



## CV20\_01 INFOMAR Survey Report Area: Celtic Sea & Atlantic Ocean

For:

Marine Institute & Geological Survey Ireland

*RV Celtic Voyager*

June 2020

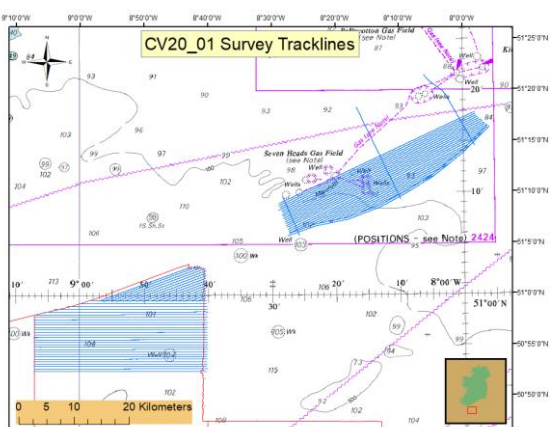
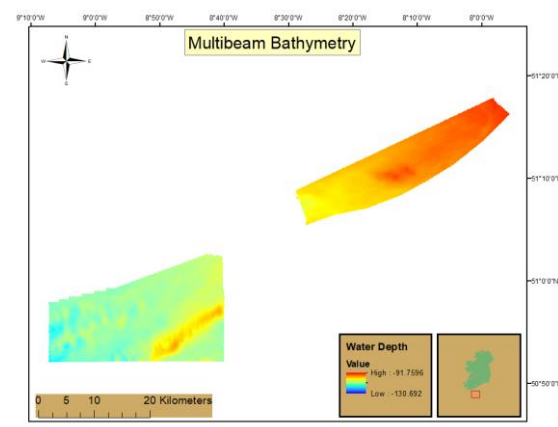
Prepared by Kevin Sheehan & INFOMAR Survey Team

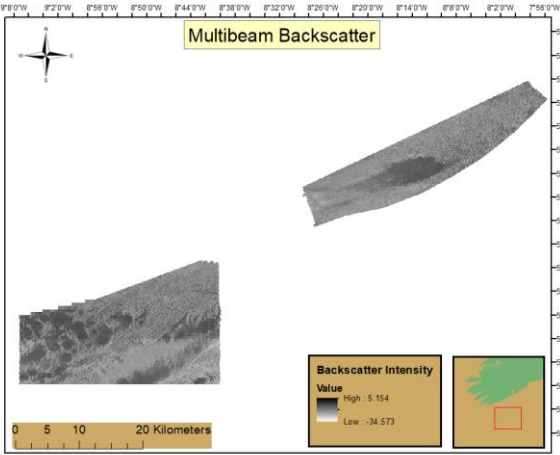
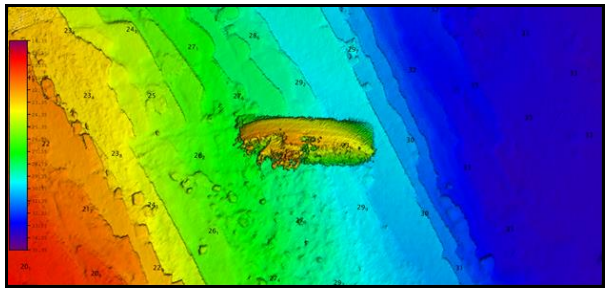
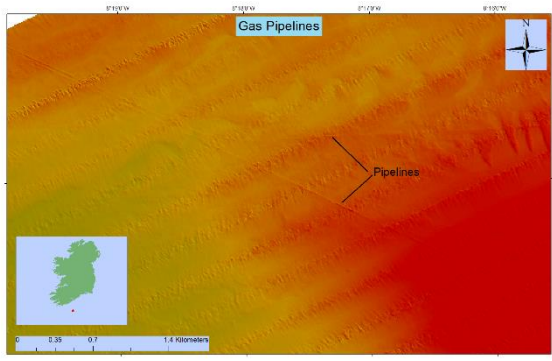
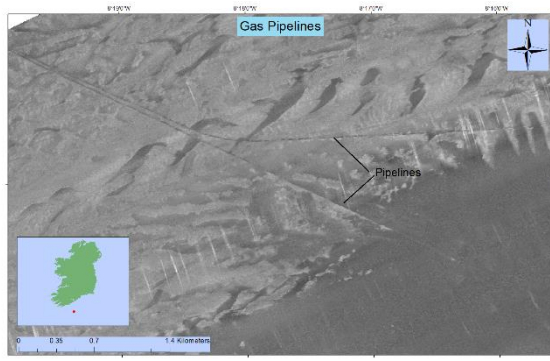
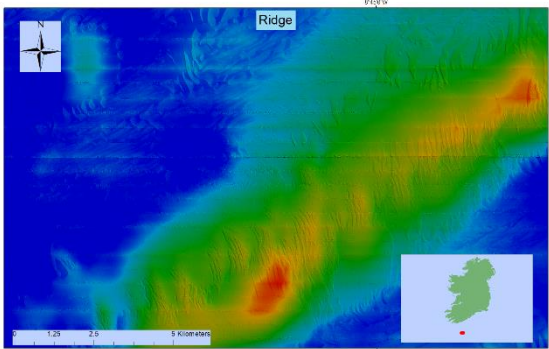
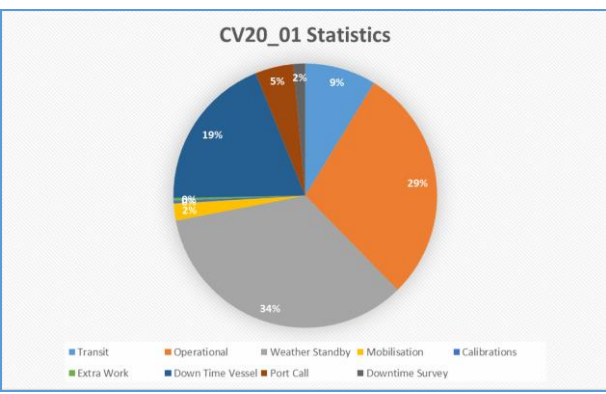


Marine Institute Reference No:	Survey Report: CV20_01
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		Signature	Date
Compiled by	Kevin Sheehan	<i>Kevin Sheehan</i>	08/04/2021
Checked	Oisín McManus	<i>Oisín McManus</i>	19/04/2021
Project Managers: Marine Institute & Geological Survey Ireland			

Issue	Date	Description	Author	Approved
1	08/04/2021	Draft	Kevin Sheehan	
2	19/04/2021	Final	Kevin Sheehan	Oisín McManus

<b>Executive Summary</b>			
<b>Survey Summary</b>			
<b>Survey Vessel:</b>	RV <i>Celtic Voyager</i>	<b>Survey Leg:</b>	CV20_01
<b>Mobilisation:</b>	Galway	<b>Demobilisation:</b>	Galway
<b>Survey Areas:</b>	Celtic Sea	<b>Start Date:</b> <b>End Date:</b>	01/06/2020 23/06/2020
<b>Northeast Boundary</b>	51° 17.885N -7° 58.479W	<b>Southwest Boundary</b>	50° 52.420N -9° 07.190W
<b>UKHO Admiralty</b>	0002 (1:1,500,000), 1123 (1:500,000) & 2649 (1:500,000)		
<b>Key References</b>	CV20_01 Survey Leg Report & CV20_01 Executive Report		
<b>Equipment Used</b>	Kongsberg EM2040 MBES, Knudsen 3260 Chirp sub-bottom profiler, SeaSpy magnetometer, AML MVP200, Valeport SVP Mini, C-Nav 3050 GNSS.		
<b>Survey Statistics</b>			
<b>Minimum Water Depth (VORF LAT):</b>	91.8 m	<b>Maximum Water Depth (VORF LAT):</b>	130.7 m
<b>Area Covered:</b>	734 km <sup>2</sup>	<b>Survey Line Kilometres:</b>	2005 km
<b>Approximate Operational:</b>	29%	<b>Approximate Downtime :</b>	53%
<b>Groundtruthing Stations:</b>	0	<b>Wrecks</b>	2
<b>H525 forms issues (wrecks)</b>	2	<b>H102 forms issued (shoals)</b>	0
<b>Survey Track Lines</b>		<b>MBES Bathymetry Overview</b>	
			

<b>Survey Images</b>																					
<p><b>MBES Backscatter</b></p>	<p><b>MBES Bathymetry Wreck 1</b></p>																				
 <p>Multibeam Backscatter</p>																					
<p><b>Gas Pipelines Bathymetry Image</b></p>	<p><b>Gas Pipelines Backscatter Image</b></p>																				
 <p>Gas Pipelines</p>	 <p>Gas Pipelines</p>																				
<p><b>MBES Bathymetry of Ridge</b></p>	<p><b>Survey Statistics</b></p>																				
 <p>Ridge</p>	 <p>CV20_01 Statistics</p> <table border="1"> <thead> <tr> <th>Category</th> <th>Percentage</th> </tr> </thead> <tbody> <tr> <td>Transit</td> <td>19%</td> </tr> <tr> <td>Operational</td> <td>29%</td> </tr> <tr> <td>Weather Standby</td> <td>34%</td> </tr> <tr> <td>Mobilisation</td> <td>2%</td> </tr> <tr> <td>Calibrations</td> <td>9%</td> </tr> <tr> <td>Extra Work</td> <td>9%</td> </tr> <tr> <td>Down Time Vessel</td> <td>2%</td> </tr> <tr> <td>Port Call</td> <td>5%</td> </tr> <tr> <td>Downtime Survey</td> <td>2%</td> </tr> </tbody> </table>	Category	Percentage	Transit	19%	Operational	29%	Weather Standby	34%	Mobilisation	2%	Calibrations	9%	Extra Work	9%	Down Time Vessel	2%	Port Call	5%	Downtime Survey	2%
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## List of Acronyms Used Within This Report

<b>Acronym</b>	<b>Full Name</b>
AML	AML Oceanographic
CUBE	Combined Uncertainty and Bathymetry Estimator
DECC	Department of the Environment, Climate and Communications
DGNSS	Differential Global Navigation Satellite Systems
DPR	Daily Progress Report
FMGT	Fledermaus Geocoder Tool
GIS	Geographic Information System
GNSS	Global Navigation Satellite Systems
GSI	Geological Survey Ireland
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 Profiler
TPU	Total Propagated Uncertainty
UKHO	UK Hydrographic Office
UTC	Coordinated Universal Time
VORF	Vertical Offshore Reference Frame
WGS	World Geodetic System

## **1. Introduction**

### **1.1 Project Overview and Objectives**

Geological Survey Ireland (GSI) and Marine Institute (MI) conducted seabed mapping between 2003 and 2005 under the auspices of the Irish National Seabed Survey (INSS) and this continued from 2006 to present day under the INTe grated mapping FO r the sustainable development of Irelands MA rine 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 the Environment, Climate and Communications (DECC).

INFOMAR Phase 1, 2006 to 2015 focused on mapping 26 priority bays and 3 priority areas around Ireland and creating a range of integrated mapping products of the physical, chemical and biological features of the seabed in those areas. INFOMAR Phase 2, 2016 to 2026 intends to map the remainder of Ireland's entire seabed. Figure 1 shows the extent of the continental shelf mapped area under INSS and INFOMAR and the outstanding areas as of January 2020. Grey areas have already been mapped, blue, white and coloured hatched areas are unmapped. Coloured hatched areas are designated for mapping in 2020

As of 2018 the remaining survey area has been split at the 30 nautical mile (Nm) limit. The inshore survey fleet, managed by GSI is responsible for mapping inshore of the 30 Nm limit and the MI vessels are responsible for mapping the offshore. Survey areas are defined into gridded survey units known as INFOMAR Survey Units (ISUs). ISUs are all 1000 km<sup>2</sup> 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 within that ISU. Colour scales are used, to denote the three depth bands; 50 to 100m, 100 to 150m and 150m plus.

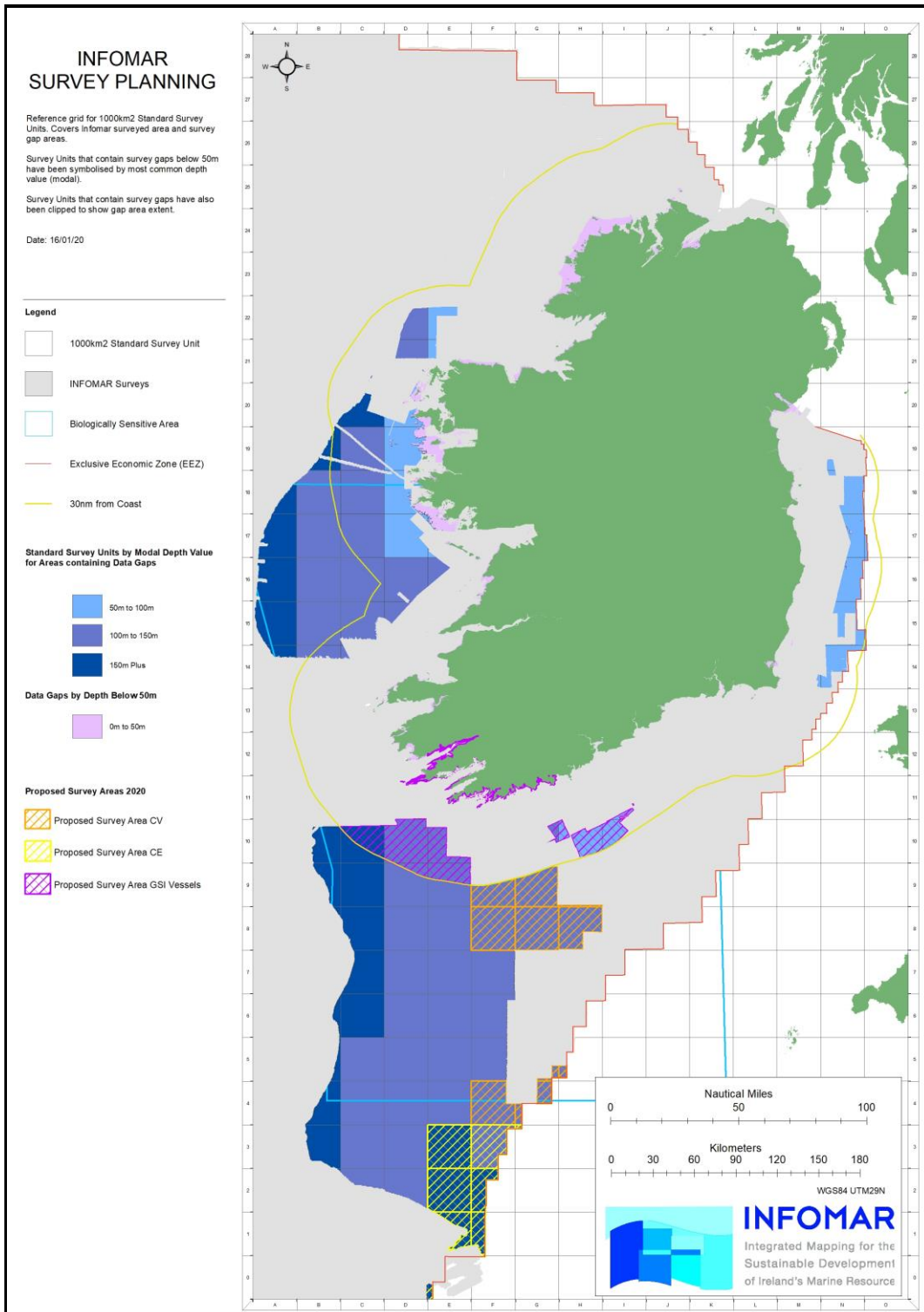


Figure 1: Survey coverage and 2020 designated operations areas.

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

The scientific aims of the survey were to:

(i) Undertake a Multibeam Echo Sounder (MBES) hydrographic survey to a minimum standard of International Hydrographic Organisation (IHO) Order 2.

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

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

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

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

(vi) Groundtruth the acoustic data with grab samples.

## **1.2 Proposed Survey Area**

The 2020 INFOMAR Operations Plan was agreed between MI and GSI at the start of the year, circulated to stakeholders and published online at <https://www.infomar.ie>. The published plan was heavily modified with the onset of the Covid19 crisis in March. Some RV *Celtic Voyager* charter days were allocated to the RV *Celtic Explorer*, an additional Explorer survey, two less Voyager surveys, survey date changes, a reduction in scientific personnel numbers and modification of the survey plans were all necessary.

Figure 2 shows the area designated for mapping by the RV *Celtic Voyager* in 2020. Two areas in the Celtic Sea were designated, one just beyond the 30 Nm boundary in the north Celtic Sea and another area approximately 150 km further south, adjacent to the Ireland/UK border.

Predicted survey coverage for the RV *Celtic Voyager* 2020 survey season as per the modified plan was 2916 km<sup>2</sup> based on annual survey statistics since 2016 and modal depth of ISUs to be surveyed. The primary target area, hatched in orange is 4190 km<sup>2</sup>.

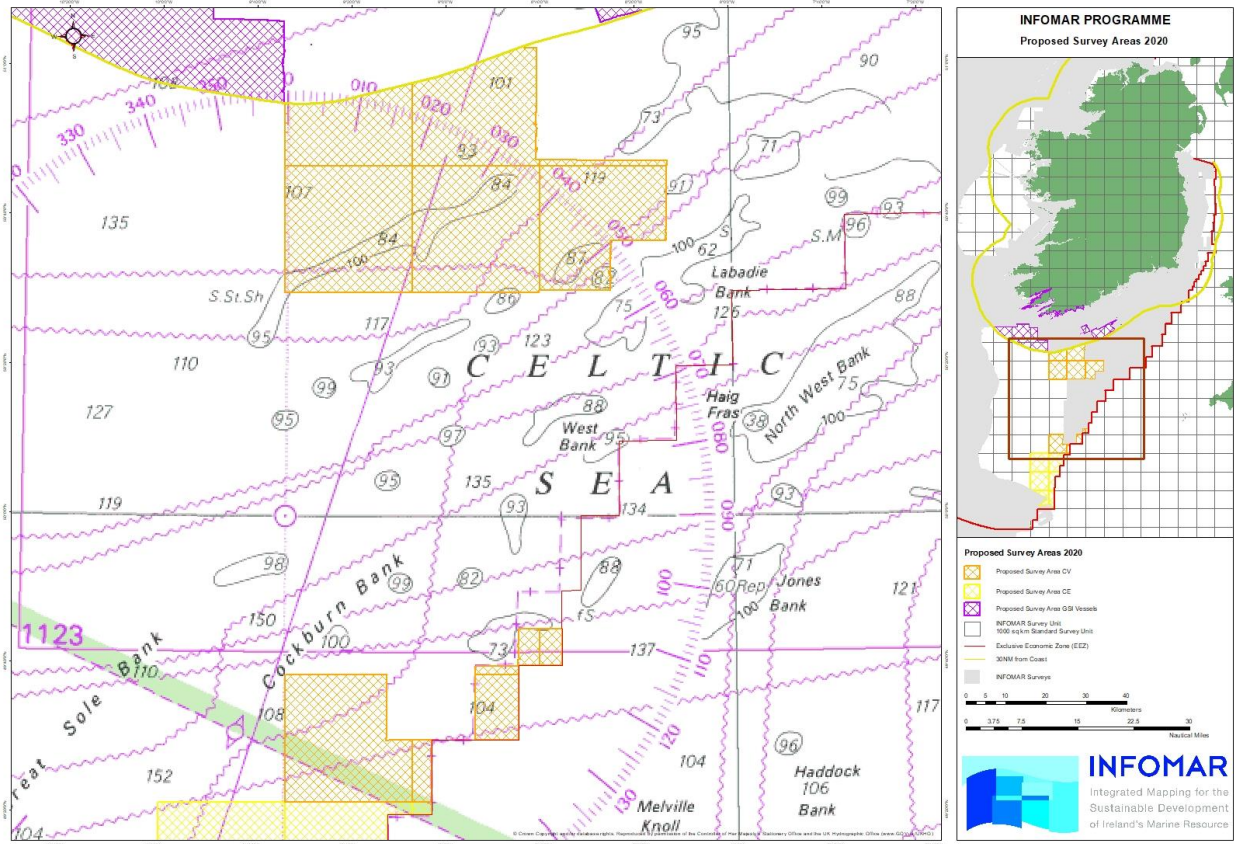


Figure 2: Proposed RV Celtic Voyager survey areas for 2020.

## **2. Operations & Survey Setup**

Mobilisation took place in Galway on 1<sup>st</sup> June with survey acquisition between 2<sup>nd</sup> and 20<sup>th</sup> June. Kevin Sheehan and Oisín McManus of the MI acted as Party Chiefs. The survey team comprised skilled personnel from the MI and freelance contractors.

A ship's crew member departed mid-way through the survey as scheduled but the normal replacement was unable to join. No suitable replacement could be found via agency in Ireland and it was deemed too risky to source a crew member from outside the country during the Covid crisis. The vessel remained in Cork until a replacement crew member from the RV *Celtic Explorer* joined 5 days later. RVOPs agreed to provide INFOMAR with the lost survey days at the end of CV20\_02 in September. The official end of survey date was pushed forward by two days to 23<sup>rd</sup> June due to poor weather and the requirement to demobilise in Galway as part of the Covid mitigation protocols. These 2 days will also be returned to INFOMAR during CV20\_02.

### **2.1 Survey Track Lines**

The final survey track line plot is shown in Figure 3. Two separate survey areas were mapped, denoted in this report as the Eastern and Western areas respectively. The eastern area was not part of the original INFOMAR 2020 Operations plan for the RV *Celtic Voyager* but personnel limitations due to Covid mitigation measures necessitated mapping inside the 30 Nm limit for part of this survey.

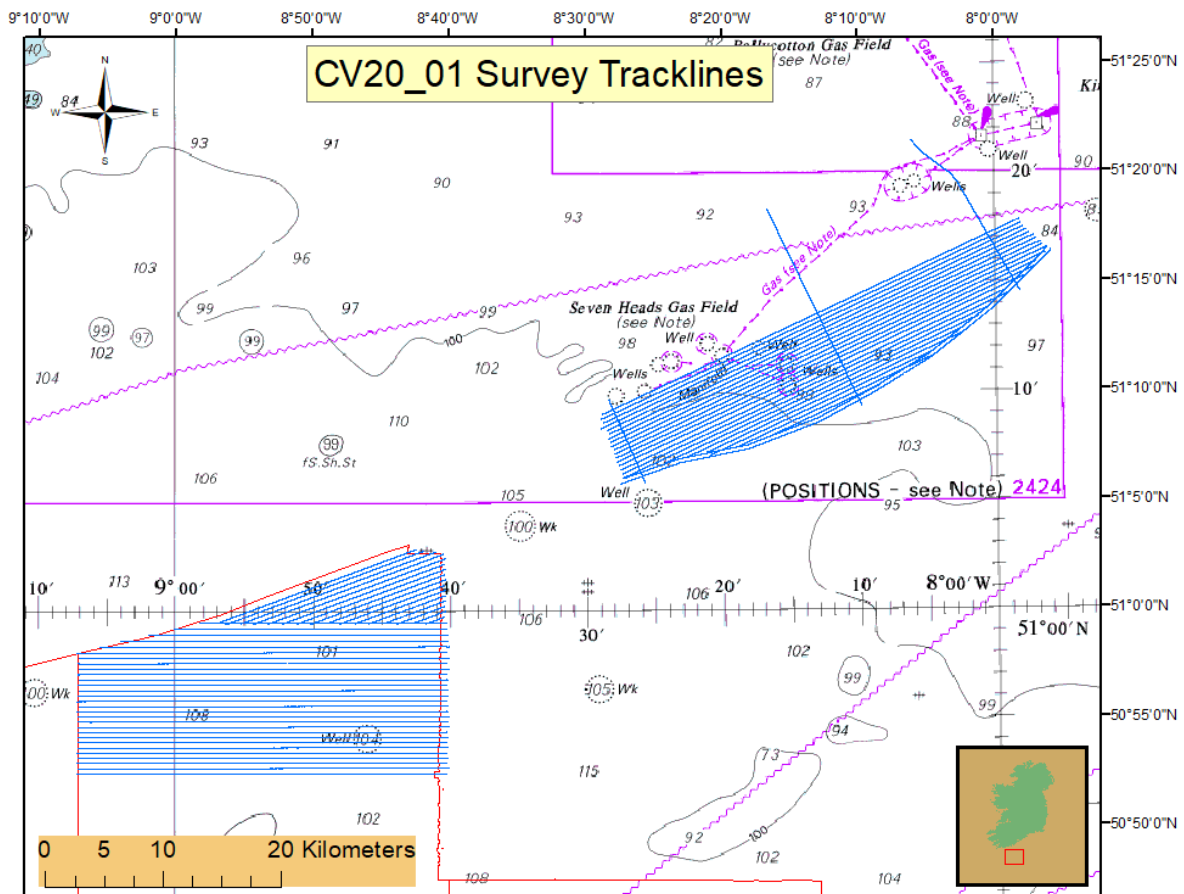


Figure 3: Survey track line plot produced in Caris and ArcGIS software.

## 2.2 Summary of Events

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

Date and time	Activity
01/06/2020 00:00	Mobilised in Galway Docks
01/06/2020 11:30	Departed Galway
01/06/2020 14:08	Commenced Patch Test
01/06/2020 16:08	Commenced Wreck Survey
01/06/2020 17:51	Commenced Transit to Celtic Sea Survey Area
03/06/2020 12:18	Vessel Hove To for Moving Vessel Profiler (MVP) Repairs
03/06/2020 13:53	Resumed Survey Acquisition
05/06/2020 14:21	Weather Standby
07/06/2020 14:54	Resumed Survey Acquisition
07/06/2020 22:28	Commenced Transit to Cork for Port Call
08/06/2020 07:00	Alongside Cork. Scientific Personnel Changed
08/06/2020 17:00	Departed Cork for Survey Area
09/06/2020 00:02	Resumed Survey Acquisition

10/06/2020 16:40	Commenced Transit to Cork for Port Call
11/06/2020 23:59	Alongside Cork for Weather Standby
12/06/2020 10:00	MBES Transducers Cleaned by Divers
13/06/2020 12:00	Scientific Personnel Changed
13/06/2020 16:00	Vessel Standby. Waiting on Replacement Crew member
18/06/2020 08:00	Departed Cork for Survey Area
18/06/2020 15:52	Resumed Survey Acquisition
20/06/2020 08:30	Commenced Transit to Cork for Weather Standby
20/06/2020 15:30	Alongside Cork for Weather Standby
23/06/2020 07:00	Weather Standby. Commenced passage to Galway
25/06/2020 23:59	Demobilisation Completed

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
Oisín McManus	MI	Party Chief /Surveyor
Fabio Sacchetti	MI	Surveyor
Agust Magnusson	Contractor	Surveyor
Jan Majcher	Contractor	Surveyor

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 SBP (pinger or chirp), MBES and sidescan sonar surveys in bays, inlets or estuaries and within 1500 m of the entrance of enclosed bays/inlets/estuaries. All operations were outside of the areas

covered under the above guidelines. No 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)	2005
Area Covered (km <sup>2</sup> )	734
Operational (%)	29
Weather Standby (%)	34
Down Time Vessel (%)	19

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 34% of the time.

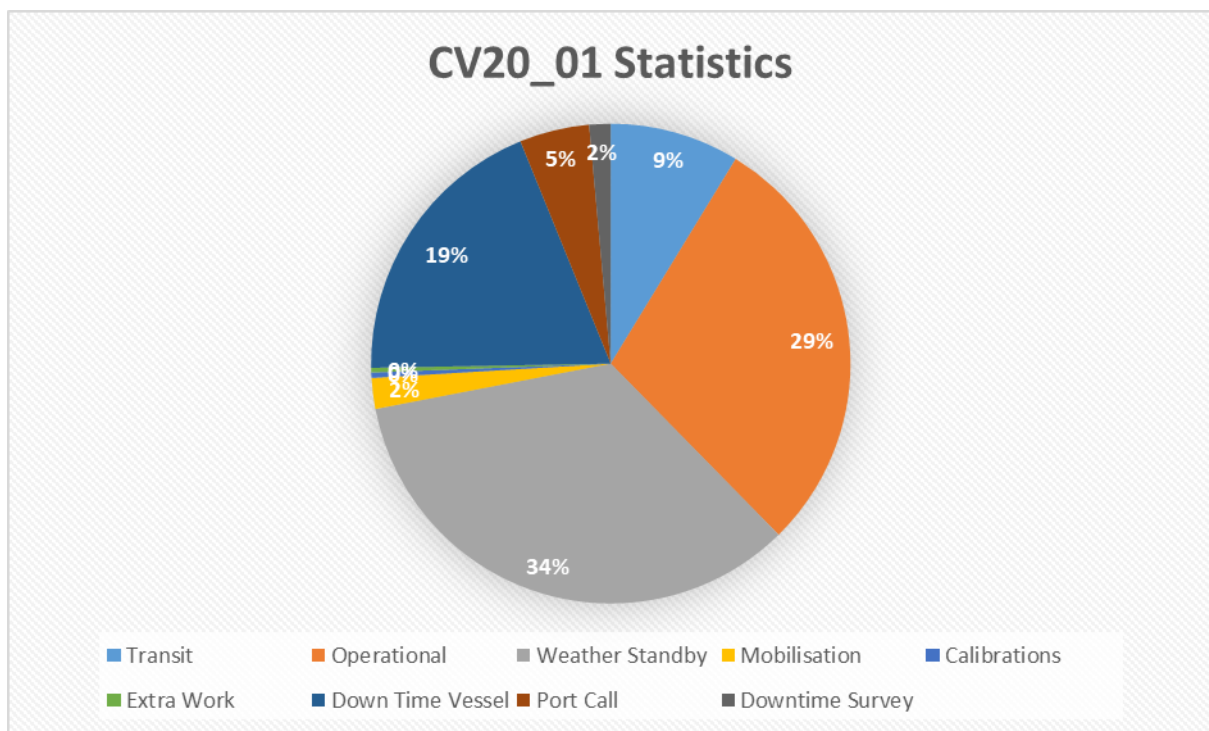


Figure 4: Survey statistics pie chart.

### 3 Survey Vessel Offsets, Equipment and Data Acquisition

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



Figure 5: The RV *Celtic Voyager*.

Detailed vessel information is contained in Table 4.

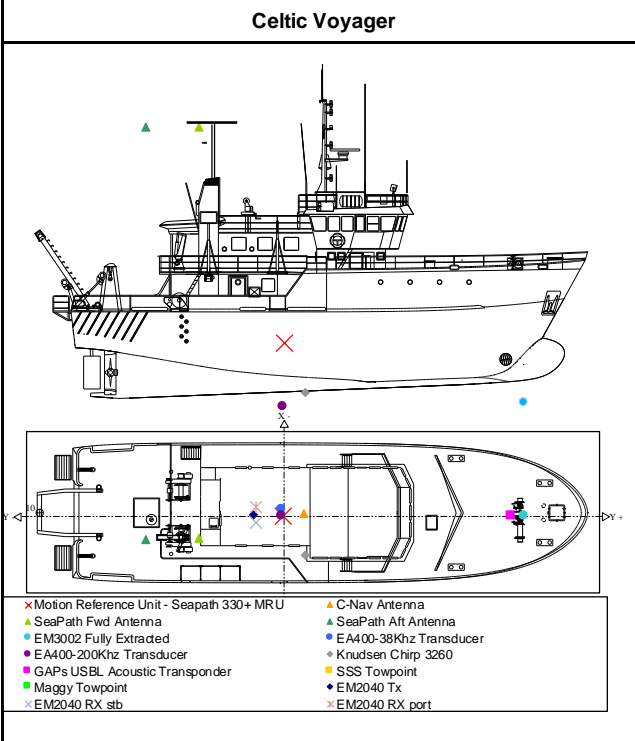
Parameter	Numeric
Length	31.4 m
Beam	8.5 m
Draught	4.0 m
Engine	1 x Baudouin 26.2 655 kW
Power Output	640 kW/1200 RPM

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

Table 4: RV *Celtic Voyager* vessel information.

### 3.1 Vessel Offsets

Bluepix performed an offset survey of the RV *Celtic Voyager* in August 2015 while in dry dock 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 Title:					
Date Last Surveyed		10-11/01/2016 - Bluepix		Date: 11/01/2016	
<b>Celtic Voyager</b>					
					
<ul style="list-style-type: none"> <li>✗ Motion Reference Unit - Seapath 330+MRU</li> <li>▲ SeaPath Fwd Antenna</li> <li>● EM3002 Fully Extracted</li> <li>● EA400-200Khz Transducer</li> <li>● GAPS USBL Acoustic Transponder</li> <li>■ Maggy Towpoint</li> <li>✗ EM2040 RX sb</li> <li>▲ C-Nav Antenna</li> <li>▲ SeaPath Aft Antenna</li> <li>● EA400-38Khz Transducer</li> <li>◆ Knudsen Chirp 3260</li> <li>■ SSS Towpoint</li> <li>◆ EM2040 Tx</li> <li>✗ EM2040 RX port</li> </ul>					
No'	Offset Name	X	Y	Z	Reason for change
	Common Reference Point (CRP)	0.000	0.000	0.000	
1	Motion Reference Unit - Seapath 330+ MRU	0.000	0.000	0.000	
2	C-Nav Antenna	-0.114	0.965	14.396	
3	SeaPath Fw d Antenna	0.924	-3.993	13.292	
4	SeaPath Aft Antenna	0.984	-6.491	13.299	
5	EM3002 Fully Extracted	-0.078	11.190	-3.532	New Position 2015
6	EA400-38Khz Transducer	-0.343	-0.122	-3.783	
7	EA400-200Khz Transducer	-0.036	-0.115	-3.783	
8	Knudsen Chirp	1.636	0.989	-3.004	
9	GAPS USBL Acoustic Transponder	-0.077	10.633	-4.332	
10	SSS Towpoint	0.000	-13.905	1.987	
11	Maggy Towpoint	-3.835	-13.905	1.987	
12	EM2040 Tx	-0.064	-1.417	-4.863	New Position
13	EM2040 RX sb	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	

<b>EM2040 geometry (Bluepix Report 10-11/01/2016)</b>			
<b>Item</b>	<b>X (forward)</b>	<b>Y (starboard)</b>	<b>Z(+Down)</b>
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
	<b>Yaw</b>	<b>Roll</b>	<b>Pitch</b>
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.

<b>CV20_01 Installation Parameters from Caris HDCS Data</b>			
<b>Item</b>	<b>Yaw</b>	<b>Roll</b>	<b>Pitch</b>
MRU 5+	-0.23	0.11	-0.09
EM2040 TX	359.95	-0.33	0.74
EM2040 RX Port	179.02	-39.62	-0.67
EM2040 RX Stb	180.69	40.36	-0.73

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 on board the RV *Celtic Voyager*.

<b>System</b>	<b>Type</b>	<b>Comment</b>
Multibeam Echo-Sounder	Kongsberg EM2040	200, 300 & 400 kHz
Singlebeam Echo-Sounder	Kongsberg EA400	38 and 200 kHz
Sub-Bottom Profiler	Knudsen Chirp 3260	3.5 – 9 kHz
Sidescan Sonar	Edgetech 4200	100 and 500 kHz
Positioning	C-Nav DGNS	Seapath330+ as secondary
USBL	IXsea-Gaps	Sonardyne Scout as secondary
Sound Velocity Profiler	Valeport SVP Mini	Sound Velocity
Moving Velocity Profiler	AML MVP200	Sound Velocity
Realtime Sound Velocity	Valeport or AML	Sound Velocity
Magnetometers	SEASPY	Overhauser Effect

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

### 3.2.1 Technical Issues

#### Knudsen SBP Coherent Noise

This was the first INFOMAR survey using the recently installed Knudsen Chirp SBP system. Periodic coherent noise was witnessed throughout the survey. Figure 6 shows the noise bursts, at regular time intervals represented as vertical lines on the seismic window and as 100% amplitudes on the gain window. Changing the Time-Varying Gain (TVG) from TVG20logR to TVGBottomRef mitigated but did not eliminate the noise and troubleshooting with the system manufacturer is ongoing.

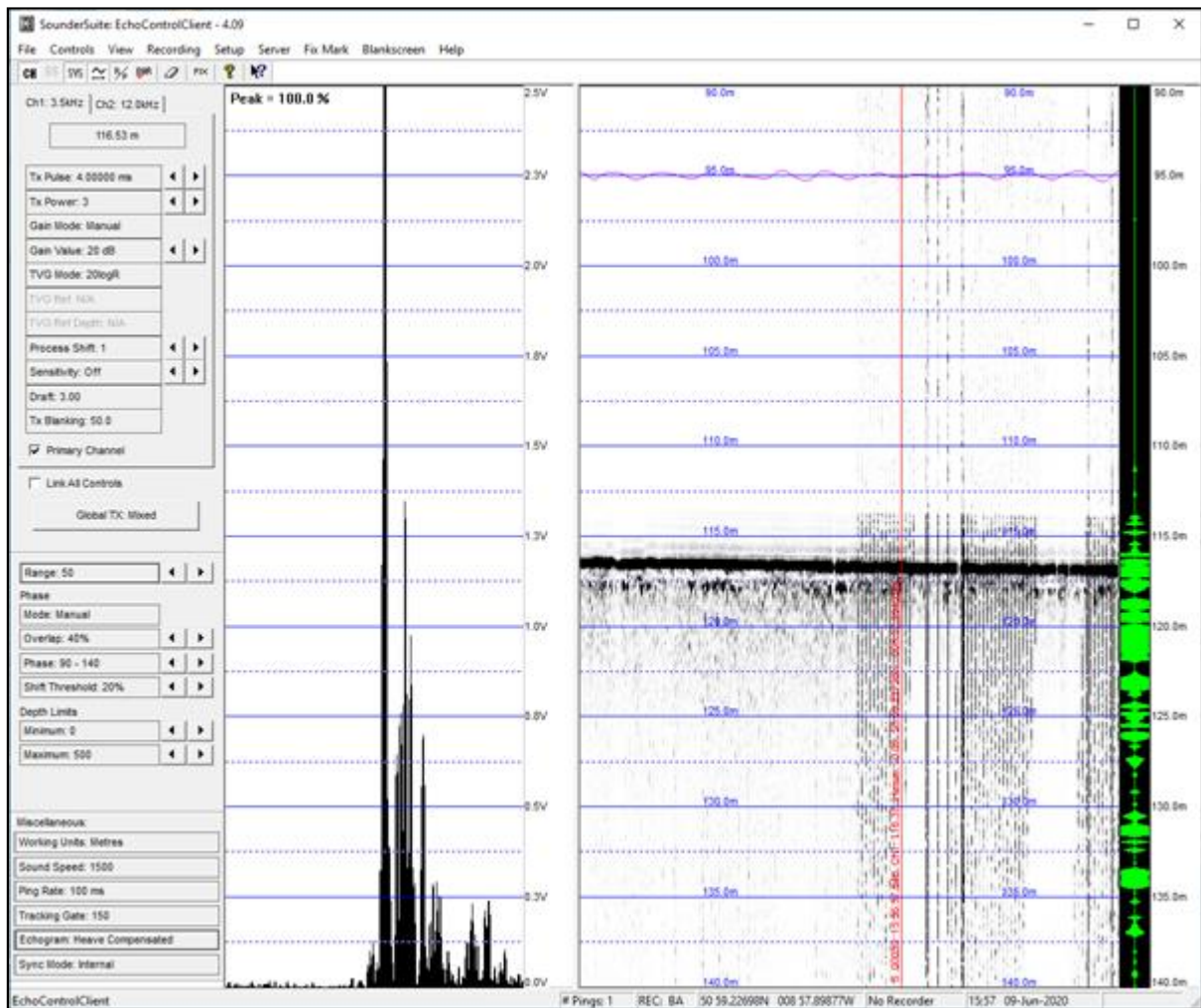


Figure 6: SBP data showing coherent noise bursts.

#### SBP Interference with MBES

SBP power level of 75% or above, along with long pulse lengths caused interference on the MBES data. Figure 7 shows the interference on the MBES backscatter real-time plot. An external trigger with the MBES as Master is recommended so that both systems ping at intervals that prevent interference.

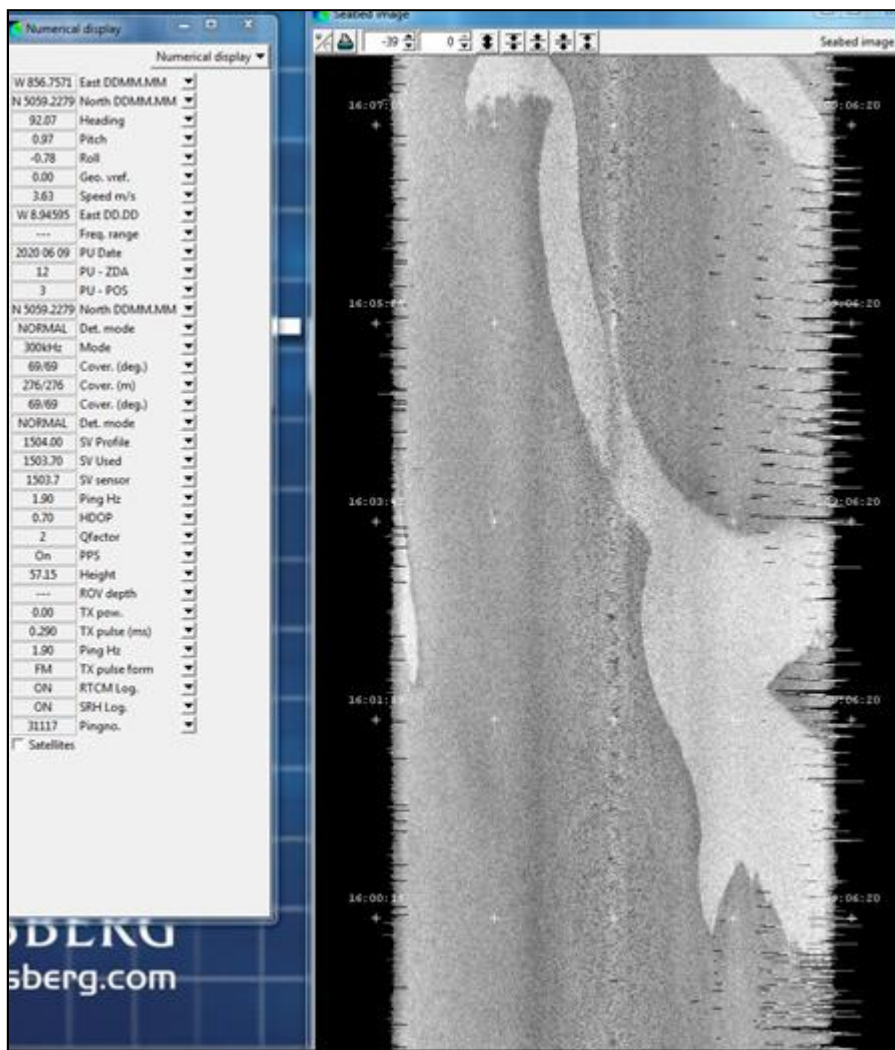


Figure 7: SBP interference on MBES data.

### SV Sensor

The real-time hull mounted SV sensor was switched mid survey as it was giving spurious readings. It is advised to send it for calibration.

### MVP Sensor

The MVP sensor was switched mid survey as it was giving spurious readings. The anode was replaced as it was heavily eroded. The replacement sensor provided reliable readings.

## 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 <sup>2</sup> )	0.0066943800
Inverse Flattening (1/f)	298.257223563
<b>Projection Parameters</b>	
Grid Projection	Universal Transverse Mercator
Central Meridian Zone 29 (CM)	009° 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 World 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 8 below.

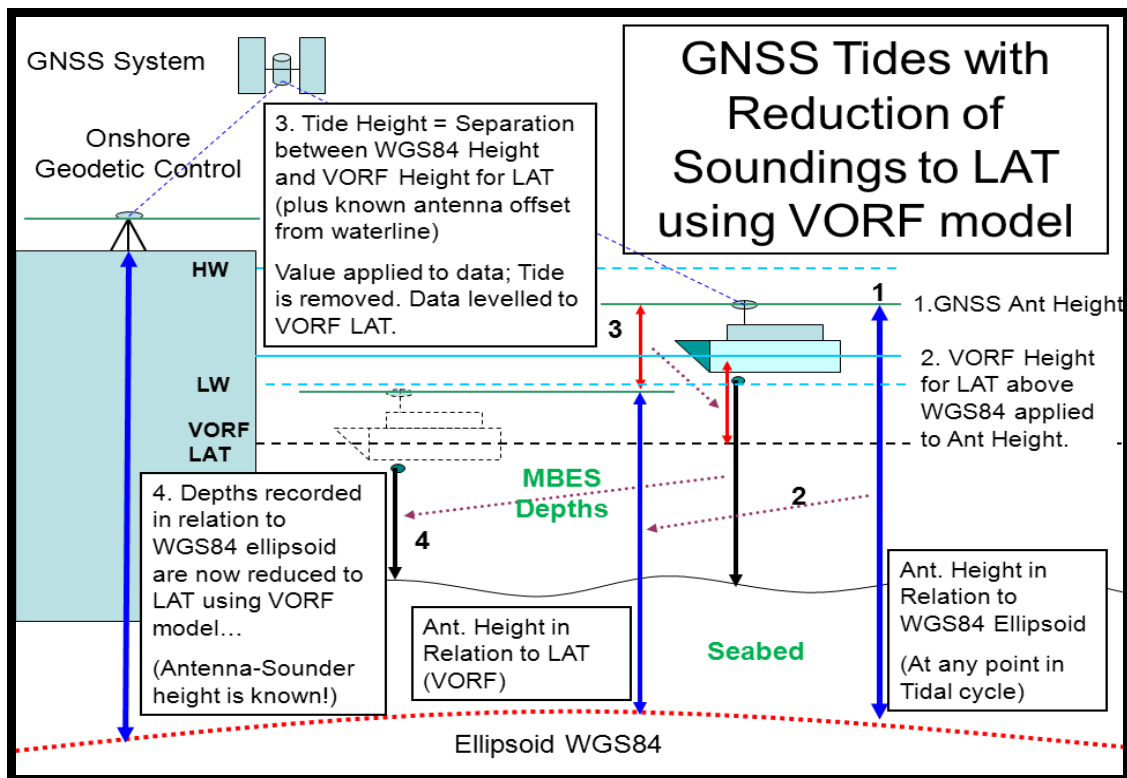


Figure 8: GNSS tides to LAT using VORF model.

### 3.3.3 Vessel Draft

Distances from known draft measuring points on the vessels port and starboard sides to the water line were measured by tape once ballasting was completed. Known vertical distances at port and starboard sides between these draft measuring points and the MRU (Common Reference Point for EM2040) and EA400 transducers respectively were used along with the tape measured vertical distances to calculate draft values for the EM2040 and EA400 echosounders. Port and starboard sides were averaged to get one value for each echosounder. Table 8 lists the tape measured draft figures along with the known vertical distances.

Measurement	Port Side	Starboard Side
Tape Measurement at EA400 Draft Mark (from mark to water) 01/06/2020	4.12	4.00
Vertical distance between Starboard Side draft mark and EA400		7.4660
Vertical distance between Port Side draft mark and EA400	7.4580	
Vertical distance between Port Side EA400 draft mark and MRU	3.6746	
Vertical distance between Starboard Side EA400 draft mark and MRU		3.6824

Table 8: Draft measured and known vales.

$$\text{Draft value for EM2040} = ((4.12 - 3.6746) + (4.00 - 3.6824))/2 = \mathbf{0.382}$$

Draft value for EA400 =  $((7.4580 - 4.12) + (7.4660 - 4.00))/2 = 3.402$

These draft values were entered in the respective software for both the EM2040 and EA400.

### 3.3.4 Acoustic Systems

A Kongsberg EM2040 high resolution MBES mounted on a retractable pole was used for swath acoustic acquisition. First bottom returns from the MBES produce highly accurate bathymetric data. Additionally, backscatter acquired by MBES sonars contains important information about the seafloor and its physical properties. 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 (0.7° each) and a single TX transducer (0.7°). The system operates at frequency ranges of 200, 300 or 400 kHz with 800 soundings per ping and allows coverage of up to 10 times water depth on a flat bottom. It has a maximum ping rate of 50 Hz. The 200 kHz frequency was used for this survey. Primary positioning was provided by C-Nav 3050 DGNSS. Seapath 330+ with integrated Seatex MRU5+ inertial unit provided secondary position and real time heading, heave, pitch, roll and velocity to the MBES system.

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

Descriptor	Metadata
Survey lines	Mainlines and Crosslines
Data Files	284
Date Created	02-06-2020 to 20-06-2020
Dataset Size	56.4 GB
File Formats	.all

Table 9: MBES metadata.

United Kingdom Hydrographic Office (UKHO) guidelines were implemented when carrying out wreck investigations. Three survey lines along the wreck's primary axis with high overlap and one or more lines across its secondary axis to ensure full wreck coverage along both axes were acquired. The water column logging functionality in SIS was used throughout the investigation. Beam angles, survey speed, operational frequency and pulse

length were configured for maximum resolution. Wrecks were reported to the UKHO using the standard UKHO “H-Forms”. A total of two wrecks were surveyed in detail.

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

<b>Descriptor</b>	<b>Metadata</b>
Survey lines	NA
Data Files	311
Date Created	02-06-2020 to 20-06-2020
Dataset Size	7.1 GB
File Formats	.kea, .keb & .sgy

Table 10: SBP metadata.

### 3.3.5 Magnetometer

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

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

<b>Descriptor</b>	<b>Metadata</b>
Survey lines	NA
Data Files	1

Date Created	02-06-2020 to 20-06-2020
Dataset Size	361 MB
File Formats	.mms

Table 11: Magnetometer metadata.

### 3.3.6 DGPS Systems

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

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

Seapath 330+ provided the secondary navigation. Seapath and C-Nav data were monitored continuously in Quality Integrated Navigation System (QINSy) software to ensure data integrity and comparison between the primary and secondary navigation systems remained within tolerance. Navigation data were recorded in .cnav3050 format using C-Nav software. One file per day was created. Metadata is contained in Table 12.

Descriptor	Metadata
Survey lines	All
Data Files	3
Date Created	02-06-2020 to 03-06-2020
Dataset Size	605 MB
File Formats	.cnav3050

Table 12: C-Nav navigation metadata.

### 3.3.7 Online Navigation

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

Survey line 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.

<b>Descriptor</b>	<b>Metadata</b>
Survey lines	NA
Data Files	374
Date Created	02-06-2020 to 20-06-2020
Dataset Size	18.0 GB
File Formats	.db & .txt

Table 13: QINSy navigation metadata.

### **3.3.8 Sound Velocity**

An AML 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 allowing more casts to be acquired and without impacting MBES data acquisition. 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 for beam steering, directly to the EM2040.

MVP deployment was controlled from the vessel Dry Lab using Rolls Royce MVP software. The probe was continually towed in the water at between 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.

A Valeport Mini SVP profiler was used instead of the MVP on a handful of occasions. Sound velocity profile data were recorded in asvp format and downloaded with DataLog X2 software. Metadata is contained in Table 14.

<b>Descriptor</b>	<b>Metadata</b>
Survey lines	NA
Data Files	880
Date Created	02-06-2020 to 20-06-2020
Dataset Size	43.5 MB
File Formats	.asvp, .calc, .eng, .log, .m1, .raw, .s10, .s52

Table 14: Sound velocity metadata.

### **3.3.9 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 daily backup of the database was made. 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 standards. Rigorous standards for position, depth accuracy, feature search, feature detection and bathymetric coverage were achieved during data acquisition and processing. IHO Order 1a and Order 2 requirements are presented in Table 15.

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

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 9 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 pulse type Medium CW or Long CW and at 300 kHz frequency 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.

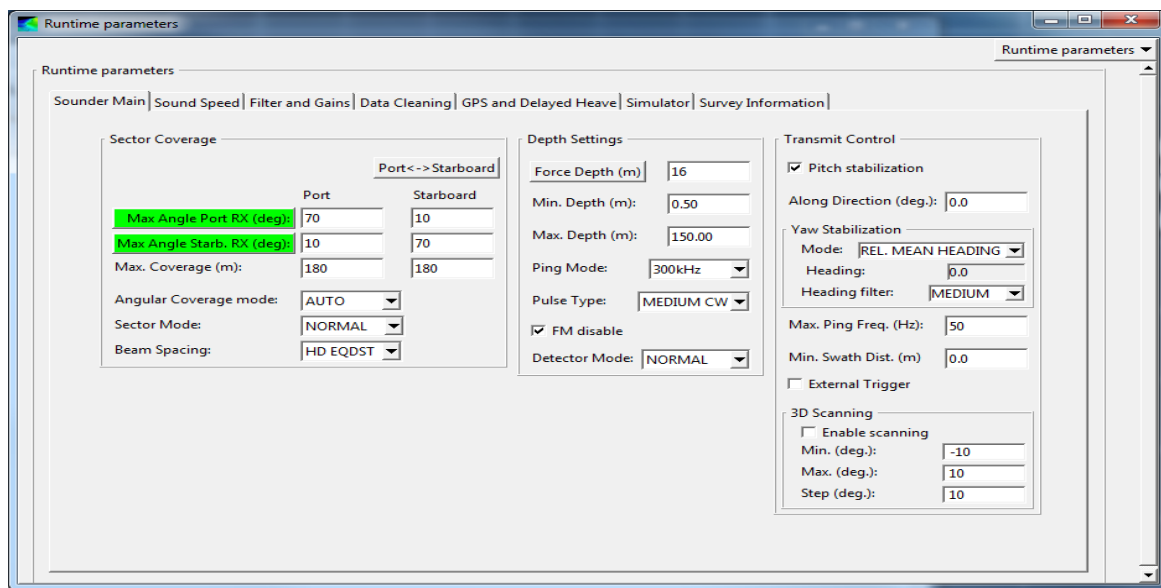


Figure 9: Runtime parameters window in SIS.

#### 4.1.2 Crossline versus Mainline Statistics

Crossline data were acquired for QC of depth soundings. A total of 3 crosslines were acquired in the eastern area for statistical analysis in Caris Hips. Crossline data were compared with mainline data. All crossline data indicated that the soundings exceeded the 95% certainty required for Order 1a specification. Crosslines for the western block were acquired during the following survey, CV20\_02. Results from the statistical analyses are presented in Table 16.

Line	Beam No.	Count	Max (+)	Min (-)	Mean	Std Dev	Special Order (%)	Order 1a (%)
East	1-800	18,706,418	1.611	1.168	0.038	0.181	99.999	100
West	1-800	14,982,986	1.166	0.957	0.043	0.180	99.98	100

Table 16: MBES crossline statistics.

#### 4.1.3 Feature Detection

The minimum standard for feature detection for an Order 1a survey are cubic features > 2 metres in depths up to 40 metres and cubic features >10% of depth beyond 40 metres. This means that in 40 metres water depth 9 soundings are required in a 2m<sup>2</sup> bin and in 100 metres water depth 9 soundings are required in a 10m<sup>2</sup> bin. Feature detection criteria are not specified in the IHO standards for Order 2 surveys.

Water depths range from 91.8 to 130.7 m. The minimum sized cubic features that require detection are 9.2 m, i.e. 10% of minimum water depth. A minimum of 9 soundings per 9.2

m<sup>2</sup> bins are required in order to attain the feature detection criteria. A bin size of 9.2 m<sup>2</sup> was selected to QC the data density and the results are shown in Figure 10. Green indicates where 9 soundings per bin were achieved and red where the 9 soundings requirement was not attained.

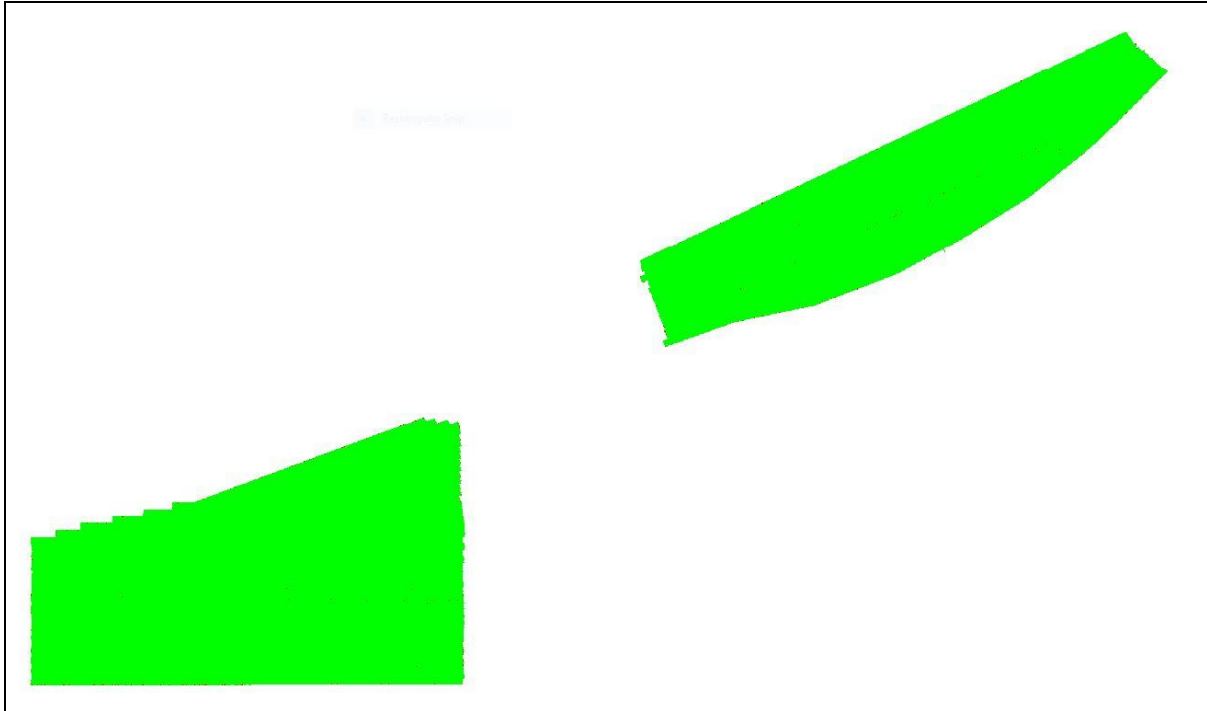


Figure 10: Sounding density traffic light plot.

The mean number of soundings per bin was computed at 90. This easily exceeded the 9 soundings required per bin. Full statistics are shown in Figure 11.

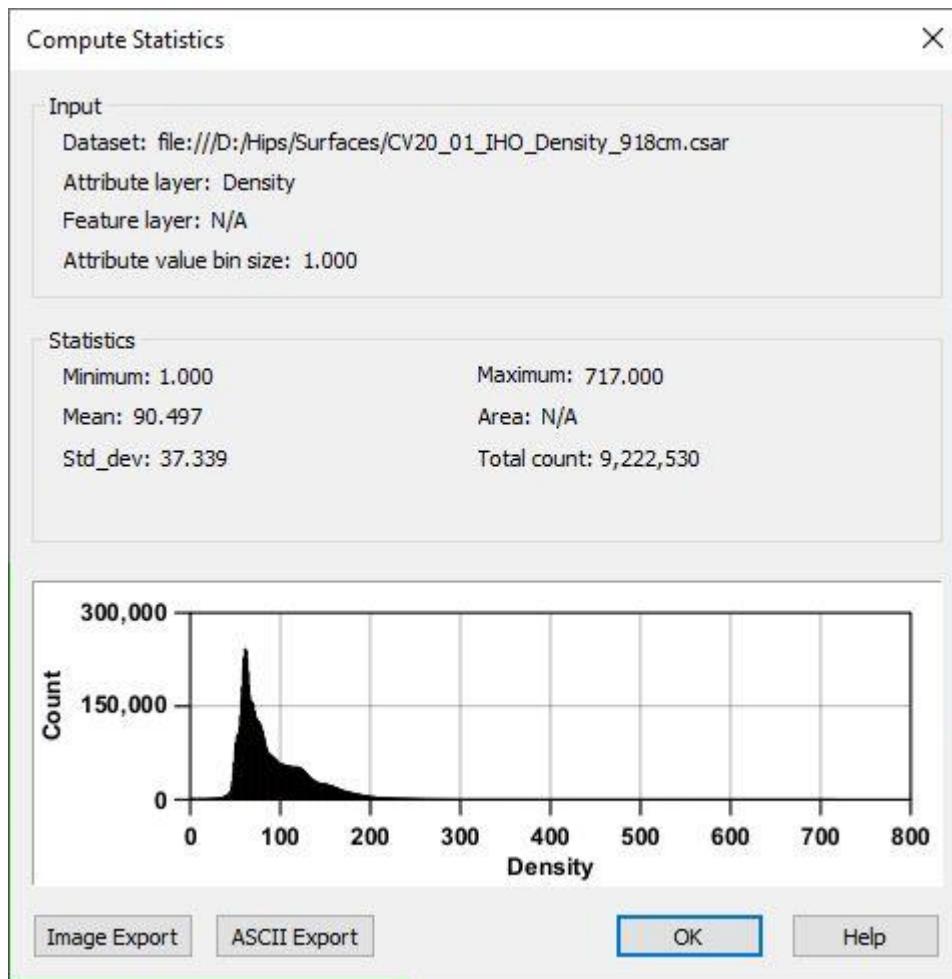


Figure 11: Sounding density statistics.

#### 4.1.4 Error Budget and Uncertainty Model

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

Table 17 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	0.065°
Heave	5 cm or 5 % Amplitude
Roll	0.01°
Pitch	0.01°
Pitch Stabilised	0.00°
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 17: Standard deviation values used in TPU calculation.

#### 4.1.5 Sound Velocity Control

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

An MVP composite plot is shown in Figure 12. Sound velocity in metres per second is plotted on the x-axes and depth in metres on the y-axes. Each dot on the plot represents an individual sound velocity reading. Sound velocity falls from around 1508 m/s near the surface to 1488 m/s at 60 m depth. The sound speed increases beneath 60 m depth as pressure increases. Above describes the broad trends but there is considerable variability between profiles.

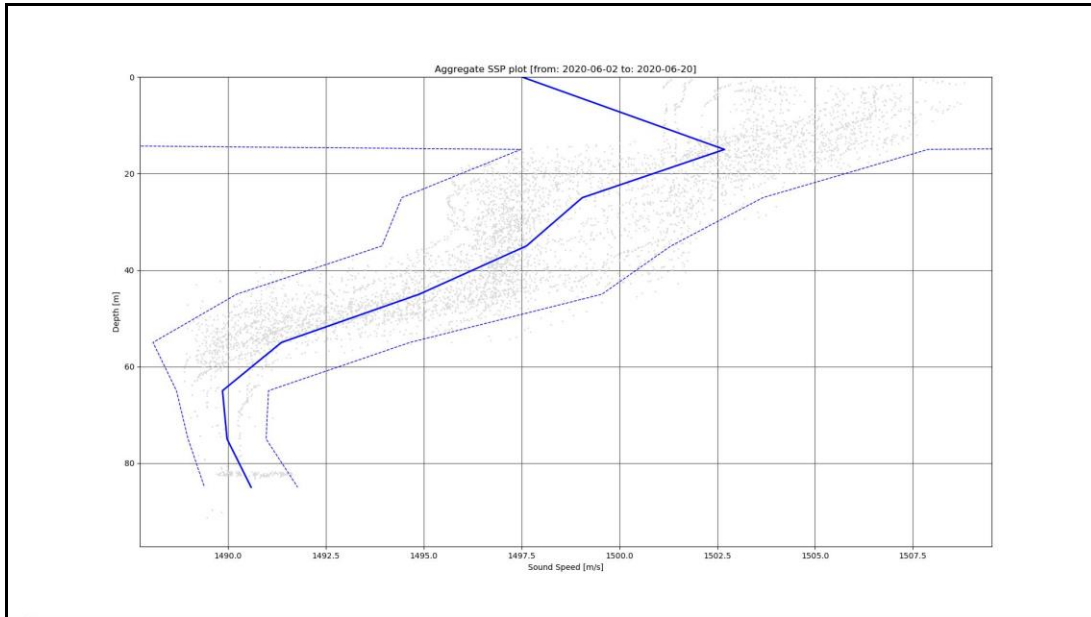


Figure 12: MVP composite plot.

Figure 13 is a plot of MVP cast distribution and application extent for the eastern area. Each circular dot denotes an MVP. Dots are coloured coded and by matching them with the survey lines colours one can ascertain the spatial extent of a casts application. The plot shows that multiple casts were acquired and applied per survey line.

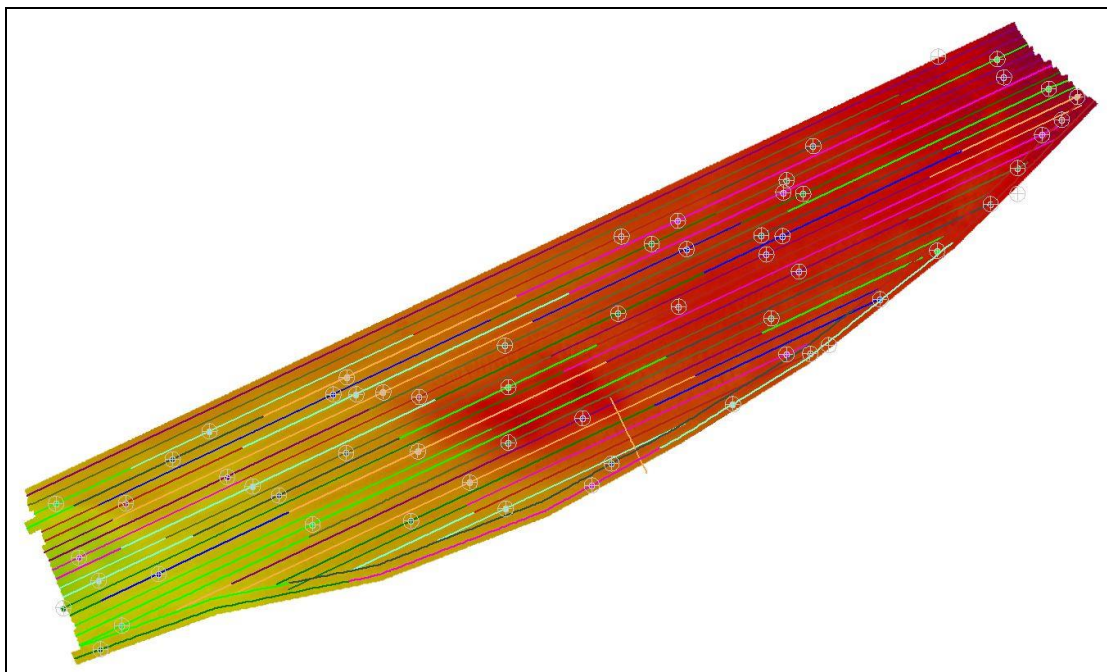


Figure 13: MVP application plot eastern area.

Figure 14 is a plot of MVP cast distribution and application extent overlain on bathymetry data for the western area. MVP casts were applied based on a range of algorithms, like nearest in time, nearest in distance and a combination of time and distance.

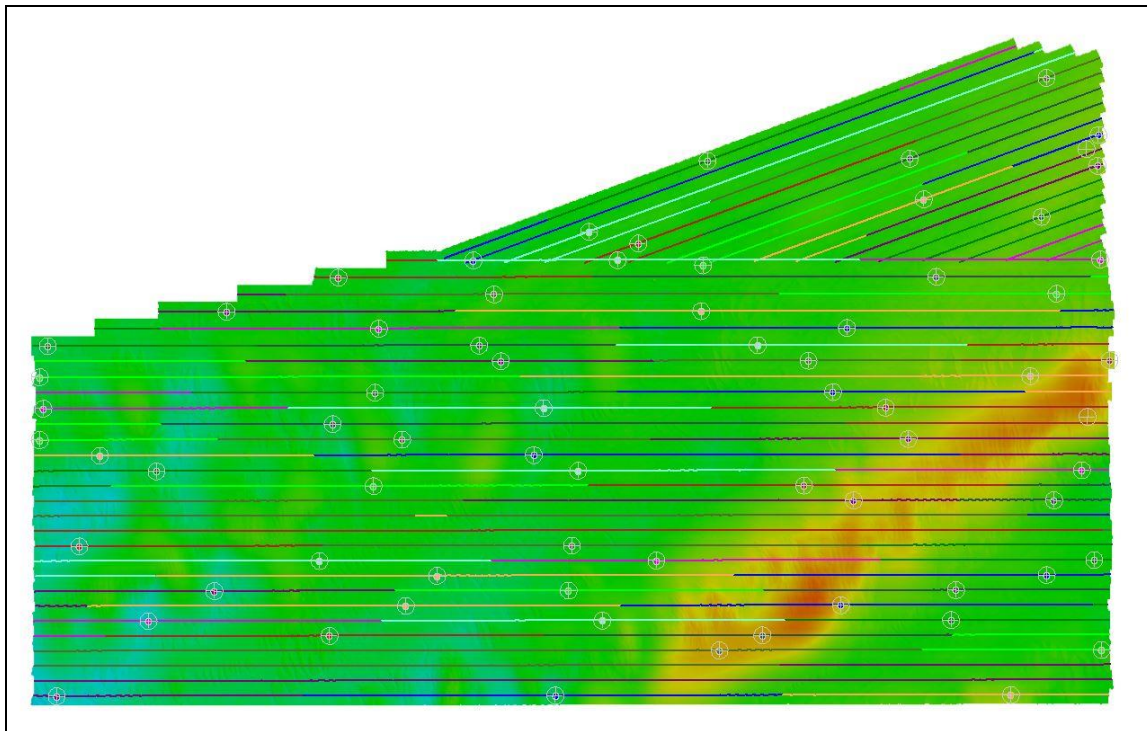


Figure 14: MVP application plot western area.

## 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 ( $\pm 20$  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

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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. SVP data were applied to correct for refraction errors caused by water column heterogeneity. A range of SV algorithms were used to determine the most suitable method of applying SV corrections, for example: nearest in distance versus nearest in time.
5. Qimera's "*TU Delft Sound Speed Inversion*" tool was used to correct refraction issues.
6. Subset Editing was performed in CARIS to clean large "noise" spikes from the data.
7. A CARIS Combined Uncertainty and Bathymetry Estimator (CUBE) base surface was then created to allow CUBE automatic filtering.
8. Final verification of sounding consistency and absence of spikes was carried out using subset editing.

#### **4.2.3 Backscatter Mosaic Generation**

Backscatter is a function of the hardness and roughness of the seafloor. Raw MBES data was put through the Geocoder engine in Caris HIPS to produce backscatter mosaics of different resolutions.

Raw MBES backscatter data were also analysed using QPS FMGT, an equivalent backscatter analysis software but 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 MBES 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 15 to 19) output for this report.

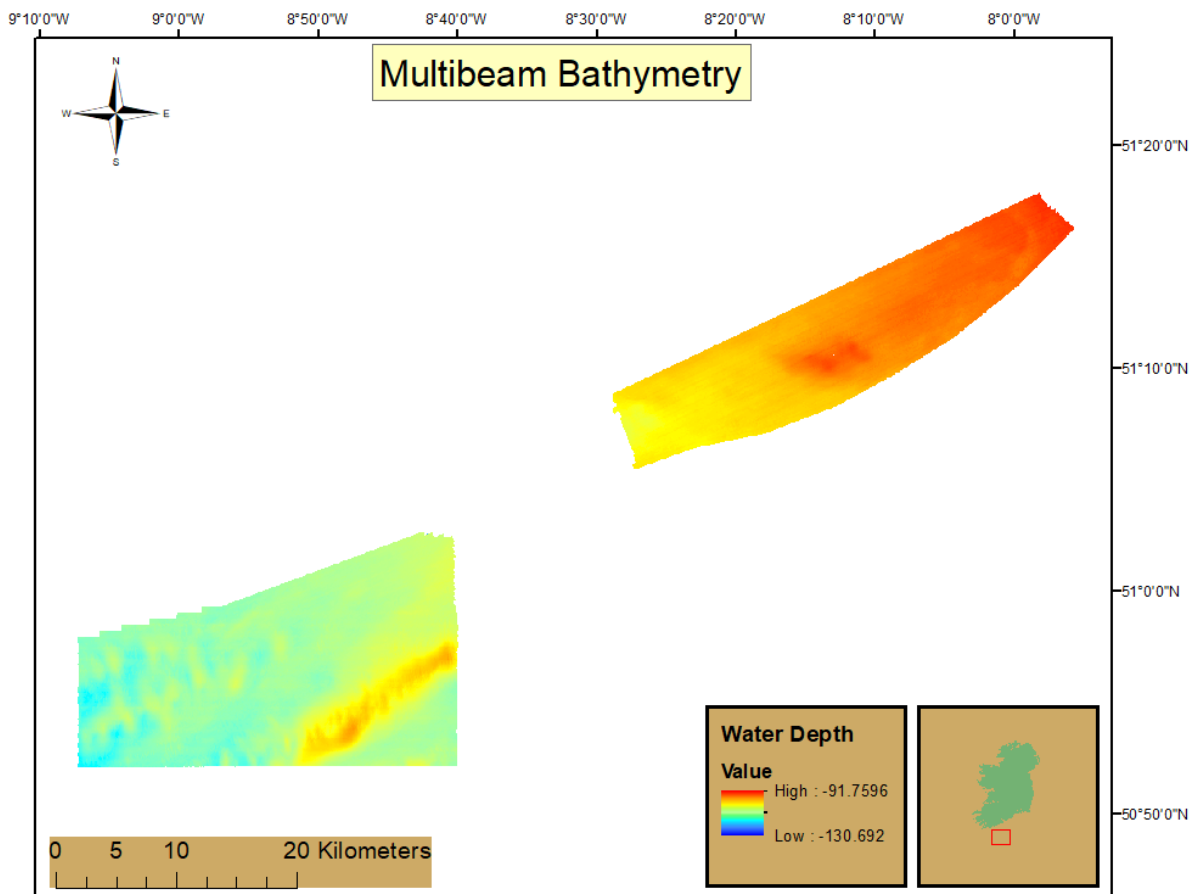


Figure 15: MBES bathymetry.

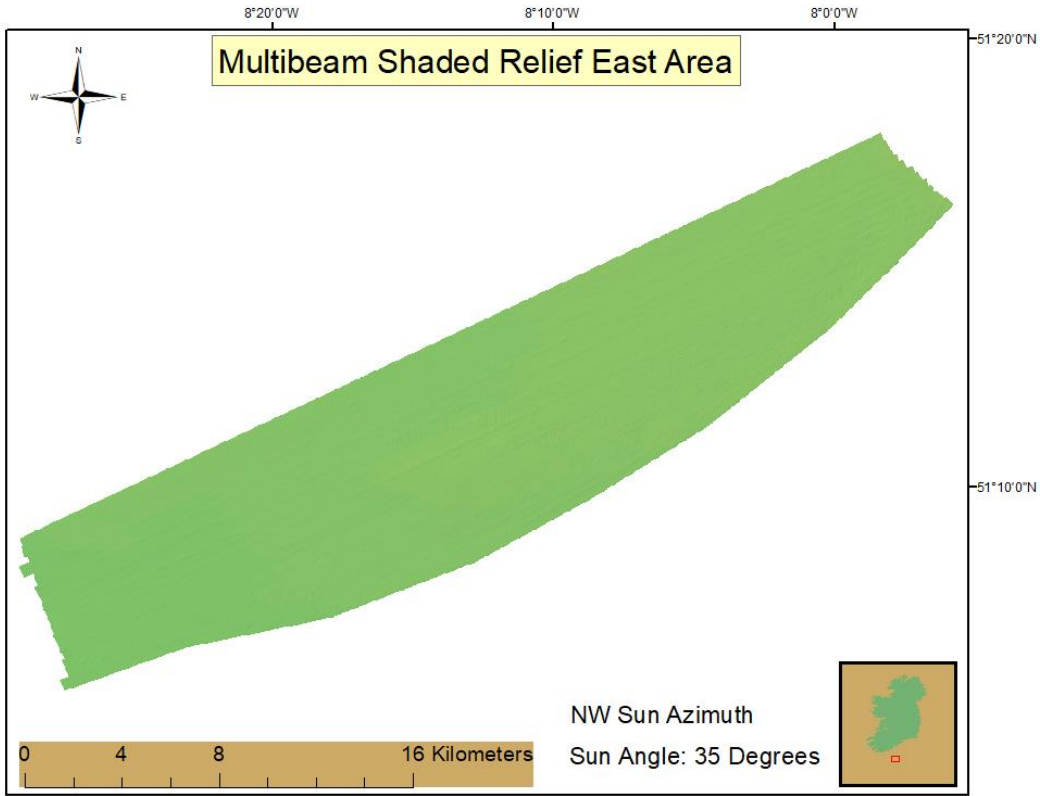


Figure 16: MBES shaded relief eastern area.

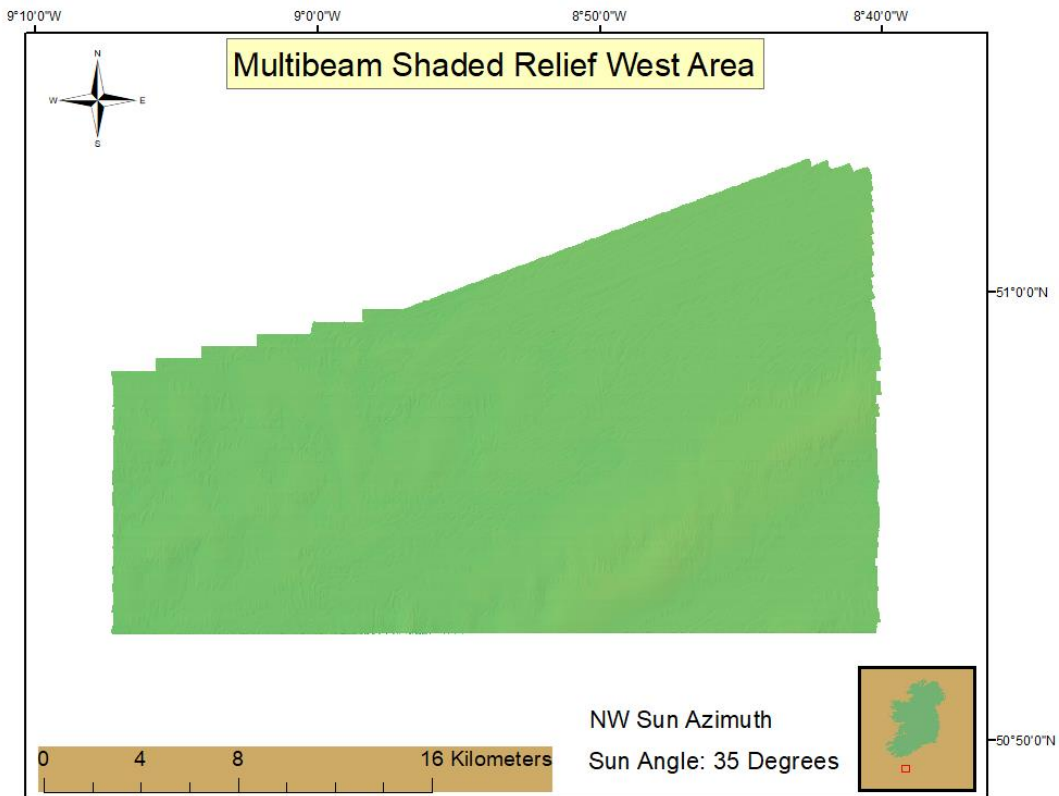


Figure 17: MBES shaded relief western area.

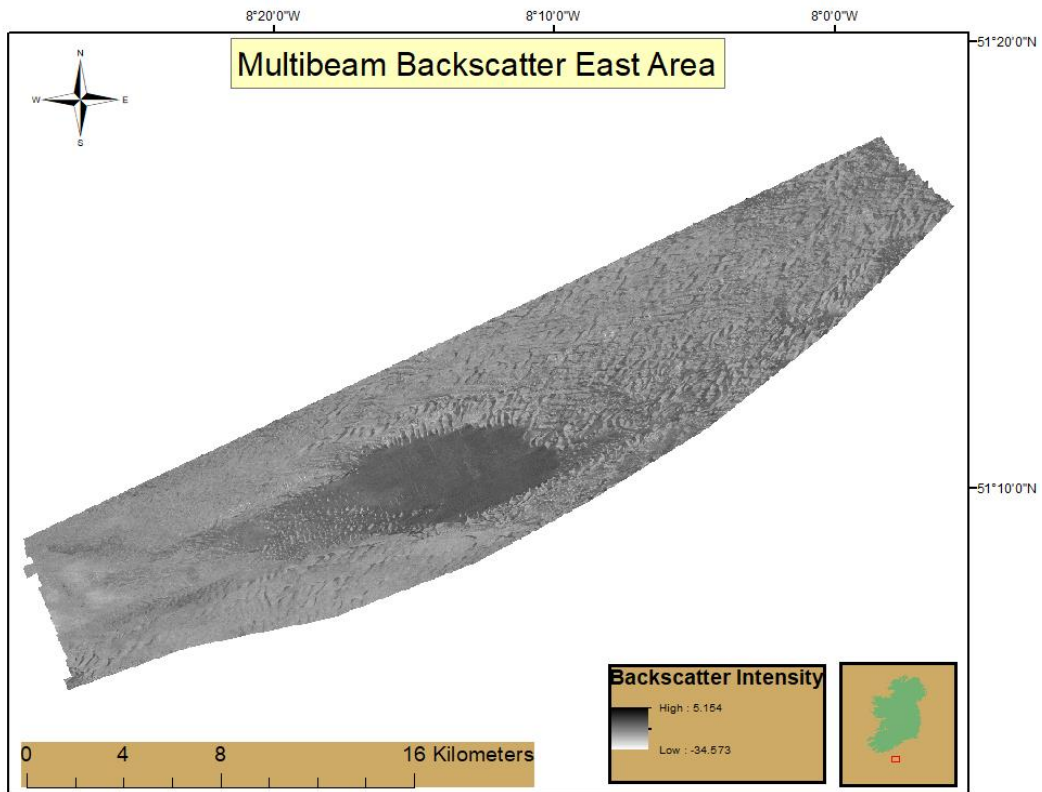


Figure 18: MBES backscatter mosaic eastern area.

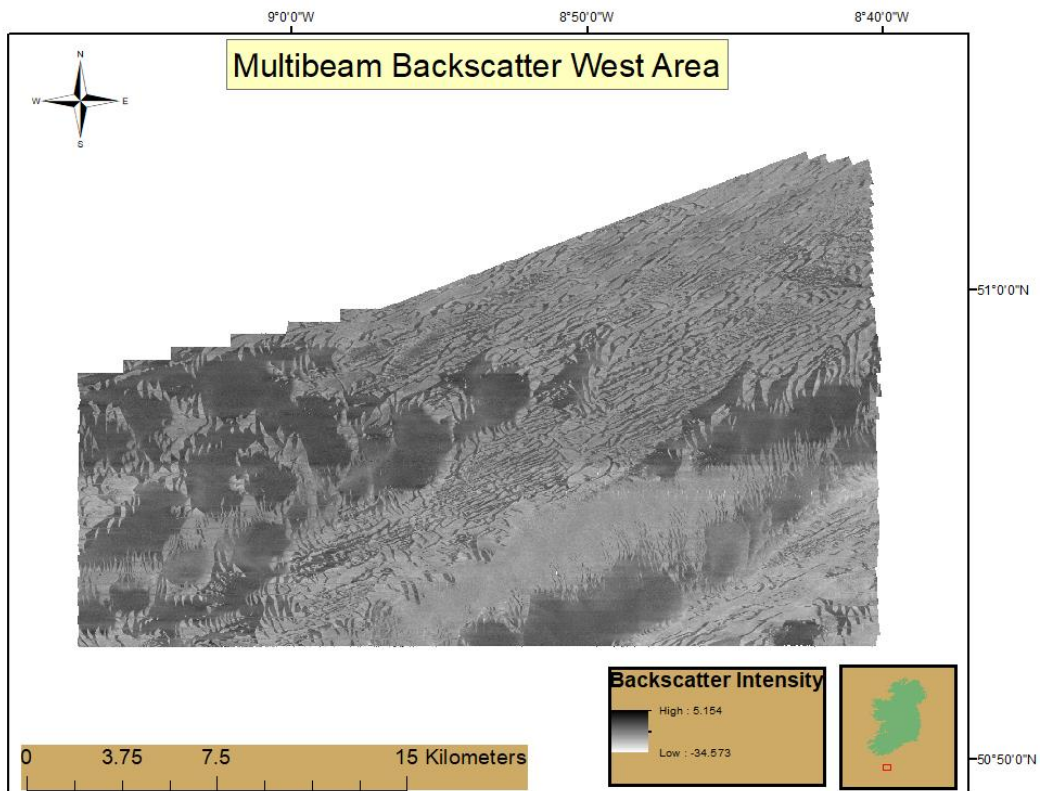


Figure 19: MBES backscatter mosaic western area.

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### **4.3.2 Shallow Geology Analysis**

SBP data quality was generally poor as a result of noise issues with the system and environmental factors relating to sea state and sub-bottom reflector 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 SBP data acquisition. Sea state varied significantly during the survey and in general the seabed and sub-bottom sediments are hard apart from sand ribbons. A persistent coherent noise issue was present throughout which Knudsen are attempting to trace and resolve. This combination of factors resulted in poor sub-bottom penetration and sub-surface horizon delineation.

SounderSuite software recorded data in proprietary Knudsen .kea and .keb formats initially. Modification of the data recording options mid-survey allowed .sgy data format logging also. SGY data were converted to coda format using Coda File Utilities™ software. Coda files were replayed in Coda GeoSurvey™ software and tiff images created. Profile lines 252 and 271 are selected for discussion here. Their geographical locations are shown in Figure 20 where the profile extents have been overlain on backscatter data. Both profiles were acquired in the western area.

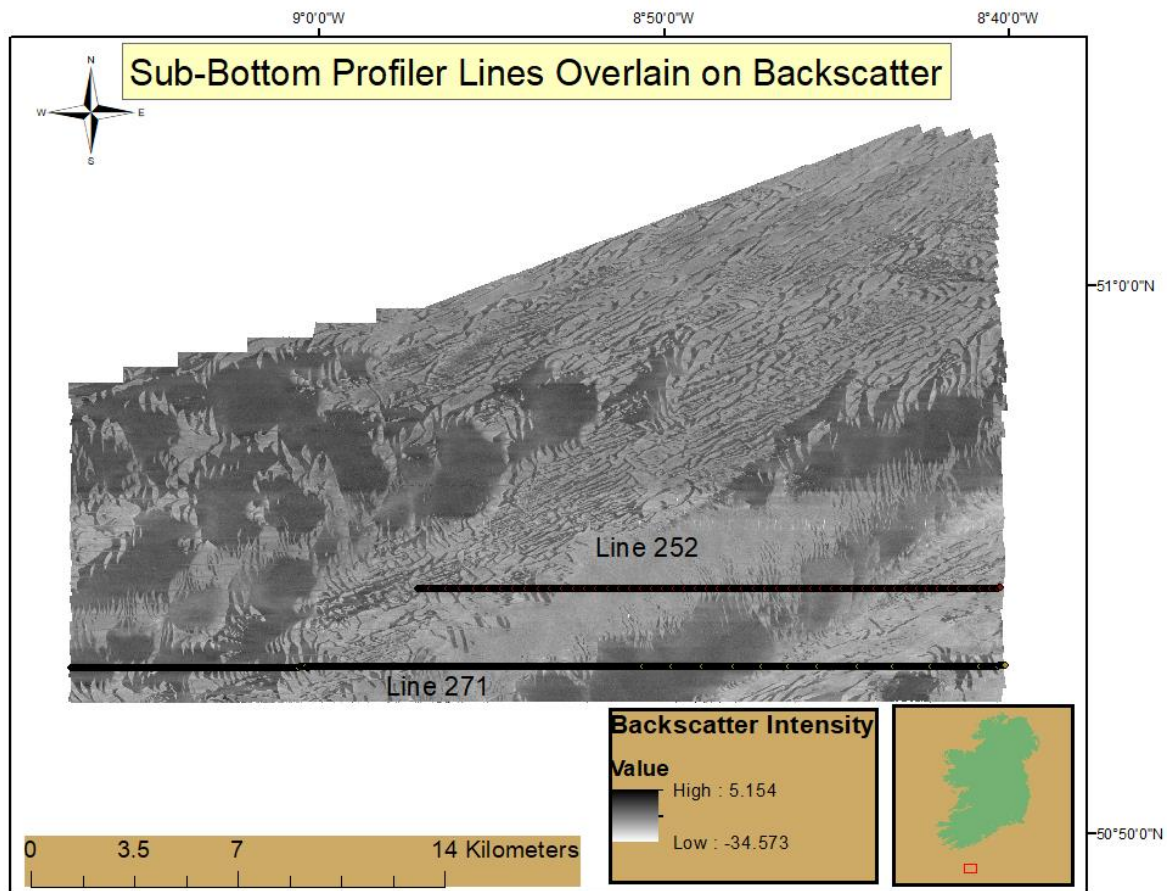


Figure 20: SBP lines 252 & 271 overlain on backscatter data.

Interpreted SBP tiff images of profile lines 271 and 252 are shown in Figures 21 and 22 respectively. A bandpass filter with low cut 1.7 kHz and high cut 4.7 kHz was applied in processing, along with a suitable gain. Seabed tracking and heave compensation are applied to the images. Horizontal scale lines are at 10 m intervals.

Profile 271 in Figure 21 is 36.6 km in length. The profile was acquired from west to east. Data quality is poor to moderate due to the issues outlined above. Loss of seabed tracking in places is due to weak signal return from the seabed and results in data clipping. An acoustically transparent unit of unknown thickness is the base unit throughout. This is annotated as Unit 1. Unit 1 is unconformably overlain by Unit 2. Sand ribbons interspersed with coarse sediment lag deposits are found either side of a prominent ridge. These sand ribbons are less than 1 m in amplitude and are up to several hundred metres in width. They are clearly visible on the backscatter mosaic. Coarse sediments deposited are in areas of low seabed relief and appear as diffractions on the acoustic signature.

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Profile 252 in Figure 22 is 19.6 km in length. The survey line was acquired from west to east. Signal penetration is poor and data quality poor to moderate due to the factors listed previously. Observed artefacts in Figure 22 include data dropouts due to cavitation, ringing in the near sub-surface and lost seabed tracking due to weak signal returns.

Unit 1 is the base unit throughout the profile extent. It is characterised by an absence of internal reflectors. It is overlain unconformably by Unit 2. The reflector denoting the base of Unit 2 is best observed either side of the prominent ridge.

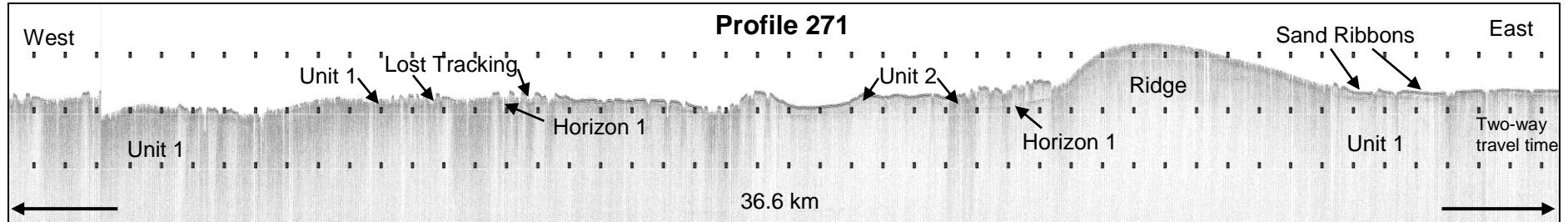


Figure 21: SBP interpreted image, line 271.

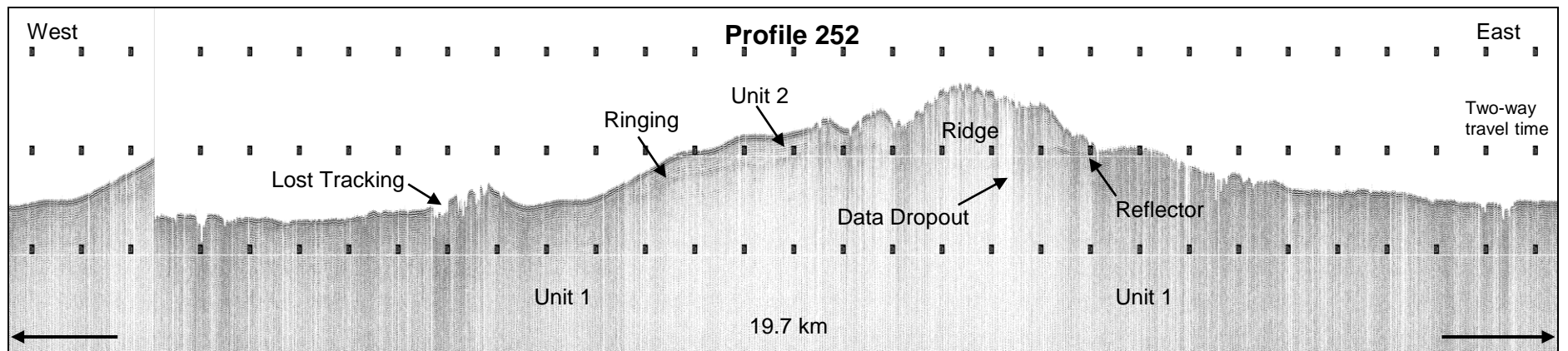


Figure 22: SBP interpreted image, line 252.

### 4.3.3 Bathymetry

Figure 23 shows the colour coded MBES bathymetry image for both the eastern and western areas. Water depth varies from 92 to 106 m in the east area and from 98 to 131 m in the west area. Very gentle seafloor gradients are found throughout. The most prominent bathymetric feature is a ridge in the western area. It is 30 m in amplitude and up to 4 km in width. The ridge is orientated NE-SW.

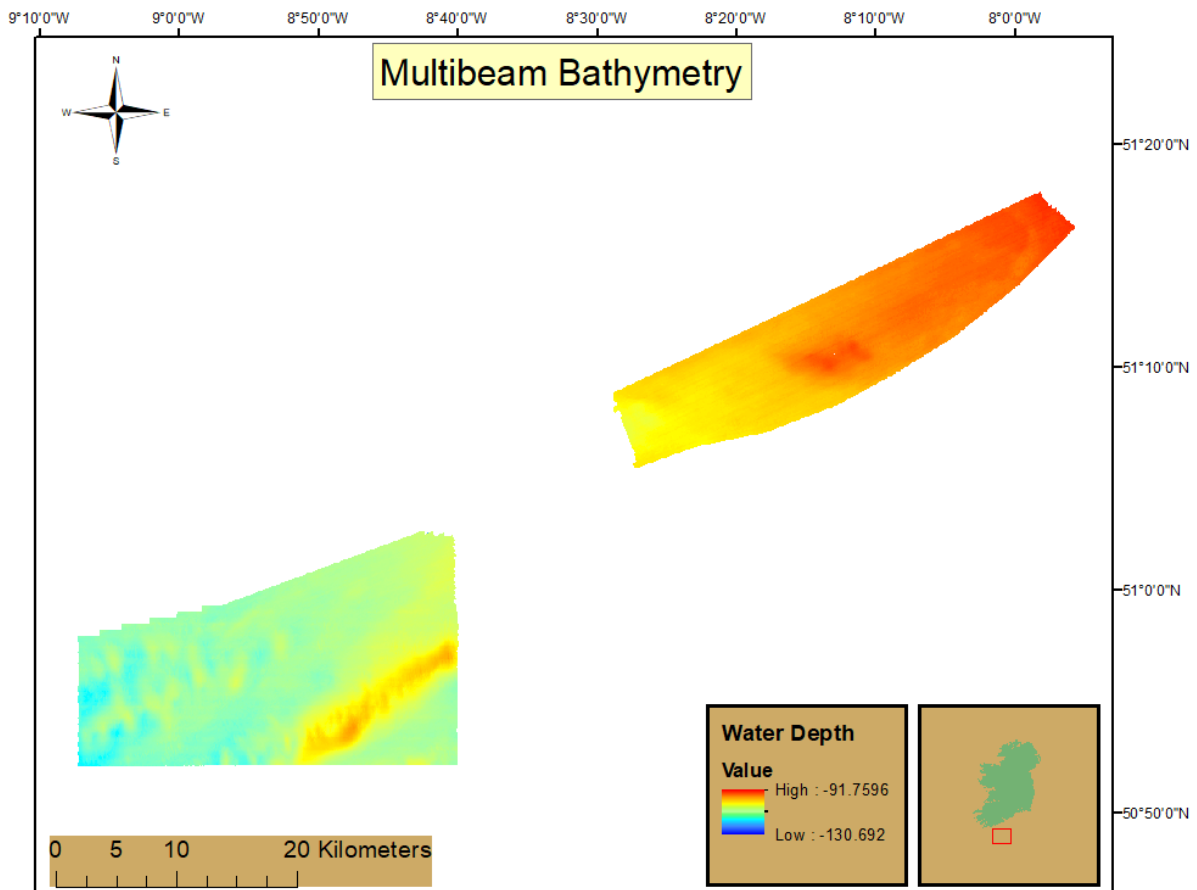


Figure 23: MBES bathymetry image both areas.

Figure 24 is a colour coded MBES bathymetry image of the ridge crest. It shows sand ribbons on the top of the ridge. The ribbons are less than 1 metre in amplitude above the surrounding seafloor. Ribbons are orientated along north – south axes.

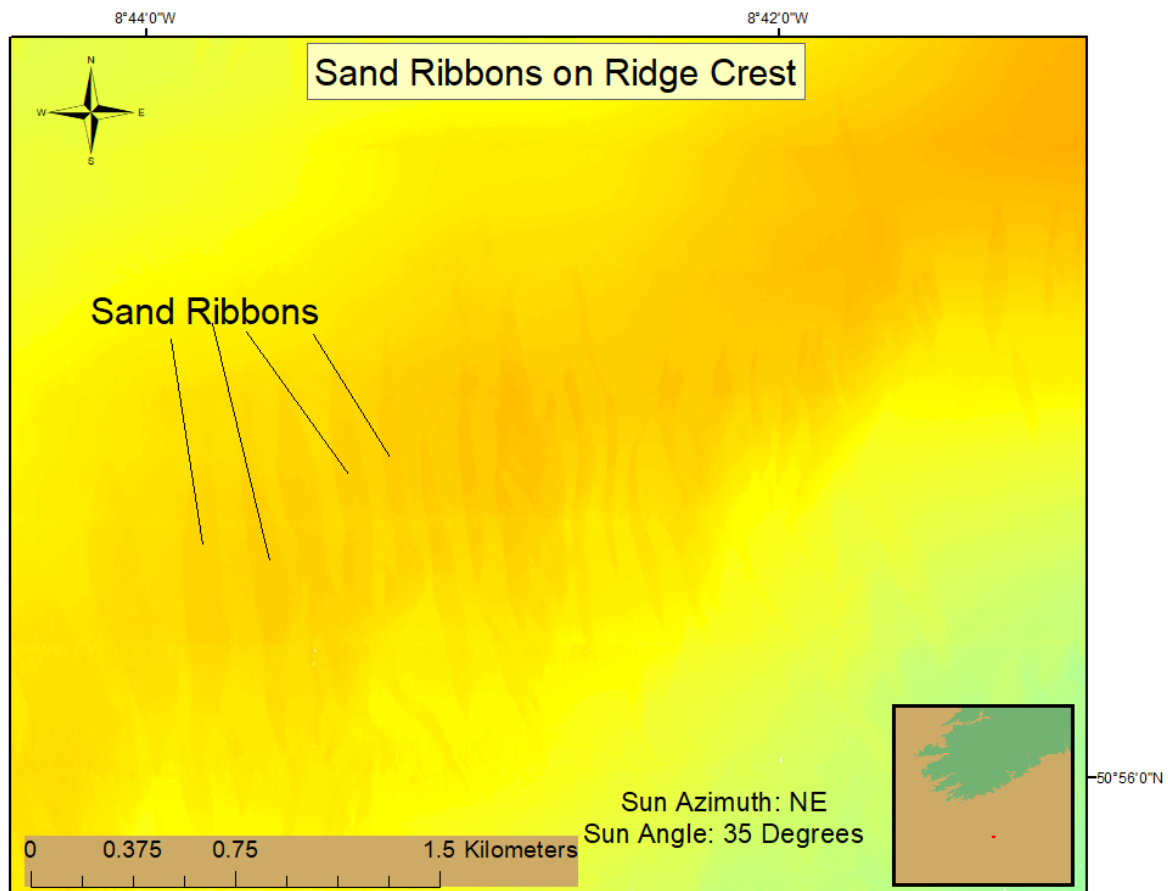


Figure 24: MBES bathymetry illustrating sand ribbons on ridge crest.

#### 4.3.4 Seabed Texture

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

Backscatter intensity values vary from 5.2 to -34.6 db. The backscatter images in section 4.3.1 show that a wide variety of backscatter responses are present, indicating a diversity of substrate types. Relatively low backscatter seabed types dominate the eastern area. The western area has a roughly equal split between relatively high and relatively low backscatter types.

Figure 25 shows backscatter data from a subset of the western area. The convention used in this report is that dark coloured areas represent relatively higher backscatter intensity than light coloured areas. Groundtruthing data is unavailable for the western area. Evidence from adjacent areas show that the high backscatter regions are gravel dominated seabed and that the low backscatter regions are sand dominated.

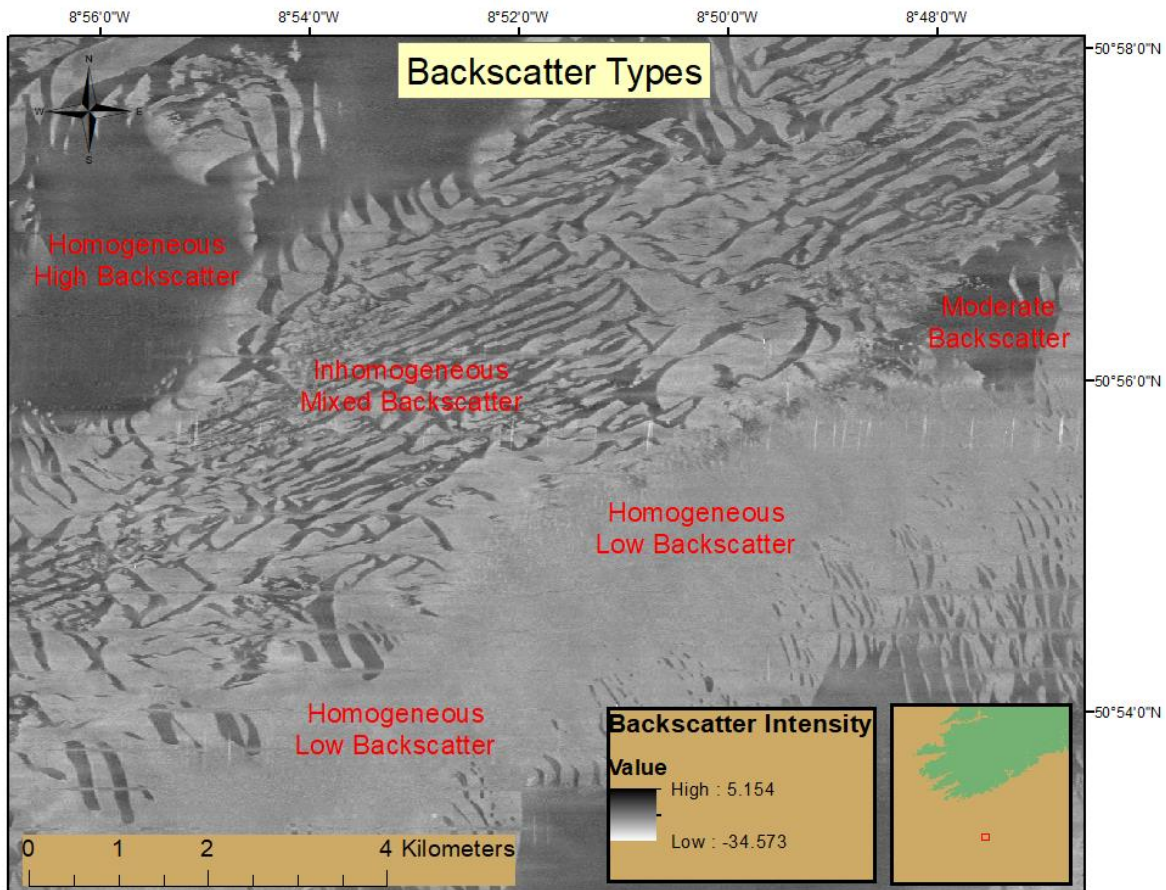


Figure 25: Backscatter data illustrating backscatter types in the western area.

Figure 26 shows a subset of backscatter mosaic data for the eastern area. An area of homogeneous high backscatter substrate is surrounded by inhomogeneous mixed backscatter. Based on grab data the homogeneous high backscatter area comprises mainly gravels. Poorly sorted sediments of gravel, sand and mud are found in the inhomogeneous mixed backscatter areas.

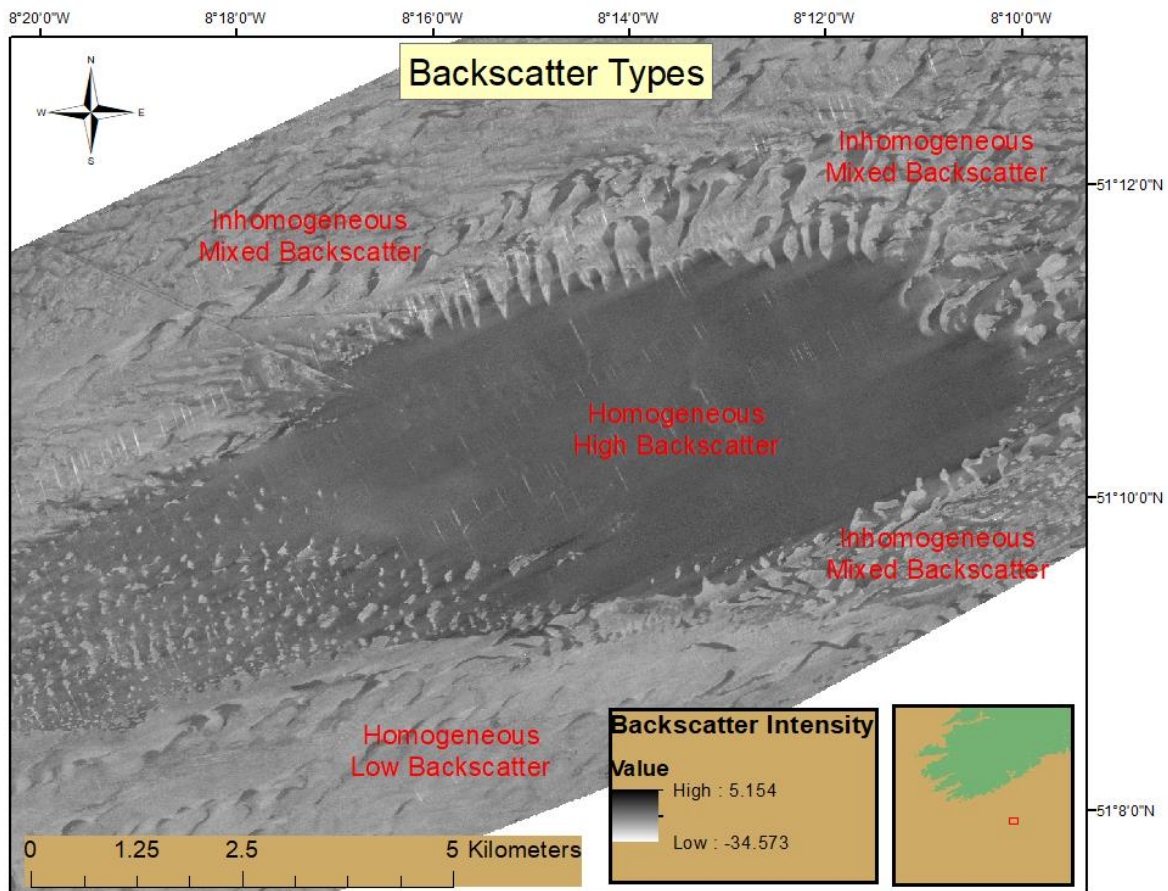


Figure 26: MBES backscatter illustrating backscatter types east area.

#### 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 35° angle over the depth colour coded MBES bathymetry dataset.

Figure 27 is a shaded relief image of part of the western area. Sun illumination is from the north-west at an angle of 35°. Sand ribbons and scoured substrate are highlighted in the image.

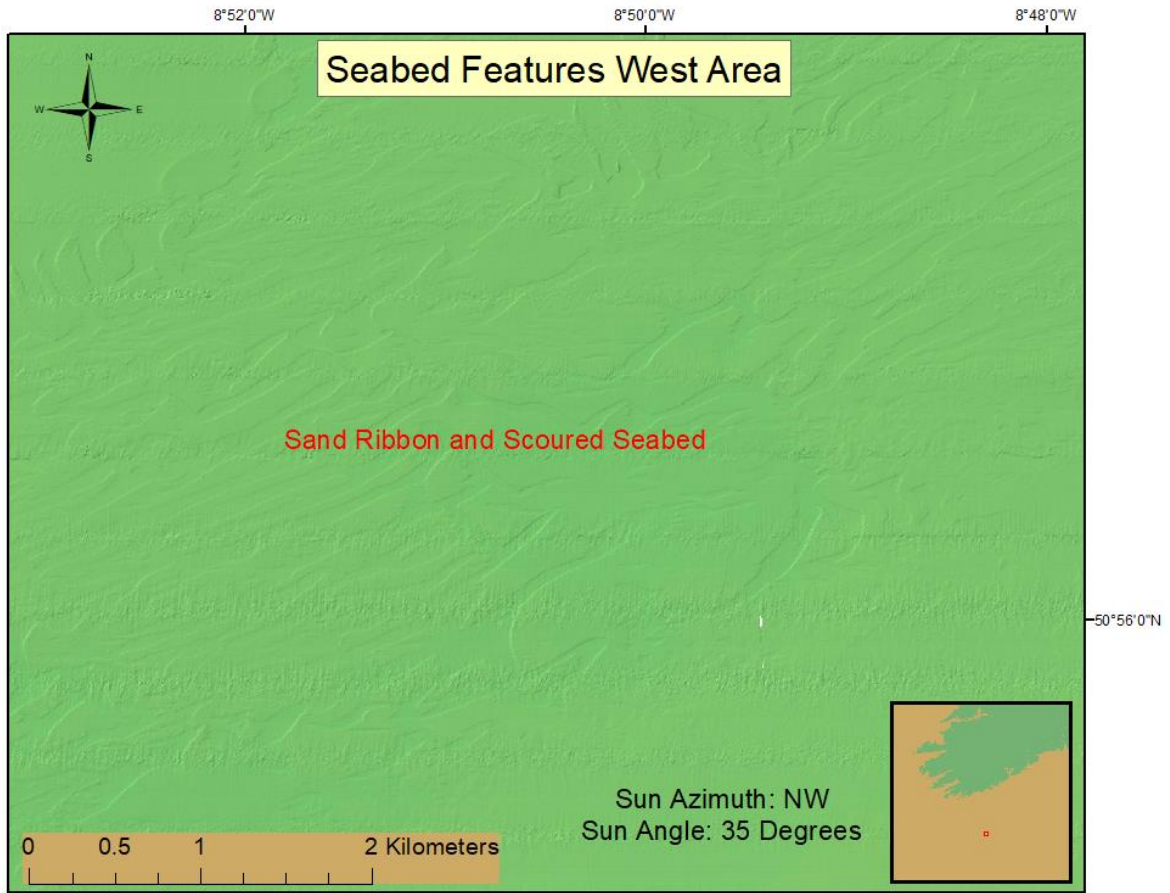


Figure 27: MBES shaded relief illustrating seabed variability.

Figure 28 is a shaded relief image of the ridge crest in the western area. Sun illumination is from the north-east at an angle of 35°. The sun azimuth clearly illustrates the scouring and ribbon features on the ridge crest.

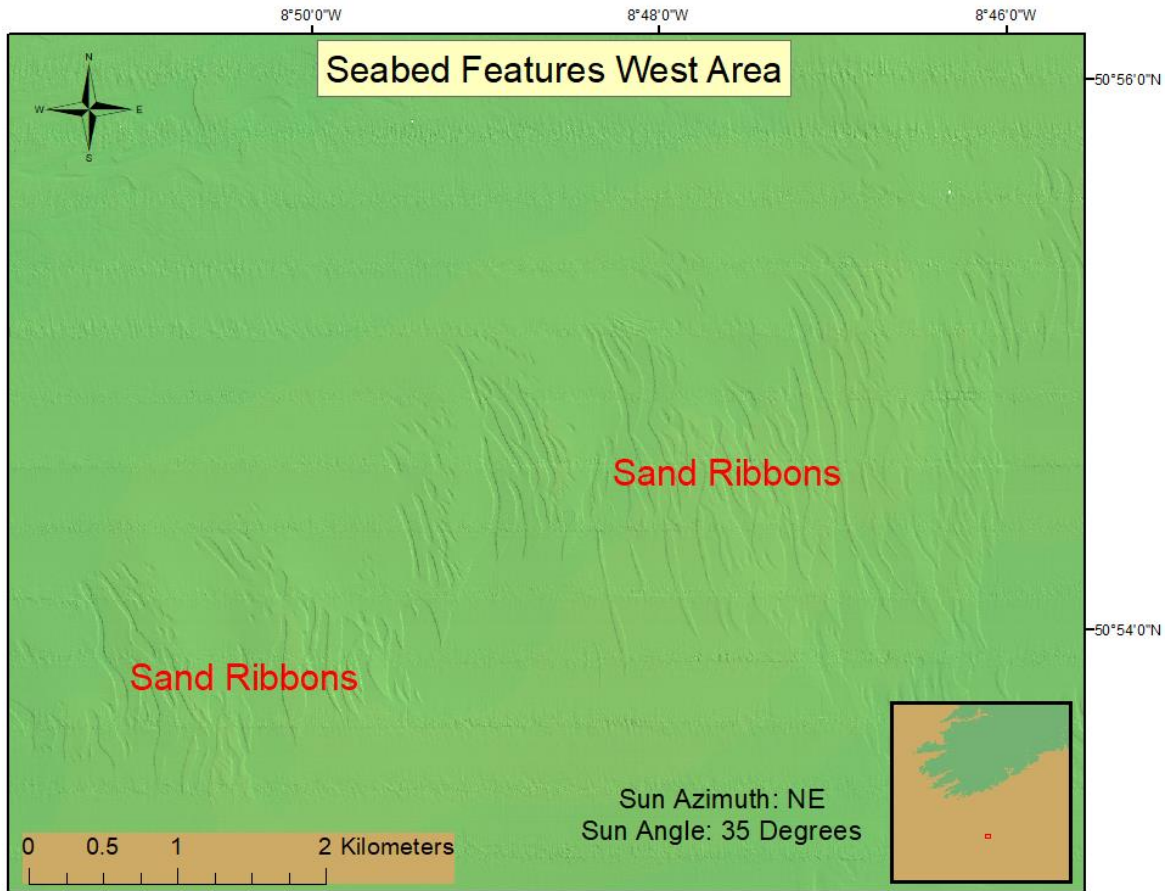


Figure 28: MBES shaded relief illustrating sand ribbons.

#### 4.4 Groundtruthing

Groundtruthing was not undertaken during this survey however Day Grab data acquired during 2011 is available. These grabs were acquired on part of the eastern area as part of another project. Particle size analysis results on the data has been completed and the Folk Classification results are shown in Figure 29. Results indicate a wide variety of sediment types, from gravels to sands and muds with a wide variation in sediment sorting between stations.

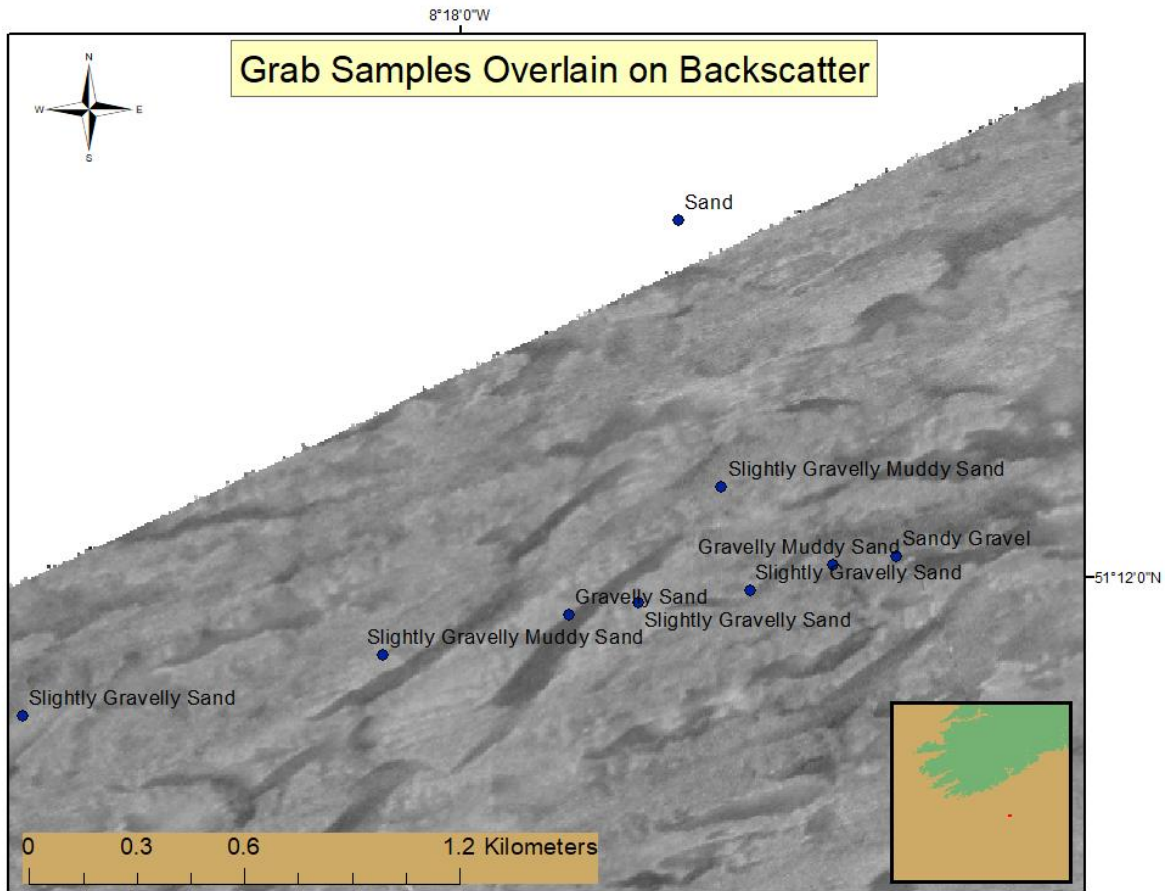


Figure 29: Folk classification from grab data overlain on backscatter.

#### 4.5 Wrecks

Two wrecks were mapped in detail. A H525 form was filled out for each and sent to the UKHO. Admiralty charts will be updated in due course. Table 18 provides the wreck metadata for the mapped wrecks.

Number	Latitude	Longitude
1	53° 09.6304 N	-009° 41.0148 W
2	50° 59.1884 N	-008° 51.6219 W

Table 18: Wreck investigation metadata.

Figure 30 shows the mapped wreck locations. Note that one of the wrecks was mapped in Galway Bay enroute to the survey area.

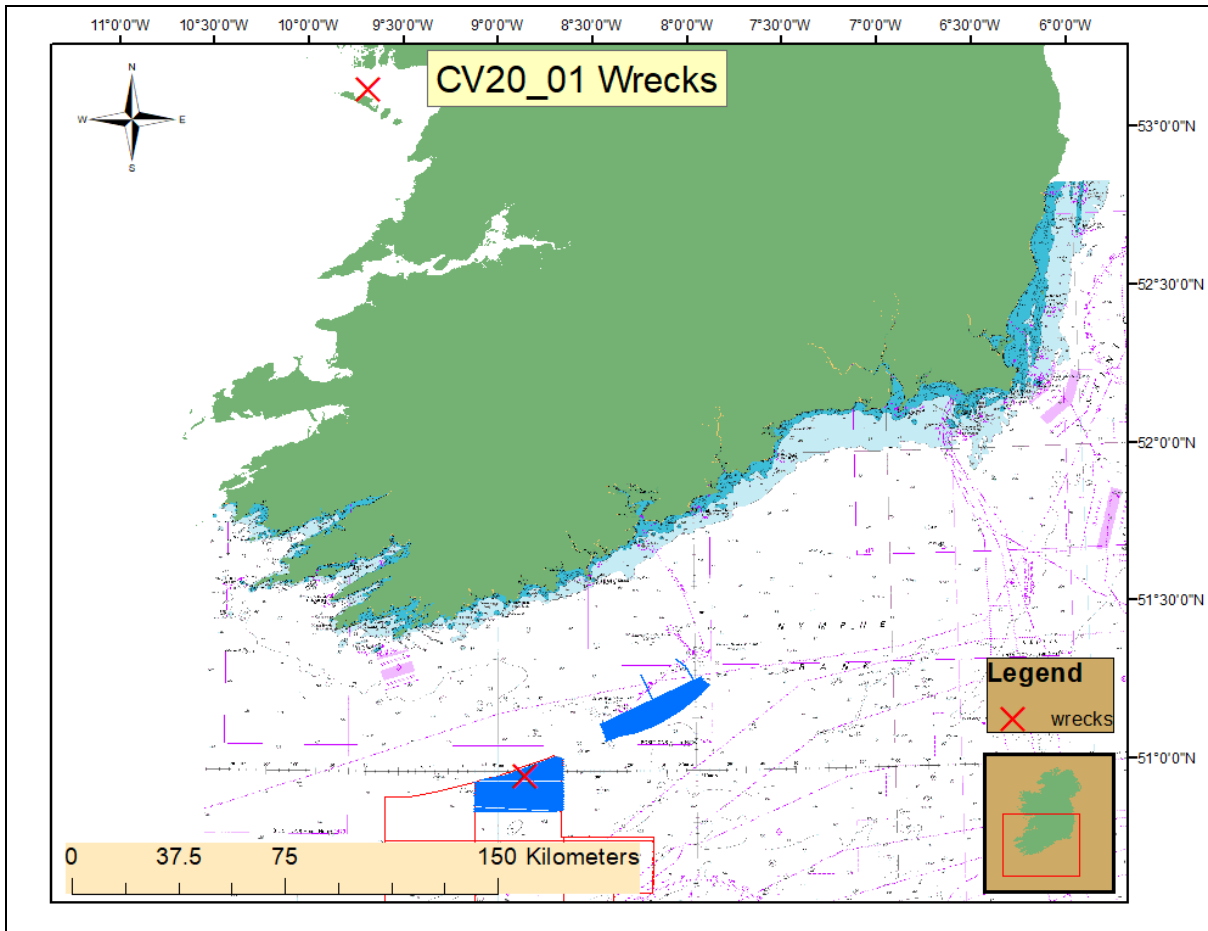


Figure 30: Mapped wreck location plot.

Table 19 contains MBES data images of the mapped wrecks.

Wreck 1	Wreck 2
<p>This image shows a 3D bathymetric view of a shipwreck. The wreck is a dark, elongated object resting on the seabed. The surrounding seabed is colored in shades of green and yellow, indicating depth variations. A vertical scale bar on the left side of the image shows depth values from 20.4 to 20.4 meters.</p>	<p>This image shows a 3D bathymetric view of a shipwreck. The wreck is a dark, elongated object resting on the seabed. The surrounding seabed is colored in shades of blue and green, indicating depth variations. The image is displayed within a software interface with various toolbars and panels.</p>

Table 19: MBES wreck images.