Greater Dublin Drainage Scheme:

Hydrographic Survey Report GEO13_GDD

Fingal County Council

TW/13/PRJ-012

30th May 2013

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Private and Confidential

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1. Introduction

1.1 Executive Summary

Between 6th February and 3rd March 2013, TechWorks Marine conducted a set of near-shore seabed surveys on behalf of Fingal County Council (FCC) in two areas North of Dublin. The purpose of these surveys was to investigate the seabed properties of each area and to ascertain their suitability for the optimum location of a marine outfall pipeline to serve the new WWTP of the greater Dublin area. This process involved the acquisition and analysis of high resolution bathymetry and backscatter data in order to build up an overview of the surface and shallow geology for each of the possible candidate sites. This report details bathymetric analysis carried out for the potential sites off Skerries (Site A) and Howth (Site B) Co. Dublin.

The survey results and data obtained from the investigation will be used by Jacob's Engineering team to determine the optimum location of the marine pipeline.

Site A

Running from West to East the Skerries area features agricultural land slopping gradually to the cliff edge (50mOD – 10mOD). The cliff then drops down 6mOD to the high tide mark. The coastline here is characterised by sandy inlets and jutting outcrops of limestone and shale. The rocky shore line meets the fine sedimentary layer and a gradual sandy sloping seabed deepens from-3mOD to -18mOD with rocky outcrops in places. Beneath the sediment layer the depth to the bedrock varies from < 2m to c. 30m but is generally <12m thick in most areas with the largest values recorded in the east.

Site B

The Howth site is characterised by flat sandy beaches and a gradual featureless sloping seabed. Running from West to East the land slopes gradually NE to the channel (20m-0m OD) in front of the Portmarnock golf course. The land then rises up to the sand dunes (8m OD) before sloping down to the high tide mark. The very flat nature of the beach means the intertidal zone stretches >250m to the LAT mark. The featureless sedimentary seabed gradually slopes from -3mOD to -22mOD in the east. Beneath the sediment layer the depth to the bedrock varies from < 2m to c. 30m but is generally <16m thick in most areas with the largest values recorded in the east.

2. Project Overview

2.1 Survey Area Site A

Survey work was carried out on the South East coast of Skerries Islands, Co. Dublin between Ballyhavil in the north and Loughshinny to the south. The Survey area extends approximately 4km east offshore from Rockabill View and covers depths ranging from 0-20 metres LAT (lowest Astronomical Tide).

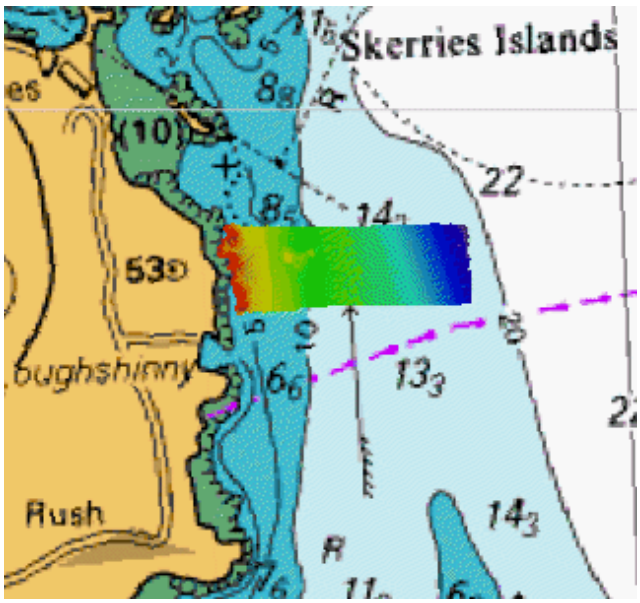


Figure 1- TechWorks Marine Project survey area Site A

2.2 Survey Area Site B

Survey work was carried out on the North coast of Ireland's Eye, Co. Dublin. The Survey area extends approximately 5km east offshore from Portmarnock Beach and covers depths ranging from 0-25 metres LAT (lowest Astronomical Tide).

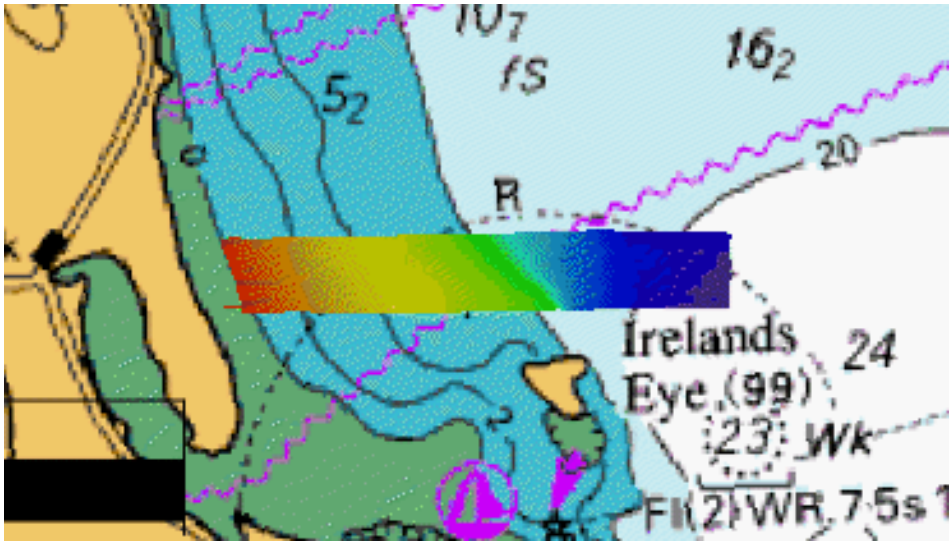


Figure 2 - TechWorks Marine Project Survey area Site B

2.3 Lat/Long coordinates

Table 1 -Survey area boundaries

Point	Easting's	Northings	Latitude	Longitude (-ve)
Area A				
A	326171.317	258204.199	53o 33'31.585''	6o 5'48.225''
B	330431.034	258204.199	53o 33'27.841''	6o 1'56.956''
C	326171.317	257242.853	53o 33'0.508''	6o 5'49.62''
D	330431.034	257242.853	53o 32'56.765''	6o 1'58.398''
Area B				
A	323422.398	242699.988	53o 25'12.714''	6o 8'39.408''
B	330431.034	242699.988	53o 25'6.65''	6o 2'20.13''
C	323422.398	242038.541	53o 24'51.33''	6o 8'40.399''
D	330431.034	242038.541	53o 24'45.267''	6o 2'21.114''

2.4 Survey Platform

Survey work for both sites was carried out by the RV Geo, which is run by the Geological Survey of Ireland for use on the INFOMAR programme.

The RV Geo is a 7.5 m RIB used to map very shallow/ intertidal water depths. She is equipped with a SEA (Systems Engineering and Analysis) Swathplus interferometric mapping system allowing for wide swath coverage in shallow water depths. Much can be inferred by examining the high resolution bathymetric data from the RV Geo. Positioning, heading and motion information is provided using an Applanix POS-MV integrated system. The RV Geo is typically crewed by a team of two individuals.

Figure 3 - GSI owned RV GEO Dun Laoghaire Marina

Table 2 -Survey Vessel Specifications

R.V. Geo Vessel Specifications	
Length	7.5 m
Beam (moulded)	2.5 m
Draught	1.5 m (With transducer down)
Engines	250hp Yamaha
Speed	28 knots
Fuel	200 lt Diesel
Generator	Panda 8 kVA
Max passenger and crew	4 persons
Passenger Licence	P6

2.5 Survey Equipment

Table 3- Survey Equipment on board the R.V. Geo

Survey Equipment		
System	**Type**	**Comment**
Interferometer	SEA SWATH System	468 kHz
Positioning system	POS-MV 320	With PosPac PPK software
Differential GPS	Hemisphere RTCM DGPS	Coastguard broadcast
RTK GPS	Leica GPS	Shore based logging (PPP)
R/T Sound Velocity Probe	AML SVP 'smart probe'	Mounted with Swath head
Sound Velocity Probe	Castaway	Backup: AML Smartprobe

2.6 Survey Team

Survey operations for GEO13_GDD were conducted by the personnel listed in Table 2

Table 4 -Personnel on board the R.V. Geo

GEO13_GDD Survey Team		
Adam Partington	Marine Scientist	TechWorks Marine
Ronan O'Toole	Surveyor	GSI
John Deasy	Surveyor	Independent

2.7 Geodetic Parameters

Geodetic Parameters	
GEO12_01 Vessel Geodetic Parameters	
Datum	ITRS89
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
Local Datum Geodetic Parameters	
Datum	ETRS89
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 29/30 (CM)	009º West or 003º West (depending on survey site)
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	Metres

2.8 Base of Operations

The base of operations for survey leg GEO13_GDD began in DunLaoghaire Harbour, Co. Dublin. From here, the R.V. Geo conducted calibration lines in the harbour before it transited north to conduct survey operations in Survey area B (Howth site - Ireland's Eye). While working in the survey area B, the R.V. Geo mapped everything in as shallow as possible depending on tide and weather conditions. During survey operations in area B, the R.V. Geo was moored in Howth Yacht club. Once survey area B was completed, the R.V. Geo Survey base of operations was moved to Malahide harbour further north. This reduced the transit time to the second area (Skerries) - Area A. The RV Geo also ran some exploratory lines into Howth and Malahide harbour channels.

2.9 Survey Statistics

For a full list of daily logs and activities. Please see the attached document (Daily logs.xls)

Table 5 - Cumulative survey statistics

Category	Percentage	Duration (hours:min:secs)
Port Call	73.07852675	262:54:00
Standby	4.17882789	15:02:00
Mobilisation	1.908732916	6:52:00
Transit	5.235116979	18:50:00
Operational	14.25526986	51:17:00
Down Time Vessel	0.203845263	0:44:00
Downtime Survey	1.139680334	4:06:00
TOTAL	100	359:45:00

Table 6 -Breakdown of Event Descriptors

Descriptor	Events Covered
Port Call	Vessel Alongside, usually for night hours, PR events
Operational Standby	Vessel is working but not acquiring survey data
Downtime Vessel	Operations ceased due to problem with vessel systems
Downtime Survey	Operations ceased due to problem with survey systems
Transit	Vessel is operational and travelling to destination
Mobilisation	Raising/lowering transducer heads, loading/unloading vessel

2.10 Survey Vertical Datum and VORF Model

TechWorks Marine has used the UKHO VORF (Vertical Offshore Reference Frame) sea surface model which is integral to processing data from GSI vessels. This model allows the use of 'GNSS tides' and relates all depth soundings to the WGS 84 ellipsoid. INFOMAR has gridded this model to a 1km resolution around Ireland to 15km offshore for reducing all soundings to Lowest Astronomical Tide - LAT (VORF). By utilising 'GNSS tides' there is no requirement to adjust for draft or squat.

2.11 Survey Order and Objectives

Survey work was carried out to International Hydrographic Organisation (IHO) Order 1A standard. The objective for this survey leg (GEO13_GDD) was to acquire high resolution bathymetric data and backscatter imagery for the shallow waters of two areas which are potential locations for a new marine outfall pipe.

2.12 Health, Safety, Environment (HSE) and Licensing

All personnel joining the vessel were given a safety induction tour. All survey personnel hold valid STCW95 marine safety training certificates and ENG11 medicals.

The R.V. Geo was equipped with all the necessary safety equipment for a P6 license including flares, extinguishers, EPIRB (emergency position-indicating radio beacons) and life buoys.

All on-deck operations were carried out by the survey crew and were performed with personnel wearing correct PPE.

The necessary licences were acquired for survey operations in both areas.

No loss time accidents occurred.

2.13 Challenges, Incidents and Troubleshooting

1. The vessel incurred 12 days of weather downtime and 1 day of standby while the vessel was lifted from the water for a structural survey

2. Minor episodes of troubleshooting were required from time to time, such as system restarts and PC timing checks.

3. The survey area was littered with lobster pots and there were several occasions where survey lines had to be adjusted to avoid prop fouling.

No other issues or troubleshooting occurred during the course of the survey.

2.14 MMO (Marine Mammal Observations)

Figure 4 - Photograph taken on 2/3//2013 of harbour seal spotted in transit to survey site A

Please see **Appendix C** for full MMO reports. The surveys conducted in this project abided by the National Parks and Wildlife Service's (NPWS) Code of Practice for the Protection of Marine Mammals during Acoustic Seafloor Surveys in Irish Waters. There was one marine mammal spotted during transit to survey Area A from Malahide harbour on the 02/03/2013 at 12:20. The harbour seal was spotted following a fishing vessel out of the marina. At the time the sonar system on the R.V. Geo was not running. As usual, once the crew arrived at the survey area a soft start was carried out in accordance with NPWS.

2.15 Soft Starts

In accordance with legislation from the NPWS, the survey team carried out 'soft starts' at the beginning of each survey day to reduce any potential impacts to marine mammals in the area.

Both crew members engaged in observations in transit to survey areas. After half an hour observational scans, the sonar was started for 20minutes in the following manner

1 min ON, 5min OFF, 1min ON 5min OFF, 1min ON, 1min OFF, 1min ON, 1min OFF, 1min ON, 1min OFF, 1min ON, 1min OFF.

This procedure was carried out during the stabilisation period for the POS MV navigation system.

3. Data Analysis

Results and conclusions from this study are based on an examination of key datasets acquired during TechWorks survey leg GEO13_GDD. These datasets and the associated software used to process them are described below.

3.1 Survey Site A – Skerries

Site "A" outlined in Figure 4 is located just south of the Skerries Islands and is bound by the green area in the image.

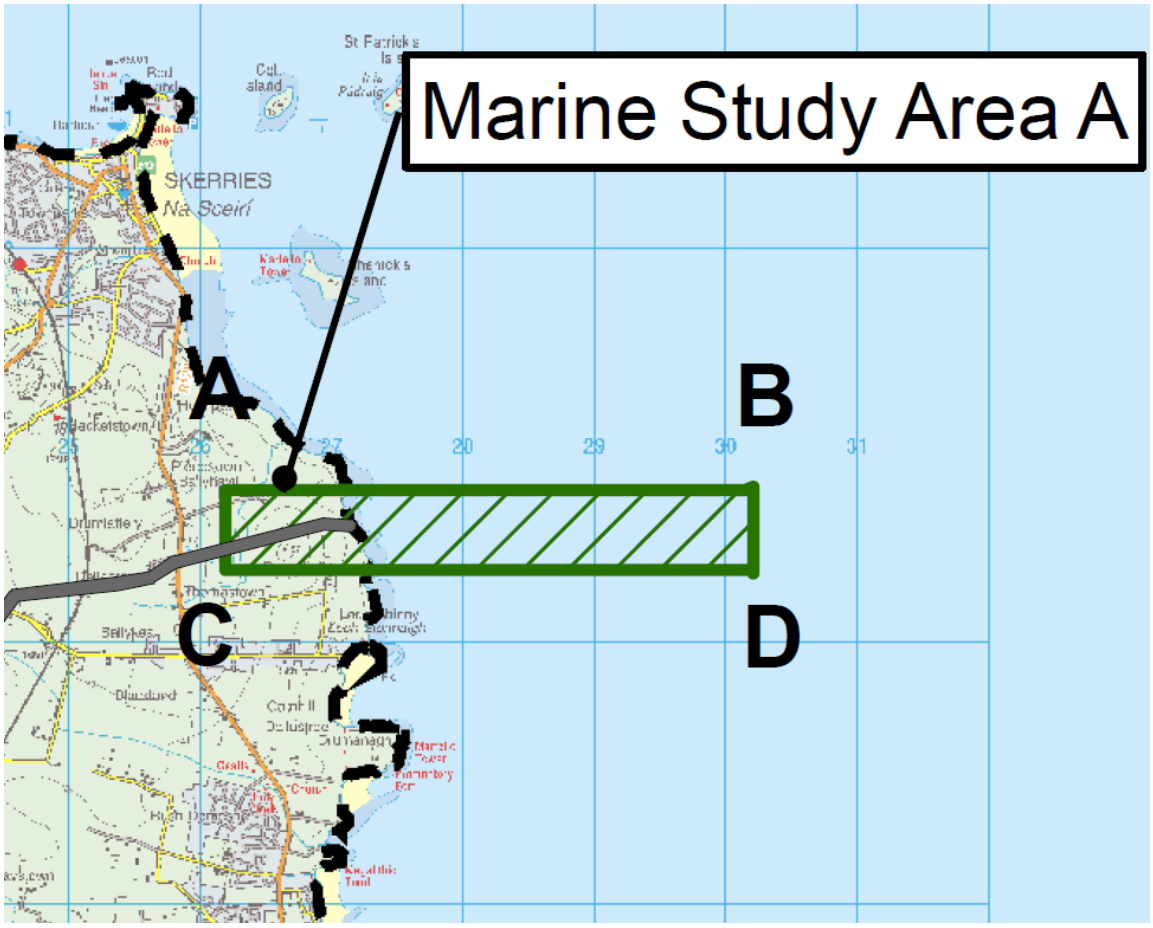


Figure 5- OSI map showing Survey Area of site A

The coast is characterised by small coves, inlets and cliffs along the extent of Site "A".

Figure 6- Google earth image of Site A survey area. The red lines represent the intended track lines of the survey vessel

Examination of Google Earth photographic imagery provides good evidence for the seabed characteristics in found in site "A". Figure 5 reveals steeply inclined bedrock overlain in places by a sedimentary infill. The image strongly suggests that this sedimentary cover (seen here as a blue/grey colouration) is sandy in nature. This is in agreement with bathymetric results seen in Figure 7.

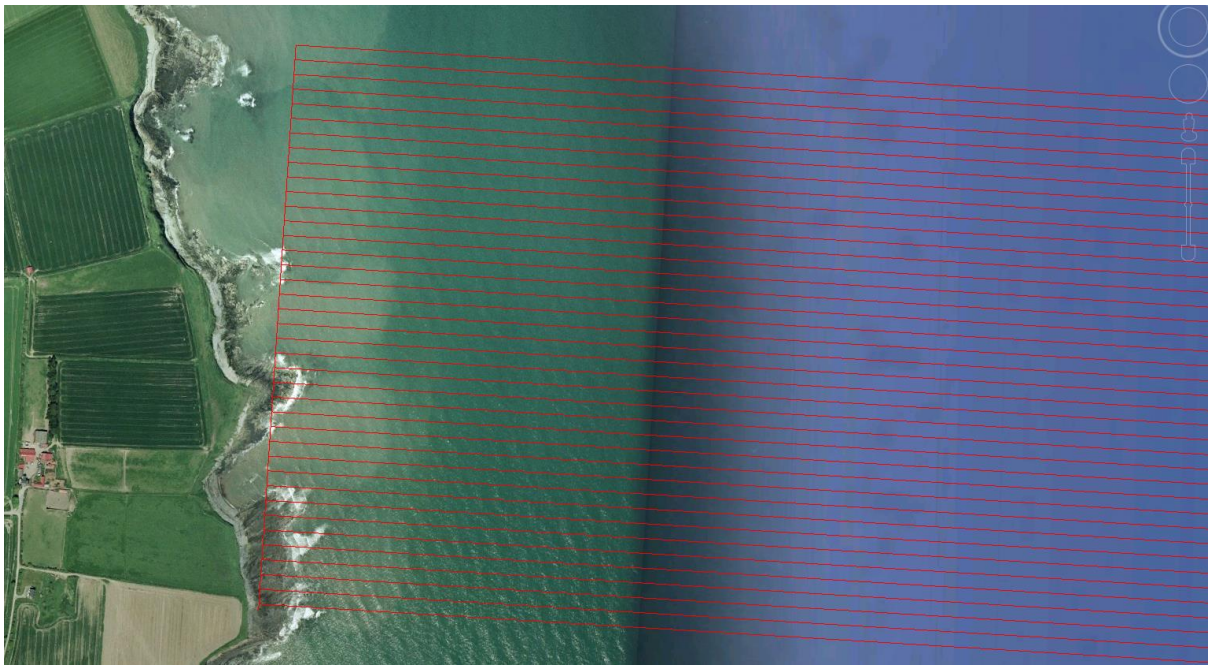


Figure 7- Google earth image of survey site A

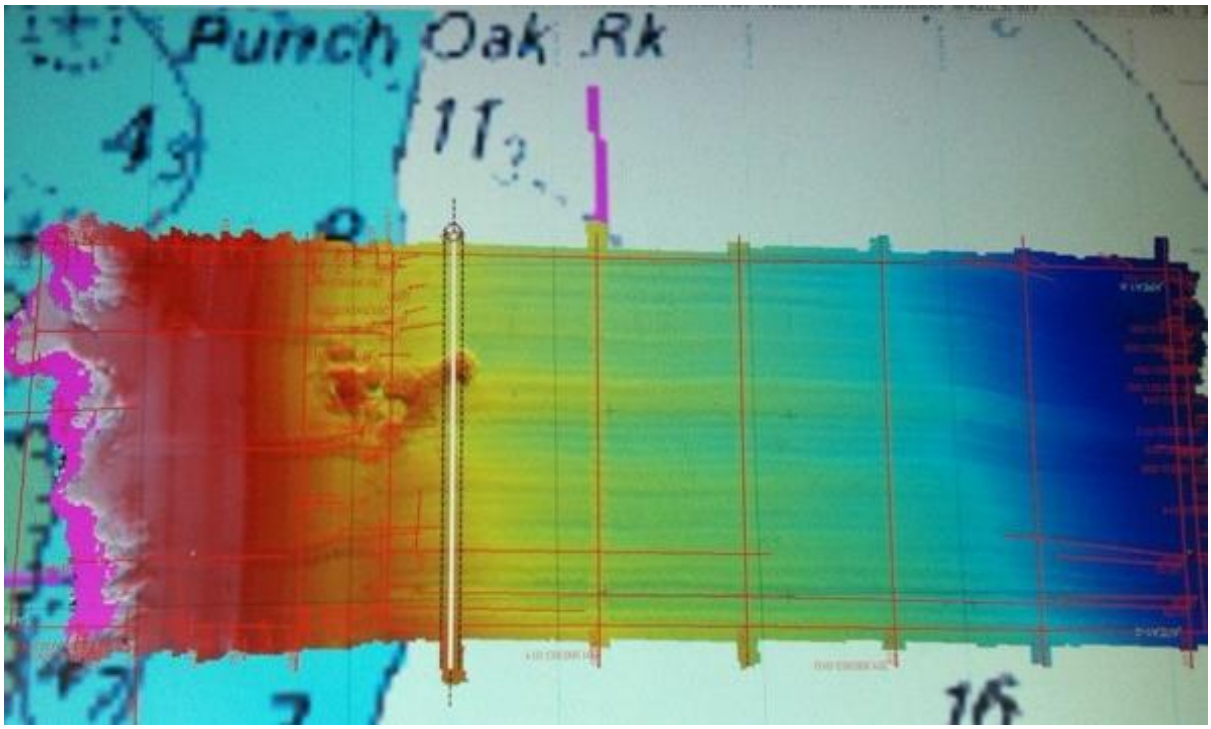


Figure 8 - Screen shot from the Swath image onboard the RV Geo showing the pre-processed Inteferometric sonar data

3.2 Survey Site B – Howth

Site "B" outlined in Figure 9 is located just north of the Howth headland and is bound by the green area in the image.

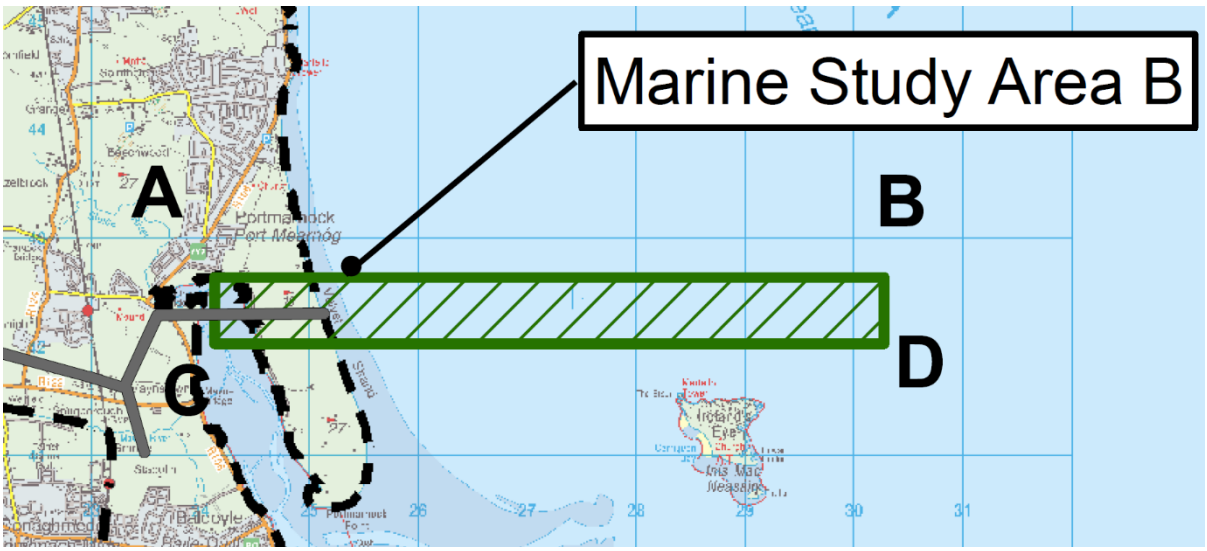


Figure 9- OSI map showing the extent of the survey area at site B

The coast is characterised by sandy beaches with a gradual sloping along the extent of Site "A".

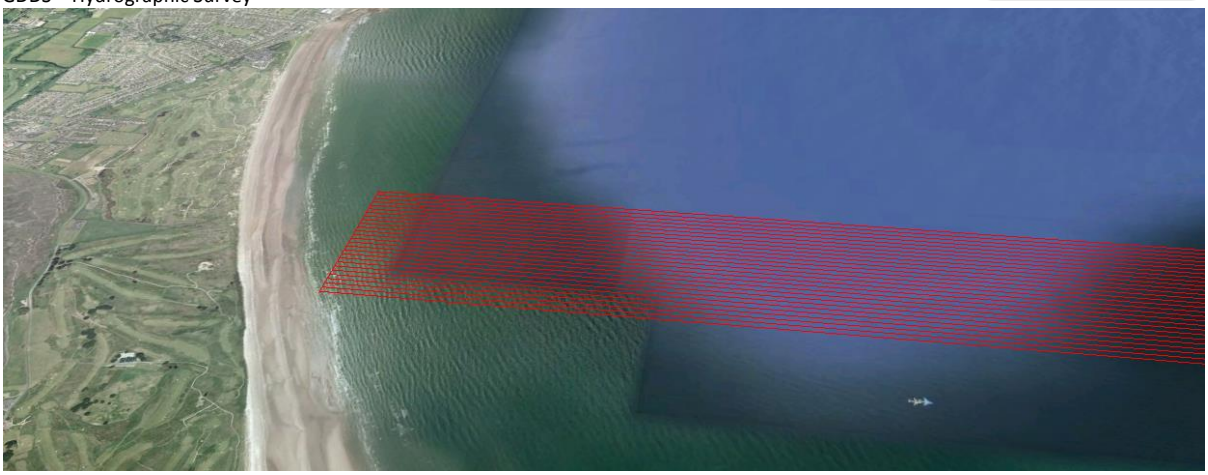


Figure 10 -Google earth image showing the survey area site B

Examination of Google Earth photographic imagery provides good evidence for the seabed characteristics in found in site “B”. Figure 10 reveals the gradual sloped sandy shoreline. The image suggests that this sedimentary cover is sandy in nature. This is in agreement with interferometric results seen in Figure 11.

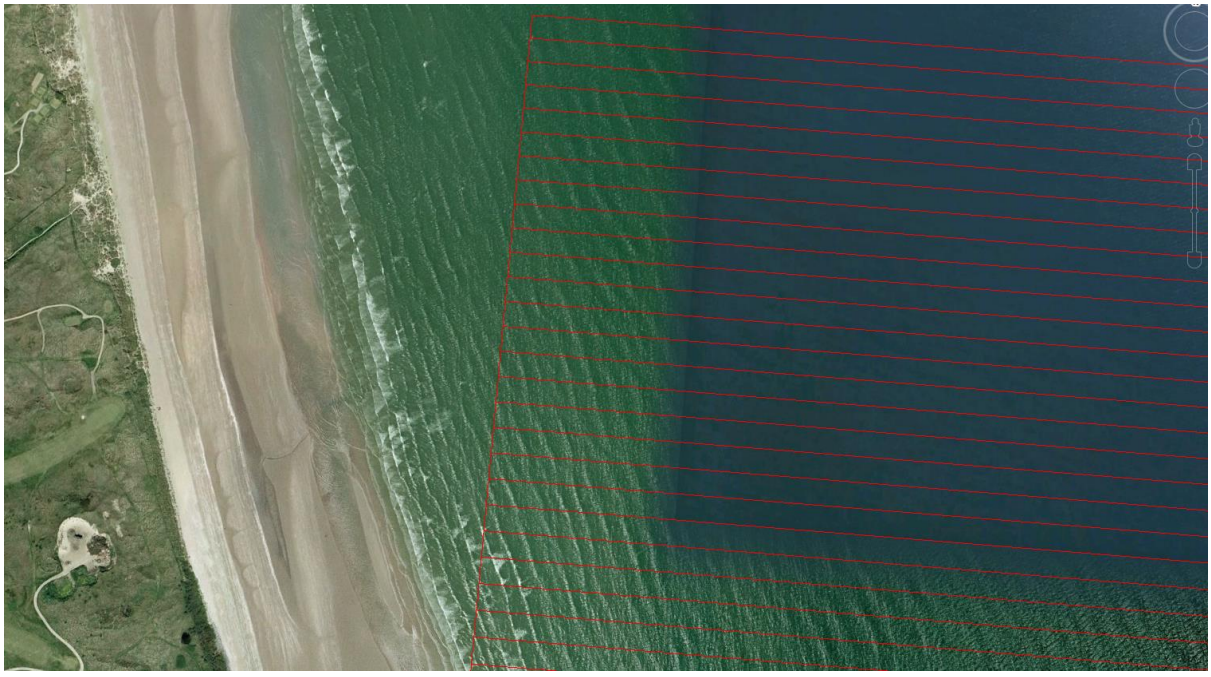


Figure 11 - Google earth image showing the survey area site B

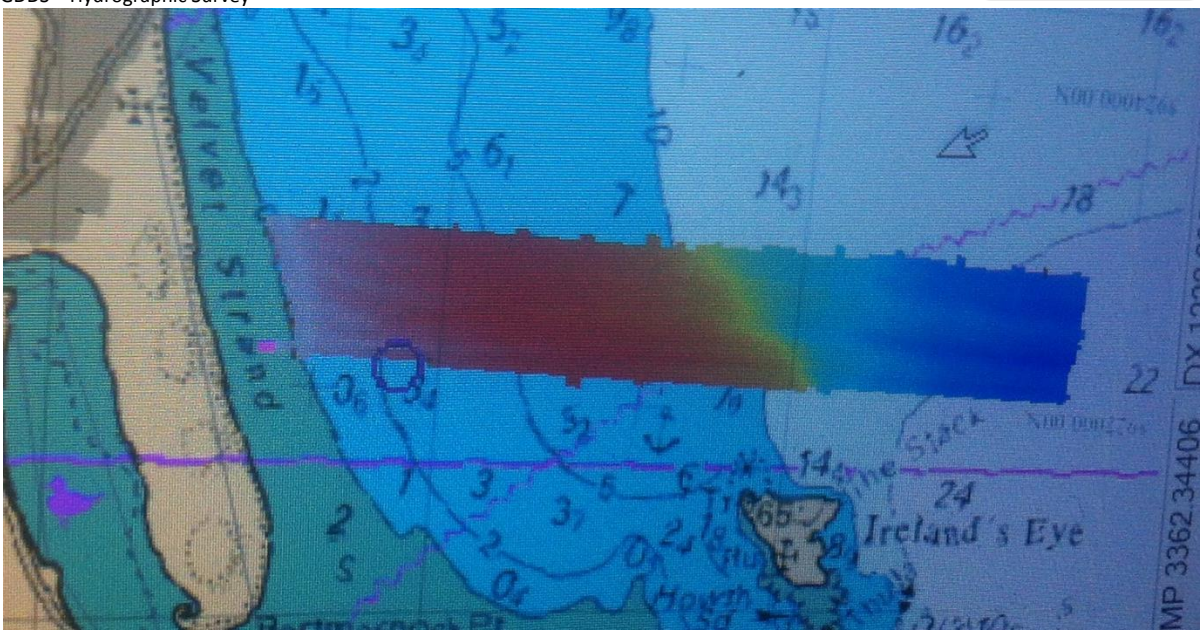


Figure 12 -Screenshot taken from onboard the RV Geo showing the Inteferometric coverage of survey area B

3.4 Sidescan sonar data

3.4.1 Site A

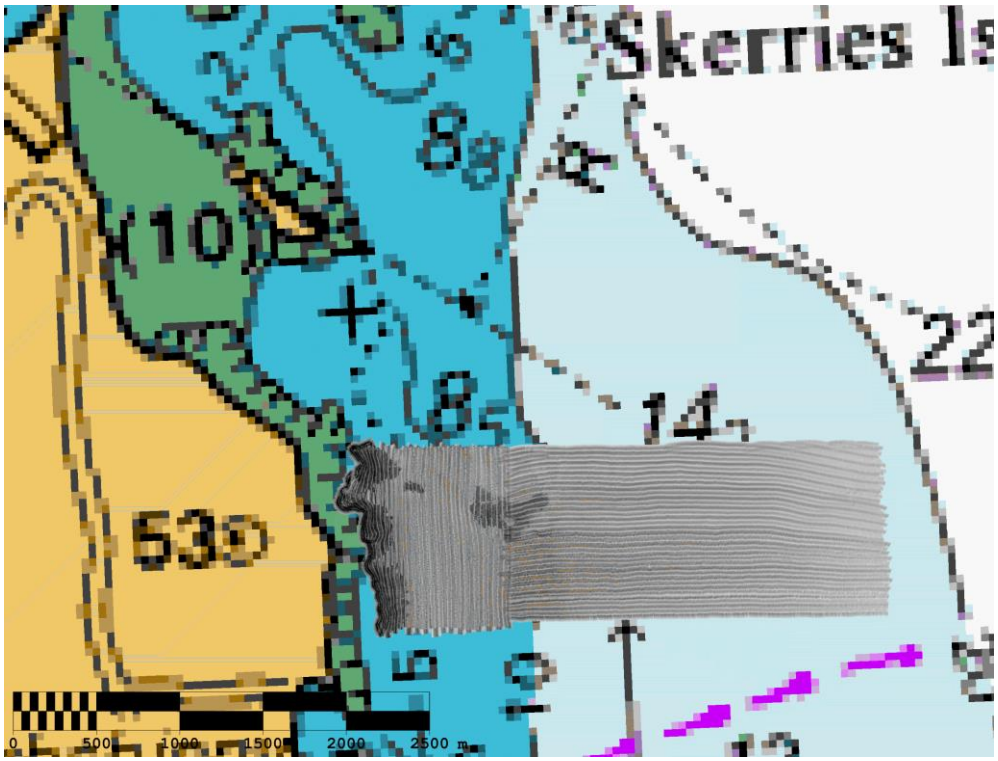


Figure 13- Processed backscatter data from survey site A

3.4.2 Site B

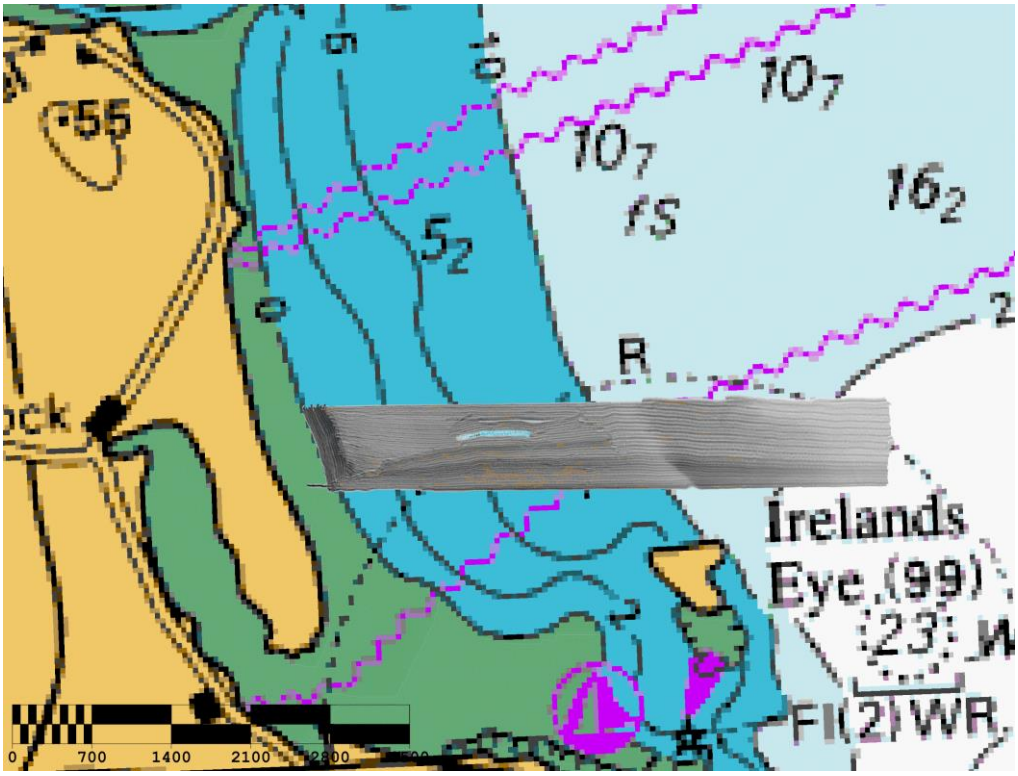


Figure 14 - Processed backscatter data from survey site B

4. Data Processing

4.1 Software

The primary data processing software packages used to process survey data are listed in Table 1.

Table 7 - Data Processing Software

CARIS HIPS and SIPS	Version: 7.1 with Hotfixes 1 to 6 (Feb 2013)
Applanix, POS PAC	Version: 6.1

4.2 SEA Swath Data

Inteferometric data on the survey was acquired using a SEA (Systems Engineering and Assessment Ltd.) Inteferometric SWATH System. Swath data was recorded in .sxr format through the swath system and in .xtf format using QPS QINSy software. This software was used for online quality control. A datagram from the SEA Swath software was sent to QPS QINSy software, which was used to display survey coverage and undertake survey line planning when necessary. Both the .sxr format and the .xtf format files were backed up to the portable hard drive at the end of each day and backed up to the servers in TechWorks Marine.

This data was exported from SEA Swath Processor Software and imported to CARIS 6.1 where the data was checked for consistency and accuracy. Data cleaning was undertaken to remove

incorrect depth information, while tidal effects and navigation spikes were compensated for using reprocessed navigation data from POS PAC 5.4. The resulting bathymetric imagery used in this report was exported from CARIS 6.1 and visualised in ARC GIS 9.3.1

Table 8 -Sonar Data logged during GEO_GDD

Main Lines	192
Calibration Lines	7
Crosslines	21
Data Files	440
Dataset size	57.8 GB
File format	.sxr and .xtf

4.3 Sound Velocity Data

During survey operations water-column environmental data was acquired using an YSI "Castaway" CTD to provide temperature, conductivity and salinity used to calculate the speed of sound data. This instrument also incorporates an inbuilt GPS sensor allowing water column data to be analysed easily with respect to position and time. Several casts were made throughout each day's survey operations with the resultant sound velocity measurements converted into a set format for use with CARIS HIPS and SIPS processing software. A Valeport mini SV probe was used to record real time sound velocity at the sonar heads.

Table 9 -Sound Velocity Data logged during survey GEO_GDD

Sound Velocity Data Files	309		
Dataset size	2.87 MB		
File formats	Raw: .ctd	Caris: .svp	
Daily SVP Casts JD (Julian Days) – no. of casts	JD039 - 5	JD040 - 13	JD050 - 25
	JD051 - 5	JD055 - 10	JD056 - 25
	JD057 - 3	JD058 - 8	JD059 - 8
	JD060 - 20	JD061 - 16	JD062 - 11

4.4 Navigation / Attitude Data

Applanix POS- MV navigation and attitude raw data was imported to Applanix POS-PAC software. Here the data was post processed with a combination of OSI rinex data from the active station at Swords and the GNSS base station data set up for the duration of the survey at Malahide. Once the navigation / attitude data was processed, POS-PAC produced a series of output files which were then applied as corrections to the raw hydrographic data using CARIS HIPS and SIPS.

Table 10 -Locations used to generate rinex files for navigation post processing.

Station Name	Latitude	Longitude	Ellipsoid Height (m)
OSI Swords Active	53° 27' 32.59727" N	6° 13' 08.51778" W	94.6162
GNSS Base Station Malahide	53° 27' 23.98148" N	6° 09' 14.21487" W	62.1969

Table 11 - Navigation / Attitude Data

Navigation Data Processing for GEO_GDD	
POSPAC Projects	14
Dataset size	57.4 GB
File Format	.000, .001, etc. POS format
Files and Folders	GEO_GDD-NonCaris/GEO_GDD_NavReprocess

5. Data Processing Methodology

5.1 Navigation Data

1. Raw navigation/attitude data files logged by POSview software were loaded into an individual POSPAC project for survey each day.
2. Initially rinex data from the OSI active station in Swords was used to as base station data to process the vessel data. This allowed sonar data to be corrected and cleaned.
3. The processed POSPAC outputs, .sbet and .smrmsg, files were used to apply navigation/attitude and error corrections to the sonar data.
4. Rinex data from the Leica GNSS 1200 series base station set up in Malahide for the duration of the survey was used to replace OSI rinex where available. Data from Malahide was not available JD050, JD051, JD055, JD056 and JD057 as storage space on the base station was exceeded.

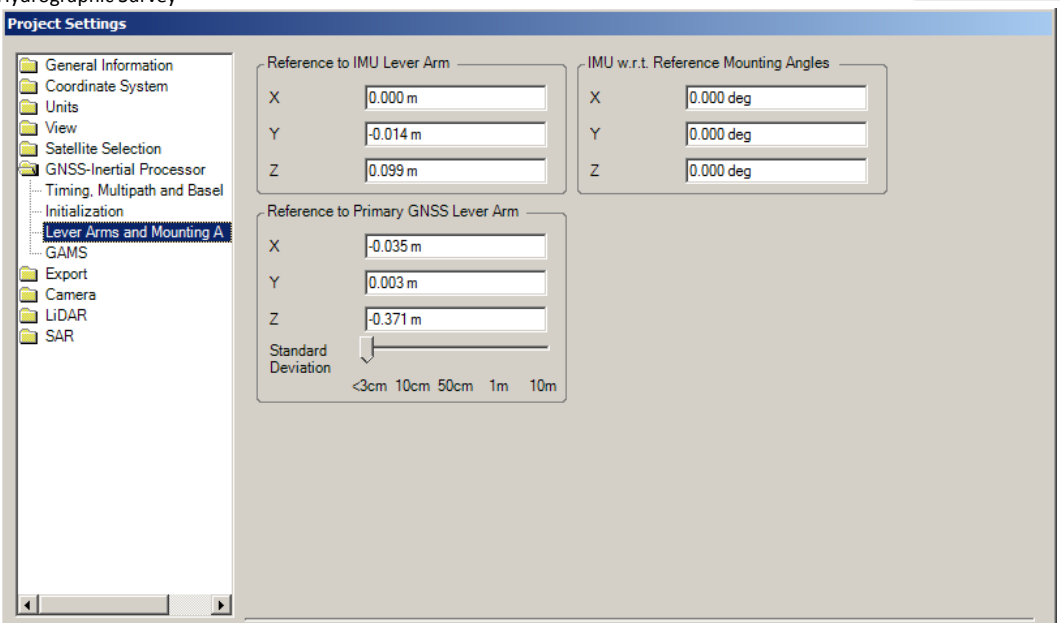


Figure 15 -Vessel offsets used in navigation processing

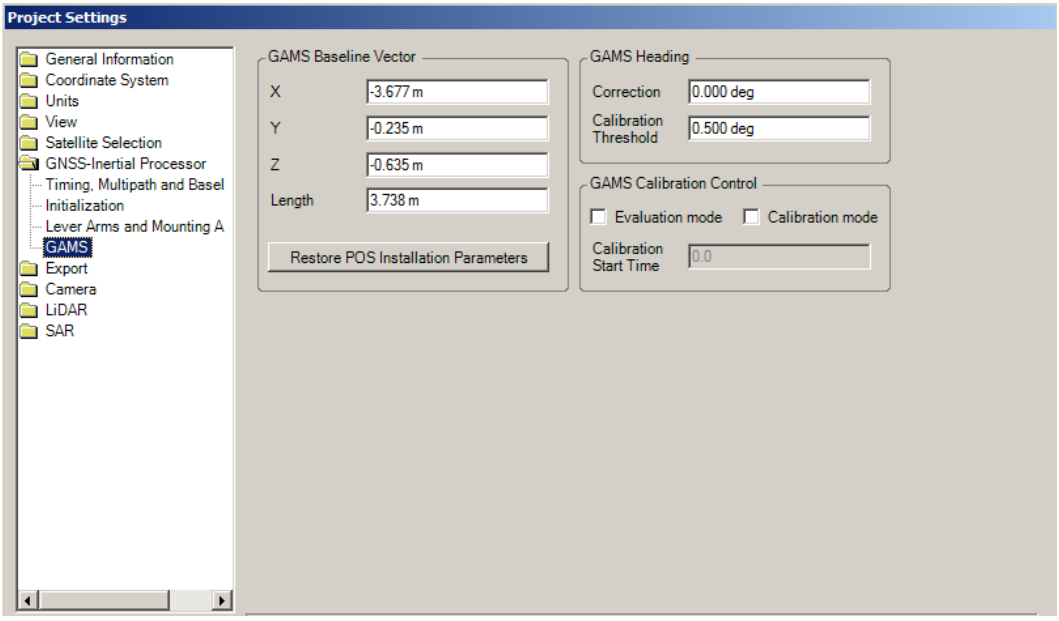


Figure 16- GAMS values and Antenna baseline length used in navigation processing

5.2 Sound Velocity Data

1. Raw data was exported from YSI castaway software in Caris format .svp format.
2. Individual casts were merged to one file for the full survey day.
3. Using Caris SVP editor these casts were quality controlled and extended to 50 m.
4. Files were saved and named e.g. JD040_ALL.svp

Note: all raw and processed files have been submitted with final report

5.3 Sonar Data

Sonar data files in .XTF format were converted and imported into CARIS HIPS and SIPS software. Once converted, survey data was then organised by specific Julian day and the following workflow commenced:

1. True Heave was derived from raw POS-MV logged data and applied to survey data.
2. Reprocessed navigation data from POS-PAC was applied to survey data.
3. Navigation error data was calculated from POS-PAC processing and applied to survey data in CARIS.
4. GPS tides were computed using the UKHO's VORF model. This reduced the MBES depth soundings to LAT. (Lowest Astronomical Tide) GPS Tide Results were then checked for quality and consistency.
5. SVP (Sound Velocity Profile) Data was then 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. At this point the day's survey data was merged in CARIS and TPU (Total Propagated Uncertainty) values were calculated. A log-file of TPU results was created automatically and was stored within the CARIS project structure.
7. Swath editing (data cleaning) was carried out in CARIS HIPS and SIPS to clean large "noise" spikes from the data. A CARIS base surface was then created to guide subset editing.
8. Refraction edits were performed to correct errors in the dataset for refraction errors caused by water column heterogeneity
9. A 2 m CUBE (Combined Uncertainty Bathymetric Estimate) surface was generated in CARIS using the shallow water setting shown below.

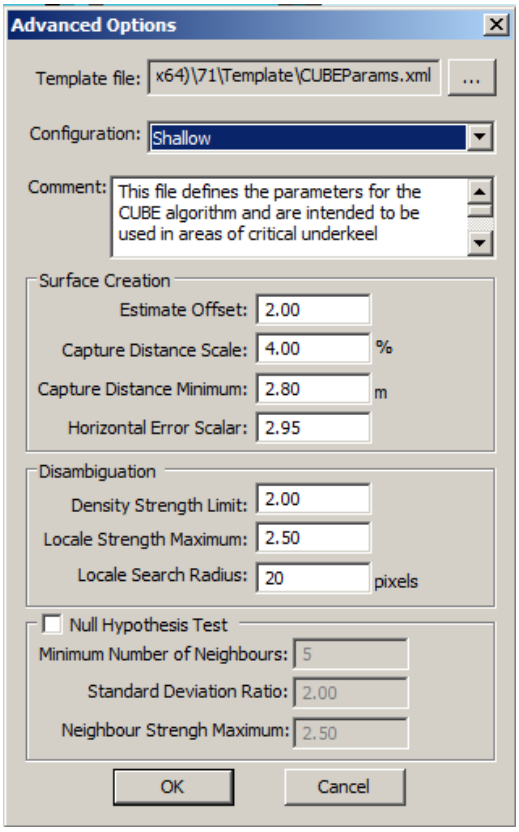


Figure 17 -Adjusting the shallow water settings in CARIS

10. The southern survey area and area east of the rock outcrops on the northern area were deemed to be suitable to run a surface cleaning filter on to remove erroneous soundings and improve the CUBE hypothesis for the surface due to the relatively flat sandy nature of the area. Settings used by the surface filter shown below.

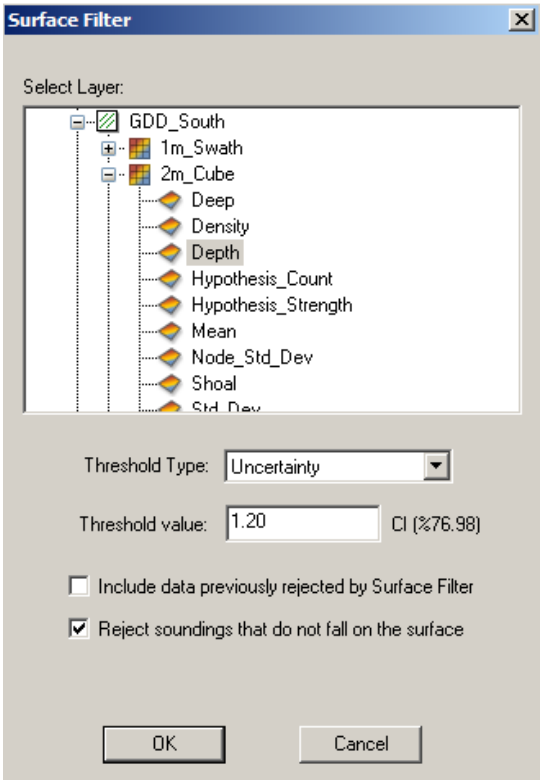


Figure 18 - Running the Surface filter function in Caris software

11. The results were examined for accuracy.
12. The areas around the rock outcrops in the northern area were not suitable for surface filtering as too much good data was rejected by the cleaning process. In this situation the area was cleaned of erroneous soundings using the subset editor tool in Caris.
13. Soundings were reduced to Malin Ordnance Datum using values from OS Grid Inquest to generate boundary points for northern and southern survey areas giving the separation from ellipsoid height to orthometric height.

5.4 Backscatter Mosaics

Backscatter is the measure of the returning acoustic energy to the sonar head after interaction with the seabed. The resulting measurements can be indicative of the seabed type as sonar returns behave differently depending on the ground type on the seafloor, e.g. rock gives a strong return whereas mud will return a weaker signal. This is represented in the greyscale backscatter mosaic as dark areas (strong return) and lighter areas (weaker return).

1. Amplitude data in both DB and Byte format were exported from Caris using the HIPS to ASCII export function. This gave two files with Easting, Northing and Amplitude figures for both the northern and southern survey areas. These were exported in the UTM29N projection.

2. Using the DMAGIC program in Fledermaus these ungridded files were gridded to a resolution of 25cm. The resulting dataset was exported in arc grid format.

3. Using ArcGIS 10 these grids were converted to rasters and the image was fine tuned to improve the visual appearance making interpretation easier.

4. The final images were exported as georeferenced tiff images at 300 and 600 dpi using ITM projection.

5.5 Reference to Malin Ordnance Datum

Vertical measurements on board the R.V. GEO all are referenced from height above a referenced ellipsoid height. The depth data was requested referenced to Malin Head OD or orthometric heights. To perform this conversion, the Ordnance Survey Grid Inquest was used to calculate a separation value between the reference ellipsoid and the geoid in the survey area. This allowed depths to be referenced to orthometric height, choosing Malin Head OD as the datum.

1. Latitude and longitude co-ordinates of the limits of each survey area were exported from Caris.
2. These values were inserted into the OS Grid Inquest and converted. A model file of the Latitude, Longitude and separation between ellipsoid and orthometric height for north and south survey areas was created to input into Caris (.xyz format) under the Process > Compute GPS tide menu.
3. After processing, the sonar data was referenced to Malin OD.

Table 12 - Values from Ordnance Survey Grid Inquest software

Northern Area

Node	Lat (DD)	Long (DD)	Ellipsoid to Orthometric Separation (m)
NW	53.561367	-6.083292	56.02
NE	53.559967	-6.026522	55.97
SE	53.545272	-6.027553	55.96
SW	53.546669	-6.084303	56.02

Southern Area

Node	Lat (DD)	Long (DD)	Ellipsoid to Orthometric Separation (m)
NW	53.424983	-6.125181	56.04
NE	53.42215	-6.021558	55.92
SE	53.405136	-6.022744	55.90
SW	53.407675	-6.126303	56.02

5.6 Tide gauges

The tide gauges installed in Skerries and Howth harbour were collected after the survey work was completed. The pressure tide gauges were set up to take readings every 30 seconds. The data which was downloaded from the tide gauges was processed in SeaBird Plot 39 software. The measurements were then averaged every 10minutes and the depth values were adjusted to the control point from the RTK surveys to give a value corrected to Malin Head datum. The tidal curve from the gauge is compared with the vessel's GPS computed tidal curve for the same tidal period in order to verify the VORF model.

For full details on the tide gauge deployments please see accompanying document. Bathymetric Survey GDDS - Geodetic control.docx

6. Quality Control

6.1 QC Procedures

Quality Control (QC) is carried out during survey operations using a combination of techniques including vessel handling, online acquisition quality checks and post-acquisition quality checks (processing). A broad overview of the QC procedures employed during survey leg GEO13_GDD is discussed below.

6.2 Operational QC Procedures

During survey operations, interferometric data quality was enhanced by maintaining outer beam angles of not greater than 68 degrees for each transducer head. Close attention was paid to sea state and weather conditions. Survey grounds were examined for sheltered areas to suit changing conditions. High swath overlap and correct survey speeds (5-6 knots) ensured good data quality and safe operation of the vessel within shallow areas. A strong focus on acquiring plenty of sound velocity profiles during each day's data acquisition allowed the onboard data processor to easily correct for refraction errors. POS-MV navigation data was logged statically for a minimum of 20 minutes prior to departure, then continuously throughout the day and for 20 minutes after arrival to port on completion of each day's survey operations. (In the event of a POS-MV failure and system restart; data would be logged for 20 minutes before resuming survey operations). Cross lines were run at the required 20 times mainline spacing.

6.3 Online QC Procedures

Data quality was monitored during acquisition by the online surveyor. Navigation data was monitored for accuracy, timing errors and satellite geometry using Applanix POS-MV software. Interferometric data was monitored for data quality using their standard acquisition software readings. QPS QINSy software provided an additional real-time check as most of the acquisition systems are interfaced with this software.

6.4 Post Data Acquisition QC Procedures

Navigation Data was checked for quality by the onboard data processor. Applanix POSPAC software was used to evaluate the POS-MV data for consistency and errors. Interferometric data was checked for quality using CARIS HIPS and SIPS software, in attitude editor and subset editor. Survey statistics and error/uncertainty values were examined in the software to ensure IHO standards were maintained.

6.5 Crossline Quality Control

Crosslines were run at the required 20 times mainline spacing. These were processed independently of the main lines and not used to generate the bathymetric dataset.

1. Crosslines were processed in Caris using the same method as mainlines.
2. Where ping range was not manually reduced at data collection stage, the data was filtered by an angle of 65 degrees either side of the nadir.
3. QC checks were run between crosslines and 2m_CUBE base surface for north and south survey areas.
4. QC reports for north and south survey areas were generated with each area achieving the specified survey standard.

Table 13 - Results of crossline QC for southern survey area.

Beam Angle	Count	Max (+)	Min (-)	Mean	Std Dev	Special Order (%)	Order 1a (%)	Order 1b (%)	Order 2 (%)
-65 - -60	204,043	0.99	0.412	-0.03	0.062	99.823	99.995	99.995	100
-60 - -55	195,538	0.939	0.407	-0.025	0.045	99.978	99.996	99.996	100
-55 - -50	181,877	0.327	0.5	-0.02	0.045	99.979	100	100	100
-50 - -45	225,665	0.362	0.405	-0.003	0.051	99.976	100	100	100
-45 - -40	247,680	0.422	0.417	0.009	0.054	99.963	100	100	100
-40 - -35	292,704	0.349	0.442	0.012	0.06	99.981	100	100	100
-35 - -30	314,714	0.333	0.6	0.019	0.06	99.997	100	100	100
-30 - -25	275,713	0.431	0.39	0.019	0.061	99.97	100	100	100
-25 - -20	237,897	0.382	0.347	0.012	0.061	99.987	100	100	100
-20 - -15	196,953	0.427	0.315	-0.001	0.062	99.97	100	100	100
-15 - -10	145,755	0.378	0.328	-0.013	0.059	99.955	100	100	100
-10 - -5	75,914	0.265	0.313	-0.029	0.056	99.992	100	100	100
-5 - 0	24,980	0.329	0.302	-0.055	0.056	99.98	100	100	100
0.0 - 5.0	23,754	0.508	0.307	-0.064	0.059	99.962	100	100	100
5.0 - 10.0	68,404	0.595	0.365	-0.039	0.06	99.937	99.999	99.999	100
10.0 - 15.0	132,474	0.535	0.391	-0.025	0.061	99.94	100	100	100
15.0 - 20.0	184,612	0.511	0.327	-0.013	0.062	99.953	100	100	100
20.0 - 25.0	230,500	0.415	0.306	-0.007	0.061	99.988	100	100	100
25.0 - 30.0	271,464	0.369	0.348	-0.003	0.062	99.993	100	100	100

30.0 - 35.0	312,489	0.465	0.361	-0.001	0.062	99.944	100	100	100
35.0 - 40.0	304,539	0.634	0.371	-0.006	0.061	99.927	99.996	99.996	100
40.0 - 45.0	252,776	0.607	0.31	-0.01	0.053	99.962	99.999	99.999	100
45.0 - 50.0	221,192	0.358	0.318	-0.017	0.05	99.996	100	100	100
50.0 - 55.0	202,136	0.321	0.541	-0.026	0.047	99.973	100	100	100
55.0 - 60.0	201,209	0.323	0.424	-0.032	0.044	99.978	100	100	100
60.0 - 65.0	191,657	0.355	0.406	-0.026	0.068	99.781	100	100	100

Table 14- Results of crossline QC for northern survey area.

Beam Angle	Count	Max (+)	Min (-)	Mean	Std Dev	Special Order (%)	Order 1a (%)	Order 1b (%)	Order 2 (%)
-65 - -60	177,042	1.585	2.078	0	0.146	94.853	98.564	98.564	99.85
-60 - -55	274,205	1.487	1.536	-0.012	0.104	97.706	99.25	99.25	99.951
-55 - -50	360,232	1.356	1.413	-0.007	0.093	98.449	99.383	99.383	99.979
-50 - -45	358,028	1.182	1.511	0	0.085	98.679	99.501	99.501	99.98
-45 - -40	348,106	1.151	1.47	0.008	0.085	98.731	99.507	99.507	99.967
-40 - -35	308,886	1.193	1.479	0.008	0.083	98.81	99.609	99.609	99.978
-35 - -30	290,058	1.109	1.21	0.015	0.08	99.031	99.691	99.691	99.985
-30 - -25	278,528	1.112	1.456	0.018	0.08	99.229	99.727	99.727	99.989
-25 - -20	240,650	1.2	1.517	0.013	0.08	99.273	99.687	99.687	99.972
-20 - -15	195,516	1.096	1.545	-0.005	0.083	99.27	99.645	99.645	99.945
-15 - -10	142,706	1.086	1.601	-0.018	0.082	99.163	99.641	99.641	99.94

-10 - -5	79,011	1.064	1.478	-0.035	0.081	99.127	99.595	99.595	99.939
-5 - 0	31,442	0.898	1.539	-0.064	0.076	99.186	99.612	99.612	99.971
0.0 - 5.0	22,974	0.876	1.323	-0.067	0.075	99.112	99.743	99.743	99.961
5.0 - 10.0	62,895	1.039	1.976	-0.04	0.081	98.96	99.603	99.603	99.963
10.0 - 15.0	126,762	1.178	1.657	-0.029	0.081	99.114	99.695	99.695	99.952
15.0 - 20.0	178,901	1.227	1.944	-0.017	0.082	99.145	99.734	99.734	99.96
20.0 - 25.0	230,032	1.09	2.363	-0.015	0.086	99.039	99.67	99.67	99.96
25.0 - 30.0	272,150	1.235	2.221	-0.011	0.09	98.837	99.584	99.584	99.935
30.0 - 35.0	300,610	1.302	1.994	-0.009	0.094	98.626	99.454	99.454	99.922
35.0 - 40.0	315,023	1.341	1.842	-0.02	0.1	98.198	99.284	99.284	99.902
40.0 - 45.0	345,621	2.04	1.888	-0.025	0.104	98.065	99.12	99.12	99.865
45.0 - 50.0	355,699	1.962	1.9	-0.033	0.103	98.066	99.125	99.125	99.875
50.0 - 55.0	388,939	1.078	2.061	-0.034	0.103	98.113	99.173	99.173	99.884
55.0 - 60.0	314,882	1.092	1.831	-0.044	0.118	96.677	98.848	98.848	99.892
60.0 - 65.0	187,098	1.244	1.456	-0.016	0.169	92.593	97.74	97.74	99.753

6.6 Dimension Control Survey

A dimension control survey was carried out on the vessel to determine the offsets between the central reference point (designated the MRU on the RV GEO) and the sonar transducer heads and GPS antenna. The resulting offset measurements are detailed below in Table 8.

Table 15 -Offsets from dimension control survey.

	X	Y	Z
STBD Transducer centre	0.092080496	-0.126042747	-1.960718485
Aft GPS (front of)	-0.214974088	-2.722987527	0.905078847
Fwd GPS (front of)	0.003212503	0.087304528	0.364065062
PORT TxRx Centre	-0.049828157	-0.110714977	-1.961908607
MRU	0	0	0

Note sign convention may change depending on the specific requirements of the software.

7. Calibration

7.2 Swath System

A full set of calibration lines were run in Dun Laoghaire on 08/02/2013 for the R.V. GEO interferometric swath system before the survey operations were commenced. These values provided to the processor were assessed using CARIS HIPS and SIPS software. The results were found to be in good agreement with values used during the previous INFOMAR survey season and contained in the existing vessel file.

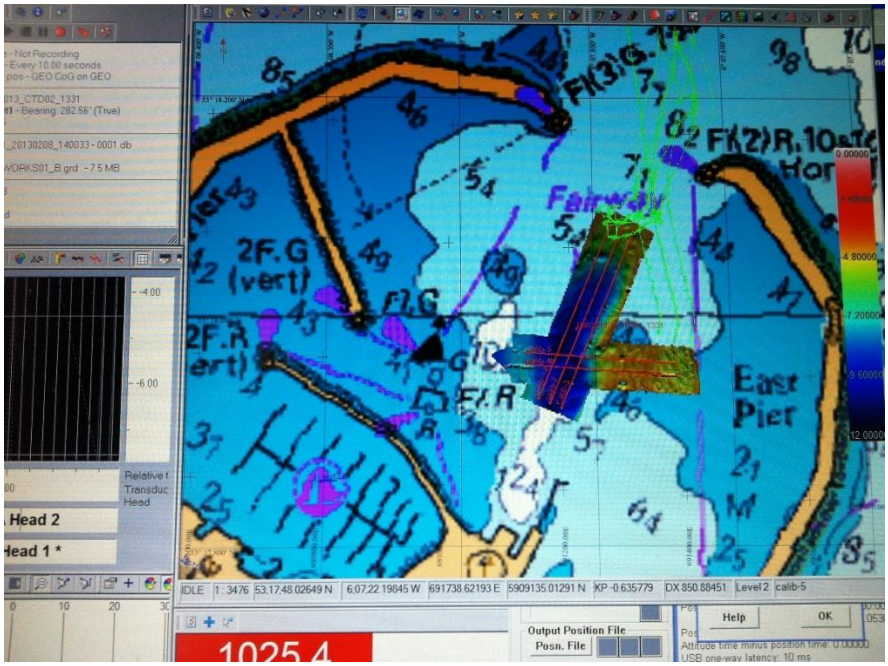


Figure 19 - Calibration lines run in DunLaoghaire at the start of survey operations

7.2.1 Latency

Timing issues on the RV GEO are eliminated with the use of 1PPS timing trigger from the POS MV system.

7.2.2 Pitch

Examination of the calibration lines and mainline data during processing showed no evidence of pitch artefacts in the data and so values for pitch remained unchanged.

7.2.3 Roll

Examination of the calibration lines and mainline data during processing showed evidence of very slight pitch artefacts in the data. Roll adjustments were made as follows and the vessel file was edited to reflect these changes;

Port Roll Calibration = -0.20

Starboard Roll calibration = 0.00

7.2.4 Yaw

Examination of the calibration lines and mainline data during processing showed no evidence of yaw artefacts in the data and so values for yaw remained unchanged.

7.2.5 Draught

As the vessel MRU and sonar heads are coupled and based on satellite observations changes in the vessels draught do not affect the sounding solution.

7.3 GAMS Calibration

A full GAMS (GPS Azimuth Measurement System) Calibration of the Applanix POS-MV system onboard the R.V. GEO was performed during vessel mobilisation. This automated procedure for calibrating the vessel's heading readings was undertaken and results and accuracies met all requirements for the survey. Attitude, heading, position, velocity and heave results were monitored continuously during all subsequent operations by the online surveyor for fluctuations and any deviation from established accuracy thresholds for the R.V. GEO's Applanix POS-MV system. (Max: 0.05 degrees HDG) (Max: 1.0m horizontal and 0.5m vertical-) POS-MV System accuracy was monitored in this manner throughout survey GEO13_02 and found to be satisfactory. These online quality checks were validated by the survey's data processor during post-processing of navigation data.

7.4 Sound Velocity Sensors

Real-time sound velocity (R/T-SV) readings at the MBES transducers are provided using a Valeport Mini SV probe. This data is input directly to the sonar acquisition software Swathplus. The sensor is calibrated periodically by Valeport and sound velocity readings at the transducer heads are verified using the vessel's sound velocity measurement devices.

The YSI CASTAWAY CTD device was also quality controlled using data from an AML CTD device and the results were examined and deemed satisfactory.

Site A

Running from West to East the Skerries area features agricultural land slopping gradually to the cliff edge (50mOD – 10mOD) (figure 20 – AUV surveys). The cliff then drops down 6mOD to the high tide mark. The coastline here is characterised by sandy inlets and jutting outcrops of limestone and shale. The rocky shore line meets the fine sedimentary layer and a gradual sandy sloping seabed deepens from-3mOD to -18mOD with rocky outcrops in places. Beneath the sediment layer the depth to the bedrock varies from < 2m to c. 30m but is generally <12m thick in most areas with the largest values recorded in the east (Figure 35&36).

Site B

The Howth site is characterised by flat sandy beaches and a gradual featureless sloping seabed. Running from West to East the land slopes gradually NE to the channel (20m-0m OD) in front of the Portmarnock golf course (figure 21 – AUV surveys). The land then rises up to the sand dunes (8m OD) before sloping down to the high tide mark. The very flat nature of the beach means the intertidal zone stretches >250m to the LAT mark. The featureless sedimentary seabed gradually slopes from -3mOD to -22mOD in the east. Beneath the sediment layer the depth to the bedrock varies from < 2m to c. 30m but is generally <16m thick in most areas with the largest values recorded in the east (Figure 37&38).

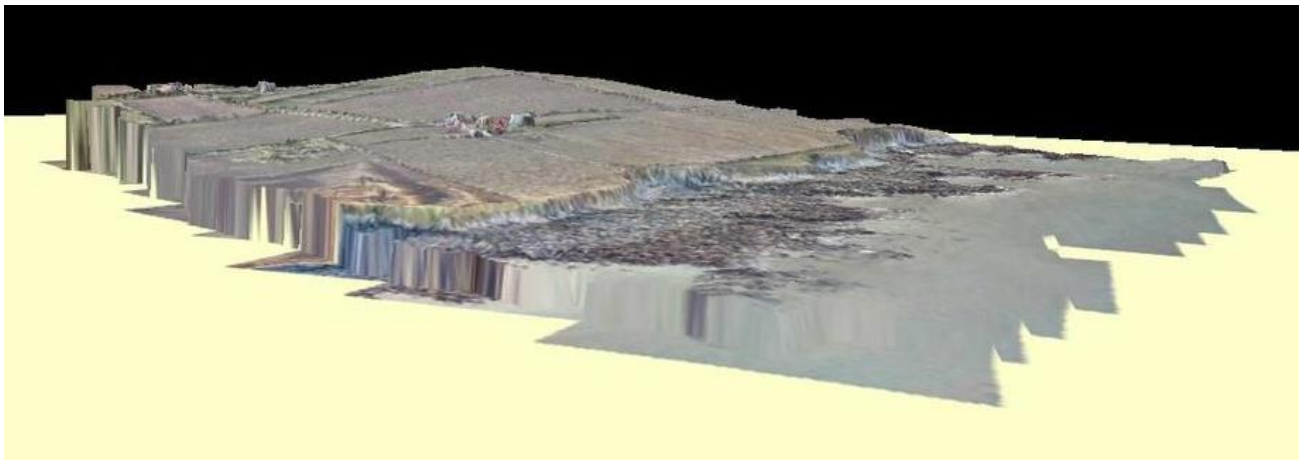


Figure 20 - AUV survey image showing the sloping agricultural land and the cliffs in the Northern area - Skerries

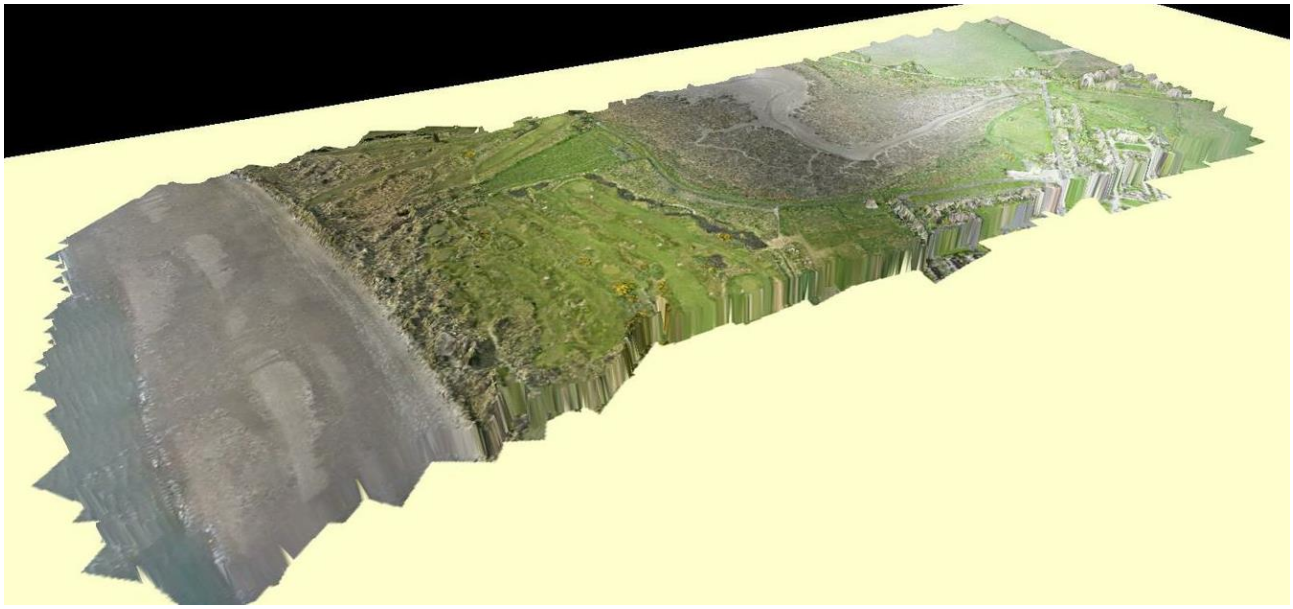


Figure 21 - AUV survey image showing the channel and golf course in the Southern area- Portmarnock

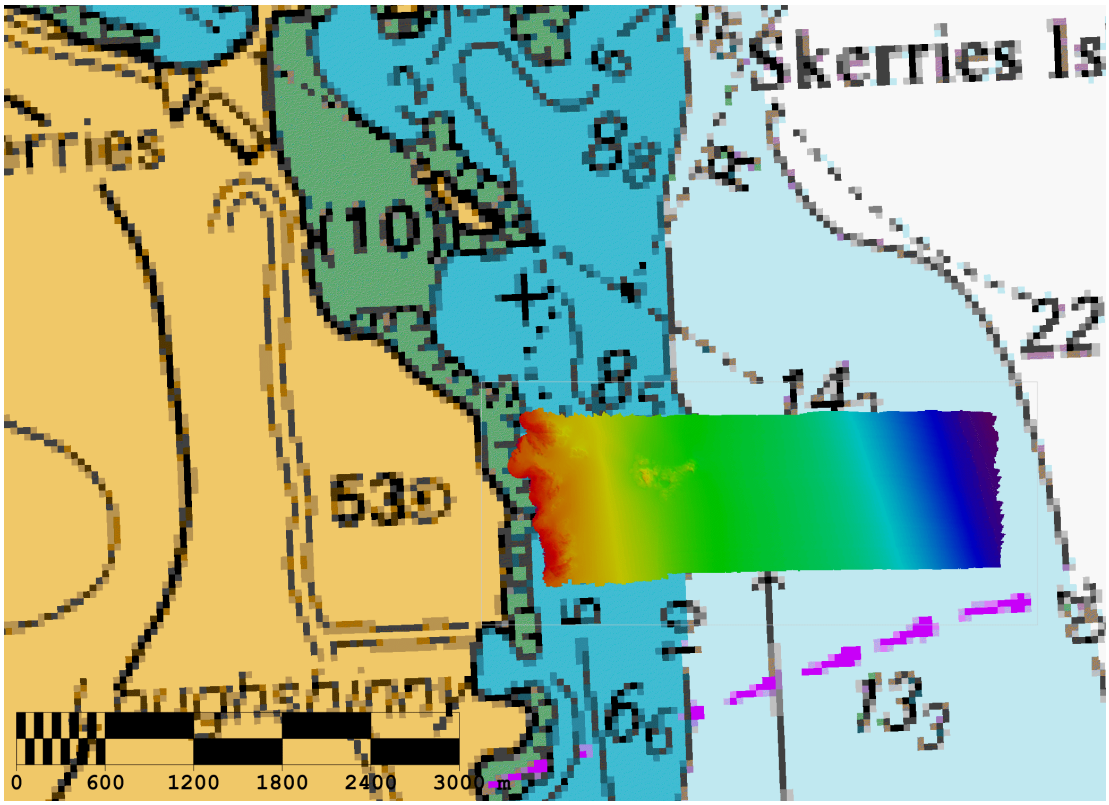


Figure 22- Overview of northern area south of Skerries Islands.

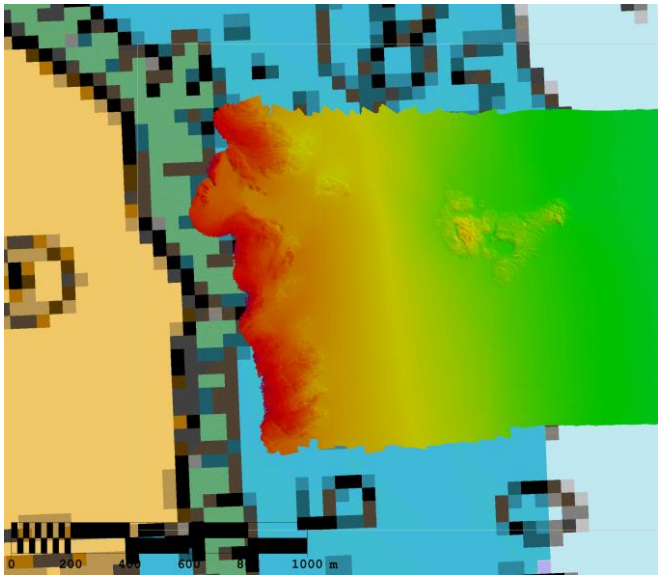


Figure 23- Detail of rock outcrops off Lough Shinny in the northern survey area.

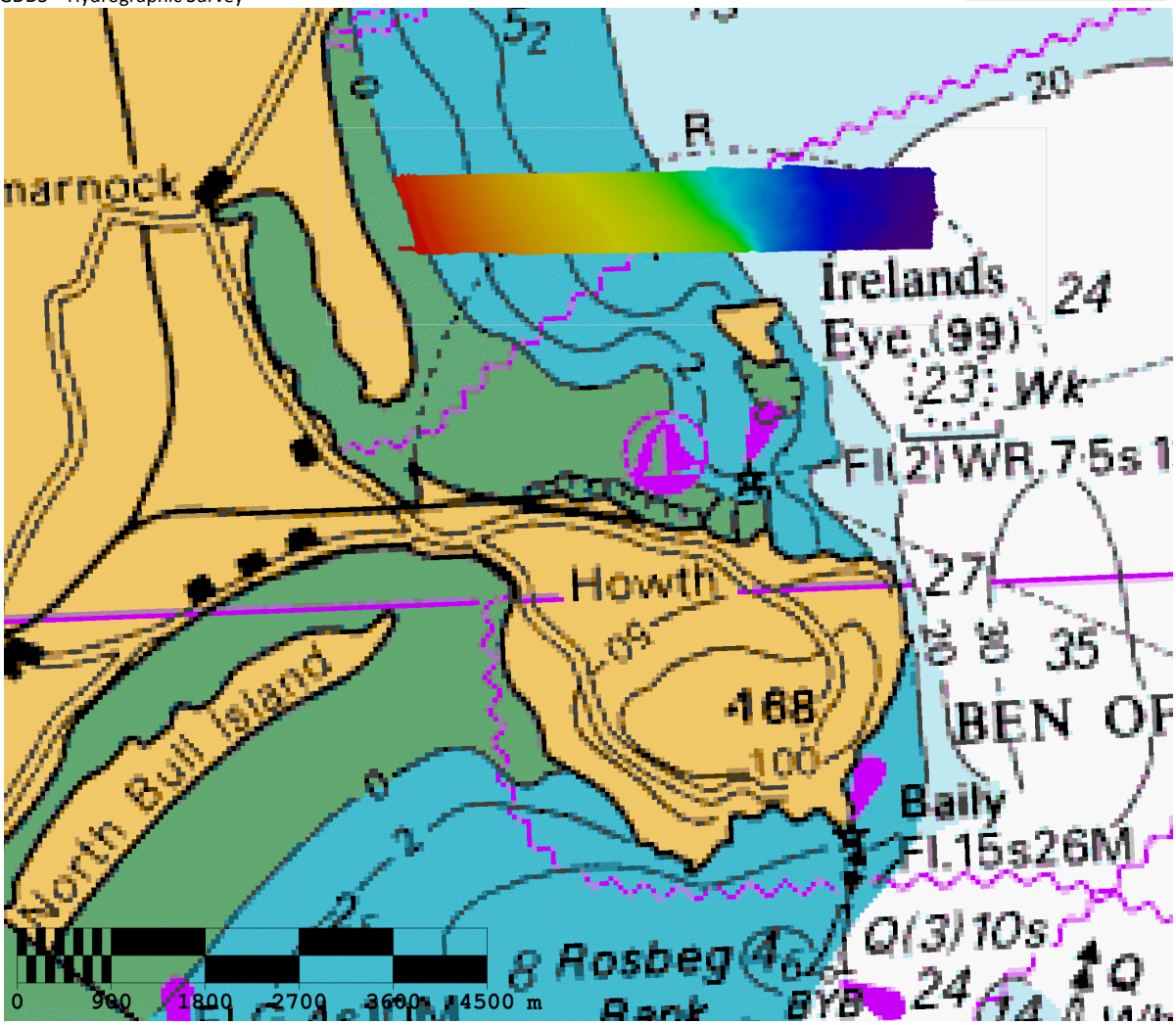


Figure 24 -Overview of southern area north of Howth Head.

8.3 Contour plots

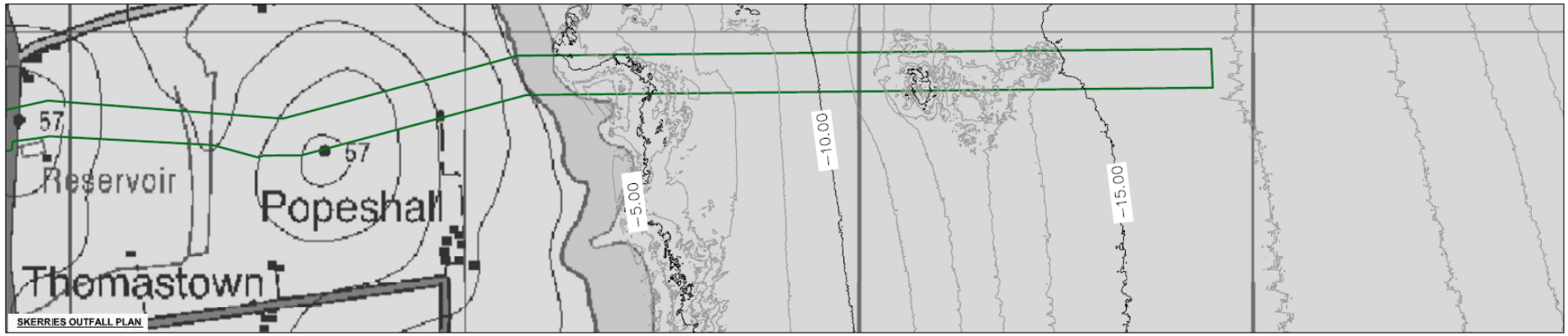


Figure 25 - Contour plot showing depth to seabed in Northern Area – Skerries

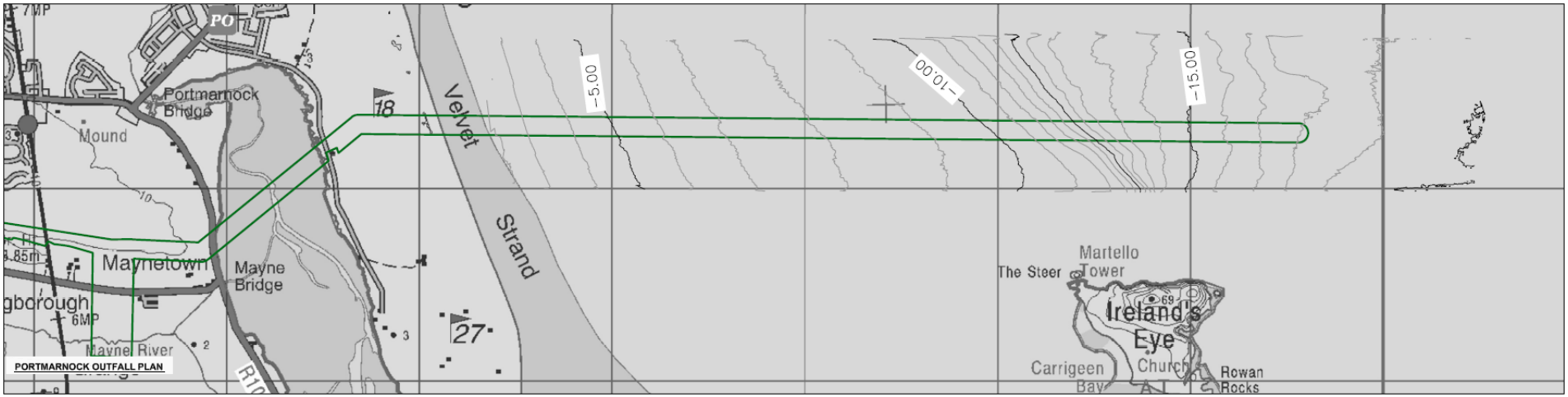


Figure 26 -Contour plot showing depth of seabed in Southern Area - Portmarnock

8.4 Fledermaus 3D viewer images

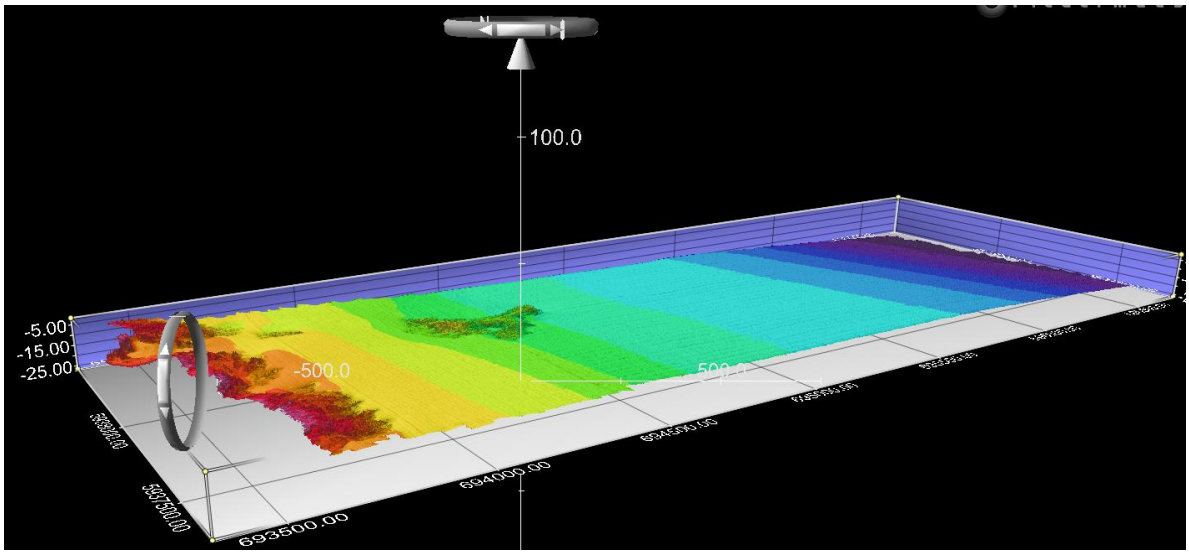


Figure 27 - Screen shot showing the full extent of the Northern Skerries site taken from Fledermaus 3D viewer

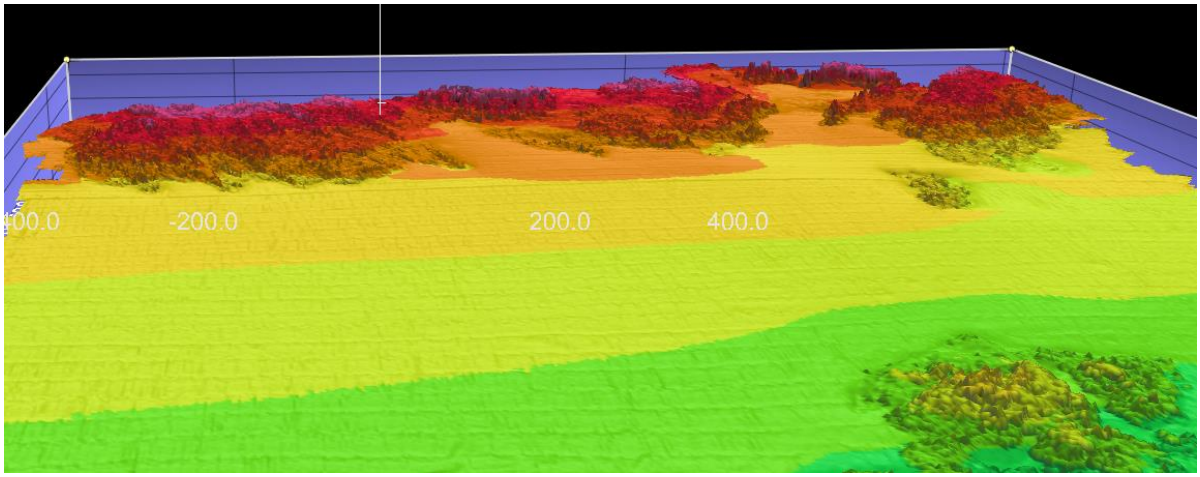


Figure 28 - Screen shots of the Northern area taken from Fledermaus 3D viewer

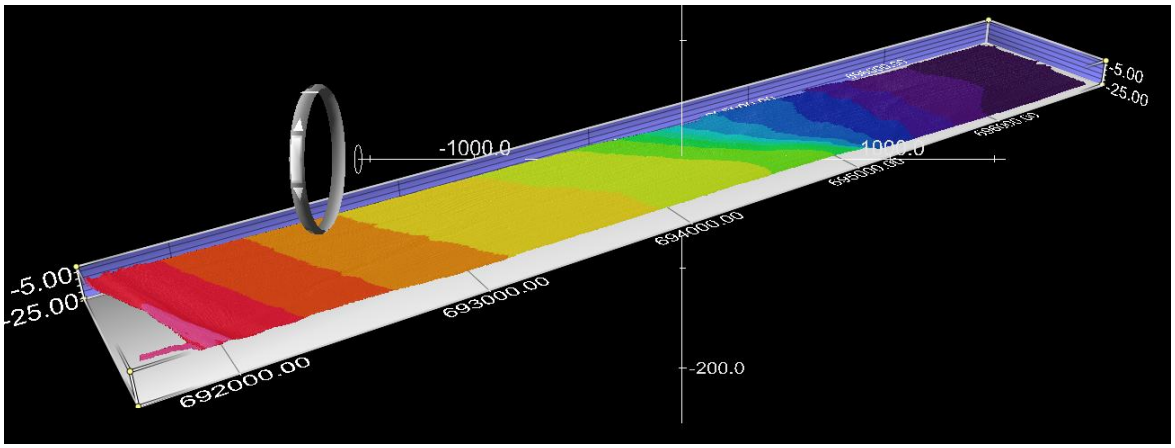


Figure 29 - Screenshot from the Southern Area viewed in Fledermaus 3D viewer

8.5 Backscatter Mosaics

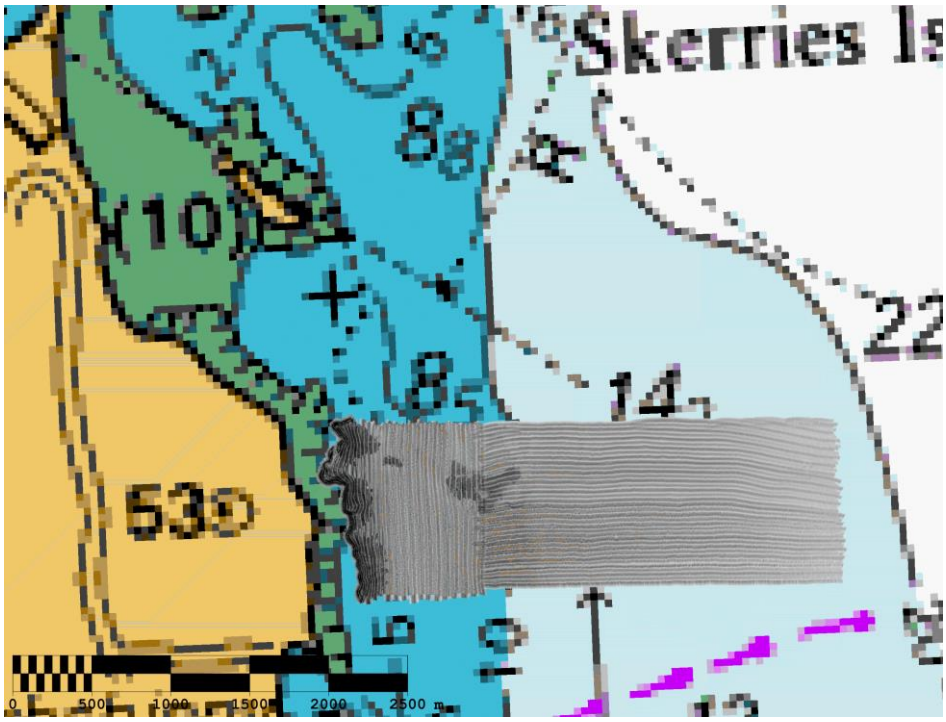


Figure 30- Overview of backscatter mosaic for northern area south of Skerries Island.

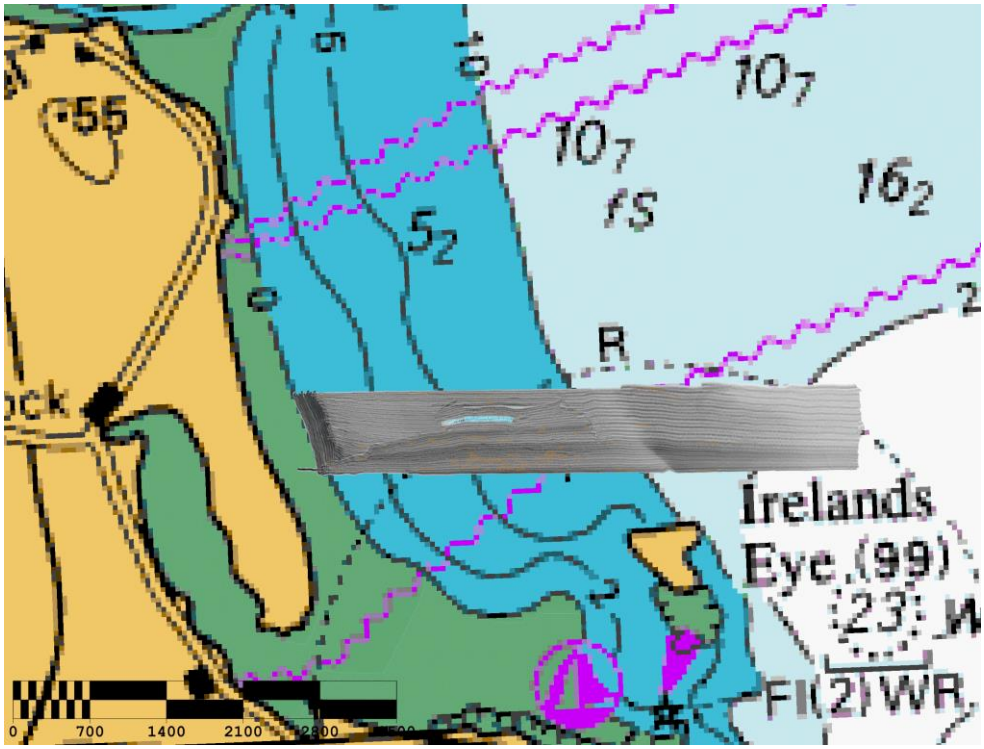


Figure 31- Overview of backscatter mosaic for southern area north of Howth Head.

8.6 Survey Lines

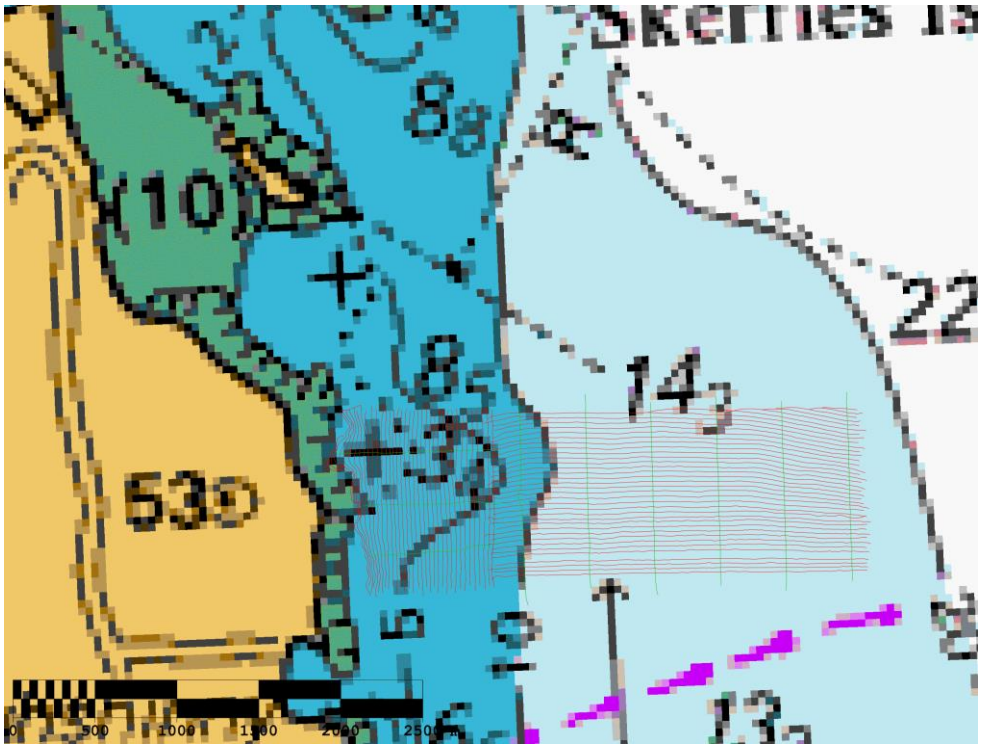


Figure 32- Overview of survey lines for northern area south of Skerries Island. Mainlines in red. Crosslines in green

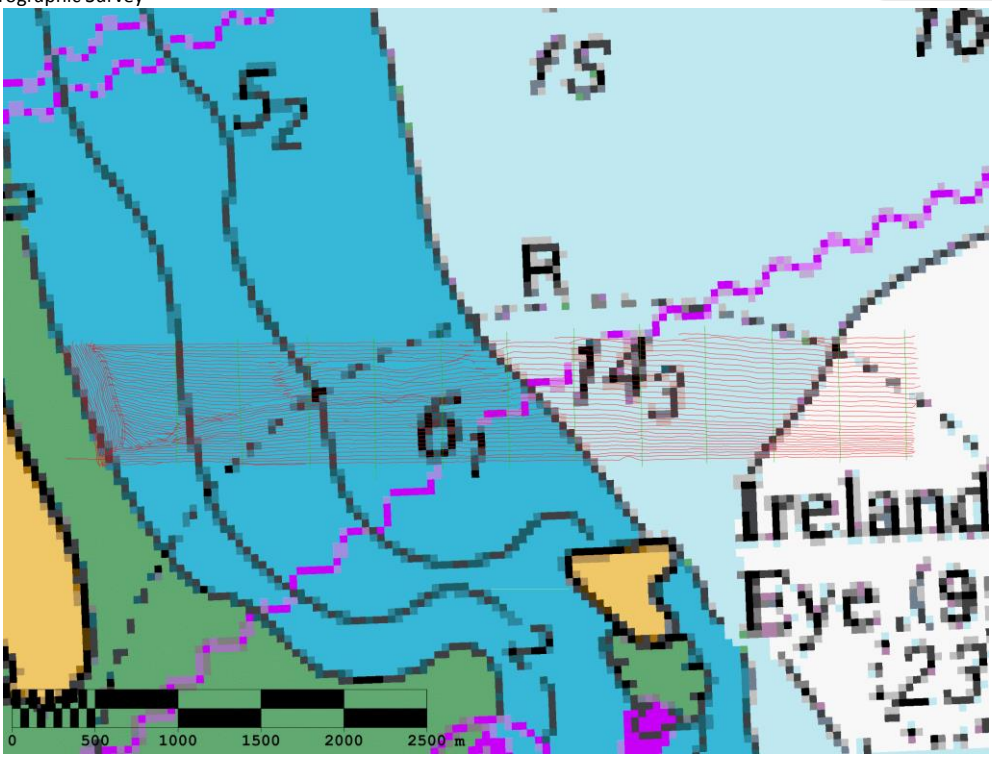


Figure 33- Overview of survey lines for southern area north of Howth Head. Mainlines in red. Crosslines in green

8.8 Bedrock analysis

Note: For full details of bedrock analysis see accompanying APEX report

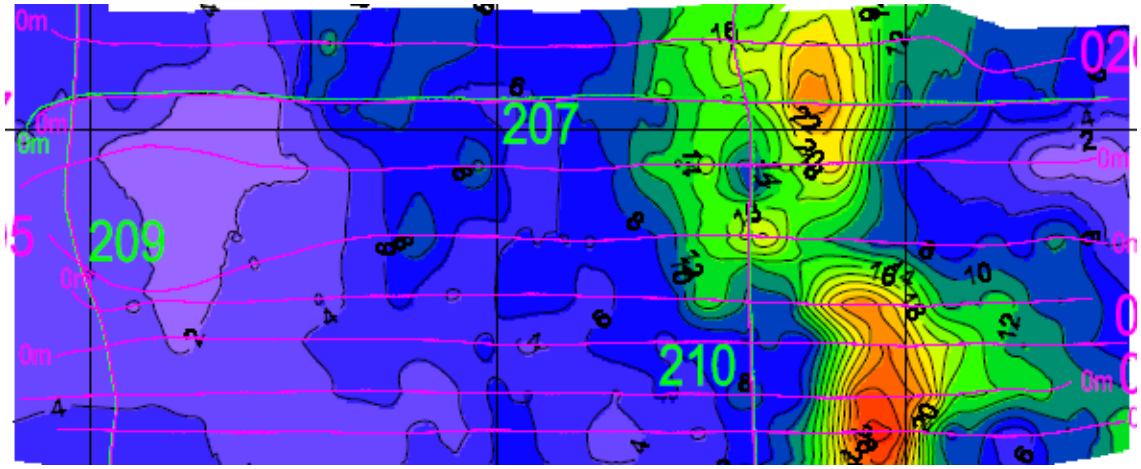


Figure 33 - Skerries Overburden/Sediment thickness Map

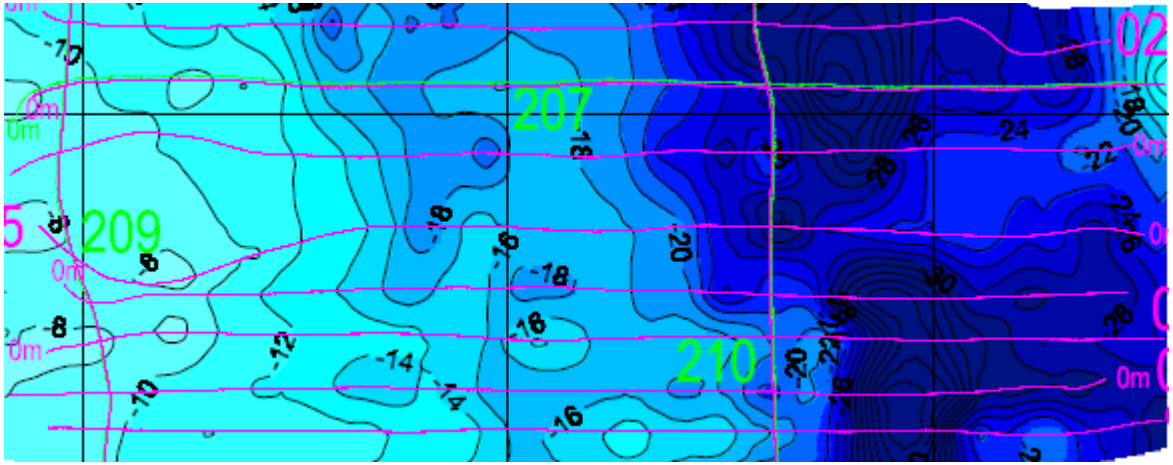


Figure 34 - Skerries Bedrock elevation contour Map

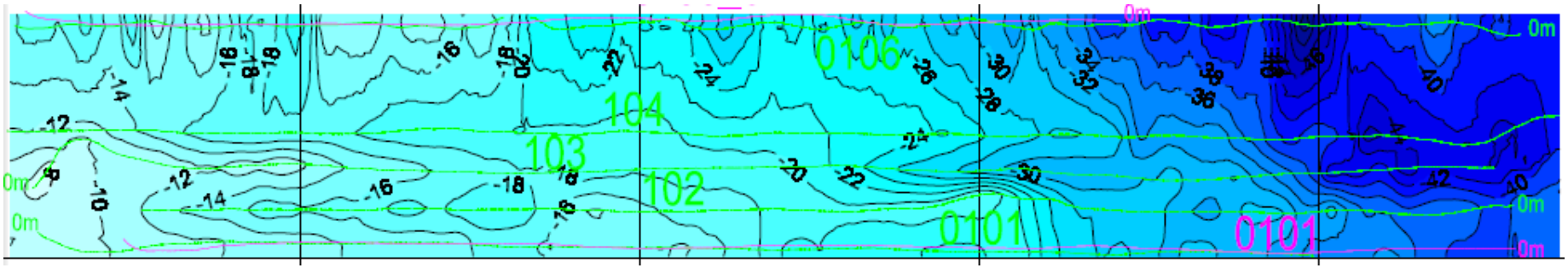


Figure 345 - Portmarnock Bedrock elevation contour Map

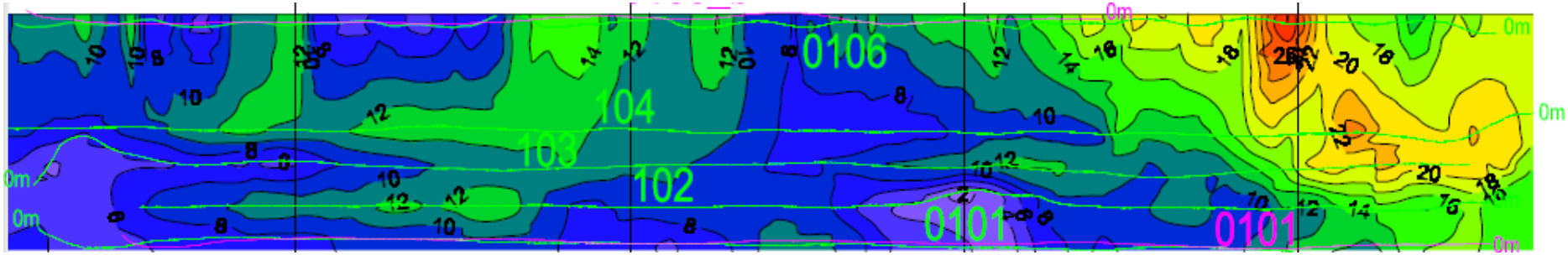


Figure 356 - Portmarnock Overburden/Sediment thickness Map

Table 16 - Final Data Processing applied to Survey Data by Julian Day

Data Processing JD 039 (08/02/2013)	
Data Processor (initials)	JD
CARIS Version	7.1
POS PAC Version	6.1
# Lines Converted to CARIS	9 (2 Mainlines and 7 Calibration lines)
Navigation Reprocessing	GNSS base station rinex
SVP Instrument	YSI Castaway
# SVPs for JD	5
True Heave Loaded	Yes
Navigation Loaded	Yes
Error / RMS Data Loaded	Yes
GPS Tide Computed	Yes
SVP Corrections Applied	Yes
SVP Algorithm	Nearest in Distance within 2 hours
Data Merged	Yes
Data Added to Base Surface	Yes
Data Cleaned	Swath Editing, CUBE, Surface Filter, Subset Editing
Data Quality / Issues	Refraction over all

Data Processing JD 040 (09/02/2013)	
Data Processor (initials)	JD
CARIS Version	7.1
POS PAC Version	6.1
# Lines Converted to CARIS	16
Navigation Reprocessing	GNSS base station rinex
SVP Instrument	YSI Castaway
# SVPs for JD	13 mainlines
True Heave Loaded	Yes
Navigation Loaded	Yes
Error / RMS Data Loaded	Yes
GPS Tide Computed	Yes
SVP Corrections Applied	Yes
SVP Algorithm	Nearest in Distance within 2 hours
Data Merged	Yes
Data Added to Base Surface	Yes
Data Cleaned	Swath Editing, CUBE, Surface Filter, Subset Editing
Data Quality / Issues	Noise on 0004 and 0005 and Refraction over all

Data Processing JD 050 (19/02/2013)	
Data Processor (initials)	JD
CARIS Version	7.1
POS PAC Version	6.1
# Lines Converted to CARIS	29 (22 mainlines and 7 crosslines)
Navigation Reprocessing	OSI rinex
SVP Instrument	YSI Castaway
# SVPs for JD	24
True Heave Loaded	Yes
Navigation Loaded	Yes
Error / RMS Data Loaded	Yes
GPS Tide Computed	Yes
SVP Corrections Applied	Yes
SVP Algorithm	Nearest in Distance within 4 hours
Data Merged	Yes
Data Added to Base Surface	Yes
Data Cleaned	Swath Editing, CUBE, Surface Filter, Subset Editing
Data Quality / Issues	Noise on 0004 and 0005 and Refraction over all

Data Processing JD 051 (20/02/2013)	
Data Processor (initials)	JD
CARIS Version	7.1
POS PAC Version	6.1
# Lines Converted to CARIS	4 mainlines
Navigation Reprocessing	OSI rinex
SVP Instrument	YSI Castaway
# SVPs for JD	5
True Heave Loaded	Yes
Navigation Loaded	Yes
Error / RMS Data Loaded	Yes
GPS Tide Computed	Yes
SVP Corrections Applied	Yes
SVP Algorithm	Nearest in Distance within 4 hours
Data Merged	Yes
Data Added to Base Surface	Yes
Data Cleaned	Swath Editing, CUBE, Surface Filter, Subset Editing
Data Quality / Issues	Refraction over all

Data Processing JD 055 (24/02/2013)	
Data Processor (initials)	JD
CARIS Version	7.1
POS PAC Version	6.1
# Lines Converted to CARIS	18 mainlines
Navigation Reprocessing	OSI rinex
SVP Instrument	YSI Castaway
# SVPs for JD	10
True Heave Loaded	Yes
Navigation Loaded	Yes
Error / RMS Data Loaded	Yes
GPS Tide Computed	Yes
SVP Corrections Applied	Yes
SVP Algorithm	Nearest in Distance within 4 hours
Data Merged	Yes
Data Added to Base Surface	Yes
Data Cleaned	Swath Editing, CUBE, Surface Filter, Subset Editing
Data Quality / Issues	Noisy data due to weather and Refraction over all

Data Processing JD 056 (25/02/2013)	
Data Processor (initials)	JD
CARIS Version	7.1
POS PAC Version	6.1
# Lines Converted to CARIS	53 lines (48 mainlines and 5 crosslines)
Navigation Reprocessing	OSI rinex
SVP Instrument	YSI Castaway
# SVPs for JD	25
True Heave Loaded	Yes
Navigation Loaded	Yes
Error / RMS Data Loaded	Yes
GPS Tide Computed	Yes
SVP Corrections Applied	Yes
SVP Algorithm	Nearest in Distance within 4 hours
Data Merged	Yes
Data Added to Base Surface	Yes
Data Cleaned	Swath Editing, CUBE, Surface Filter, Subset Editing
Data Quality / Issues	Refraction over all

Data Processing JD 057 (26/02/2013)	
Data Processor (initials)	JD
CARIS Version	7.1
POS PAC Version	6.1
# Lines Converted to CARIS	3 mainlines
Navigation Reprocessing	OSI rinex
SVP Instrument	YSI Castaway
# SVPs for JD	3
True Heave Loaded	Yes
Navigation Loaded	Yes
Error / RMS Data Loaded	Yes
GPS Tide Computed	Yes
SVP Corrections Applied	Yes
SVP Algorithm	Nearest in Distance within 4 hours
Data Merged	Yes
Data Added to Base Surface	Yes
Data Cleaned	Swath Editing, CUBE, Surface Filter, Subset Editing
Data Quality / Issues	Refraction over all

Data Processing JD 058 (27/02/2013)	
Data Processor (initials)	JD
CARIS Version	7.1
POS PAC Version	6.1
# Lines Converted to CARIS	4 mainlines
Navigation Reprocessing	GNSS base station rinex
SVP Instrument	YSI Castaway
# SVPs for JD	8
True Heave Loaded	Yes
Navigation Loaded	Yes
Error / RMS Data Loaded	Yes
GPS Tide Computed	Yes
SVP Corrections Applied	Yes
SVP Algorithm	Nearest in Distance within 4 hours
Data Merged	Yes
Data Added to Base Surface	Yes
Data Cleaned	Swath Editing, CUBE, Surface Filter, Subset Editing
Data Quality / Issues	Refraction over all

Data Processing JD 059 (28/02/2013)	
Data Processor (initials)	JD
CARIS Version	7.1
POS PAC Version	6.1
# Lines Converted to CARIS	6 mainlines
Navigation Reprocessing	GNSS base station rinex
SVP Instrument	YSI Castaway
# SVPs for JD	8
True Heave Loaded	Yes
Navigation Loaded	Yes
Error / RMS Data Loaded	Yes
GPS Tide Computed	Yes
SVP Corrections Applied	Yes
SVP Algorithm	Nearest in Time
Data Merged	Yes
Data Added to Base Surface	Yes
Data Cleaned	Swath Editing, CUBE, Surface Filter, Subset Editing
Data Quality / Issues	Refraction over all

Data Processing JD 060 (01/03/2013)	
Data Processor (initials)	JD
CARIS Version	7.1
POS PAC Version	6.1
# Lines Converted to CARIS	30 mainlines
Navigation Reprocessing	GNSS base station rinex
SVP Instrument	YSI Castaway
# SVPs for JD	20
True Heave Loaded	Yes
Navigation Loaded	Yes
Error / RMS Data Loaded	Yes
GPS Tide Computed	Yes
SVP Corrections Applied	Yes
SVP Algorithm	Nearest in Distance within 4 hours
Data Merged	Yes
Data Added to Base Surface	Yes
Data Cleaned	Swath Editing, CUBE, Surface Filter, Subset Editing
Data Quality / Issues	Refraction over all

Data Processing JD 061 (02/03/2013)	
Data Processor (initials)	JD
CARIS Version	7.1
POS PAC Version	6.1
# Lines Converted to CARIS	28 lines (25 mainlines and 3 crosslines)
Navigation Reprocessing	GNSS base station rinex
SVP Instrument	YSI Castaway
# SVPs for JD	16
True Heave Loaded	Yes
Navigation Loaded	Yes
Error / RMS Data Loaded	Yes
GPS Tide Computed	Yes
SVP Corrections Applied	Yes
SVP Algorithm	Nearest in Distance within 4 hours
Data Merged	Yes
Data Added to Base Surface	Yes
Data Cleaned	Swath Editing, CUBE, Surface Filter, Subset Editing
Data Quality / Issues	Refraction over all

Data Processing JD 062 (03/03/2013)	
Data Processor (initials)	JD
CARIS Version	7.1
POS PAC Version	6.1
# Lines Converted to CARIS	20 lines (14 mainlines and 6 crosslines)
Navigation Reprocessing	GNSS base station rinex
SVP Instrument	YSI Castaway
# SVPs for JD	11
True Heave Loaded	Yes
Navigation Loaded	Yes
Error / RMS Data Loaded	Yes
GPS Tide Computed	Yes
SVP Corrections Applied	Yes
SVP Algorithm	Nearest in Distance within 4 hours
Data Merged	Yes
Data Added to Base Surface	Yes
Data Cleaned	Swath Editing, CUBE, Surface Filter, Subset Editing
Data Quality / Issues	Good

8.9 Data Processing Outputs

The following outputs were produced by the data processor. All data was collected in WGS1984 UTM29N projection. All data is by default provided in UTM29N. The data was requested in Irish Transverse Mercator (ITM) projection so all geotiffs and esri grids were reprojected using ArcGIS 10. In some cases grids were generated in Latitude and Longitude (decimal degrees) to ensure accuracy.

- Shaded relief images are saved as geotiffs, ITM projection, 2m cells size, 24bit, 0 to 30 m depth range, rainbow colour scale, sun illuminated from 45 degrees and 315 degrees.
- Backscatter images are saved as geotiffs, ITM projection, 25cm cell size, 8 bit, greyscale.
- ArcGIS/ESRI grids are saved in esri grid format, 2m and 5m grid resolution, ITM projection for both North and South areas.
- Trackline shapefiles are in ArcGIS .shp format, ITM projection
- Crossline QC reports are shown above and were generated for both north and south survey areas using crosslines from the relevant areas.
- Fledermaus files are saved in UTM29N projection and sd files can be viewed by installing the Iview 4d software provided and following the 'how to' provided in the Fledermaus Data folder.
- Sounding data is in Latitude and Longitude (Decimal Degrees), Depth, Amplitude (db) and Beam and are saved by individual line.

Table 17 -Data Processing outputs

Data Processed Outputs		
Output	**Created By**	**Date**
XYZ soundings	John Deasy	20/03/2013
Average Grid (ASCII)	John Deasy	20/03/2013
Fledermaus Grid (From SD files)	John Deasy	20/03/2013
ARC-GIS/ESRI Grid	John Deasy	20/03/2013
Tracklines	John Deasy	20/03/2013
CARIS Export Geo-tiff Shaded Relief NE CARIS Export Geo-tiff Shaded Relief NW	John Deasy John Deasy	20/03/2013 20/03/2013
CARIS Export Geo-tiff Backscatter	John Deasy	20/03/2013
Crossline QC Reports	John Deasy	20/03/2013

Appendix A – Geodetic Control

Bathymetric Survey GDDS: Fingal County Council

Geodetic Control

22/01/2013

TW/13/PRJ-012

TechWorks Marine Limited
1, Harbour Road
Dun Laoghaire
Co. Dublin, Ireland

Private and Confidential

Contents

1. Introduction

TechWorks Marine has been commissioned by Fingal council to carry out surveys at two areas proposed for a new outfall pipe from a waste water treatment plant. In addition to this, two tide gauges will be placed at strategic coastal locations to collect sea surface height data.

1.1 Site Location

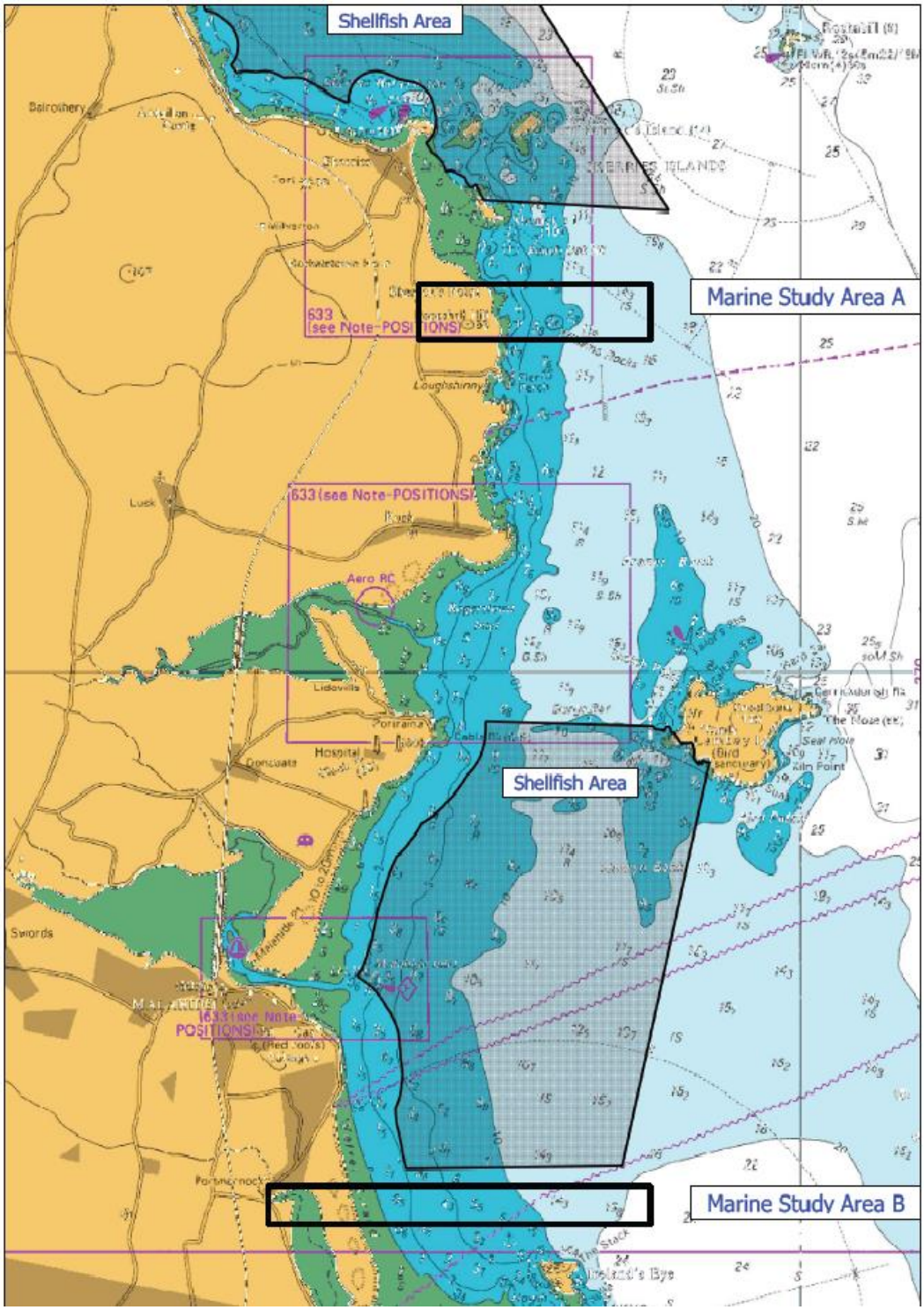


Figure 36 - Ordinance Survey Map with overlay showing the proposed deployment sites

2. Geodetic Control

Geodetic Control over survey operations is established by recording continuous satellite observations at a series of Geodetic Control points onshore in the vicinity of a survey area using GNSS Base Stations. Ordinance Survey of Ireland (OSI) active GPS data is used to provide additional geodetic accuracy.

Tide gauges are levelled to control points established next to or near to the tide gauge installation. The levels of recorded tidal data are then adjusted to established vertical datum and used to provide quality control over survey results and to validate the UKHO's VORF model.

Sounding captured during this survey are reduced to LAT using the UKHO's Vertical Offshore Reference Frame (VORF) model. This process is undertaken using the "Compute GPS tide" function in CARIS HIPS and SIPS processing software. The tidal curve from the gauges is compared with the vessel's GPS computed tidal curve for the same tidal period in order to verify the model. The tide gauge deployment was carried out in the weeks leading up to the survey with tidal data being recorded for a short period after a survey.

3. Tide Gauge Deployment

Personnel – Adam Partington, Kieran Harper

Tidal level is measured in relation to the Datum at Malin head. The Marine Institutes tidal gauge network has tide gauges positioned all around the Irish coastline including one in Howth and Skerries. RTK (Real-Time Kinetic) surveys had previously left a metal pin in the ground at both sites at a known distance above the Malin Head datum. TechWorks measured the distance of the SBE 39 tide gauges from this pin so the depth of the tide gauge could later be converted to depth in relation to the datum.

The SBE 39 tide gauges were fastened to the end of a stainless steel pole and lowered approximately 1 metre below the surface at low tide. The distance from the pin on the floor of the pier to the tide gauge was measured.

3.1 Skerries Tide gauge

Deployed 23/01/2013 latitude **53.585039** longitude **-6.107942**

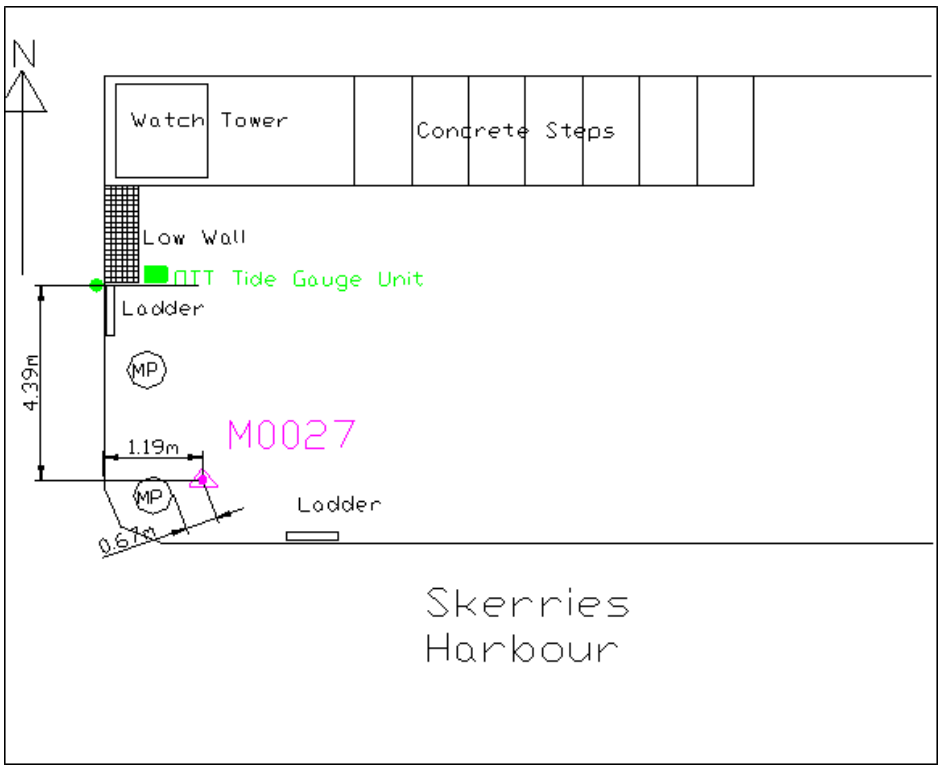


Figure 37 - Skerries Tide Gauge Station

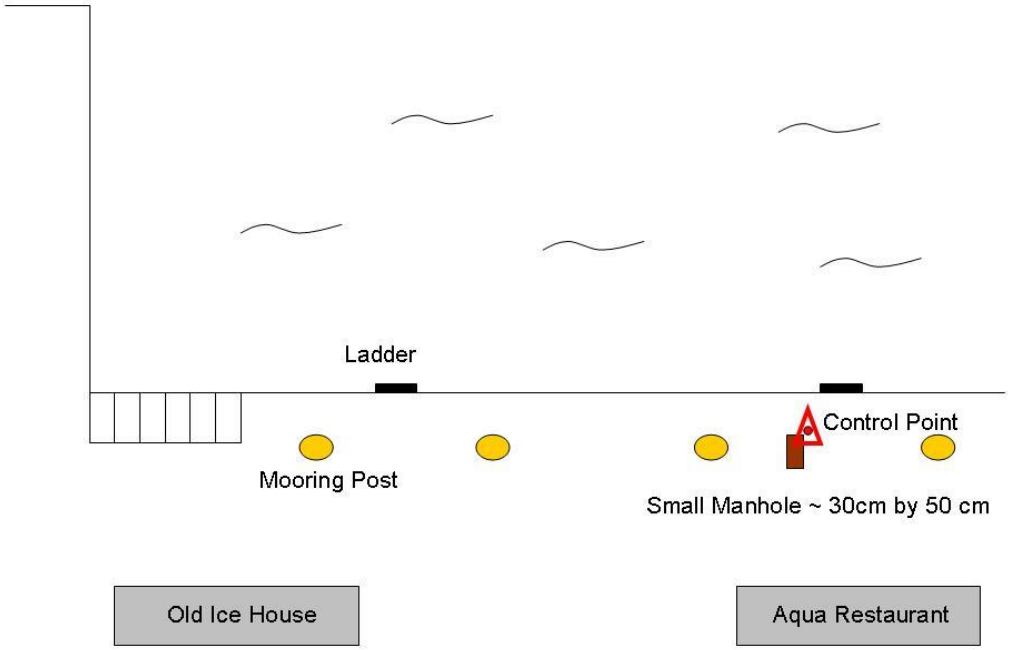
Tide Gauge Deployment - Skerries	
Tide Gauge serial number	SBE 39 5224
Distance from pole tip to tide gauge	578cm
Distance from pole tip to reference point	47.6cm
Reference point to tide gauge	625.6cm
15:35 23/01/2013 pole tip to sea level	419cm
Reference point to sea level = 466.6	466.6cm
Skerries reference point above Malin Head Datum	329.1cm

3.2 Howth Tide gauge

Deployed 23/01/2013 **Latitude** 53.392213 N **Longitude** 06.069091 W

Tide Gauge Deployment - Howth	
Tide gauge serial number	SBE 39 5225
Distance from pole tip to tide gauge	539cm
Distance from pole tip to reference point	- 13cm
Reference point to tide gauge	526cm
17:18 23/01/2013 pole tip to sea level	401cm
Reference point to sea level	388cm
Howth reference point above Malin Head Datum	335cm

West Pier, Howth, Co. Dublin



4. TechWorks Marine GPS rover base station installation

Deployment report 05/02/2013 Personnel – Adam Partington, Ronan O'Toole

The GPS base station for the project will be the active OSI (Ordinance Survey Ireland) located in Swords. Data is available for download directly from the OSI website:-

StationName	stationID	itmEast	itmNorth	latDeg	latMin	latSec	longDeg	longMin	longSec	ellHeight
FingalCC	SWRD	718270.3	746920.8	53	27	32.59727	-6	13	8.51778	94.616

The rover station was installed in Malahide Harbour. This site was chosen as it lies equally spaced between the two survey areas and offered a secure location for the equipment. (see figure 6)

TechWorks Marine mobilised from the office in DunLaoghaire to Malahide harbour. The Tripod was set up on top of a steel container. A coin was glued to the roof of the container to act as a reference

point. The reference point was centred beneath the Tripod head using the viewing window before the reciever head was mounted along with the GNSS system. The distance from the reference point to the GNSS system was then measured with a drop down tape measure and this was input into the systems software. The digital display showed that GPS system had good coverage with 12 satellites in view. The system was set up to take readings every second for 3 hours.

Rinex data was downloaded from the OSI website for the base station in Swords. This will be compared with the data from the rover station in Malahide to validate the accuracy of the GPS system.

Once the survey begins, the GNSS system will be re-deployed in the same location for the duration of the survey.

Figure 38 - Mallahide. View from the container on which the GNSS station was deployed

Figure 39 - The Leica High Performance GNSS 1200 series

Figure 40 - Reference point

The platform was chosen because it offered an elevated point from the Harbour giving better satellite coverage and a 360^{o} field of view. This meant that it was not possible to drill in a more permanent reference point.

Figure 41 - GPS reciever fixed to the Tripod

Figure 42 - The GNSS system mounted on the Tripod

5. Processing Summary

5.1 Project Information

Project name:	Techworks
Date created:	02/05/2013 17:16:47
Time zone:	0h 00'
Coordinate system name:	WGS 1984
Application software:	LEICA Geo Office 8.1
Start date and time:	02/05/2013 13:08:39
End date and time:	02/05/2013 16:12:09
Manually occupied points:	4
Processing kernel:	PSI-Pro 3.0
Processed:	02/06/2013 17:22:08

5.2 Processing Parameters

Parameters	Selected
Cut-off angle:	15°
Ephemeris type:	Broadcast
Solution type:	Automatic
GNSS type:	GPS
Frequency:	Automatic
Fix ambiguities up to:	80 km
Min. duration for float solution (static):	5' 00"
Sampling rate:	Use all
Tropospheric model:	Hopfield
Ionospheric model:	Automatic
Use stochastic modelling:	Yes
Min. distance:	8 km
Ionospheric activity:	Automatic

5.3 Baseline Overview

SWRD - 0001	Reference: SWRD	Rover: 0001
Coordinates:		
Latitude:	53° 27' 32.59727" N	53° 27' 23.98144" N
Longitude:	6° 13' 08.51778" W	6° 09' 14.21482" W
Ellip. Hgt:	94.6162 m	62.1900 m
Solution type:	Phase: all fix	
GNSS type:	GPS	
Frequency:	L1/E1 and L2	
Ambiguity:	Yes	

SWRD - 0001	Reference: SWRD	Rover: 0001
Coordinates:		
Latitude:	53° 27' 32.59727" N	53° 27' 23.98153" N

Longitude:	6° 13' 08.51778" W	6° 09' 14.21468" W
Ellip. Hgt:	94.6162 m	62.1924 m
Solution type:	Phase: all fix	
GNSS type:	GPS	
Frequency:	L1/E1 and L2	
Ambiguity:	Yes	

SWRD - 0001	**Reference: SWRD**	**Rover: 0001**
Coordinates:		
Latitude:	53° 27' 32.59727" N	53° 27' 23.98158" N
Longitude:	6° 13' 08.51778" W	6° 09' 14.21485" W
Ellip. Hgt:	94.6162 m	62.2030 m
Solution type:	Phase: all fix	
GNSS type:	GPS	
Frequency:	L1/E1 and L2	
Ambiguity:	Yes	

SWRD - 0001	**Reference: SWRD**	**Rover: 0001**
Coordinates:		
Latitude:	53° 27' 32.59727" N	53° 27' 23.98138" N
Longitude:	6° 13' 08.51778" W	6° 09' 14.21514" W
Ellip. Hgt:	94.6162 m	62.2022 m
Solution type:	Phase: all fix	
GNSS type:	GPS	
Frequency:	L1/E1 and L2	
Ambiguity:	Yes	

6. Geodetic control summary

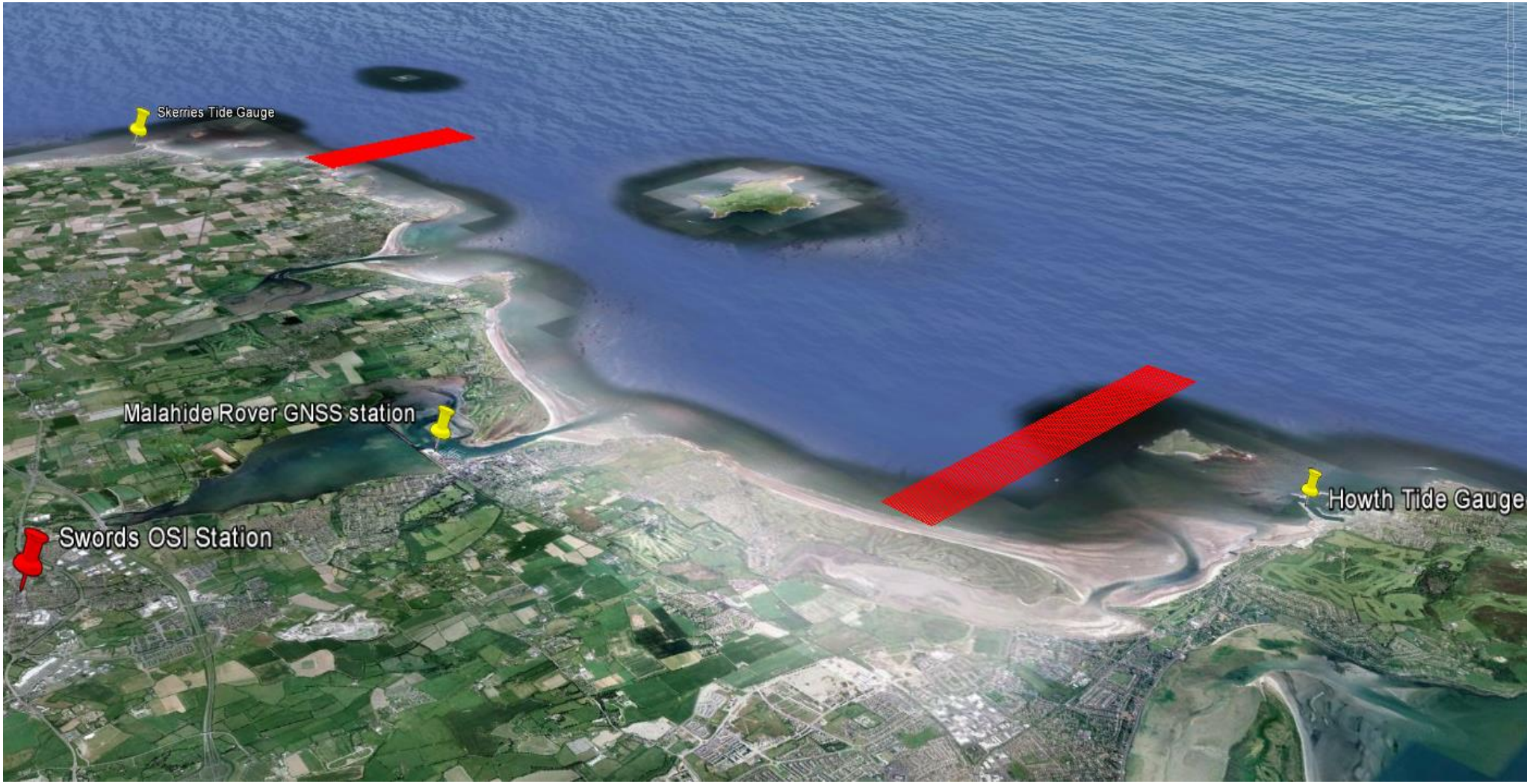


Figure 43 - Google earth image showing locations of Geodetic control elements for the survey

Appendix B – Topographical Survey

Greater Dublin Drainage Scheme:

Topographical survey GEO13_GDD

Fingal County Council

TW/13/PRJ-012

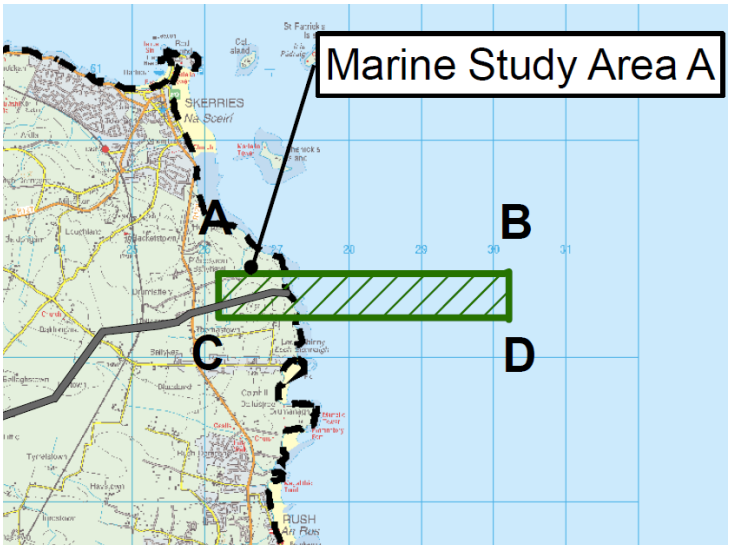
15th April 2013

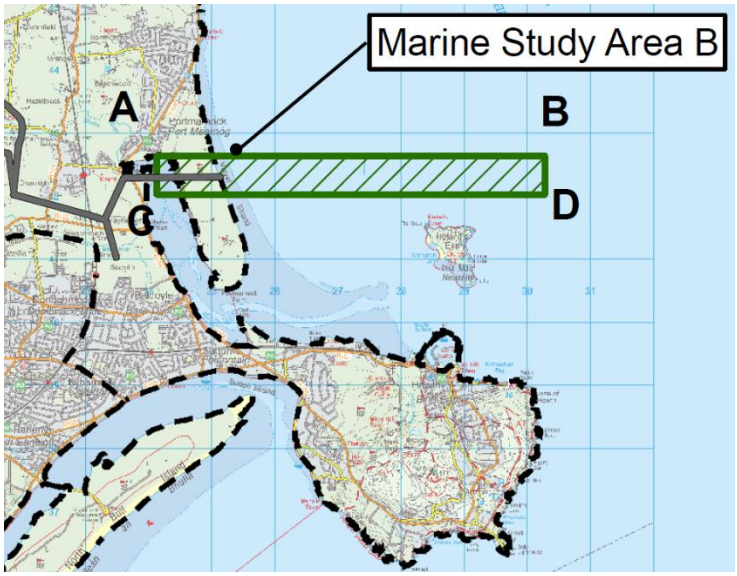
TechWorks Marine Limited
1, Harbour Road
Dun Laoghaire
Co. Dublin, Ireland

Private and Confidential

1. Introduction

This document accompanies the Hydrographic survey report GEO13_GDD. The document relates to the land based extent of the survey for the areas. The report includes analysis of the local bedrock geology and the aerial surveys conducted.





2. AUV Surveys

The senseFLY swinglet CAM produces full ortho rectified, high resolution data to provide 3D mapping used for planning and engineering purposes.

Figure 44 - The senseFLY system used to map the land-extent of the survey area

An example of the finished images can be seen below

3. Skerries

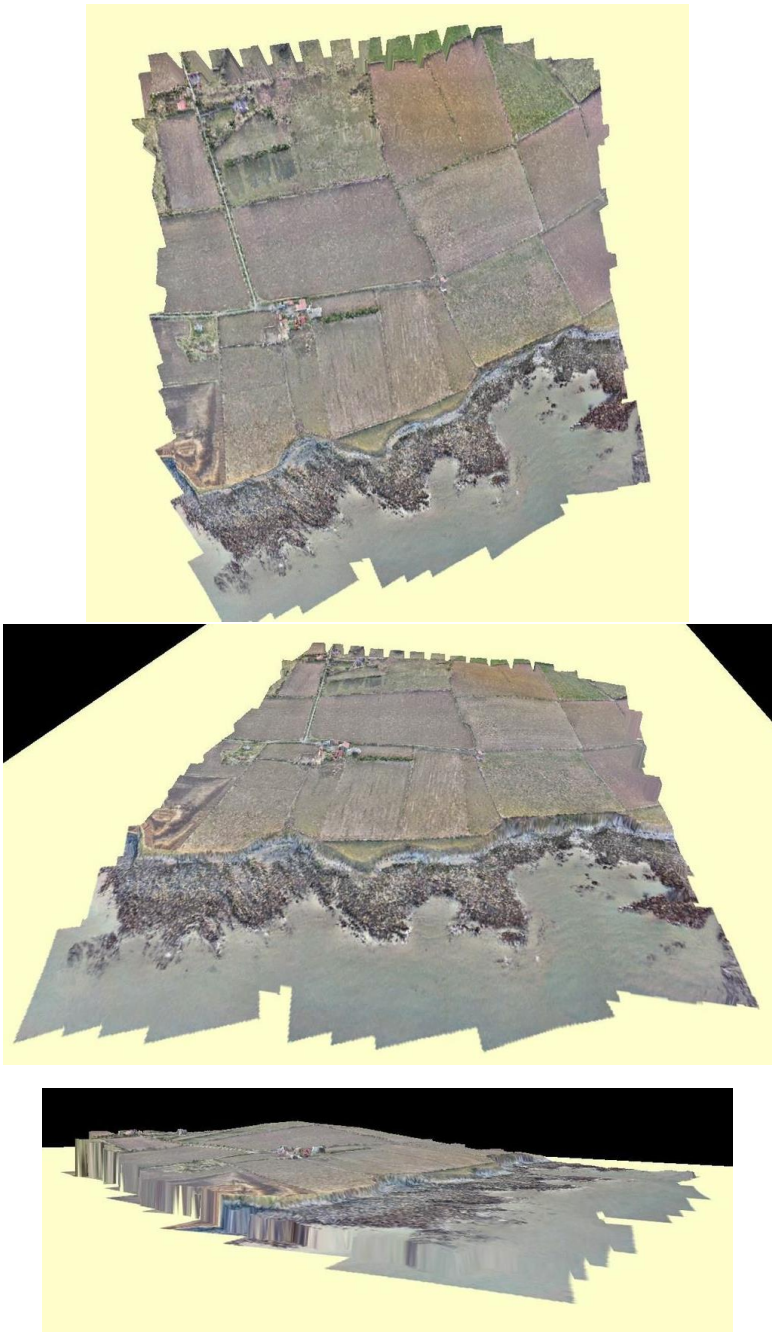


Figure 45 - Orthorectified images taken for the Skerries site

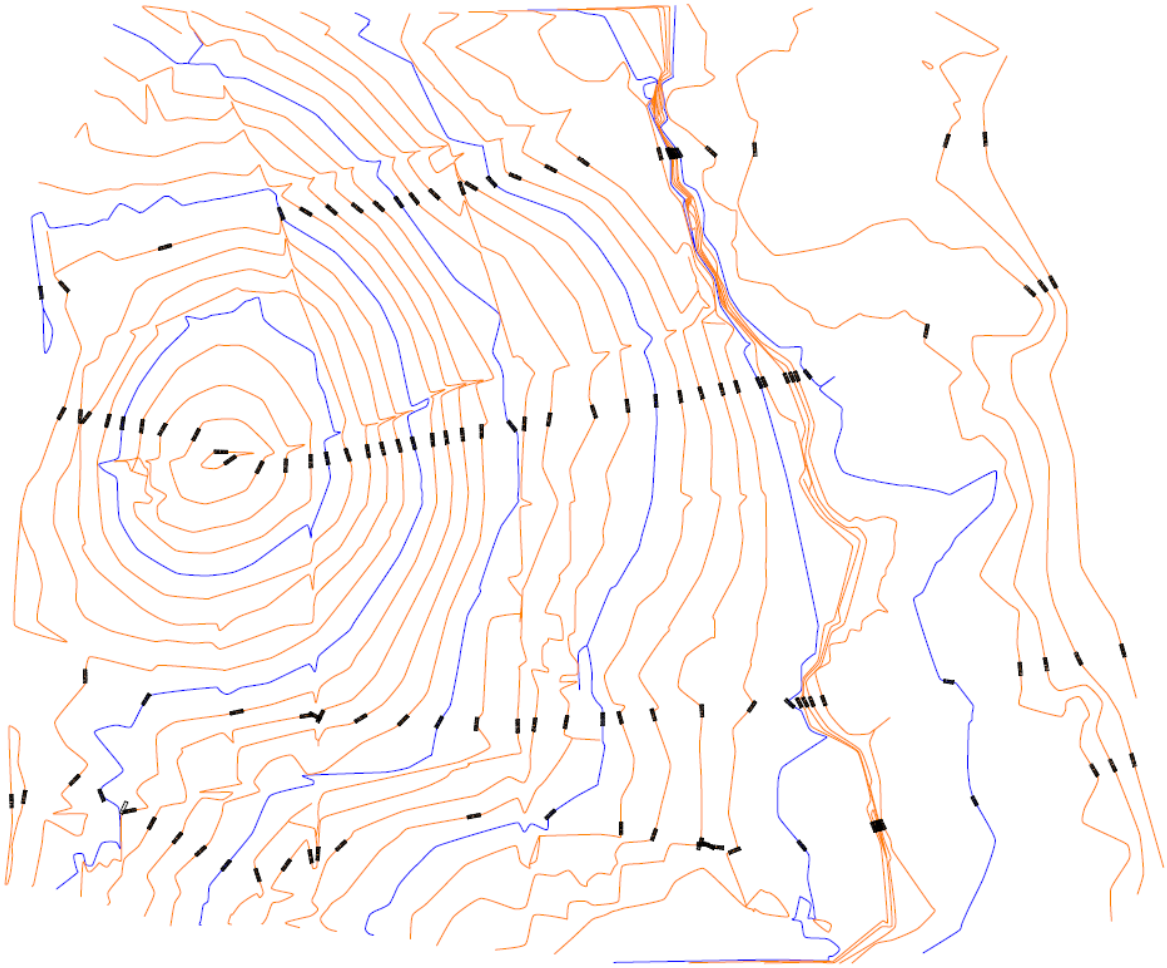


Figure 46 - Contour map showing altitudes at Skerries site

4. Portmarnock

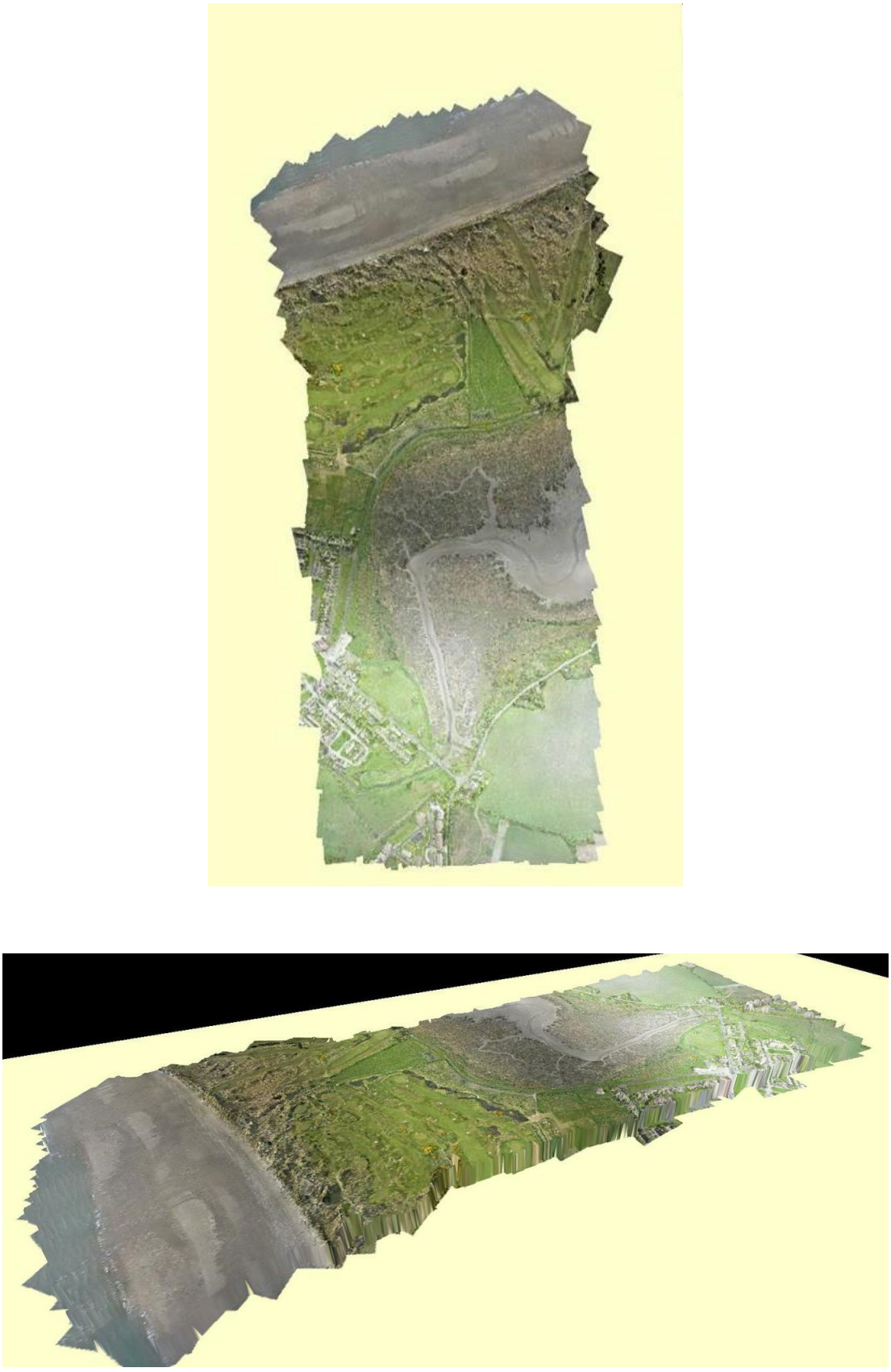


Figure 47 - Orthorectified images from the topographical survey at the Howth site

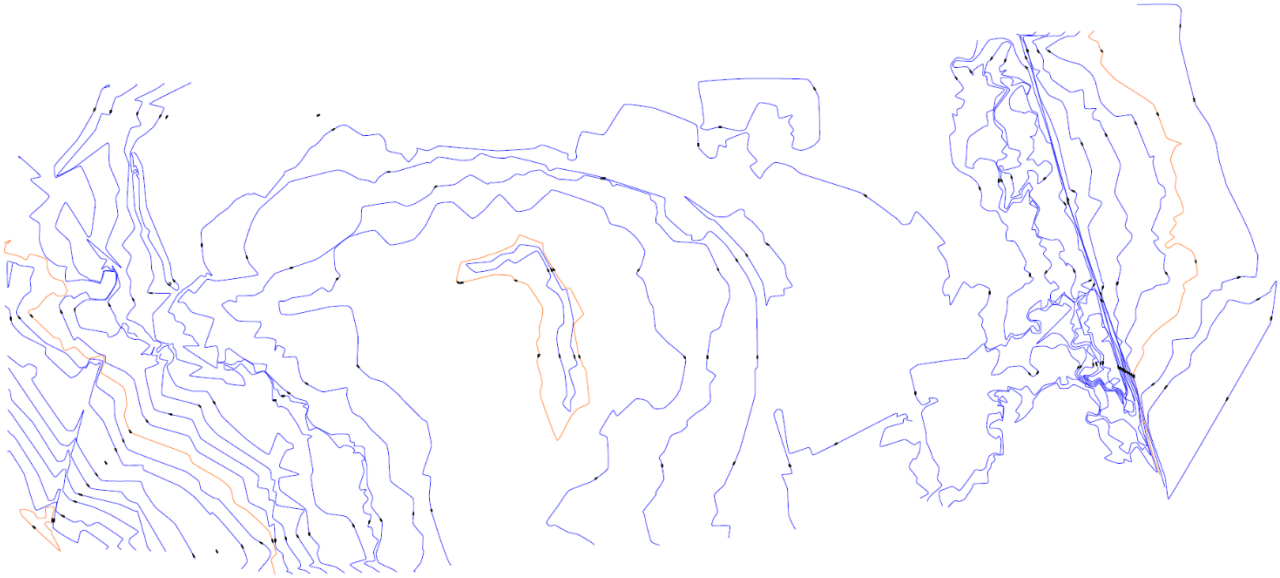


Figure 48 - Contour map from the topographical survey

Appendix C – MMO Reports (RV Geo & RV Keary)

Greater Dublin Drainage Scheme:

Marine Mammal Observation Report GEO13_GDD

Fingal County Council

TW/13/PRJ-012

15th April 2013

TechWorks Marine Limited
1, Harbour Road
Dun Laoghaire
Co. Dublin, Ireland

Private and Confidential

1. Introduction

The waters around Ireland's Coastline represent one of the most important cetacean (whales, dolphins and porpoise) habitats in Europe. To date 24 species of cetacean have been recorded in Irish waters (see Appendix A).

All cetacean species in Irish waters are protected by the 1976 wildlife act (and wildlife amendment act 2000) and Irish waters, including the EEZ were declared a whale and dolphin sanctuary in 1991. All cetacean species are protected under the EU habitats directive and the harbour porpoise and bottlenose dolphin are listed under annexe II of the habitats directive, requiring the designation of special areas of conservation (SACs) for their protection.

During 2005, the National Parks and Wildlife Service (Department of the Environment) agreed a draft set of 'guidelines for vessels engaged in seabed exploration and research using multi-beam, side-scan, seismic surveys and acoustic techniques to mitigate potential effects on marine mammals' for use in Irish waters.

These guidelines were updated and re-issued by the National Parks and Wildlife Service on 21st July 2007. The new measures "*Code of Practice for the protection of marine mammals during acoustic seafloor surveys within Irish waters*" were developed through extensive consultation with interested parties including the IWDG, CMRC, Petroleum Affairs Division and the industry.

They apply to all seismic surveys and some interferometric and sidescan sonar surveys. These guidelines are implemented during each leg of the GDDS bathymetric survey.

2. Date and location of Survey

Howth and Skerries - 6th February to 3rd March 2013

2.1 Survey Vessel

The R.V. Geo (see figure 1)

Figure 49: R.V. Geo

2.2 Qualified MMO

- Ronan O Toole – course date 4th September 2008 – 5 years ship experience
- Casual observations – Adam Partington – Marine Scientist

3. Survey area

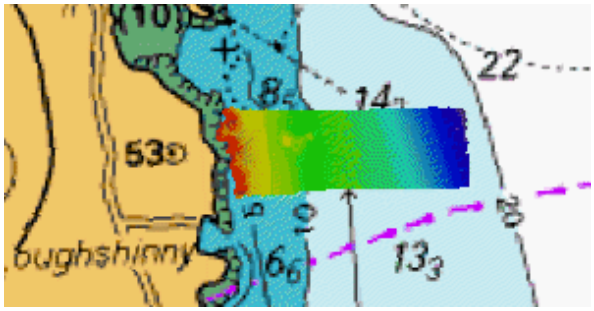


Figure 50: Bathymetric mapping coverage in Skerries

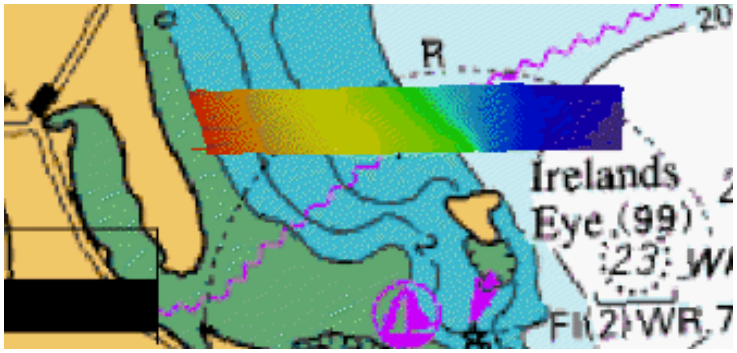


Figure 51 - Bathymetric mapping coverage in Howth

Table 18 - Boundary coordinates of survey areas

Point	Easting's	Northings	Latitude	Longitude (-ve)
Area A				
A	326171.317	258204.199	53o 33'31.585''	6o 5'48.225''
B	330431.034	258204.199	53o 33'27.841''	6o 1'56.956''
C	326171.317	257242.853	53o 33'0.508''	6o 5'49.62''
D	330431.034	257242.853	53o 32'56.765''	6o 1'58.398''
Area B				
A	323422.398	242699.988	53o 25'12.714''	6o 8'39.408''
B	330431.034	242699.988	53o 25'6.65''	6o 2'20.13''
C	323422.398	242038.541	53o 24'51.33''	6o 8'40.399''
D	330431.034	242038.541	53o 24'45.267''	6o 2'21.114''

4. Methods

The MMO Survey was conducted from the cabin vessel of the R.V Geo. Cetacean observations were carried during daylight hours by the casual observer and the MMO weather permitting (Beaufort Sea state 4 or less). The area was scanned during these hours by eye and by binoculars. Any sightings were recorded in the appropriate forms as included in the code of practice. A note was made of the date, time, species and position of the mammal.

4.1 Acoustic equipment

Interferometric Swath System operating at 468 kHz

Implementation of the Irish guidelines for mitigation of the effects of acoustic surveys on marine mammals.

Prior to the commencement of the survey, a briefing was given to all personnel on the nature of the Irish NPWS guidelines for mitigation of the effects of acoustic surveys on marine mammals and the practical aspects of their implementation during the survey. Soft copies of the guidelines were circulated to all personnel. A single harbour seal was spotted following a fishing vessel out of the marina. At the time the sonar system on the R.V. Geo was not running. As usual, once the crew arrived at the survey area a soft start was carried out in accordance with NPWS.

5. Marine mammal sightings

All marine mammal sightings are recorded in the MMO Cetacean records form. A single harbour seal was sighted during the leg of the survey.

Table 19 -Recorded sightings of marine mammals in survey area

Sighting No.	Date	Time	Species	No. of individuals	Location
	02/03/2013	12:20	*Phoca vitulina* (Harbour Seal)	1	53.524174, -6.071860

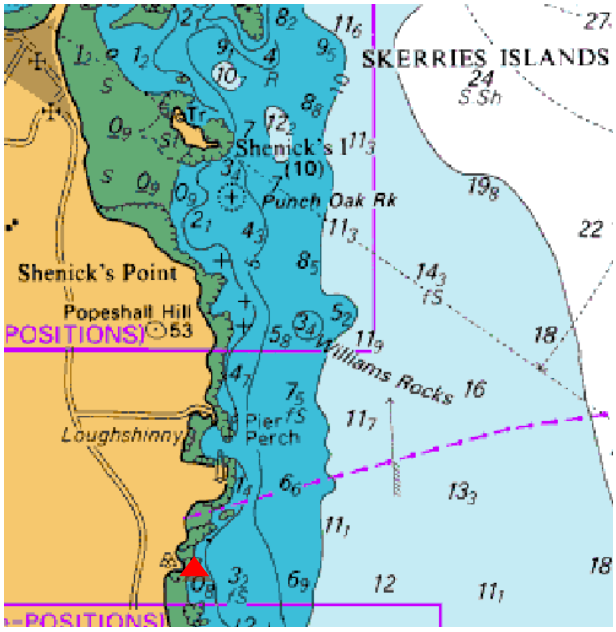


Figure 52 - Positions of seal sightings taken from GPS readings aboard the RV GEO

Figure 53 - Image taken from aboard the RV GEO - the Harbour seal in transit to survey area A

Appendix A - Below is a list of cetacean species spotted in Irish waters.

Atlantic White-Sided Dolphin	*Lagenorhynchus actus*	co / os / br
Beluga	*Delphinapterus leucas*	va / arc /
Blue Whale	*Balaenoptera musculus*	uc / os / se
Bottlenose Dolphin	*Tursiops truncatus*	co / br
Common Dolphin	*Delphis delphis*	co / br
Cuvier's Beaked Whale	*Ziphius cavirostris*	uc / os
False Killer Whale	*Pseudorca crassidens*	uc / os
Fin Whale	*Balaenoptera physalus*	co / se
Gervais' Beaked Whale	Mesplodon europaeus	va / st
Harbour Porpoise	*Phocoena phocoena*	co / is / br
Humpback Whale	*Megaptera novaeangliae*	ra / se
Killer Whale	*Orcinus orca*	sp / br[?]
Minke Whale	*Balaenoptera acutorostrata*	co / br[?]
Northern Bottlenose Whale	*Hyperoodon ampullatus*	uc / os
Northern Right Whale		
Eubalaena glacialis	va / os	
Pilot Whale (long-finned)	*Globicephala melas*	co / os / br
Pygmy Sperm Whale	*Kogia breviceps*	uc / os
Risso's Dolphin	*Grampus griseus*	co / br
Sei Whale	*Balaenoptera borealis*	uc
Sowerby's Beaked Whale	*Mesplodon bidens*	uc / os
Sperm Whale	*Physeter macrocephalus*	co / os / br[?]
Striped Dolphin	*Stenella coeruleoalba*	uc / os
True's Beaked Whale	*Mesplodon mirus*	uc / os
White-Beaked Dolphin	*Lagenorhynchus albirostris*	uc / os

co – common; os – offshore species; br – breeds in Irish waters; va – vagrant; arc – arctic species; uc – uncommon; se – seasonal; st – known only from strandings; is – inshore species; sp – sporadic.

Greater Dublin Drainage Scheme:

Marine Mammal Observer Report – RV Keary

Fingal County Council

TW/13/PRJ-012

20th May 2013

TechWorks Marine Limited
1, Harbour Road
Dun Laoghaire
Co. Dublin, Ireland

Private and Confidential

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List of figures

Executive summary

A high resolution sub-bottom survey was carried out on 20/05/2013 and 22/05/2013 on two sites offshore Co. Dublin.

Techworks Marine were contracted by Fingal County Council Greater Dublin Drainage Scheme to carry out the survey.

The survey platform was the RV Keary operated by the Geological Survey of Ireland.

Geophysical devices which emit acoustic energy used during the survey were a sparker and a chirp.

The National Parks and Wildlife Code of Practise for the Protection of Marine Mammals during Acoustic Seafloor Surveys in Irish Waters (2007) apply to the use of equipment of this kind so a qualified and experienced marine mammal observer (MMO) was employed for the duration of the survey.

There was one sighting of harbour porpoises (*Phocoena phocoena*) on 22/05/2013, no mitigating action was required.

The operators and contractor were fully in compliance with the NPWS Code of Practise throughout the survey.

1. Introduction

The waters of Ireland's Exclusive Economic Zone (EEZ) represent one of the most important cetacean (whales, dolphins and porpoise) habitats in Europe. To date 24 species of cetacean have been recorded in Irish waters (see Appendix IV). All cetacean species in Irish waters are protected by the 1976 Wildlife Act (and Wildlife Amendment Act 2000) and Irish waters, including the EEZ were declared a Whale and Dolphin Sanctuary in 1991. All cetacean species and their habitats are protected under the EU Habitats Directive (Annex IV), while harbour porpoise and bottlenose dolphin are listed under Annex II requiring the designation of Special Areas of Conservation (SACs) for their protection. Two species of seal (common seal and grey seal) breed in Ireland. In 2005, a total estimate of 5,509-7,083 individuals of grey seals was generated for Ireland. The common (harbour) seal is also found throughout Ireland, with an estimate of 2,905 animals present in Ireland in August 2003 (www.npws.ie).

Since August 2007, there exists a requirement for all seismic, multibeam and side scan sonar operators in the Irish EEZ to adhere to the Code of Practise for the Protection of Marine Mammals during Acoustic Seafloor Surveys in Irish Waters (2007), issued by the National Parks and Wildlife Service of the Department of the Environment, Heritage and Local Government. These guidelines require that `Qualified and experienced Marine Mammal Observers (MMOs) must be present on board all vessels conducting seismic (including boomers) or electromagnetic surveys at all times during the survey.

This MMO report describes a sub-bottom seismic survey of two days duration carried out by Techworks Marine on the RV Keary on two near-shore sites off Co. Dublin. The purpose of the survey was to ascertain the relative suitability of the two sites for a proposed outfall pipe as part of the infrastructure of the Greater Dublin Drainage Scheme.

2. Methods

2.1 Vessel

The survey was carried out using the RV Keary, a 15m catamaran operated by the Geological Survey of Ireland.

2.2 Geophysical equipment

Acoustic devices used during the course of the survey and subject to the NPWS Code of Practise were a Geo-Source 200-400 multi-tip Sparker operating at 300kJ towed behind the vessel and a hull-mounted Edge-Tech 3300 Chirp.

2.3 Survey location

The survey area consisted of two separate sites; the northern site was a polygon bounded by the following corner positions:

53° 33’ 30.62”N 006° 04’ 43.98”W

53° 33’ 28.06”N 006° 01’ 56.98”W

53° 32’ 59.79”N 006° 04’ 45.53”W

53° 32’ 57.26”N 006° 01’ 58.14”W

The southern site was also a polygon, bounded by the following corner positions:

53° 25’ 11.18”N 006° 06’ 51.47”W

53° 25’ 06.86”N 006° 02’ 20.16”W

53° 24’ 50.01”N 006° 06’ 52.44”W

53° 24’ 45.77”N 006° 02’ 21.17”W

Survey tracks consisted of parallel lines oriented east-west as per Figure 1. Data were also acquired on a number of cross-lines.

2.4 MMO watches

The MMO performed watches prior to and during soft starting of the Sparker from the platform on top of the wheelhouse which afforded unobstructed views around the vessel. Eye height was approximately 5m. Following these, watches were maintained throughout the survey, mostly from inside the wheelhouse.

2.5 Soft starting

Soft starting of the Sparker consisted of steadily increasing the energy output of the device while switching it on and off. Full power and constant output was reached after 20 minutes. The Chirp was started after the Sparker reached full power.

Figure 54- Chart showing the two sites surveyed offshore Co. Dublin

2. Results

3.1 Survey activity

Acoustic devices were active for 6 hrs 30 mins on 20 May and 10 hrs 57 mins on 22 May. There was one soft start carried out on each day and at least one source was active continuously thereafter. As line turns were shorter than the length of time required for a soft start there was no requirement to shut down at the end of the lines. Vessel speed averaged 4.9 knots during data acquisition.

3.2 MMO watches

The MMO was on watch prior to and during all operations on both days, 7 hrs 40 mins of visual watch was carried out on 20 May and 10 hrs 57 mins on 22 May.

3.3 Marine mammal sighting

There was a sighting of two harbour porpoise *Phocoena phocoena* at the northern site on 22 May at 18:05; they approached to within 100m of the survey vessel. The Chirp was active at the time and no mitigating actions were required (see Appendix III).

3.4 Environmental conditions

Conditions for visual watches were generally good throughout the survey, there was no rain, mist or fog and sea states did not exceed four. The sea state was two during both pre-soft start watches for marine mammals affording good opportunity to observe any marine mammals present.

4 Conclusion

The surveyors Techworks Marine and the vessel operators Geological Survey of Ireland were in full compliance with the NPWS Code of Practise for the Protection of Marine Mammals during Acoustic Seafloor Surveys in Irish Waters (2007) during the survey. Communication and cooperation between the survey and the MMO were excellent, and conditions were good for visual watches for marine mammals. No animals were observed during pre-soft start and soft start watches and the only sighting was of two porpoises which approached the vessel to within 100m while the Chirp was active, indicating no evidence of disturbance from the acoustic source.

Appendices

Appendix I: Location and effort data

Table 20 - Location and effort data

Ship name	Ship type	Survey type	Date	Observer	Start time	Stop time	Watch duration	Time source active	Wind force and direction	Sea state	Swell	Visibility
RV Keary	Survey vessel	Sparker and chirp	20/05/2013	Stephen Comerford	10:30	18:10	07:40	06:30	2-4 NW-W	2	1	3
			20/05/2013		07:33	18:30	10:57	10:06	4-5 NW	2 - 4	1	3

Appendix II: Record of operations

Table 21 - Record of operations

Ship	Client	Seismic Contractor	Date	Device	Soft start	Full Power	Output Stop	Observer name	Pre-shoot search	Search end	Mammals during pre-watch
RV Keary	GDDS	Techworks Marine	20/05/2013	Sparker	11:40	12:00	13:45	Stephen Comerford	10:30	13:45	None
			20/05/2013	Chirp		12:00	18:10		10:30	18:10	None
			22/05/2013	Sparker	08:24	08:44	17:05		07:33	17:05	None
			22/05/2013	Chirp		08:44	18:30		07:33	18:30	None

MARINE MAMMAL RECORDING FORM

Date 22/05/2013	**Time** (GMT) 18:05		**Sighting no.** 1

How did this sighting occur? (please tick box)

While you were keeping a continuous watch for marine mammals	X
Spotted incidentally by you or someone else	_
Other (please specify)	_

Ship name	**Observer name**
RV Keary	Stephen Comerford

Ship's position (latitude and longitude)	**Water depth** (metres)
53° 33.01N 006° 02.49W	15

Species	**Certainty of identification (underline)**
Phocoena phocoena	*Definite / probable / possible*

Total number	**Number of adults 2**
2	**Number of juveniles 0**

Description (include features such as overall size; shape of head; colour and pattern; size, shape and position of dorsal fin; height, direction and shape of blow)	**Photograph or video taken** *Yes / No*
	Direction of travel of animals in relation to ship (draw arrow)

Behaviour	**Direction of travel of animals** (compass points)
Travelling	000°

Activity of ship	**Airguns firing** (when animals first seen)	**Closest distance of animals from airguns** (metres) (Record even if not firing)
Chirp active, on survey	*Yes / No / Soft-start*	100

Appendix D – Method Statement

TechWorks Marine: Fingal County Council - GDDS Bathymetric Survey

Method Statement

This documentation will summarize the procedure for carrying out the bathymetric survey as part of the GDDS (Greater Dublin Drainage Scheme). The methodology will be carried out to meet the obligations set out in the scope of works document for this project (G100-G200).

Vessel Specifications

Figure 55 - The RV Geo moored in DunLaoghaire harbour

The survey vessel carrying out the work is the RV Geo.

7.5m draft 1.5m (with transducers deployed). P6 license approved. 250 HP diesel inboard engine. Full independent set of Raymarine depth sounder DSC VHF radio + handheld back up radio.

8KVA Generator on board. – Supplies independent power from the engine to all on board survey equipment and computers.

Safety equipment

Flares (orange/red), smoke canisters, fog horn, personal EPIRB (Emergency Position Indicating Radio Beacon). Life jackets worn at all times with licensed crew. Fire extinguishers (CO_2 (engine) +Powder for cabin).

Survey equipment

- **Side Scan Sonar SEA Swath plus Interferometer** (dual head) Swath approx. 30m - *high performance bathymetry and sidescan system, suitable for use on dedicated survey vessels.*
- **AML smart probe** attached to transducer heads for real-time sound velocity at the surface. *AML's Smart SV probe is a low-cost instrument ideal for measuring sound velocity during fast profiles or tow speeds. The probe is ideal for integration into existing data collection platforms or OEM equipment.*
- **Positioning and motion reference system - Applanix** – *The system integrates motion reference with GPS. Inertially-Aided Real-Time Kinematic (IARTK) technology is used to provide accurate attitude, heading, heave, position, and velocity data. These systems are designed for use with sonar systems, enabling adherence to IHO (International Hydrographic Organisation) requirements*
- **Software** - MV POSview v 6.0
- **Magnetometer** (Seatronics RE Magnetometer)
  - 50m of tow cable
  - Isolation transceiver
  - RS-232 cable
  - 24V universal AC power supply
  - BOB logging and GPS capability software for Windows
- **SBP** – Innomar parametric sub-bottom profiler series SES-2000 can be used to visualise sediment structures for dredging, geological surveys and the location of embedded objects like wrecks, pipelines or boulders with excellent resolution and penetration.
- **Acquisition software** - Splash Sea Software for interferometer configuration and settings. QPS QINSy for navigation and data acquisition
- **YSI castaway CTD** measurements for profiles
- **Seabed sampling via hand grab** –
- **VideoRay ROV/ Drop down camera** for ground truthing

Methodology

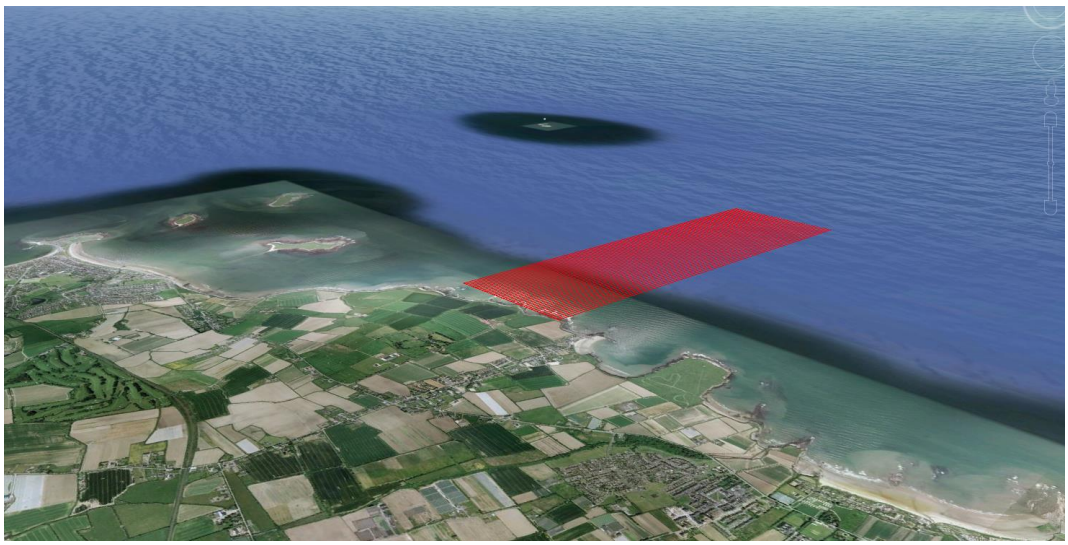
A- Execution of works

B- Equipment used

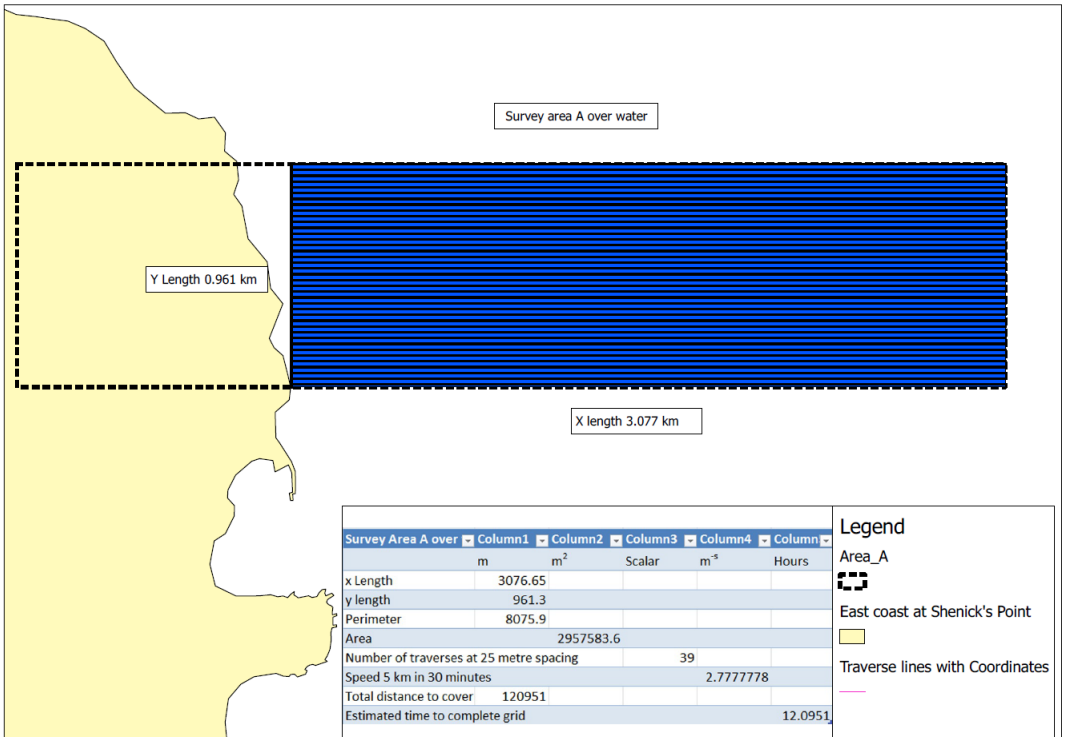
C- Impact Assessment

A

1) **Bathymetric survey and ground discrimination for both survey areas (A & B).** RV Geo to transit to agreed survey locations and carry out survey according to standards specified in scope of works utilising to the equipment mentioned above.

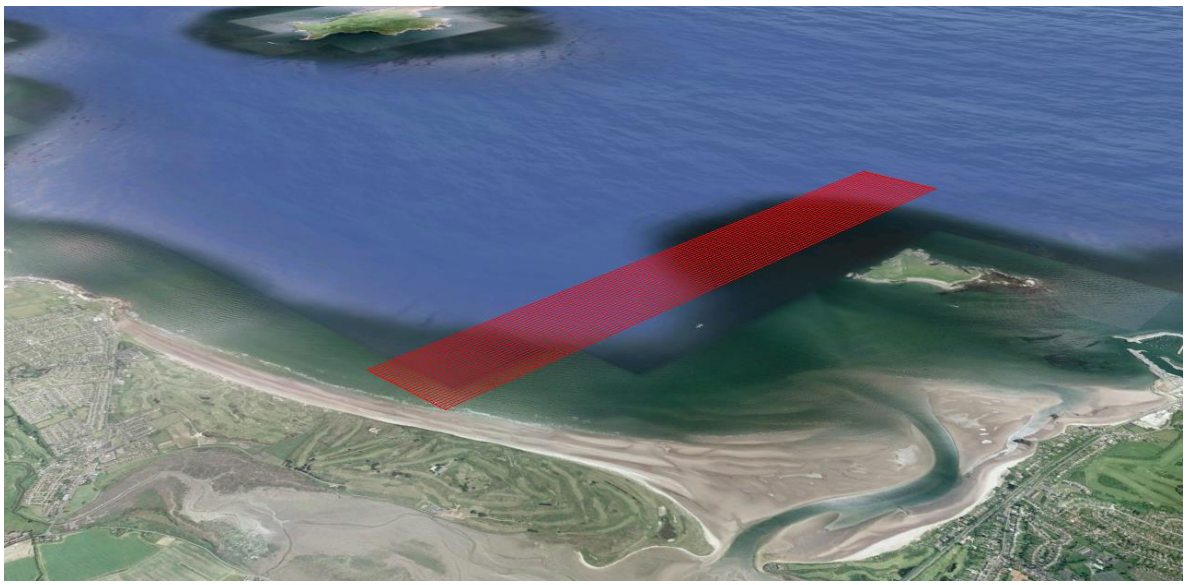


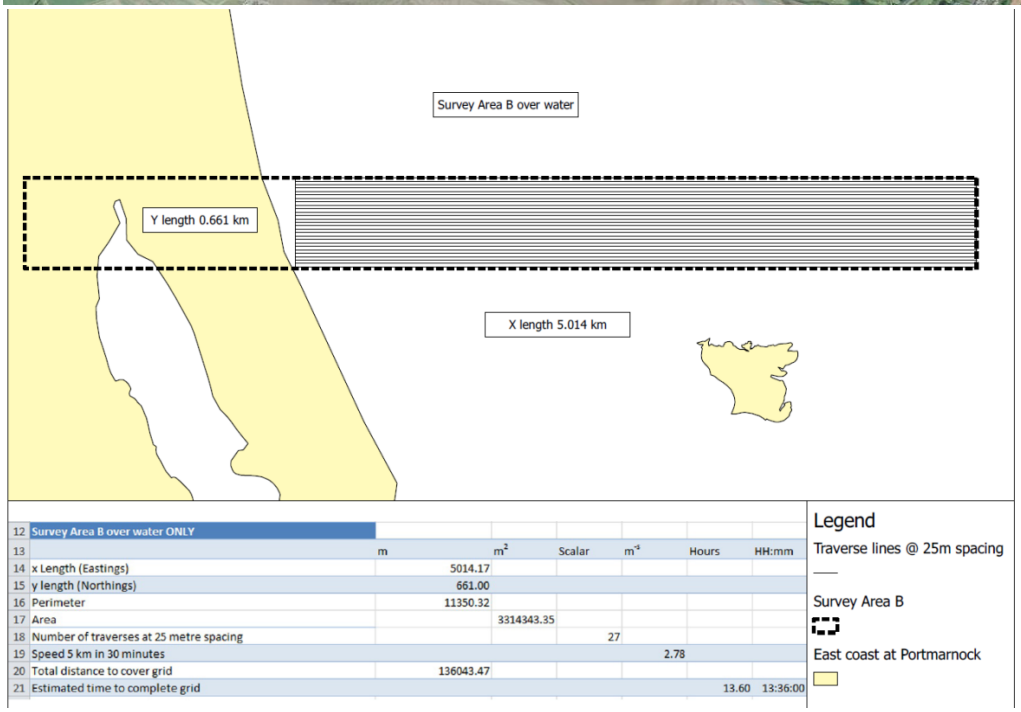
Site A



Survey Area A over	Column1	Column2	Column3	Column4	Column
	m	m^2	Scalar	m^{-s}	Hours
x Length	3076.65				
y length	961.3				
Perimeter	8075.9				
Area		2957583.6			
Number of traverses at 25 metre spacing			39		
Speed 5 km in 30 minutes				2.7777778	
Total distance to cover	120951				
Estimated time to complete grid					12.0951

Site B





12	Survey Area B over water ONLY						
13		m	m^2	Scalar	m^{-1}	Hours	HH:mm
14	x Length (Eastings)	5014.17					
15	y length (Northings)	661.00					
16	Perimeter	11350.32					
17	Area		3314343.35				
18	Number of traverses at 25 metre spacing			27			
19	Speed 5 km in 30 minutes				2.78		
20	Total distance to cover grid	136043.47					
21	Estimated time to complete grid					13.60	13:36:00

Legend
Traverse lines @ 25m spacing
Survey Area B
East coast at Portmarnock

2) **Magnetic and Sub-bottom Investigation**

A magnetometer will be used to assist in the detection and classification of any wrecks.

On completion of bathymetric survey, SBP and Magnetometer will be mobilised on board the RV Geo and survey data will be acquired. The SBP will be will be pole mounted and the Magnetometer will be towed 50m behind the vessel.

Positioning information will be applied to both data sets from the vessels on-board QINSY navigation system.

3) **Ground truthing - (Camera and grab sampling)**

Seabed sampling will be carried out intermittently during survey. Quantity of samples will be dictated by level of seafloor variation within the survey area with the minimum of 1 sample taken for every identified seabed class. Where seabed composition changes, further investigation will be carried out using a drop camera or an ROV.

4) **Object/ Contact investigation**

All potential man made contacts will be investigated using VideoRay ROV and/or drop down camera.

Any further investigative works will be carried out based upon the bathymetric and magnetic data.

5) **CTD Profiling**

YSI castaway CTD profiler will be deployed throughout survey operations. This information will be used to determine variations in the speed of sound through the water column. This information will be used to correct for refractions in the acoustic data.

6) **Static Observation (Base Station GNSS ground station observations)**

Typically GNSS static observations will be recorded simultaneous to bathymetric data acquisition. Results obtained will be applied to vessel navigation data during the post-processing stage. OSI active base stations located near to the survey area may also be utilised for this purpose.(PPK processing) In the event that both sources of position information are inadequate, satellite ephemeris (PPP) data, once available, will be applied to post process navigation data.

7) **MMO (marine mammal Observations)** - log all events

Survey will be run according to guidelines set in NPWS in relation to geophysical acoustic surveys. An MMO report will be furnished as an appendix to the final report of the survey. Observations made in the field will be recorded by a qualified MMO according to the guidelines.

8) **Tide Gauge Data Acquisition**

Tide Gauges installed (SBE 39s). Base station to be installed prior to works carried out (Locations of tide gauges in Howth and Skerries referenced to Datum at Malin Head). Gauges will be retrieved after completion of all survey work. Data will be downloaded from instruments and used to validate vessels on board GPS system.

9) **Post Acquisition data processing** - VORF model application

Bathymetric and navigation survey data will be processed on shore utilising Applanix POSPACK software and CARIS HIPS and SIPS (bathymetric data processing software). Final data quality control will be carried out during this stage of the operation

10) **Online data quality assurance**

Survey data will be monitored in real-time by the on-board survey team for required accuracy thresholds, spikes and other anomalies. Where such erroneous data errors occur, appropriate action will be taken to re-acquire the data should the required data standards be affected.

Survey lines will be run in a manner allowing the generation of data adhering to IHO S-44 order 1A standards. Weather conditions on the site will be monitored and Survey operations will be postponed when adverse weather affects the required level of data quality.

Details of this process and a surveyors log will be included in the final report.

11) **Survey Vessel operation**

Personal Sea survival training - All personnel carrying out the survey have all the necessary qualifications including Personal Survival Techniques (PST) STCW95 and ENG 11 Medical. Skipper has a full BIM passenger boat license with Category A commercial endorsement.

Vessel has a P6 license as certified by the MSO.

Survey Data will be acquired along transects at a speed of 6kots.

12) **Report of Survey**

Will be produced after all survey data has been acquired and processed (CARIS base surface xyz esri grid). A template will be provided by GSI for reference

13) **Base of operations**

Decision on BOO during survey work and will be guided by current and forecasted weather as well as security. Potential BOO are Howth, Skerries and DunLaoghaire. Infrastructure and facilities at each are adequate for requirements.

14) **Geodetic control**

Will be provided by the establishment of an onshore base station for logging static observations, a tide gauge levelled to known vertical datum and the vessel itself will record its position and depth in relation to the WGS 84 elipsoid. The UKHO's VORF model will be employed to reduce measured depths to LAT (Lowest Astronomical Tide) and OD Malin prior to final data delivery.

Appendix E – Magnetometer Survey

Greater Dublin Drainage Scheme:

Magnetometer survey

Fingal County Council

TW/13/PRJ-012

22th May 2013

TechWorks Marine Limited
1, Harbour Road
Dun Laoghaire
Co. Dublin, Ireland

Private and Confidential

1. Introduction

On the 20th of May TechWorks Marine undertook a magnetometer survey in the survey areas to search for archaeological features on the seafloor. The SeaSPY magnetometer (figure 2) was towed 50m behind the RV Keary (figure 1). Survey tracks consisted of parallel lines oriented east-west in both areas.

2. Vessel

The survey platform was the RV Keary operated by the Geological Survey of Ireland.

Figure 56 - The RV Keary

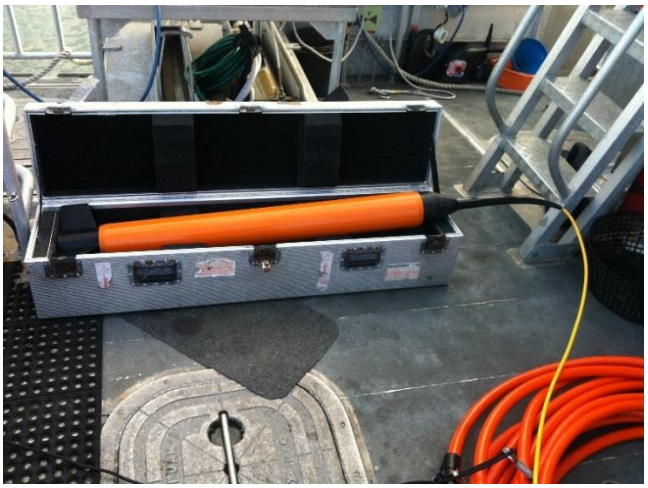


Figure 57 - The Marine Magnetics SeaSPY magnetometer on the deck of the RV Keary

Magnetometer (Seatronics RE Magnetometer)

- 50m of tow cable
- Isolation transceiver
- BOB logging and GPS capability software for Windows

3. Survey location

The survey area consisted of two separate sites; the northern site was a polygon bounded by the following corner positions:

53° 33’ 30.62”N 006° 04’ 43.98”W

53° 33’ 28.06”N 006° 01’ 56.98”W

53° 32’ 59.79”N 006° 04’ 45.53”W

53° 32’ 57.26”N 006° 01’ 58.14”W

The southern site was also a polygon, bounded by the following corner positions:

53° 25’ 11.18”N 006° 06’ 51.47”W

53° 25’ 06.86”N 006° 02’ 20.16”W

53° 24’ 50.01”N 006° 06’ 52.44”W

53° 24’ 45.77”N 006° 02’ 21.17”W

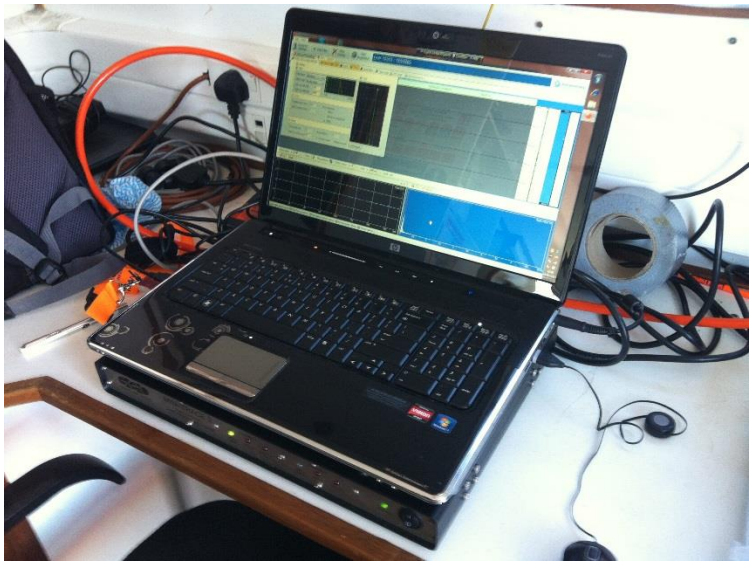


Figure 58 - Figure 3 - Deck unit for the magnetometer. An onboard surveyor monitored the readouts from the magnetometer.

4. Results

The magnetometer is connected to an interface box which records the position of the ship from the onboard GPS system. The data acquired from the magnetometer

Table 22 - Example of the readouts from the magnetometer

Date	Time	Field_Mag1	Depth_Mag1	Longitude	Latitude	UTM_Easting	UTM_Northing	UTM_Zone
20/05/2013	16:38:37	49086.453	-1.3m	-6.10012	53.415333	692715.5	5922392	29U
20/05/2013	16:38:37	49086.633	-1.4m	-6.10012	53.41534	692715.5	5922392.8	29U
20/05/2013	16:38:37	49086.703	-1.4m	-6.10012	53.41535	692715.5	5922393.9	29U
20/05/2013	16:38:38	49086.488	-1.4m	-6.10012	53.415357	692715.4	5922394.6	29U
20/05/2013	16:38:38	49087.227	-1.4m	-6.10012	53.415367	692715.4	5922395.7	29U
20/05/2013	16:38:38	49087.395	-1.3m	-6.10012	53.415373	692715.4	5922396.4	29U
20/05/2013	16:38:39	49087.707	-1.4m	-6.100119	53.415383	692715.4	5922397.5	29U
20/05/2013	16:38:39	49088.242	-1.4m	-6.100119	53.415389	692715.4	5922398.2	29U
20/05/2013	16:38:39	49088.082	-1.4m	-6.100118	53.415398	692715.4	5922399.3	29U

4.1 Site A

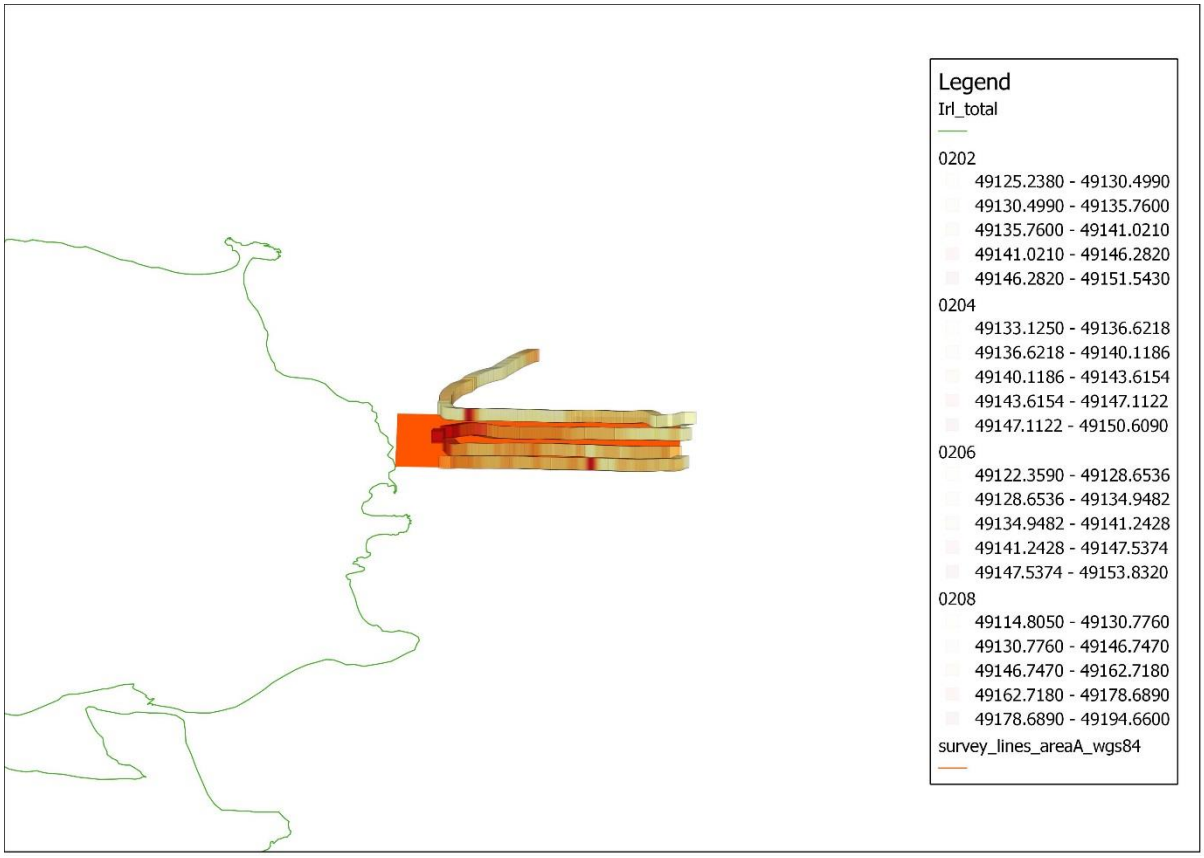


Figure 59- Map showing the Tracklines from the magnetometer survey in Area A (Skerries)

4.2 Site B

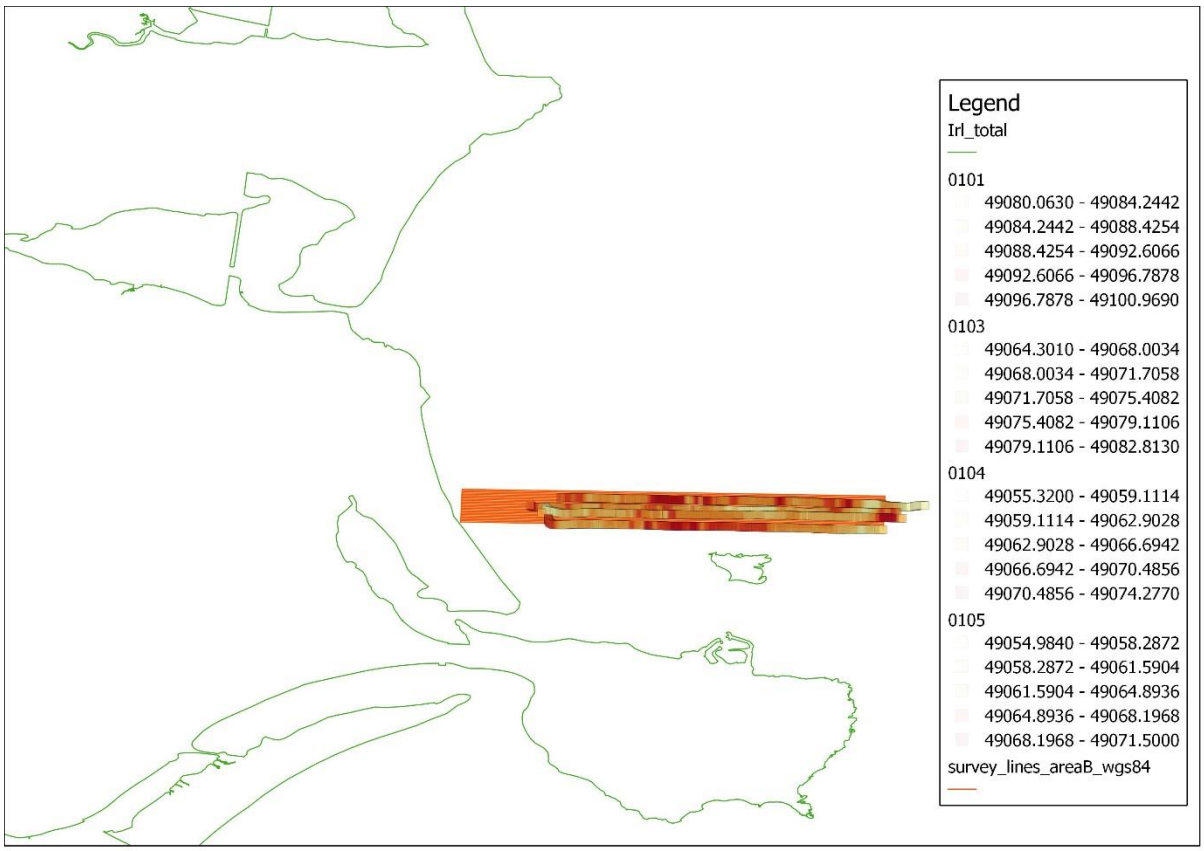


Figure 60 - Map showing Tracklines of the magnetometer survey in Area B (Howth)

The magnetometer survey revealed very little variation in the magnetic field suggesting that there were no archaeological artefacts, pipes or shipwrecks in either of the survey areas. The colour scale shows the variation in the magnetometer fluctuates between 41922.3590- 49194.660 in the Northern site (Area A) and 49054.9840 – 49100.9690 in the Southern site (Area B). This small variation is due to background noise.

Appendix F – Bedrock Geology

1. Bedrock Geology

Site A – Skerries

Rock classification

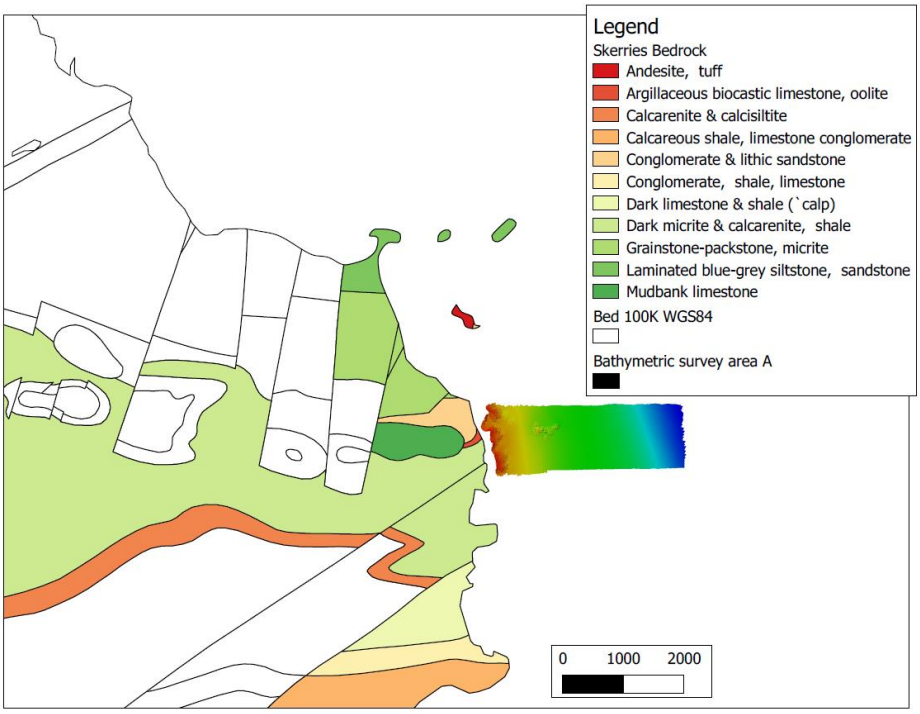


Figure 61 - Map showing the classification of rock types in the Skerries area

Name of formations

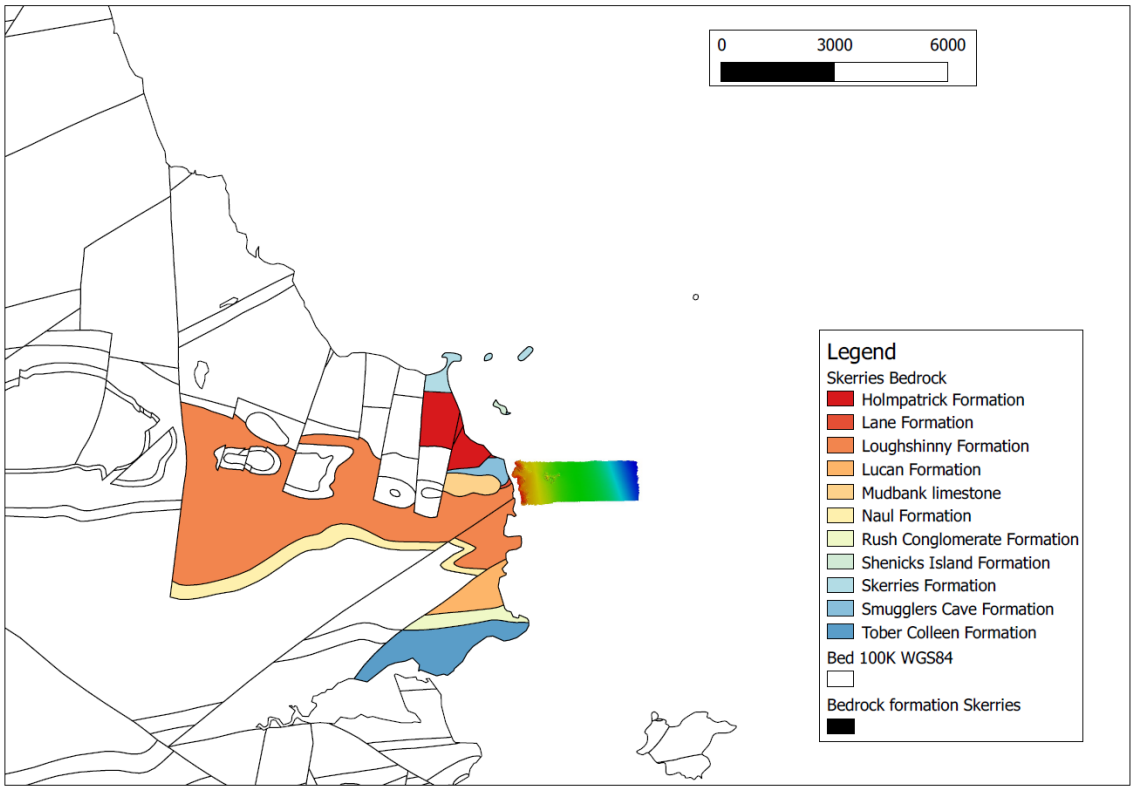


Figure 62 - Map showing the names of the rock formations at the Skerries site

Site B – Howth

Rock classification

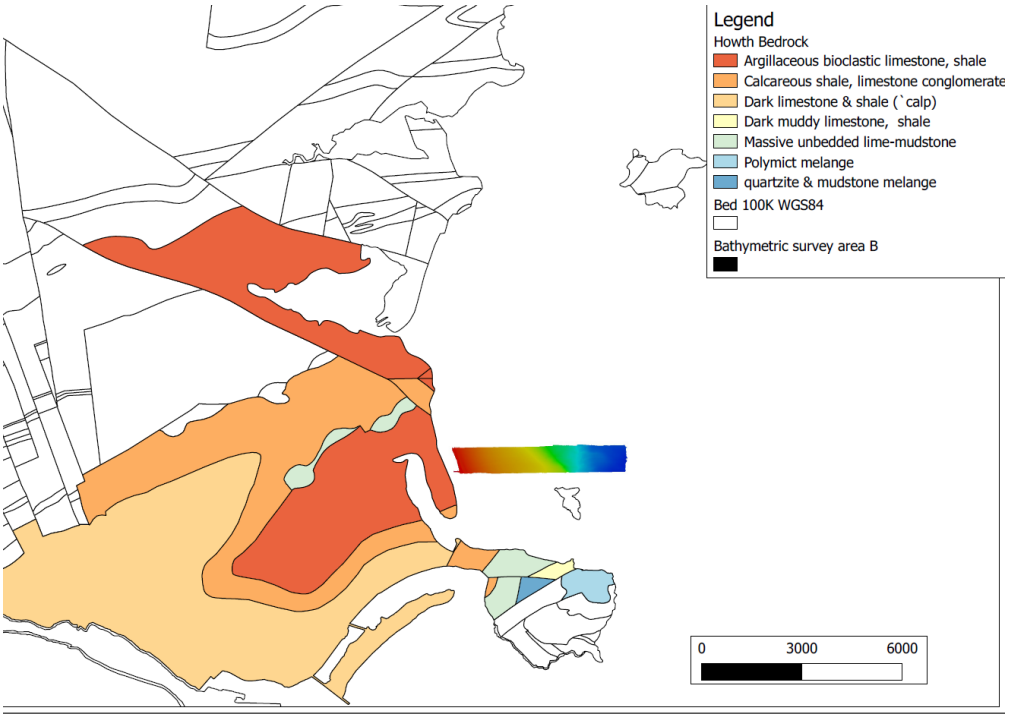


Figure 63 - Map showing the rock classifications at the Howth site

Name of formations

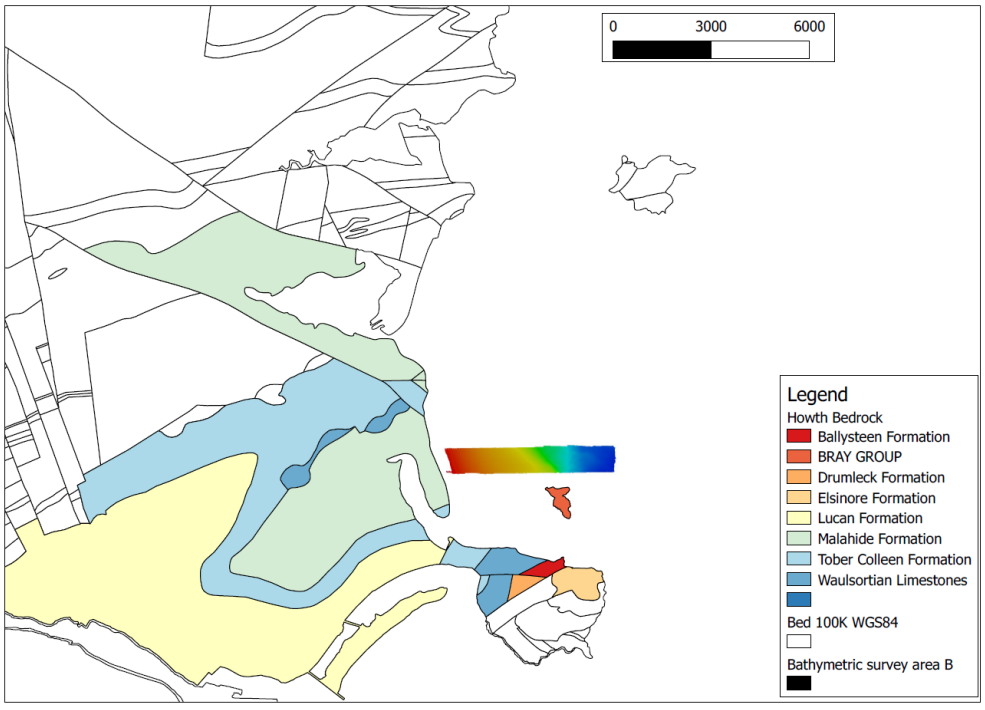


Figure 64 - Map showing the rock formations at the Howth site

Appendix G – Sub bottom Analysis – APEX report

Greater Dublin Drainage Scheme:

Sub- Bottom Analysis

Fingal County Council

TW/13/PRJ-012

14th June 2013

TechWorks Marine Limited

1, Harbour Road

Dun Laoghaire

Co. Dublin, Ireland

Private and Confidential

AGL13110

REPORT ON THE

GEOPHYSICAL INVESTIGATION

FOR THE

GREATER DUBLIN DRAINAGE SCHEME

FOR

TECHWORKS MARINE

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14TH JUNE 2013

PRIVATE AND CONFIDENTIAL

THE FINDINGS OF THIS REPORT ARE THE RESULT OF A GEOPHYSICAL SURVEY USING NON-INVASIVE SURVEY TECHNIQUES CARRIED OUT AT THE GROUND SURFACE. INTERPRETATIONS CONTAINED IN THIS REPORT ARE DERIVED FROM A KNOWLEDGE OF THE GROUND CONDITIONS, THE GEOPHYSICAL RESPONSES OF GROUND MATERIALS AND THE EXPERIENCE OF THE AUTHOR. APEX GEOSERVICES LTD. HAS PREPARED THIS REPORT IN LINE WITH BEST CURRENT PRACTICE AND WITH ALL REASONABLE SKILL, CARE AND DILIGENCE IN CONSIDERATION OF THE LIMITS IMPOSED BY THE SURVEY TECHNIQUES USED AND THE RESOURCES DEVOTED TO IT BY AGREEMENT WITH THE CLIENT. THE INTERPRETATIVE BASIS OF THE CONCLUSIONS CONTAINED IN THIS REPORT SHOULD BE TAKEN INTO ACCOUNT IN ANY FUTURE USE OF THIS REPORT.

PROJECT REFERENCE	AGL13110 GREATER DUBLIN DRAINAGE SCHEME		
AUTHOR	**CHECKED**	**REPORT STATUS**	**DATE**
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CONTENTS

1. EXECUTIVE SUMMARY

- APEX Geoservices Limited was requested by Techworks Marine to carry out a geophysical investigation over two sites as part of the off shore investigations for the Greater Dublin Drainage Scheme.

- The objectives of the geophysical investigation were to conduct seismic data processing and interpretation of existing datasets and provide information on sub-bottom layers and sediment / overburden thickness.

- The seismic data allowed for the interpretation of a number of horizons, the seabed, sedimentary layers and base of sediments / overburden.

- In both survey areas the thickness of the sediments / overburden varies from < 2m to c. 30m. With the largest values recorded in the east.

- In the southern survey area (Area 1), offshore Portmarnock, these layers are generally < 16m thick and are mainly < 12m thick in the northern area (Area 2), offshore Skerries.

- Across both survey areas a channel feature, where the sediments are thickest, is well defined and oriented southeast – northwest in the southern area and south – north in the northern area.

- The seabed elevation varies between c. -3mOD to -22mOD from west to east in Area 1, offshore Portmarnock, and c. -3mOD to -18mOD in Area 2, offshore Skerries.

- The bedrock elevation varies from -2 to -52mOD in Area 1 and -8m to -44mOD in Area 2. Over both sites the bedrock elevation below mOD is greatest further out to sea and within the channel areas.

- It is recommended the interpretation of the data be reviewed when intrusive investigation data becomes available.

2. INTRODUCTION

APEX Geoservices Limited was requested by Techworks Marine to carry out a geophysical investigation, based on existing client supplied datasets, at two offshore sites near Portmarnock and Skerries, County Dublin. The purpose of the investigation is to provide information on the sub bottom strata, including depth to bedrock across the site.

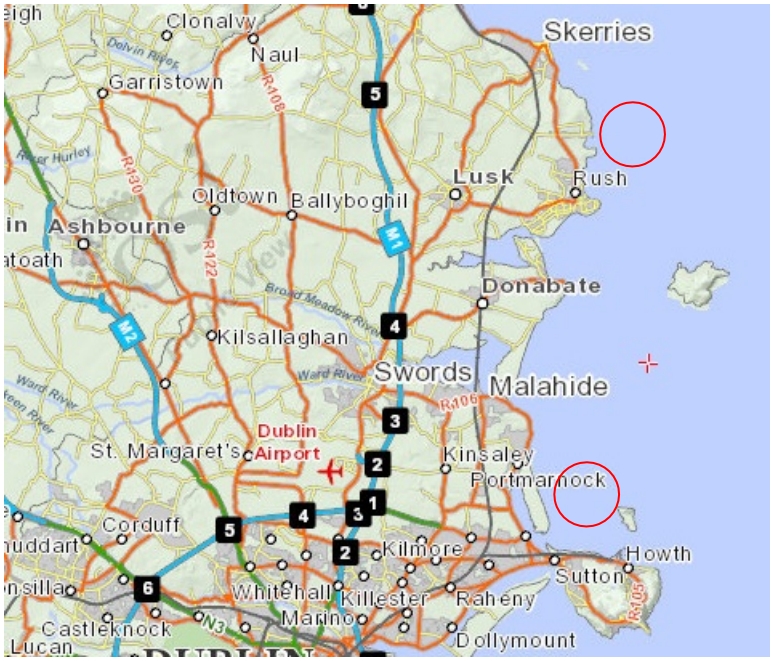


Figure 2.1: Survey areas off Partmarnock and Skerries (survey areas outlined in red).

2.1 Survey Objectives

The objectives of the geophysical investigation were to:

- Carry out seismic processing on Sparker and CHIRP data to provide information on the sub-bottom layers.
- Produce contour maps of sediment thickness.
- Identify and comment on any features of interest in the sediment and bedrock structure.

2.2 Site Background

As part of a seismic survey 12 CHIRP profiles and 8 Sparker profiles were acquired by the client over the two sites. Area 1 lies in the south, off Portmarnock, and measures approximately 4.7km x 0.8km and lies in water depths of approximately < 6m – 25m. The northern area, Area 2, is off Skerries and measures c. 2.7 Km x 1.5 Km. The water depth in this survey area varies between c. 5m and 23m.

2.3 Geology

The Geological Survey of Ireland (GSI) map does not show rock type for this sector of the Irish Sea but the rocks around Portmarnock are marine shelf and ramp facies consisting of argillaceous dark grey bioclastic limestones and shales.
The lithologies around Skerries consist of marine shelf facies, limestone and shales and dark grey argillaceous and cherty limestones.
The GSI seabed survey maps show the expected water depth to the east of the survey areas is > 20m.

Fig. 2.2: GSI Geology Map showing survey areas in red.

2.4 Survey Rationale

Single channel seismic surveys including Sparker and CHIRP datasets are used to image sediments and bedrock below the seabed. The raw seismic data can contain unwanted noise and signal which can impede interpretation of the data. The application of a seismic data processing test sequence can improve the visual display of the data and the imaging of geological boundaries and structure.

Further information on the detailed processing methodology employed in this investigation is given in **APPENDIX B: DETAILED GEOPHYSICAL METHODOLOGY**.

3. FINDINGS

The findings from the investigation have been presented on Drawings 13110_01 – 13110_04.

3.1 Sparker and CHIRP Seismic Data

During the interpretation process the following horizons were picked in the time domain;

- Seabed
- Sedimentary horizons
- Base of sediments / overburden

The conversion of the time picks to depth values was performed based on a number of assumptions;

- The deepest reflector imaged by the survey represents the base of the sediments / overburden layer thickness.
- The data was converted using a sedimentary velocity of 1750m/s.

Based on the above conversion velocity of 1750m/s the horizon depth accuracy is +/- 10%.

While the overall data quality was good the Sparker data showed more detailed imaging of the base of the sediments / overburden than the CHIRP data.

One CHIRP profile, 109, was of generally low data quality and was not used in the interpretation.

Where sedimentary layers were present as dipping strong reflections on the CHIRP data the underlying base of sediments / overburden was not always well imaged. In such cases the energy from the Sparker data did penetrate the sediments and image the deeper events.

3.2 Area 1 Offshore Portmarnock

The seabed elevation is displayed in Drawing 13110_01 Figure 2 and shows the seabed dips eastwards between c. -3mOD in the west and -22mOD in the east.

For Area 1, offshore Portmarnock, the thickness of sedimentary layers / overburden is shown on Drawing 13110_02 Figure 2 and the data is in the range < 2 – c. 30m. The thickness values are generally 6 – 16m over most of the site with an increase to > 22m in the east of the area. This area is interpreted as a southeast - northwest channel (see Drawing 13110_02).

The bedrock elevation contour data is displayed on Drawing 13110_02 Figure 1 and is in the range -2 to c. -52mOD. In the west of the site the elevation is generally -8 to -24 mOD. The bedrock is deepest in the east in the area of the channel.

3.3 Area 2 Offshore Skerries

The offshore Skerries data shows the seabed elevation varies from c. -3mOD in the west to -18mOD in the east. In the far northeast the seabed rises again from -18mOD to -8mOD.

The interpreted sedimentary layers are less than 12m thick over most of the western part of this survey area (see drawing 13110_04 Figure 2). Over the course of approximately 150m there is an increase in thickness to >20m. This change represents a south – north oriented channel in the top of the bedrock which has been filled with sediments.

In the northern part of this channel there is a localised decrease in sediment thickness to c. 12m. This represents a small area where the bedrock thickness decreases. This change in sediment thickness was interpreted across four of the seismic profiles.

Drawing 13110_04 Figure 1 represents the elevation of the bedrock in mOD. The elevation ranges c. -8m to -44mOD and shows the depth to bedrock is greatest in the east in the area of the channel.

The bedrock elevation contour map also shows a northeast – southwest oriented increase in elevation, which cuts the channel area. This indicates the bedrock shallows in the far northeast of the site.

3.4 Recommendations

It is recommended that the interpretation of the data be reviewed when any invasive investigation data is available.

Generally the Sparker data has given better resolution of the base of the sediments / overburden, particularly where a dipping event is overlain by a strong reflection. If more single channel data is to be acquired priority should be given to Sparker acquisition.

4. APPENDIX A: DRAWINGS

13110_01	Figure 1: Area 1,Portmarnock, Seismic Survey Location Map	1:10000 @ A1
	Figure 2: Area 1, Portmarnock, Seabed Elevation (mOD)	1:10000 @ A1
13110_02	Figure 1: Area 1,Portmarnock, Bedrock Elevation Contour Map	1:10000 @ A1
	Figure 2: Area 1, Sediment / Overburden Thickness Map	1:10000 @ A1
13110_03	Figure 1: Area 2, Skerries, Seismic Survey Location Map	1:10000 @ A1
	Figure 2: Area 2, Skerries, Seabed Elevation (mOD)	1:10000 @ A1
13110_04	Figure 1: Area 2, Skerries, Bedrock Elevation Contour Map	1:10000 @ A1
	Figure 2: Area 2, Skerries / Overburden Thickness Map	1:10000 @ A1

FIGURE 1: Area 1, Portmarnock, Seismic Survey Location Map

Scale 1:10000

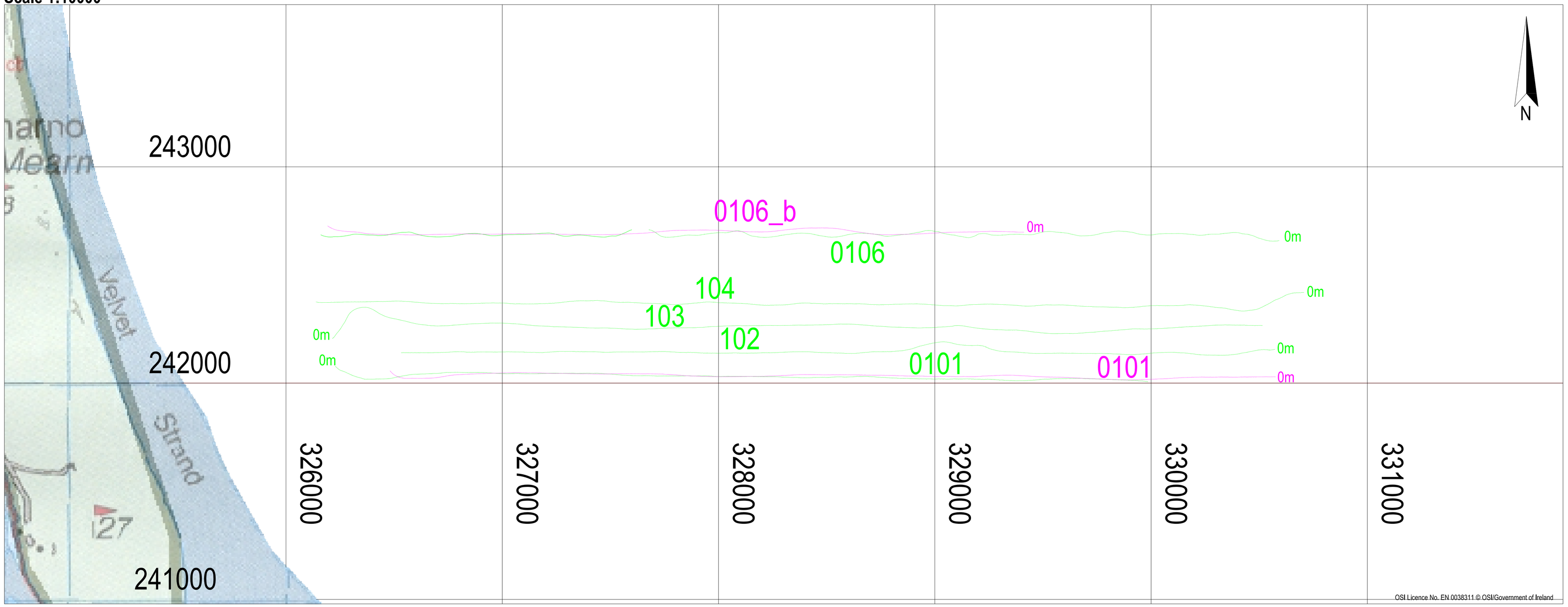
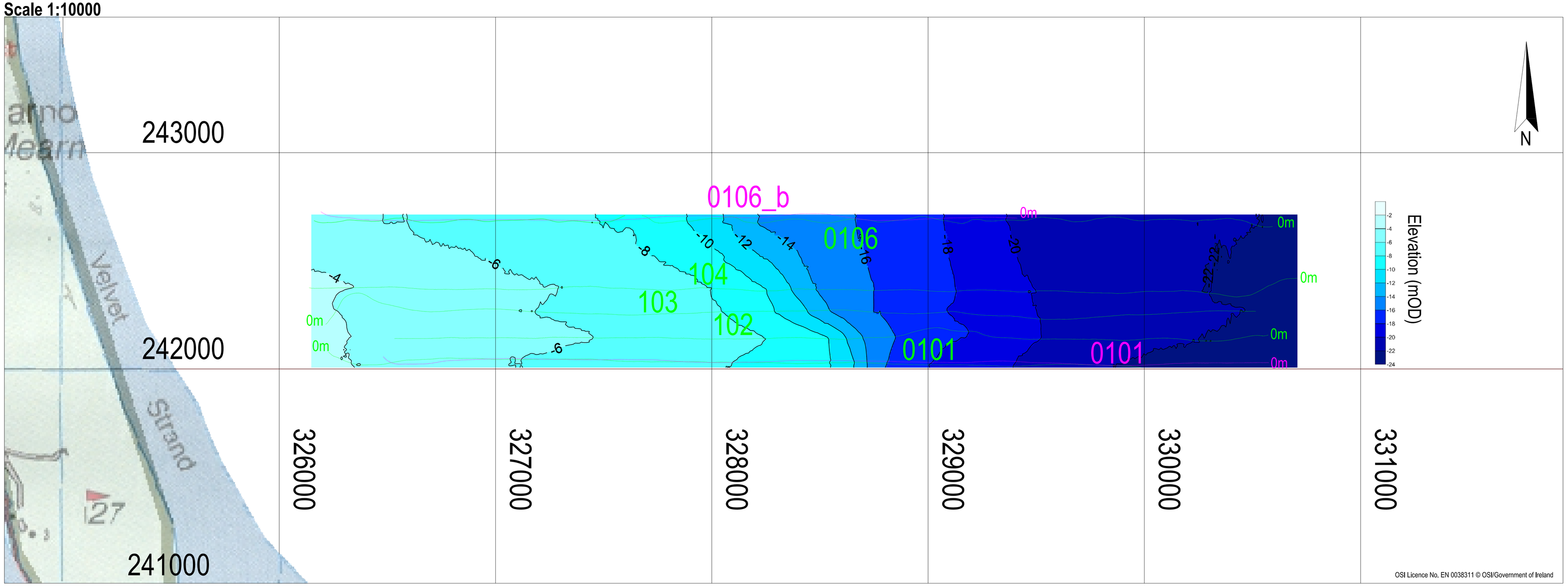


FIGURE 2: Area 1, Portmarnock, Seabed Elevation (mOD)

Scale 1:10000



INDEX MAP:

LEGEND:

101 Sparker Profile

101 Chirp Profile

NOTES:

PROJECT:
GREATER DUBLIN DRAINAGE SCHEME

CLIENT:
TECHWORKS MARINE

DRAWING NUMBER:
13110_01.DWG

SCALE:
1:10000 @ A1

DATE:
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FIGURE 1: Area 1, Portmarnock, Bedrock Elevation Contour Map

Scale 1:10000

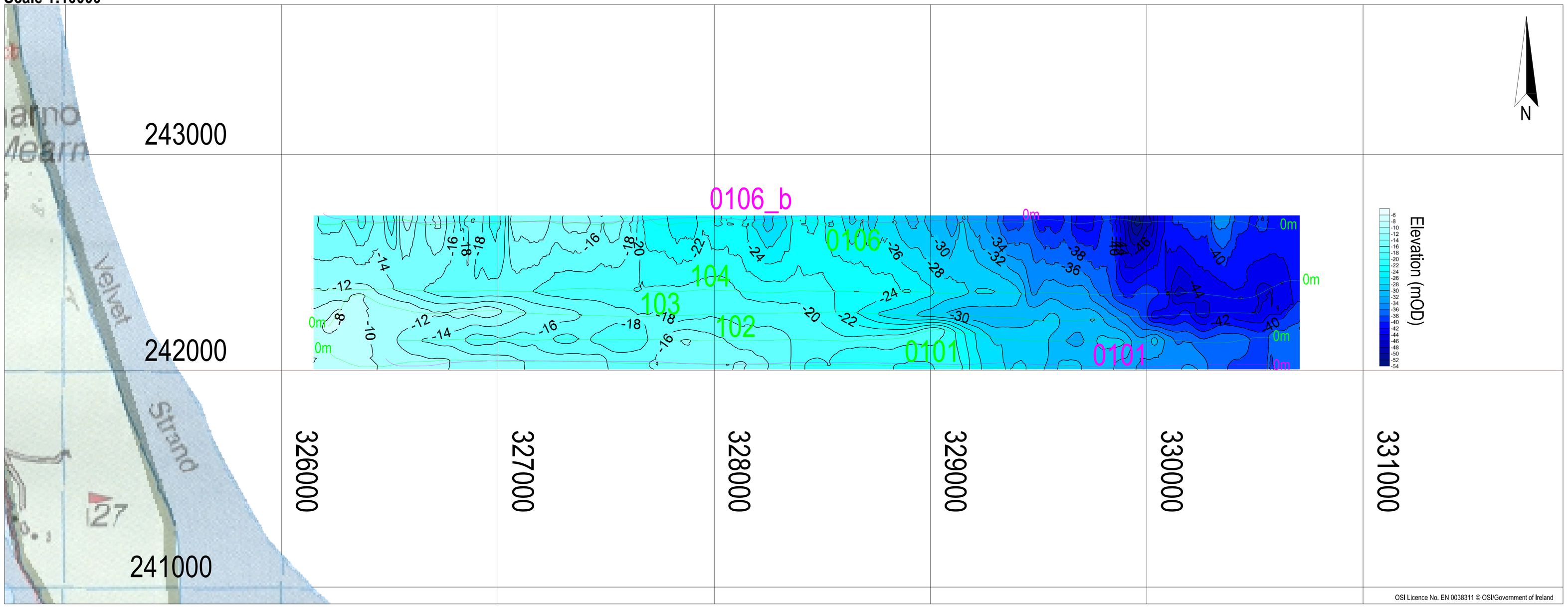
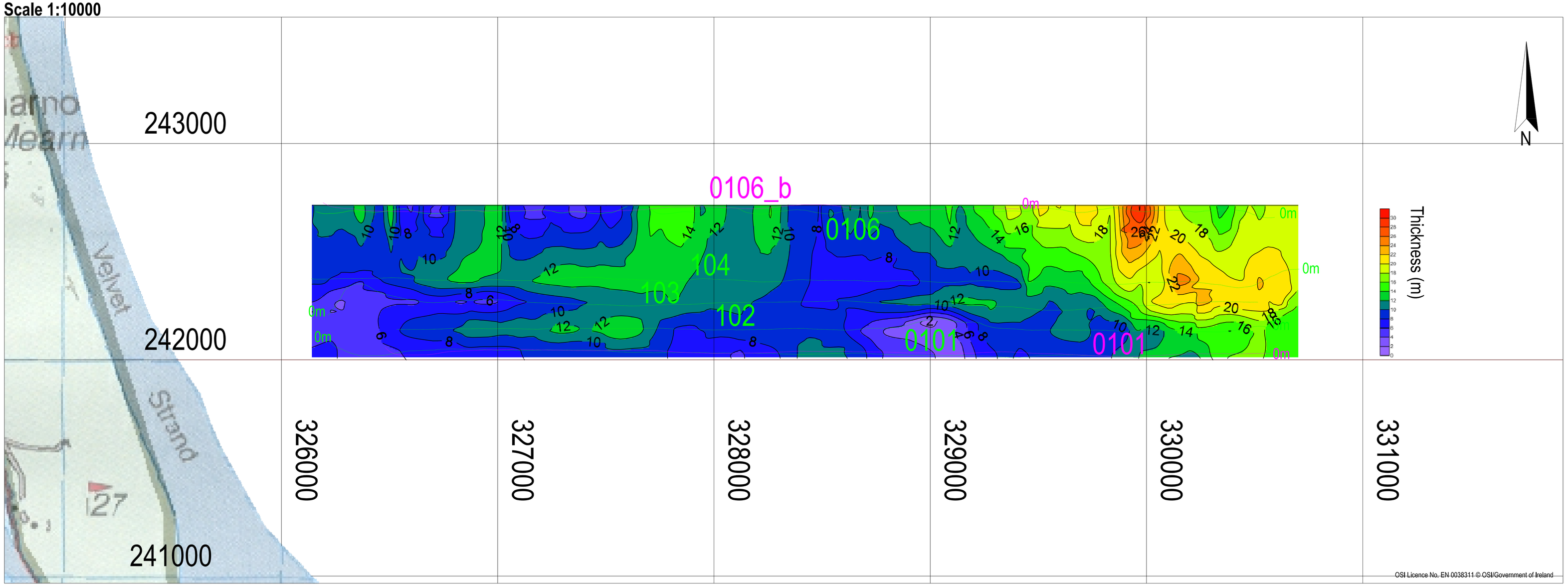


FIGURE 2: Area 1, Portmarnock,Sediment / Overburden Thickness Map (m)

Scale 1:10000



INDEX MAP:

LEGEND:

101 Sparker Profile

101 Chirp Profile

NOTES:

PROJECT:
GREATER DUBLIN DRAINAGE SCHEME

CLIENT:
TECHWORKS MARINE

DRAWING NUMBER:
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FIGURE 1: Area 2, Skerries, Seismic Survey Location Map

Scale 1:10000

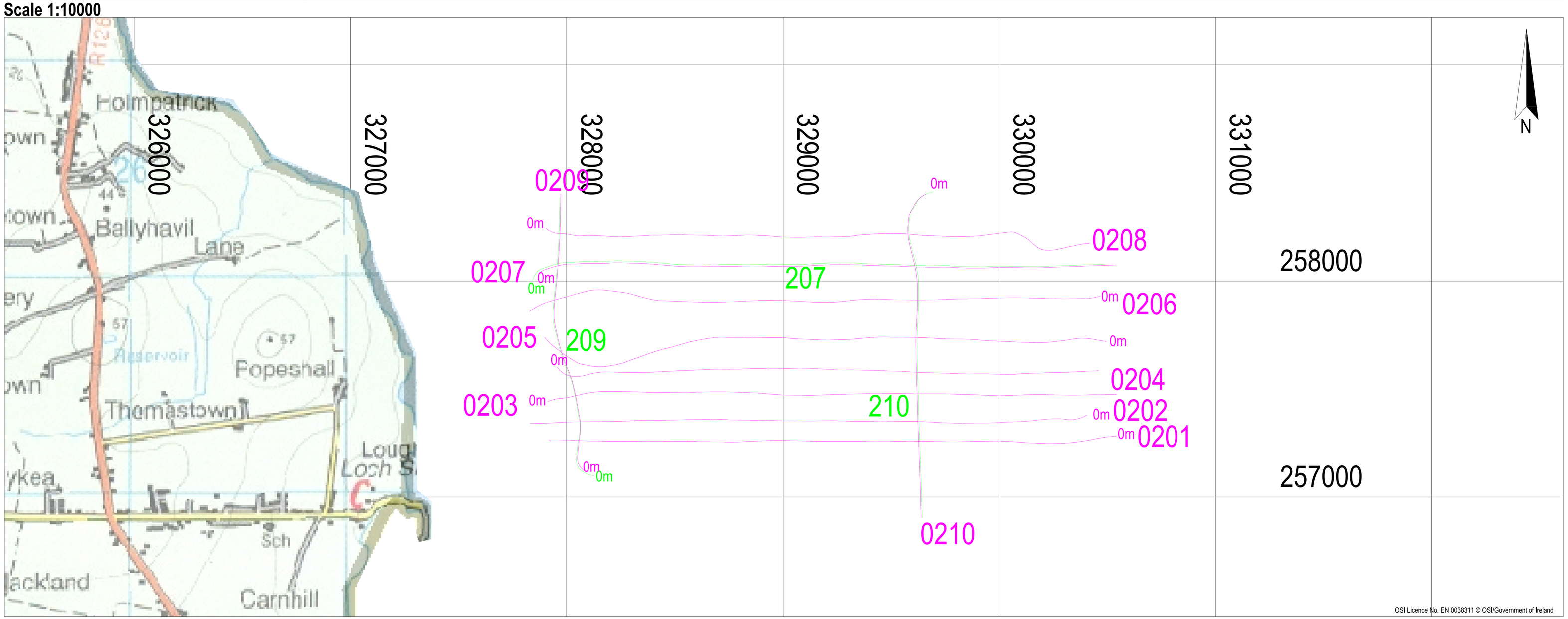
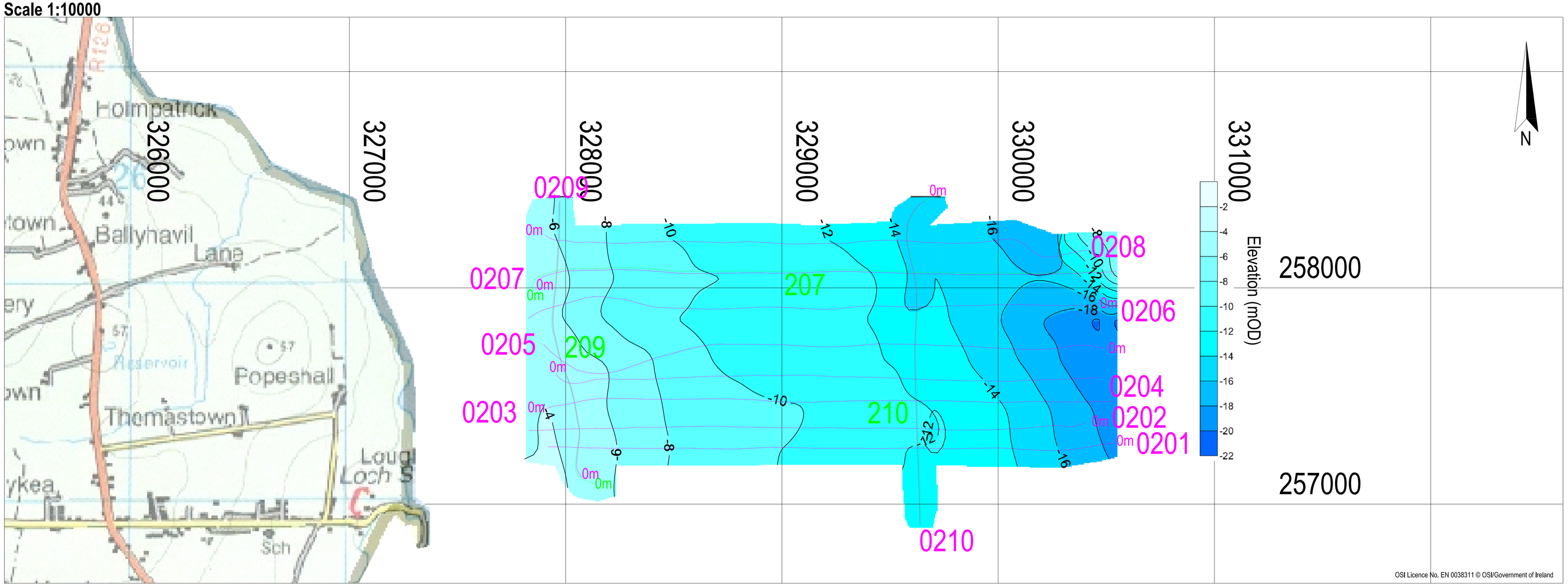
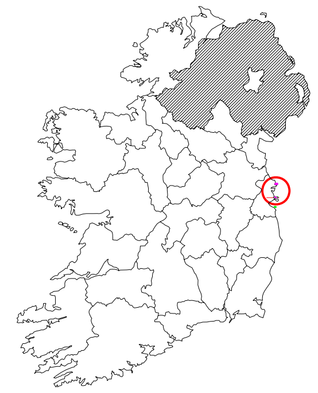


FIGURE 2: Area 2, Skerries, Seabed Elevation (mOD)

Scale 1:10000



INDEX MAP:



LEGEND:

101 Sparker Profile

101 Chirp Profile

NOTES:

PROJECT:
GREATER DUBLIN DRAINAGE SCHEME

CLIENT:
TECHWORKS MARINE

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FIGURE 1: Area 2, Skerries, Bedrock Elevation Contour Map

Scale 1:10000

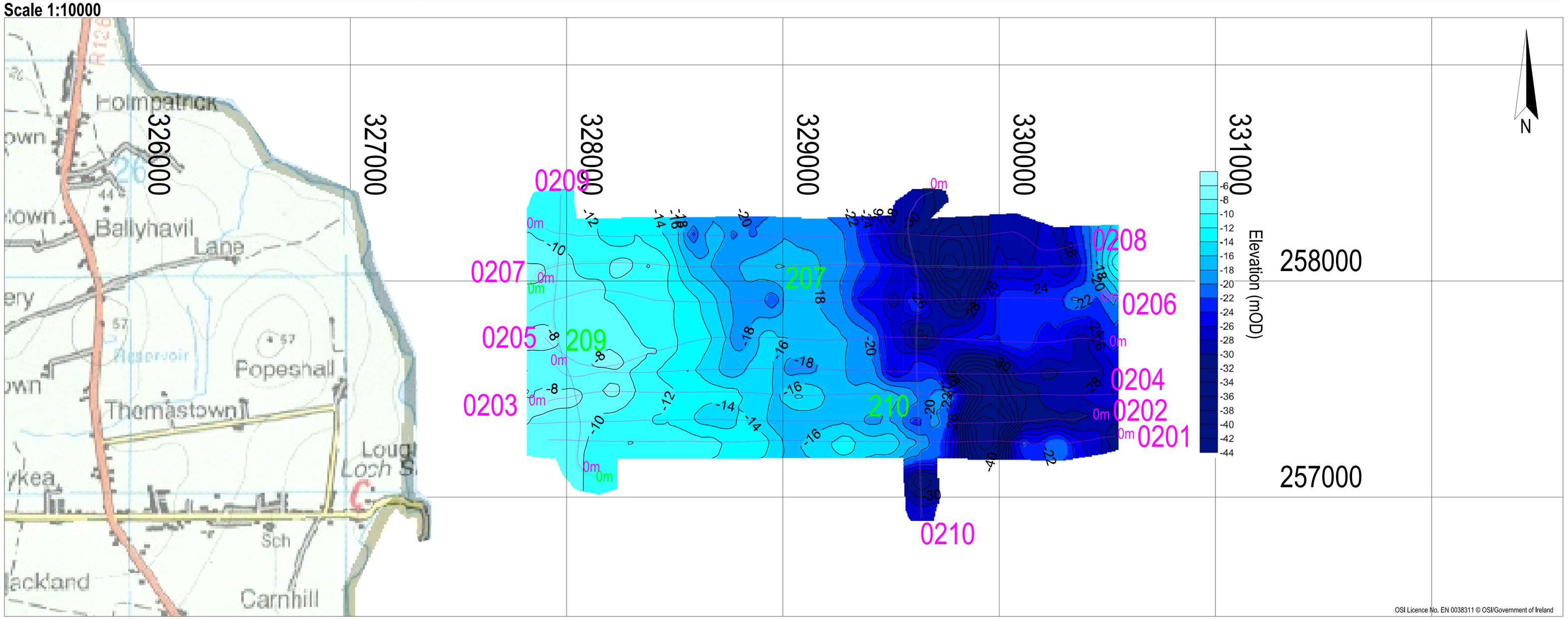
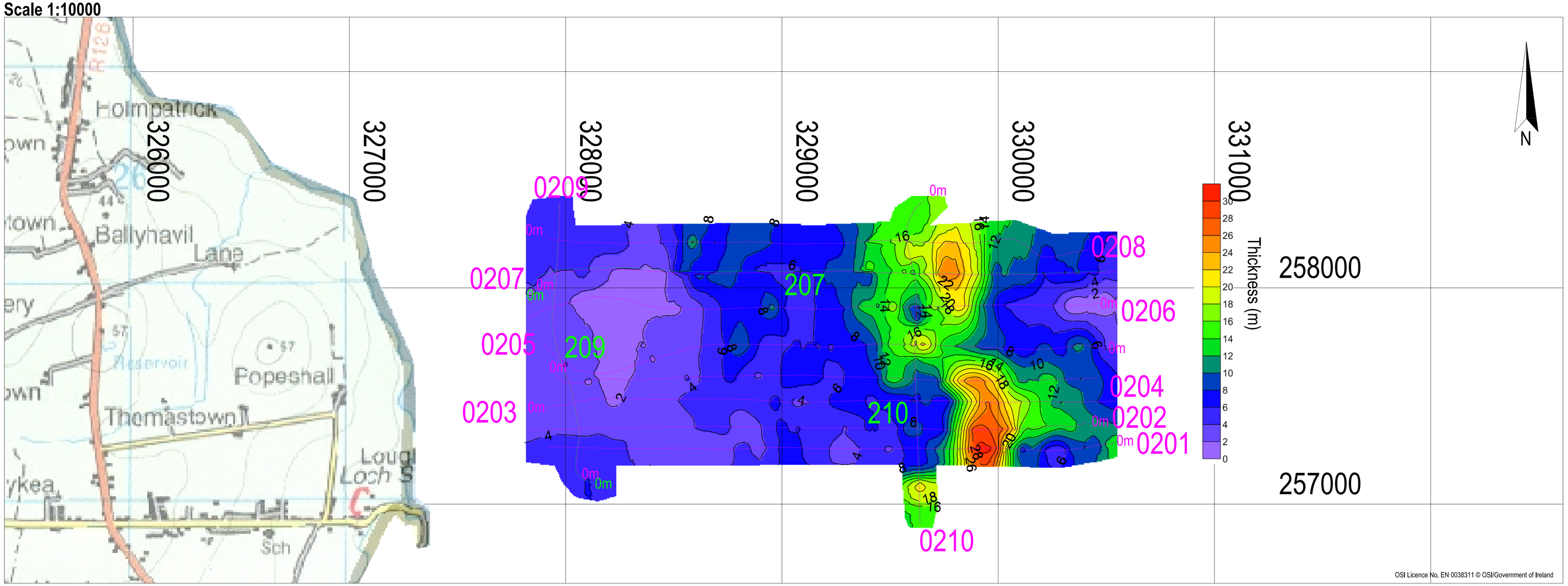


FIGURE 2: Area 2, Skerries,Sediment / Overburden Thickness Map (m)

Scale 1:10000



INDEX MAP:

LEGEND:

101 Sparker Profile

101 Chirp Profile

NOTES:

PROJECT:
GREATER DUBLIN DRAINAGE SCHEME

CLIENT:
TECHWORKS MARINE

DRAWING NUMBER:
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5. APPENDIX B: DETAILED METHODOLOGY

The investigation consisted of a robust seismic processing testing sequence which resulted in the application of a number of processing steps to the Sparker and CHIRP data.

5.1 Data Processing Sequence

5.1.1 Finalised Processing

The finalised data processing sequence included;

Sequence	Process	Parameterisation
1	Data Conversion	Convert client supplied SegY files to internal format for Processing.
2	Geometry	Apply navigation data in Irish National Grid coordinates. Remove duplicate traces
3	Filter	Bandpass Butterworth filter
4	Running Average	A running average filter over 3 traces was applied to suppress trace dependent noise and emphasise horizontal coherent energy (applied to Sparker data only)
5	Gain	A time variant gain was chosen to improve overall visual clarity of the data.
6	Interpretation	A number of geological boundaries including the seabed, internal sedimentary layers and the base of sediments / over burden were picked in the time domain.
7	Depth conversion	The picked horizons were converted to depth using a sedimentary velocity of 1750m/s.
8	Tidal Correction	A tidal correction, appropriate to each survey profile, was applied to give finalised depth values for the picked horizons.

5.1.1 Additional Processing Testing

During the data processing other sequences were also tested. These included;

- Various filtering options
- Gain functions
- Deconvolution for multiple suppression
- Water bottom multiple suppression via subtracting average filters
- Sedimentary multiple suppression techniques

A number of the above techniques were not used in the final processing as they did not result in enhanced imaging of the target horizons and on some profiles had a negative impact on primary reflection events.

6. APPENDIX C: DATA EXAMPLES

The following Figures show data examples from the Sparker and CHIRP data over the two survey areas. The locations of the profiles are shown in Drawing 13110_01 and 13110_03. More detailed imaging of the horizons is seen on the Sparker data. The vertical axis shows time in ms and the horizontal shows trace no. (not true distance).

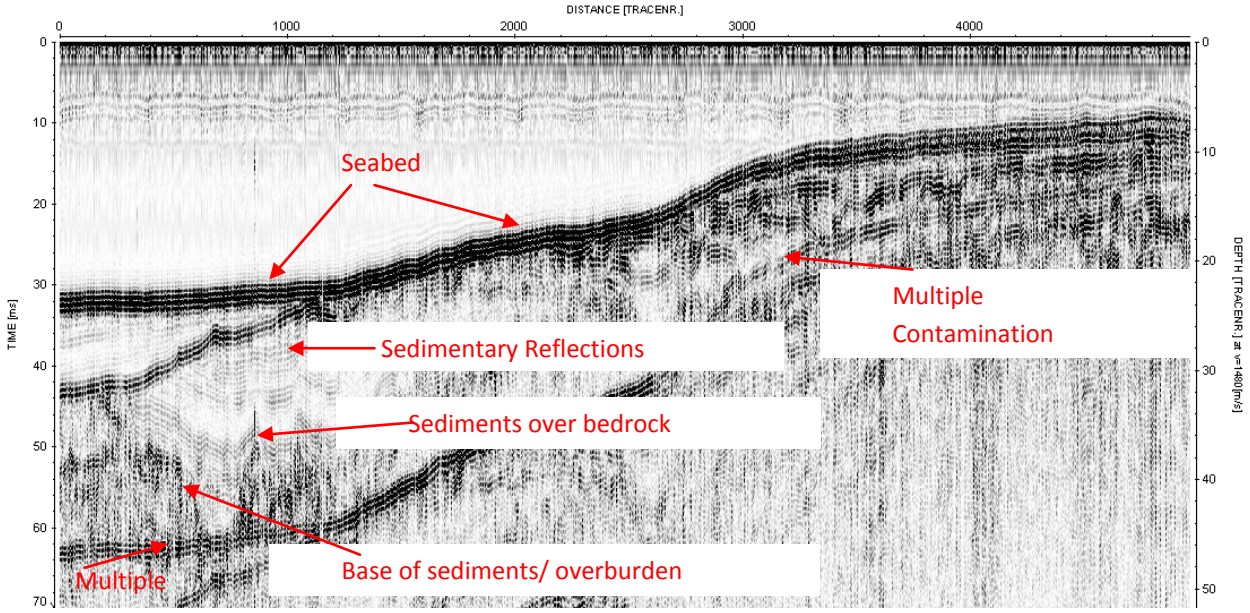

Figure 6.1: Sparker Profile 106 from the southern survey area, Portmarnock (plotted east - west).

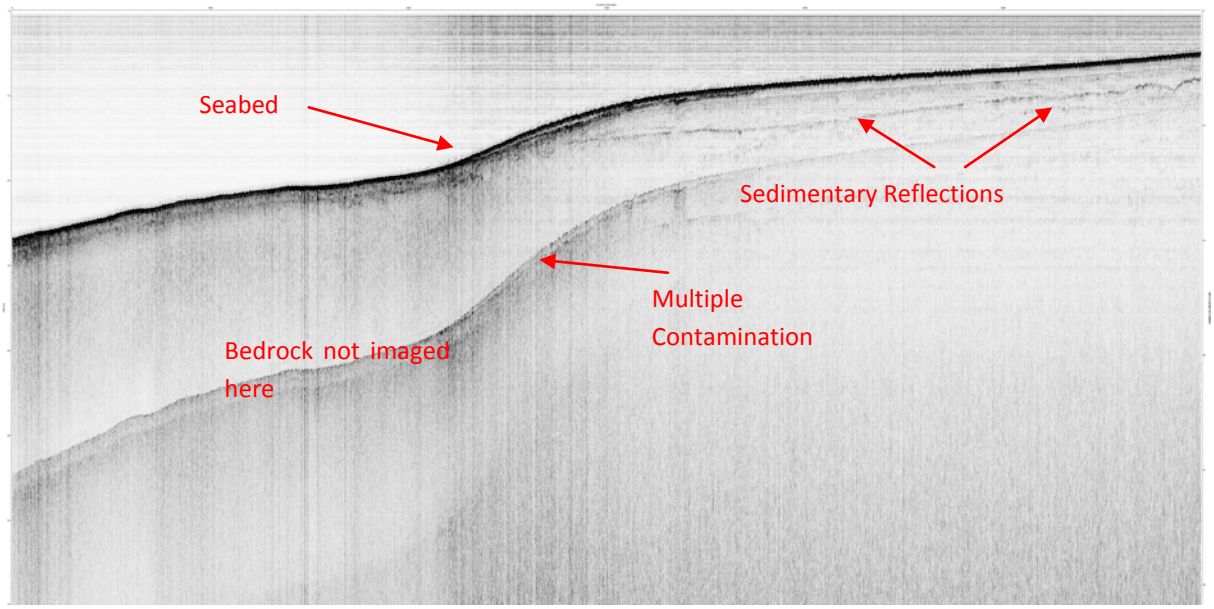

Figure 6.2: CHIRP Profile 106 from the southern survey area, Portmarnock (plotted east - west).

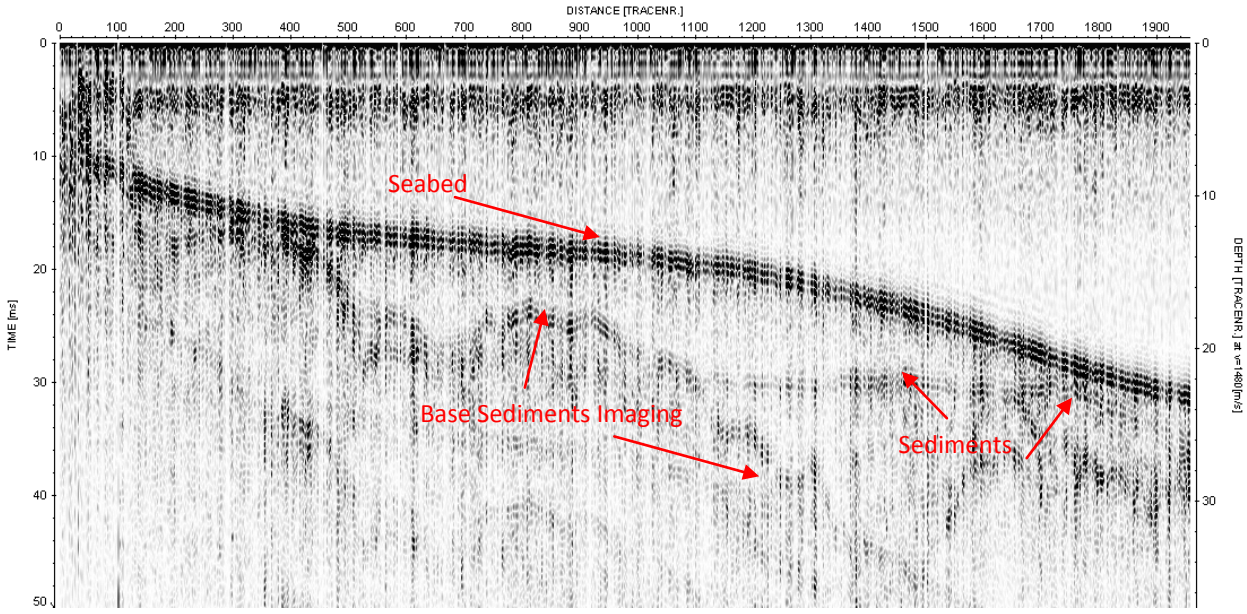

Figure 6.3: Sparker Profile 207 from the northern survey area, Skerries (plotted west – east).

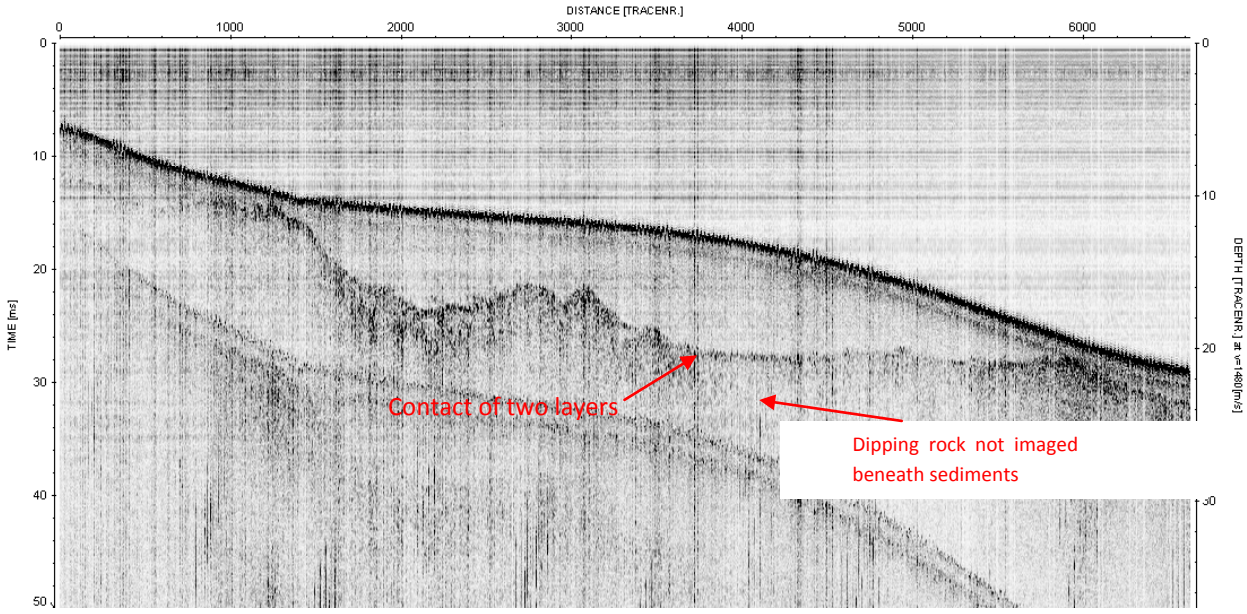

Figure 6.4: CHIRP Profile 207 from the northern survey area, Skerries (plotted west – east).