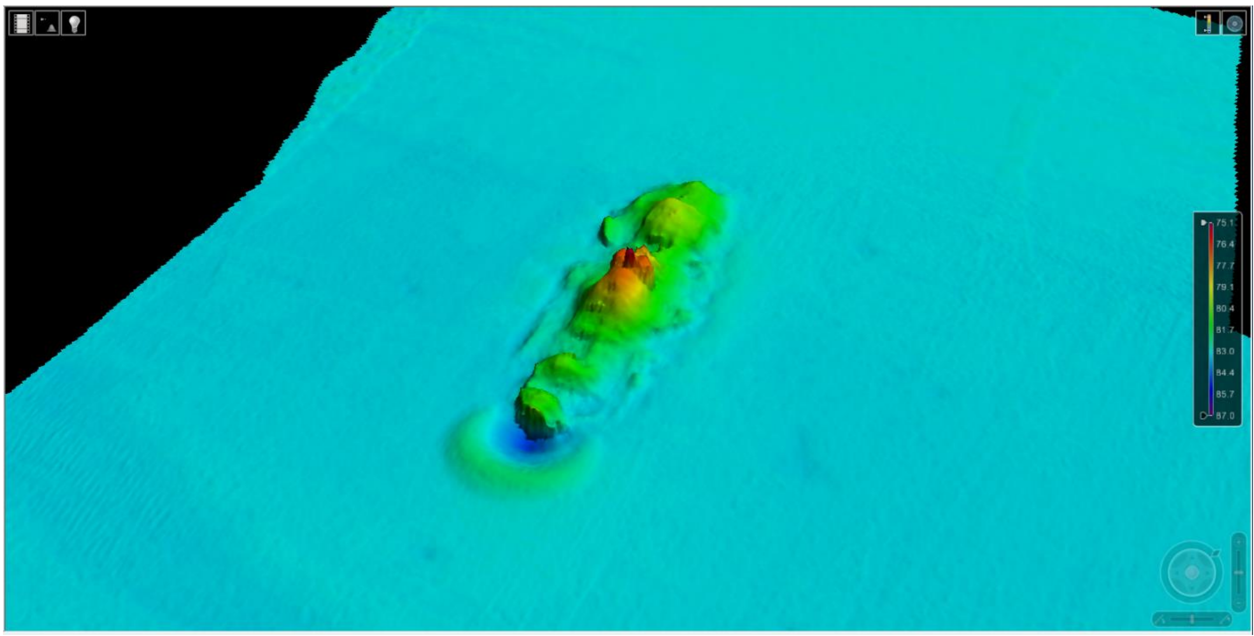

Figure 35: Multibeam bathymetry image of wreck 1.

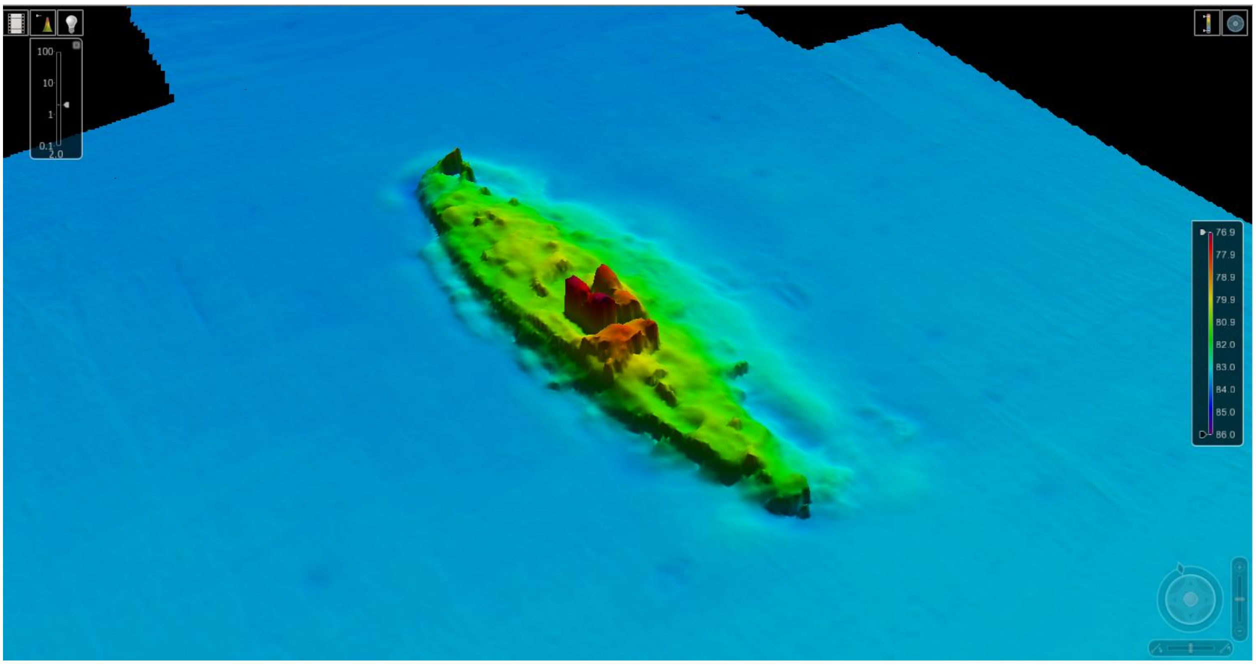

Figure 36: Multibeam bathymetry image of wreck 2.

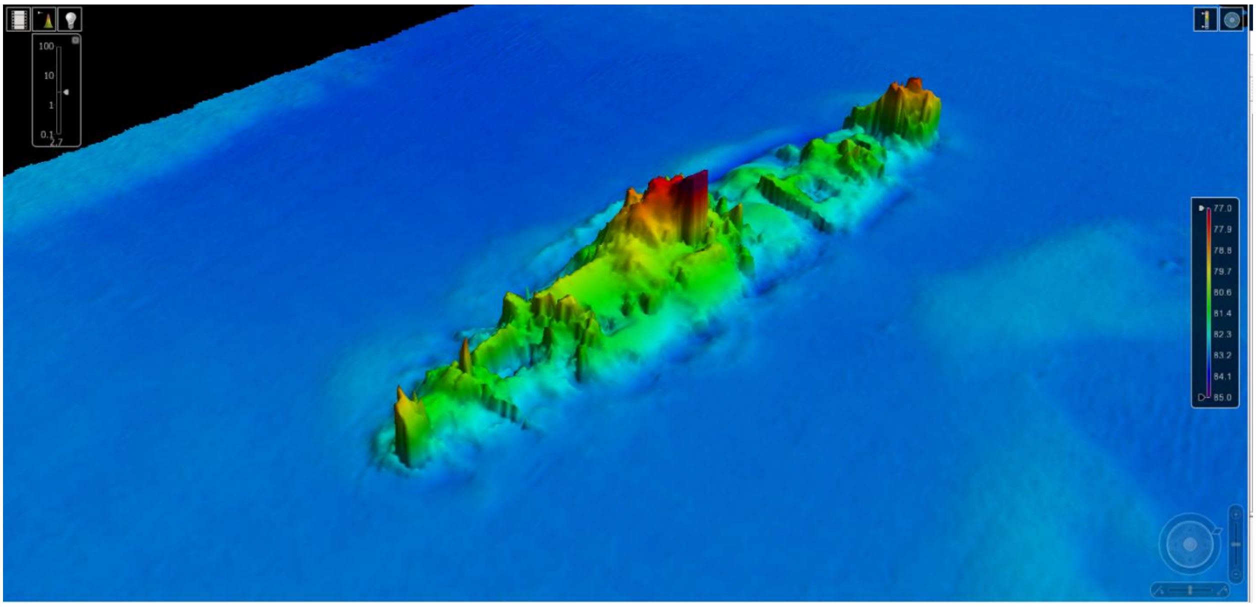

Figure 37: Multibeam bathymetry image of wreck 3.

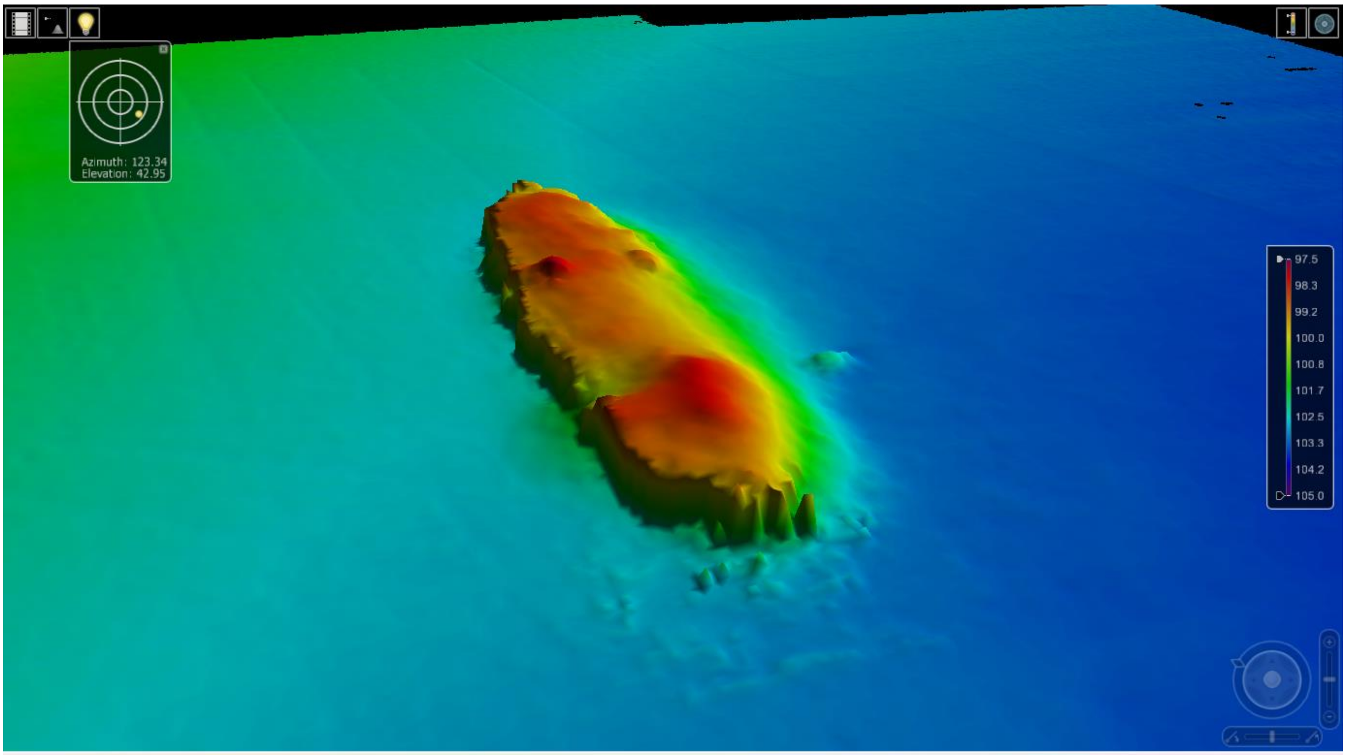

Figure 38: Multibeam bathymetry image of wreck 4.