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

INFOMAR Survey Report: CV18_03
Area: Celtic Sea

For:
Marine Institute & Geological Survey Ireland

RV *Celtic Voyager*

July & August 2018

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: CV18_03

		Signature	Date
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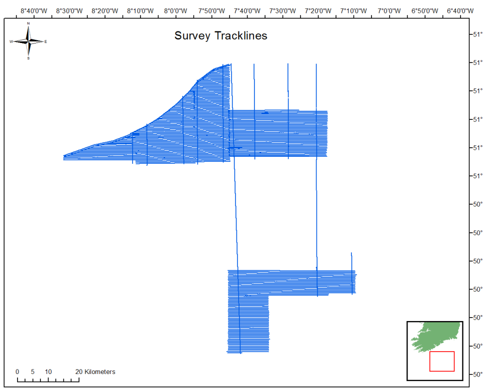
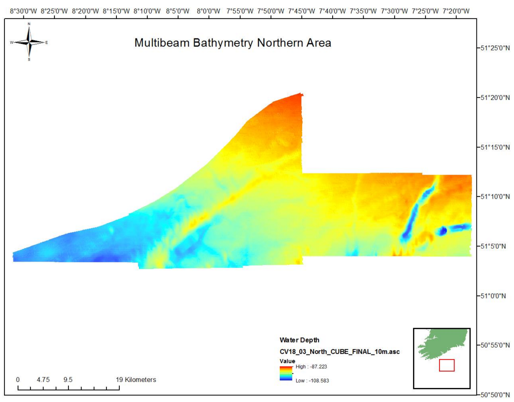
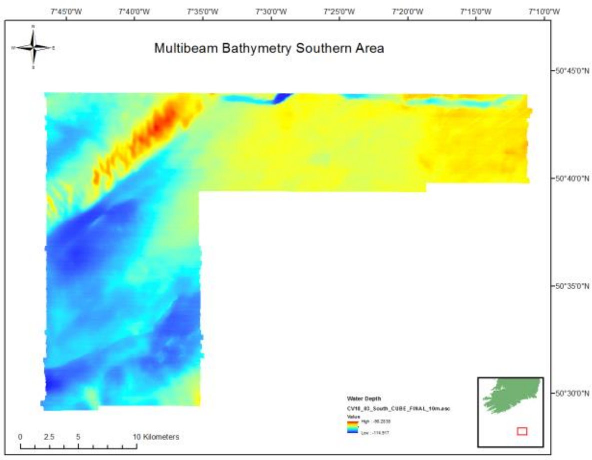
Project Managers: Marine Institute & Geological Survey Ireland			

Issue	Change	Date	Description	By	Approved
1		25/03/2019	Draft	K. Sheehan	
2		29/03/2019	Final	K. Sheehan	F.Sacchetti

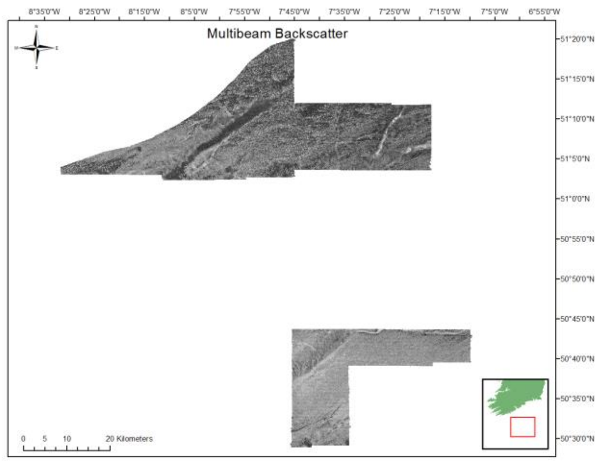
Executive Summary			
Survey Summary			
Survey Vessel:	RV *Celtic Voyager*	**Survey Leg:**	CV18_03
Mobilisation:	Cork	**Demobilisation:**	Cork
Survey Areas:	Celtic Sea	**Start Date:** **End Date:**	27/08/2018 29/09/2018
Northwest Boundary	51º 20.853N 7º 45.502W	**Southeast Boundary**	50º 43.898N 7º 11.428W
UKHO Admiralty	1123 (1:500,000)		
Key References	CV18_03 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):	87 m	**Maximum Water Depth (VORF LAT):**	115 m
Area Covered:	1997 km^2	**Survey Line Kilometres:**	5165 km
Approximate Operational:	55%	**Approximate Downtime :**	32%
Groundtruthing Stations:	59	**Wrecks**	8
H525 forms issues (wrecks)	8	**H102 forms issued (shoals)**	0
Survey Tracklines		**Bathymetry North Area**	
			

Survey Images

Bathymetry South Area



Backscatter



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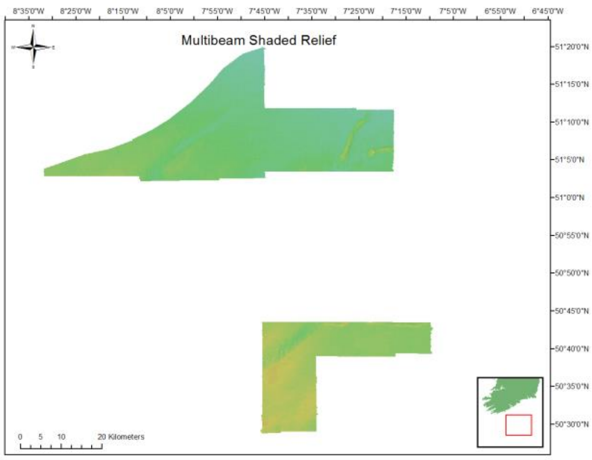
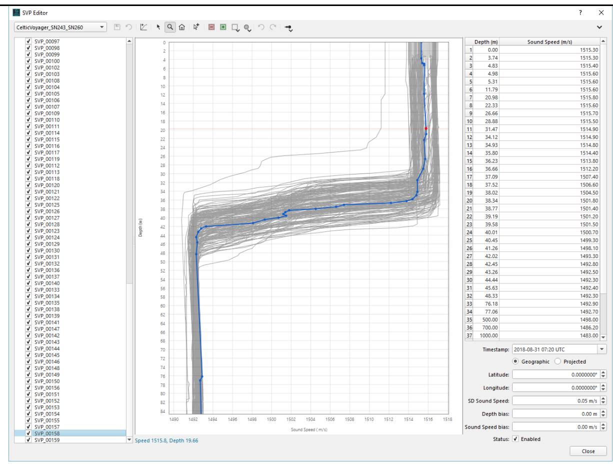
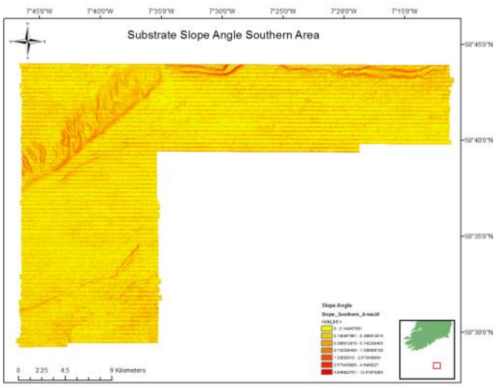


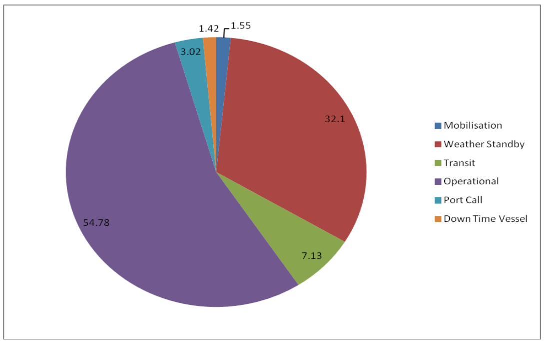
MVP Composite Graph



Substrate Slope Southern Area



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

The 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. INFOMAR is a joint venture between the GSI and the MI. The INSS was one of the largest marine mapping programmes ever undertaken globally, with a focus on deep water mapping. INFOMAR 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 2018. Grey have already been mapped, blue 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.

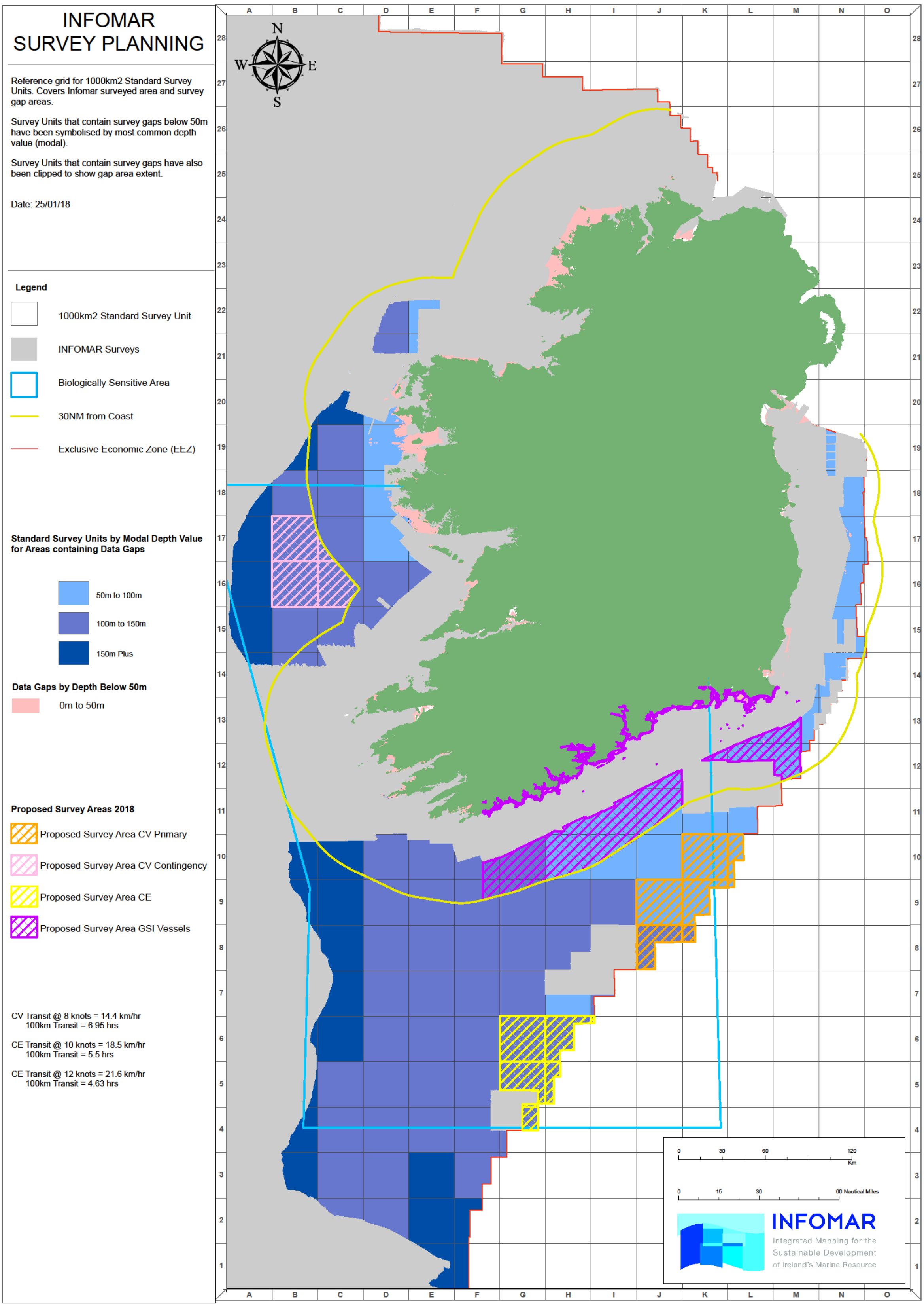


Figure 1: Survey coverage status January 2018.

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 2018. The entire area is in the Celtic Sea in water depths ranging from 75 to 125 m depth and is bounded by the UK/Ireland border to the east. Predicted survey coverage for the RV *Celtic Voyager* 2018 survey season is 3400 km^2 based on survey rates achieved in the 2016 and 2017 seasons respectively. The actual hatched area in figure 2 is 3580 km^2 as hatched boundaries were drawn along existing ISU boundaries. Approximately 80% of the area lies in the 50 to 100 m depth zone and 20% 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.

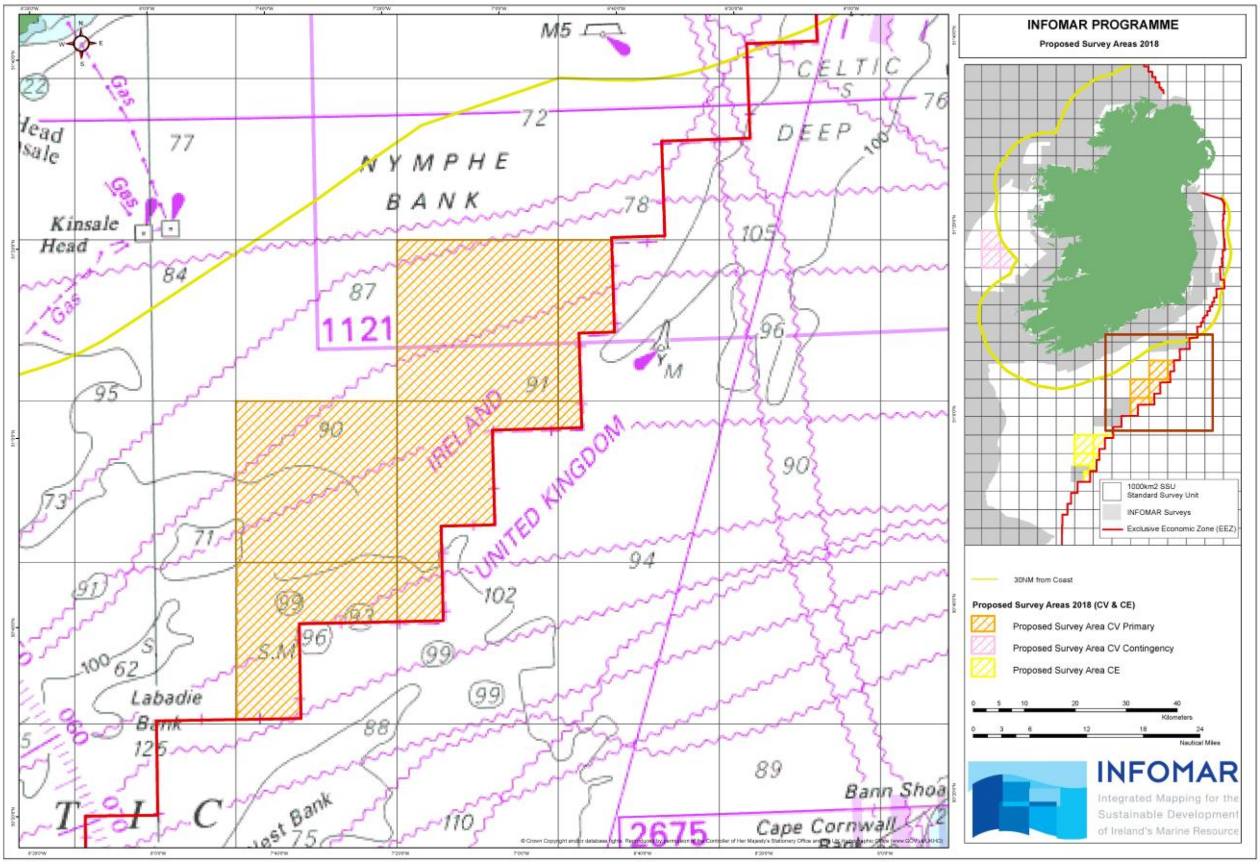


Figure 2: Proposed survey area for 2018.

2. Operations & Survey Setup

Mobilisation took place in Cork on 27th August. Survey acquisition took place between 28th August and 28th September. Kevin Sheehan and Vera Quinlan of the MI acted as Party Chiefs. The survey team comprised skilled personnel from the MI and freelance contractors.

2.1 Survey Tracklines

The final survey trackline plot is contained in figure 3. Mainlines were acquired on east – west reciprocal headings apart from boundary lines acquired along the 30 Nm limit. The 30 Nm limit defined the western borde of the northern block. Two separate survey polygons were mapped, denoted in this report as the northern area and southern area respectively.

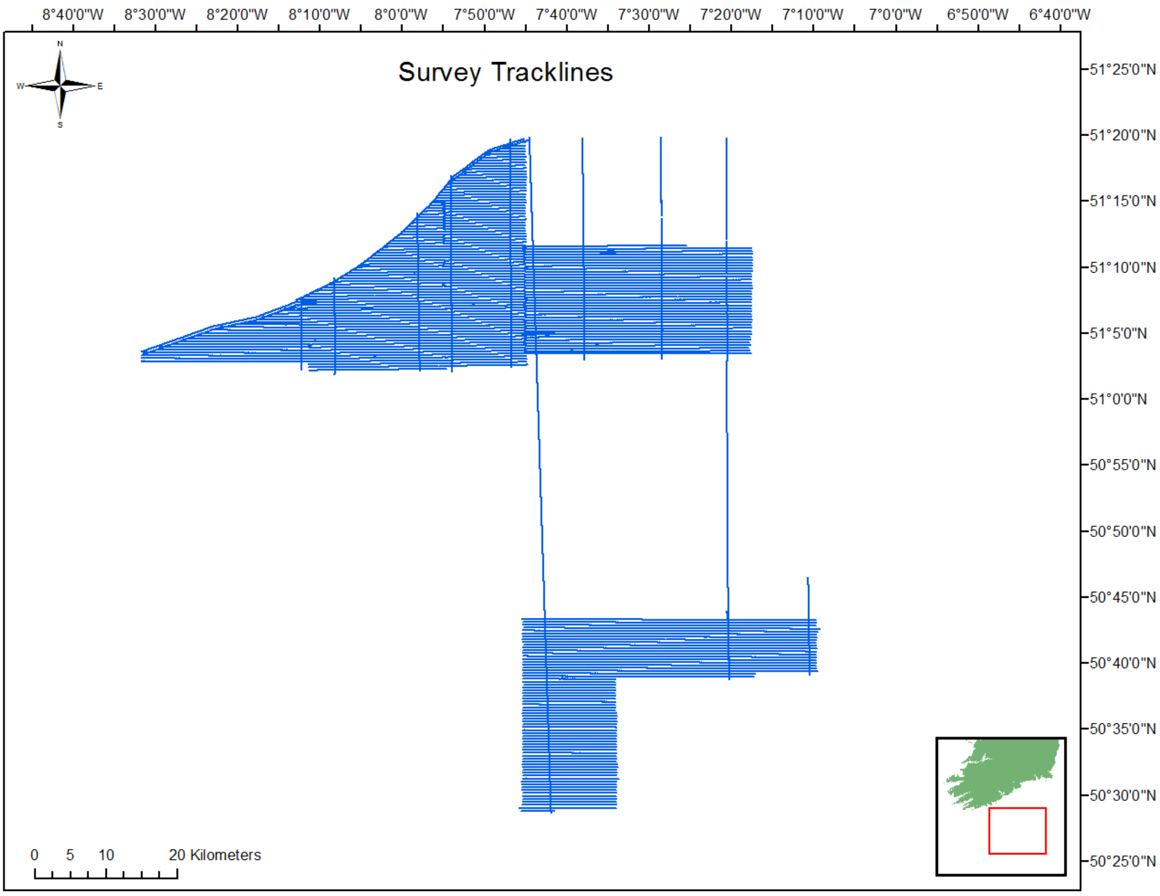


Figure 3: Survey trackline plot produced in Caris and ArcGIS software.

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
27/08/2018 00:00	Mobilised in Cork City
27/08/2018 13:00	Weather Standby
27/08/2018 20:00	Depart Cork for survey site.
28/08/2018 07:16	Commenced data acquisition. Reboot of EM2040 PU due to noise.
30/08/2018 07:44	Groundtruthing of CV18_02 survey area. 17 stations.
30/08/2018 19:47	Resumed Acoustic survey.
01/09/2018 09:58	Groundtruthing. 13 stations.
01/09/2018 15:55	Resumed Acoustic survey.
02/09/2018 19:01	Completed survey of southern block. Started cross line heading north.
03/09/2018 12:00	MVP failed and recovered on deck.
04/09/2018 00:50	Commenced survey of northern block.
04/09/2018 10:00	UPS failure on C Nav. Switched to spare UPS.
07/09/2018 00:28	Transit to Cork.
07/09/2018 07:40	Port-call Cork. Fuel, water, stores and MVP re-terminated. Personnel change. VQ & DOS replace KS, OMM, MA.
07/09/2018 18:00	Weather standby.
11/09/2018 19:00	Departed Cork for survey site.
12/09/2018 06:11	Resumed survey acquisition.
15/09/2018 19:55	Weather Standby. Hove too.
16/09/2018 05:50	Resumed survey.
17/09/2018 01:31	Transit to Cork. Weather Standby.
18/09/2018 11:00	Personnel change; VQ & DOS off, KS & OMM on.
23/09/2018 17:05	Transit to survey site.
24/09/2018 00:47	Resumed survey acquisition.
25/09/2018 22:35	MVP communications lost. Switched to SVP.
26/09/2018 08:39	Commenced groundtruthing.
27/09/2018 00:00	Resumed acoustic survey.
28/09/2018 23:19	Survey completed. Commenced transit to Cork.
29/09/2018 09:00	Alongside Cork.
29/09/2018 00:00	Demobilisation complete.

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
Vera Quinlan	MI	Party Chief /Surveyor
Oisin McManus	MI	Surveyor
Michael Arrigan	Contractor	Data Processor
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, grab 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)	5165
Area Covered (km^2)	1997
Operational (%)	55
Weather Standby (%)	32
Transit (%)	7
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 59% of the time.

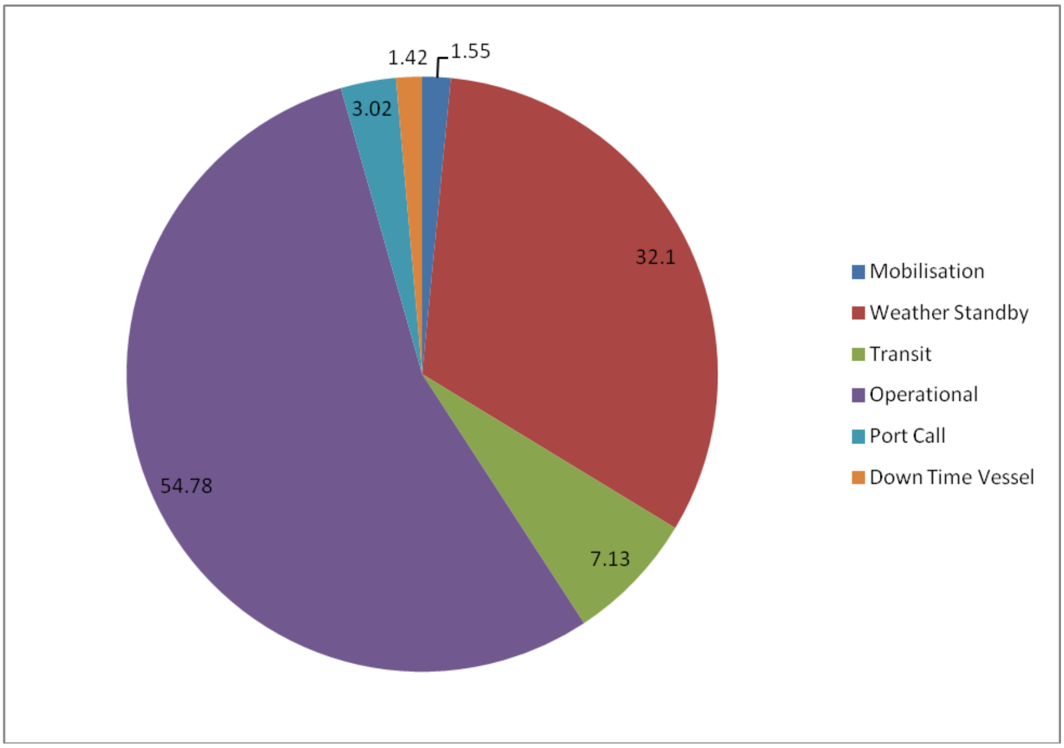


Figure 4: Survey statistics pie chart.

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 two hull mounted high resolution MBES systems, 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.

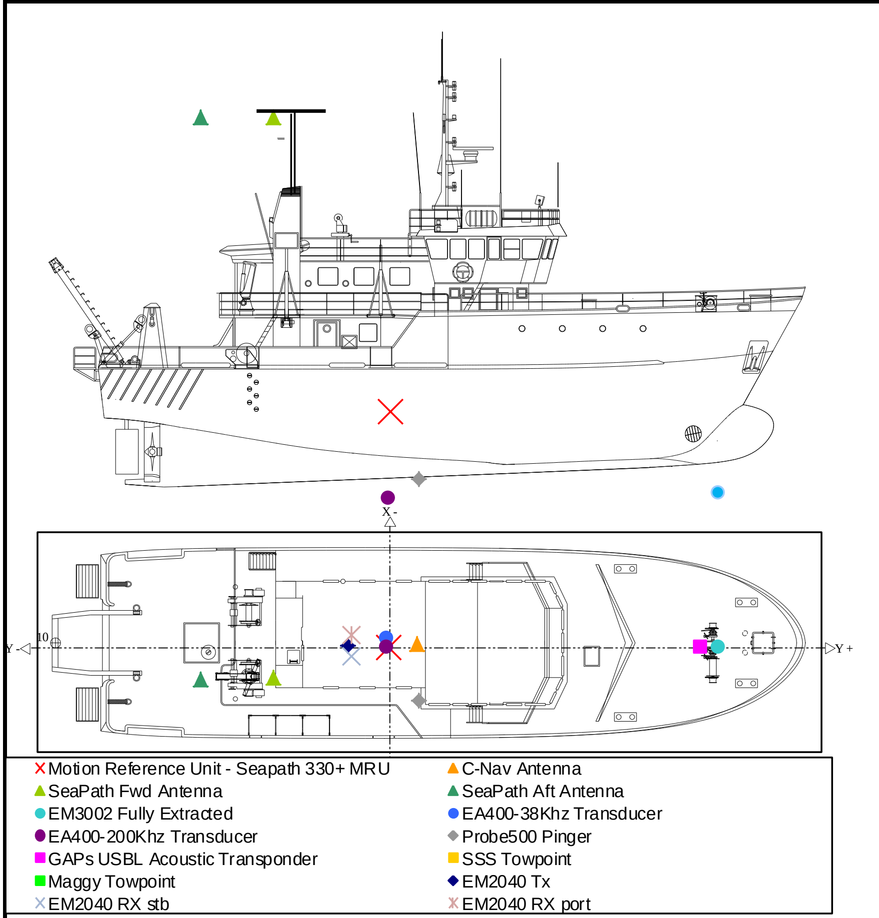
3.1 Vessel Offsets

The EM3002 transducer was moved from a retractable pole amidships to the bow in August 2015. This coincided with the movement of the EM2040 transducers from their bow position to the retractable pole amidships. 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
Multibeam Echo-Sounder	Kongsberg EM3002	300 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.

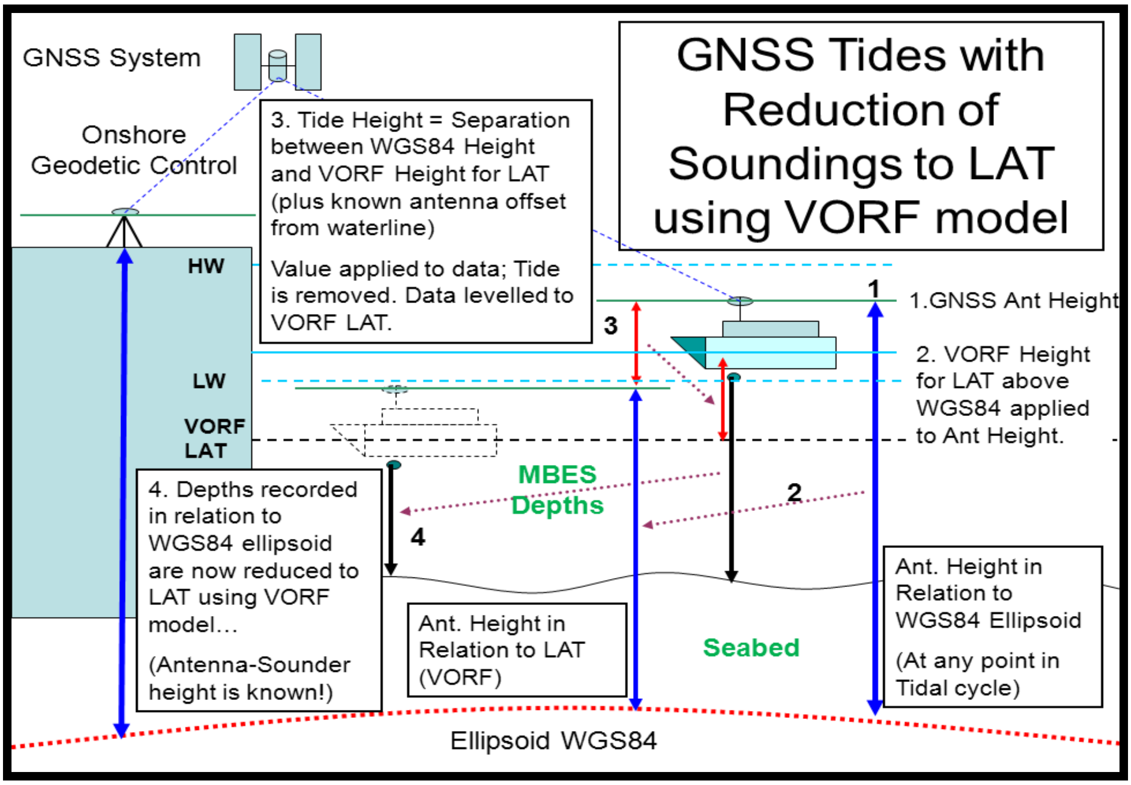


Figure 6: GNSS tides to LAT using VORF model.

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 multibeam produce highly accurate bathymetric data. Additionally, backscatter acquired by multibeam 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.

Descriptor	Metadata
Survey lines	NA
Data Files	773
Date Created	28-08-2018 to 28-09-2018
Dataset Size	157 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 8 wrecks survey were mapped.

Water column data were acquired on all survey lines. Water column data acquired on wreck investigations were backed up to the vessel server and delivered on the final survey disk. Remaining water column data were wrote to a separate disk due to their large file size. This disk was connected directly to the EM2040 PC. Table 9 contains wreck investigation water column metadata information.

Descriptor	Metadata
MBES water Column Lines	33
Dataset Size	30 GB

Table 9: Wreck investigation water column logging files.

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 Coda DA4G acted as the topside trigger and acquisition system. Raw data was recorded in native coda format 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 10 contains SBP metadata.

Descriptor	Metadata
Survey lines	NA
Data Files	701
Date Created	28-08-2018 to 28-09-2018
Dataset Size	60 GB
File Formats	.cod & .tiff

Table 10: 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 software and output in proprietary BOB format as .mms file. Metadata is contained in table 11.

Descriptor	Metadata
Survey lines	NA
Data Files	2
Date Created	28-08-2018 to 28-09-2018
Dataset Size	1.4 GB
File Formats	.mms, .txt

Table 11: 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 12.

Descriptor	Metadata
Survey lines	All
Data Files	32
Date Created	28-08-2018 to 28-09-2018
Dataset Size	7.0 GB
File Formats	.cnav3050

Table 12: 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 13.

Descriptor	Metadata
Survey lines	NA
Data Files	1060
Date Created	28-08-2018 to 28-09-2018
Dataset Size	31.1 GB
File Formats	.db & .txt

Table 13: 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 14.

Descriptor	**Metadata**
Survey lines	NA
Data Files	815
Date Created	28-08-2018 to 28-09-2018
Dataset Size	24.9 MB
File Formats	.asvp

Table 14: 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.

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 15.

	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 15: 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.

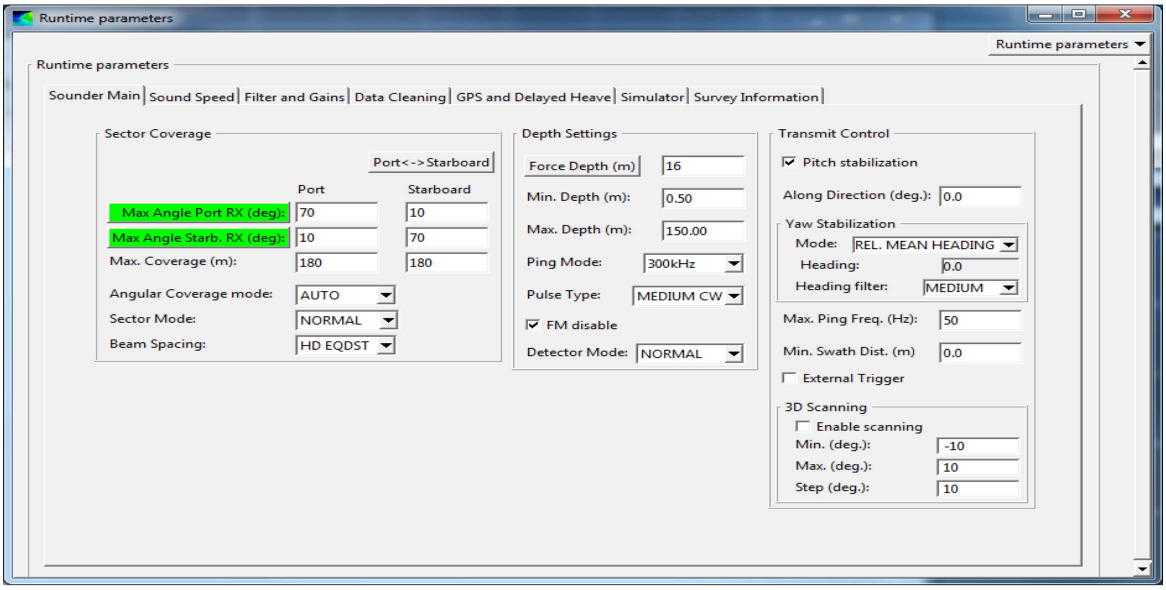


Figure 7: Runtime parameters window in SIS.

4.1.2 Crossline versus Mainline Statistics

Crossline data were acquired for QC of depth soundings. A total of 34 crosslines were acquired for statistical analysis in Caris Hips. The crosslines were split during acquisition in order to acquire groundtruthing data at pre-planned stations. Crossline data were compared with mainline data and all crossline data indicated that the soundings exceeded the 95% certainty required for Order 1a specification.

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 the Order 2 survey specification. Water depths range from 87 to 109 m in the northern area and 98 to 115 m in the southern one. The minimum sized cubic features that require detection are 8.7 and 9.8 m in the northern and southern areas respectively, i.e. 10% of water depth. A minimum of 9 soundings per 8.7 and 9.8 m bins are required in order to attain the feature detection criteria for the north and south areas respectively.

Sounding statistics were computed in Caris using 8 and 9 m (rounded down) bin sizes for the respective areas. The mean number of soundings per bin for the northern and southern areas was computed at 43 and 66. This easily exceeded the 9 soundings required per bin. Figures 8 and 9 are plots of both areas showing where 9 soundings per bin were achieved (green) and where the 9 soundings requirement was not met (red).

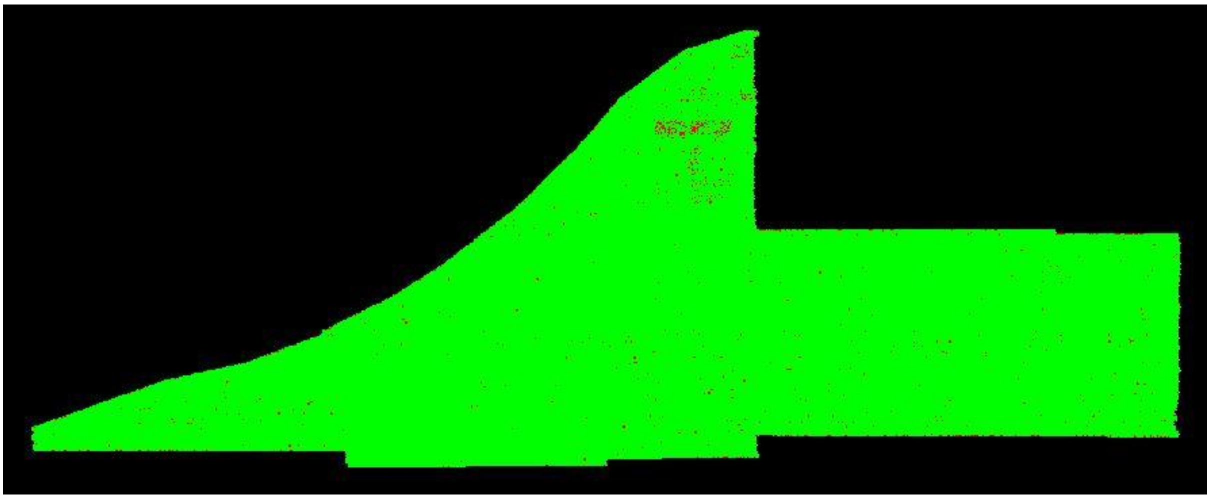


Figure 8: Sounding density traffic light plot northern area.

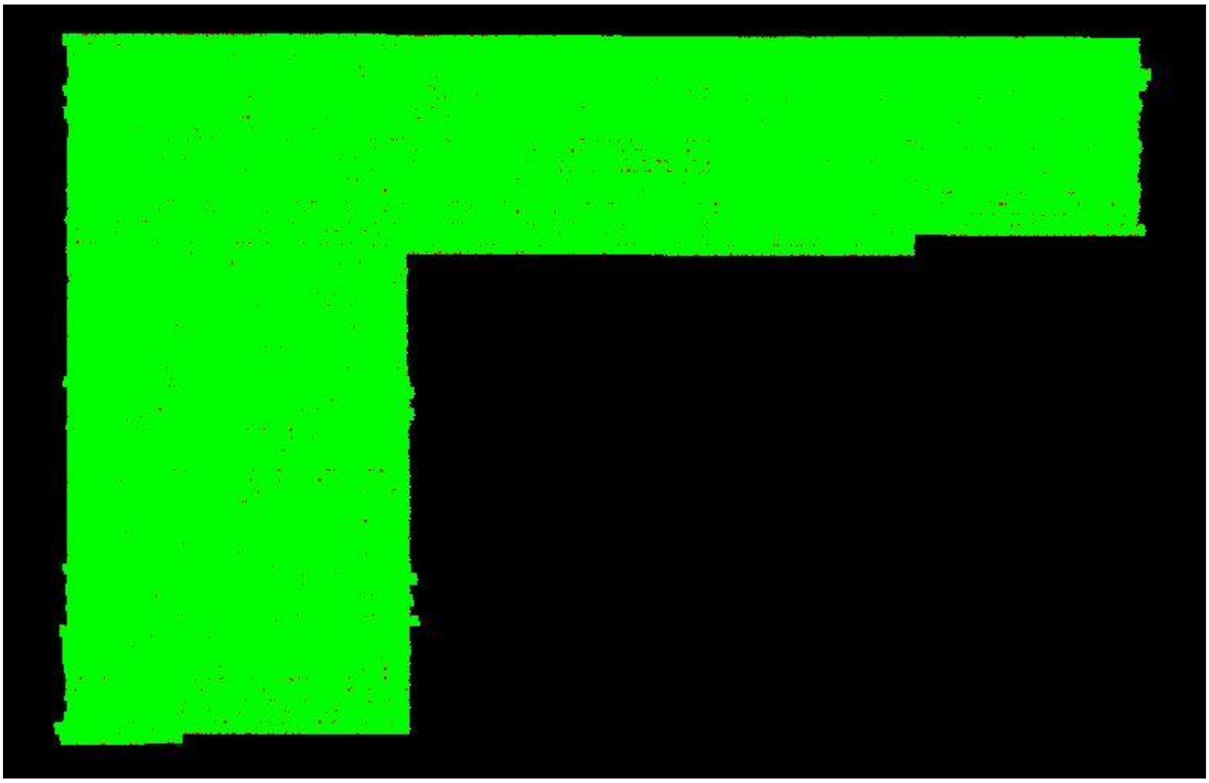


Figure 9: Sounding density traffic light plot southern area.

Figures 10 and 11 show the sounding density statistics for both areas.

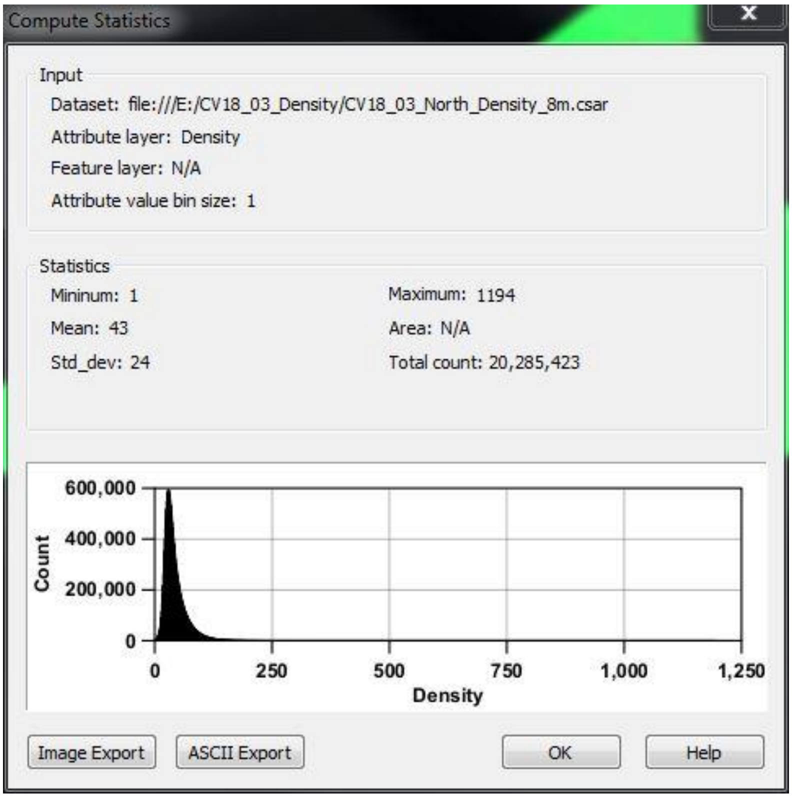


Figure 10: Sounding density statistics, north area.

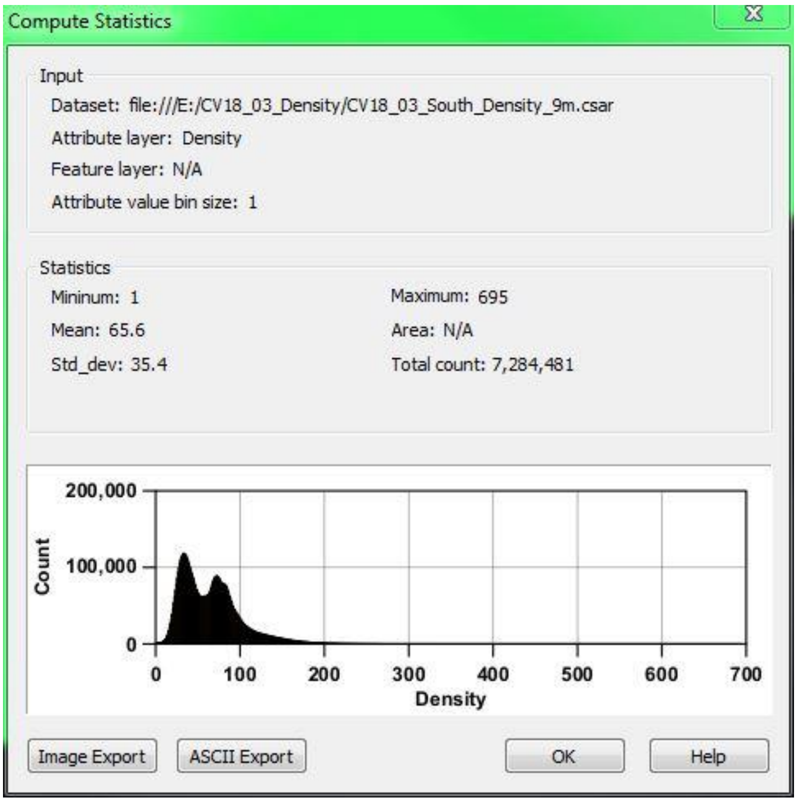


Figure 11: Sounding density statistics, south area.

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 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. Data from MVP casts for the 31st August, representative of the sound velocity regime during the survey are plotted in figure 12. Each cast is named by date and number. Sound velocity in metres per second is plotted on the x axis and depth in metres on the y axis.

Profiles show a large difference between near surface sound velocities and velocities at depth with a range of up to approximately 25 m/s. Sound velocity is fastest near the surface where water temperatures are highest. A distinct thermocline is present at between 30 m and 50 m water depths. The water body beneath the thermocline is much colder than above. Sound velocity increases linearly beneath the thermocline where pressure is the dominant variable affecting it.

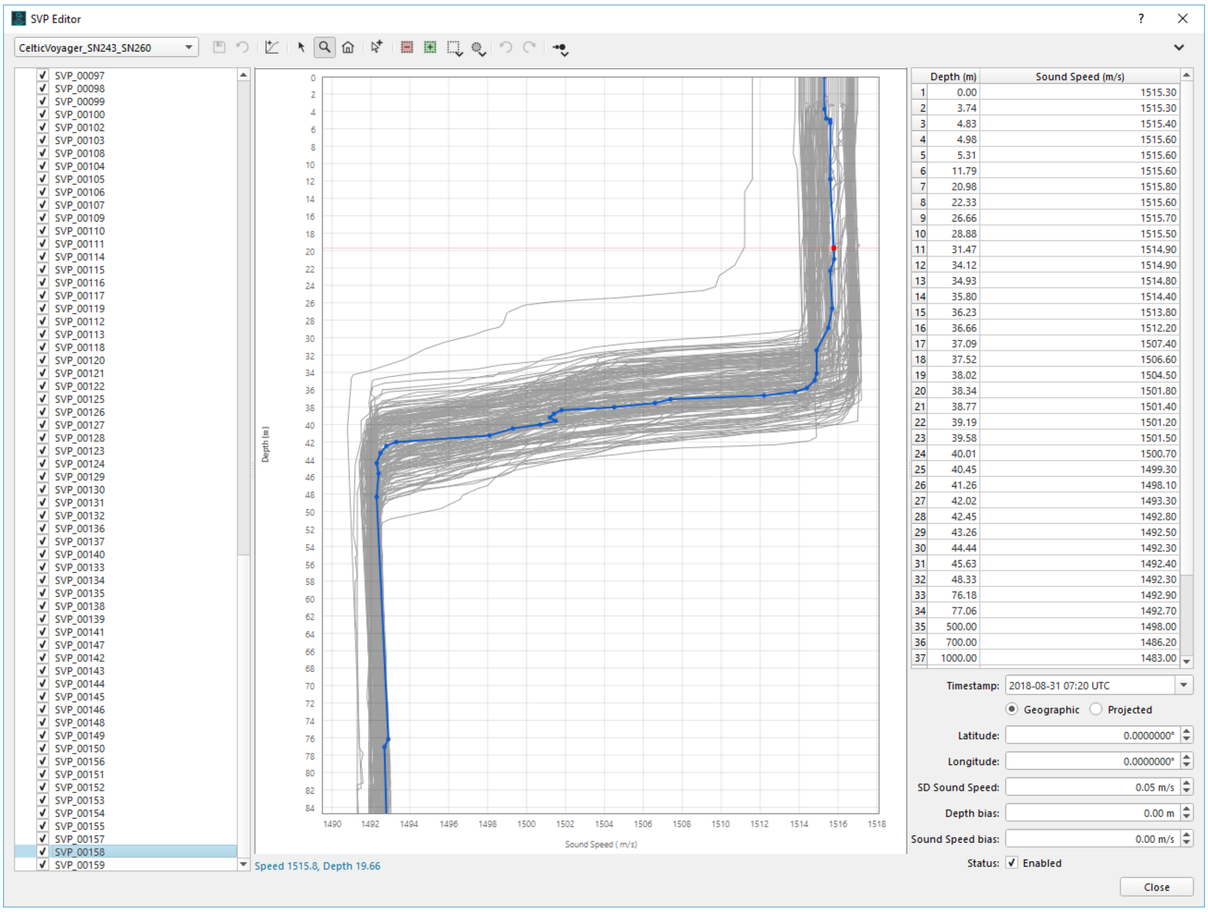


Figure 12: Composite MVP plot 31st August

The MVP failed twice during the survey, on the 3rd and 25th September respectively. Figure 13 shows the MVP software interface after one of these failures. The blue curve shows the

MVP depth and indicates that communications were lost soon after the profiler was shot. The cable was reterminated each time, once at the end of the survey. SVPs were acquired during the MVP downtime periods.

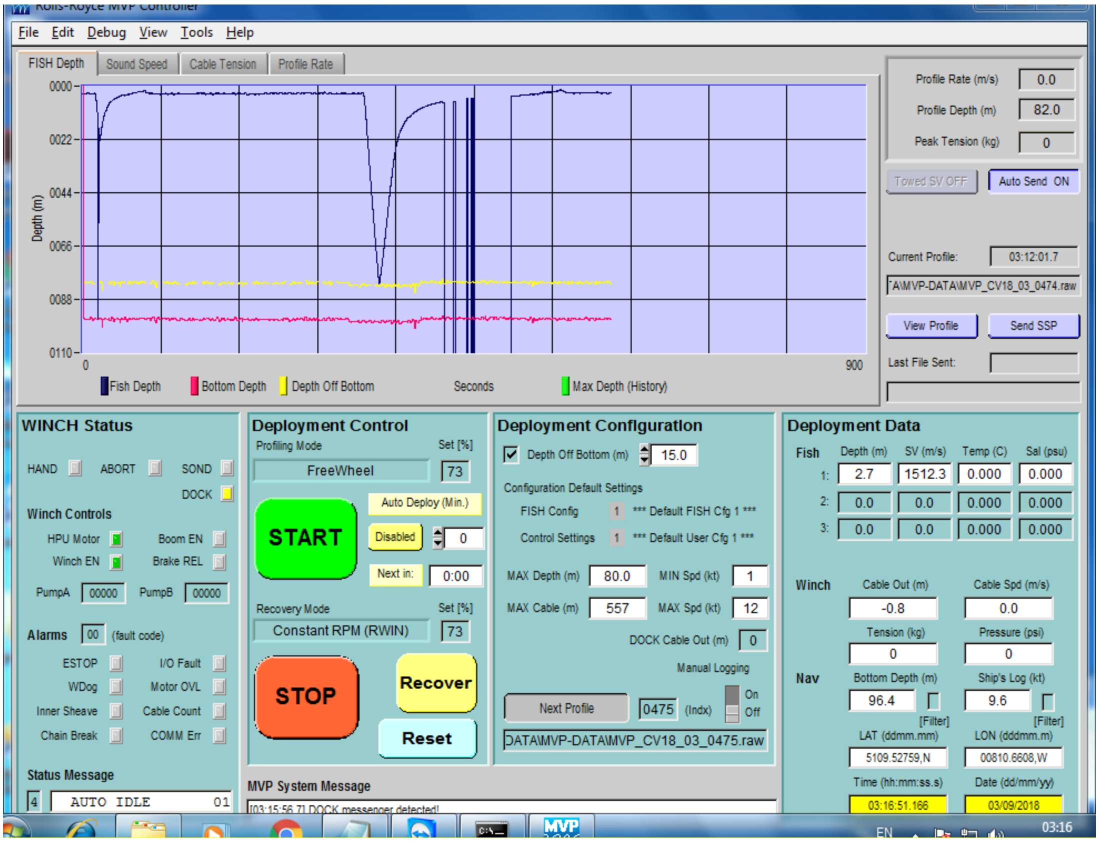


Figure 13: MVP data dropouts on acquisition software.

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 are also 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 Caris Hips software of MBES bathymetry and shaded relief. Backscatter mosaics were created in FMGT. Geotiffs and grids were imported into ArcGIS and images (figures 14 to 19) output for this report.

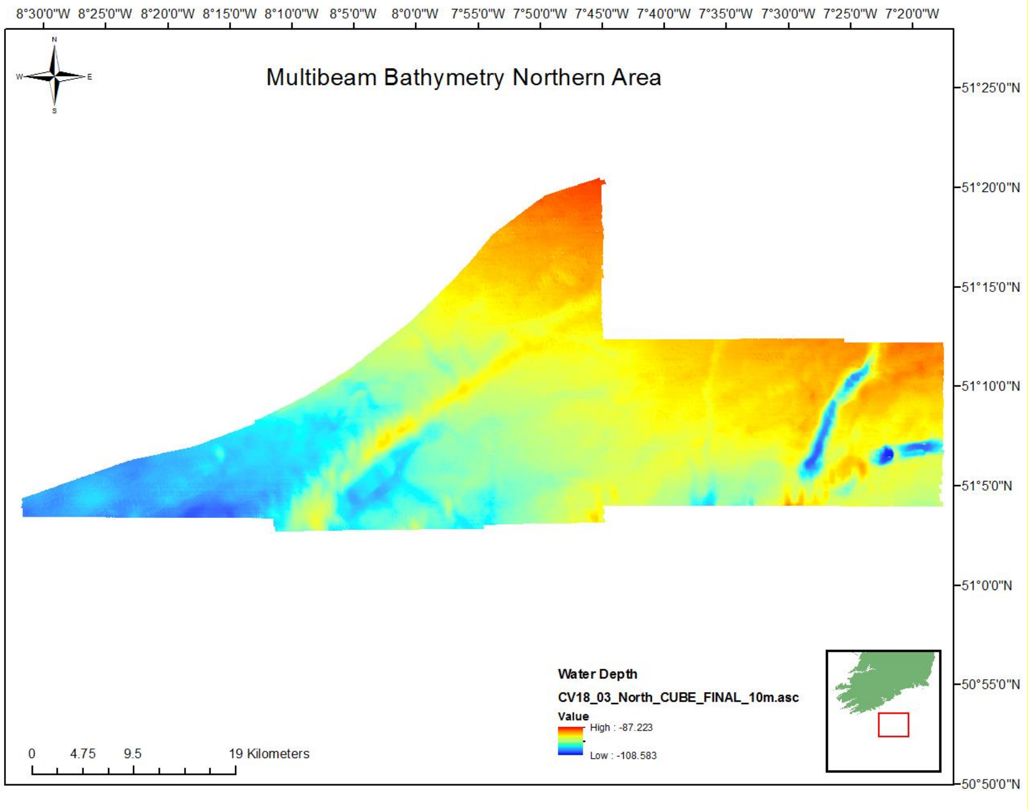


Figure 14: Multibeam bathymetry northern area image.

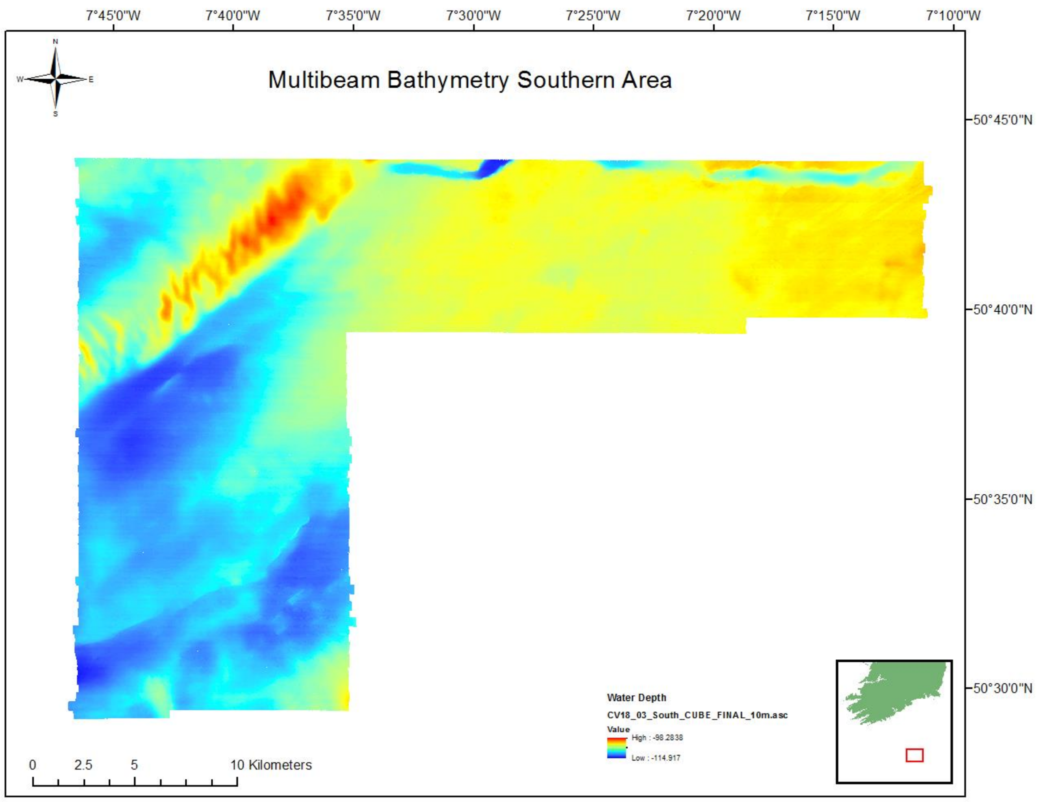


Figure 15: Multibeam bathymetry southern area image.

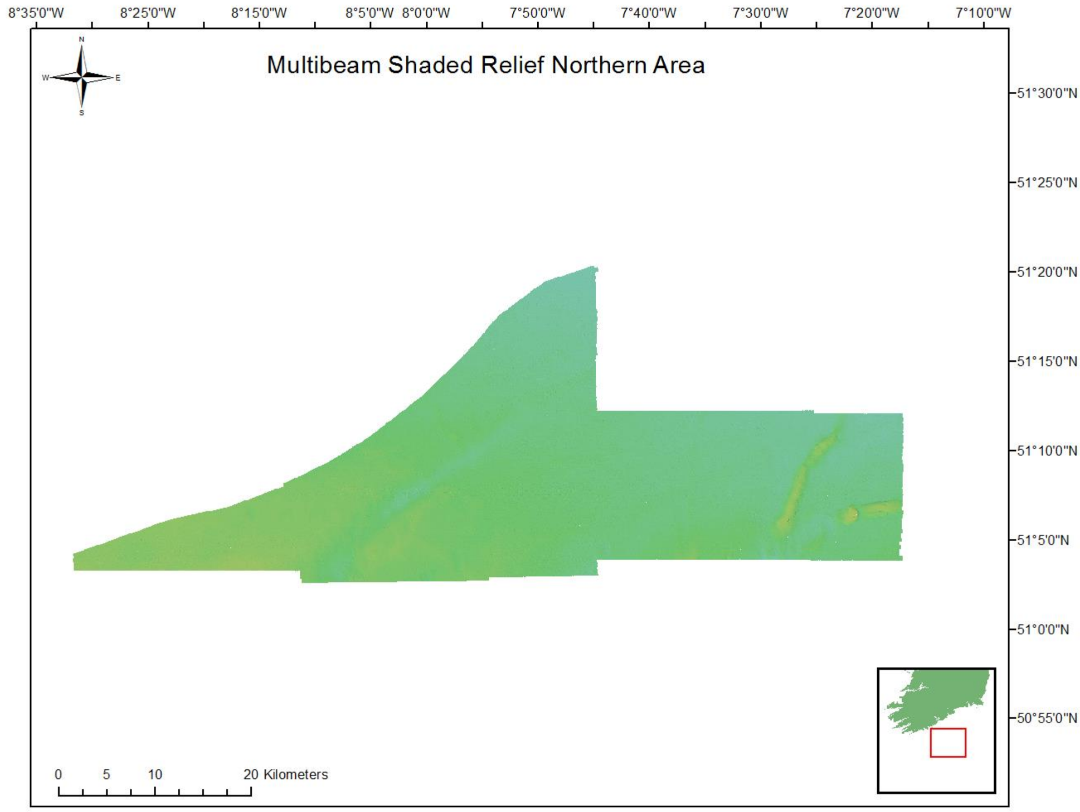


Figure 16: Multibeam shaded relief northern area.

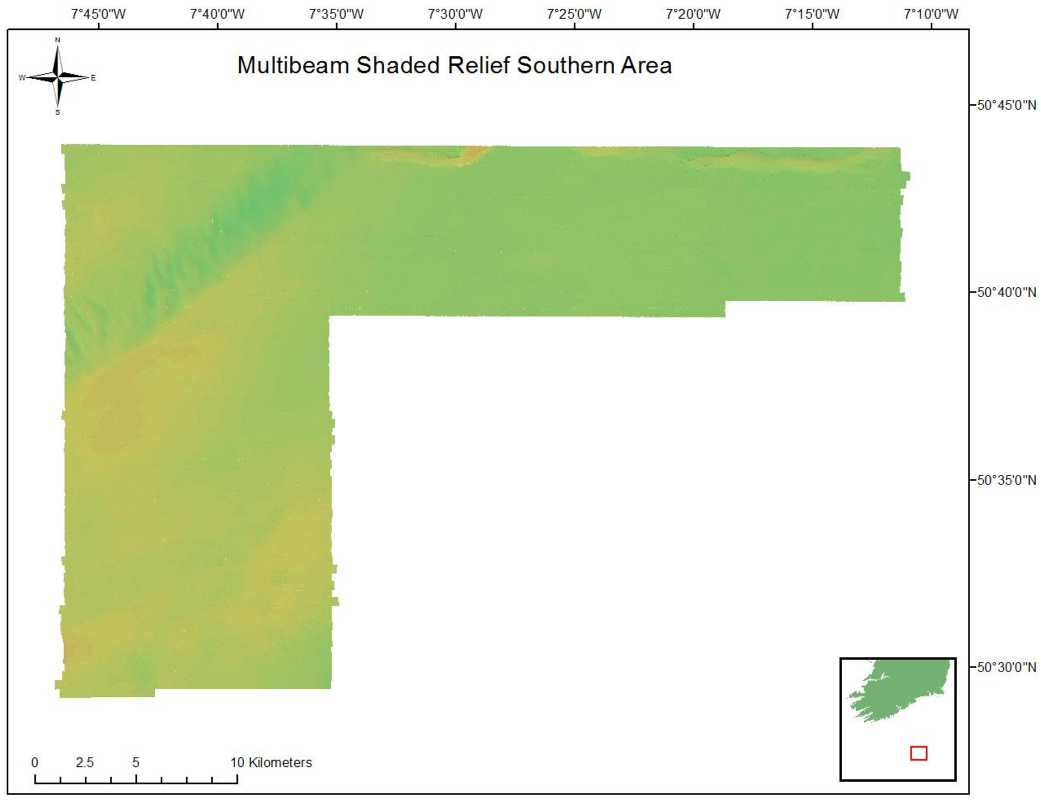


Figure 17: Multibeam shaded relief southern area.

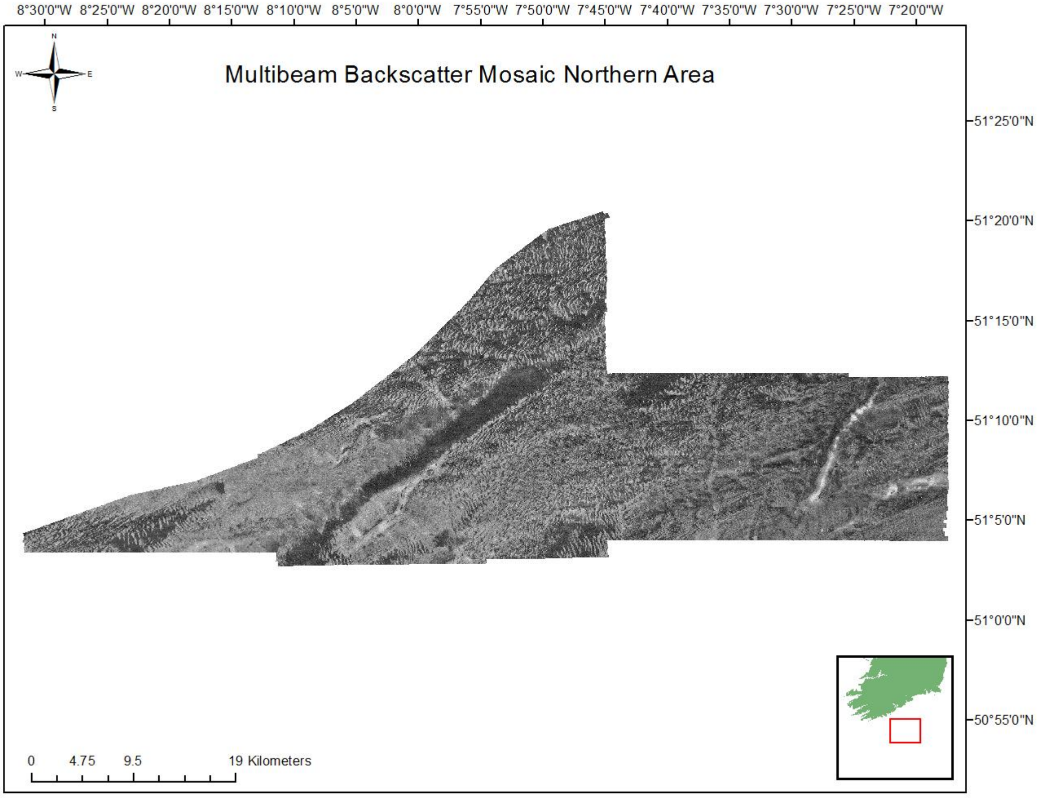


Figure 18: Multibeam backscatter mosaic northern area.

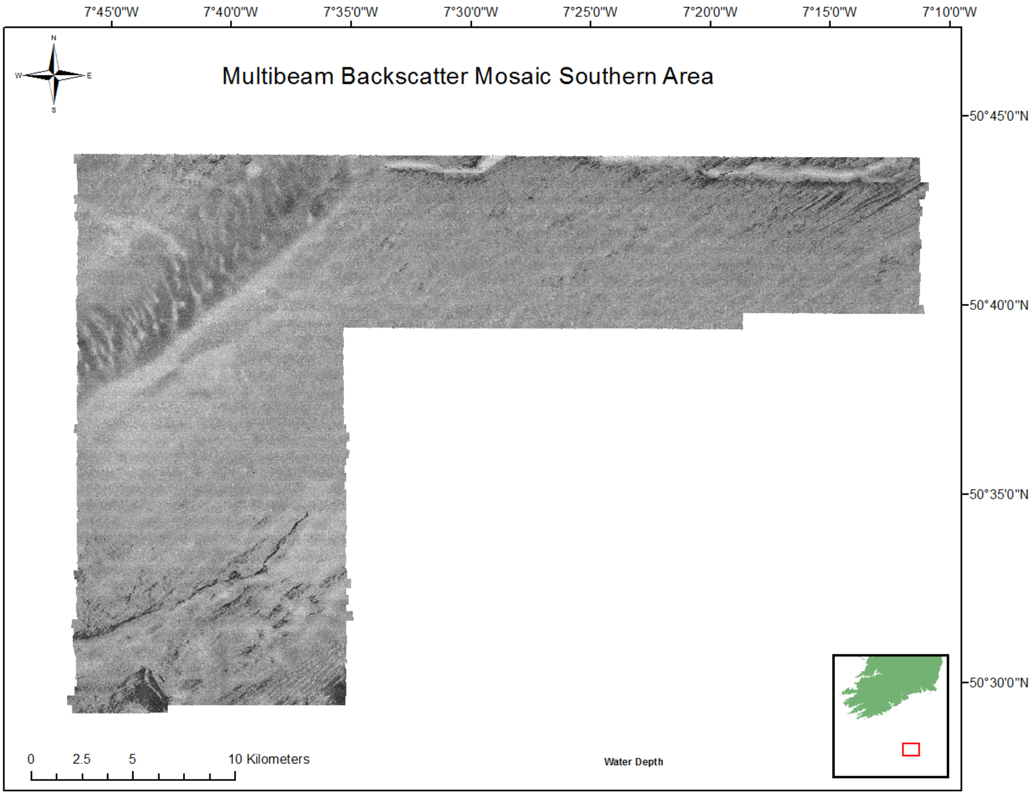


Figure 19: Multibeam backscatter mosaic southern area.

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 coda format seismic files were recorded for all SBP lines. Profile lines 087, 128 and 568 are selected for discussion here. Their geographical locations are shown in figure 20 where the profile extents have been overlain on shaded relief data. Profile 087 was acquired on a southerly heading in the southern data block. Profiles 128 and 586 were acquired on easterly headings in the southern and northern data blocks respectively.

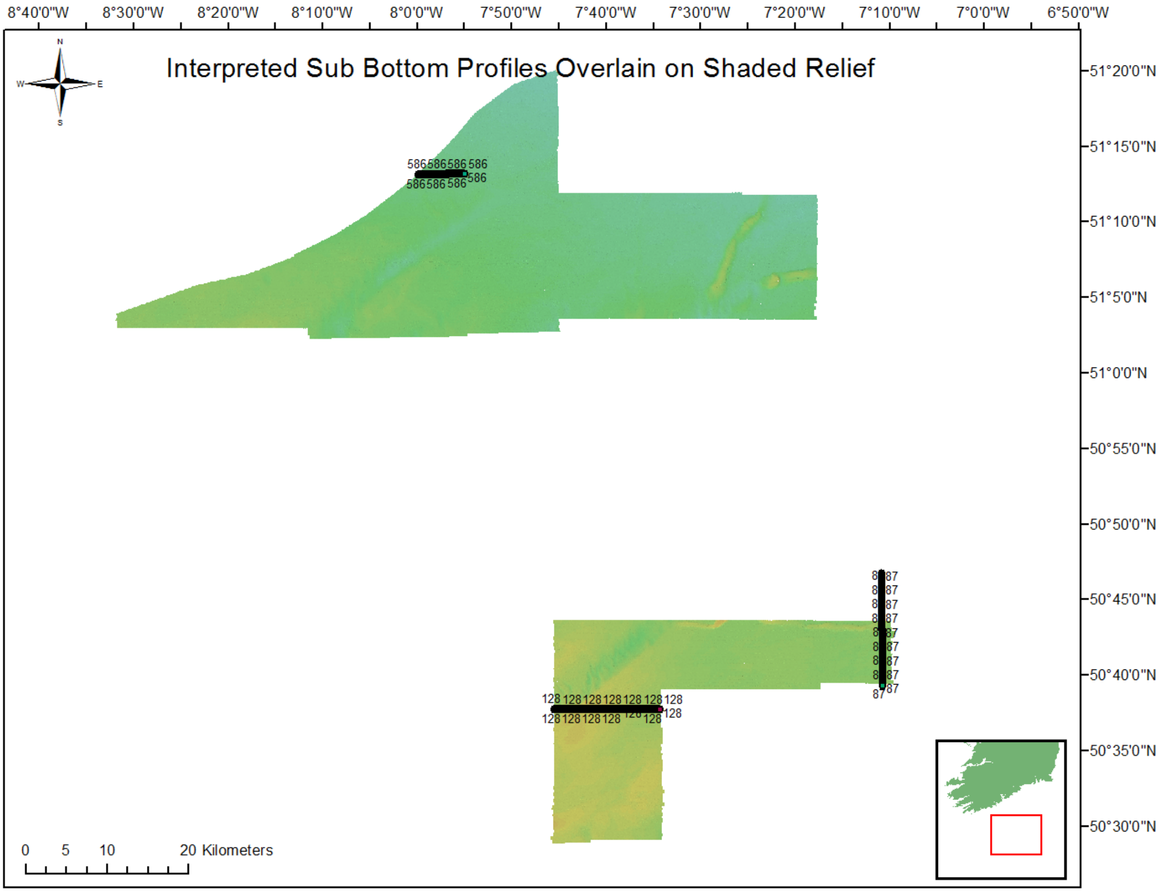


Figure 20: Sub bottom profile lines 087, 128 & 586 overlain on shaded relief data.

Interpreted sub bottom profiler tiff images of survey lines 087, 128 and 586 are shown in figures 21, 22 and 23 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 both sub bottom images below.

Profile 087 (figure 21), acquired in the eastern side of the southern block is 13.7 km in length. Part of this profile extends beyond the multibeam data for this survey as the survey line is a crossline for both this survey leg and a previous leg. Outcropping bedrock is prevalent over most of the northern section. A channel is located in the middle of the profile. It is flanked by outcropping bedrock. The channel is approximately 6 m in depth and 1.5 km in width. Minor amounts of soft sediment infill are found at the base of the channel. Further south, outcropping bedrock transitions to bedrock overlain by a thin veneer of surficial sediments. The sediments are less than 2 m in thickness.

Profile 128 in figure 22 is acquired on an easterly heading in the southern data block. The profile is 13 km in length. The base unit is bedrock. The bedrock sporadically outcrops near the middle of the profile. Elsewhere the bedrock is unconformably overlain by fine sediment. This sediment is typically 1 or 2 m in thickness but attains a maximum thickness of almost 10 m at the base of a broad channel.

Profile 586 in figure 23 is 5.7 km in length and acquired from west to east in the northern survey block. Signal penetration is poor along the entire profile due to the acoustic properties of the substrate sediments. The substrate shows small sections of high topography interspersed with sections of low topography. Topographic highs are interpreted as sand ribbons, from correlation with multibeam and groundtruthing data. Sand ribbons have maximum amplitudes of 1 m. Topographic lows are filled with coarser, mixed sediments.

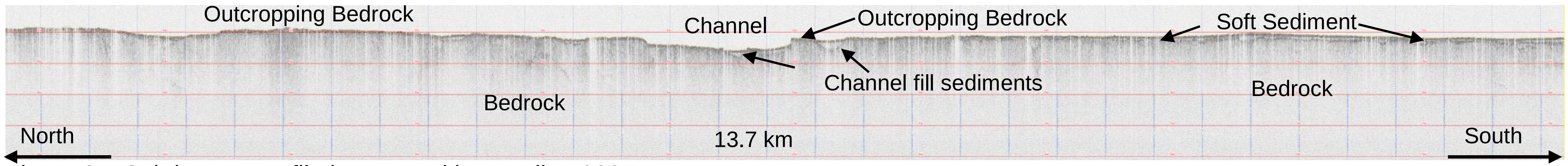


Figure 21: Sub bottom profile interpreted image, line 0087.

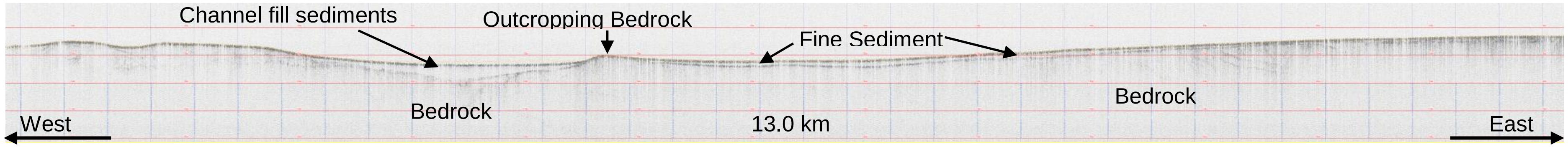


Figure 22: Sub bottom profile interpreted image, line 0128.

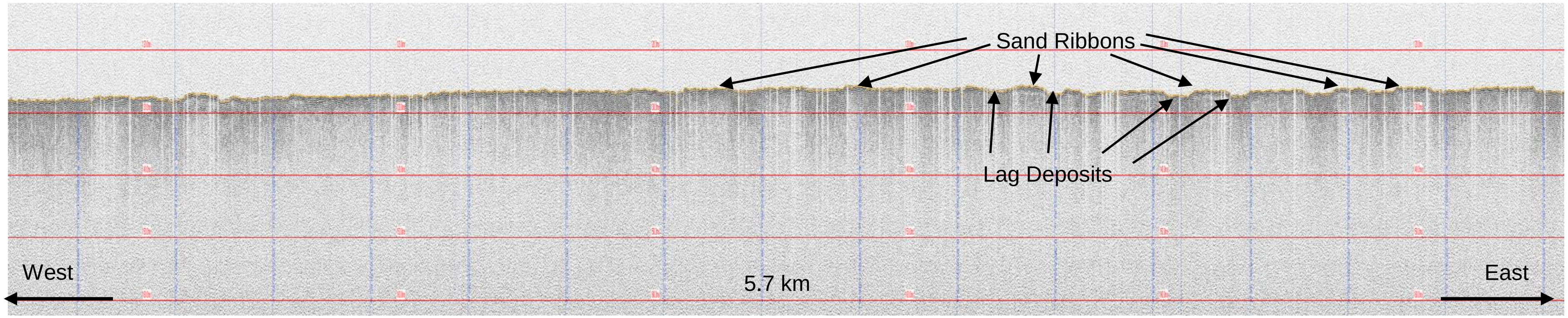


Figure 23: Sub bottom profile interpreted image, line 0586.

4.3.3 Bathymetry

Figure 24 shows the colour coded multibeam bathymetry image for the northern area. Water depth varies from 87 to 109 m. Depth generally increases from north-east to south-west with the exception of two channels in the east and a ridge feature to the west. Greatest depths are attained within the channels. The relief between channel substrates and channel margins is in the order of 15 m. The larger of the two channels is between 1.2 and 2 km in width. Extensive sand ribbons are evident on the bathymetry image.

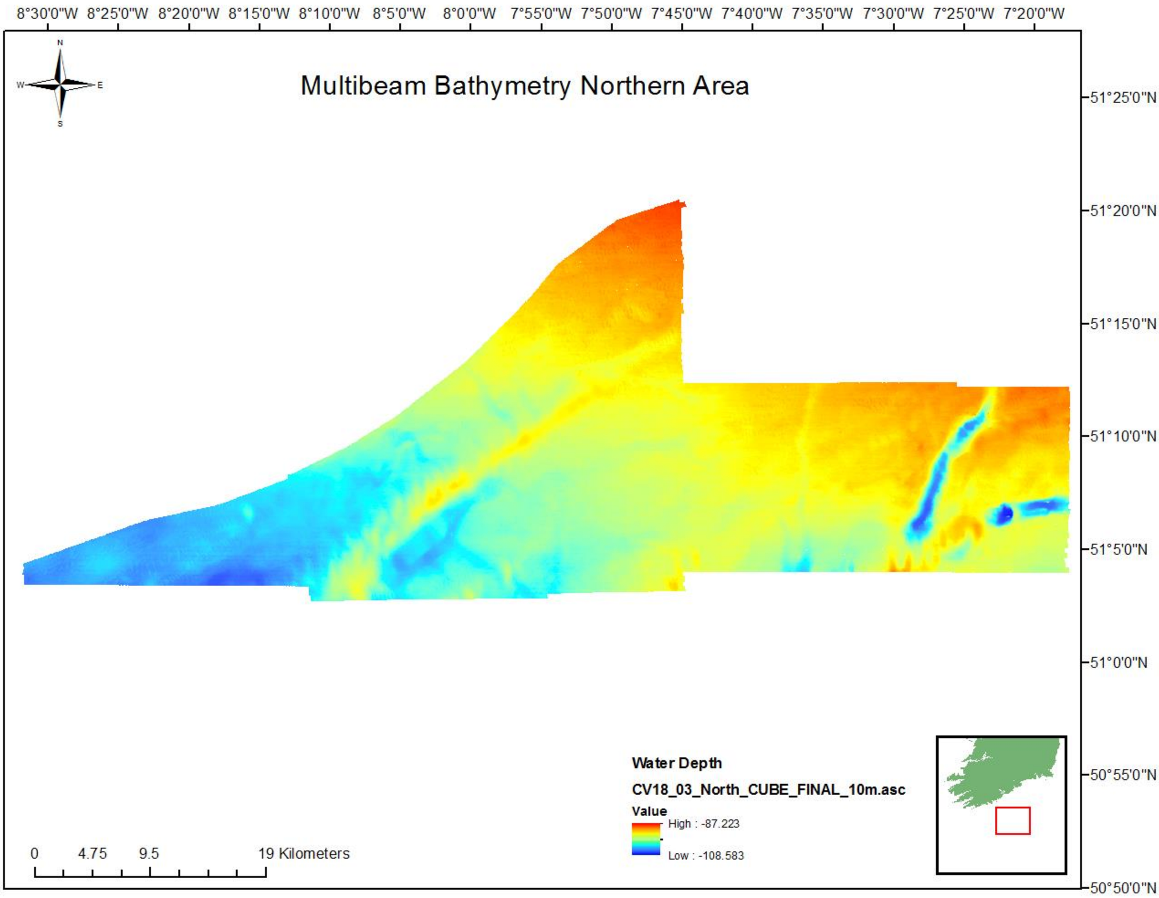


Figure 24: Multibeam bathymetry image northern area.

Figure 25 shows the annotated bathymetry image for the southern area. The main features are a ridge, channels and an escarpment. Water depth ranges from 98 to 115. Depth generally increases from north - east to south – west. The ridge feature is orientated along a north – east to south – west axis. It is approximately 10 metres amplitude and up to 3 km in width. The top of the ridge is marked by a number of transverse lobes.

Two channels are observed in the north of the area. The deepest one is up to 10 metres beneath the surrounding seabed and the greatest depth sounding in this survey block is located within it.

An escarpment is located in the southern part of the area. It trends along a north – east to south – west axis. The southern block of this escarpment is the deeper one. The vertical displacement between both sides of the feature varies from 1 to 2 metres.

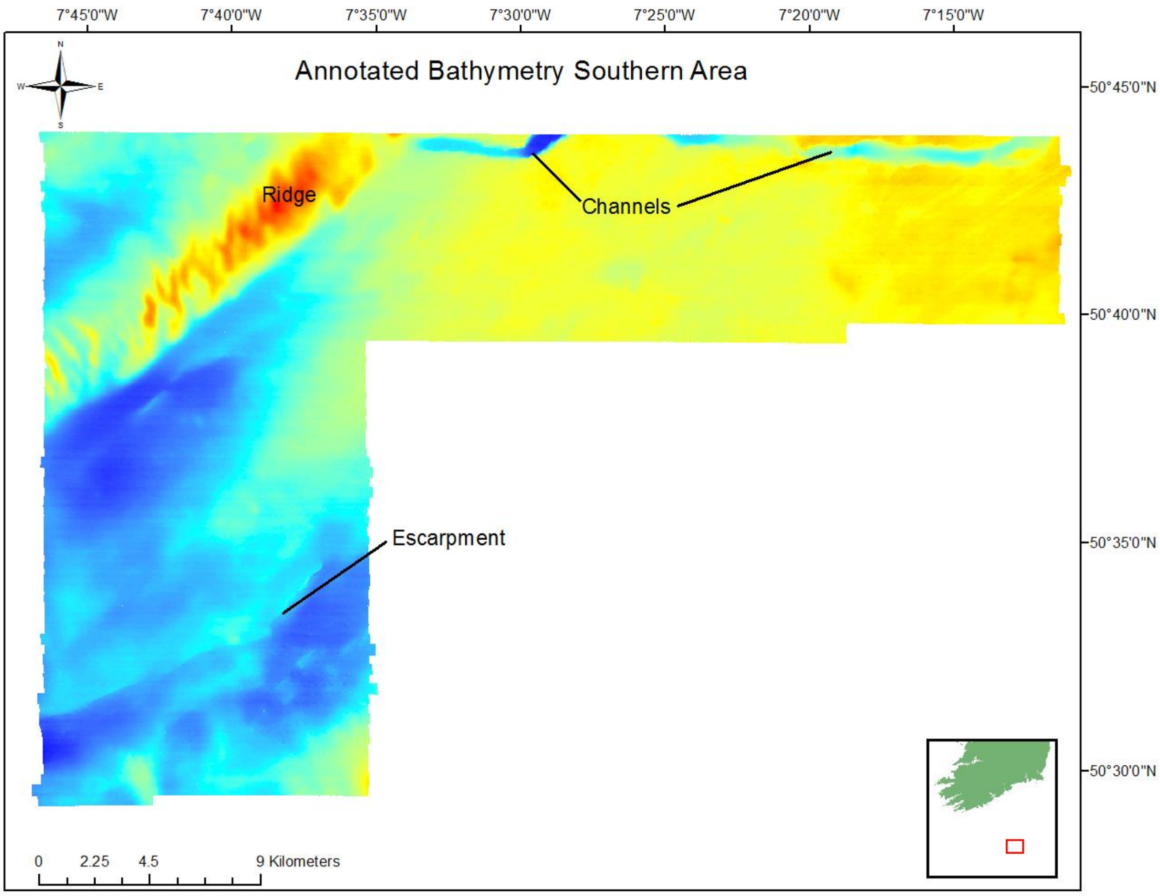


Figure 25: Annotated multibeam bathymetry image southern area.

A statistical analysis of substrate slopes was performed for both areas. ArcGIS tools were used to calculate the slopes. Figures 26 and 27 show the substrate slope angle plots for the northern and southern areas respectively. Very low angle substrate slopes are the dominant characteristics of both areas. The northern area has moderately sloping substrate adjacent to parts of the channels margins. Maximum slope angle is 16 degrees. The southern area shows evidence of data artefacts in the calculated slope angles. The artefact is survey line parallel and is at its greatest magnitude midway between survey lines. It is probably due to sound velocity issues on the outer beams. Maximum slope angles of over 12 degrees are found in the southern area. Highest slope angles correlate with channel margins, ridge and lobe features and the escarpment in the south.

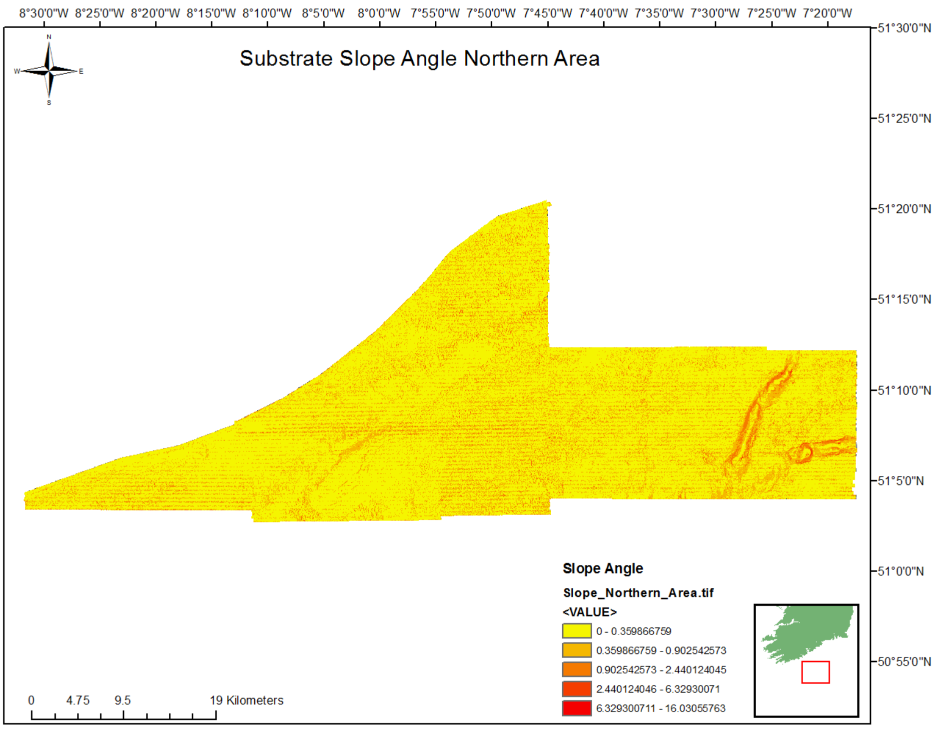


Figure 26: Substrate slope analysis northern area.

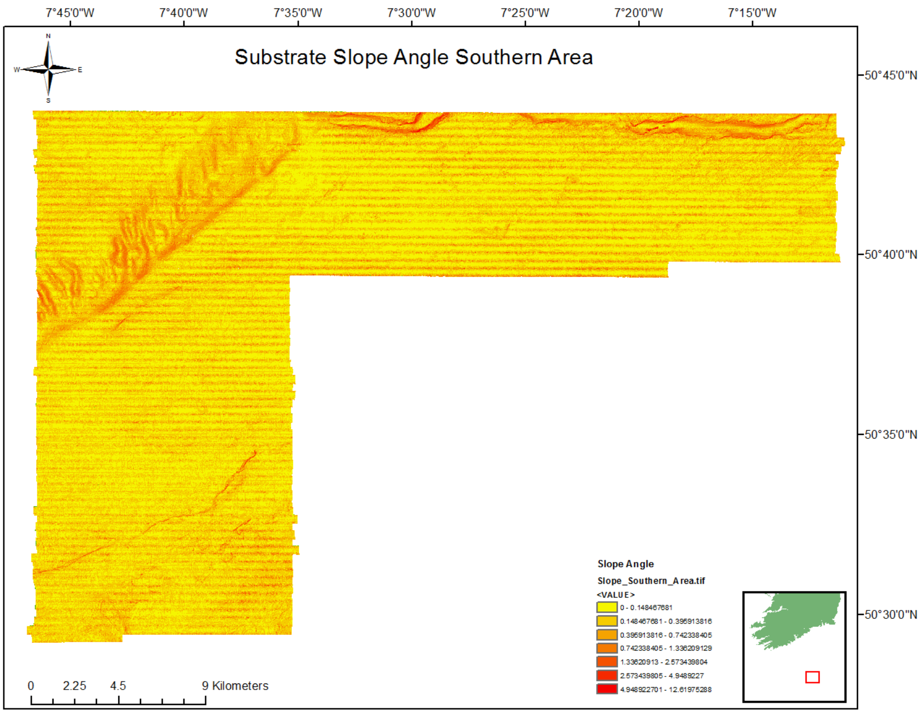


Figure 27: Substrate slope analysis southern area.

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, smooth surface.

Figure 28 shows the substrate interpreted backscatter mosaic for the northern area. The convention used in this image is that dark coloured areas represent relatively higher backscatter intensity than light coloured areas. The substrate exhibits a wide diversity of backscatter responses. Areas of high backscatter and very low backscatter are annotated on the image below. The high backscatter correlates with a ridge feature and the very low backscatter type correlates with a channel. Relatively low backscatter returns correlate with sandy sediments and muddy sands. Small patches of relatively low backscatter are interpreted as sand ribbons.

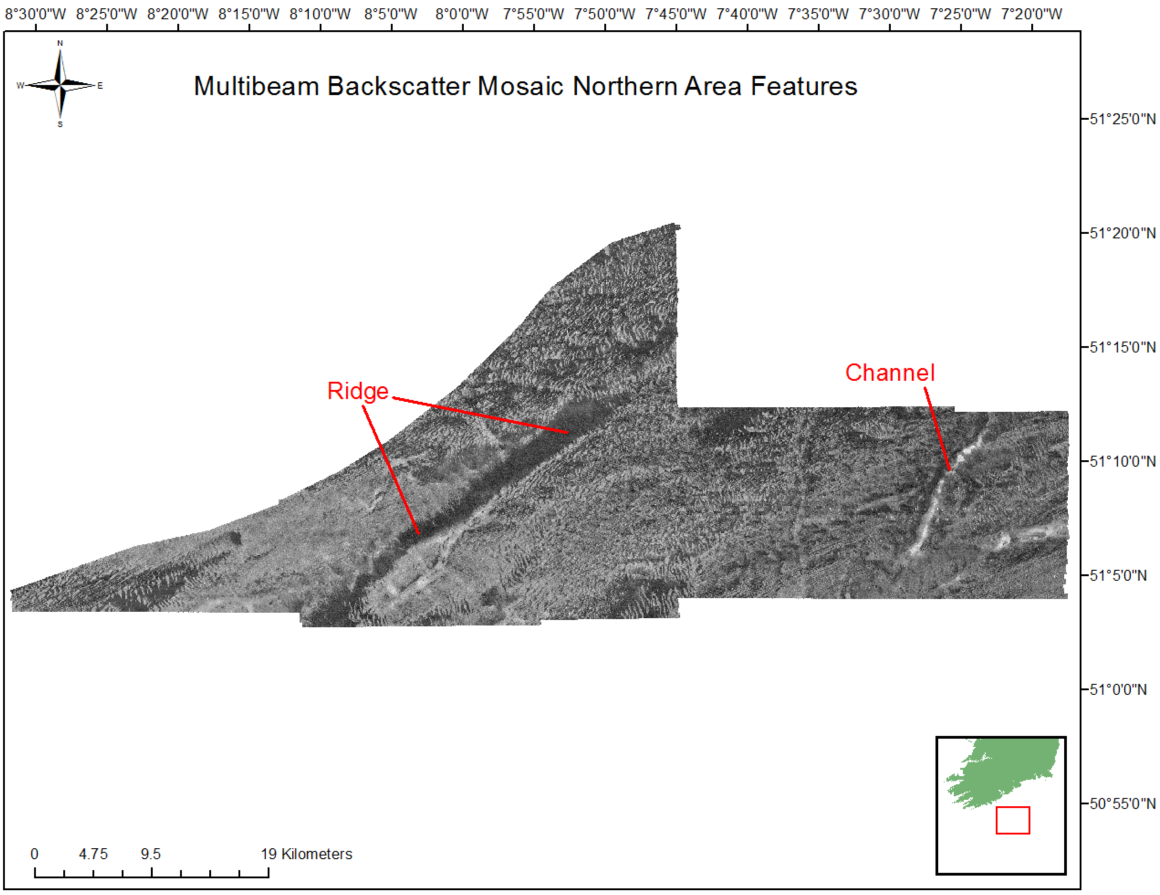


Figure 28: Interpreted multibeam backscatter, northern area.

Figure 29 shows the substrate interpreted backscatter mosaic for the southern area. Channel and ridge features are prominent, and they are characterised by relatively low and high backscatter returns respectively. The ridge is straddled by a series of sub-parallel lobes, transverse to the main ridge axis. These lobes have a lower backscatter than other parts of the ridge crest. A homogeneous area of low backscatter is evident running parallel to the ridge and to its south. A narrow band of very low backscatter returns in the north of the image denotes an east / west orientated channel. A northeast – southwest orientated fabric is prevalent in the backscatter data, where narrow bands of relatively high intensity backscatter and interspersed with areas of relatively lower intensity backscatter. The escarpment previously mentioned in the bathymetry section is also evident in the backscatter. It shows up as very narrow band of relatively high intensity backscatter which is discontinuous in several places.

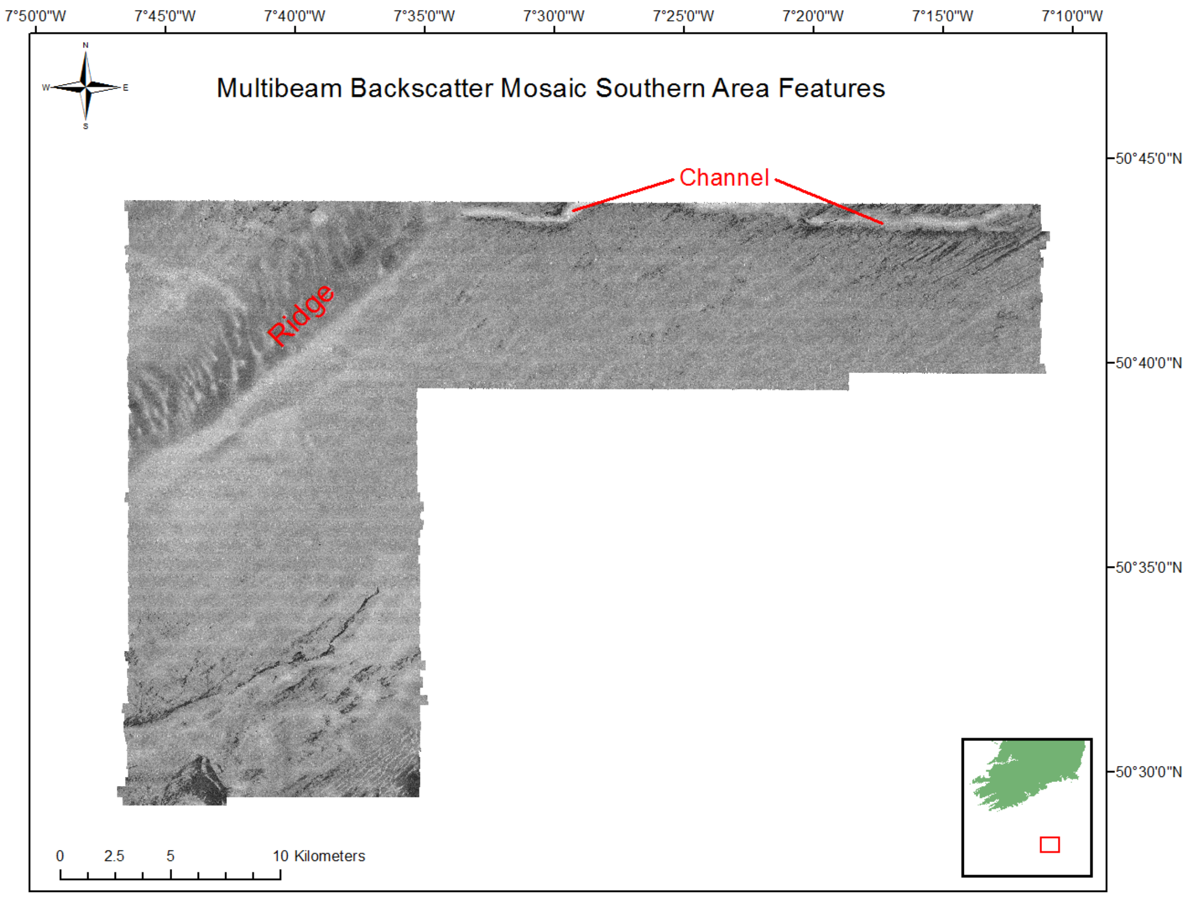


Figure 29: Multibeam backscatter mosaic with substrate interpretation, southern area.

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.

Figure 30 shows a multibeam shaded relief image for part of the northern survey area. The image is focussed on the southeast of this area. Two channels are evident on the image. One is orientated approximately east – west and the other northeast – southwest. The east west orientated channel is approximately 1. 6 km in width and is 108 m at its deepest. Channel slopes of up to 9 degrees are evident. The northeast – southwest orientated channel is 1.2 to 2 km in width. The channel substrate varies from 100 to 106 m in depth and the channel floor is up to 15 m beneath surrounding substrate. Outcropping bedrock is found along parts of the channel margins.

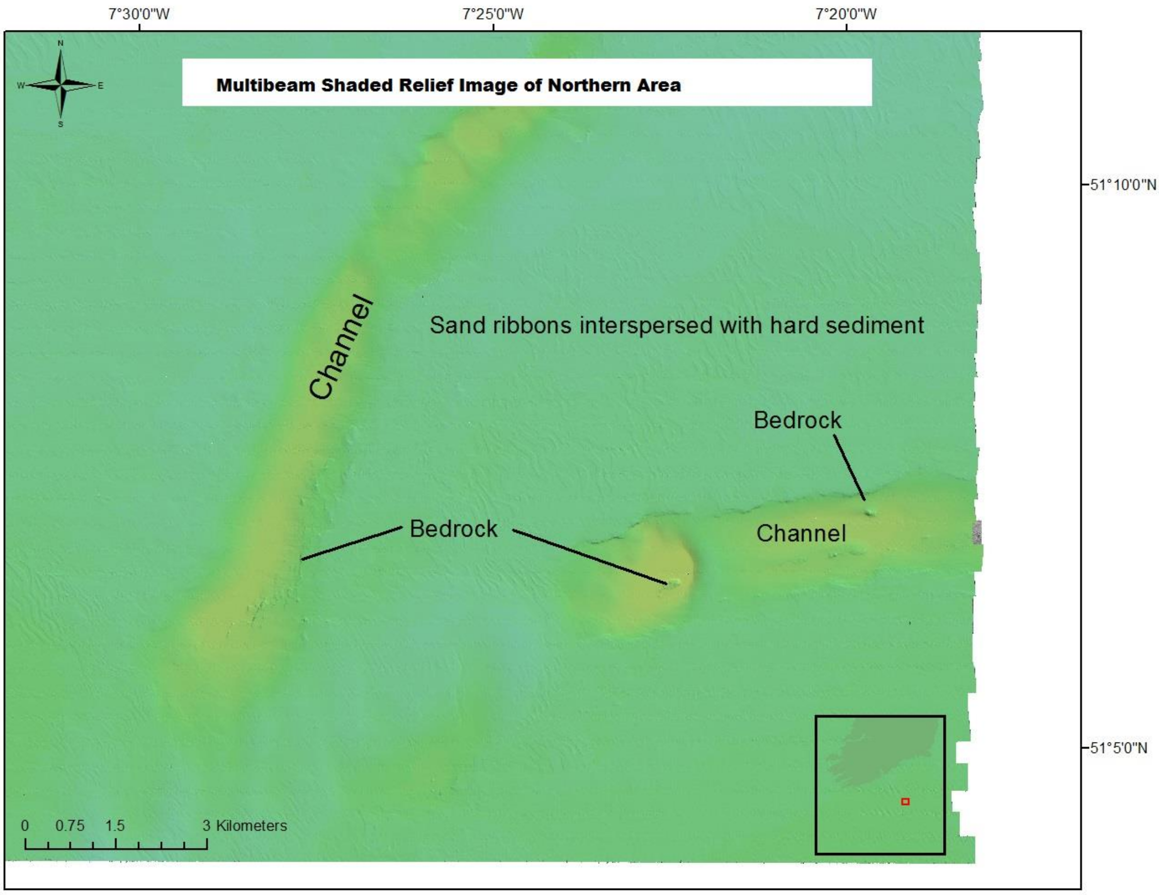


Figure 30: Multibeam shaded relief showing channels in northern area.

4.4 Groundtruthing

Groundtruthing stations were acquired using a combination of Day grab and Shipek grab. The Day Grab was deployed from the aft deck and gave consistently good returns. The Shipek grab was deployed from the starboard side. Grab locations were selected based on the multibeam backscatter data and geographical spread when possible. Opportunistic samples were acquired at SVP stations occasionally. A total of 59 grabs were acquired. Samples were photographed, described and data entered into a bespoke database. Samples were bagged and sent to a laboratory for particle size analysis, the results of which will be used to create substrate maps. Groundtruthing stations are plotted overlain on the backscatter mosaic in figure 31. Stations 32 to 90 inclusive were acquired during this survey.

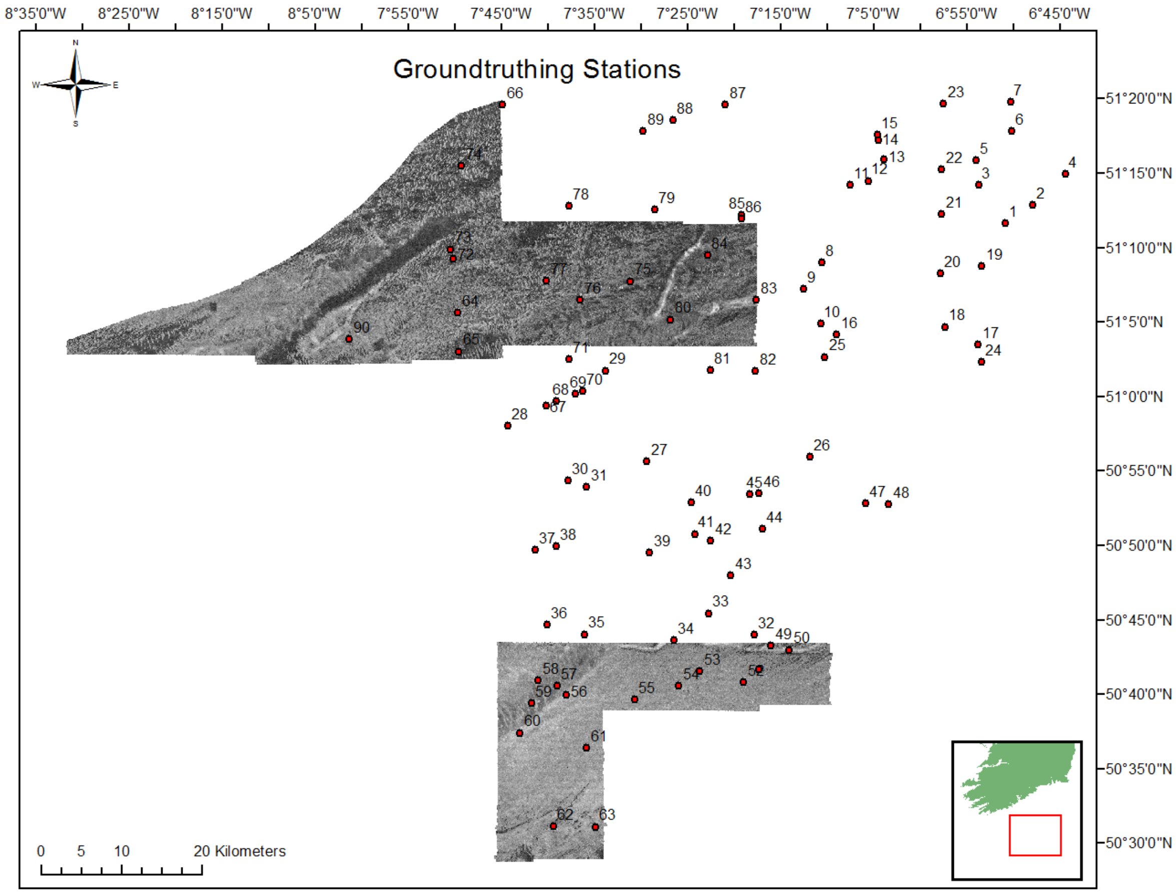


Figure 31: Groundtruthing stations plotted on backscatter mosaic.

Table 17 contains grab station metadata and sediment description assigned during acquisition. The station numbering starts at 032 as each year stations 001 to 031 were acquired on previous survey during 2018.

Station	Lat	Long	Sediment

032	50.74371° N	-7.32273° W	Fine Sand
033	50.768632° N	-7.402528° W	Muddy Sand
034	50.739663° N	-7.464889° W	Sandy Mud
035	50.747883° N	-7.622353° W	Silty Mud
036	50.759207° N	-7.68761° W	Silty Mud
037	50.843026° N	-7.706904° W	Silty Mud
038	50.847204° N	-7.66915° W	Muddy Sand
039	50.83816° N	-7.504004° W	Medium Sand
040	50.893124° N	-7.42904° W	Muddy Sand
041	50.857734° N	-7.42373° W	Gravelly Muddy Sand
042	50.850077° N	-7.395291° W	Muddy Sand
043	50.810236° N	-7.361694° W	Muddy Sand
044	50.861606° N	-7.304225° W	Sand
045	50.900591° N	-7.324526° W	Gravelly Sand
046	50.901886° N	-7.30837° W	Shelly Muddy Gravelly Sand
047	50.887794° N	-7.120304° W	Muddy Sand
048	50.885804° N	-7.07936° W	Muddy Sand
049	50.730311° N	-7.293697° W	Sand
050	50.725571° N	-7.261454° W	Sandy Mud
051	50.70464° N	-7.315429° W	Muddy Sand
052	50.690828° N	-7.343421° W	Muddy Sand
053	50.703712° N	-7.41968° W	Muddy Sand
054	50.687634° N	-7.457639° W	Muddy Sand
055	50.674148° N	-7.536075° W	Sandy Mud
056	50.680714° N	-7.655554° W	Sandy Mud
057	50.69031° N	-7.672037° W	Muddy Sand
058	50.697578° N	-7.705° W	Sandy Mud
059	50.671499° N	-7.717833° W	Sand
060	50.638805° N	-7.738929° W	Sandy Mud
061	50.62103° N	-7.621895° W	Sandy Mud
062	50.533047° N	-7.683393° W	Sandy Mud
063	50.531993° N	-7.609012° W	Sandy Mud
064	51.11049° N	-7.836508° W	Muddy Gravelly Sand
065	50.066994° N	-7.835859° W	Gravelly Sand
066	51.34287° N	-7.75016° W	Muddy Gravelly Sand
067	51.005103° N	-7.68269° W	Mud
068	51.009117° N	-7.664939° W	NA
069	51.017225° N	-7.629803° W	Muddy Sandy Gravel
070	51.020326° N	-7.617118° W	Muddy Sand
071	51.056357° N	-7.640993° W	Muddy Sand
072	51.170682° N	-7.843057° W	Sandy Gravel
073	51.181615° N	-7.847741° W	Muddy Sand
074	51.275047° N	-7.825402° W	Muddy Sandy Gravel
075	51.142283° N	-7.528689° W	Muddy Sandy Gravel
076	51.122107° N	-7.618695° W	Muddy Sand
077	51.144263° N	-7.678119° W	Muddy Sand
078	51.227603° N	-7.635705° W	Muddy Sandy Gravel
079	51.222242° N	-7.482541° W	Sandy Gravel
080	51.098408° N	-7.458706° W	Sand
081	51.04057° N	-7.389805° W	Sand

082	51.038371° N	-7.309666° W	Muddy sand
083	51.118287° N	-7.305073° W	Muddy Sand
084	51.169229° N	-7.390626° W	Sand
085	51.213362° N	-7.328608° W	Muddy Sand
086	51.209813° N	-7.328432° W	Muddy Sandy Gravel
087	51.338012° N	-7.352552° W	Gravelly Muddy Sand
088	51.321627° N	-7.446466° W	Sandy Gravel
089	51.30984° N	-7.499948° W	Gravelly Sand
090	51.082446° N	-8.030207° W	Sand 6439843

Table 17: Groundtruthing metadata.

4.5 Wrecks

A total of 8 wrecks were identified from multibeam and magnetometer data and a detailed wreck survey was completed. Watercolumn data was logged on each wreck survey line. Survey speed was reduced to 3 or 4 knots for wreck investigations. Table 18 lists the associated metadata. Hydrographic wreck reports (H525) were created and sent to the UKHO.

Number	Wreck No	Latitude	Longitude
1	15969	50º 44.6009 N	-007º 22.0800 W
2	NA	51º 08.2434 N	-007º 51.7961 W
3	11470	51º 08.1232 N	-007º 52.6207 W
4	11465	51º 10.7283 N	-007º 58.8976 W
5	NA	51º 04.7646 N	-007º 40.0380 W
6	NA	51º 05.0640 N	-007º 37.0738 W
7	NA	51º 05.8268 N	-008º 10.9663 W
8	NA	51º 04.4256 N	-008º 03.8364 W

Table 18: Wreck investigation metadata.

Mapped wrecks are plotted in figure 32 below.

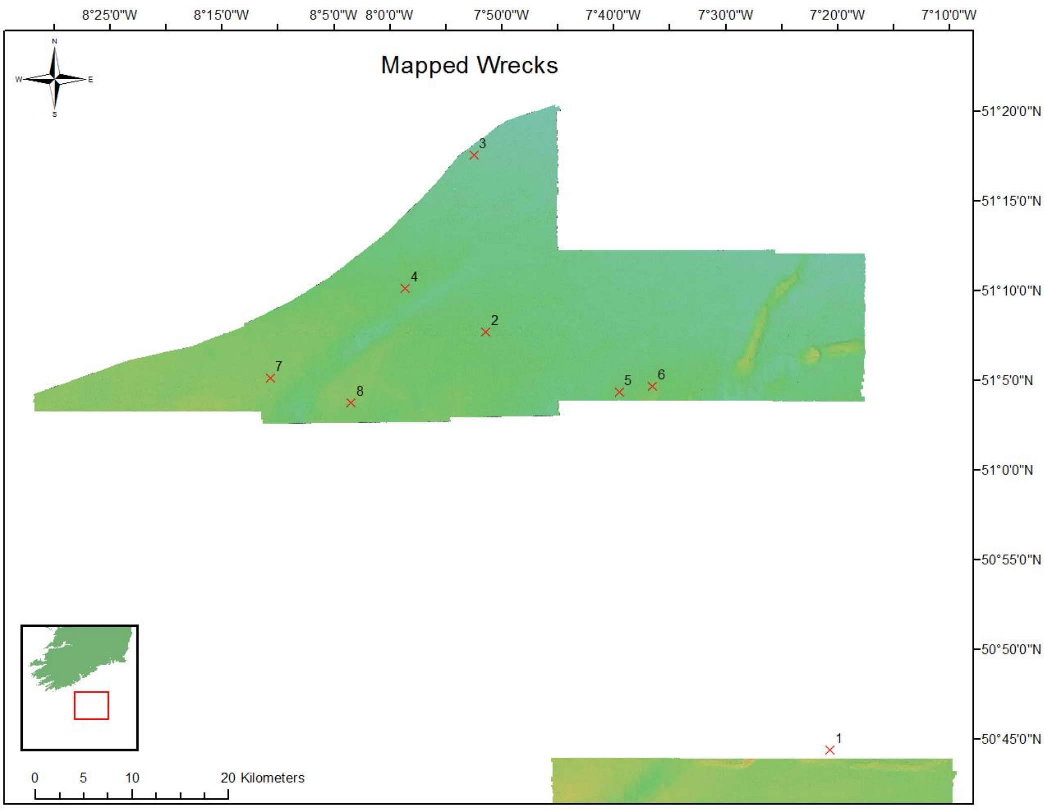


Figure 32: Mapped wrecks plotted overlain on multibeam data.

Figure 33 shows mapped wreck number 1. Imagery of all mapped wrecks are included in their respective wreck reports.

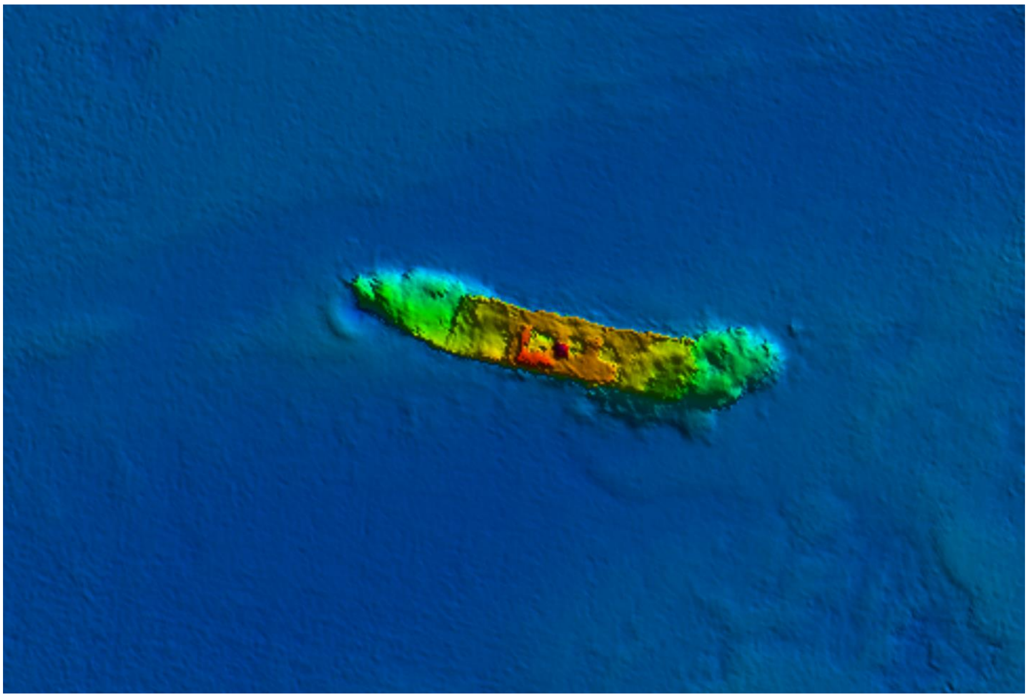


Figure 33: Mapped wreck, number 1.