BRE_AO5 AREA
OFFSHORE SUBSTATION
UHR SEISMIC SURVEY

BRE_TEC_46_RESULTS REPORT – SEISMIC SURVEY – AO5 OSS AREA_0.3

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RESULTS REPORT

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ABBREVIATIONS

ASV	Assumed Seismic Velocity
BSB	Below Seabed
CM	Central Meridian

ABBREVIATIONS

DGEC	Direction Générale de l'Énergie et du Climat
Km	Kilometre
LAT	Lowest Astronomical Tide
m	Metre
MD	Measured Depth
m/s	Metres Per Second
ms	Milliseconds
MSL	Mean Sea-level
MBES	Multibeam Echosounder
RTE	Réseau de Transport d'Électricité
TWT	Two-Way Travel Time
USBL	Ultra-short Baseline
UTC	Coordinated Universal Time
UTM	Universal Transverse Mercator
VR	Vertical Resolution
WGS84	World Geodetic System 1984

EXECUTIVE SUMMARY

According to the detected bathymetric results in the acquired lines of the offshore substation survey area, water depths vary between -81.4 m in the south-east and gradually deepen to -88.8 m in the north-west. The slopes are high in this area due to the presence of rock outcrops. The average slope values are 3.42º, maximum values of 12.34º and minimum values of 0º.

The UHR seismic data display an intermittent thin veneer of Plio-Quaternary sediments of SAND mixed with gravel pebbles overlying outcropping/subcropping bedrock (Palaocene dolomite). Due to the nature of the seismic response of the dolomite no internal features are visible.

1. INTRODUCTION

1.1. PROJECT OVERVIEW

Tecnoambiente carried out a geophysical survey over the proposed BRE_AO5 lot located approximately 20 km off the coast of Lorient in the Bay of Biscay. The survey area is approximately 25 km x 13 km with water depths ranging from 74 – 100 m. The site is under consideration for a windfarm and offshore substation. The Offshore Substation (OSS) survey area is approximately 2.5 km x 1.6 km with water depths ranging from 81.4 - 88.8 m.
The following data were used in the study:

- 43.173 km of MBES and UHRS data
- Background data as discussed in section 3.2 of this report

Figure 1-1 shows the location overview. Figure 1-2 shows the survey line plan.

Figure 1-1: Windfarm area (OWF) and Offshore Substation (OSS) in the BRE_AO5 Survey area.

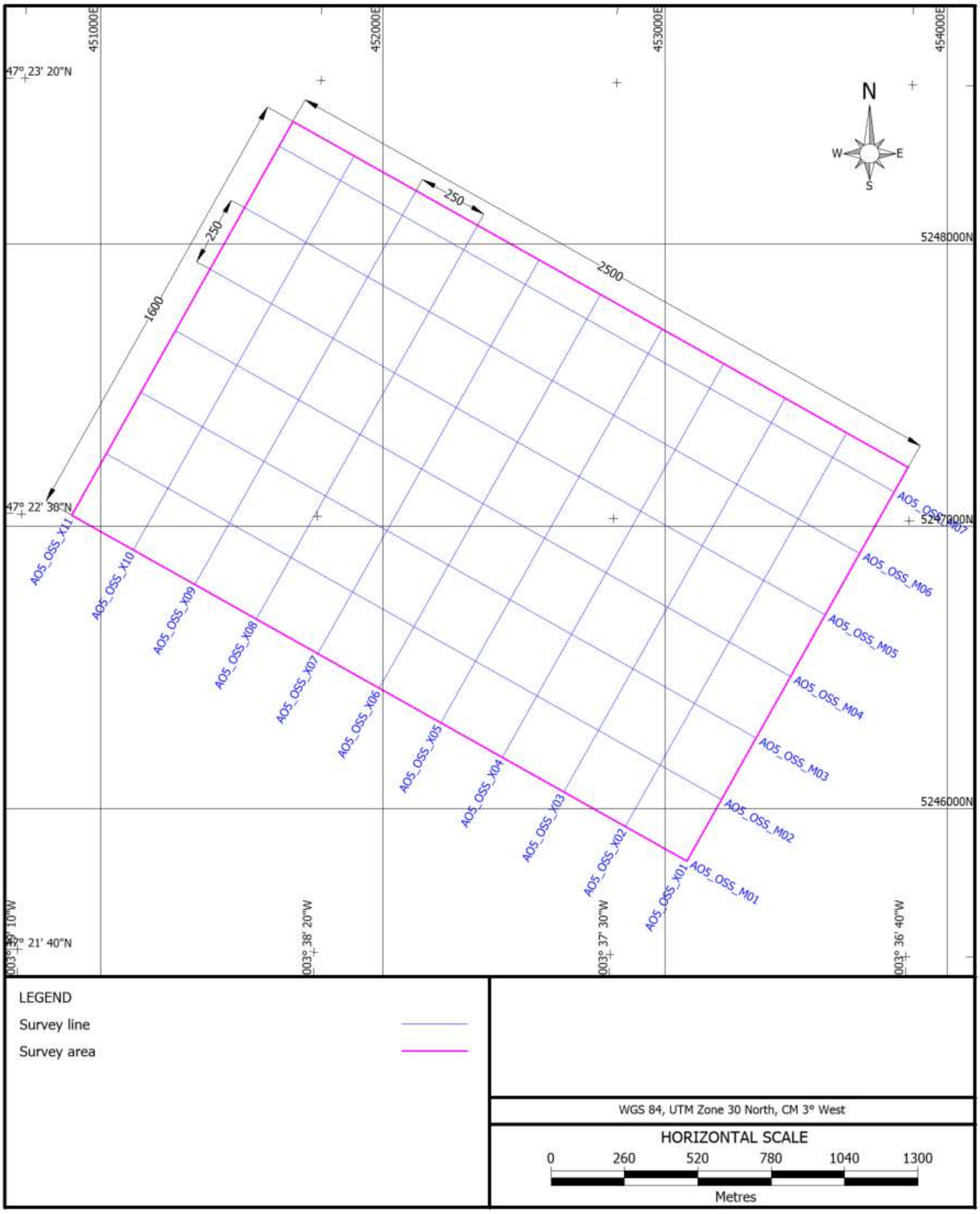


Figure 1-2: Line plan for BRE_AO5 Substation area (OSS).

1.2. SCOPE OF WORK

The objective of the site survey was to perform a geophysical survey over the proposed OSS site comprising MBES and UHRS datasets. The purpose of this was to:

- To define the water depths and seabed topography
- To define the shallow subsurface geology

The main purpose of the study is to provide an interpretation of the geophysical data to provide a preliminary ground model over the BRE_AO5 OSS site.

Near-surface (shallow) geophysics investigations include engineering, environmental, geohazards, infrastructure and archaeological applications and are generally defined as the use of geophysical methods to investigate the upper few metres to hundreds of metres of the Earth's crust[1].

1.3. GEODETIC PARAMETERS

1.3.1. Survey datum

These parameters are detailed below.

Table 1: Datum parameters table

DATUM	
Survey Datum:	WGS 84
Spheroid	GRS 1980
Semi-Major Axis (a)	6.378.137,000
Semi-Minor Axis (b)	6.356.752,31424
Inverse Flattening (1/f)	1/298,257223563

[1] https://seg.org/News-Resources/Near-Surface/About

Table 2: Projection parameters table.

PROJECTION	
Projection	UTM
False Easting	500000
False Northing	0
Latitude of Origin	0º00’00.000000’’
Central Meridian	3º00’00.000000’’
UTM Zone	30 N
Scale Factor on CM	0.9996
Units:	Meters
Altimetry correction	LAT with VORF model

1.3.2. Vertical datum

Vertical datum at Qinsy software is LAT Bathyelli v2 geoid published by the SHOM in December 2013. The Bathyelli LAT (SHOM 2013) is a surface based on the GRS 1980 spheroid.

2. DATA ACQUISITION

2.1. MULTIBEAM ECHOSOUNDER

The objective during the data acquisition is the referencing of the acquired seismic data.

During the data acquisition, the vessel's master must follow the previously programmed routes of the project lines, governed by the indications of the computer screen (Helmsmann indicator), which is shown, by means of visual and audible alarms, when it separates from the its course more than a specified amount (variable according to weather conditions in the area, but never more than 2.5 metres from the theoretical line), and also when there is a problem in a peripheral, such as the loss of GPS corrections.

While the master follows the navigation lines, the acquisition module of the hydrography program captures all the position data sent by the GPS, as well as the soundings sent by the multibeam sounder for each transmission pulse, as well as the values of the heading, wave height, roll and head angles sent by the Hydrins III MRU.

Parallel to the data entry, the data acquired by the equipment and peripherals is synchronized. This process is carried out by QINSy itself, complemented by the input of the time and the pulse per second (PPS) provided by the MRU, so that all the data is time synchronised.

The guidelines followed by Tecnoambiente during the surveying for MBES data acquisition were:

- IT-CM-01. Guidelines for Hydrography Project management, 5
- IT-CM-04. Bathymetric survey, 1
- IT-CM-14 Survey Basics Guidance, 1
- IT-CM-15 Online Surveying procedure, 3

These guidelines can be found in the quality plan document NOR_TEC_05_QUALITY PLAN.

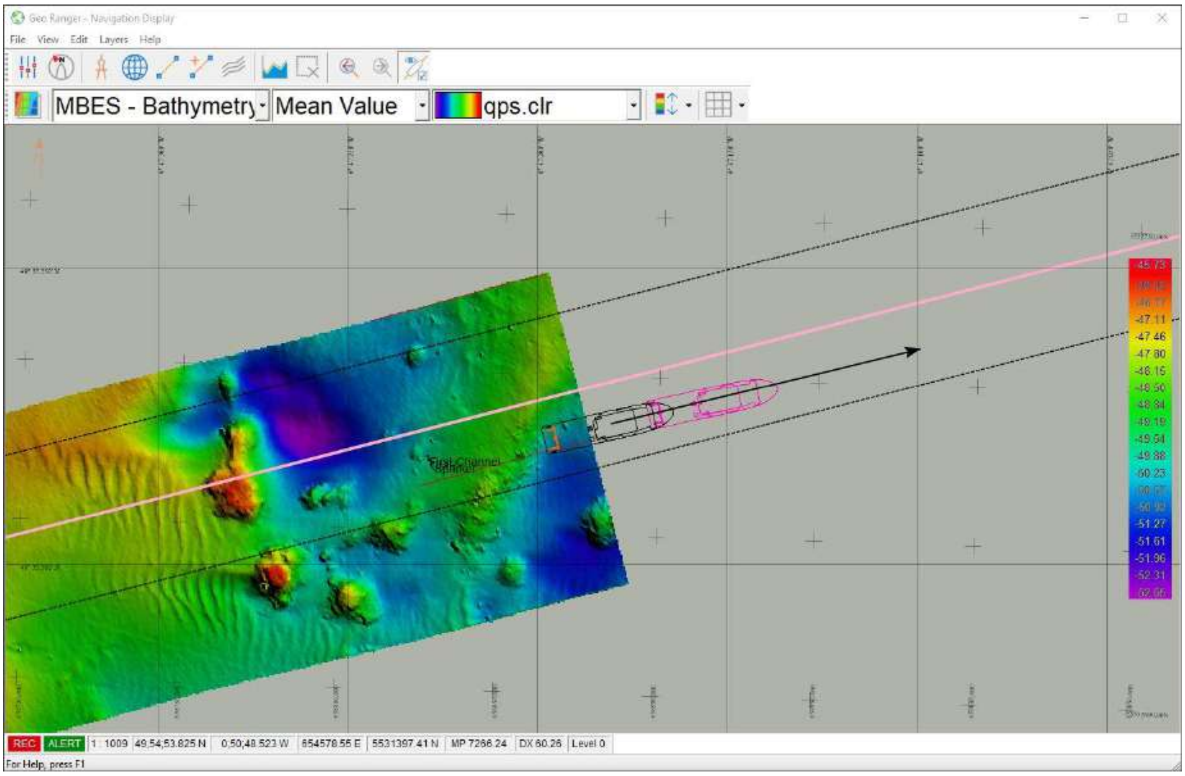


Figure 2-1: MBES bathymetry data acquisition with the QINSy software.

During data acquisition, limits have been applied to reduce the soundings noise. These limits in the recording correspond to static gates of the equipment software that reduce the acquired registers noise according to statistical calculations of vertical uncertainty.

Along the processing phase of the acquired data, the lines on the screen are processed in order to manually correct the noise that appears in the records, noise produced by multiple factors such as, multipath in position, air bubbles, cetaceans, motor interference of the boat, etc. in the digital register of soundings. To certify the complete removal of the noise in the soundings spike filters and spline filters have been applied.

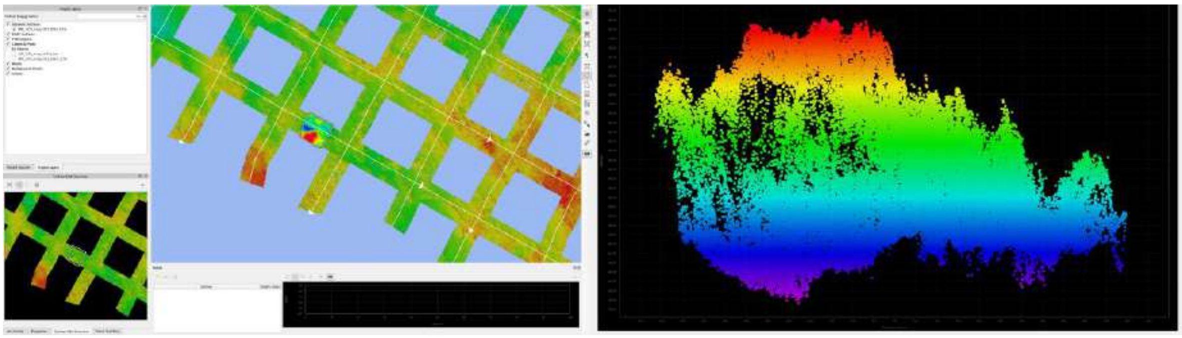


Figure 2-2: Processing screen of MBES bathymetry data with the Qimera software.

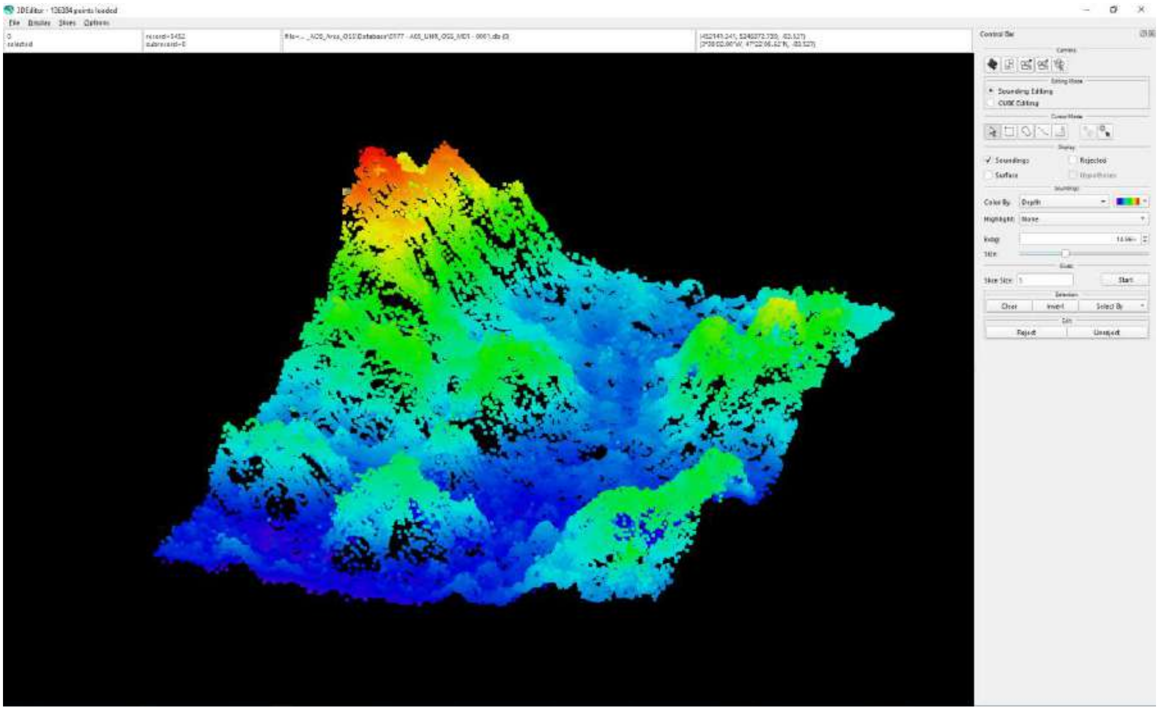


Figure 2-3: 3D image of the MBES bathymetry processing.

Once the possible existing errors in the records have been deleted, a digital model of the terrain with 0.5 x 0.5 m grid size has been made with a minimum cell size to obtain the maximum resolution of the seabed.

2.2. UHR SEISMIC

The guidelines followed by Tecnoambiente during the surveying for UHR Seismic data acquisition as provided by TTS were:

- IT-CM-17 Sparker Deployment Recovery, 1
- IT-TTS- 01_Geoeel Instrument Verification Procedure
- IT-TTS-02_Multichannel Seismic Streamer Procedure
- IT-TTS-03_Sparker Pulse Test Procedures
- IT-TTS-04_Streamer Recovery

These guidelines can be found in the quality plan document NOR_TEC_05_QUALITY PLAN.

The shallow geology/foundation conditions (0-200m BSB) have been interpreted and investigated from 2D UHR multi-channel seismic data. 2D UHR SEGY data has been recorded to 220ms TWT. No reflectors are noticed in the UHR data set beyond the resolution of this UHR system.

<u>2D UHR – High Frequency</u>

The 2D UHR data shows a dominant frequency of approximately 400Hz in the upper section. The lower frequency content of the UHR data when compared to the wider OWF area is attributed to the lack of any significant unconsolidated overburden of the bedrock within the OSS area.

The 2D UHR data has been zero phase converted and adjusted to the bathymetry, as such the central positive of the Ricker wavelet represents the seabed.

The raw field data was recorded in SEG polarity (positive acoustic pressure written as negative numbers on tape), but after processing the polarity is NON-SEG, with positive pressure as positive numbers.

SEGY data were loaded into a Kingdom workstation once processing had been completed and basic QC of the data took place. Seabed position was checked against time converted MBES xyz data, a VatMAX amplitude extraction covering the seabed was used to check amplitude balance across the site and arbitrary lines between mainlines and crossline were checked. Key horizons were then picked, and all data was checked for possible shallow gas hazards using an iterative visual data assessment. Final exports for this site comprised isopach map contours in DXF format / interpreted seismic sections.

3. RESULTS

3.1. BATHYMETRY

The detailed resolution of the bathymetry grid (Digital Elevation Model for seabed data following QUA-01-B GIS specifications) allows for enhanced visualization of depth and interesting seafloor features. The main use of the multibeam data is to reference the seismic profiles to the real seafloor (LAT Bathyelli v2 geoid). Bathymetry data have been reduced to Shom Bathyelli v2.0 and all depths are quoted to this. An overview of the bathymetry data is presented on Figure 3-2.

Water depths vary between -81.4 m in the south-east and gradually deepen to -88.8 m in the north-west. Given these water depths of greater than 60 m across AO5 OSS area it is understood that turbines will be floating and not fixed to the seabed.

A colour table for the representation of the three-dimensional terrain model was created, from red -81.25 meters depth and magenta for the maximum depth -89.53 meters.

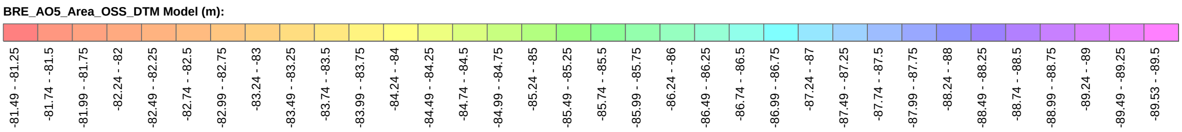


Figure 3-1: Color table for the representation of the MBES terrain model.

Bathymetric data from the vessel multibeam sensor has been processed into a 0.5 meter grid size bathymetry for all the acquired lines.

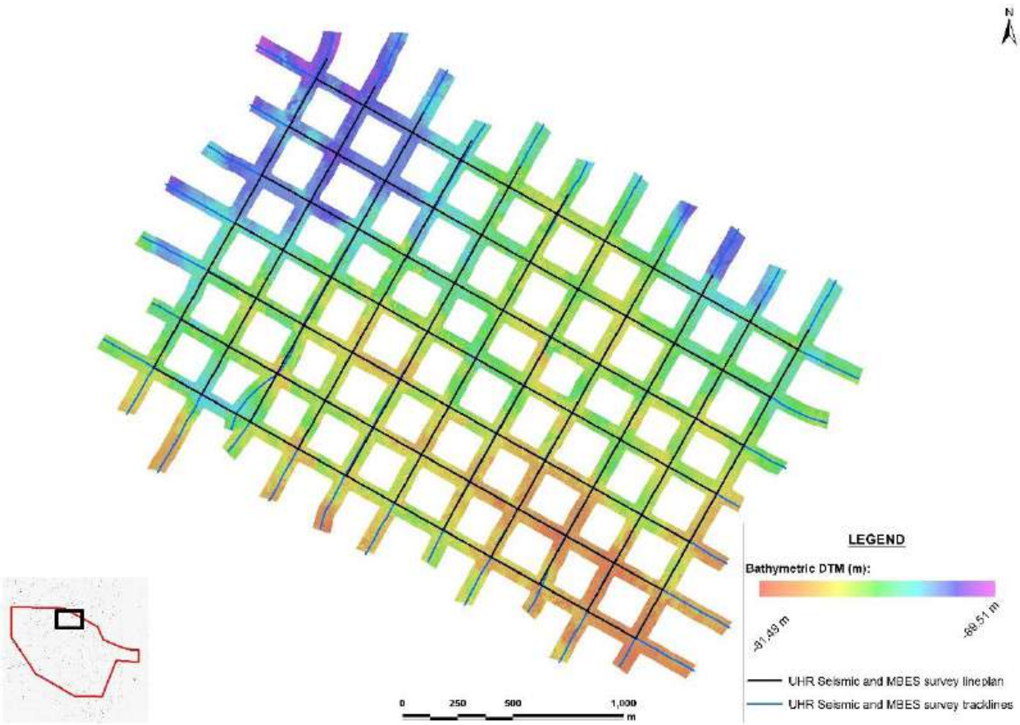


Figure 3-2: Whole bathymetric data grid model (0.5 x 0.5 m) with survey lines and tracklines for the offshore substation of the BRE_AO5 area.

Several examples of the results of the MBES processed data are shown below:

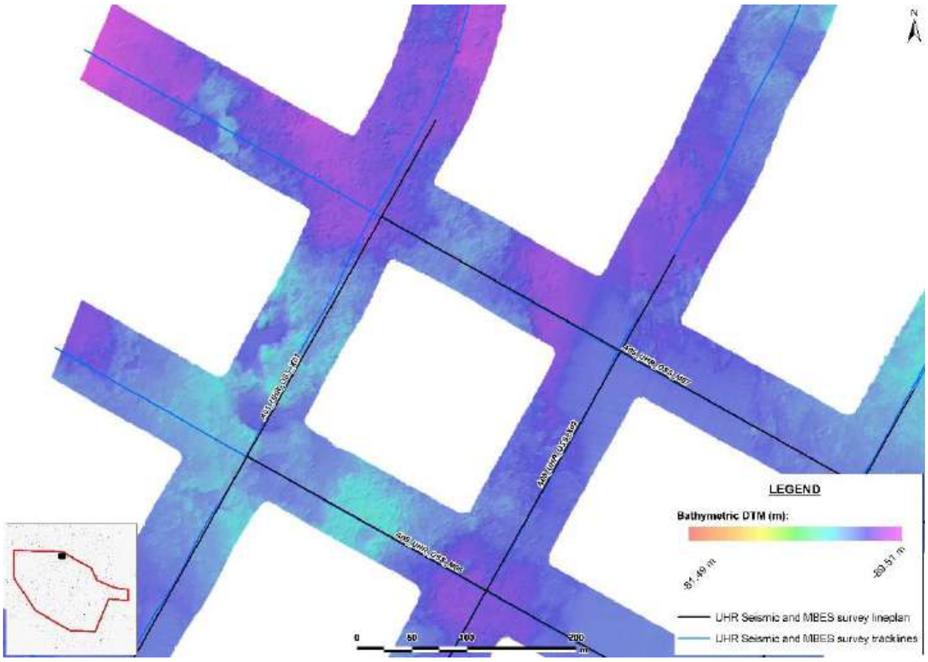


Figure 3-3: Detail of the bathymetric data grid model (0.5 x 0.5 m) for the offshore substation of the BRE_AO5 area – Survey lines and tracklines A05_UHR_OSS_X01-X02 // A05_UHR_OSS_M06-M07.

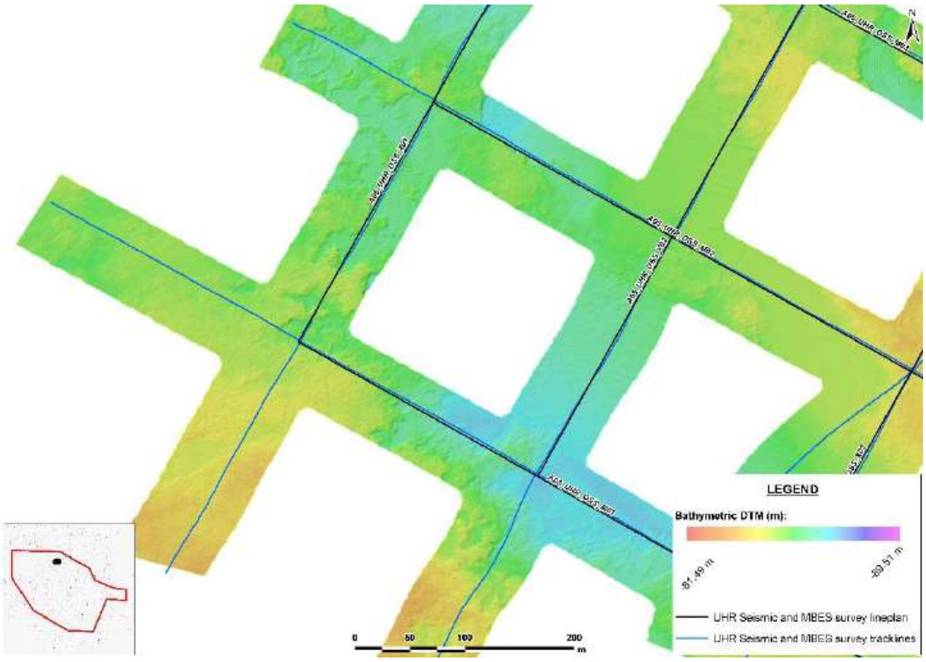


Figure 3-4: Detail of the bathymetric data grid model (0.5 x 0.5 m) for the offshore substation of the BRE_AO5 area – Survey lines and tracklines A05_UHR_OSS_X01-X03 // A05_UHR_OSS_M01-M02.

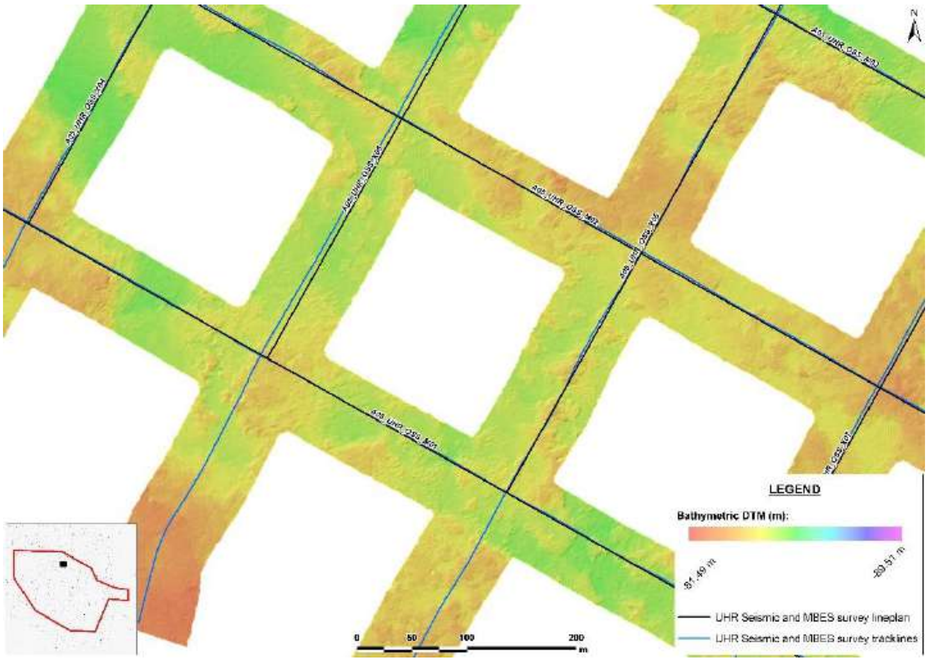


Figure 3-5: Detail of the bathymetric data grid model (0.5 x 0.5 m) for the offshore substation of the BRE_AO5 area – Survey lines and tracklines A05_UHR_OSS_X04-X07 // A05_UHR_OSS_M01-M02.

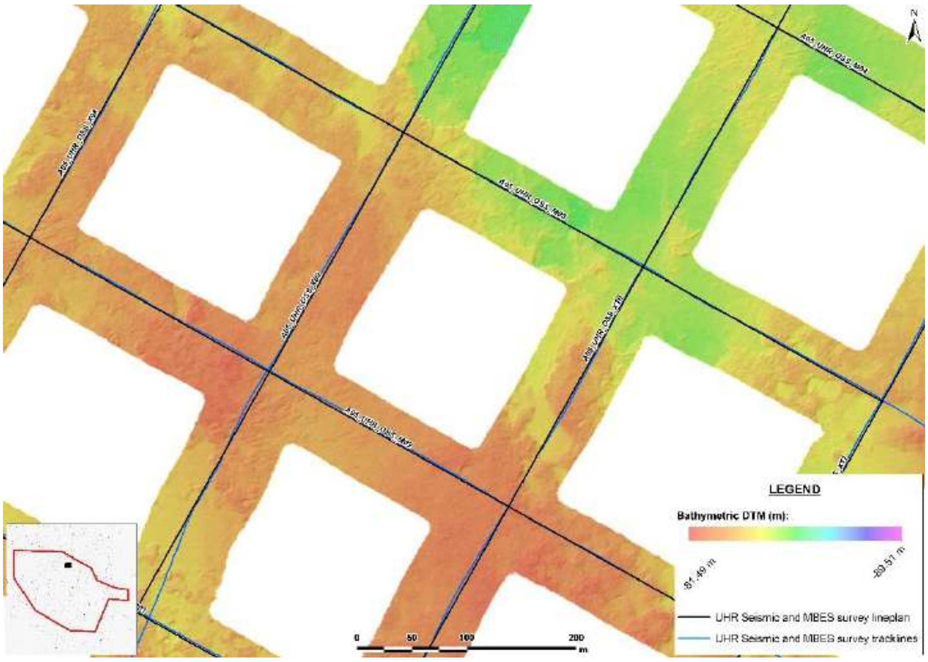


Figure 3-6: Detail of the bathymetric data grid model (0.5 x 0.5 m) for the offshore substation of the BRE_AO5 area – Survey lines and tracklines A05_UHR_OSS_X08-X011 // A05_UHR_OSS_M01-M03.

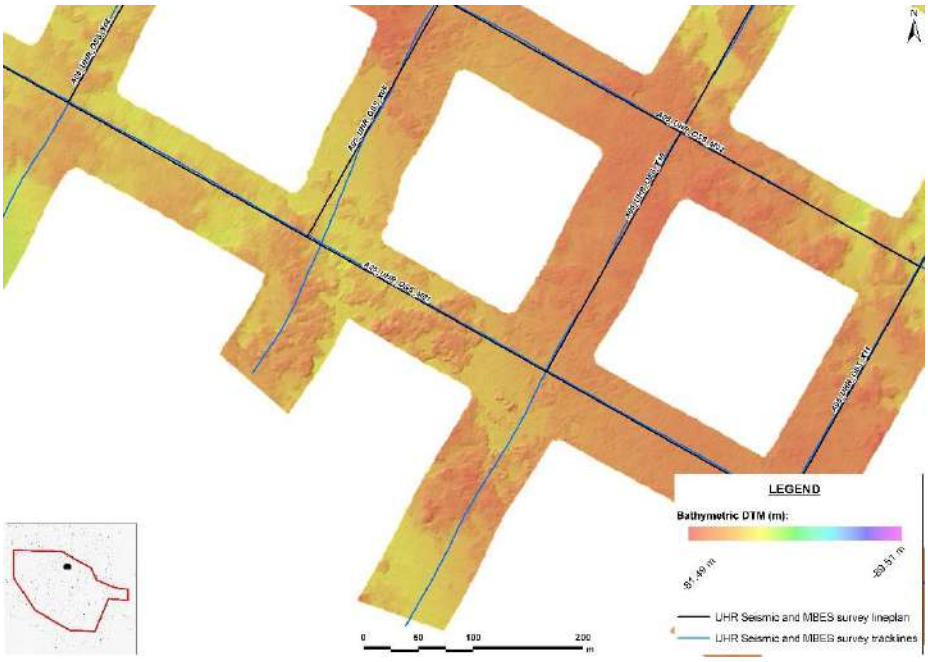


Figure 3-7: Detail of the bathymetric data grid model (0.5 x 0.5 m) for the offshore substation of the BRE_AO5 area – Survey lines and tracklines A05_UHR_OSS_X09-X10 // A05_UHR_OSS_M01.

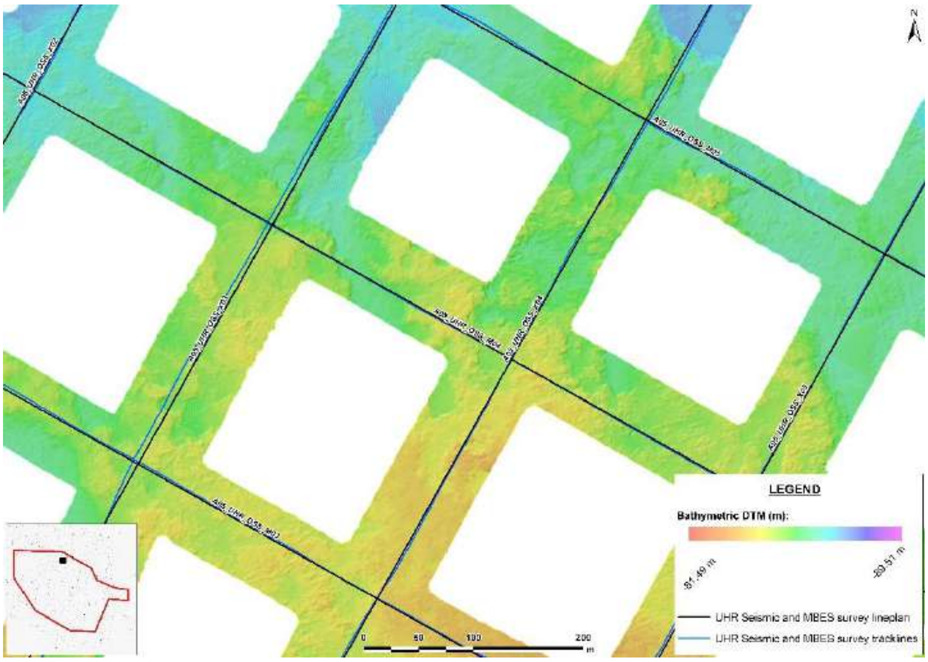


Figure 3-8: Detail of the bathymetric data grid model (0.5 x 0.5 m) for the offshore substation of the BRE_AO5 area – Survey lines and tracklines A05_UHR_OSS_X03-X04 // A05_UHR_OSS_M04.

The seabed gradient across the A05 OSS site (Figure 3-9) is generally gentle with average slope < 5° but does increase to 12° in localized areas due to outcropping bedrock.

Figure 3-9: Slope map

Regarding the calculation of horizontal and vertical uncertainty in the MBES data acquired at the offshore windfarm, it has been calculated and rendered in the Qimera software. The following images represent these values for all acquired lines.

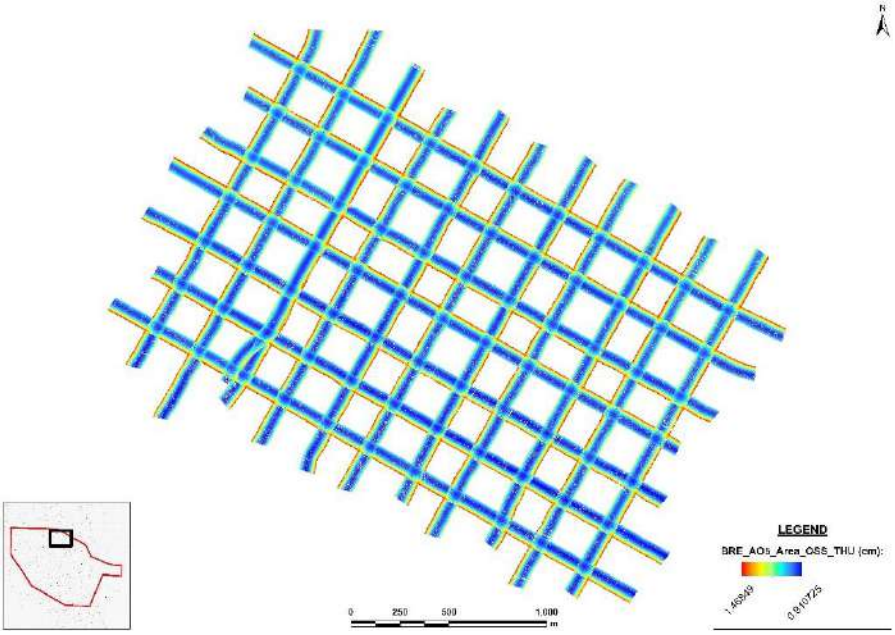


Figure 3-10: Results for the total horizontal uncertainty in the offshore substation of the BRE_AO5 area – General.

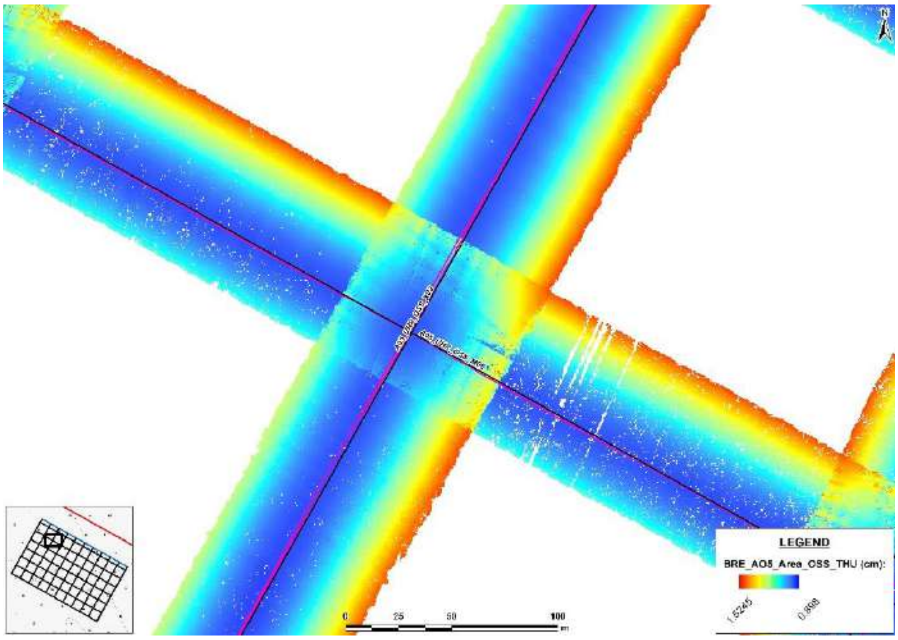


Figure 3-11: Example in detail of the results for the total horizontal uncertainty in the offshore substation of the BRE_AO5 area.

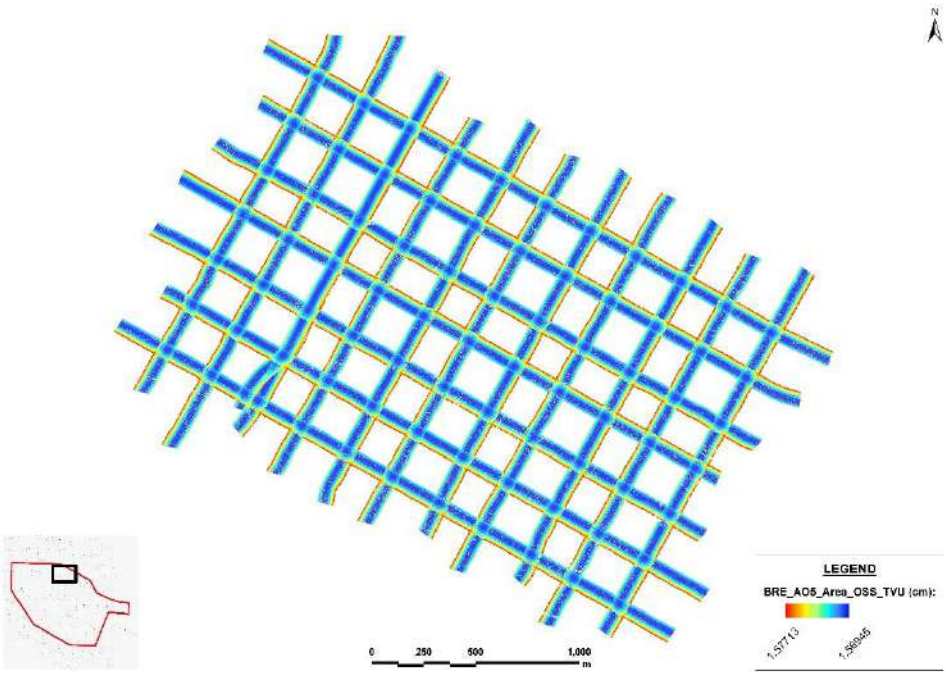


Figure 3-12: Results for the total vertical uncertainty in the offshore substation of the BRE_AO5 area – General.

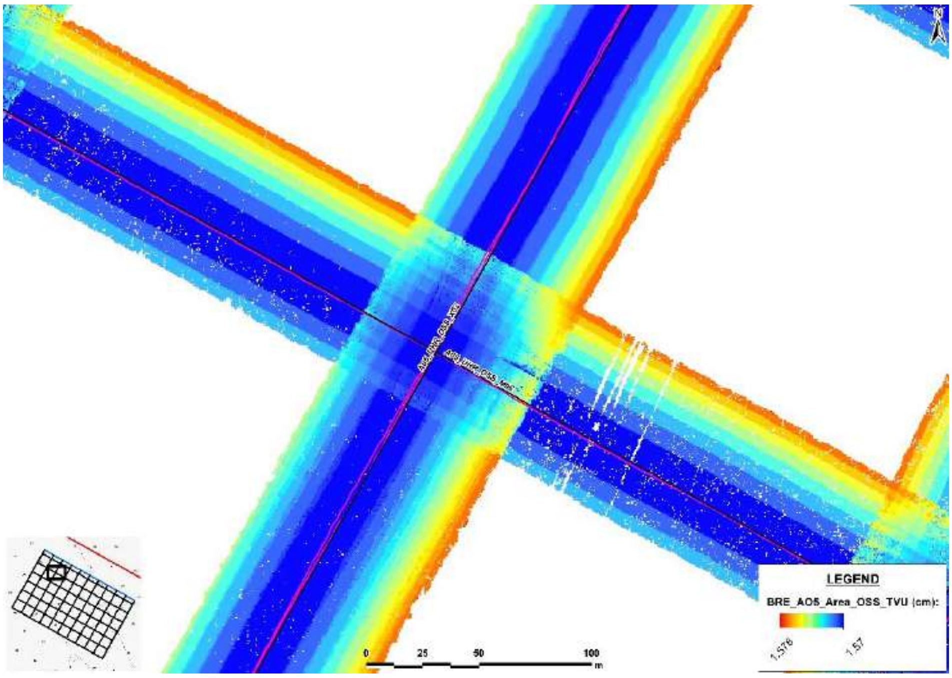


Figure 3-13: Example in detail of the results for the total vertical uncertainty in the offshore substation of the BRE_AO5 area.

The total horizontal uncertainty statistics are presented below:

- Maximum value: 1.5244 cm
- Minimum value: 0.8980 cm
- Average value: 1.0931 cm
- Standard deviation: 0.1431 cm

The total vertical uncertainty statistics are presented below:

- Maximum value: 1.5779 cm
- Minimum value: 1.5700 cm
- Average value: 1.5719 cm
- Standard deviation: 0.0019 cm

3.2. GEOLOGY

3.2.1. Data limitations

To support interpretation of the preliminary ground model the extents of bedrock outcropping on the seabed were mapped from prior multibeam bathymetry data DEM (SHOM, 2021). These extents were correlated with the UHR seismic data to map the bedrock outcrop in the subsurface, and the thickness of the overlying sedimentary unit. Due to bedrock acoustic character and the resolution of the UHR system utilised, no reflectors have been observed in the full record length within the AO5 OSS survey area.

Higher resolution sub-bottom profiler (e.g., Innomar[2] / chirp) seismic data, in combination with sidescan sonar data, would be required to identify if a thin veneer of sediments (Figure 3-14) overlay the bedrock and to map its extents.

[2] https://www.innomar.com/sbp-standard.php

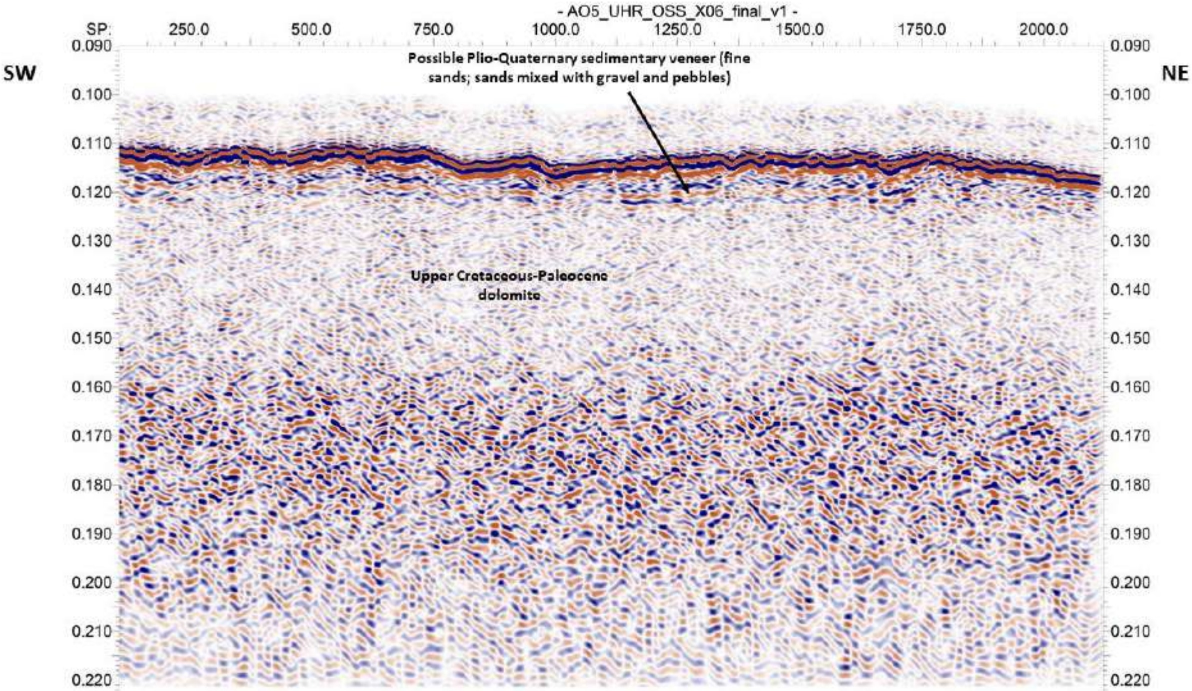


Figure 3-14: Example of UHR seismic data limitation

Higher resolution sub-bottom seismic data with sidescan sonar data could increase mapping resolution for near-surface geological constraints, identify potential anthropogenic debris, and confirm the presence of thin veneers of sub-metre resolution sediment at the specified location of the offshore substation fixed structure.

In (Figure 3-15) below, orange and yellow colours of the SHOM 2021 multibeam bathymetry DEM represent bedrock outcropping on the seabed and green represents areas of possible sediment veneer.

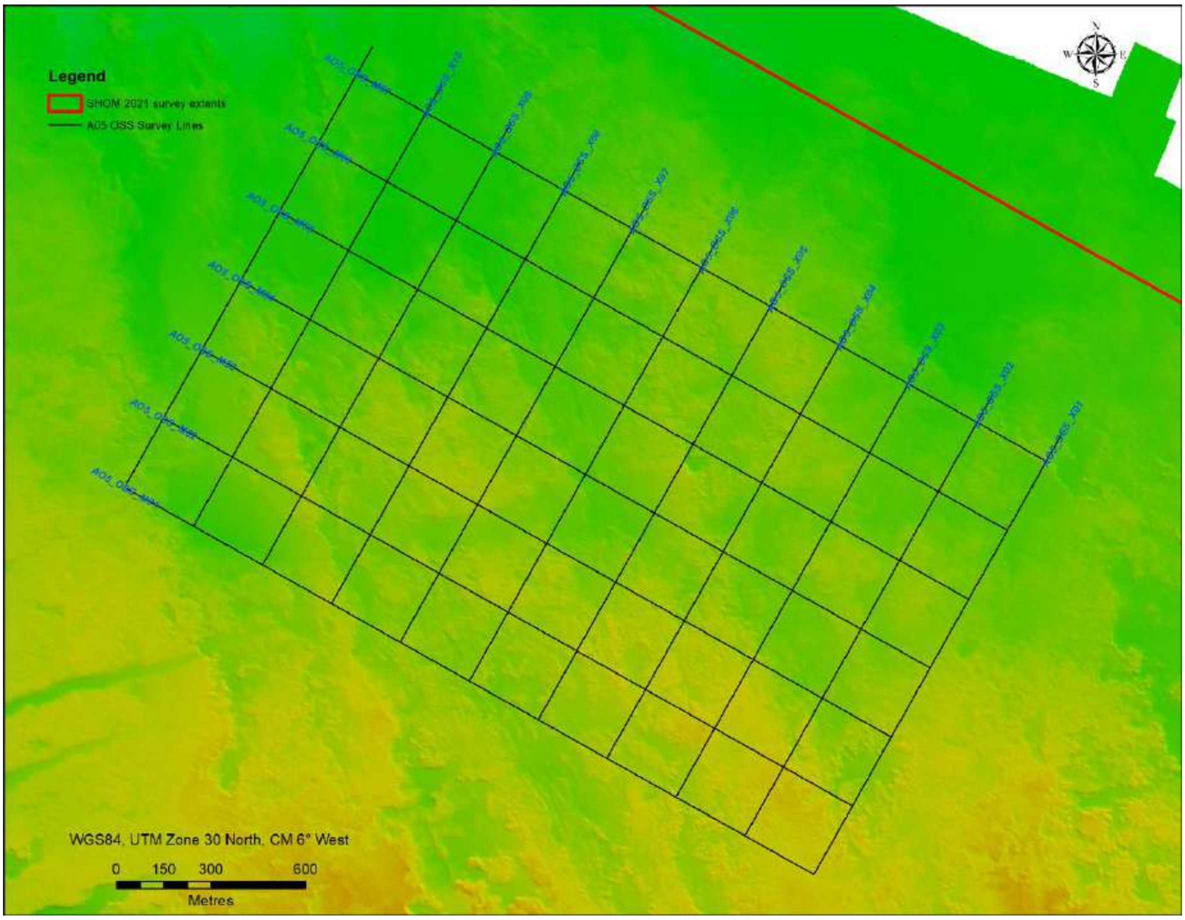


Figure 3-15. Bedrock outcrop evident from multibeam bathymetry survey (SHOM, 2021).

3.2.2. Geological setting from background data

To support a tender call for offshore wind power in area BRE_AO5, situated in the Bay of Biscay (Figure 3-16), Gaia- Blue Earth prepared a geological bibliographic study of Southern Brittany (Gaia - Blue Earth, 2021).

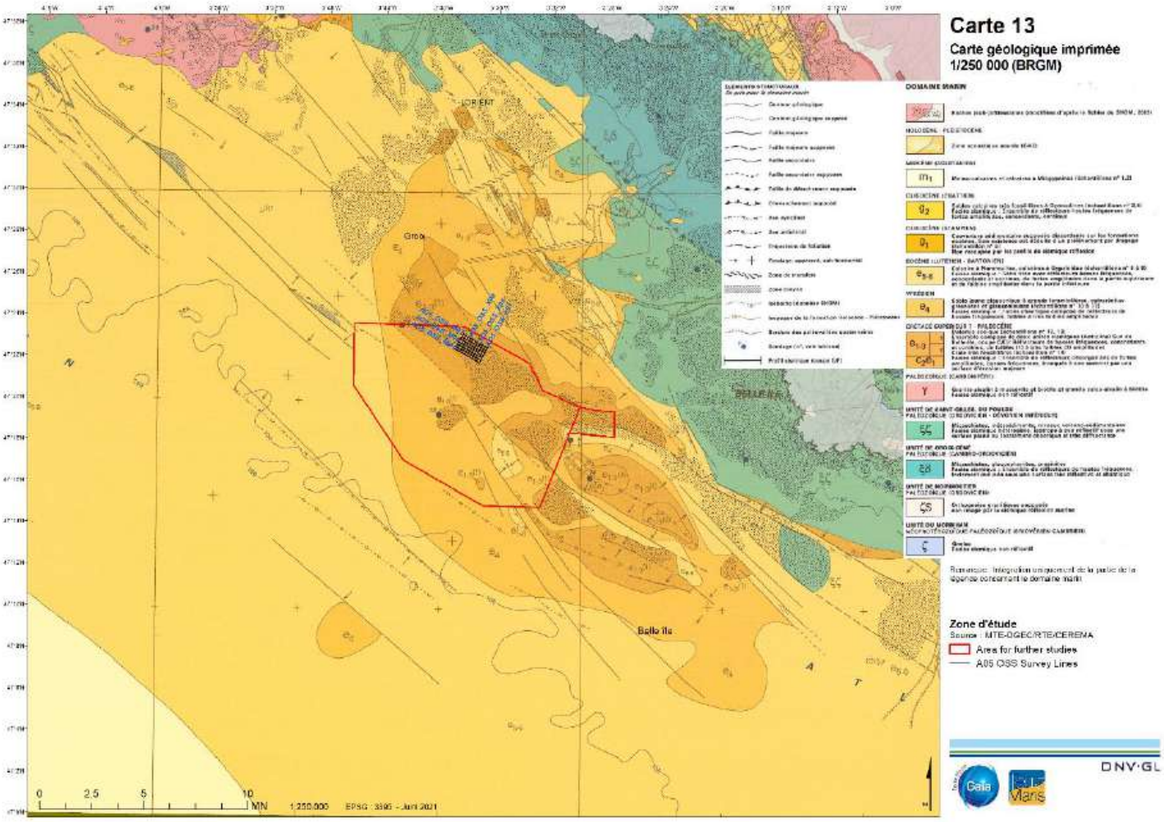


Figure 3-16: Location of AO5 OSS in Southern Brittany (modified after GAIA, 2021).

In the Southern Brittany region, the subsurface is composed of magmatic, metamorphic and sedimentary rocks. The geological formation of the AO5 OSS area is dolomite from the Upper Cretaceous (?) – Paleocene (Figure 3-17). Throughout AO5 OSS this geological formation, $e_{1\text{-}3}^{(1)}$, is observed to outcrop and pass through the sediment layer in many areas thus forming a rocky seafloor.

The sub-outcropping rocks were sampled by BRGM using a core sampler. The predominant rock type is dolomite (carbonate sediment rich in calcium and magnesium) with an abundant presence of sandstone (detrital rock composed of sand) also observed.

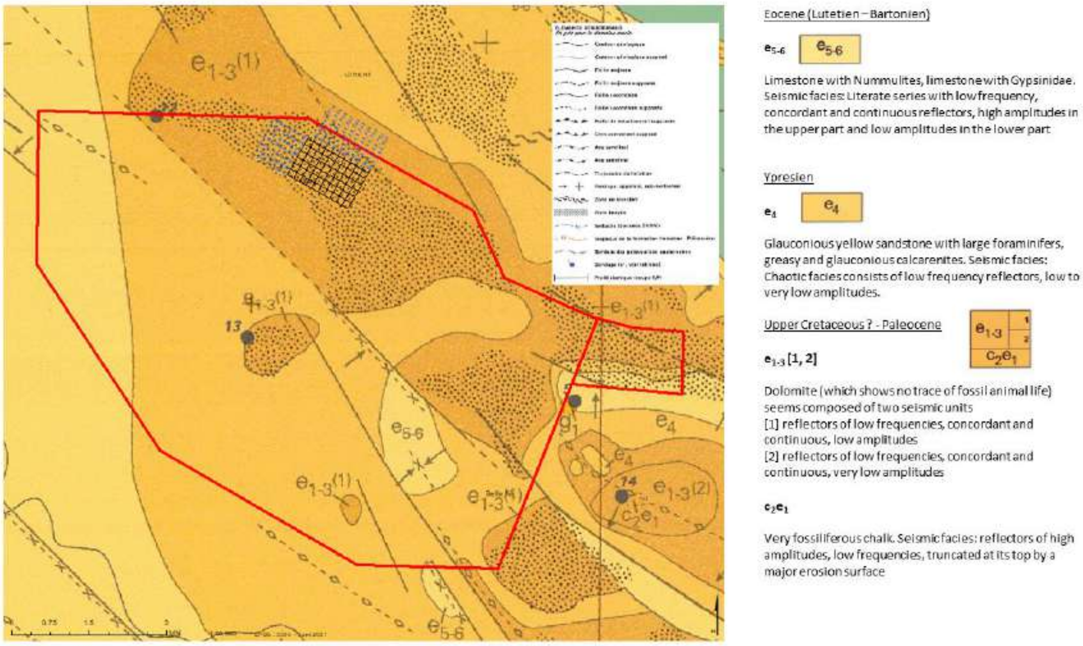


Figure 3-17. Extract from Geological map of France at 1: 250,000 from the continental margin, Lorient Bretagne South in the EMR zone (Tinon et al, 2010).

In April to May 2021, DGEC acquired sub-bottom seismic profiler data across the A05 site using an Echoes 3500 T3 from iXblue. According to technical specifications, the vertical resolution of the Echoes 3500 T3 is 20 cm. The location of the A05 OSS UHR seismic survey lines has been superimposed on the Echoes 3 3500 T3 SBP survey lines (Figure 3-18). Of the ten Echoes 3500 T3 sub-bottom profiles used by DGEC for sediment thickness analysis, three cross through the AO5 OSS survey area:

- Traversier 1 (BORDA-20210518-123729), Profile (1)
- Traversier 2 (BORDA-20210518-082824), Profile (2)
- Profil Nord (BORDA-20210518-151645), Profile (9)

The three Echoes 3500 T3 sub-bottom profiles collectively indicate limited to absence of a sediment veneer (above orange horizon) over the A04 OSS, indicated approximately with dashed rectangle. The study conducted by DGEC concluded the maximum sediment thickness as ~7 m using an assumed seismic velocity of 1,950 m/s, although these conclusions are based on a limited analysis of ten sub-bottom profiles, not from complete coverage isopach mapping.

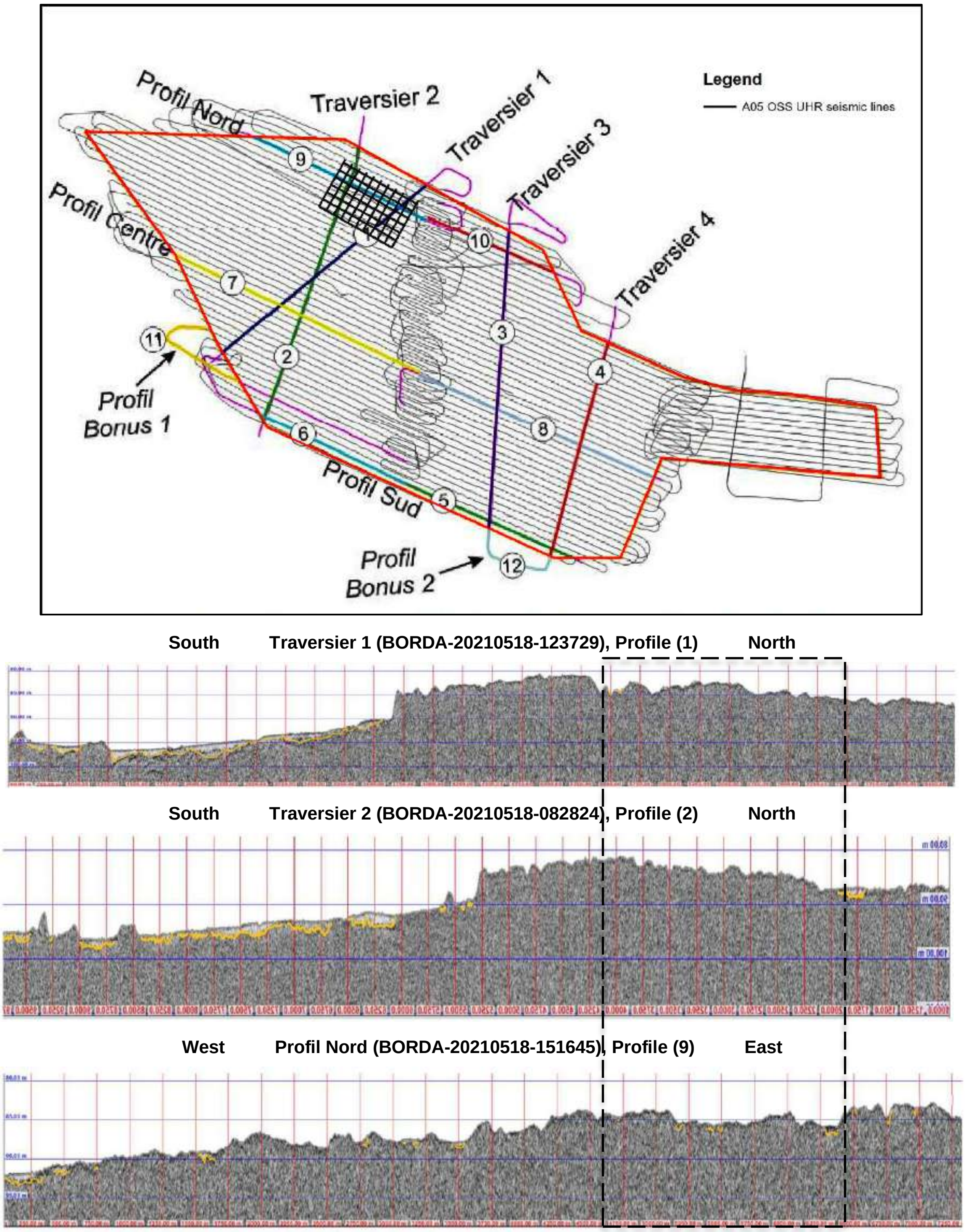


Figure 3-18: Echoes 3 3500 T3 SBP survey lines and select interpreted profiles (DGEC, 2021)

3.2.3. Geological sequence

An extract from the 1:150,000 sedimentary map of the Quiberon peninsula in Les Sables d'Olonne (Hudier et al., 2015) illustrates that the AO5 OSS area (Figure 3-19) comprises rocks and bioclastic gravel.

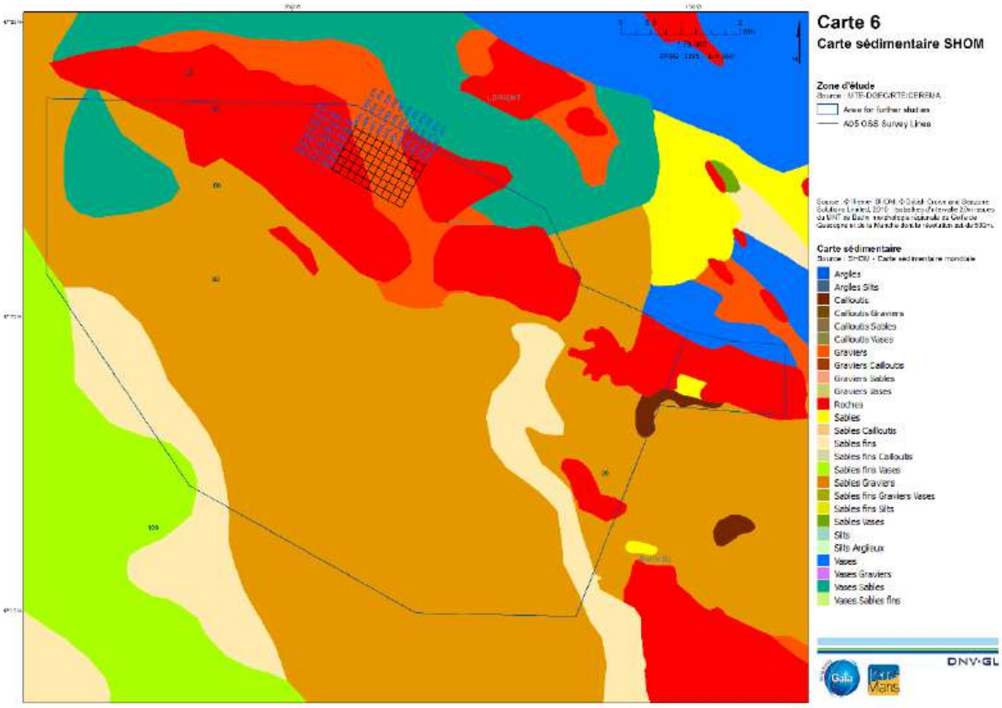
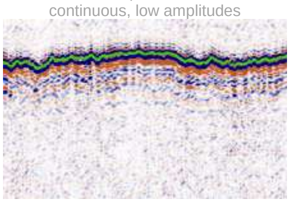


Figure 3-19: Extract of sedimentary map at 1:150,000 (Hudier et al., 2015).

The shallow (~200 m BSB) geology within the AO5 OSS area comprises one unit (Table 3) with an illustration provided in Figure 3-20. This unit is recognised as that established for the Geological map of France at 1: 250,000 from the continental margin (Tinon et al, 2010).

Table 3. Shallow Geological Units of AO5 OSS Survey Area.

Unit	Upper surface / Lower surface	Description	Seismic character	Depositional Environment
$e_{1\text{-}3}^{(1)}$	Seabed (top bedrock)	Upper Cretaceous (?) – Paleocene Dolomite	Reflectors of low frequencies, concordant and continuous, low amplitudes 	Deep marine
	End of UHR record			

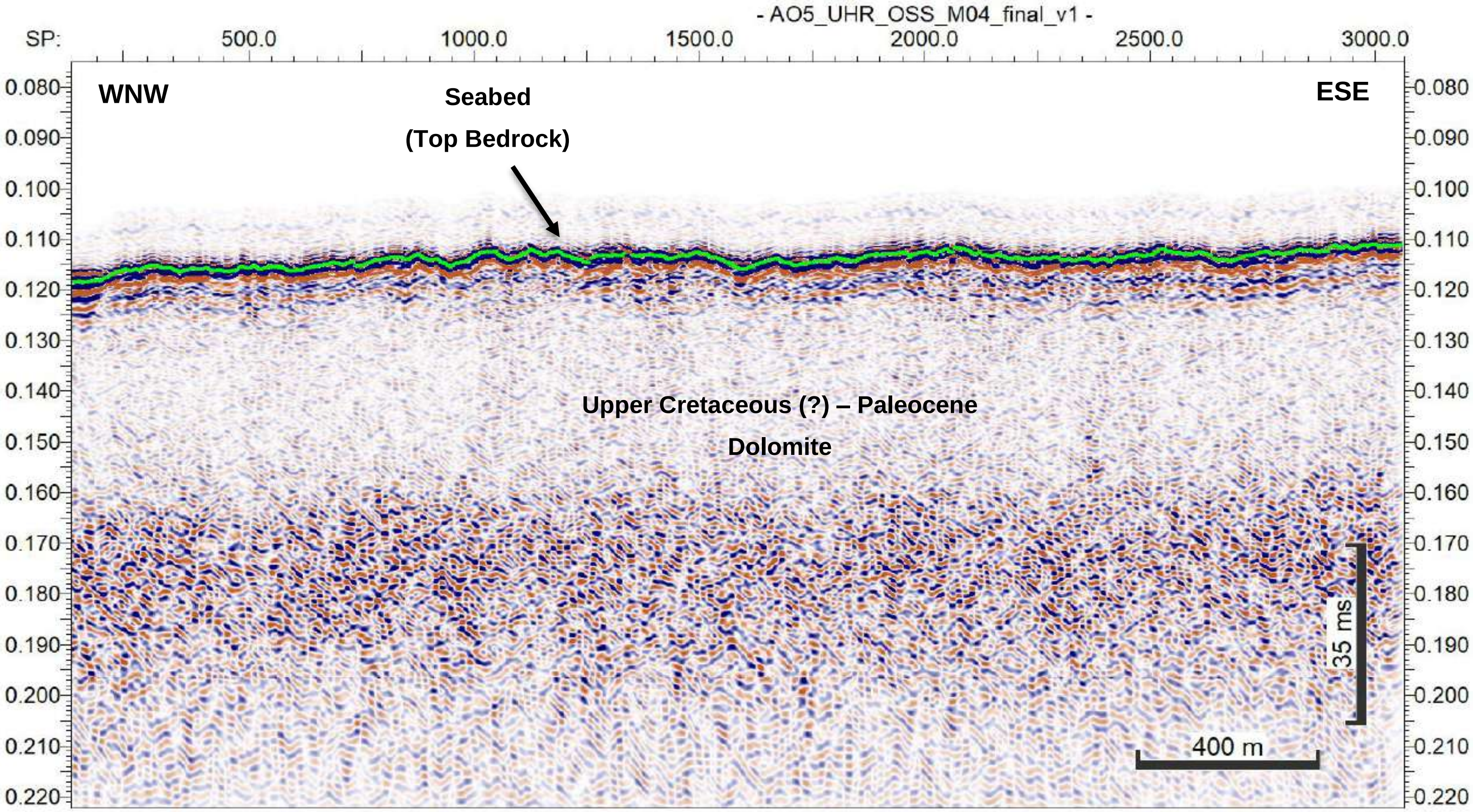


Figure 3-20. UHR line M04 illustrating bedrock outcropping on the seabed in the AO5 OSS survey area.

3.2.4. Geohazards

As the interface between power generation offshore and transmission then distribution of renewable energy to the power grid onshore via subsea cables, offshore wind substations are essential components that collect the power produced by offshore wind turbines.

Presuming the offshore substation at AO5 will comprise a topside and jacket foundation held in place by piles driven into the seabed, it is important to understand the effects of geohazards and geological uncertainties at the AO5 OSS.

At the AO5 OSS proposed offshore substation area, we have mapped the presence of out-cropping bedrock throughout the site. The planned location of the offshore substation should consider the geohazard impacts of the seabed foundation conditions as mapped with this UHR seismic data, presented below in Figure 3-21.

Velocities picked in ProMAX for the UHR seismic data were analysed to consider appropriate time to depth conversions for the soil units identified. This process confirmed the validity of 1,700 m/s for an assumed sediment velocity.

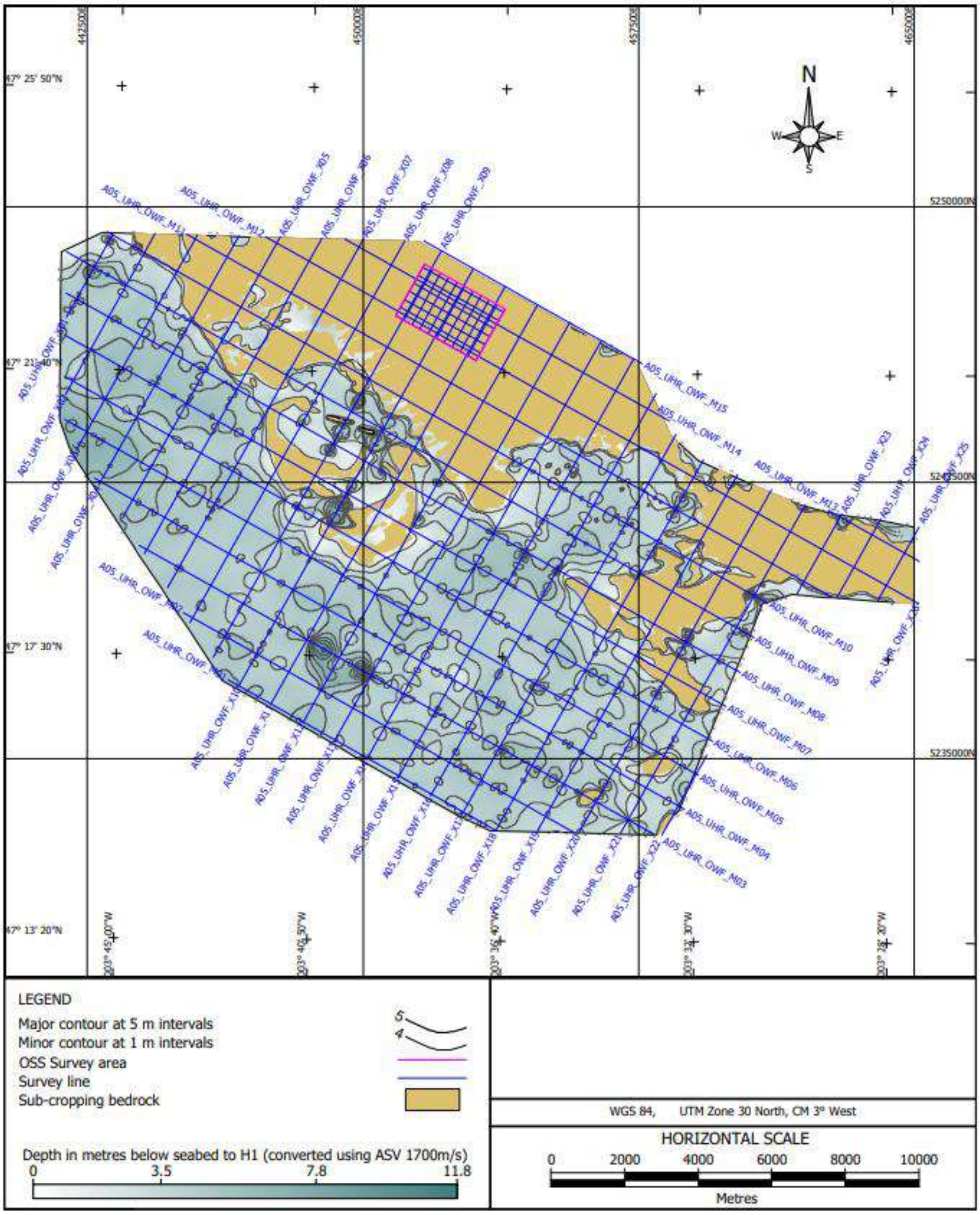


Figure 3-21. Bedrock outcrop and sediment thickness (Seabed – H1) map derived from UHR seismic data and SHOM 2021 multibeam bathymetry survey.

3.2.5. Conclusions and recommendations/comments

3.2.5.1. Conclusions:

- The new UHR seismic data does not have the resolution capability to confirm the presence of a sedimentary veneer overlying bedrock at AO5 OSS
- The delineation between areas of bedrock sub-cropping on the seafloor and areas where a sedimentary unit overlies sub-cropping bedrock surrounding the AO5 OSS survey area is more accurately mapped with the use of the new UHR seismic data in combination with a DEM of multibeam bathymetry data

3.2.5.2. Recommendations:

For proper assessment of soil conditions at the designated offshore substation fixed structure site, a site investigation following standards for marine geophysical investigations, marine soil investigations and geotechnical and foundation design considerations is recommended.

To improve knowledge of potential geological constraints and uncertainties the following data acquisition could prove beneficial.

1. High-resolution sub-bottom (e.g., Innomar / chirp) seismic data to coincide with the UHR multichannel seismic data
   a. This higher resolution sub-bottom seismic data could increase mapping resolution for near-surface geological constraints and confirm the presence of thin sediment veneers of sub-metre resolution
   b. This could be a focussed campaign for the region of AO5 OSS deemed most suitable for offshore the offshore substation site

2. Sidescan sonar imagery data to coincide with the multibeam bathymetry and backscatter data
   a. A detailed seafloor mapping with sidescan sonar data could help identify potential natural and anthropogenic seafloor geohazards

3. Seabed ground-truthing “light” geotechnical data (e.g., grab samples) to confirm the variable seafloor composition illuminated with the sidescan sonar data
4. Geotechnical boring to better understand expected soil conditions at the proposed offshore substation

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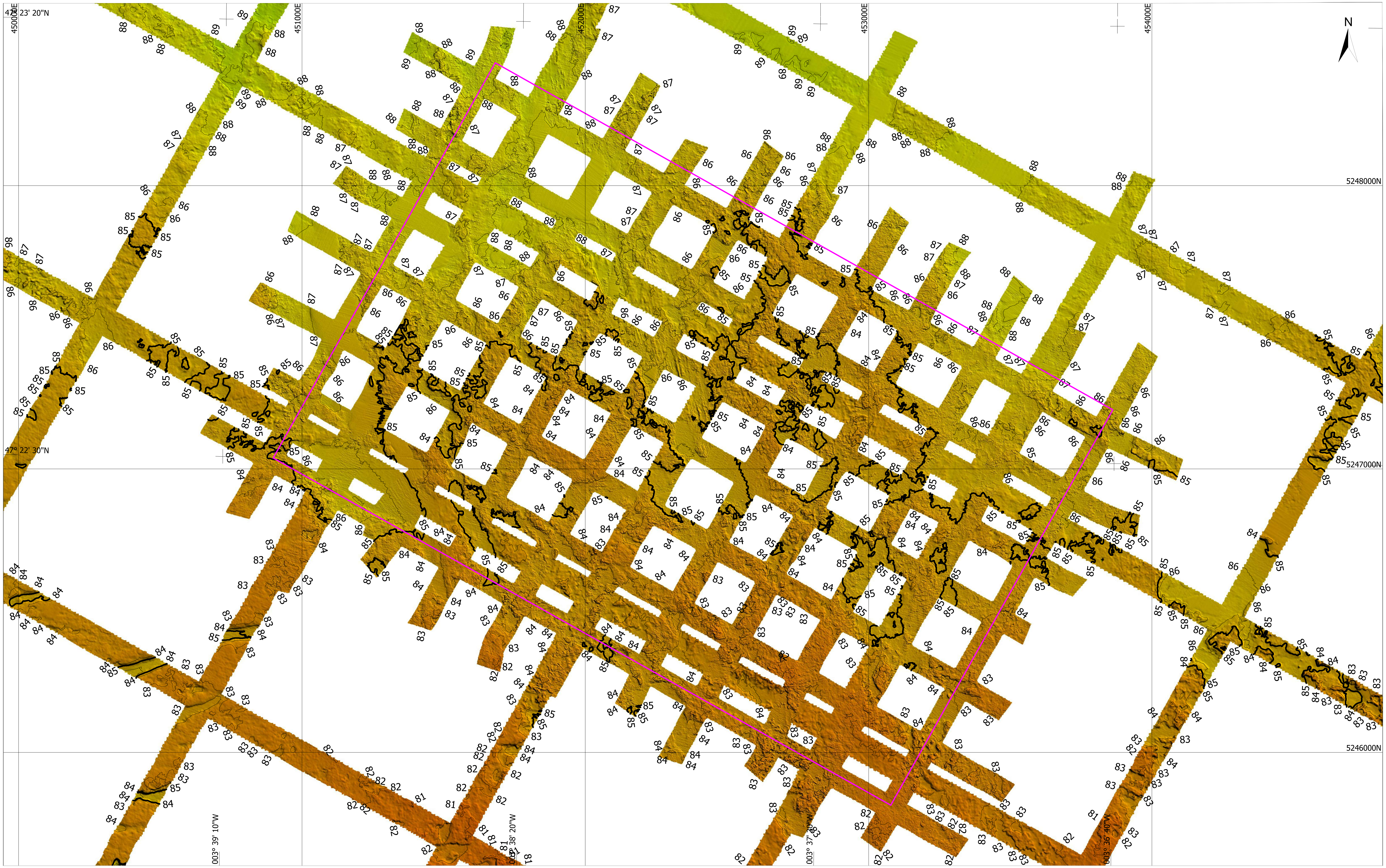
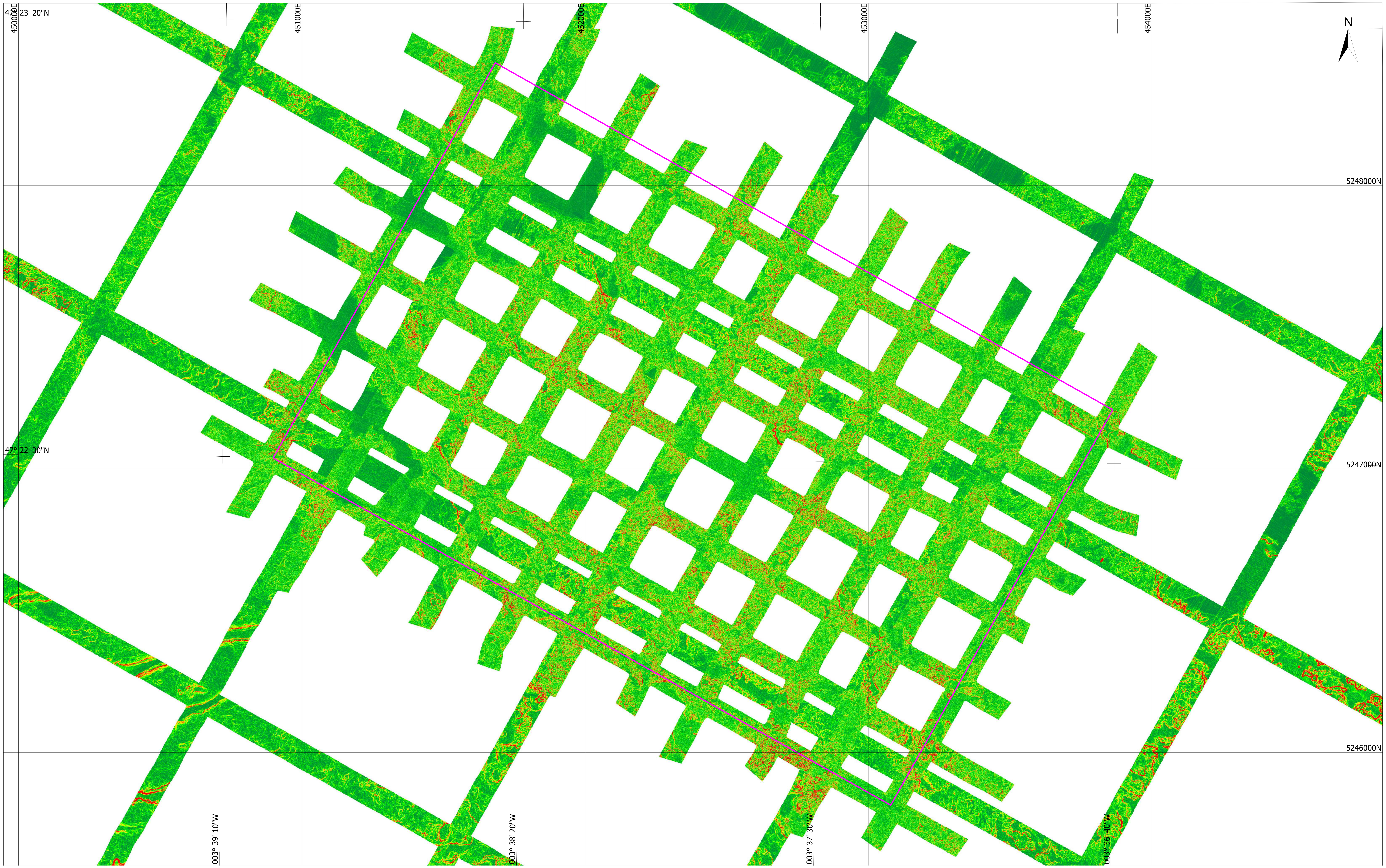
APPENDIX A – CHARTING

CHART NUMBER	CHART TITLE
1	AO5 OSS Bathymetry
2	AO5 OSS Slope Map
3	AO5 OSS Isopach of H1 Horizon
4	AO5 OSS Geological Profile Line M04
5	AO5 OSS Geological Profile Line X06



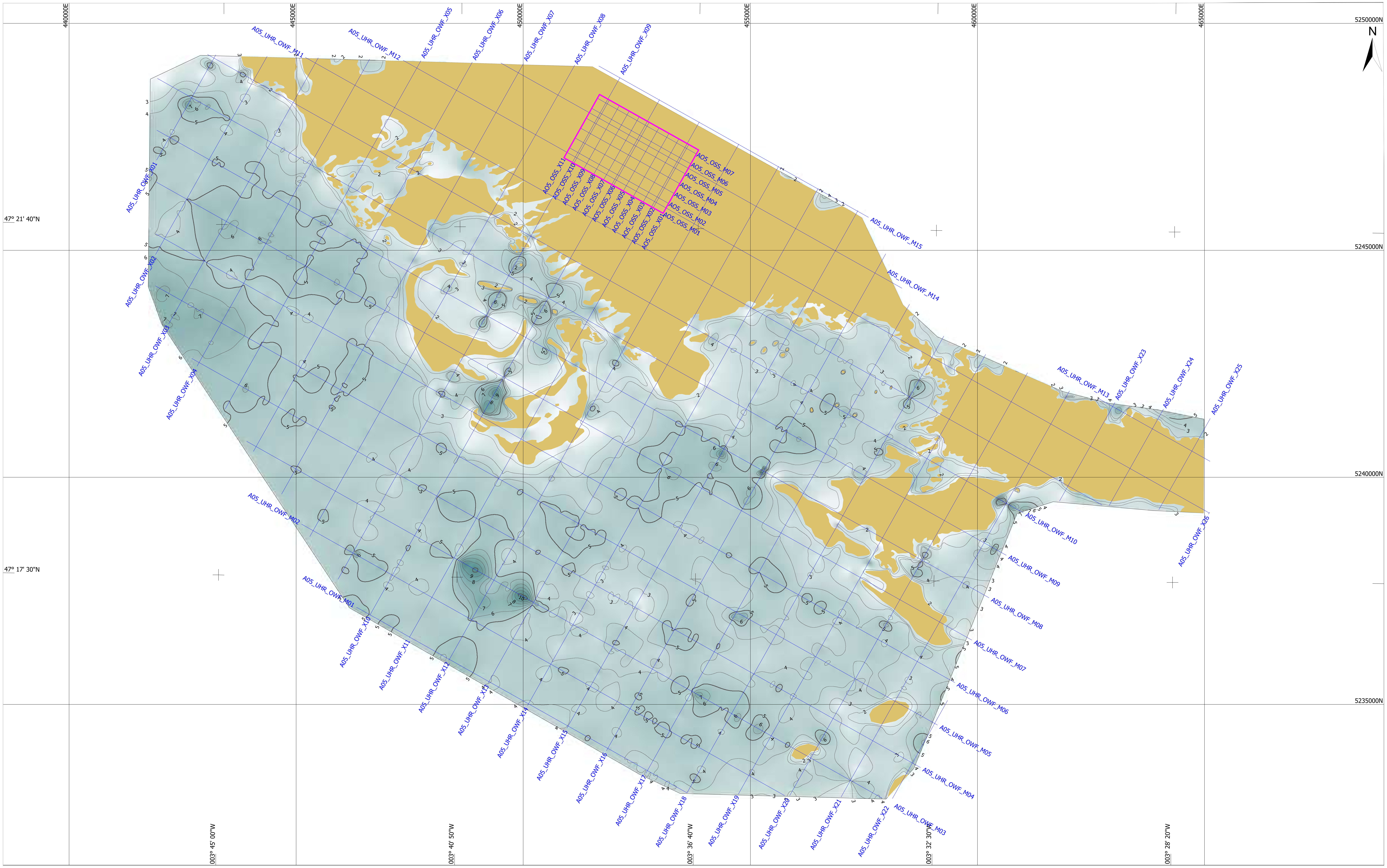
Rte · MINISTÈRE DE LA TRANSITION ÉCOLOGIQUE	TECNOAMBIENTE A TRADEBE COMPANY · GEOQUIPMARINE	CARTOGRAPHIC INFORMATION: *ELEVATIONS REDUCED TO BATHYELLI v2 GEOID*	GRAPHIC SCALE: 0 60 120 180 240 300 m	DATE: JUNE 2022	LEGEND: 85 Bathymetric major contour with labels indexed at 5 m intervals; 84 Bathymetric minor contour with labels indexed at 1 m intervals; A05 - OSS Survey Area	Depth in metres (SHOM BATHYELLI v2) DTM data gridded at 2m cell size 74 82 91 100
			DATUM: WGS 84 · PROJECTION: UTM 30 N	COMMENTS: - - -		

PROJECT TITLE:	CHART TITLE:	AREA:	CHART #:
Geophysical Survey - A05 OSS Area	A05 Bathymetry	GENERAL	1 OF 5
		REFERENCE: - - -	SCALE: 1:5000



MINISTÈRE DE LA TRANSITION ÉCOLOGIQUE	TECNOAMBIENTE A TRADEBE COMPANY / GEOQUIPMARINE	CARTOGRAPHIC INFORMATION: *ELEVATIONS REDUCED TO BATHYELLI v2 GEOID*	GRAPHIC SCALE: 0 60 120 180 240 300 m	DATE: JUNE 2022	LEGEND: A05 - OSS Survey Area
			DATUM: WGS 84 / PROJECTION: UTM 30 N	COMMENTS: - - -	Slope in degrees Data gridded at 0.5m cell size 0° 4° 8° 12°

PROJECT TITLE:	CHART TITLE:	AREA:	CHART #:
Geophysical Survey - A05 OSS Area	A05 Slope Map	GENERAL	2 OF 5
		REFERENCE: - - -	SCALE: 1:5000



MINISTÈRE DE LA TRANSITION ÉCOLOGIQUE

TECNOAMBIENTE A TRADEBE COMPANY

GEOQUIPMARINE

CARTOGRAPHIC INFORMATION: *ELEVATIONS REDUCED TO BATHYELLI v2 GEOID*	GRAPHIC SCALE: 0 360 720 1080 1440 1800 m		DATE: JUNE 2022
	DATUM: WGS 84	PROJECTION: UTM 30 N	COMMENTS: - - -

LEGEND:
- 5 Major contour with labels indexed at 5 m intervals
- 4 Minor contour with labels indexed at 1 m intervals
- Sub-cropping bedrock
- A05 - OSS Survey Area

H1 – Top Bedrock (representing sediment thickness overlaying bedrock)

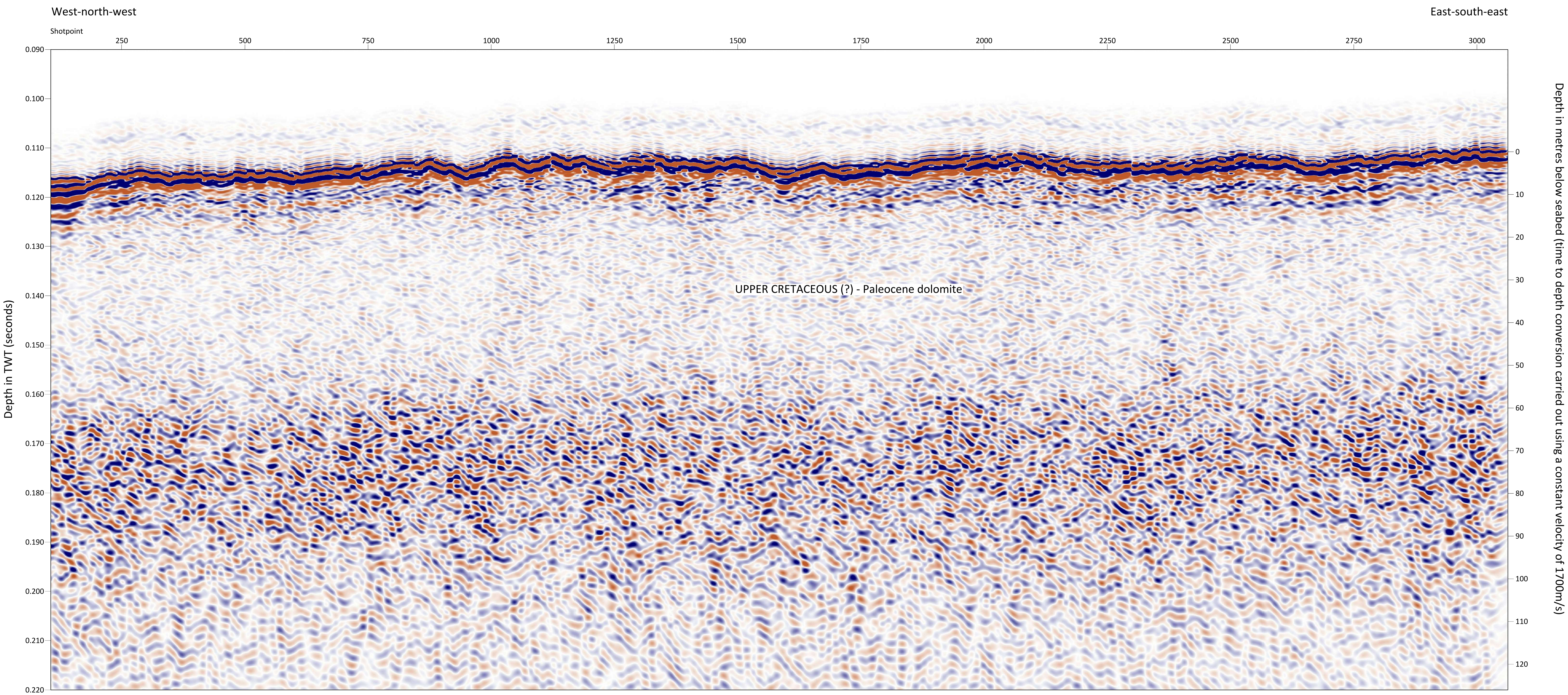
Depth converted using ASV of 1700m/s

Depth BSB to H1 in metres

0 — 11.8

PROJECT TITLE: Geophysical Survey - A05 OSS Area	CHART TITLE: Isopach of H1	AREA: GENERAL	CHART #: 3 OF 5
		REFERENCE: - - -	SCALE: 1:30000

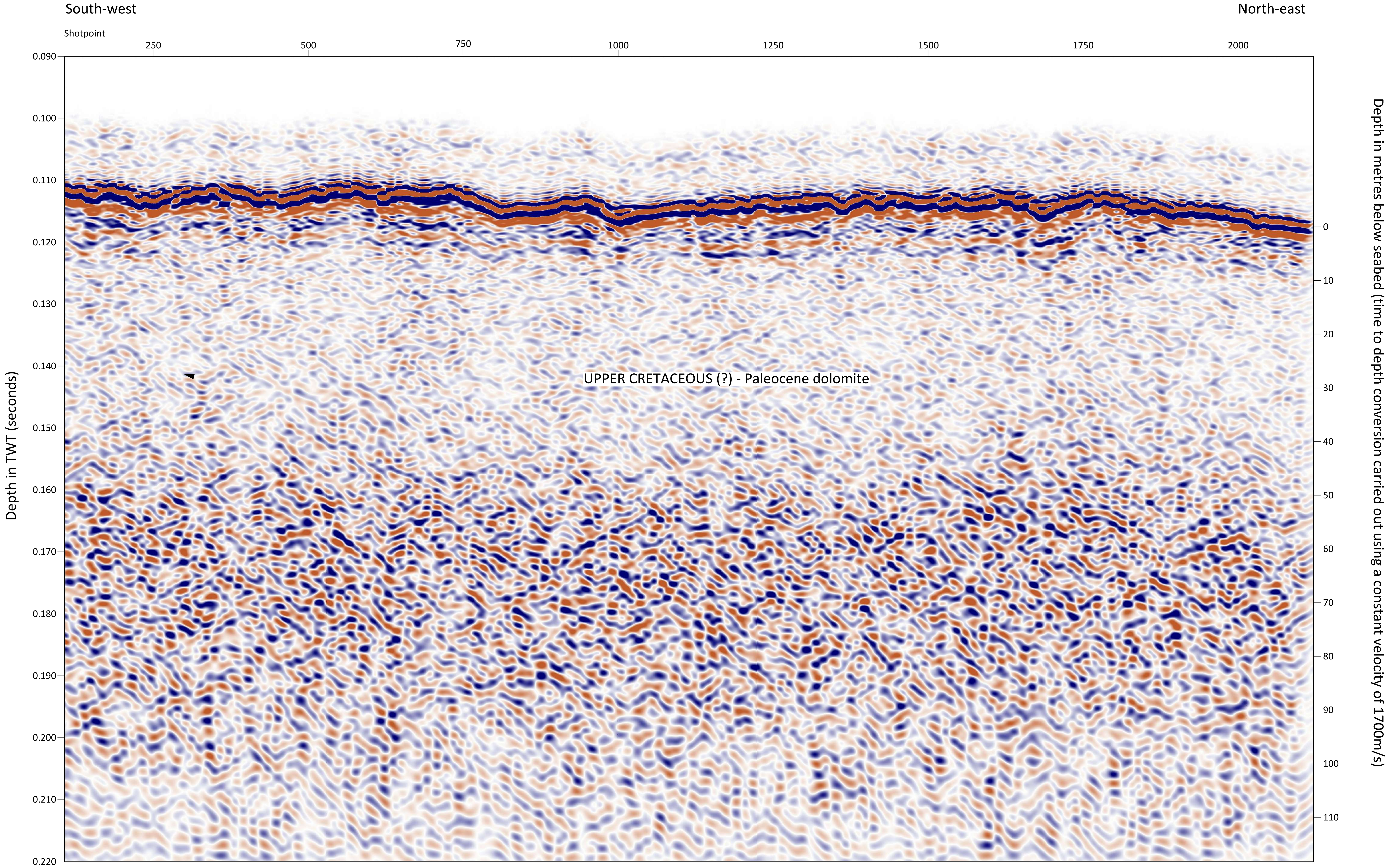
Line A05_UHR_OSS_M04



MINISTÈRE DE LA TRANSITION ÉCOLOGIQUE	TECNOAMBIENTE A TRADEBE COMPANY / GEOQUIPMARINE	CARTOGRAPHIC INFORMATION: *ELEVATIONS REDUCED TO BATHYELLI v2 GEOID*	GRAPHIC SCALE: 0 40 80 120 160 200 m	DATE: JUNE 2022	LEGEND:	PROJECT TITLE: Geophysical Survey - A05 OSS Area	CHART TITLE: Profile of Line M04	AREA: GENERAL
			DATUM WGS 84 / PROJECTION: UTM 30 N	COMMENTS: - - -				REFERENCE: - - -

CHART #:	4 OF 5
SCALE:	-

Line A05_UHR_OSS_X06



MINISTÈRE DE LA TRANSITION ÉCOLOGIQUE	TECNOAMBIENTE A TRADEBE COMPANY GEOQUIPMARINE	CARTOGRAPHIC INFORMATION: *ELEVATIONS REDUCED TO BATHYELLI v2 GEOID*	GRAPHIC SCALE: 0 40 80 120 160 200 m	DATE: JUNE 2022	LEGEND:	PROJECT TITLE: Geophysical Survey - A05 OSS Area	CHART TITLE: Profile of Line X06	AREA: GENERAL	CHART #: 5 OF 5
			DATUM WGS 84 / PROJECTION: UTM 30 N	COMMENTS: - - -				REFERENCE: - - -	SCALE: -

APPENDIX B – PROCESSING REPORT

Seismic Processing Report

Document Reference	PP2021-530 – Seismic Processing Report	
Issue Date/Version	3rd Nov 2021	Version: 1
Client	Tecnoambiente / RTE / DGCE	
Project	AO4 Windfarm	
Document Author	Tom Harrison / Hasan Abdat	
Approved By	Tony Bateson	
Reason for Issue	First issue for review.	

Contents

Figures

1. Version Control

DATE	VERSION	CHANGE
3rd Nov 2021	1	First issue for client review.

2. Seismic Data Processing

2.1. Introduction

The dataset was processed offshore by Peak Processing (October-November) using a ProMAX™ R5000.8.3.0 system.

The objective was to provide a dataset for use in geological interpretation of the area to determine suitability for wind turbine and offshore sub-station placement.

The dataset comprised:
66 2DUHR lines
Total project kms = 669.6kms

The UHR lines were acquired with a 300ms record length using a 800J, 360 tip, sparker fired every 1m. The sample interval was 0.0625ms. The receiver array consisted of a 48 channel streamer with a varying group interval – 1m for channels 1-24 and 2m for channels 24-48.

2.2. Processing Sequence and Testing

The processing sequence was tested and devised by Peak Processing. Line X-023 was used as the test dataset.

After pre-processing; quality control and navigation loading stages, velocities were picked on semblance gathers every 500m using ProMAX Velocity Function Suite for each of the lines, which were then used to produce full fold stacks.

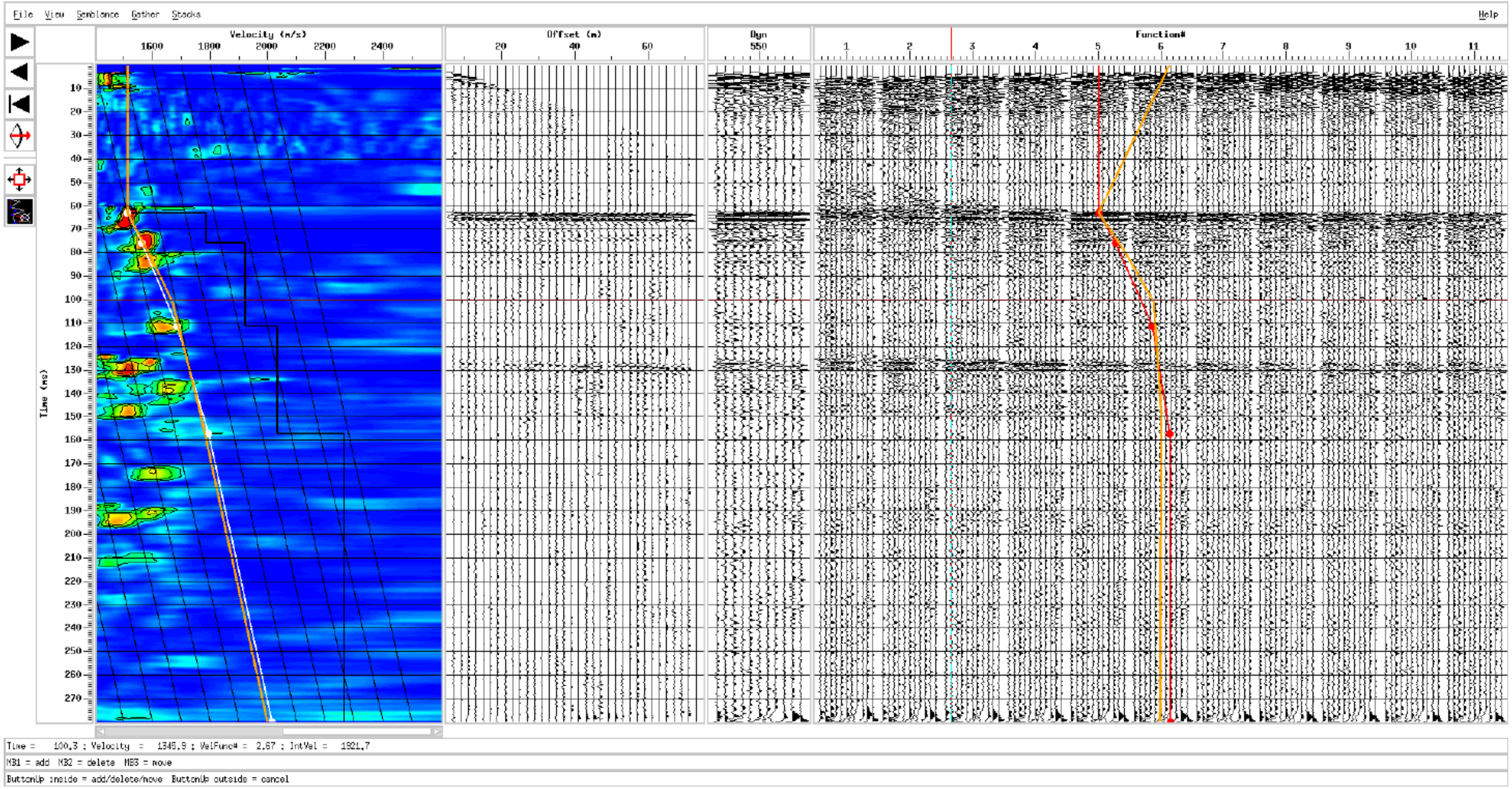


Figure 1 – Velocity Picks

The data was put through designature processing, using an ideal wavelet created from alongside signature testing, and intensive cleaning flows. Due to the short layback from the vessel and lack of boom towpoint high levels of vessel propellor noise were visible in the data, particularly on lines running into the strong current. Noise in the data was addressed with a combination of bandpass filtering, time-frequency domain (TFD) noise filter and Surface Wave Noise Attenuation.

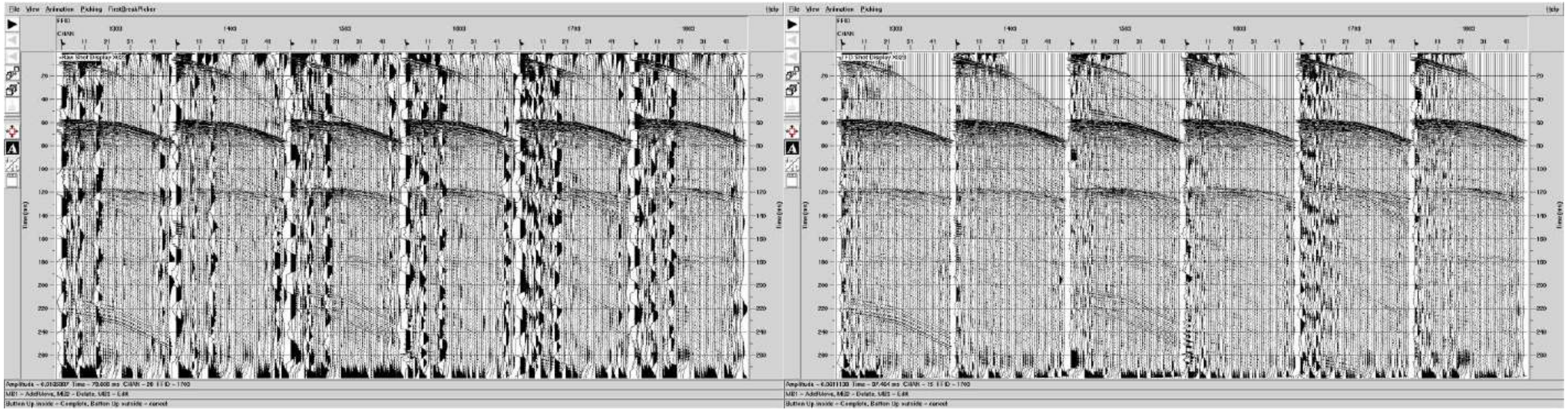


Figure 2 – TFD noise rejection at 50-450Hz with a 14ms sampling window over 7 traces – before and after display

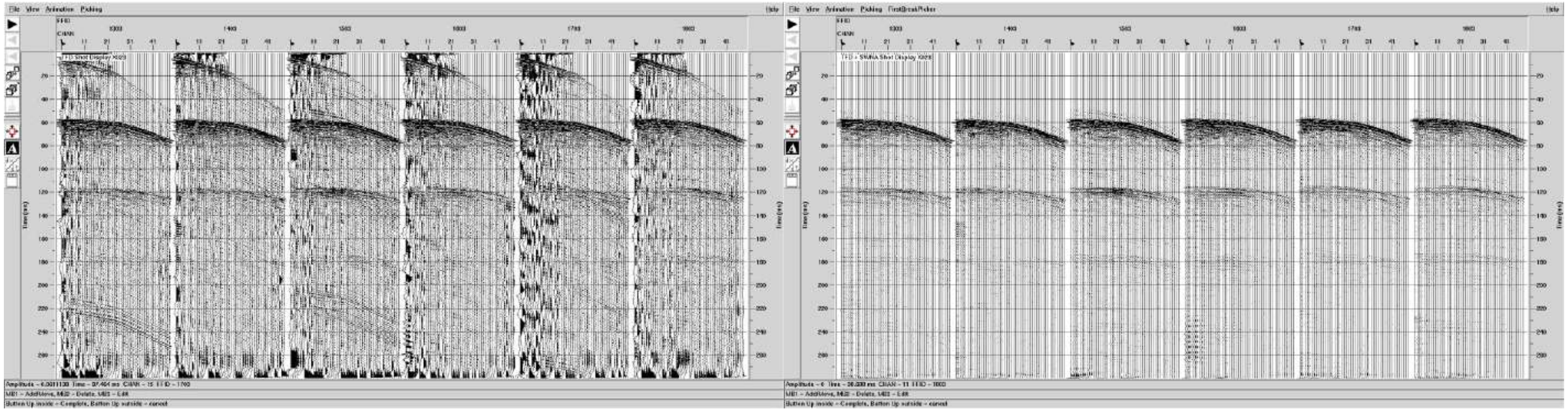


Figure 3 – SWNA noise rejection on shots 1-2000Hz with a 24-trace panel size – before and after displays

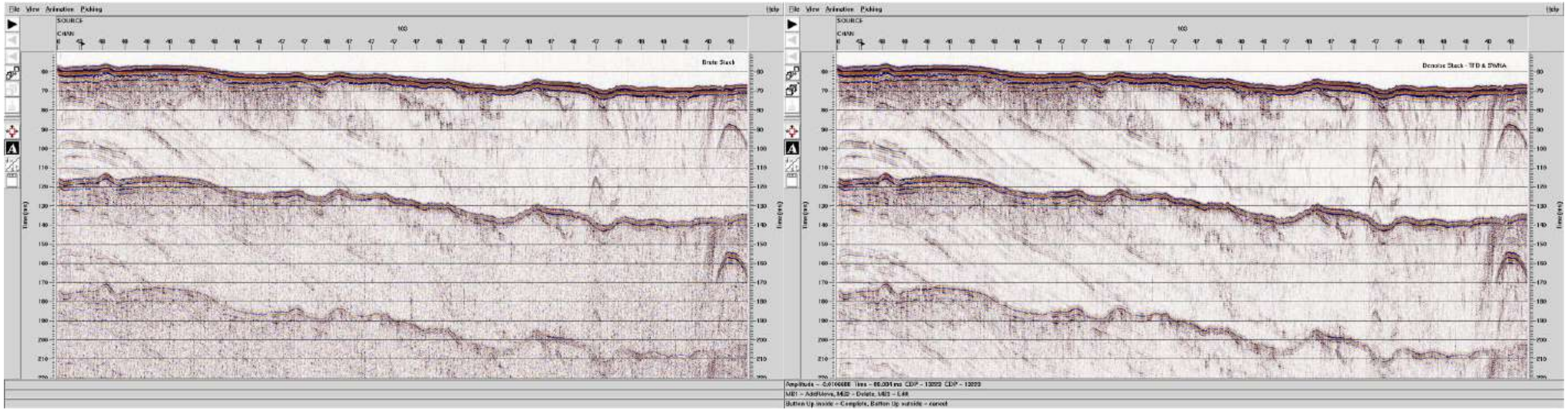


Figure 4 – Brute Stack (left), Denoise(TFD & SWNA) stack (right)

Surface Related Multiple Attenuation (SRME) was tested and applied to remove water surface multiples in the data. Best results were obtained as follows; using a spatial taper of 1.0 trace and frequency taper of 0.0 a model of the noise/multiple was obtained. A filter that matched the noise was derived and applied with a 200ms window length and a 5ms filter length. Finally, the modelled noise is subtracted in the channel domain, using a 20ms temporal window length and a 3ms filter length. The subtraction modules were quite efficient in attenuating surface multiples present in the data.

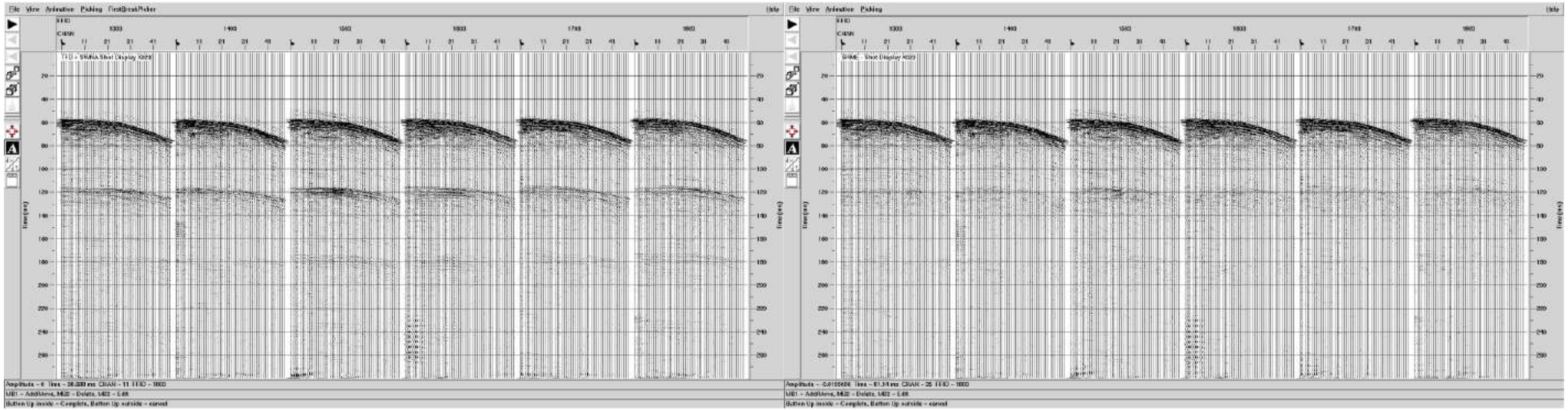


Figure 5 –Denoised shots (left) and SRME shots (right)

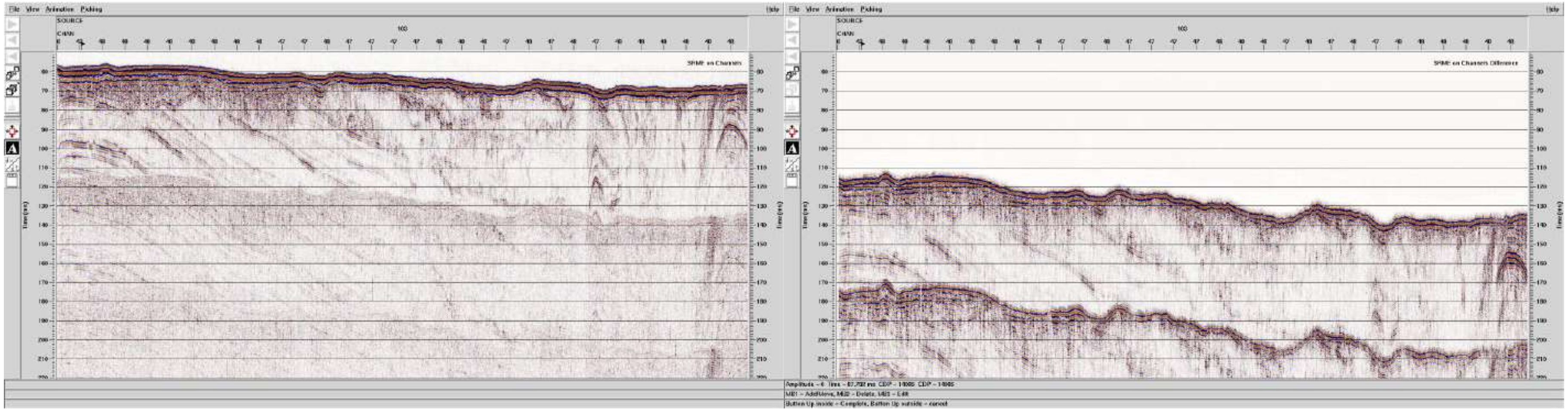


Figure 6 –SRME stack (left), difference display versus Denoise stack (right)

Further multiple removal was conducted using water bottom predictive deconvolution using CDPs with water velocity NMO applied. Optimum results were obtained with a single filter, 0.5ms operator length, with a water depth relative prediction distance.

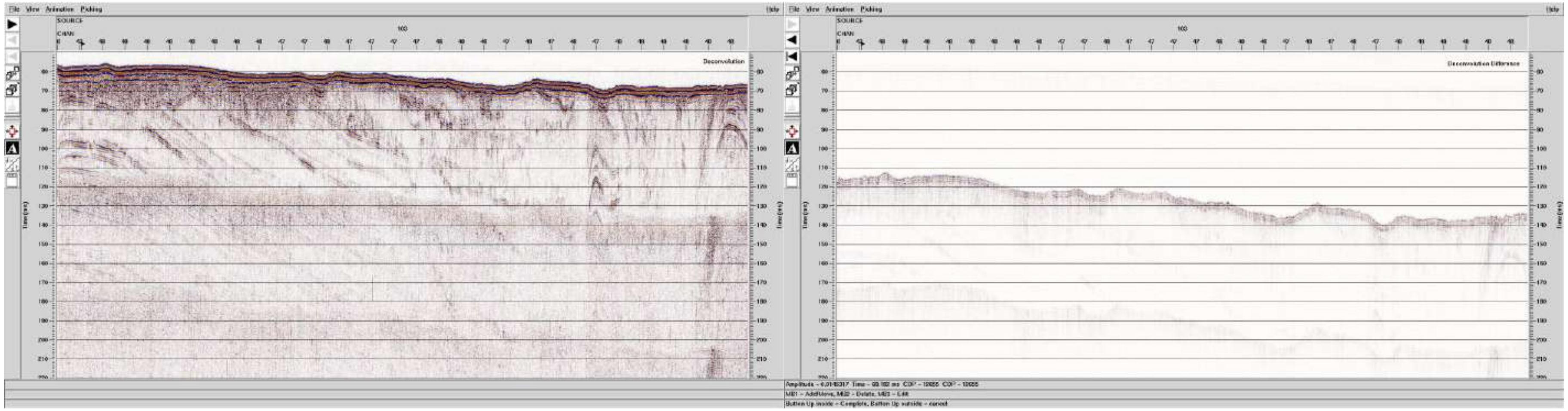


Figure 7 – Predictive Deconvolution stack (left), difference display versus SRME stack (right)

Channel static corrections were then performed on the data using automatically generated trim static shifts. Once this compensation for vertical movement of the streamer in the water had been performed, an external trace mute was also picked and applied across the dataset.

Following channel static corrections, a second pass of SRME was performed. As before, a model of the noise/multiple was obtained using a spatial taper of 1.0 trace and frequency taper of 0.0. A filter that matched the noise was again derived and applied with a 200ms window length and a 5ms filter length. This time the modelled noise is subtracted in the shot domain, using a 20ms temporal window length and a 3ms filter length.

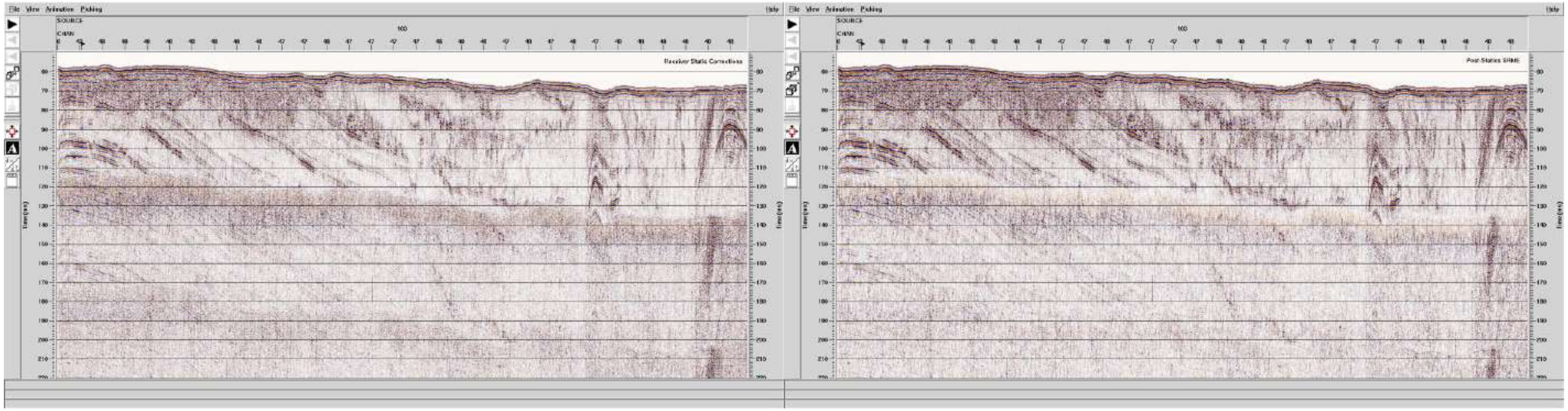


Figure 8 – Receiver Static Corrections and External Trace Mute (left), 2nd Pass of SRME post-static-corrections (right)

Post-stack, the gain was balanced throughout the record using a Time-Variant Gain function, generated and applied on a line-by-line basis, using a 50ms function. A combination of deconvolutions were then applied to further attenuate any remnant multiple, and crispen the shallow horizons. Best results were obtained with a 2ms operator and 2ms prediction distance, applied with a single gate of 0-200ms, and a 1ms operator length and water depth relative prediction distance, applied with a single time gate through the whole record.

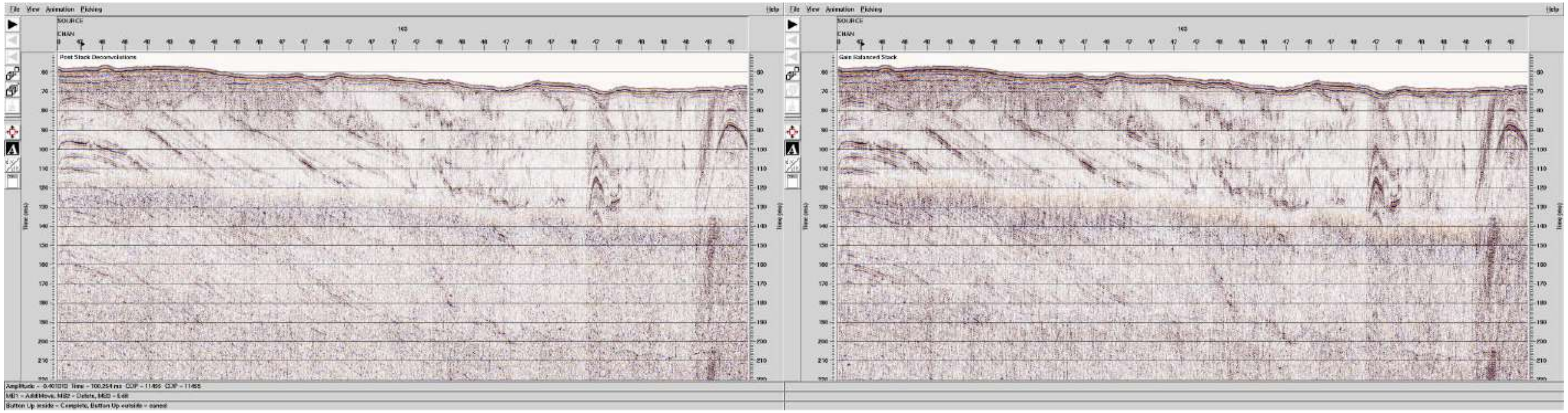


Figure 9 – Gain Balanced Stack (left), Post Stack Deconvolutions (right)

Noise levels were further reduced in the data using a combination of FK polygonal filter, and time variant bandpass filtering.

Time (ms)	Bandpass Filter Frequency Range (Hz)
70	160-1800
150	160-800
250	160-500

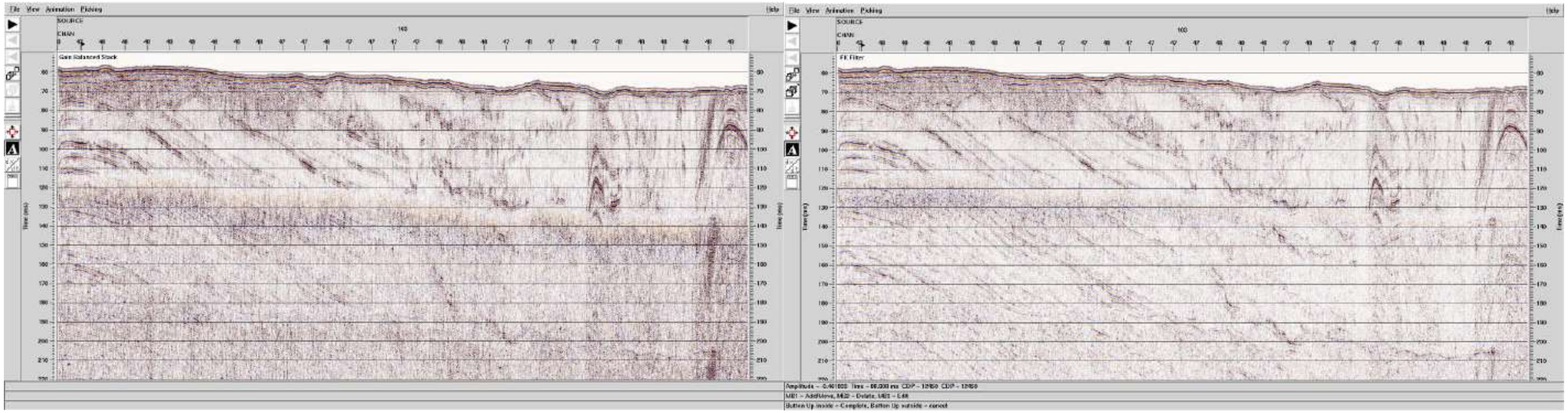


Figure 10 – Post Stack Deconvolutions (left), FK and Time-Variant Bandpass Filters (right)

After cleaning the data was migrated using ProMAX's Steep Dip Explicit algorithm, with up to 70 degrees with smoothed final velocities. Post Migration, a time variant bandpass filter was reapplied.

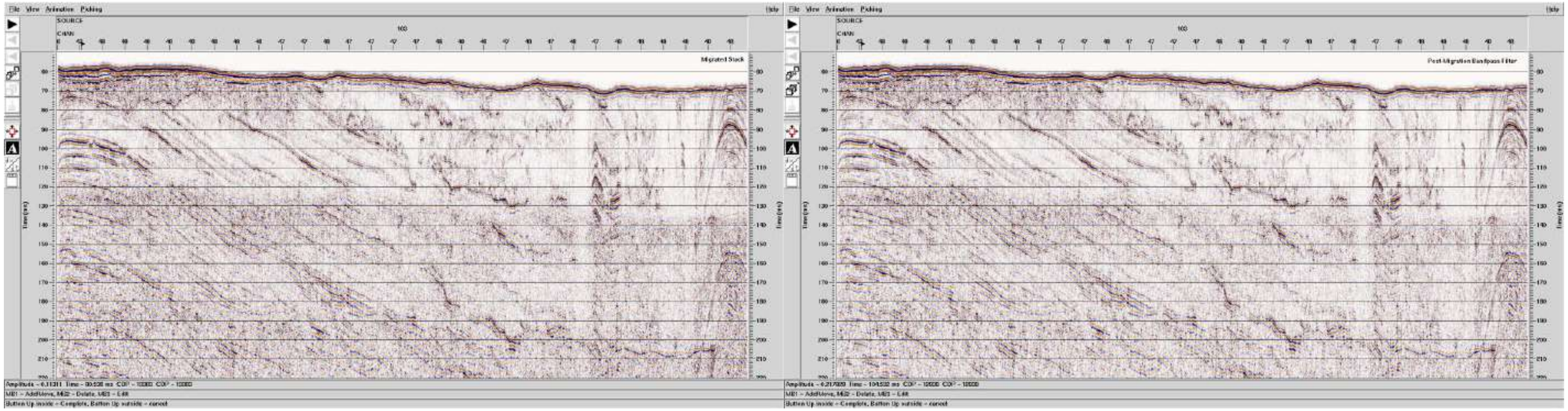


Figure 11 – Final migrated stack (left) and with Time Variant Bandpass Filter Reapplied (right)

Lastly, prior to export of the final SEGYs, static corrections were performed to correct for tide, and source & channel tow depths.

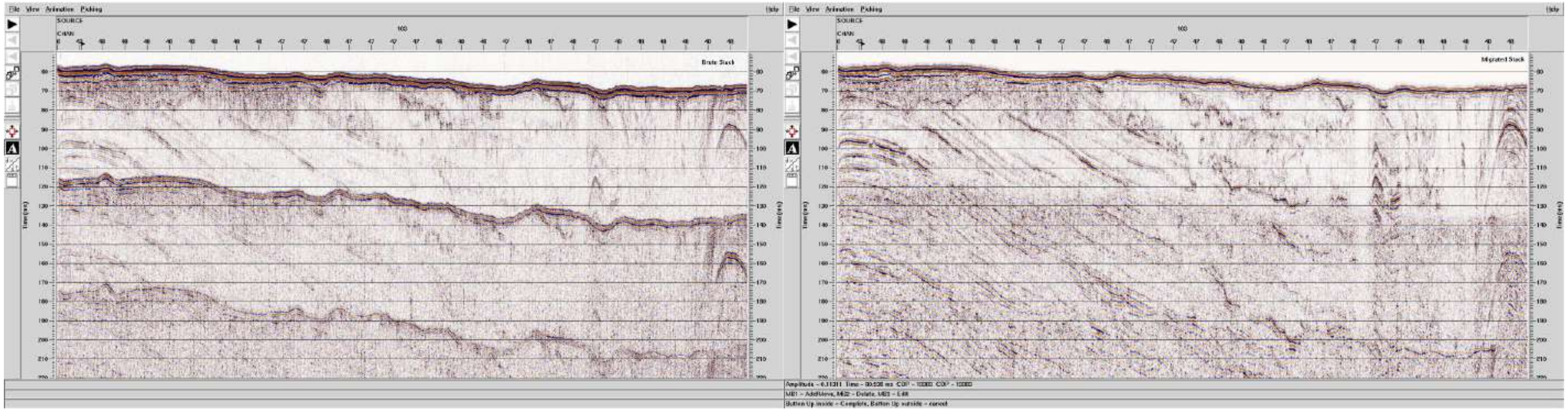
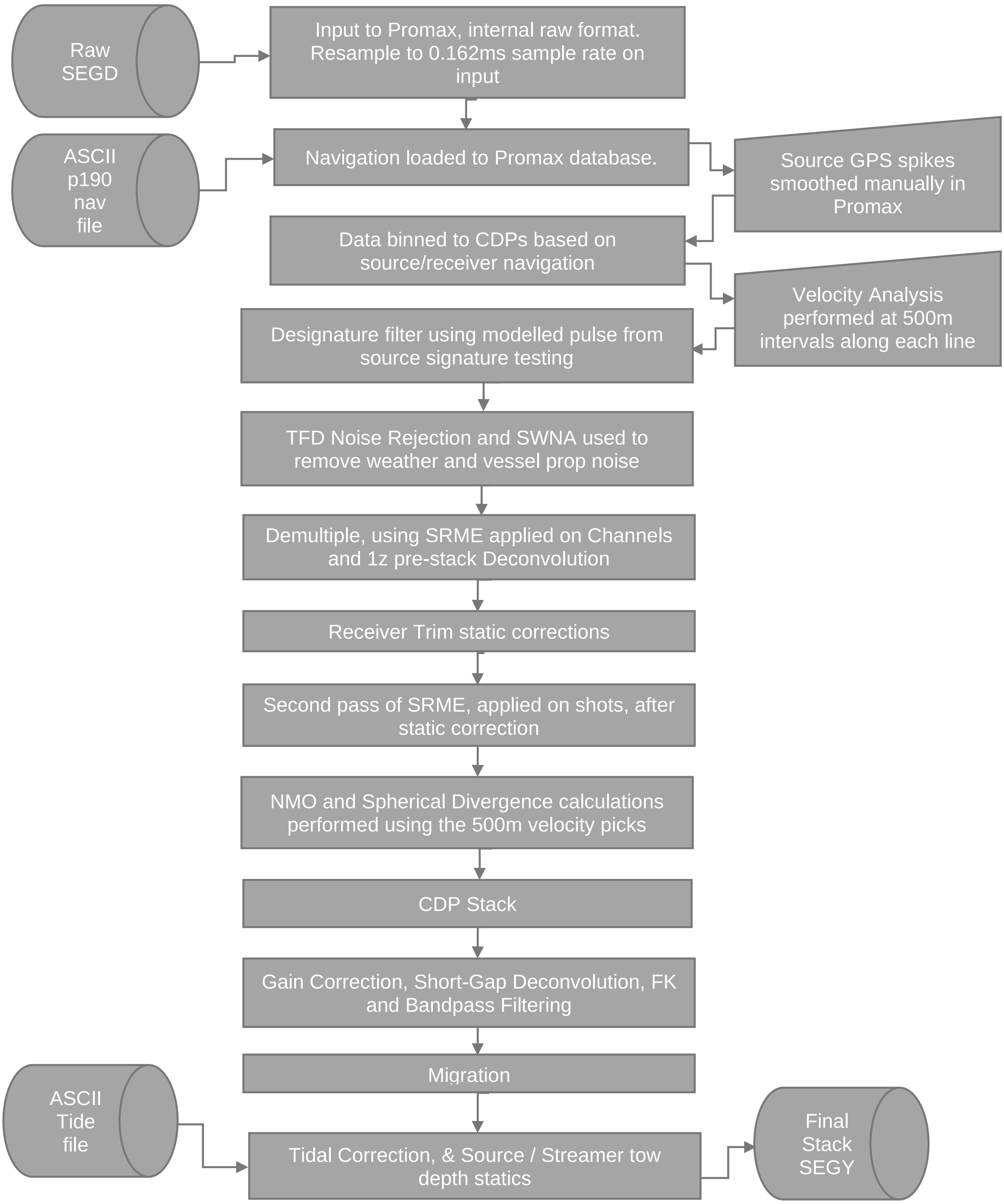


Figure 12 – Brute Stack (left) versus Final Processed Stack (right)

2.3. Processing Flow



Appendix A - Line Listing

Line Name	SOL Shot	EOL Shot	Length (km)
M001A	106	2954	2.8
M002A	129	2866	2.7
M003B	102	3000	2.9
M004A	105	3031	2.9
M005	101	3066	3.0
M006A	101	3060	3.0
M007B	108	2956	2.8
M008A	109	5006	4.9
M009A	102	5692	5.6
M010	105	17870	17.8
M011A	108	18458	18.4
M012	113	18998	18.9
M013A	107	19798	19.7
M014	105	20676	20.6
M015	108	22846	22.7
M016A	110	24015	23.9
M017	101	25135	25.0
O001A	108	14602	14.5
O002	108	11498	11.4
O003	109	21921	21.8
O004	107	20891	20.8
O005	103	14024	13.9
O006	121	17923	17.8
O007	108	9250	9.1
O008	101	7106	7.0
O009	105	12796	12.7
O010	101	13232	13.1
O011	112	16801	16.7
O012	108	14421	14.3
O013	101	13138	13.0
O013_1	106	4258	4.2
O014	108	7629	7.5
O015	107	7123	7.0
O016	106	22630	22.5
O017	101	19404	19.3
O018	108	12853	12.7
O019	107	13518	13.4
O020	101	13624	13.5
O021	110	4864	4.8
O023	111	6908	6.8
X001	108	2042	1.9
X002	107	2102	2.0
X003	101	2140	2.0

Line Name	SOL Shot	EOL Shot	Length (km)
X004	108	2041	1.9
X005	101	2147	2.0
X006	110	1993	1.9
X007	107	2288	2.2
X008	101	2082	2.0
X009	101	2138	2.0
X010	101	2138	2.0
X011A	107	2224	2.1
X012	107	3033	2.9
X013	103	6020	5.9
X014	101	10136	10.0
X015A	108	14593	14.5
X016C	101	14720	14.6
X017A	108	14521	14.4
X018	115	11604	11.5
X019	109	11304	11.2
X019_01	106	2454	2.3
X020	107	11697	11.6
X021	108	11343	11.2
X022	103	11659	11.6
X023	103	15128	15.0
X024	104	11527	11.4
X025	109	3674	3.6
		Total KM:	669.6