4. Etude des conditions naturelles Package B (Amendement-1)

- Etudes bathymétriques, détermination des profils des fonds marins, étude topographique et étude des conditions métocéan

NATURAL CONDITIONS SURVEY PACKAGE-B

PREPARATORY SURVEY ON REINFORCEMENT OF MARITIME TRANSPORT AT GOLF OF TADJOURAH

FINAL REPORT

DJIBOUTI AND TADJOURAH PORTS
REPUBLIC OF DJIBOUTI

Prepared for :

JICA STUDY TEAM

In joint venture

1	Issue for approval	O. VICAIRE	J. GASSANI		12/10/2018
Rev	**Description**	**Prepared**	**Checked**	**Approuved**	**Date :**

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1 Overview

Intervention site

The Japanese company Japan Port Consultant in partnership with the direction of the Affaires Maritimes of Djibouti engages Hydroterra Engineering to establish a field works and existing data processing/analysis for Djibouti and Tadjourah ports. The purpose of these surveys was to obtain several technical information and data as part of the project for the development of new infrastructures for the Djibouti-Tadjourah passenger vessel.

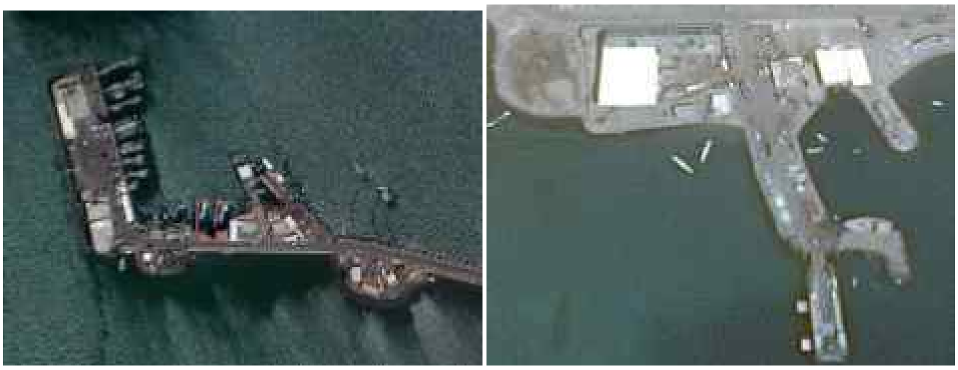


Figure 1: Intervention Zone - Satellite View of the port (left Djibouti, right Tadjourah)

Intervention date

- August 2018 to October 2018

Description

Realization of :

- ❖ Data collection of existing wind data
- ❖ Tide data collection
- ❖ Wind survey in Tadjourah
- ❖ Wave survey by ADCP (30 days)
- ❖ Bathymetric survey
- ❖ Topographic survey
- ❖ Sub-bottom profiling survey

2 Materials

Satellite receivers

- 1 proflex 800 base and its GNSS antenna
- 1 rover proflex 800 and its GNSS antenna

Mono Beam and Sub Bottom

- Tritech
- Innomar SES2000 Compact

ADCP

- ADCP RDI WH Sentinel 1200 kHz

Topographic station

- Nikon 5 C

Wind survey station and software

- Davis vantage Pro2
- Hypack and SESwin
- Autocad

3 Data collection of existing wind data and Tide Data

The Republic of Djibouti does not have long series of meteorology apart in Djibouti city. National Meteorological Agency has archived of wind measurements in Djibouti Airport and also in Tadjourah between 2014 and 2015.

Hydroterra with his partnership with the national agency of Djibouti provides :

- ➢ 2 years of daily observation of the station of Tadjourah installed on an hill above 28 meters above the sea. The wind measurement was 10 meters and the direction was in degree rose of 360°.
- ➢ More 10 years of daily observation of the station of Djibouti airport.

Figure 2 **Djibouti airport (Utm Z 38298645- 1277513) Tadjourah (270020- 1303970)**

Tide data, was collected on the site web University Of Hawaii Sea Level Center for tidal data of Djibouti https://uhslc.soest.hawaii.edu/. Design condition of tide level will be calculated by the data after 2014 Oct. because of over one year continuity data.

4 Data collection of Wave survey by acoustic Doppler current profiler (ADCP)

Hydroterra engineering installed an ADCP RDI WH Sentinel 1200 kHz, Teledyne marine at 150 m of Tadjourah portfrom 23 august to 23 september 2018 with one record by hours.

The parameters recorded were :

- For wave data, it is the height, period and direction of the waves and the tide as a function of time.

year	month	day	hour	min	sec	Hs	Tp	Dp	Tide (in meters)
18	8	22	13	32	20	0.61	3.3	252	16.079
18	8	22	14	32	20	0.67	3.5	215	16.195
18	8	22	15	32	20	0.52	3.3	241	16.293
18	8	22	16	32	20	0.29	3.1	183	16.332
18	8	22	17	32	20	0.38	3	216	16.316
18	8	22	18	32	20	0.39	3	229	16.203
18	8	22	19	32	20	0.2	2.6	0	16
18	8	22	20	32	20	0.36	3.1	220	15.745
18	8	22	21	32	20	0.21	2.7	176	15.494

Figure 3: output of Adcp with Hs(Significant hight), Tp (period in sec), Dp (Direction in °) Tide (in meters)

➢ For current data, it is the speed of the current in the water column over time.

```
"Contour Data = Velocity Magnitude mm/s"
"C:\Users\AQUATOPO\Desktop\FINAL_000_000_CUR.PD0.export final.pd0"
"Broadband 1228.8 kHz"
"Pings/Ens ="    50
"Time/Ping = 01:12.00"
"First Ensemble Date = 18/08/22"
"First Ensemble Time = 11:32:20.60"
"Ensemble Interval (s) = "      3600.00
"1st Bin Range (m) = "  1.63
"Bin Size (m) ="        0.50

Ens    YR    MO    DA    HH    MM    SS    HH          1     2     3     4     5

1      18    08    22    11    32    20    60
2      18    08    22    12    32    20    60          59    29    28    41    60
3      18    08    22    13    32    20    60          14    26    40    50    42
```

Figure 4 : Output for current data

A meteorlogical station with wind speed and direction was installed during 1 month in tadjourah. The hight of installation was 6 meters. The station recorded each 10 minute, temperature, wind speed and direction.

		Wind	Wind	Wind	Hi	Hi
Date	Time	Speed	Dir	Run	Speed	Dir
06/09/2018	17:10	3.1	ESE	1.88	5.8	ESE
06/09/2018	17:20	3.1	ESE	1.88	5.8	SSE
06/09/2018	17:30	4.0	SE	2.41	6.7	ESE

Table 1: Wind data record

Figure 5 **Wind survey (Utm Z 269352- 1303562 6 meters) adcp (269536- 1303215 17 meters below sea level)**

5 Bathymetric and Sub Bottom survey

5.1 On board safety

During the entire operations (equipment assembly and acquisition phase), particular attention was paid to the safety of the ship and the personnel on board.

No incident was reported during this mission.

5.2 Global mission schedule

The operations were carried out from 05 to 14/09/2018 for the preparation and acquisition phase and after 15/09 for the data processing, reporting and mapping part. The following table presents the chronology of the events.

Dates	Operations
05 and 06/09/2018	Surveyor mobilisation and equipment from Abidjan
07 and 08/09/2018	Geodetic and navigation project preparation, pole and devices assembly on vessel, echosounder calibration
09/09/2018	Bathymetric survey in Djibouti port (day 1)
10/09/2018	Transit to Tadjourah
11/09/2018	Bathymetric survey in Tadjourah port (day 1)
12/09/2018	Bathymetric survey in Tadjourah port (day 2)
13/09/2018	Transit to Djibouti
14/09/2018	Bathymetric survey in Djibouti port (day 2) – after passengers vessel departure
15/09/2018	Vessel demobilisation – Data processing
16 and 17/09/2018	Data processing and cartography
After 30/09/2018	Surveyor demobilisation and survey report

Table 2 : Operations schedule for bathymetric survey

Dates	Operations
22/09/2018	Equipment arrival from France – Customs formalities
23/09/2018	Sub bottom profiler (SBP) installation and equipment testing
24 and 25/09/2018	SBP survey in Djibouti port
26/09/2018	Transit to Tadjourah – SBP installation and start of survey
27/09/2018	SBPsurvey in Tadjourah port
28/09/2018	Transit to Djibouti
29/09/2018	Vessel demobilisation – Start of data processing
30/09/2018	Surveyor demobilisation
After 02/10/2018	Data processing and survey report

Table 3 : Operations schedule for Sub-Bottom

6 SURVEY STAFF

The survey participants are listed in Table 2.

Personnel	Role	Period of survey
J. Gassani	Project manager – Director of Hydroterra Engineering.	Preparation, acquisition and report
O.Vicaire	Expert surveyor - Consultant	Preparation, acquisition, data processing and report
Kassim Daoud Houmed	Responsible for logistics	Preparation and acquisition
Ali Djama	Boat pilot	Acquisition

Table 4 : Survey personnel

Each team member above had the following responsibilities:

- Project Manager (J. Gassani): customer relations, control of the smooth running of the survey verification of the report.

- Consultant (O. Vicaire): responsible for the technical preparation of the survey, installation of equipment, quality control during acquisition, post-processing of data, writing of the survey report and cartographic documents.

- Logistics (Kassim DH): contact with port and administrative authorities, responsible of transport vehicule and fuel supply for the boat.

- Pilot (Ali Djama): pilot of the vessel, in charge of safety on board.

7 TECHNICAL RESOURCES

7.1 Devices

Table 3 summarizes the means used to carry out the investigations, process the data and present the results.

Devices	Types	Accuracy
Vessel	DJ112 pirogue	
Positioning	2 x Ashtec Proflex 800 GNSS	centimetric
Echosounder	Tritech PA500	centimetric
Navigation and acquisition software	Hypack	
Processing software	Hypack	
Data presentation software	Hypack and Autocad	

Table 5 : Technical tools used during surveysof Bathymetric

Devices	Types	Accuracy
Vessel	DJ112 pirogue	
Positioning	2 x Ashtec Proflex 800 GNSS	centimetric
Sub Bottom Profiler	Innomar SES2000 Compact	centimetric
Navigation and acquisition software	Hypack and SESwin	
Processing software	Hypack and ISE2	
Data presentation	Hypack and Autocad	

software		

Table 6: Technical tools used during surveys of Sub-Bottom

7.1.1 Vessel

The vessel used for thesesurveys is a 7.5m polyester pirogue equipped with a 200 HP outboard motor (figure 2). It has a cockpit with steering wheel, a large space to install the equipment on the front and a protective cover against the sun.

This boat has all the navigation equipment necessary for the safety of personnel and on-board equipment (lifejackets, navigation chart and portable VHF).

The production of electrical energy to power the various on-board equipment (computers, echosounder, display, ...) is achieved through solar panels coupled to two 12 V batteries. One 12-200 V converter complete the device power supply.

Hydroterra Engineering has built and adapted a multi-support pole so that various equipment can be installed along the edge of the boat (figure 3).

Figure 6 : Vessel used

Figure 7 : Assembly of the Pole

7.1.2 Positioning and navigation

7.1.2.1 *Principle*

The positioning of the ship was ensured by the use of a GNSS system (Global Navigation Satellite System). The principle is based on the use of artificial satellite constellations that provide a receiver with its 3-dimensional geographic position, time and speed. The information is obtained by measuring at a time t the distance between the GNSS antenna coupled to the receiver and the different observable satellites.

A GNSS base station installed on a point whose coordinates are known precisely sending position corrections to embedded GNSS receiver via a UHF radio. The GNSS differential RTK (Real Time Kinematic) positioning mode allows a real-time centimeter correction of the positioning of the "mobile" (GNSS system embedded on the boat). The operating principle of the positioning is shown schematically in figure 4.

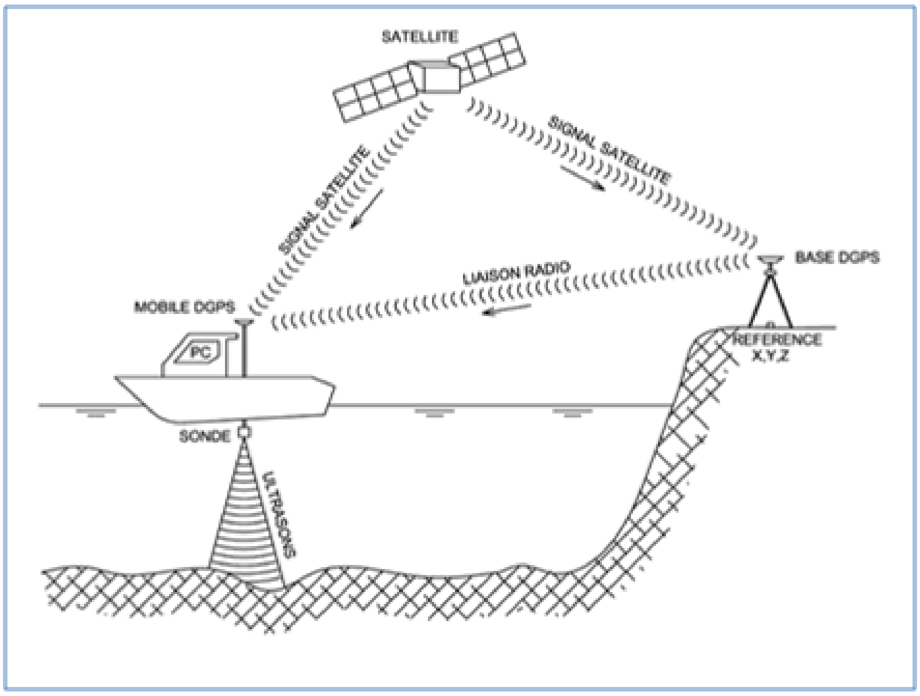


Figure 8 : Principle of GNSS operation in RTK mode

7.1.2.2 *GNSS equipement*

The positioning equipment used is composed by two Proflex 800 GNSS system developed by the company Ashtec. Each system consists of a receiver, an antenna and all associated cables and connectors. The receiver used are adapted to receive signals from US (GPS) and Russian (GLONASS) constellations.The GNSS base station is installed on a well-know geodetic point (figure 5) and the mobile is installed on board the vessel (figure 6).

Figure 9 : GNSS Base station

Figure 10 : Proflex 800 receiver(left) and associated GNSS antenna fixed on the pole

7.1.2.3 *Navigation and tracking of lines*

The navigation along predefined lines was ensured by the use of Hypack software installed on a laptop (Hypack Inc). This software makes it possible to build a site project by integrating all the elements necessary for the good progress of a survey.
This includes the choice of the geodetic parameters of the project by defining the geodetic system, the reference ellipsoid and the projection. The preparation of the project also includes the creation of the boundaries of the areas to be studied and the creation of the lines to follow on an integrated basemap.
During acquisition, the GNSS data is synchronized and stored under the Hypack software. Hypack makes it possible to control all the parameters in real time (quality of the GNSS signal, number of satellites, speed, heading, deviation from the theoretical line followed, ...).The computing device is composed of a computer and a remote screen that allows the boat pilot to follow the intended line.

7.1.3 Single beam echosounder

7.1.3.1 *Principle*

Asingle-beam echosounder transmits a short acoustic signal vertically below the ship. The instrument measures the two-way travel time of the signal, which, if the sound speed is known, gives the local water depth (figure 7). The depth is given by the following relation: D = ½ V * t / 2 (with D = depth, V = speed of propagation of sound in water, t = duration of the two-way travel time).

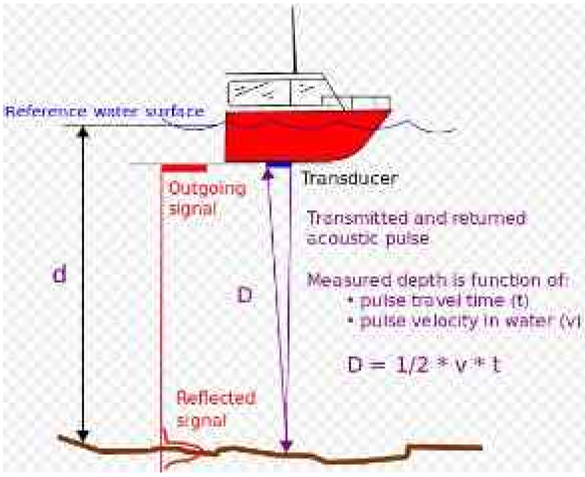


Figure 11 : Principle of single beam echosounder (Wikipedia)

7.1.3.2 *Tritech PA500 echosounder*

The single beam echosounder used during surveys is a Tritech PA500 fixed on the pole to the vertical of GNSS antenna (figure 8). This equipment operates at a 500 kHz frequency and with a 6° conical beamwidth.

Figure 12 : Tritech PA500 echosounder

The echosounder was cheked in August 2018 (see Product test Record in appendix A).

7.1.4 Sub bottom profiler

7.1.4.1 *Principle*

The principle of the sediment sounder (Sub bottom profiler or Pinger) is the same as that of a single-beam bathymetric echosounder. The sounder generates a low frequency acoustic wave (generally between 2 and 15 kHz) that measures the thickness of the sedimentary layer but does not penetrate the bedrock.
The acoustic wave, emitted from the ship, propagates in the water layer, then in the marine subsoil. The succession of shots makes it possible to reconstruct the sedimentary horizons. This gives a vertical section of the marine sub-soil, the abscissa representing the boat's progress, and the ordinate the depth of penetration (figure 7).

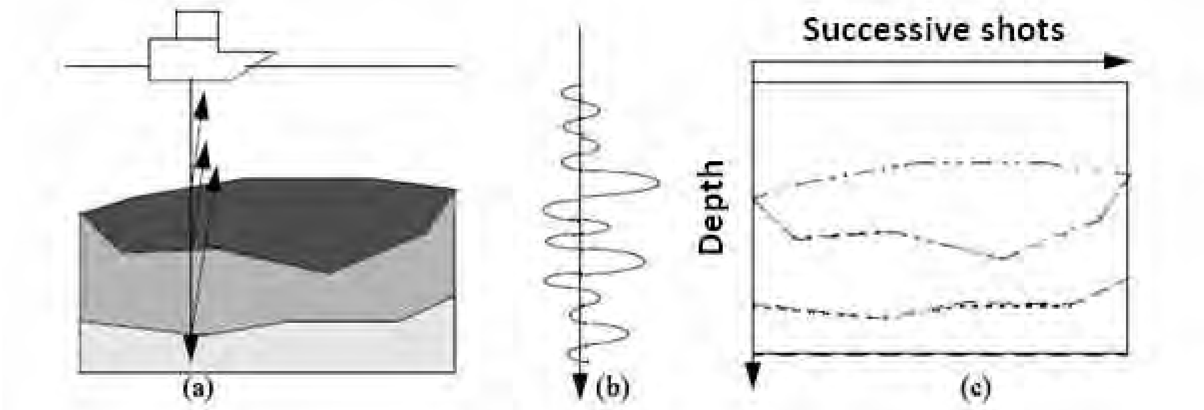


Figure 13 : Principle of sub bottom profiler

7.1.4.2 *SES2000 Compact Innomar*

The SES 2000 compact Innomar sub-bottom profiler, using parametric technology, was pole mounted and installed over the side of the vessel and utilized to investigate the sea floor.
The SES 2000 system consists of the following components:
Main system unit with the transmitters, receivers, amplifiers (figure 8),

External laptop using SESWin softwareconnected to the main system unit and to a second laptop with Hypack software (figure 8),

Transducer array used to transmit and receive the signals (figure 9).
The system is a parametric sediment sounder. This technology is based on a physical phenomenon generating low frequency waves from two high intensity acoustic signals sent simultaneously at two slightly different frequencies (primary frequency: 85-110 kHz and secondary frequencies between 4 and 15 kHz). These two frequencies interact during the propagation of the signal and generate low frequency waves. This signal is very narrow and does not have a secondary diffusion lobe, which improves the signal-to-noise ratio.
The theoretical vertical resolution is 5 cm and the horizontal resolution is less than 7% of the water depth.

Figure 14 : Main sytem unit and laptops

Figure 15 : SBP transducer fixed on pole

7.1.4.3 *Seswin software*

The recording of data on a laptop is done with the SESwin software developed by Innomar (figure 10). During acquisition, various parameters can be adjusted to obtain the best possible image of the marine basement (range, frequency, gain, rate of shots, ...).

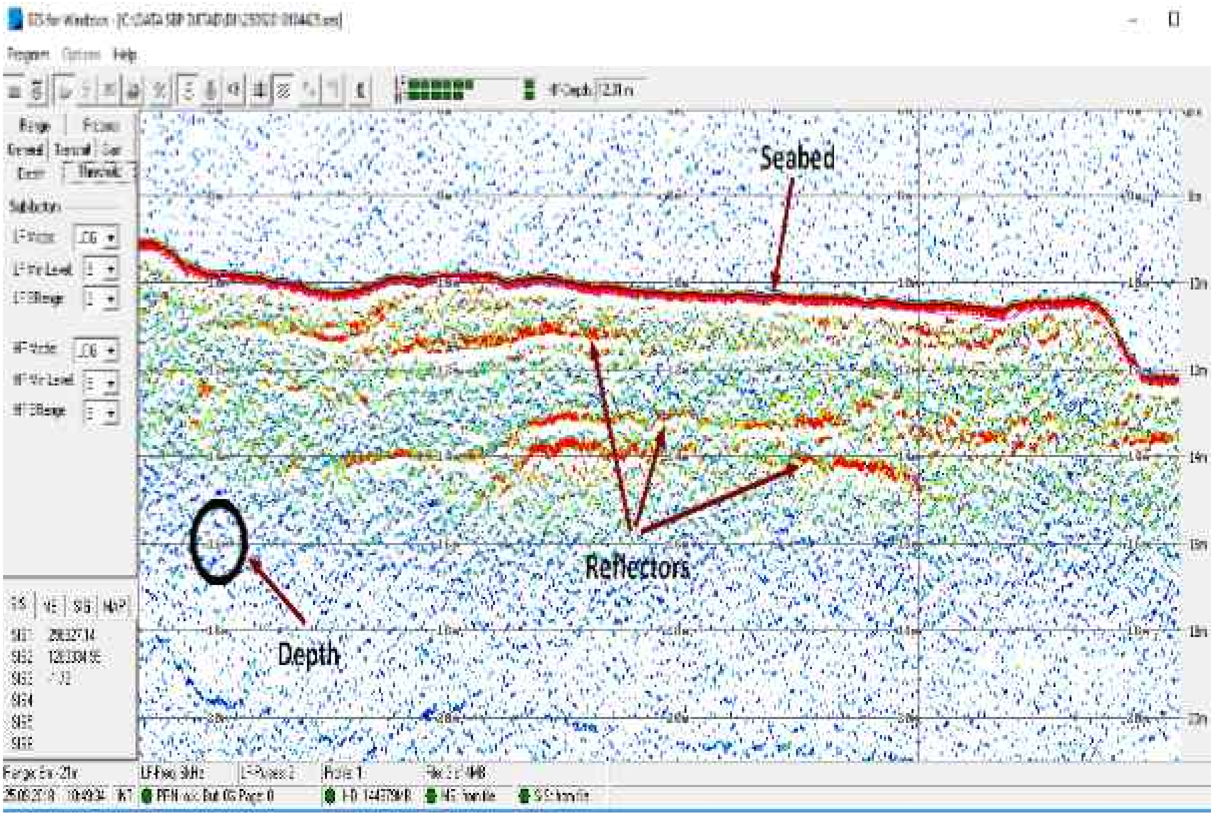


Figure 1 : Typical raw SBP image in Seswin software

On the echogram, the vertical scale corresponds to the depth below the waterline and the horizontal scale depends of the vessel speed. The first red echo is the seabed. Several reflectors can be observed below the seabed.

7.1.4.4 *ISE2 software*

Usually, file processing consists of the following main steps:
automatic or manual tracing of the water-sediment interface (bottom),
setting parameters (stacking, smoothing, TVG, filters, ...),
manual tracing of the reflectors visible on each profile (the reflector corresponds to a limit between two environment of different natures),
exporting thickness data as an ASCII file using a wave propagation speed of 1600 m / s, a value conventionally used for sandy-type sediments.

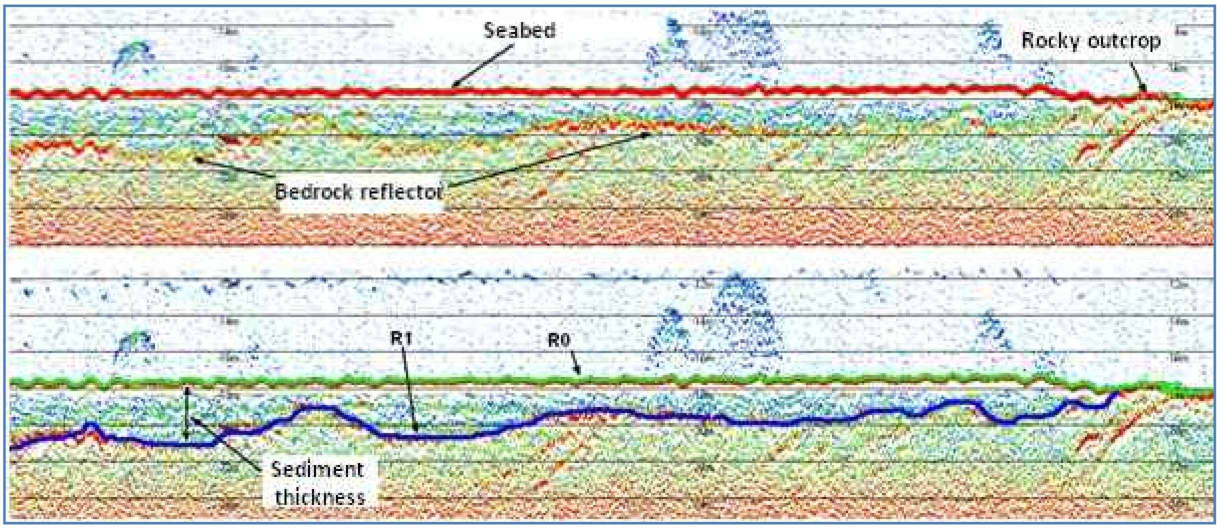


Figure 17 : Typical processed SBP line (up) and interpreted image in ISE2 software

We can distinguish the water-sediment interface (seabed) noted R0 and a reflector R1 more or less well marked and irregular depth that corresponds to a change in nature background. The reflector R1 has been interpreted as the top of the substratum.
The first step in the process is to digitize the water-sediment interface (R0 reflector) and then apply settings to improve the signal-to-noise ratio.
The second step corresponds to the digitalization of the reflector R1 which is visible only partially in the study areas.
The third step is the calculation of the sedimentary thicknesses. This calculation is based on the distance between the bottom and the reflector R1 by taking a velocity of 1600 m/s in the sediment, a value conventionally used for a sandy-type sediment.

For a given area, the observation or not of a reflector depends on several factors:

- the homogeneity of sedimentary deposits (no change in the nature of the sediments vertically),
- the sediment nature (the sediment can be too coarse like gravels or to compact as hard mud),
- The sediment thickness (the thickness can be too important in relation of the acoustic wave penetration),
- Multiple reflections (especially in very shallow water or irregular seabed).

8 METHODOLOGY

8.1 Geodetic parameters

The following parameters were applied for the duration of the project.

8.1.1 Horizontal Datum

Geodetic datum	
Datum	World Geodetic System 1984 (WGS 84)
Ellipsoid	World Geodetic System 1984
Semi-major Axis (a)	a = 6 378137.000 m
Inverse Flattening (1/f)	$^{1}/_{f}$ = 298.257223563
Projection parameters	
Map projection	Universal Transverse Mercator (UTM)
Grid system	38 North
Central Meridian	45° 00' 00''East
Latitude of Origin	0° 00' 00'' North
False Easting	500000.00 m
False Northing	0.00 m
Scale factor on Central Meridian	0.9996
Units	Metre

Table 1 : Horizontal geodetic parameters

These geodetic parameters have been entered in the Hypack navigation software (figure 9).

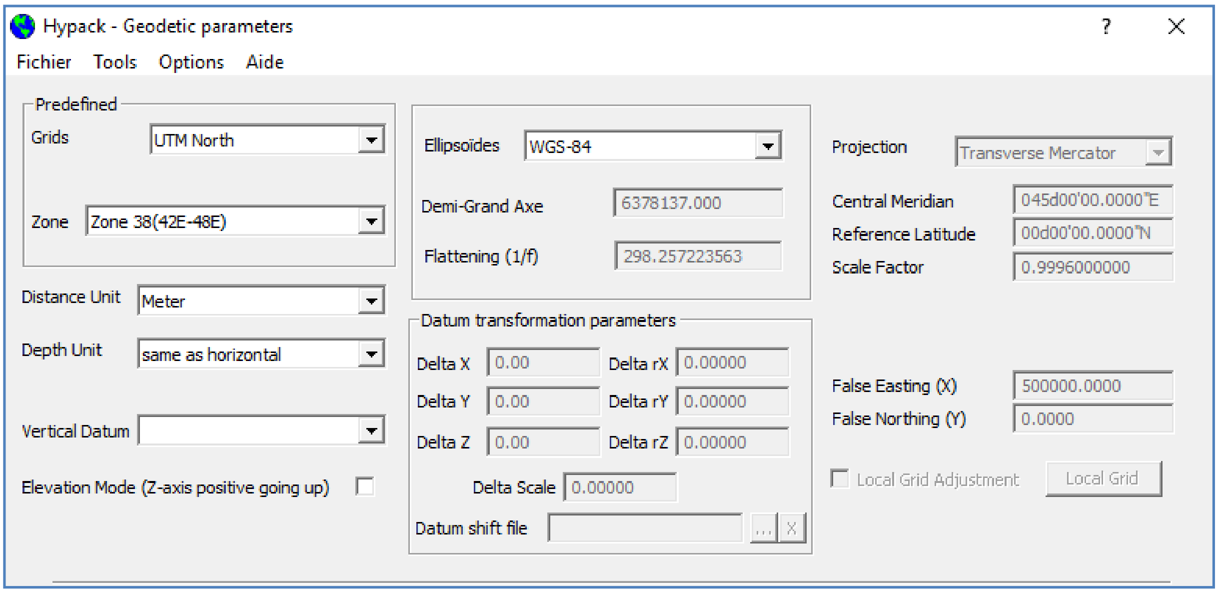


Figure 18 : Geodetic parameters in Hypack software

8.1.2 Vertical reference

The vertical reference is the Chart Datum (CD) used by the Hydrographic and Oceanographic Service of the French Navy (SHOM). The CD is approximately the level of the Lowest Astronomical Tide (LAT).

CD is 1.8m below the Mean Sea Level (MSL) in the area of Tadjourah Gulf (source from SHOM).

8.2 Offsets

On the boat, the GNSS antenna was fixed on the same pole and on the same axis as the echosounder. The reference center of positioning (X = 0, Y = 0 and Z = 0) was defined as the intersection of the pole with the water level (Table 5). The offsets were obtained using a 10m tape.

Offset Name	(X) [m]	(Y) [m]	(Z) [m]
Reference center	0.00	0.00	0.00
GNSS antenna	0.00	0.00	- 2.83
PA500	0.00	0.00	0.35

Table 2 : GNSS antenna and echosounder offsets

The same offets have been entered in the Hypack navigation software (figure 10).

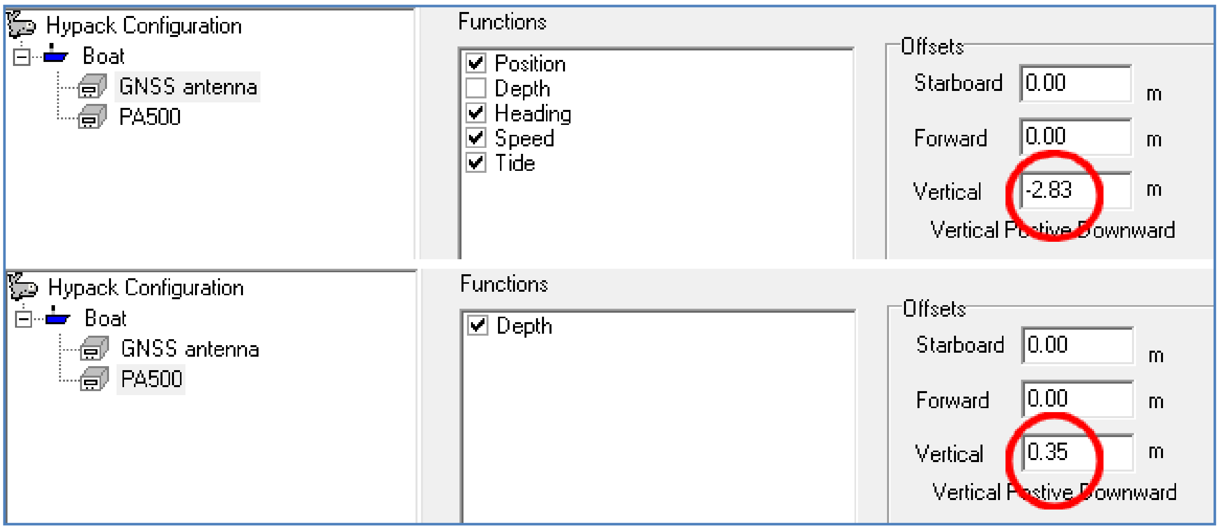


Figure 19 : Offsets in Hypack software

8.3 Survey areas

8.3.1 Djibouti port

The sector survey consits of an 184 800 m² area located in one of the oldest part of Djibouti port (figure 11).

Figure 2 : Survey area in Djibouti port

8.3.2 Tadjourah port

The sector survey consits of an 125 200 m² area located around Tadjourah port (figure 12).

Figure 3 : Survey area in Tadjourah port

8.4 Intended lines

8.4.1 Djibouti port

For this area, 27 N-S lines and 26 E-W lines with 20m spacing were intended (figure 13).

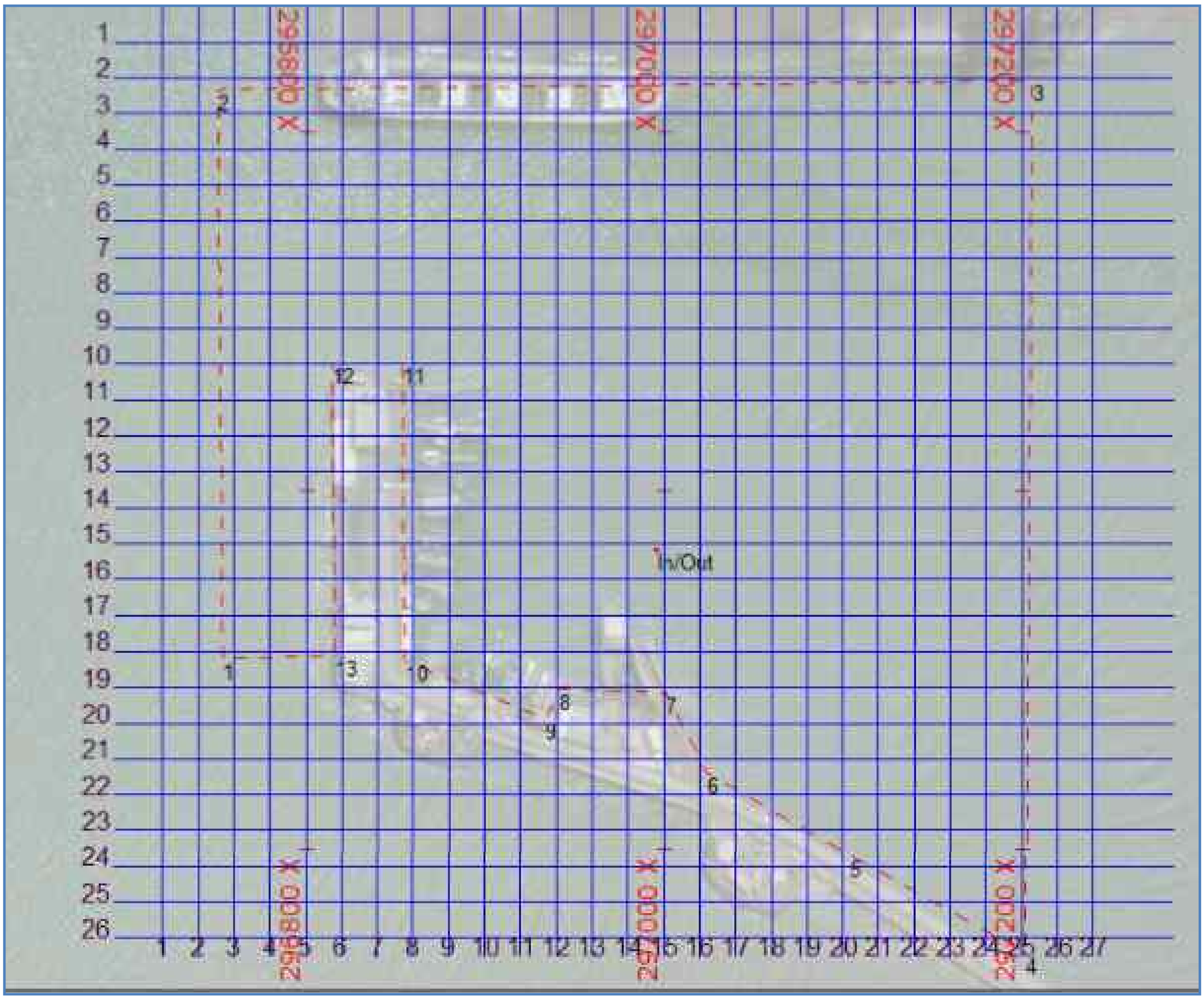


Figure 4 : Intended lines in Djibouti area

8.4.2 Tadjourah port

For this area, 23 NE-SW lines and 21NW-SE lines with 20m spacing were intended (figure 14).

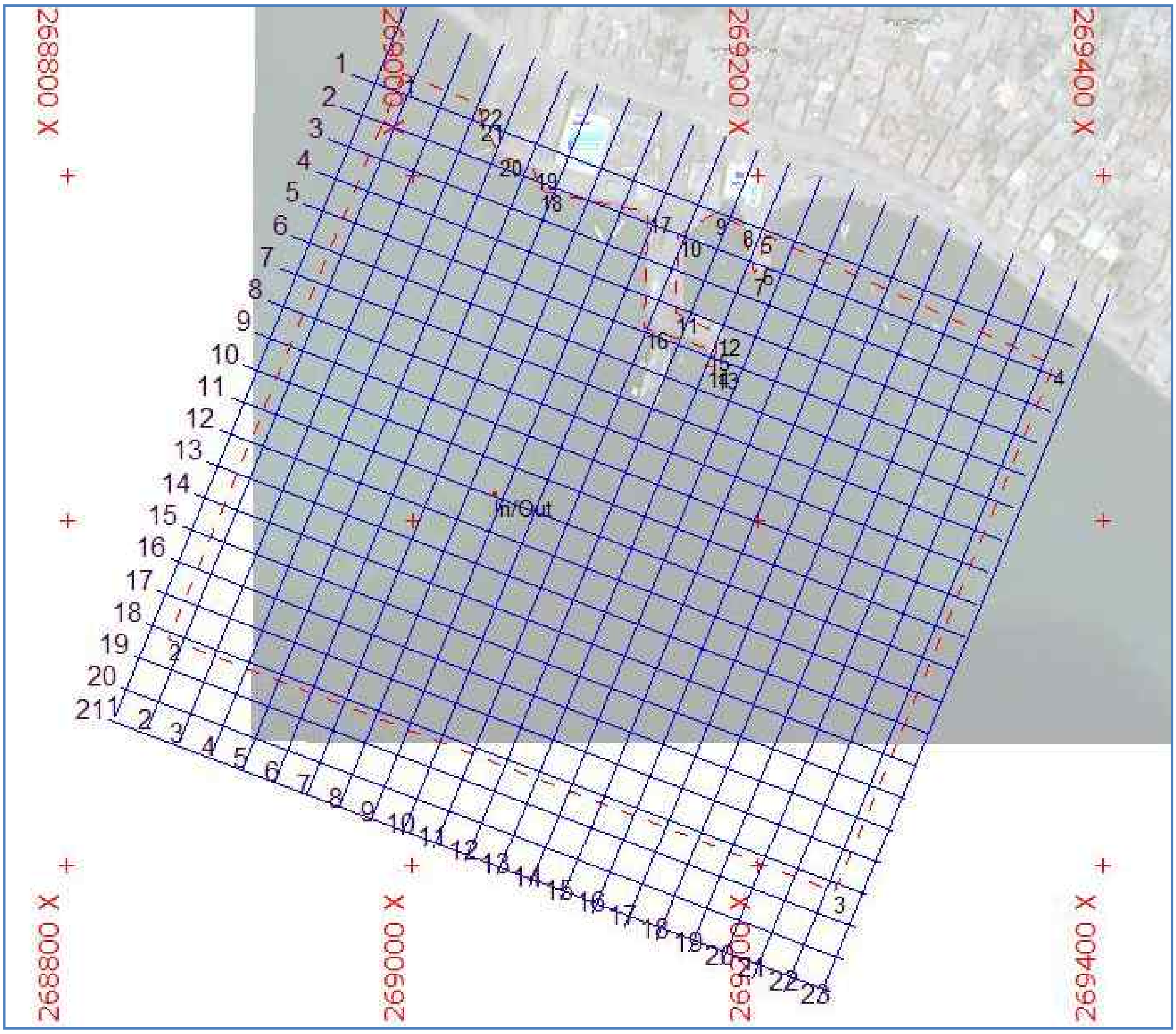


Figure 5 : Intended lines in Tadjourah area

8.5 Geodetic point for GNSS base station

8.5.1 Djibouti port

The geodetic base point of Djibouti (DJI 1) is issued from GNSS raw data recording during 6 hours and attached to aSHOM benchmark (Z) located nearby (figure 15).

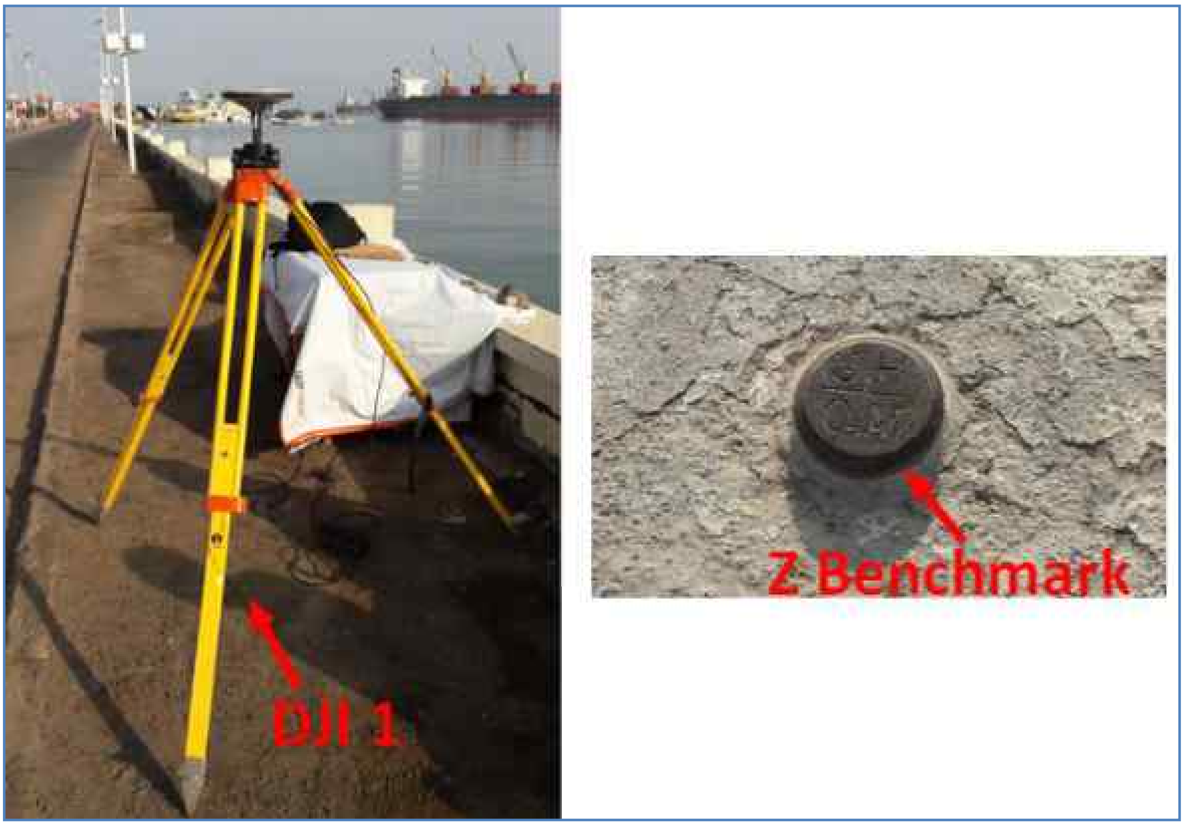


Figure 6 : Geodetic references in Djibouti area

The UTM coordinates and Z/CD of DJ1 and Z points are given in table 6.

Point Name	UTM coordinates		Z / CD (m)
	Easting (m)	Northing (m)	
DJI 1	297239.41	1282916.25	-3.56
Z (from SHOM)			-4.19

Table 3 : Benchmark points for Djibouti survey

8.5.2 Tadjourah port

The geodetic base point of Tadjourah (TAD1) is issued from SHOM GNSS raw data recording (figure 16).

Figure 7 : Geodetic references in Tadjourah area

The UTM coordinates and Z/CD of TAD 1 are given in table 7.

Point Name	UTM coordinates		Z / CD (m)
	Easting (m)	Northing (m)	
TAD 1	269171.38	1303499.25	-3.41

Table 4 : Benchmark point for Tadjourah survey

8.6 System verification

Calibrations and data quality checks were performed at the beginning and during the acquisition.

8.6.1 Control of positioning system

Several controls have been carried out to validate the positioning system on board:

- Control of geodetic parameters in Hypack,
- Control of the given position with respect to a background and a satellite image,
- Control of the reception of a fixed RTK positioning.
-

8.6.2 Echosounder calibration

A metal plate was used to calibrate the PA500. It was positioned directly below the sounder at the respective depths of 1m, 2m, 3m and 4m. This operation consists to check the accuracy of the values indicated by the sounder and determinate the speed of sound in the water. A velocity of 1545 m/s was calculated for the two areas

Figure 8 : Metal plate used for PA500 calibration

8.6.3 RTK tide verification

Controls of the tide calculted by Hypack software were realised for each days of survey in the two areas. The controls consist to compare the tide, measured with a 10m tape, between a reference point along the quay and the water level with the RTK tide in Hypack (figure 18).

Figure 9 : Reference points for tide verification

All the checks made gave differences of less than 3 cm. Comparisons of RTK tide with predicted tide from SHOM have given good results.

8.7 Real surveyed lines

8.7.1 Djibouti port

The real surveyed lines in Djibouti area represent a length of 29.6 km (figure 19).

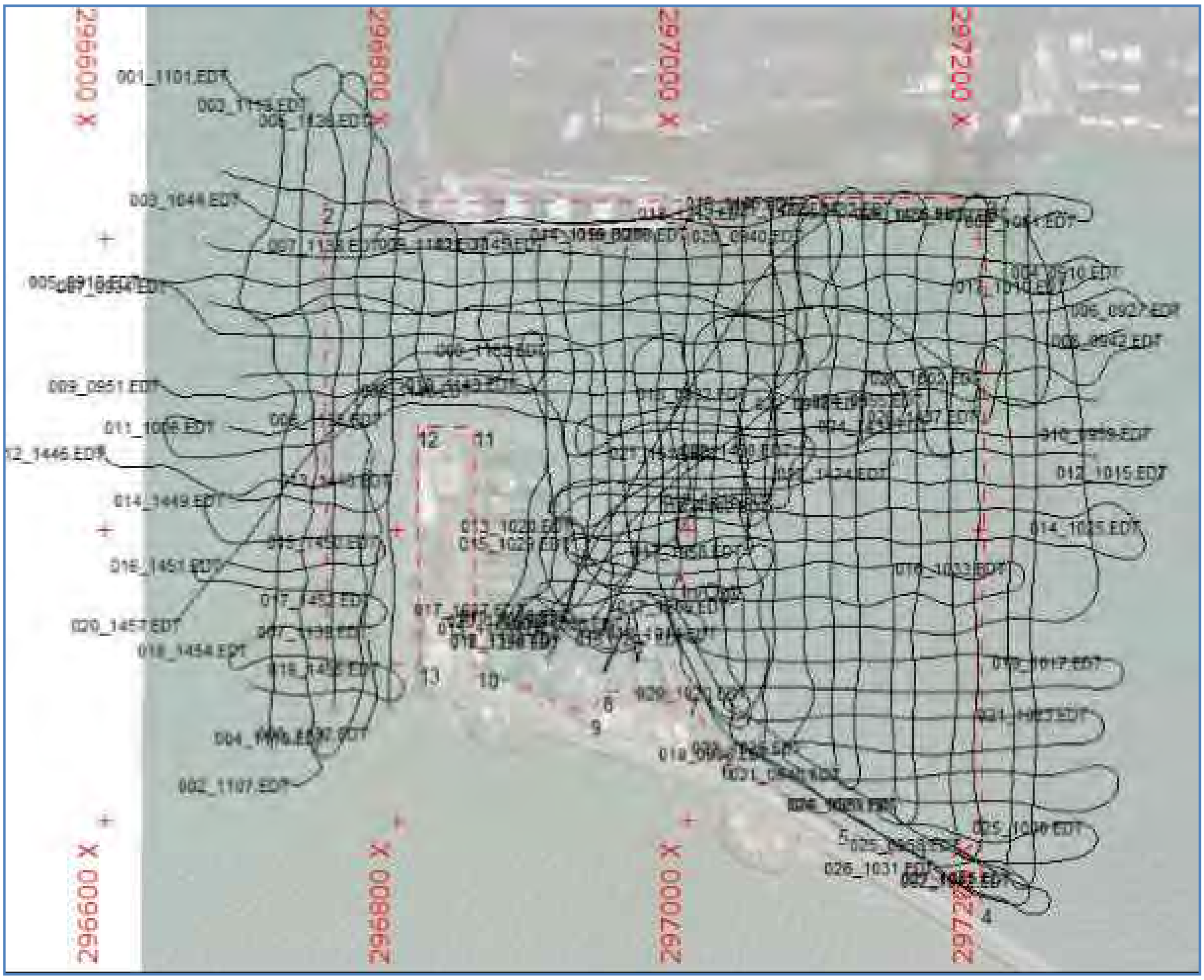


Figure 28 : Real surveyed lines in Djibouti area

8.7.2 Tadjourah port

The real surveyed lines in Tadjourah area represent a length of 22.5 km (figure 20).

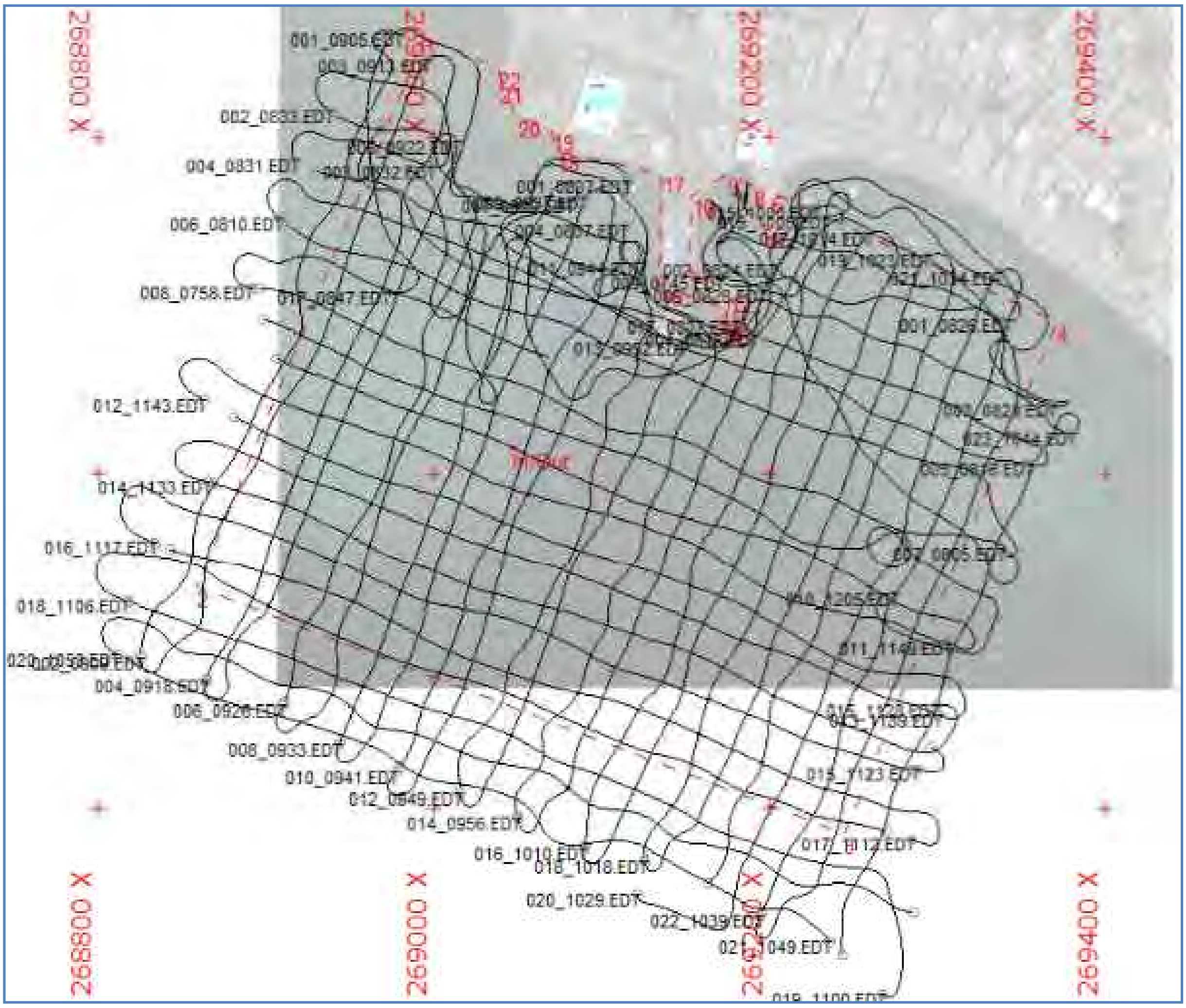


Figure 29: Real surveyed lines in Tadjourah area

8.8 Real surveyed lines

8.8.1 Djibouti port

The real surveyed lines in Djibouti area represent a length of 33.0 km (figure 20). N-S lines have run with 10m spacing and some E-W lines have been run two times with different SBP frequencies.

8.8.2 Tadjourah port

The real surveyed lines in Tadjourah area represent a length of 16.2 km (figure 21). Because of the steep slopes in the area, we chose to make the profiles parallel to the isobaths. Profiles perpendicular to the isobaths did not allow to follow the background correctly and adapt the SBP settings quickly enough.

Some lines have been run two times with different SBP frequencies.

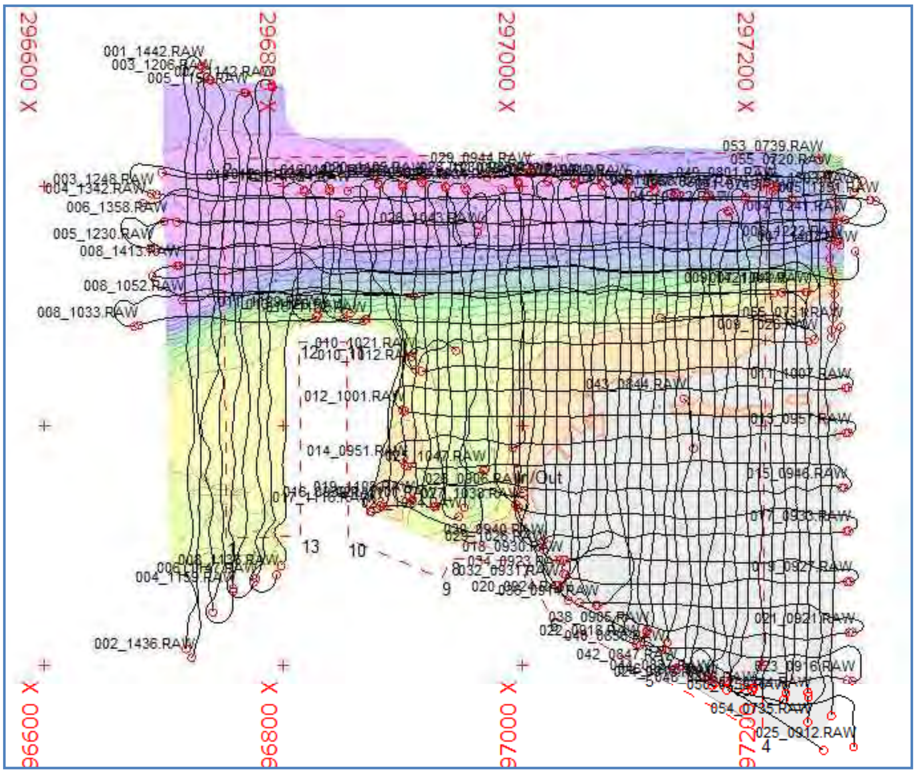


Figure 10 : Real SBP surveyed lines in Djibouti area

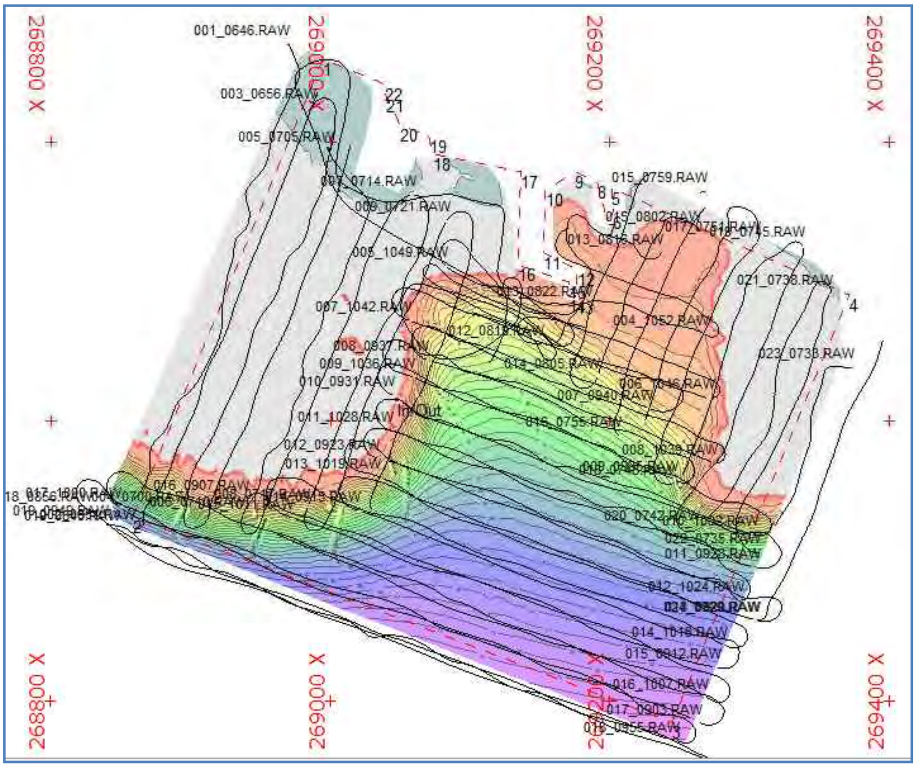


Figure 11 : Real SBP surveyed lines in Tadjourah area

9 DATA PROCESSING AND MAPPING

9.1 Data processing

All of the bathymetric lines produced were processed with the Hypack single-beameditor module.

The first step of the work is to remove all artifactsfrom the different lines (figures 21 and 22). These artifacts can be related to bad return of the sound wave due to air bubbles or waste in the water.

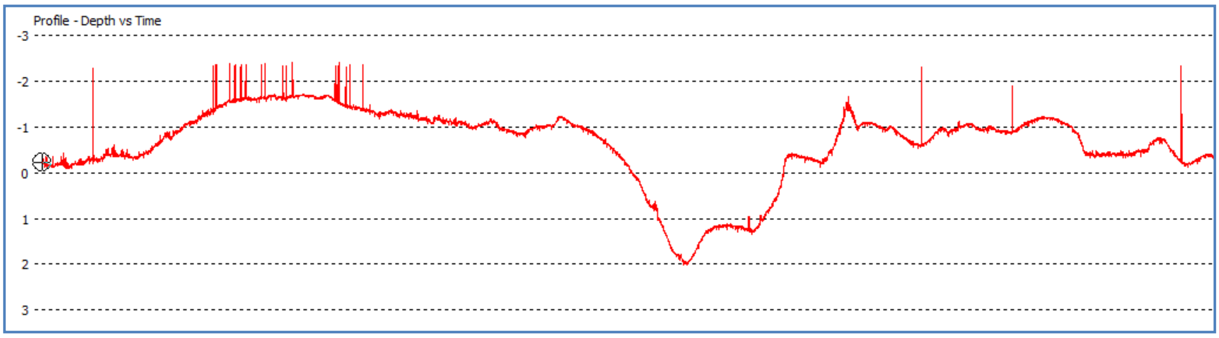


Figure 12 : Example of raw data with artifacts

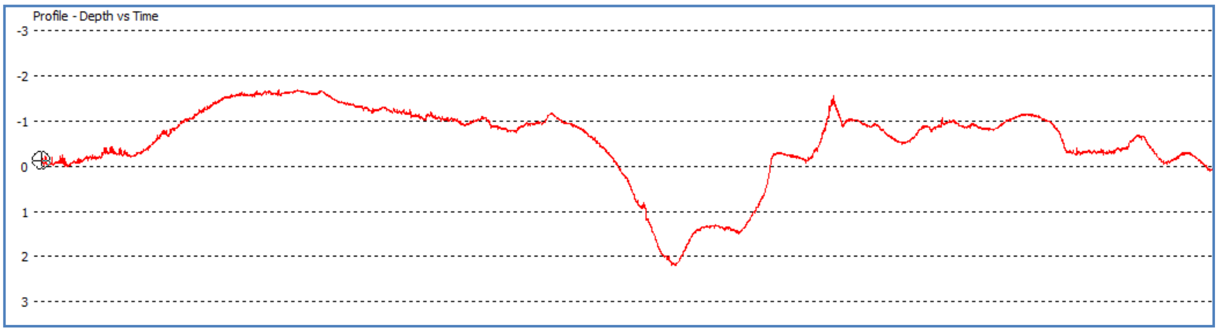


Figure 13 : Example of processed data

Once all the lines have been processed, we obtain a file of soundings corrected for artifacts, tidal variations and referenced with respect to the vertical datum used (figure 23). The soundings can be compared at the crossing points of the lines.

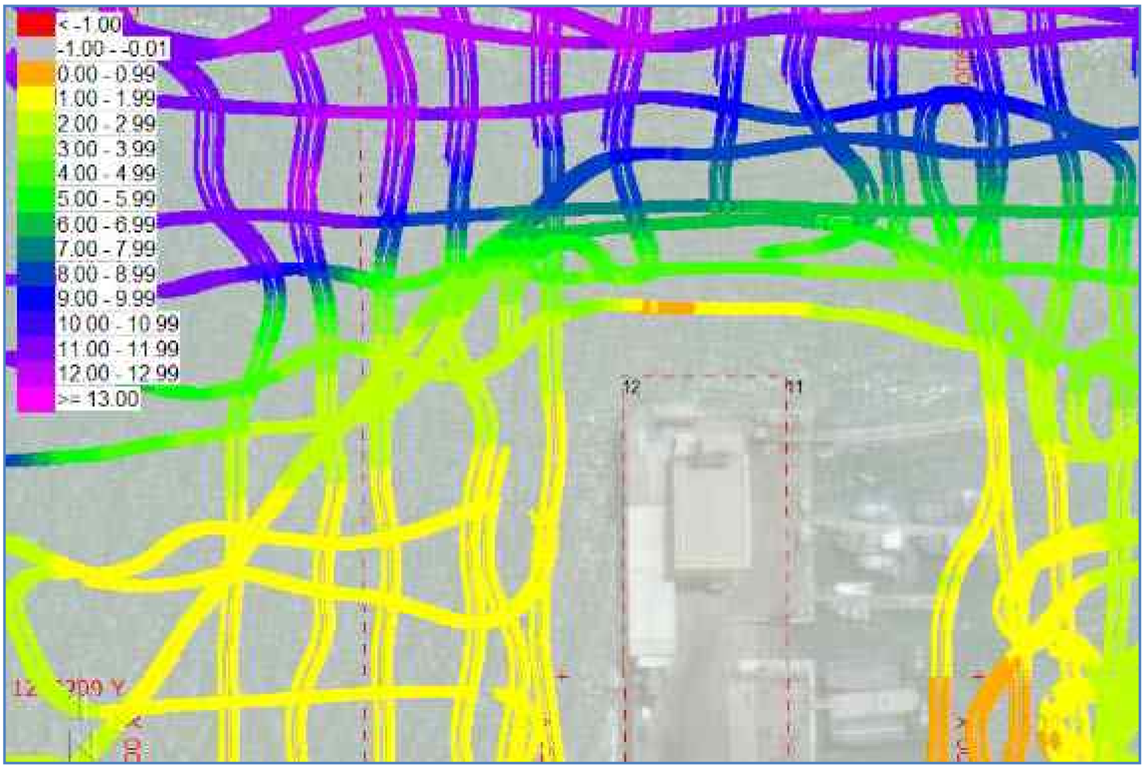


Figure 34 : Map with processed soundings

The second step is to make a choice of soundings and a digital elevation model in order to obtain a representative map of the area (figure 24).

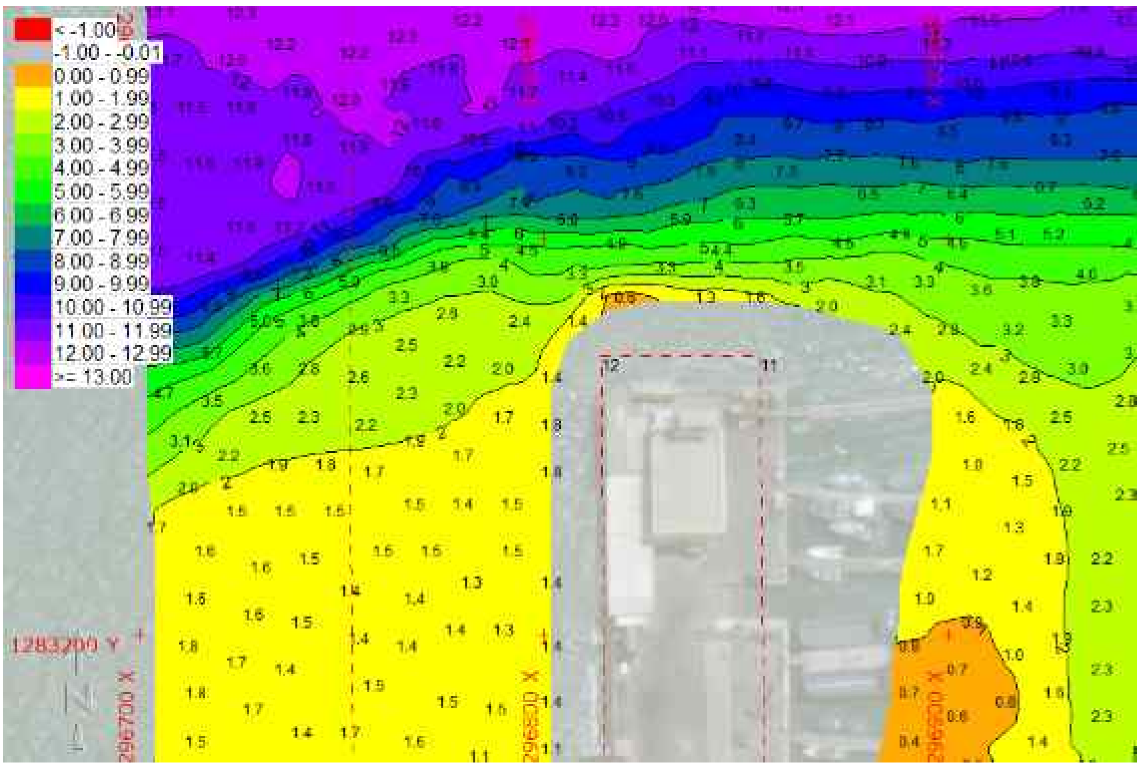


Figure 35 : Example of digital elevation model

The last step is to constitute exportable files to a software like AutoCad. The following data are exported in dxf, dwg and XYZ format:

- Border with UTM and WGS84 coordinate grid (in degrees-minutes-seconds),
- Color bar,
- Soundings,
- Isobaths,
- Color zones according to the depth.

9.2 Mapping

The bathymetric data of Djibouti and Tadjourah are presented on two maps in AutoCad format (see appendices B and C). The plans provided are printable on A1 size paper at a scale of 1/1 500.

Bathymetric survey renderings are also in the form of an ASCII file of soundings including E and N UTM positions and Z referenced to the chart datum.

9.2.1 Submarine morphology

The main features of morphology are (figure 22):

- a large areawith very shallow water (-1 to 1m CD) in the south-east part,
- a slope with depths between 2 and 11m CD,
- a dredged areawith depths between 11 and 13m CD in the northern part.

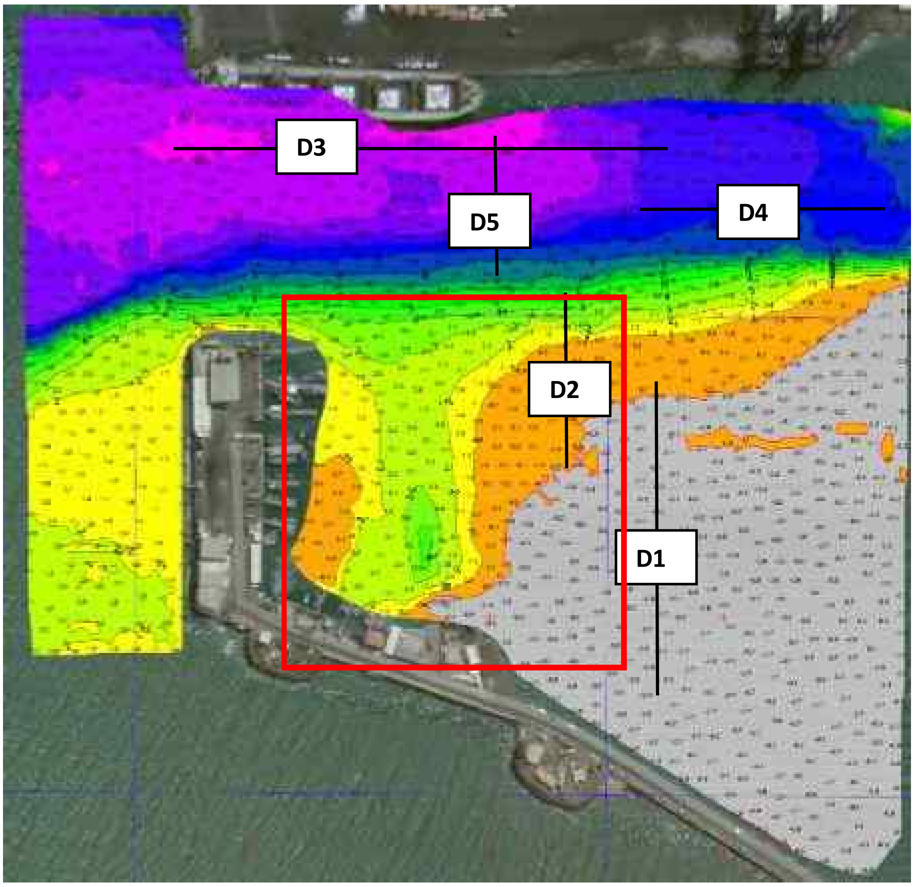


Figure 36 : Submarine morphology of Djibouti area

The lines and number lines (D1 to D5) make it possible to locate the profiles presented hereafter.

9.2.2 Examples of SBP lines

In the very shallow part, no reflector can be observed into the sediment (figure 23).

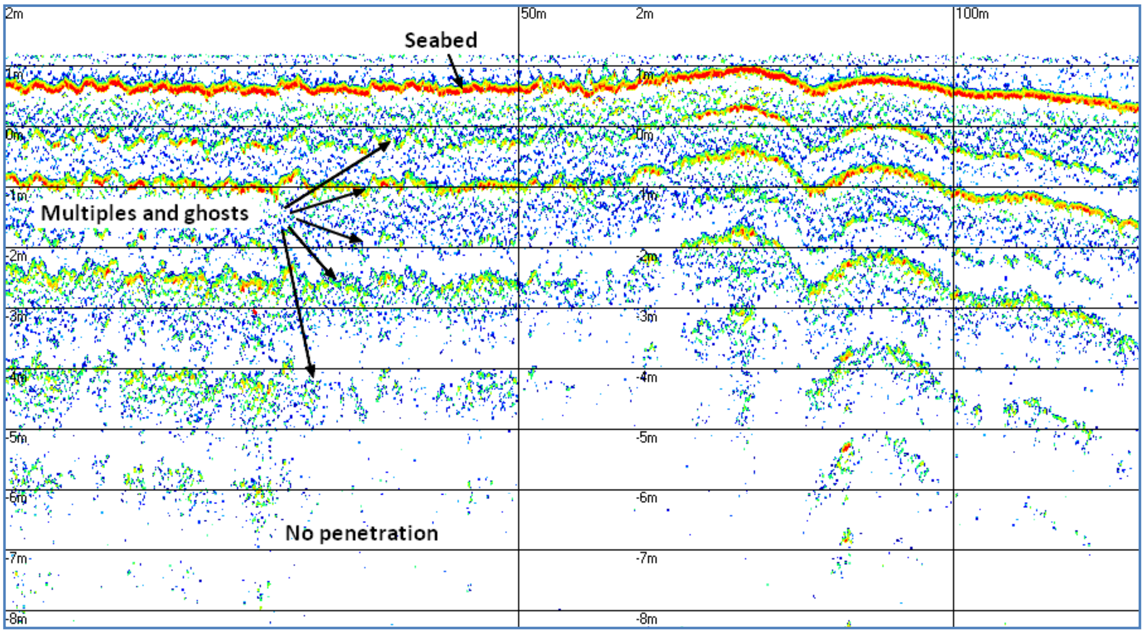


Figure 37 : Example of SBP record in very shallow water area (D1)

On the slope, between 1 and 8m CD, no reflector can be observed into the sediment (figure 24).

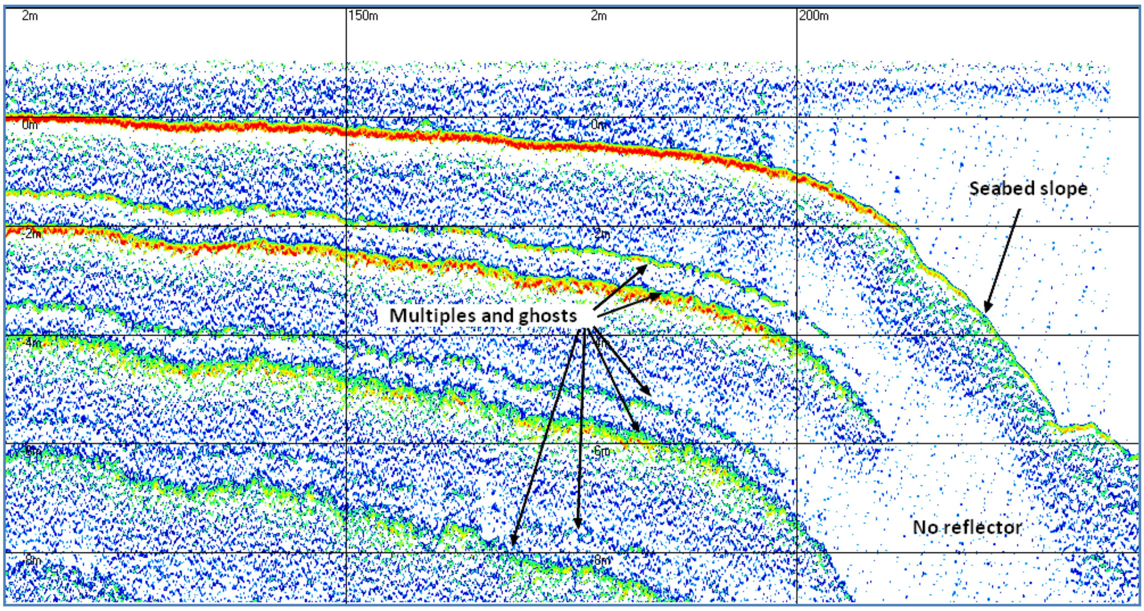


Figure 38 : Example of SBP record on the slope (D2)

In the West and central parts of the dredged area, the hard bottom is outcropping. The hard bottom could be probably coral ou volcanic rocks. On the figure 25, it is possible to observe the rock head under 2m of sediment.

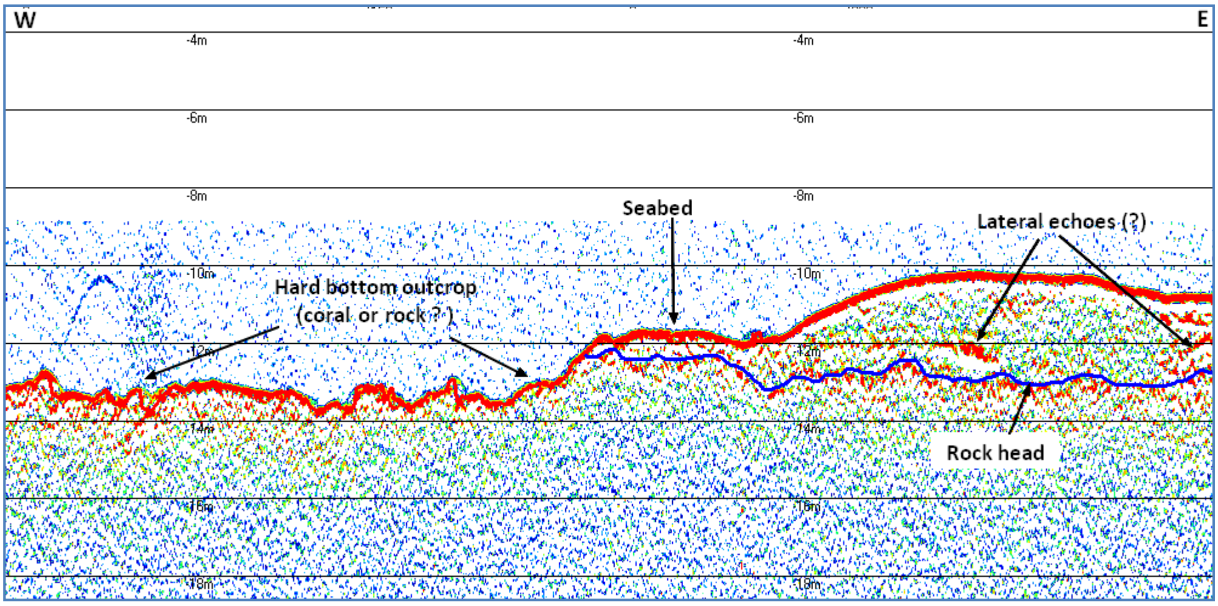


Figure 39 : Example of SBP record in the central part of the dredged area (D3)

In the East part of the dredged area, the hard bottom is under 5 to 6 m of sediment (figure 26). Some horizontal internal reflectors can be observed in the sediment.

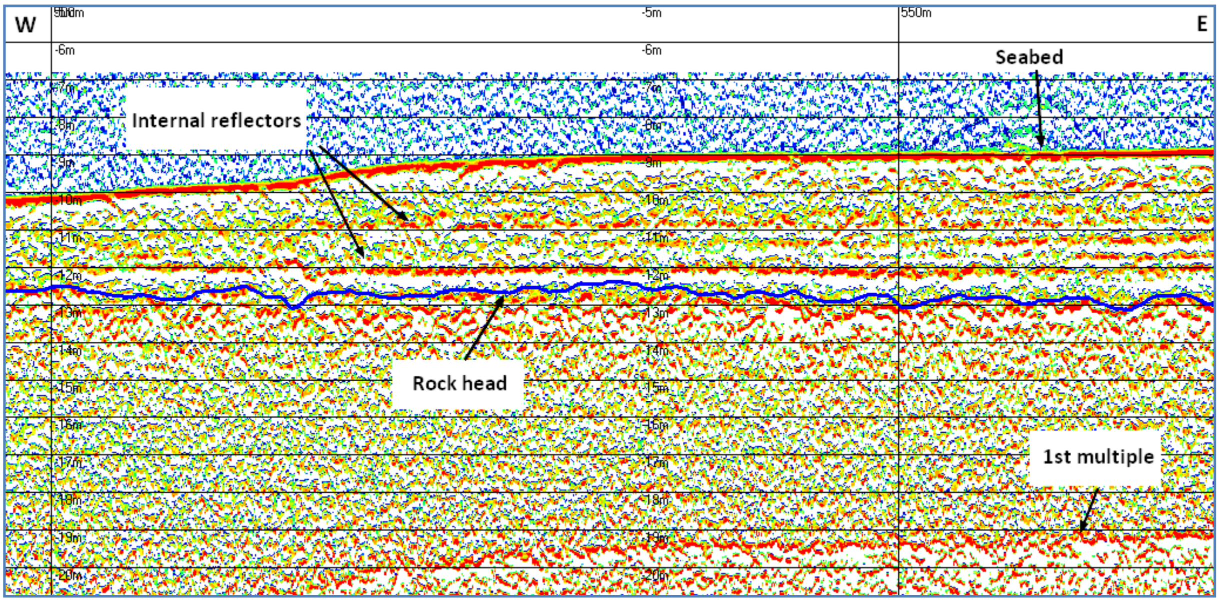


Figure 40 : Example of SBP record in the East part of the dredged area (D4)

The figure 27 shows a typical recording of sedimentation at the bottom slope (between 7 and 13m CD). The maximum sediment thickness observed is about 5 to 6m. The internal reflectors are usually discontinuous and slightly marked.

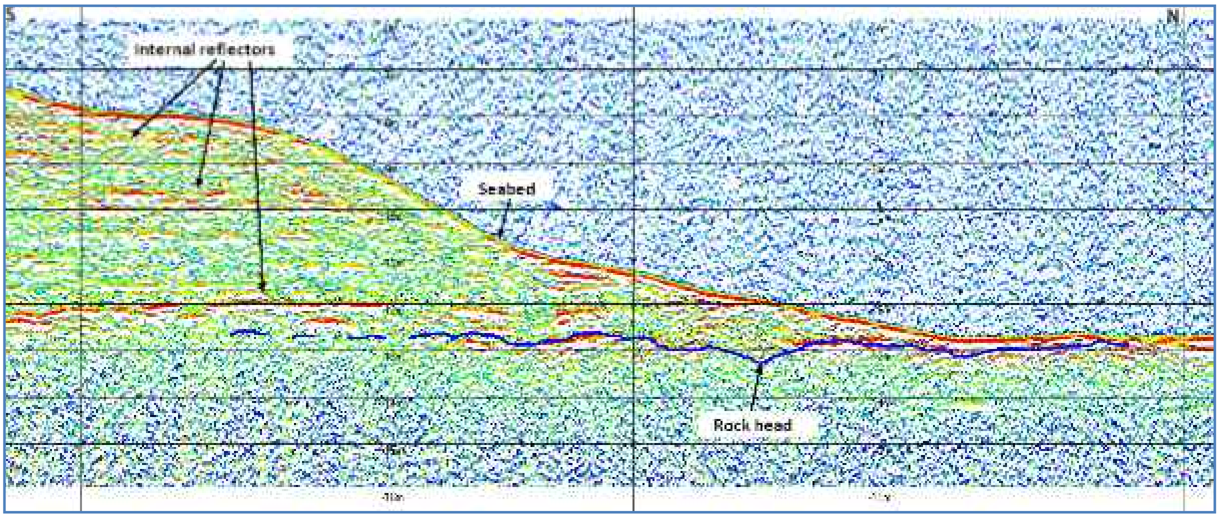


Figure 41 : Example of SBP record on the bottom slope (D5)

9.2.3 Conclusion for Djibouti area

In the very shallow area and on the slope until a depth of approximatelly 7 m, no reflector was detected (multiples problems, slope, sedimentary thickness too important). The observed sediment thickness is beetwen 1 and 3m in these areas.

<u>On all the SBP lines where the rock head is observed under the sediment, its depth is between 12 and 13m CD and its seems relatively horizontal</u>. In the surveyed area, the hard bottom is outcropping when the depth is more than 12.5m CD.

Without any coring and without knowing the nature of sediments and substratum, its difficult to do a detailed interpretation of the SBP lines. If we consider that the substratum head is relatively flat, the maximum sediment thickness could be 13 or 14m in the very shallow area (0 to -1m CD)

Most of the SBP lines completed in Djibouti are presented in Appendix A.

The estimated sediment thickness chart of Djibouti is presented on one map in AutoCad and PDF format (see appendix B). The plan provided is printable on A1 size paper at a scale of 1/1 500. An extract of these map is provided on figure 28.

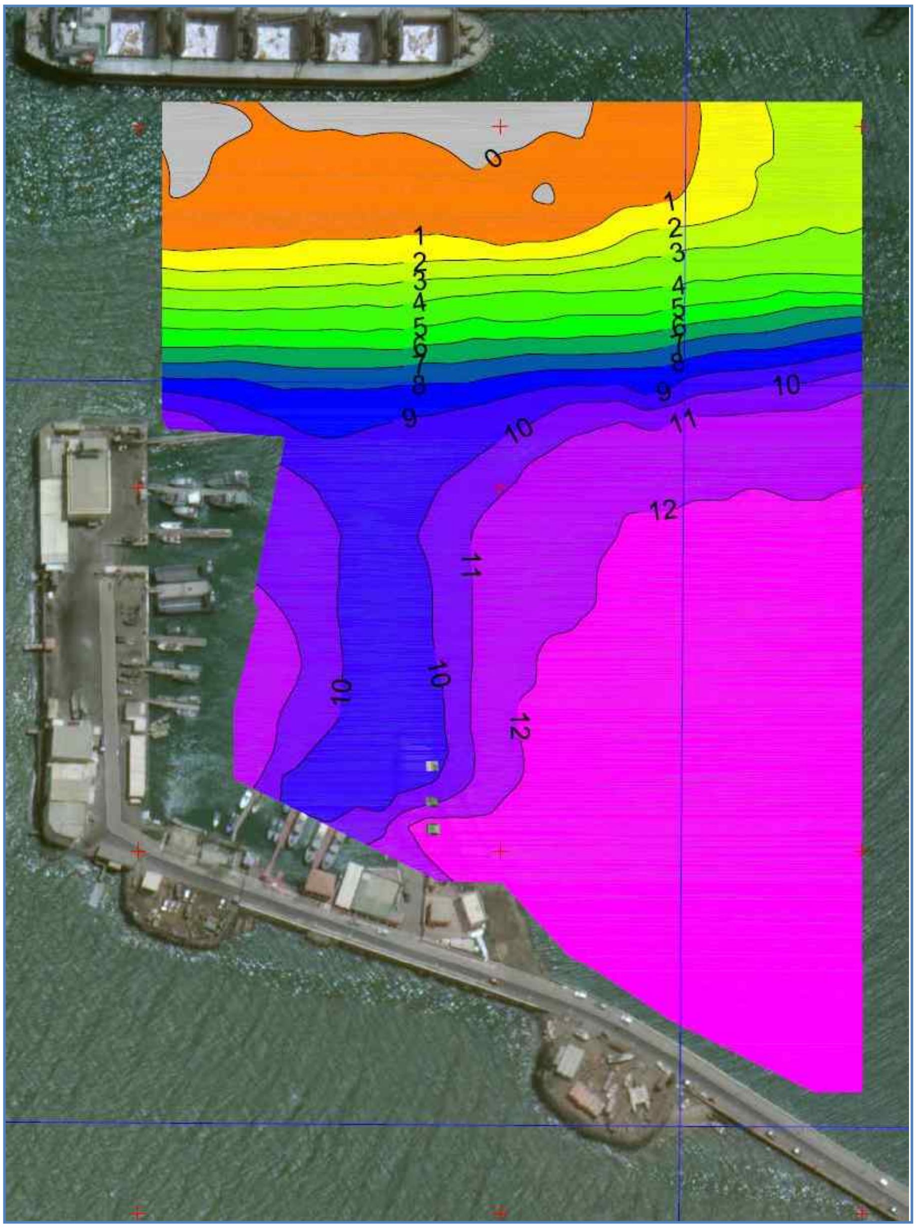


Figure 42 : Estimated sediment thickness in Djibouti area

9.2.4 Correlation Subottom Geotechnical

As a reminder, the sediment sounder (SBP), uses a higher frequency band than conventional seismic imaging systems so it is part of very high resolution seismic reflection systems. Its principle is based on the ability of low frequency acoustic waves to penetrate the sedimentary strata. Better than in seismic reflection, we know the transmitted signal (CHIRP), since it is generated by electro-acoustic transducers.

The acoustic wave, emitted from the boat, propagates in the water layer, then in the sediment. The succession of shots makes it possible to reconstruct the sedimentary horizons. We thus obtain a vertical section of the basement, the abscissa representing the advance of the boat, and the ordinate the depth of penetration. It should be noted that this depth is expressed in seconds, because the geo acoustic properties of the sediment (density and velocity) are, at this moment, still unknown.

Nevertheless, in order to get an idea of this depth, we appreciate in situ by successive iteration the speed of sound in the sediments (in this case, evaluated at 1600 m / s).

Traditionally, it is the same antenna that serves as transmitter and receiver. This acquisition configuration has two major advantages over seismic: zero offset (normal incidence reflection) and ease of implementation. In addition, the generation of the signal by electro-acoustic transducers makes it possible on the one hand to control the directivity, and on the other hand to perform a quality control in real time, since the signals received can be correlated to a replica of the signal. signal issued.

The rendering of this campaign, combined with that of bathymetry is appreciated via:

- y vertical sections of the basement of z ml on average
- and a cartography in relief of the indurated substratum starting from a gridding of a dive of the interface sediment / substratum indurated

Limitations of the method: In general, and because of the indirect nature of the geophysical method used, the results of the study are only a likely interpretation of the subsurface characteristics based on the data and / or parameters known at the time of the study and this within the limit of the method used.

Geotechnical :

In order to correlate geophysical horizons with sedimentary stratigraphy, in situ geotechnical investigations and laboratory tests were undertaken.

These investigations and tests consisted of:

- Site of Djibouti

  o An SPT survey (SC01bis) 33m deep,
  o A 10m deep SPT (SC02) survey,
  o An SPT (SC03) survey 21m deep,

Location of surveys, Djibouti site

- Site of Tadjourah

  o An SPT survey (BHT01) 21m deep,
  o An SPT survey (BHT01_modified) 12m deep,
  o An SPT survey (BHT02) 22.5m deep,

Location of boreholes, Tadjourah site

The SPT (Standard penetration test) is a dynamic solicitation of the soil at a specific depth where it is driven into the earth by the impacting energy of a dead weight. The number of impacts of a standard thickness of soil (30 cm) is called N. As a standard, the N value ranges from 0 to 50. The higher is the stiffer and the compact is the test soil. Above N = 50 the soil becomes too compact and the test is deemed completed at refusal.

The following table gives the relationship between N values and sands and clays evaluation.

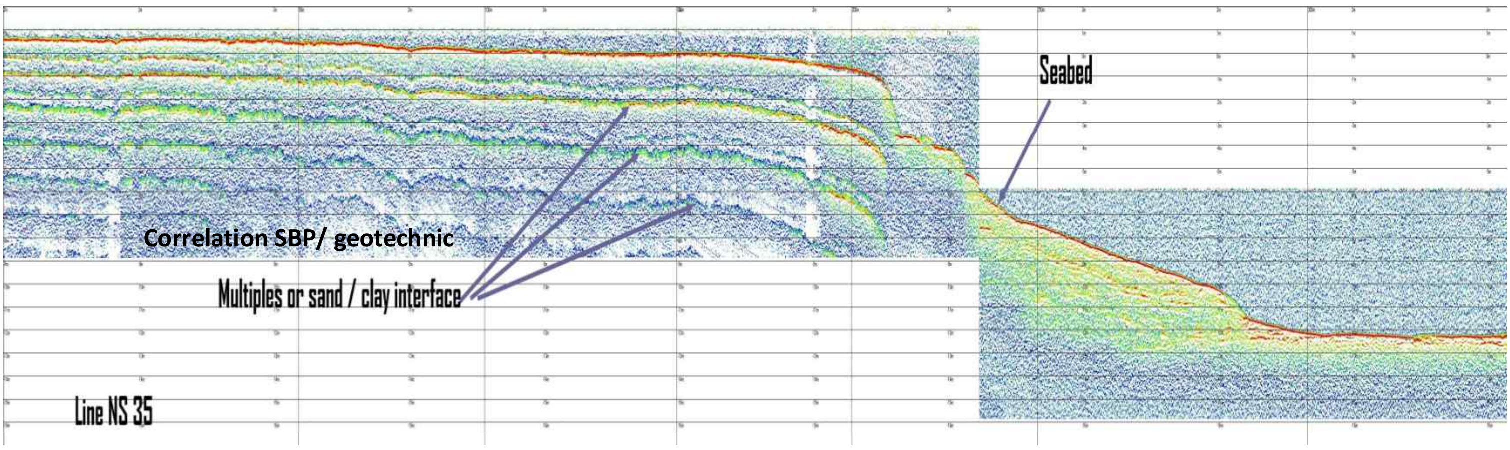
Sands (Fairly reliable)		Clays (Rather reliable)	
Number of blows per foot (30 m), N	Relative density	Number of blows per foot (30 cm), N	Consistency
		Below 2	Very soft
0-4	Very loose	2-4	Soft
4-10	Loose	4-8	Medium
10-30	Medium	8-15	Stiff
30-50	Dense	15-30	Very stiff
Over 50	Very dense	Over 30	Hard

The purpose of the SPT surveys is to qualify and define the compactness of the sedimentary horizons, but also, if necessary, to identify the depth of the indurated substratum.

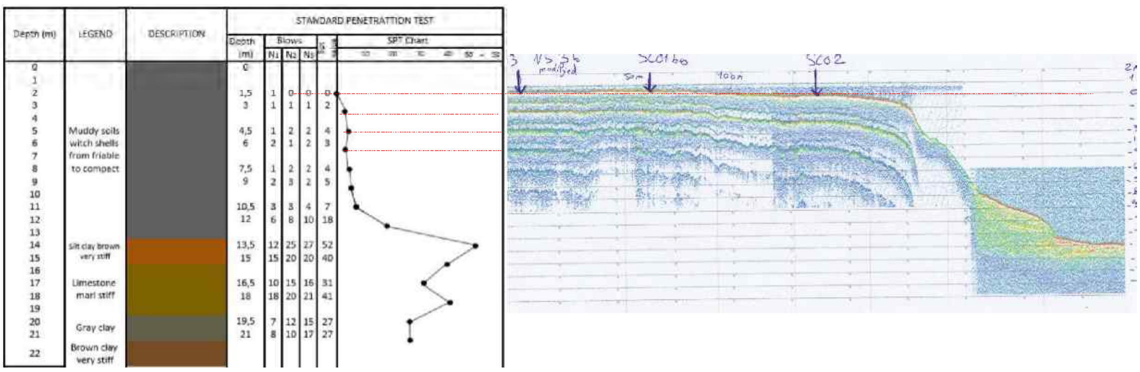
Results – Djibouti :

Subottom (SBP):

The treatment and the interpretation of the profiles made it possible to distinguish either a subparallel sedimentary structure at the bottom delimiting a sand / clay alternation or multiples. Further offshore, the propagation of acoustic waves is very diffuse and very limited in depth.



- **SPT (SC03) 21m deep with NS36,**

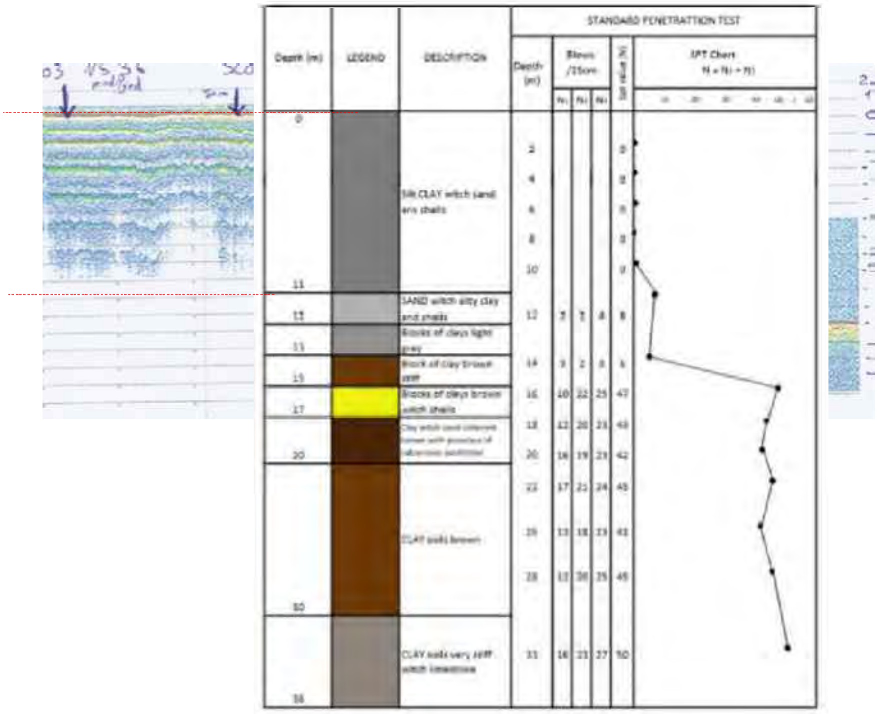


Given the very low compactness (N <5) of the clay / sand alternation, the acoustic waves have a very low investigation depth.

Visible reflectors from 0 to 6 m are either "multiples" or to be related to the aforementioned lithological alternation.

The indurated substrate was not detected on this profile via SBP. The indurated clays identified from 13.5m depth could be the alteration product of the underlying bedrock (limestone reef?).

- SPT (SC01bis) 36m deep with NS36,

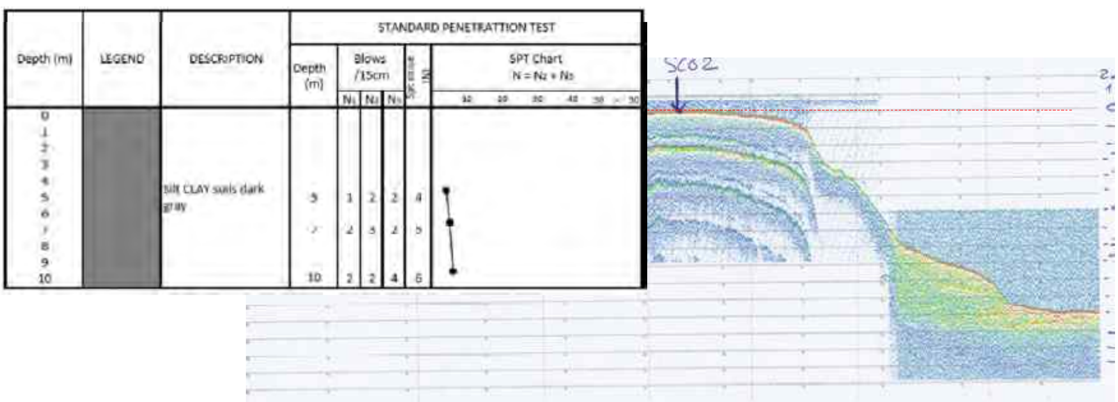


Given the very low compactness (N close to 0) of the clay / sand alternation, the acoustic waves have a very low depth of investigation.

Visible reflectors of 0 to 4 m are either "multiples" or to be related to the aforementioned lithological alternation.

The indurated substrate was not detected on this profile via SBP. Indurated clays spotted from 14m depth could be the alteration product of the underlying bedrock (limestone reef?).

- -**SPT (SC02) 10m deep with NS36,**



Given the very low compactness (no holding over the first five meters) of the clay / sand alternation, the acoustic waves have a very low depth of investigation.
Visible reflectors of 0 to 4 m are either "multiples" or to be related to the aforementioned lithological alternation.
The indurated substrate was not detected on this profile via SBP. The SPT was stopped at 10 m depth.

9.3 Tadjourah area

9.3.1 Submarine morphology

The main features of morphology are (figure 28):

- Two lateral areaswith very shallow water (-1 to 0m CD),
- a slope with depths between 0 and 38m CD,

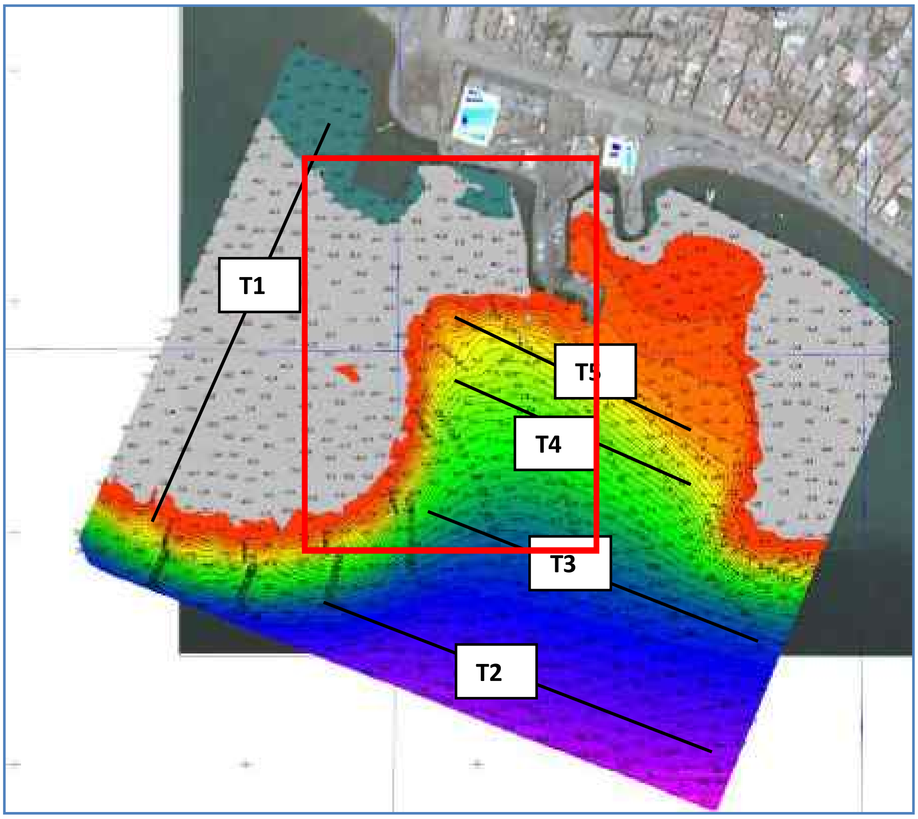


Figure 43 : Submarine morphology of Tadjourah area

The lines and number lines (T1 to T5) make it possible to locate the profiles presented hereafter

9.3.2 Examples of SBP lines

In the very shallow parts, the sea bottom is hard principally (figure 29).

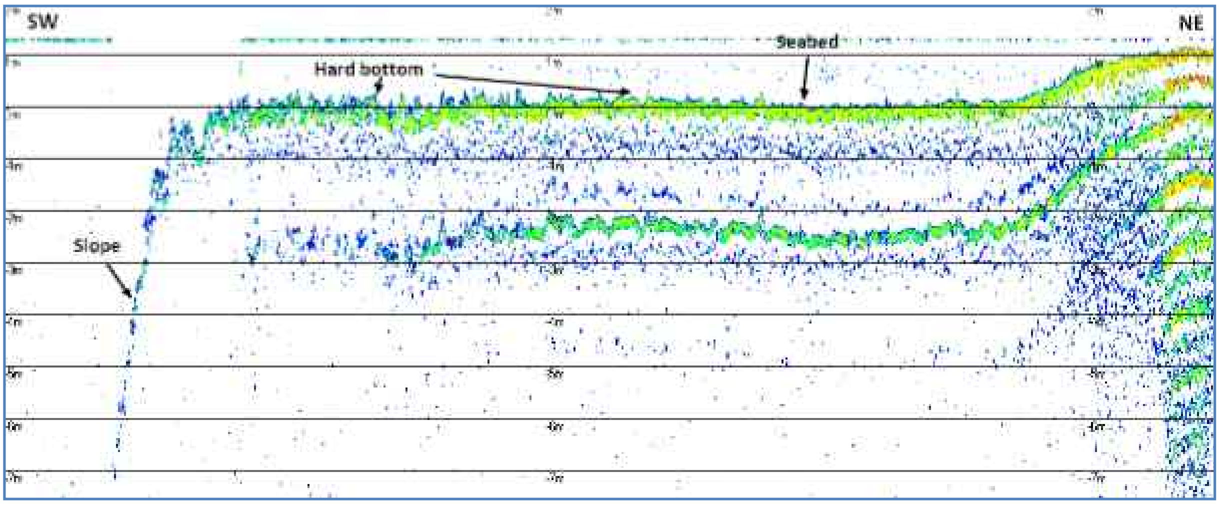


Figure 44 : Example of SBP record in very shallow water area (T1)

The seabed is composed of coral (A), coral with sediment (B), rocky blocks (C) and sand in the shallow part (D) (figure 30).

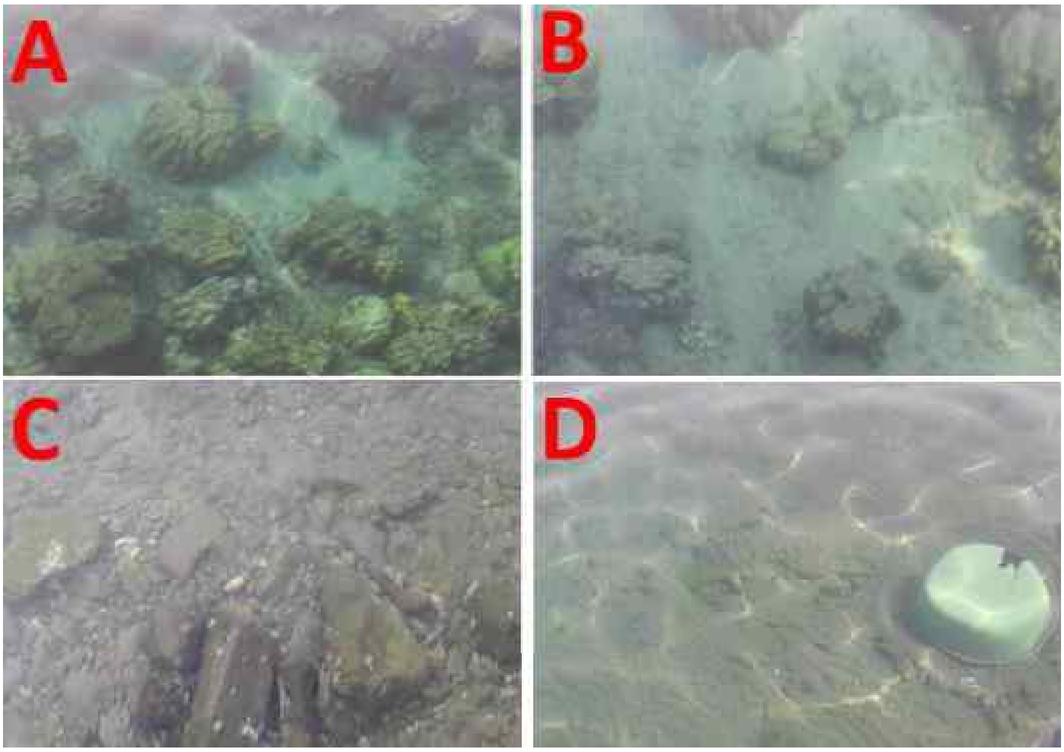


Figure 45 : Nature of seabed the shallow water area

At 32m CD, the maximum sediment thickness is about 6 to 7 m (figure 31). On the slope, there is probably no sediment (coral). The rock head depth is irregular. Some internal reflectors are visible.

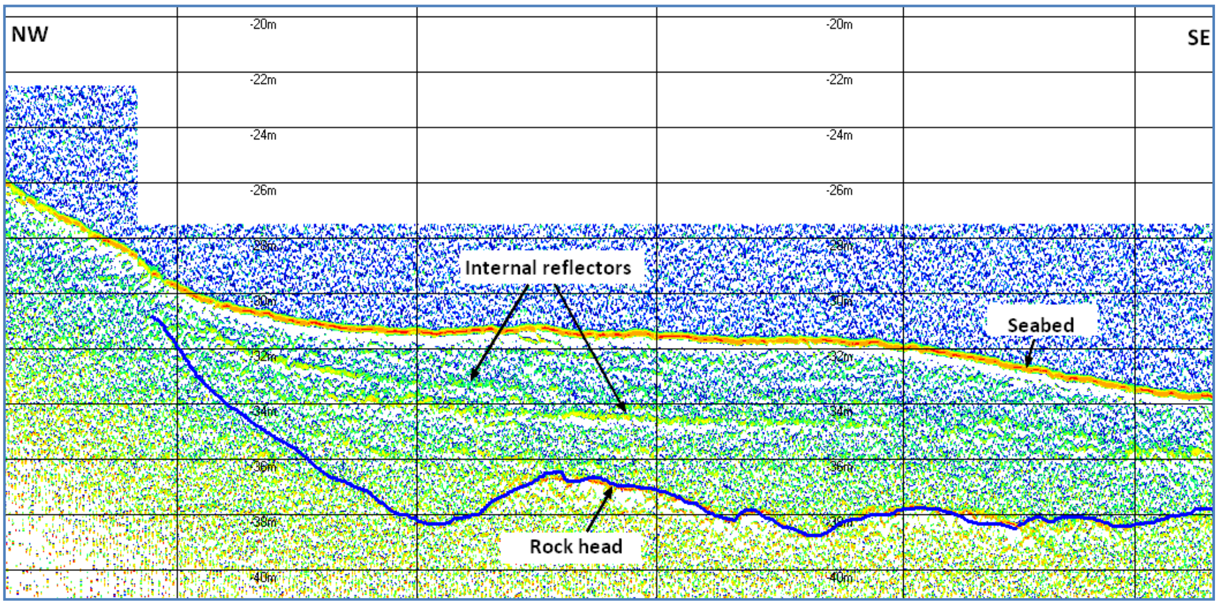


Figure 46 : Example of SBP record at 32m CD (T2)

At 25m CD, the sediment thickness is between 1 and 4 m (figure 32). The rock head depth is irregular and there is no internal reflector.

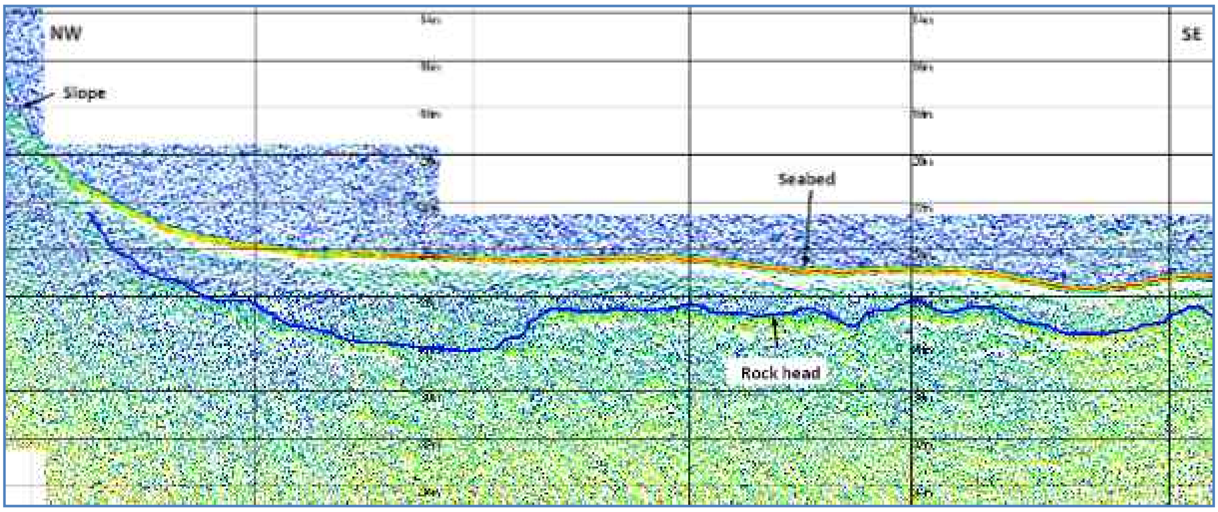


Figure47: Example of SBP record at 25m CD (T3)

Between 14 and 15m CD, the sediment thickness is at most 2m (figure 33).

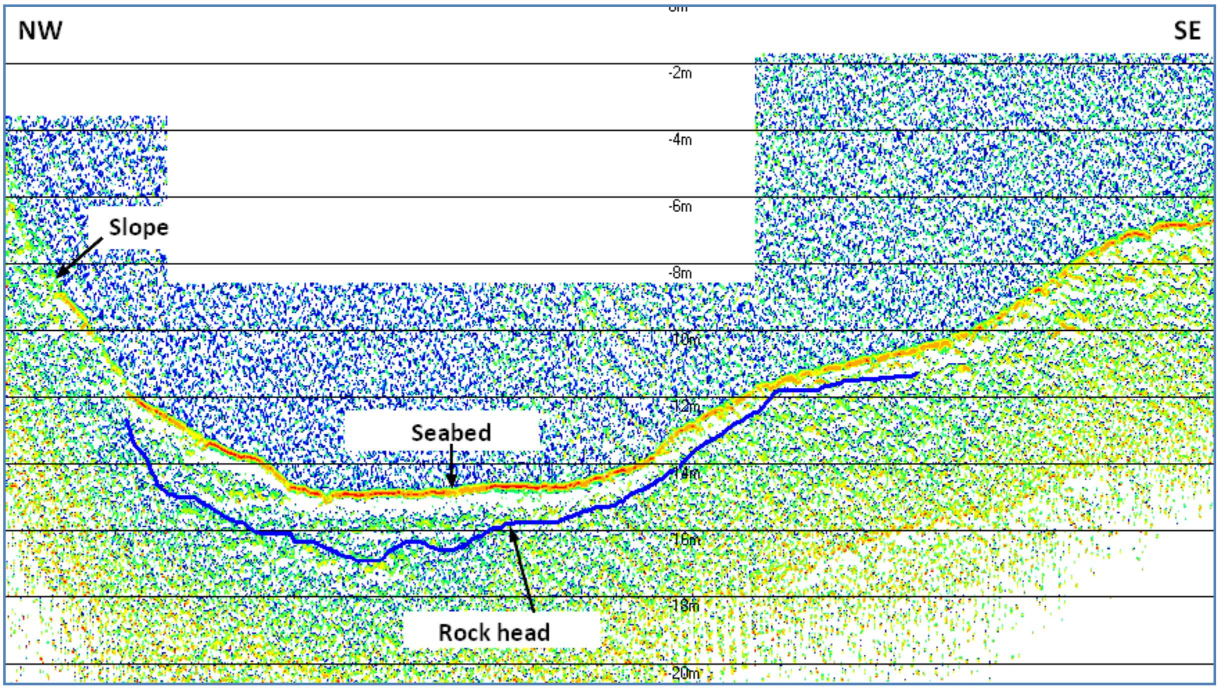


Figure 48 : Example of SBP record at 14m CD (T4)

In the dolphins area, the rock head is not well identified (figure 34). There is probably no sediment or just a few centimeters or decimetres.

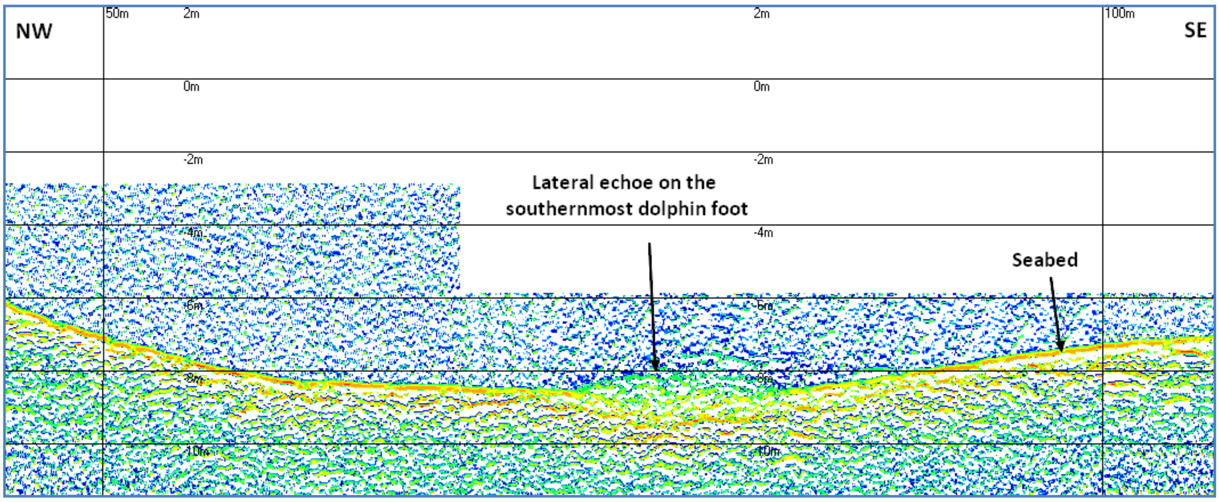


Figure 48: Example of SBP record in the dolphin area (T5)

9.3.3 Conclusion for Tadjourah area

The surveyed area of Tadjourah presents the following characteristics:

- two lateral parts with no sediment without the exception of the beaches. The sea bottom is constituted of coral and rock,
- slopes with coral and rock,
- a central part with lower slopes and an increase of sedimentary thickness from the coast to the open sea (thickness from 0 to 6 or 7m).

Most of the SBP lines completed in Tadjourah are presented in appendix C.

The estimated sediment thickness chart of Tadjourah is presented on one map in AutoCad and PDF format (see appendix D). The plan provided is printable on A1 size paper at a scale of 1/1 500. An extract of these map is provided on figure 36.

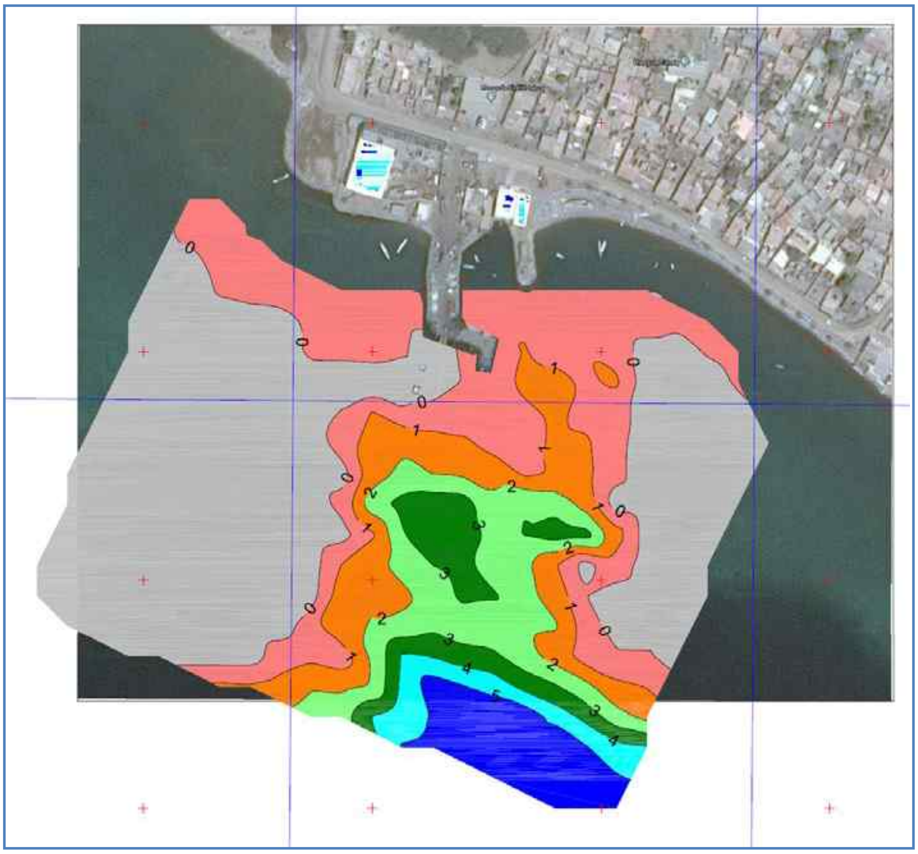


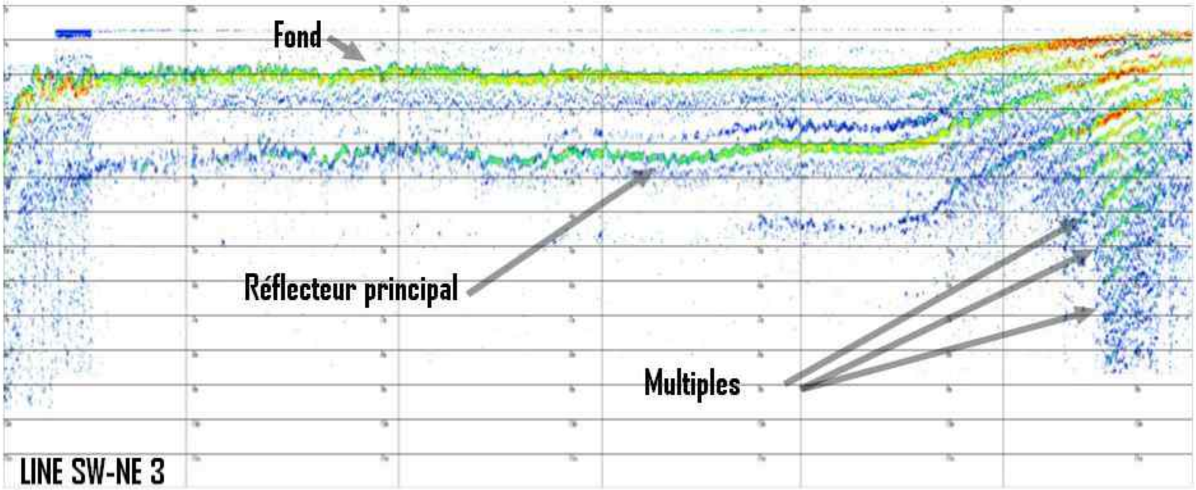
Figure 49: Estimated sediment thickness in Tadjourah area

9.3.4 Correlation Sub Bottom (SBP) geotechnical:

The treatment and the interpretation of the profiles made it possible to distinguish a single significant reflector, potentially corresponding to a subparallel sedimentary structure at the bottom delimiting a thickness layer between 0.5 m and 2.50m,

This configuration has been observed on the profiles:
- LINE SW-NE 3 - 4 - 5 - 6 - 8 - 9 - 13 - 14 - 15 - 16 - 17 - 18 - 19 - 20
- LINE NW-SE 18 - 12

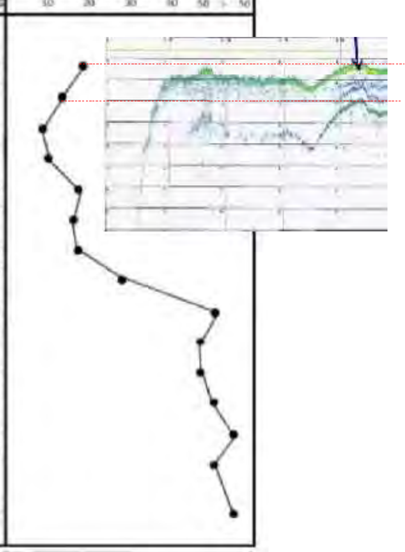
There is also a series of multiples.



The depth of investigation of the acoustic waves is in this case very small, so that the interpretation is limited to the first three meters of depth according to the profiles.

- SPT (BHT02) 22.5m deep with NS8,

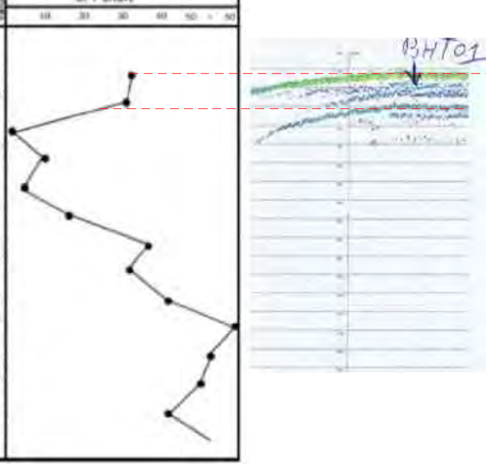
Depth (m)	LEGEND	DESCRIPTION	Depth (m)	N1	N2	N3	SPT value
0			0				
1							
2			1,5	3	7	12	19
3	Muddy soils		3	6	6	8	14
4	witch shells						
5	from friable		4,5	5	4	5	9
6	to compact		6	3	4	6	10
7							
8			7,5	7	9	9	18
9			9	9	8	8	16
10							
11	Silt clay		10,5	9	9	9	18
12	brown stiff		12	10	13	15	28
13							
14			13,5	17	24	26	50
15			15	14	26	21	47
16							
17			16,5	17	18	29	47
18			18	16	27	24	51
19	Brown clay very						
20	stiff		19,5	20	28	29	57
21			21	18	26	24	50
22							
23			22,5	20	27	28	55



Apparently, the reflector highlighted via the SBP correlates with a weakly structured and low compact sediment interface.
The indurated substrate was not detected on this profile via SBP. Indurated clays spotted from 12m depth could be the alteration product of the underlying bedrock (limestone reef?).

- SPT (BHT01) 21m of depht with NE09,

Depth (m)	LEGEND	DESCRIPTION	Depth (m)	N1	N2	N3	SPT value
0			0				
1							
2	Backfilling		1,5	10	17	20	37
3			3	9	15	21	36
4							
5			4,5	1	0	1	1
6	fine sandy		6	5	5	5	10
7	soils						
8			7,5	2	3	2	5
9			9	9	9	7	16
10							
11	Muddy soils		10,5	12	18	19	37
12	witch		12	8	14	18	32
13	presence of						
14	gravel		13,5	18	20	27	47
15			15	20	35	41	76
16							
17			16,5	18	30	24	54
18	Fragments of		18	28	18	32	50
19	natural stones						
20			19,5	24	19	23	42
21			21	18	25	27	52



The reflector highlighted via the SBP correlates with an indurated surface sediment / sandy layer sedimentary interface underlying.
The indurated substrate was not detected on this profile via SBP. From 15m, there is a very compact layer whose lithological nature suggests the near presence of the indurated bedrock.

The survey results by subottom did not fund any obstacle, such as sunken ships, etc., under the seabed.

10. Topographic survey

Two topographic surveys with a Nikon 5C total station, made it possible to lift the details of the two ports (buildings, land water limit, etc.). About 1.2 ha for Tadjourah and less than one hectare for Djibouti.

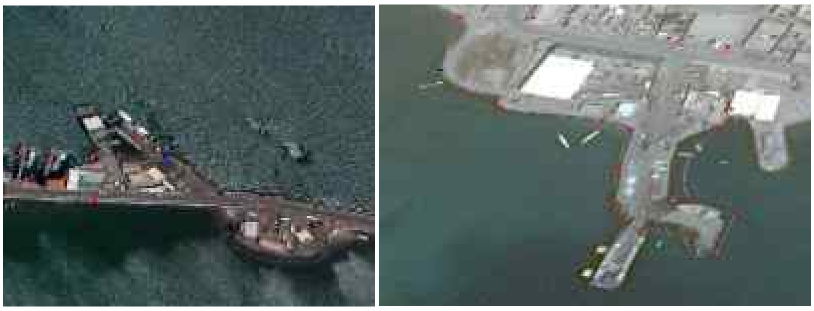


Figure 50 Topographic survey DjiboutiTopographic survey Tadjourah

DJIBOUTI	X	Y	orthometric altitude (m)	Cote/Zero Hydrographique (m)
D1	297239,408	1282916,246	2,107	-3,559
D3	297223,328	1282915,157	2,131	-3,583

Benchmark Djibouti

TADJOURAH	X	Y	orthometric altitude (m)	Cote/Zero Hydrographique (m)
Benchmark SHOM	269171,376	1303499,252	0,617	-3,414
T3	269155,175	1303510,629	0,722	-3,519

Benchmark Tadjourah

10 APPENDIX

10.1 Appendix A – Product Test Record

Tritech	Product Test Record Altimeter	Form No.	Page	Rev.
		0286-STF-00001	1 of 1	5

Part Number -	S02125 232
Serial Number -	314990
Model -	PA500/6 Altimeter S/S 4000m (Tritech)

Configuration Details

Frequency / Range (Serial)		COMMS MAIN	ANALOGUE OUT
500KHz 6deg/0.3-50m		RS232	None
Material/Depth Rating/Txducer Angle		Power	ANA Scaling
Stainless Steel/4000m/Straight		10.5-21VDC	None
Operational Outputs		SW Config	Software
Free Run ASCII		2P3 FR ZNE	V900
Zero No Echo (ZNE)		Data Format	Speed of Sound
RS485 Termination -	N/A	9600,1,8,1	1473m/s

Build Details

ITEM	Part No.	Ser. No	Rev.	Mod.
XDCR Moulding	S02459	21280-2	A	
XDCR Endcap	S02394	28521-12	C	
Body Tube	S01969	28248-36	C	
Connector Endcap	S02113	28426-33	C	
Waterblock	S00987	N/A	A	
CPU PCB	S02218	8180195	F	A
SON PCB	S08488 500	3180343	G	A
COMMS PCB	S02216	14180162	F	A
INP PCB	S10944	10180295	J	

Testing Details

TEST	Date	Tested By	Details	
Calibration	03 August 2018	JB	Voltage levels set to +/-0.2V or 1dB	
Pressure Test	06 August 2018	JB	Pressure -	6000psi
24Hr Soak Test	06 August 2018	JB		
Chassis Voltage	07 August 2018	SM	Result (mV) -	3.4
Final Inspection	07 August 2018	SM		
S05897 ONLY XDCR check	N/A	N/A	See 0286-ETP-00020	

Pinouts

Pin 1	RS232 Tx	Pin 2	RS232 Rx	Pin 3	+VDC
Pin 4	0VDC	Pin 5	N/C	Pin 6	Case

Notes

Equipment Details

Equipment Used	Cal No.
Multi-Meter	**093**
PSU	**114**
Oscilloscope	**070**
Echo Simulator	**157**
P/Test Gauge	**404**

Date Completed -	07 August 2018
Technician -	SM

10.2 Appendix A - SBP lines of Djibouti area

The SBP lines presented for Djibouti area are shown on figure 37.

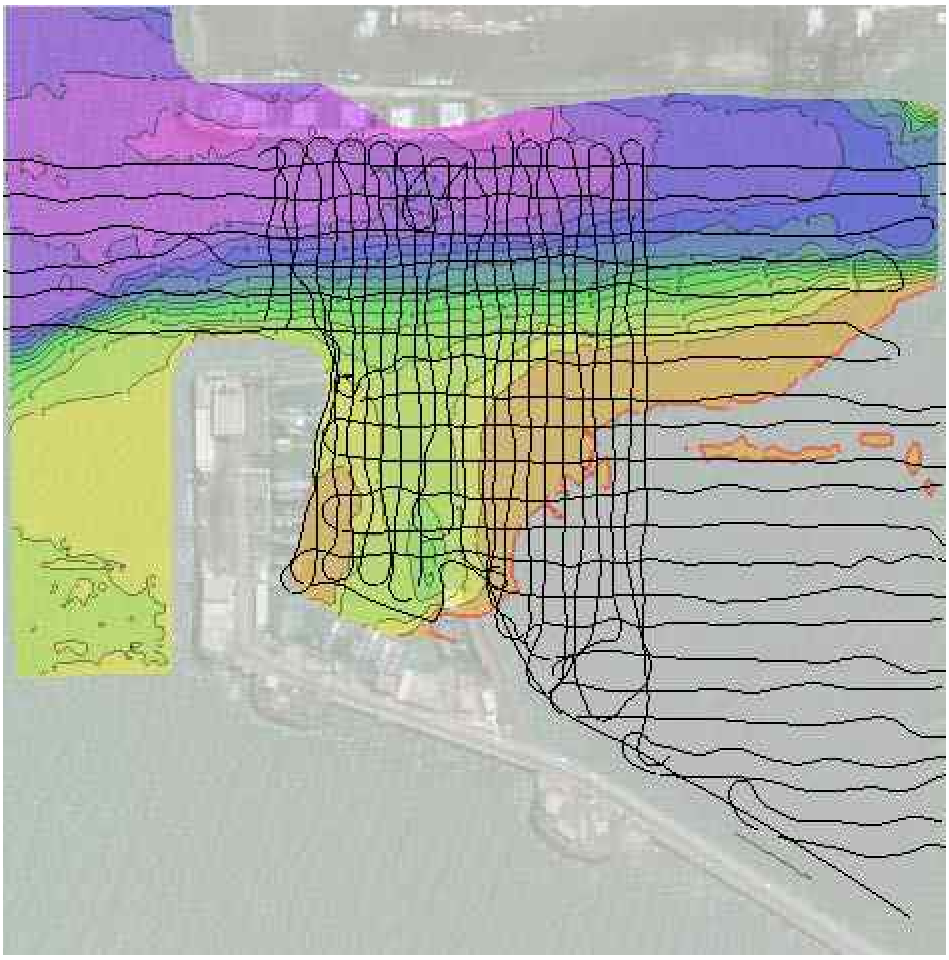
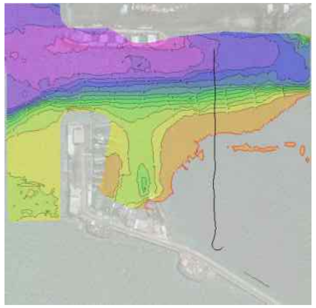
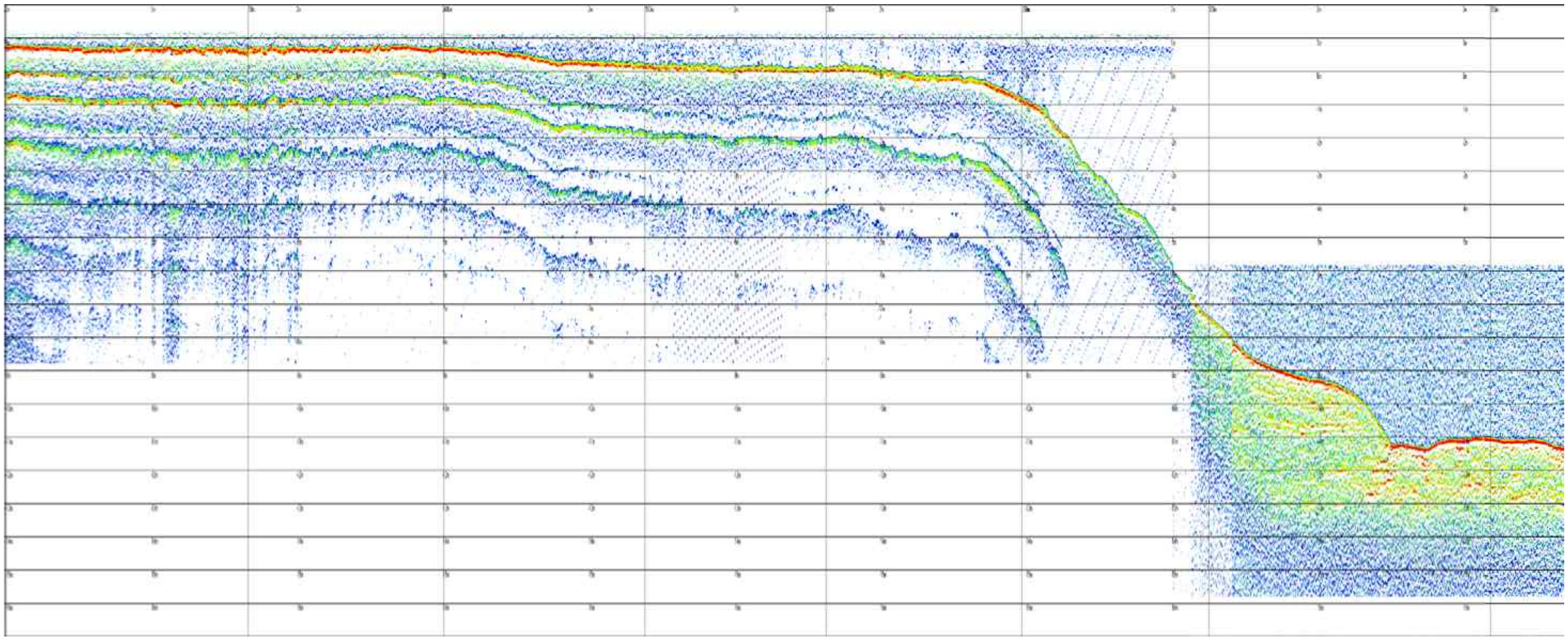


Figure 14 : Djibouti SPB lines presented in appendix A

LINE NS 38





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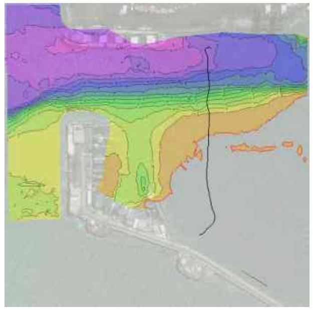

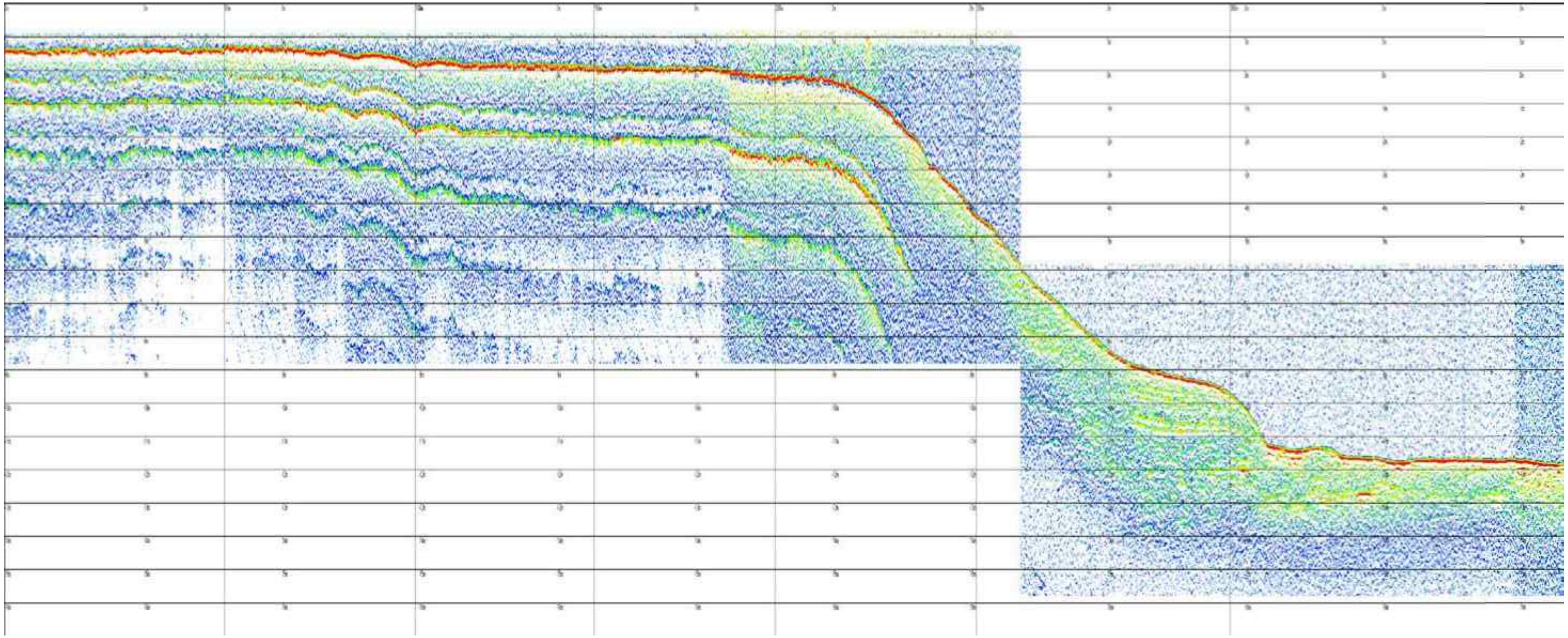

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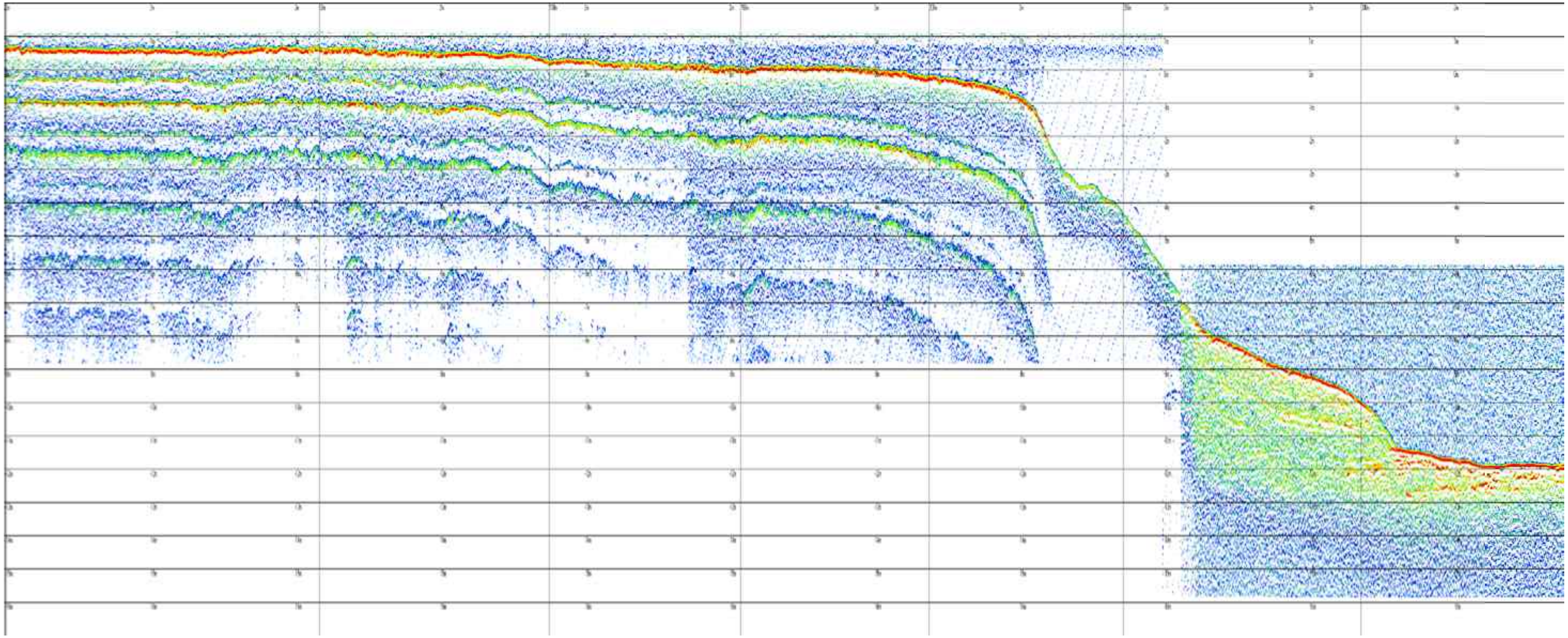

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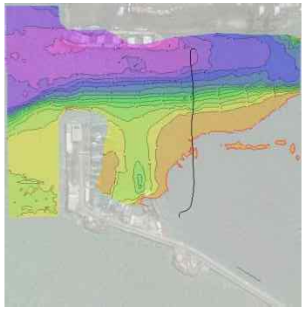

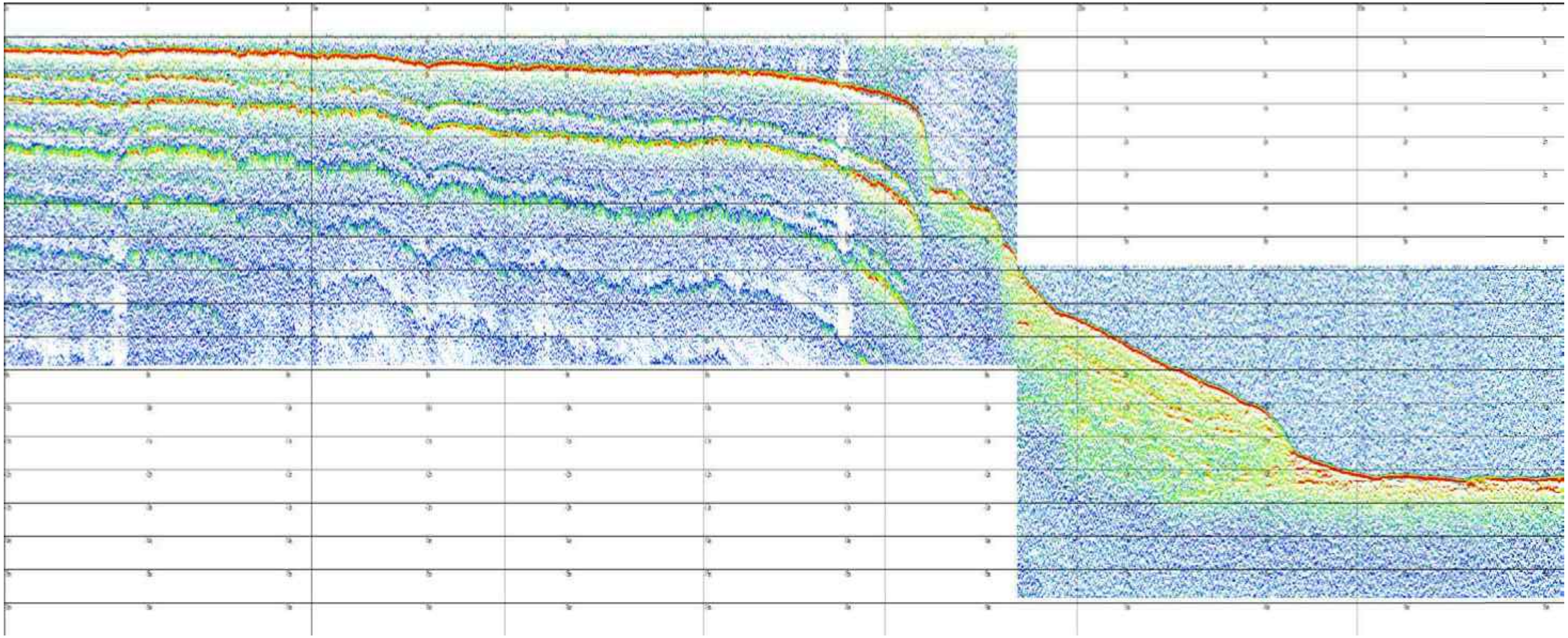

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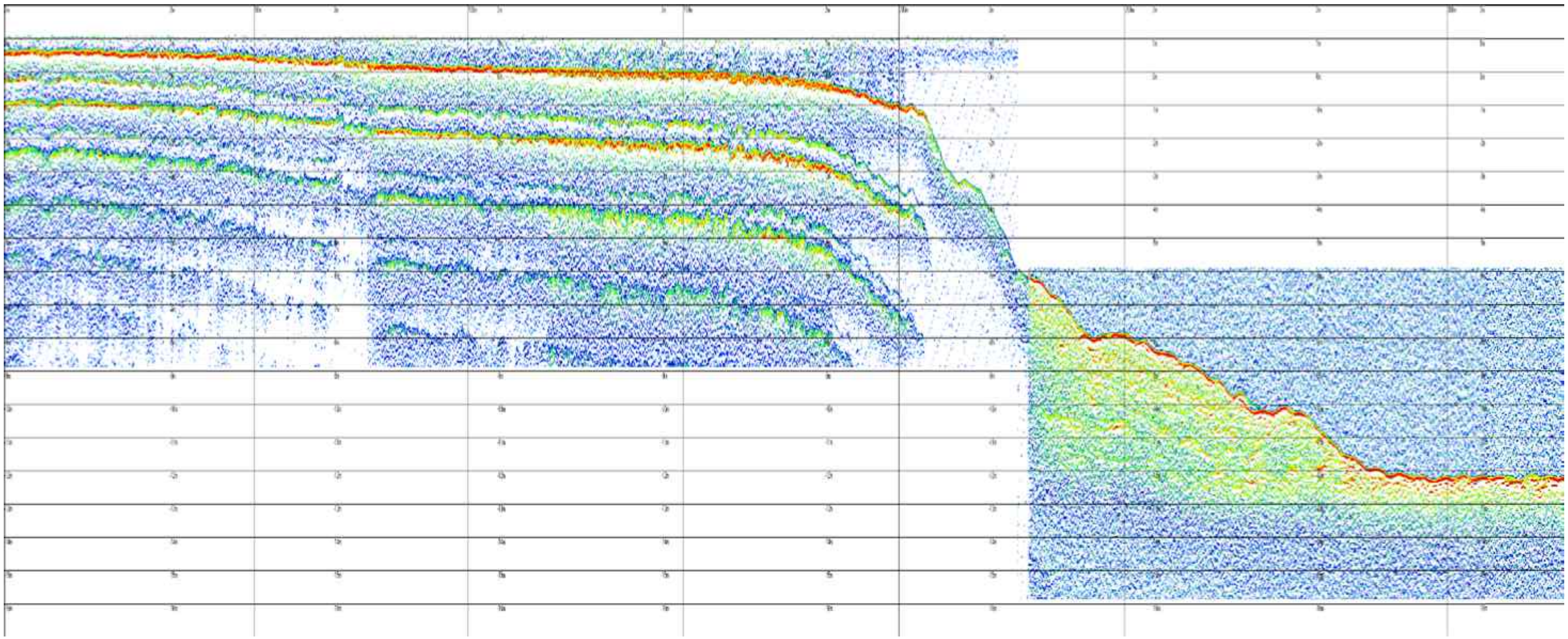

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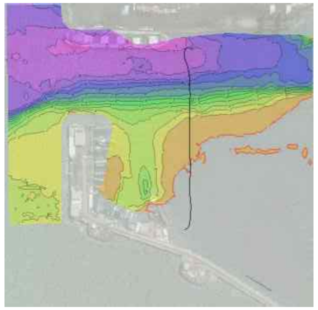

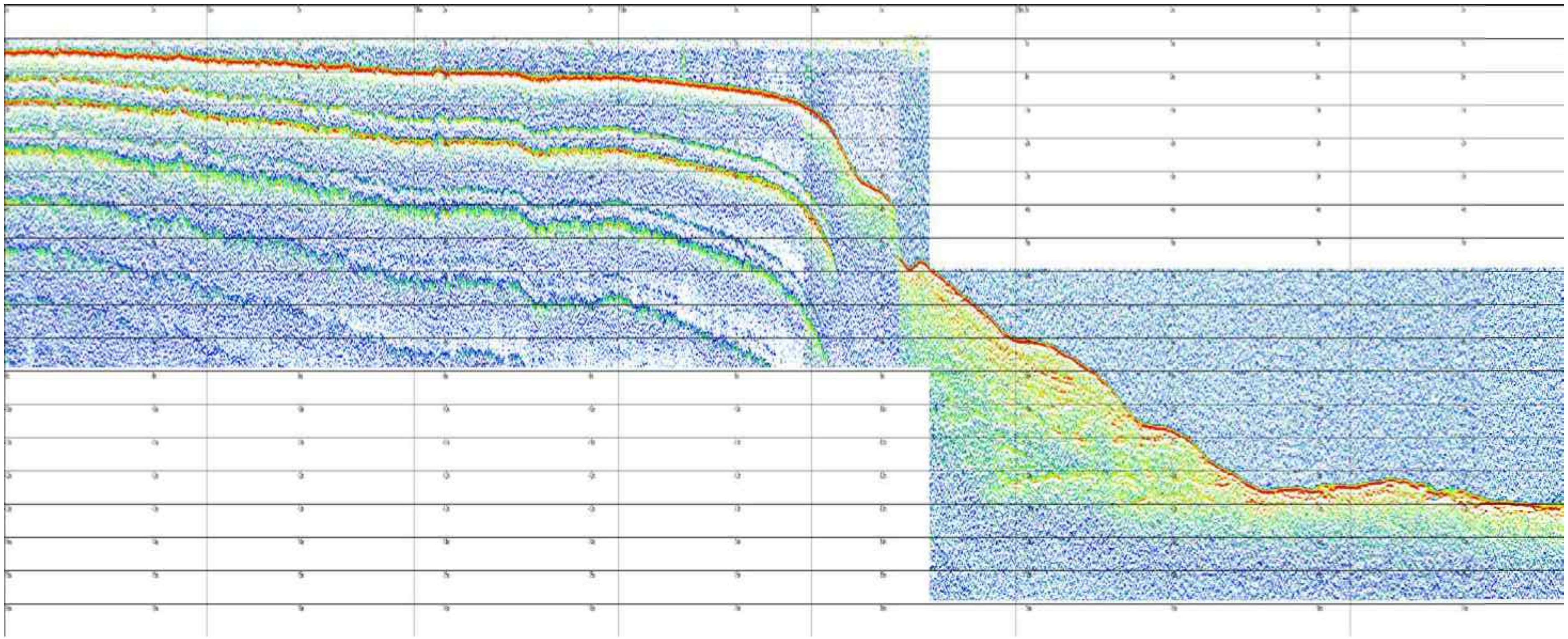

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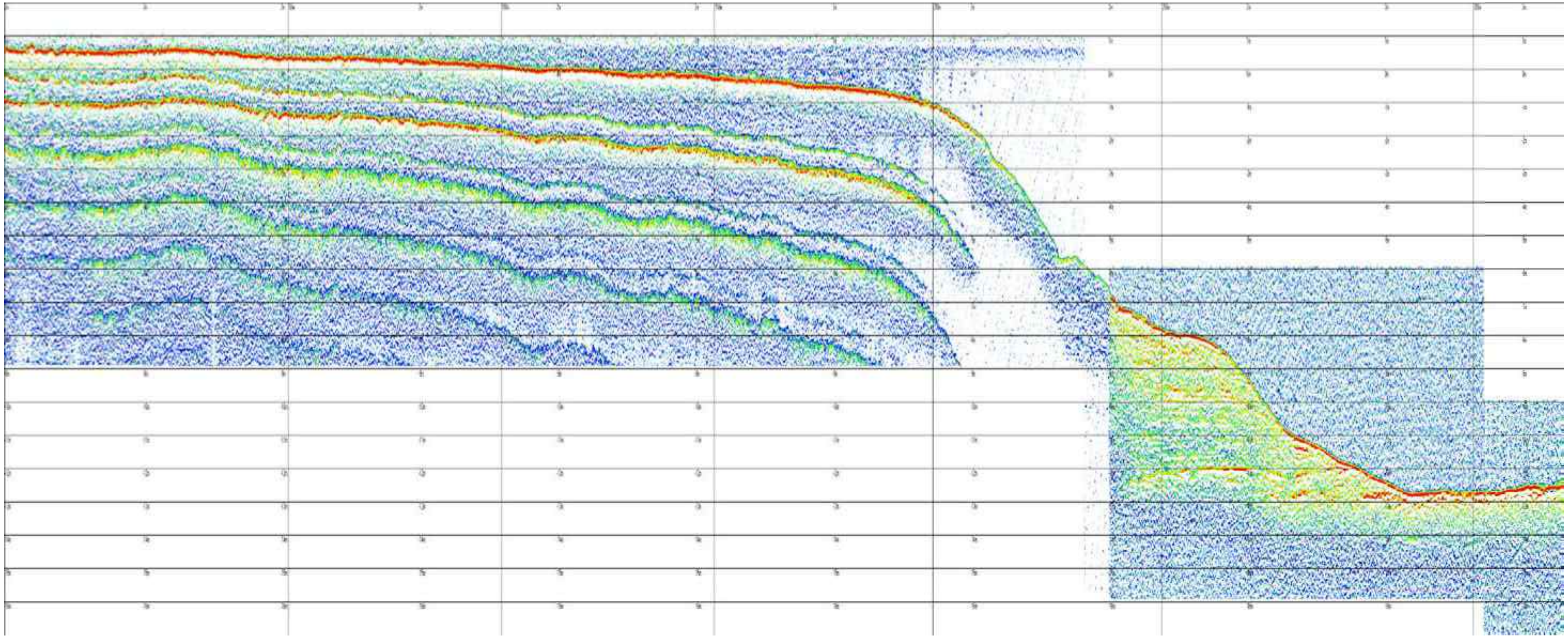

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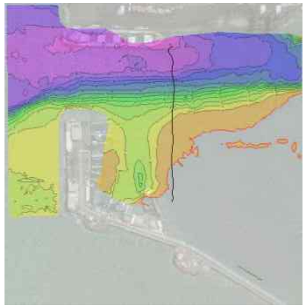

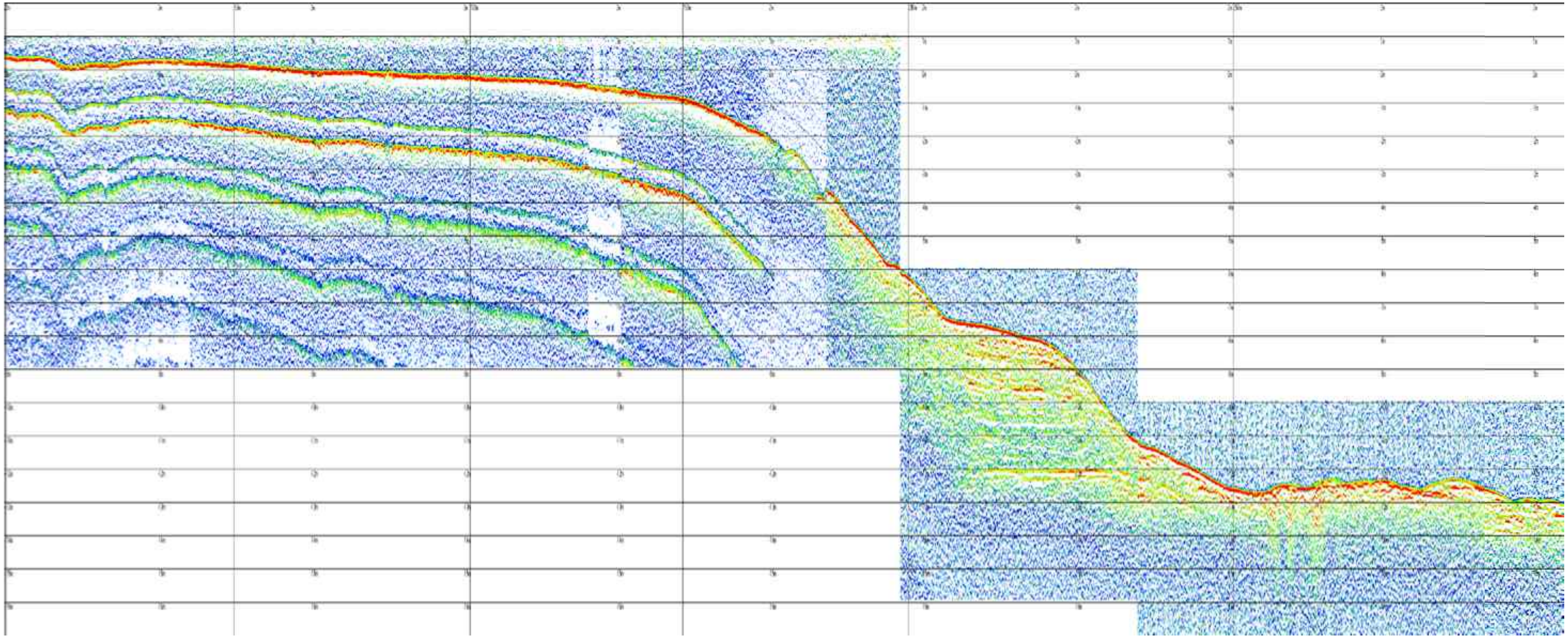

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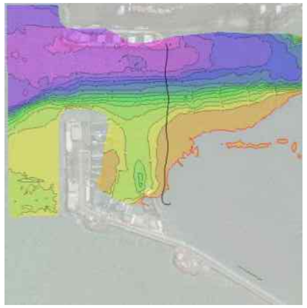

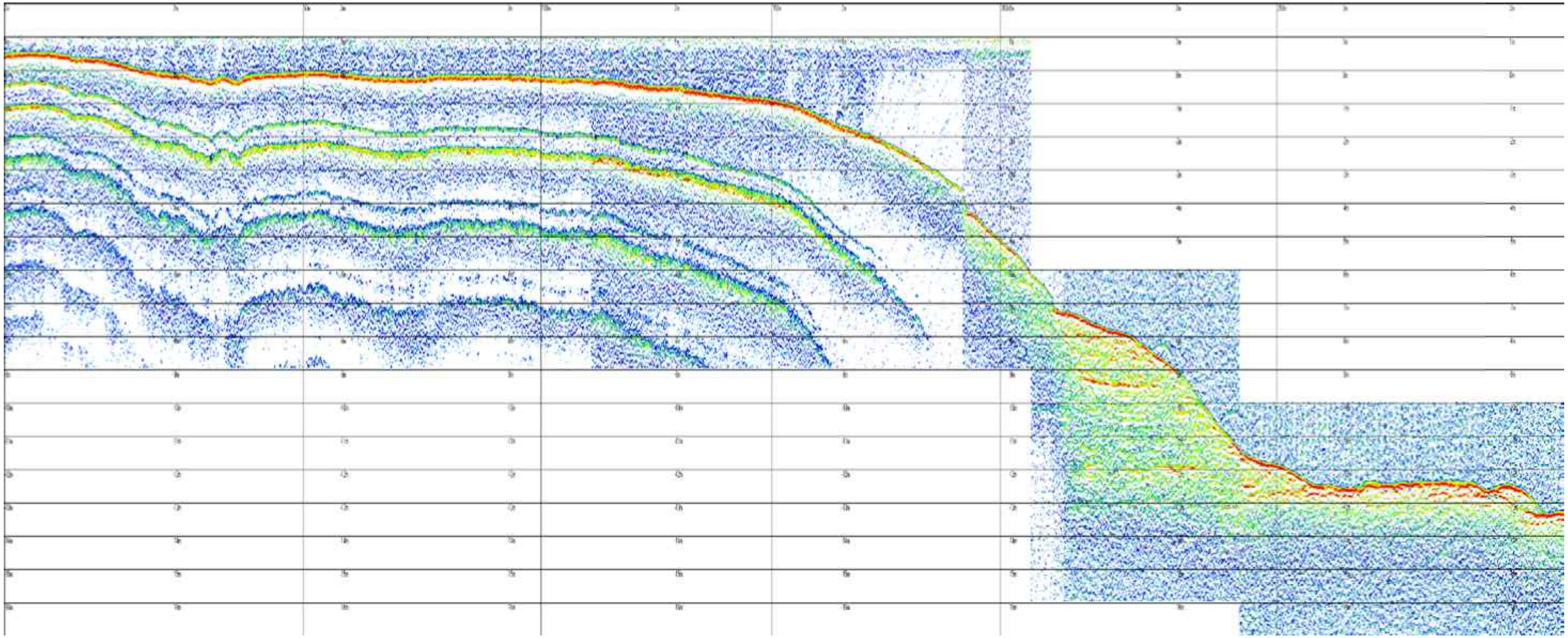

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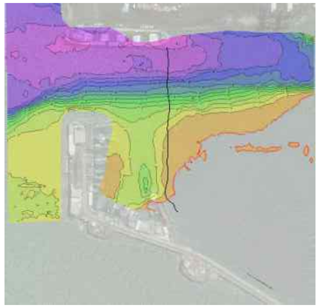

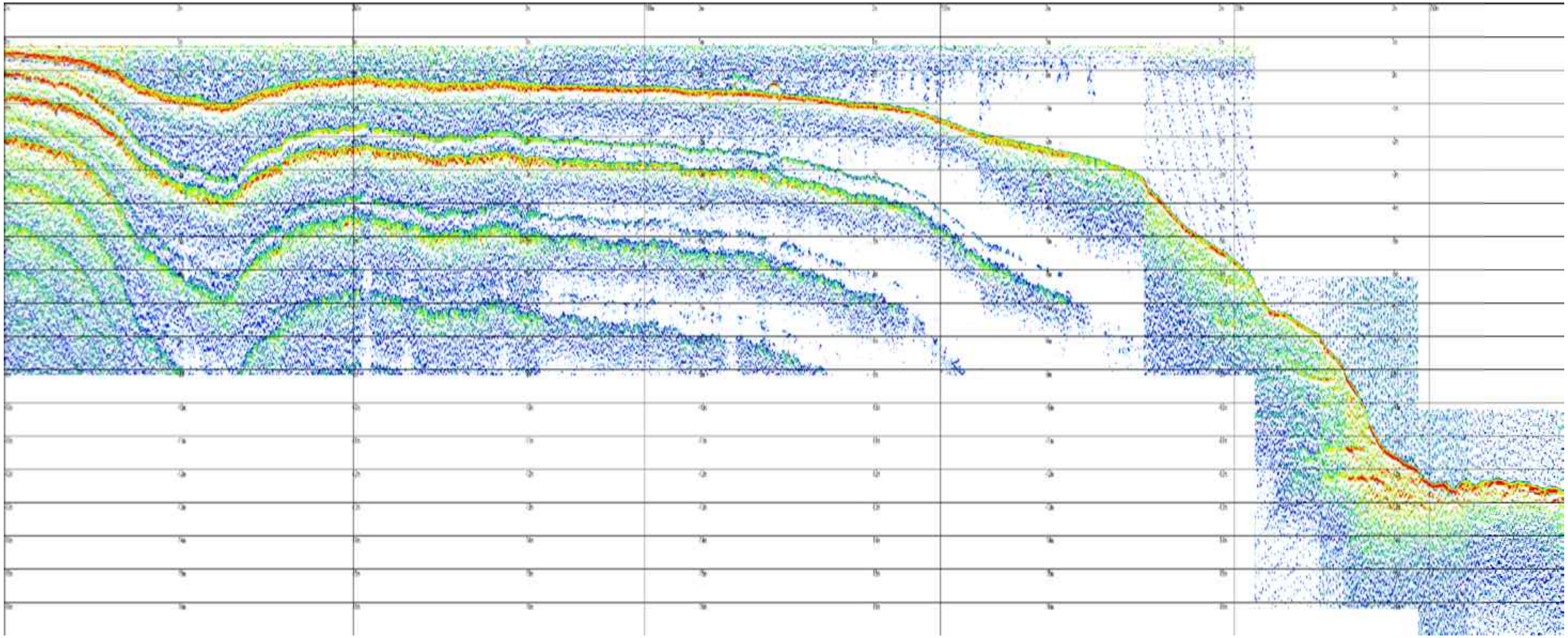

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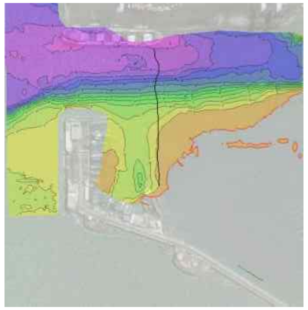

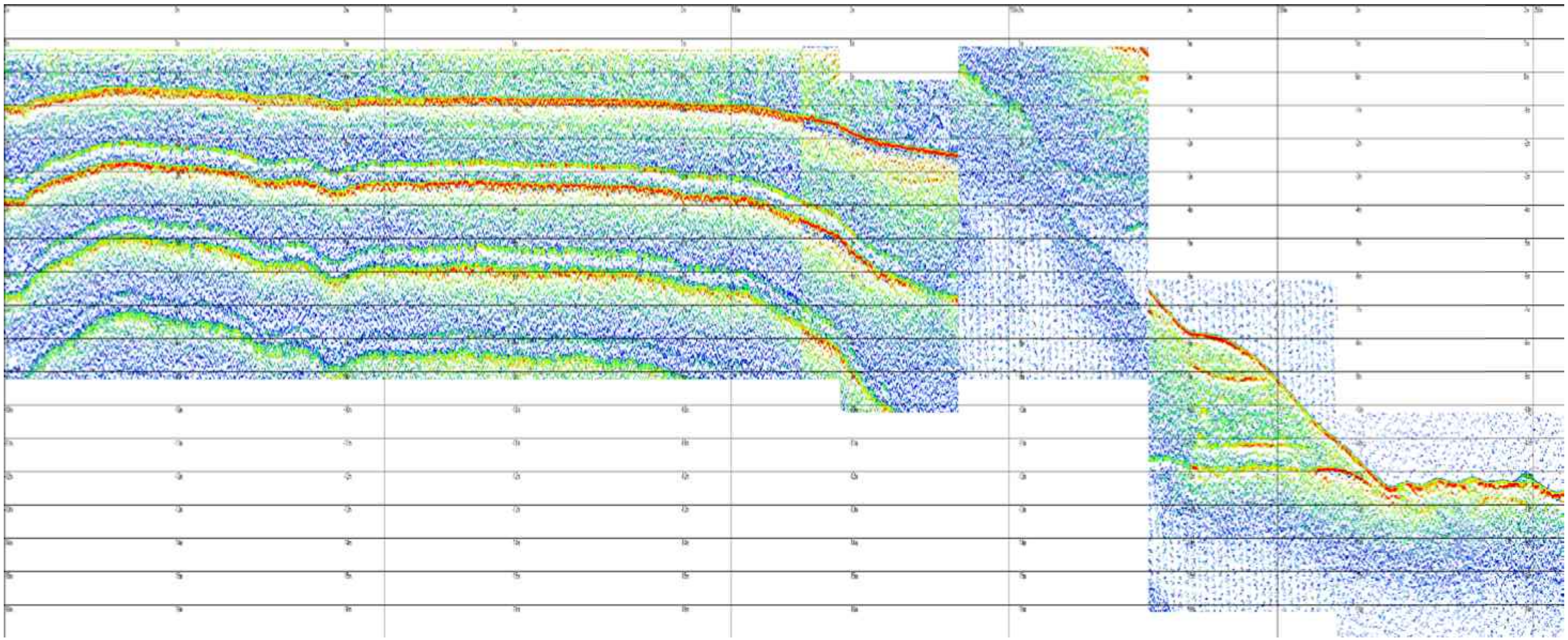

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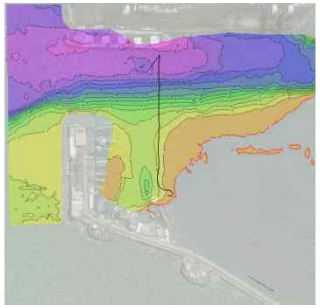

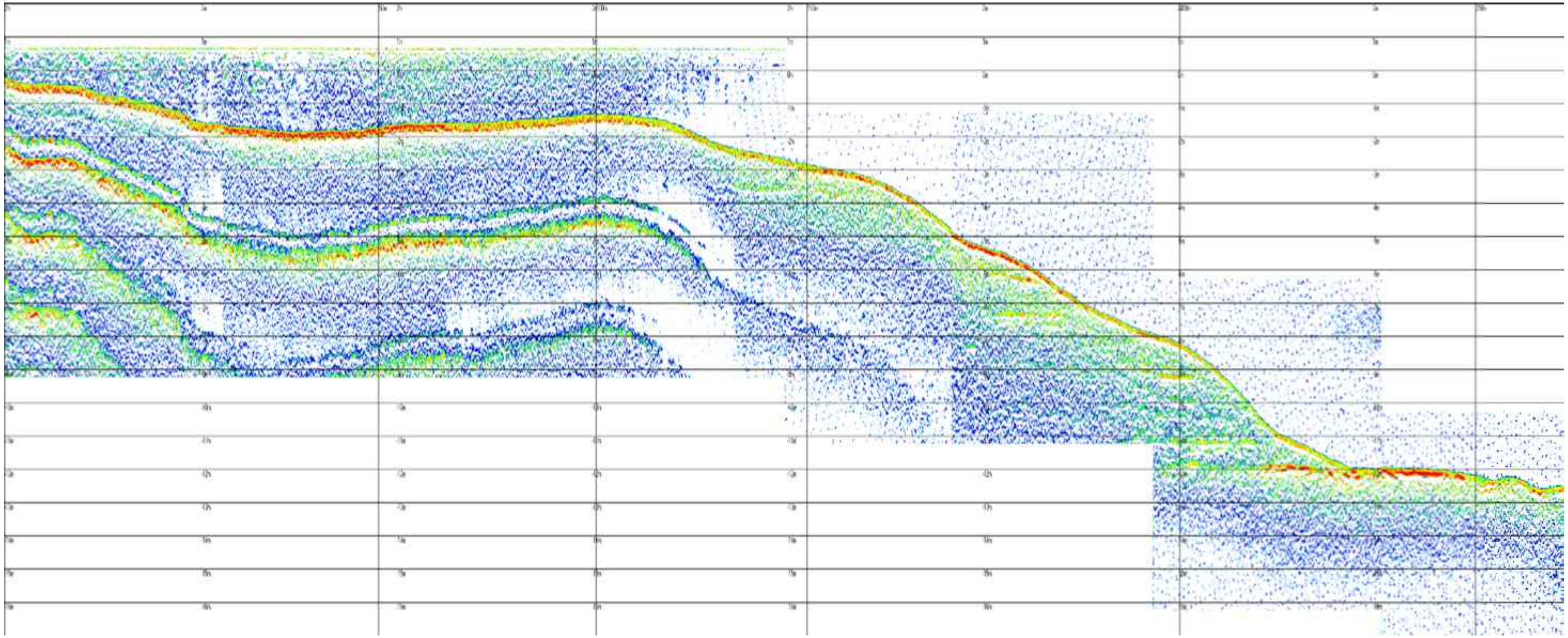

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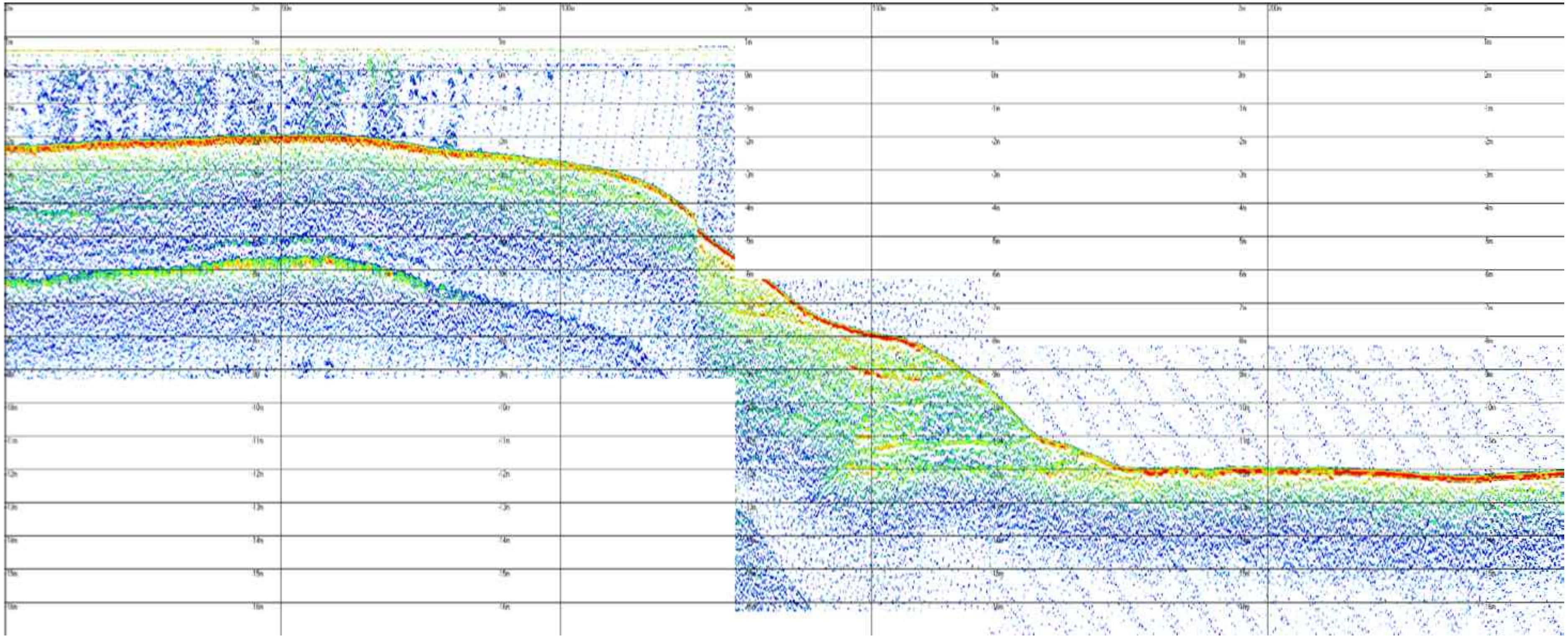

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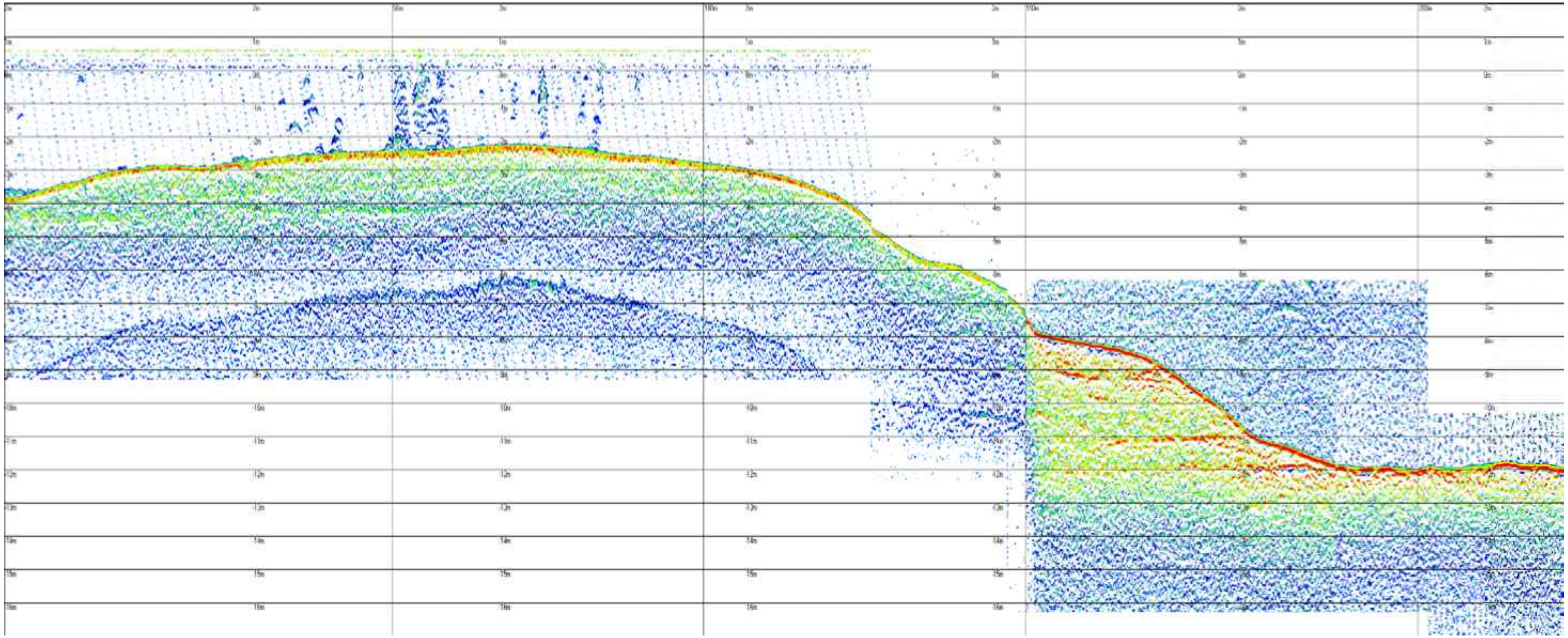

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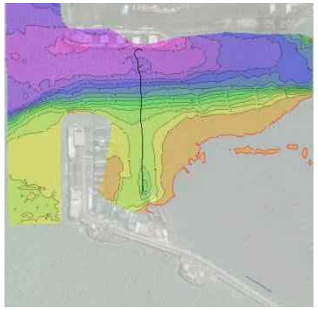

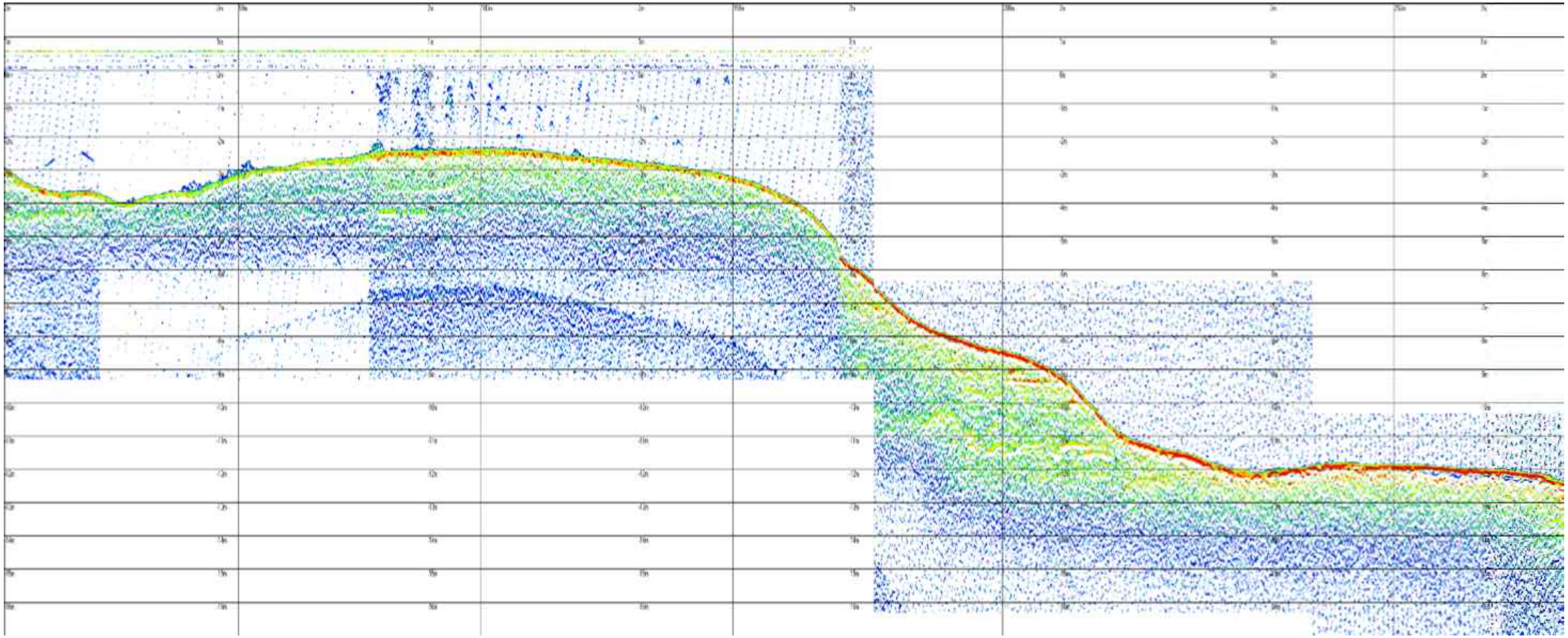

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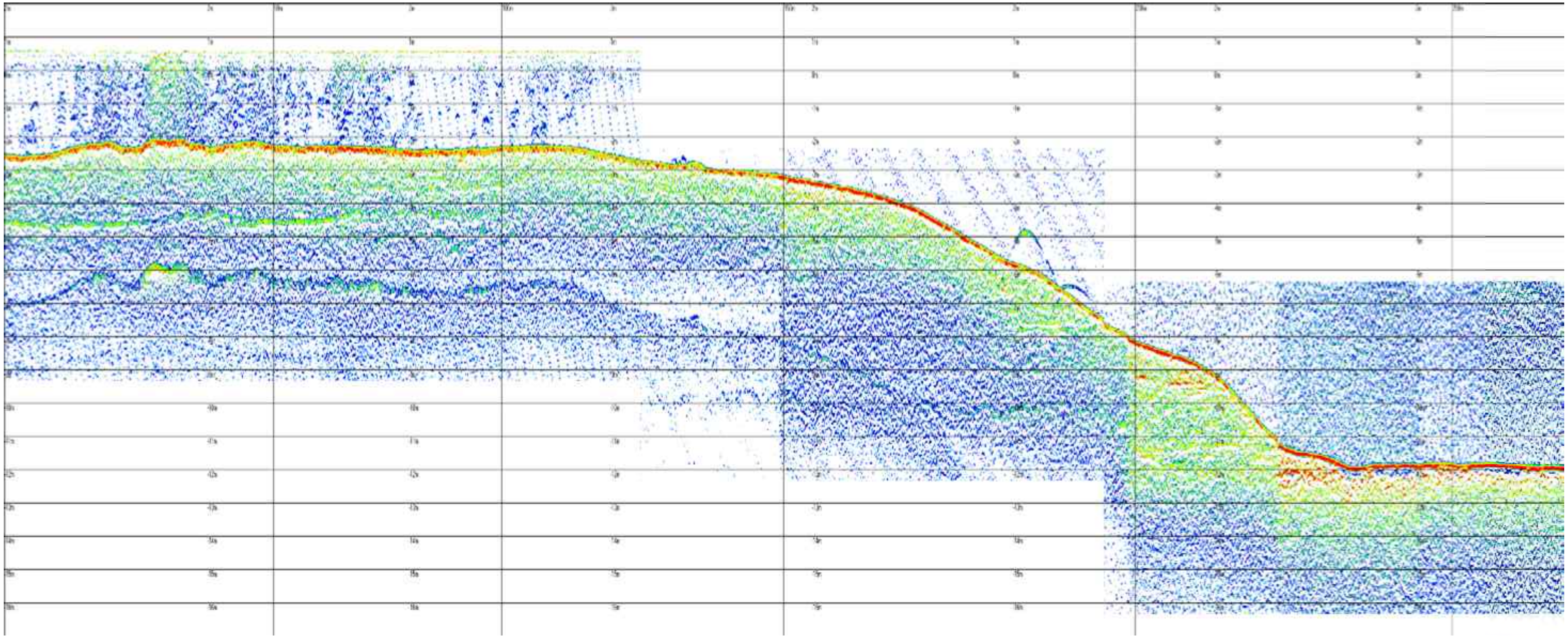

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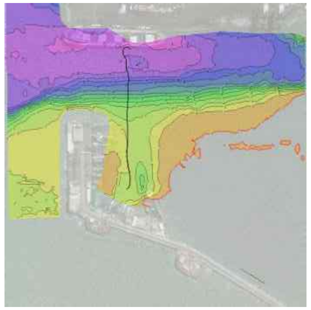

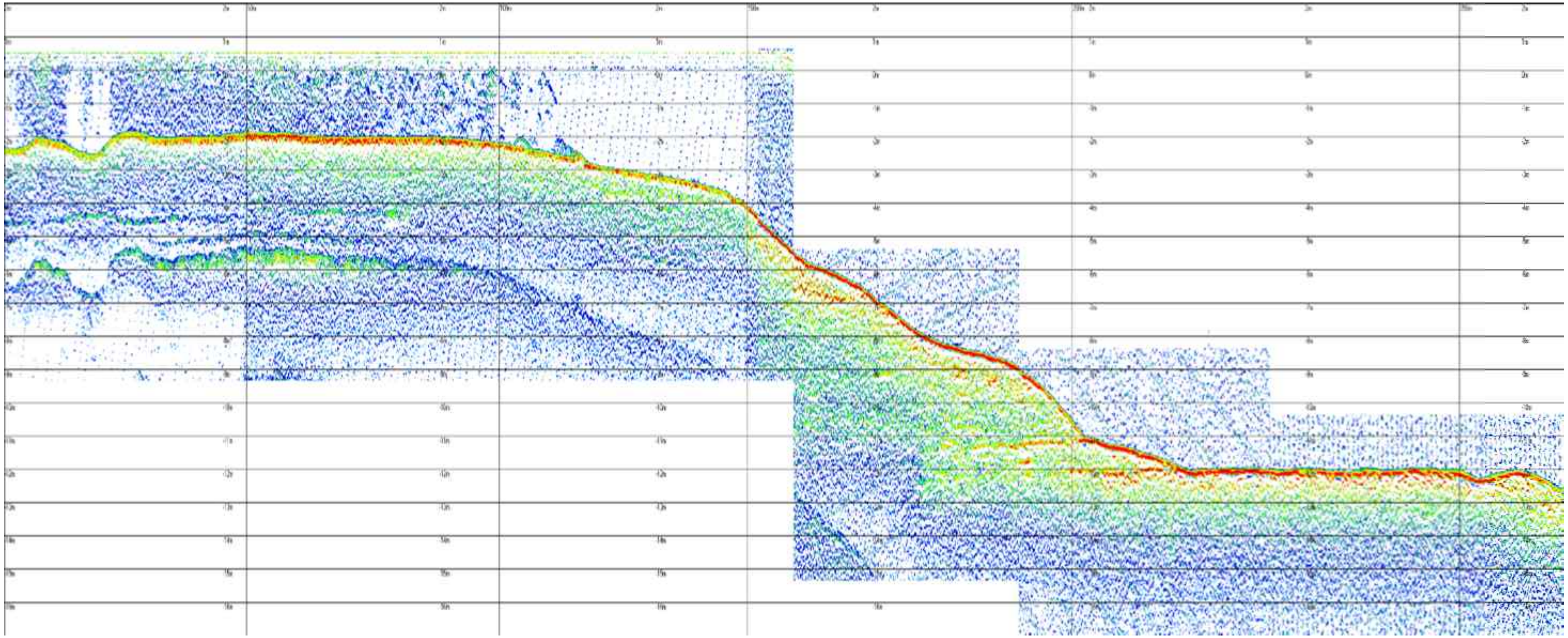

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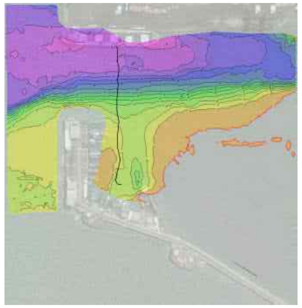

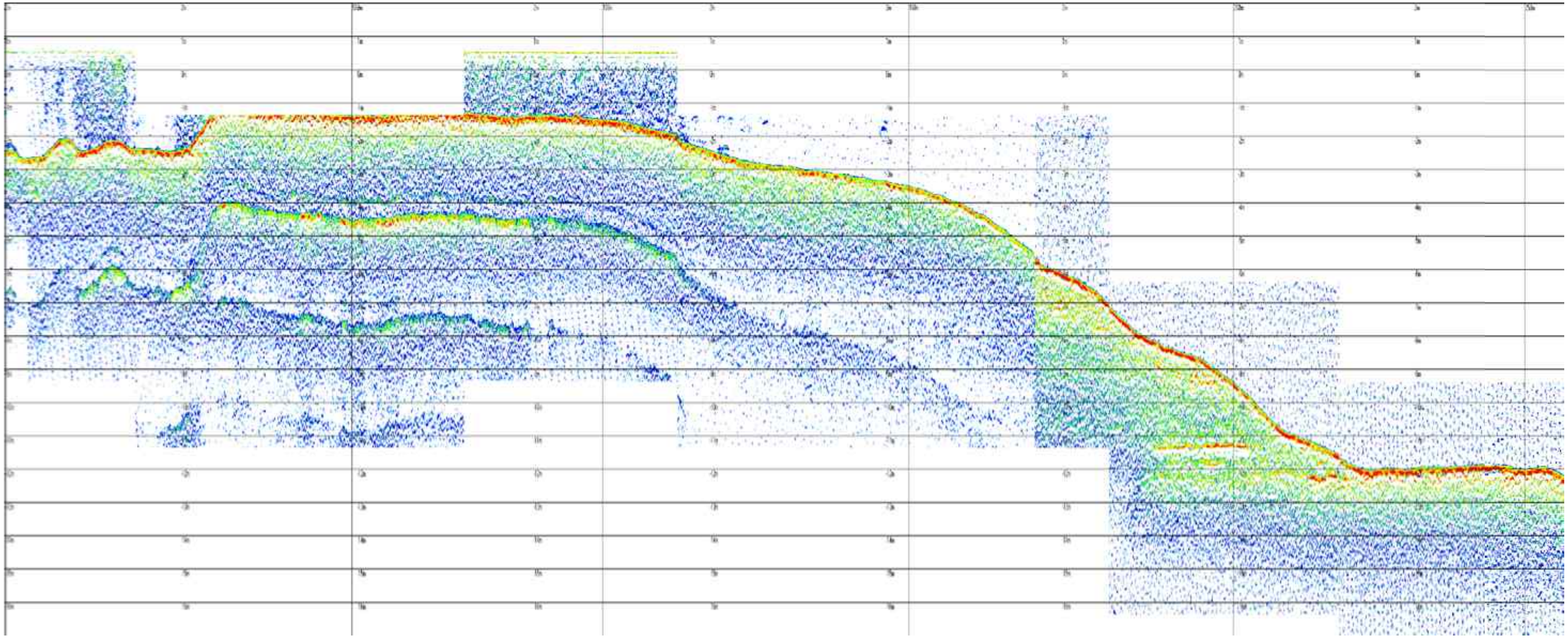

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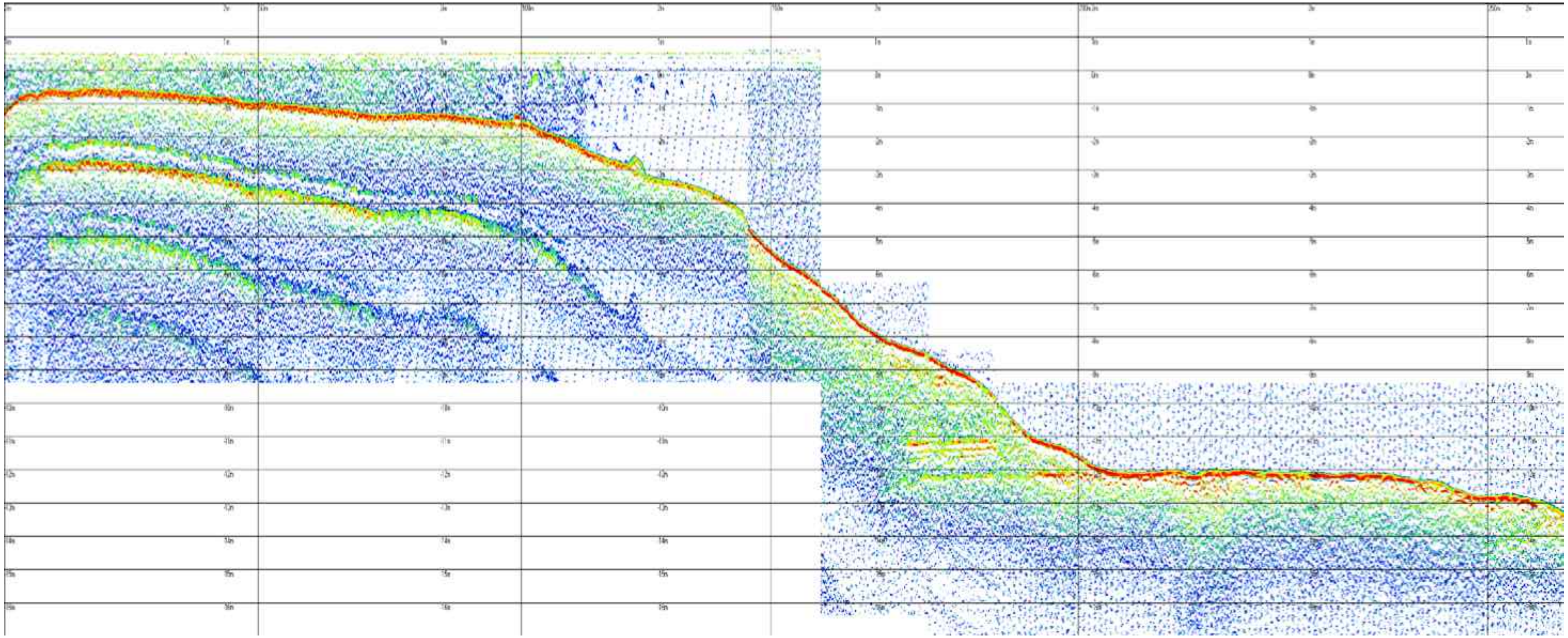

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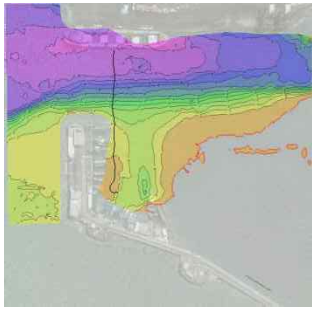

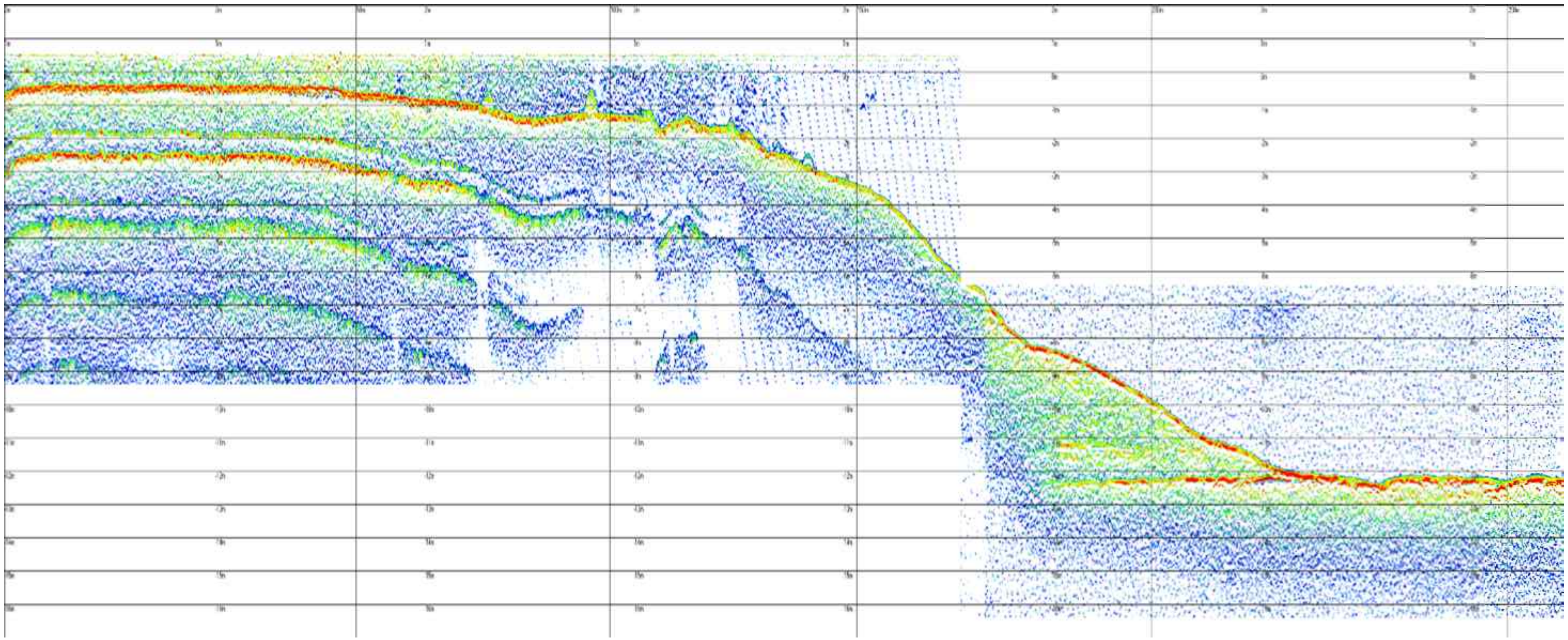

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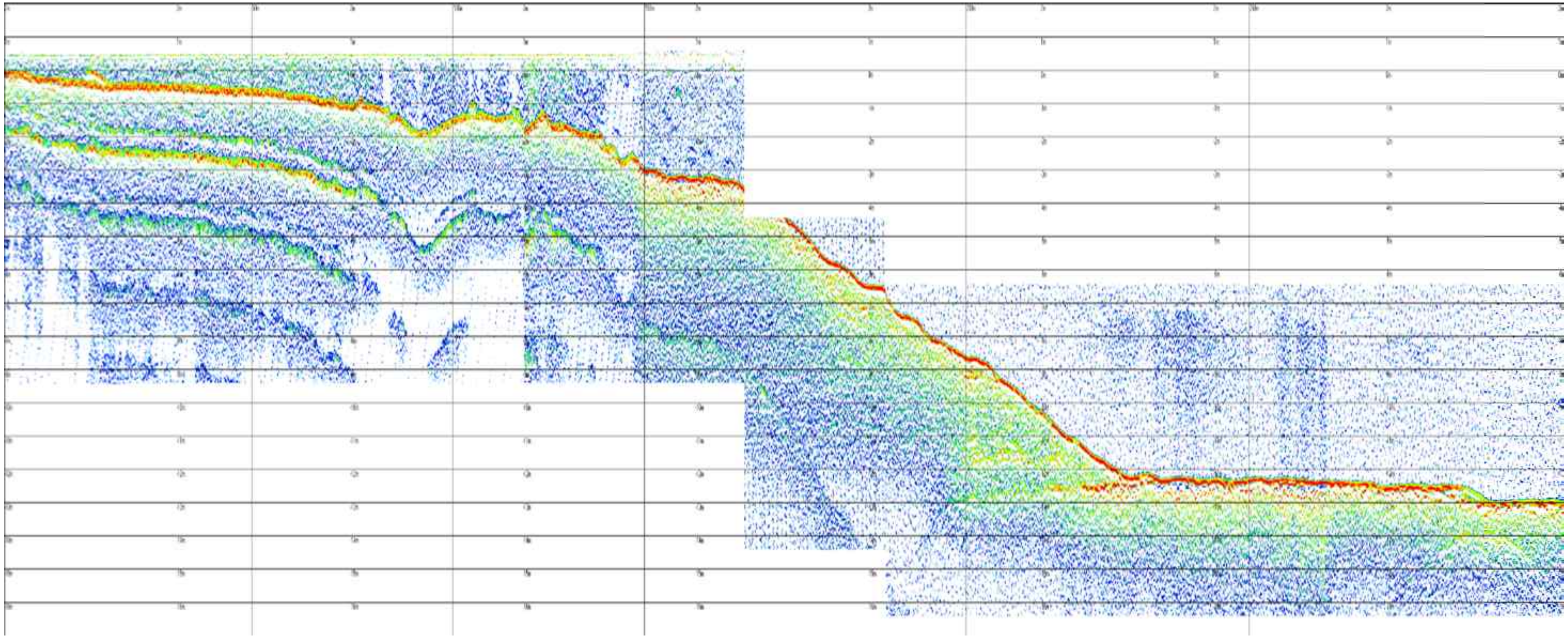

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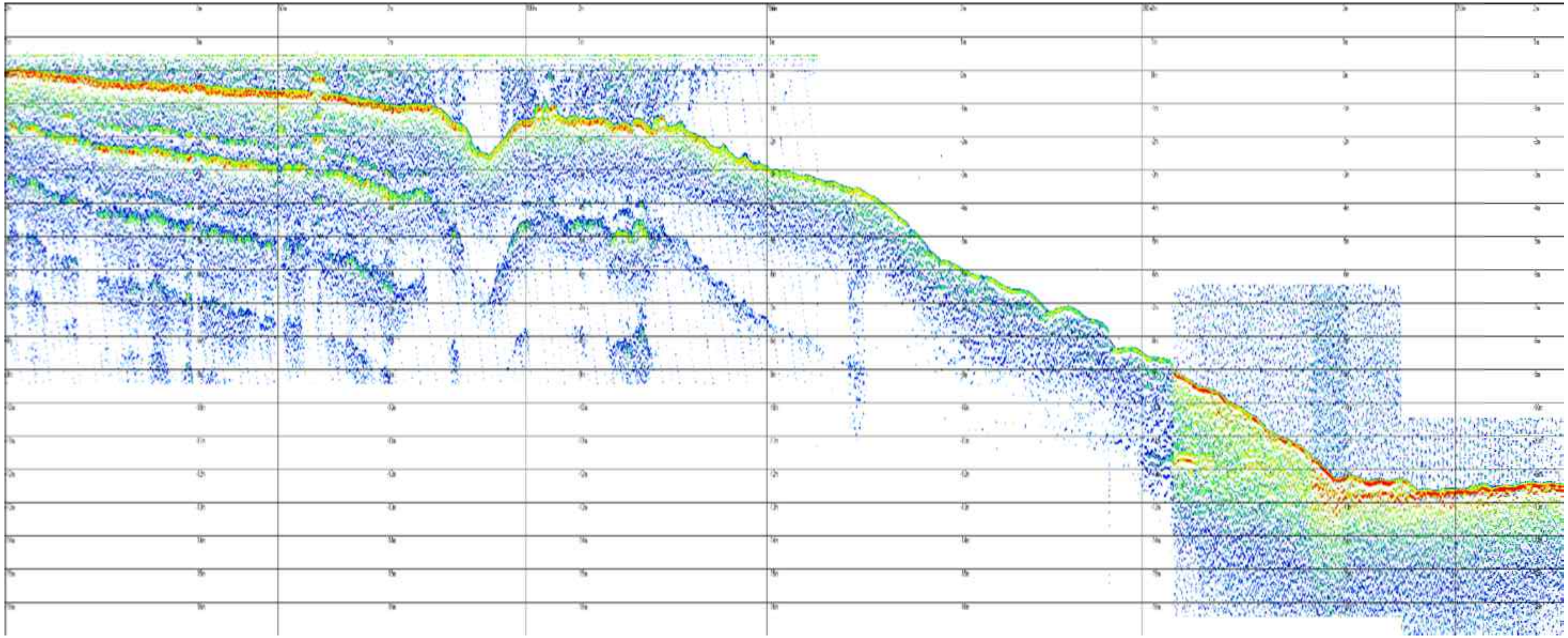

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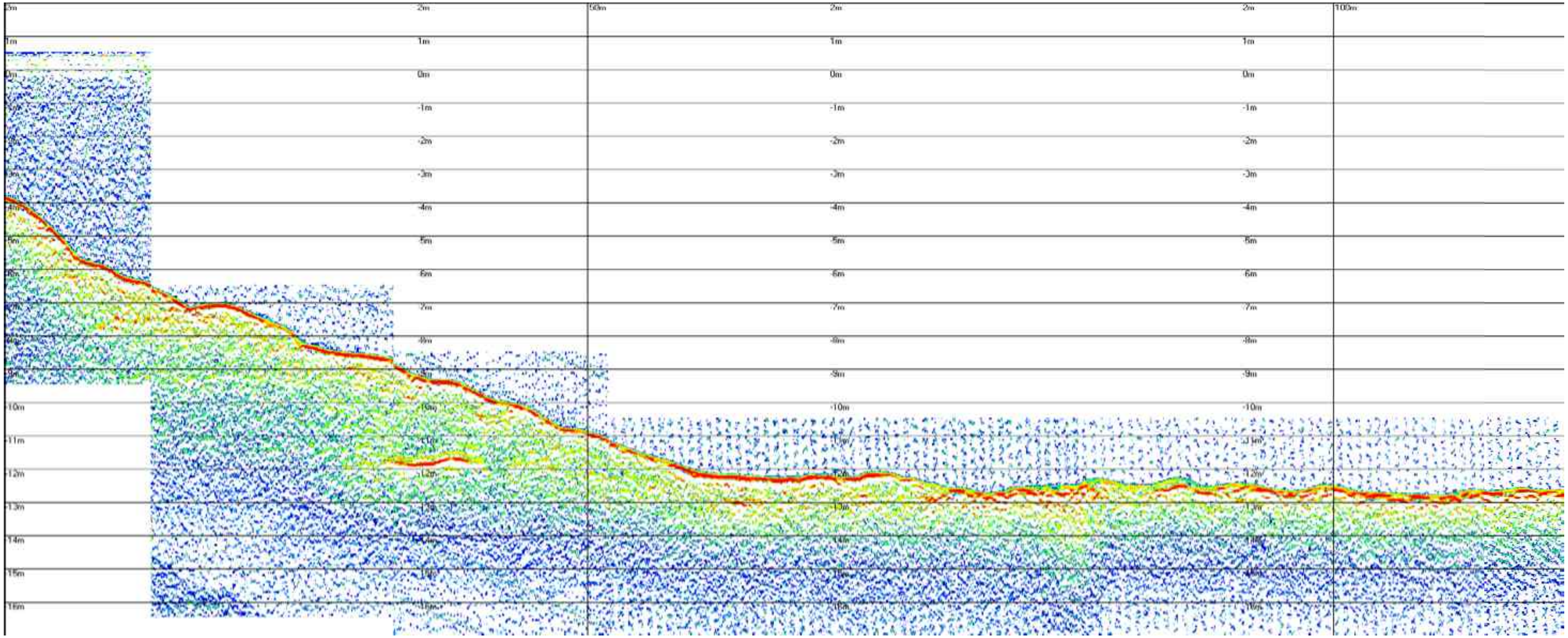

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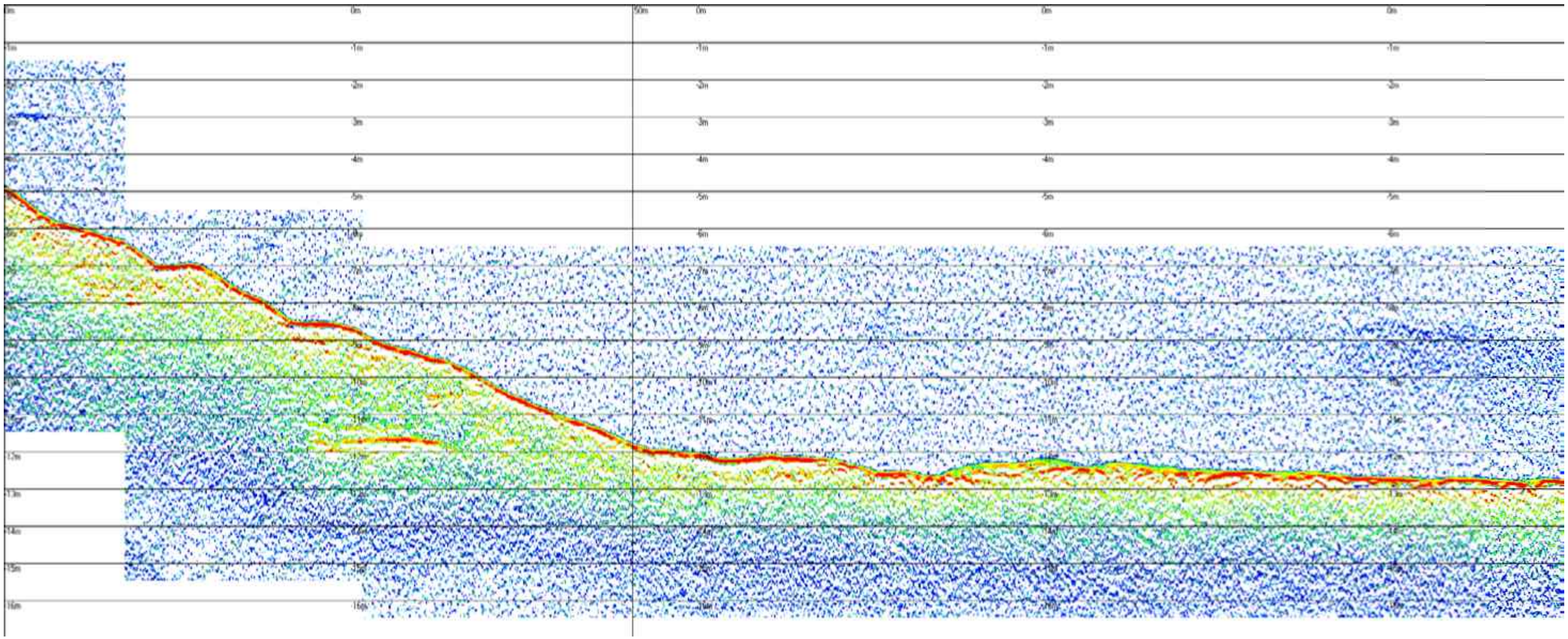

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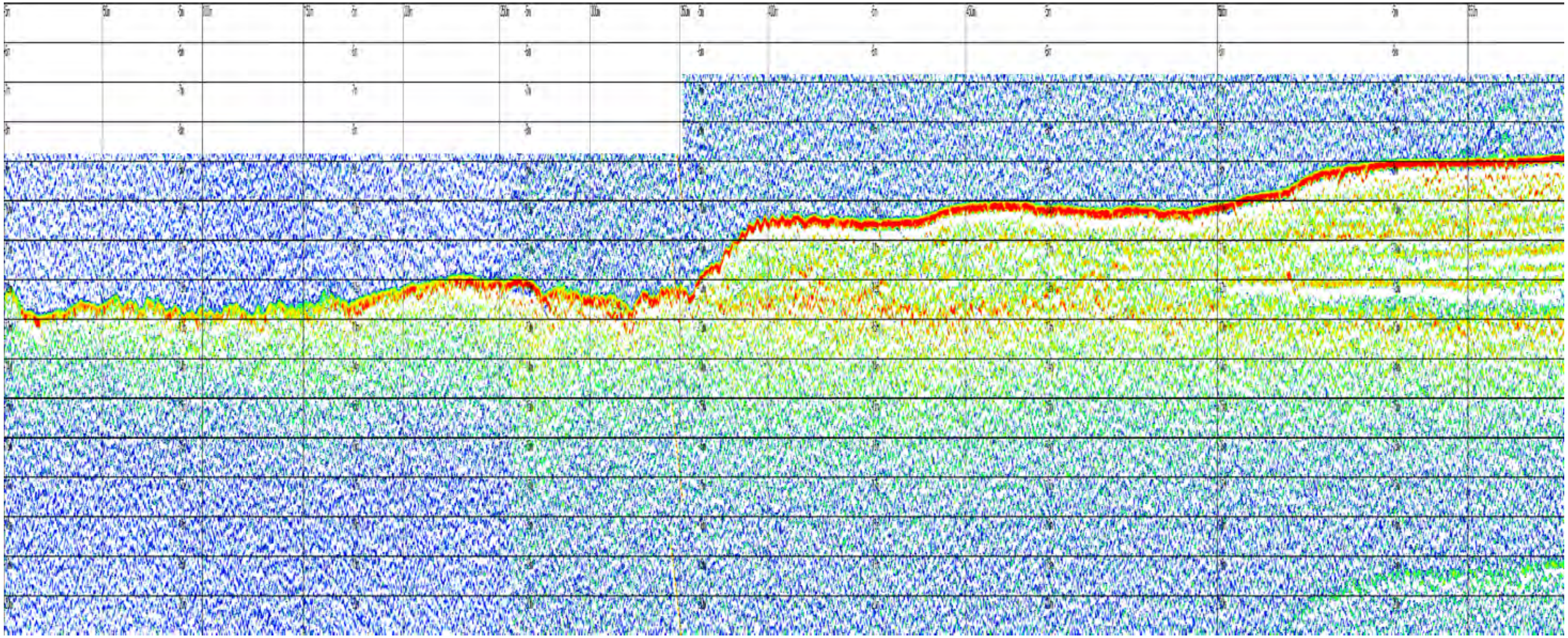

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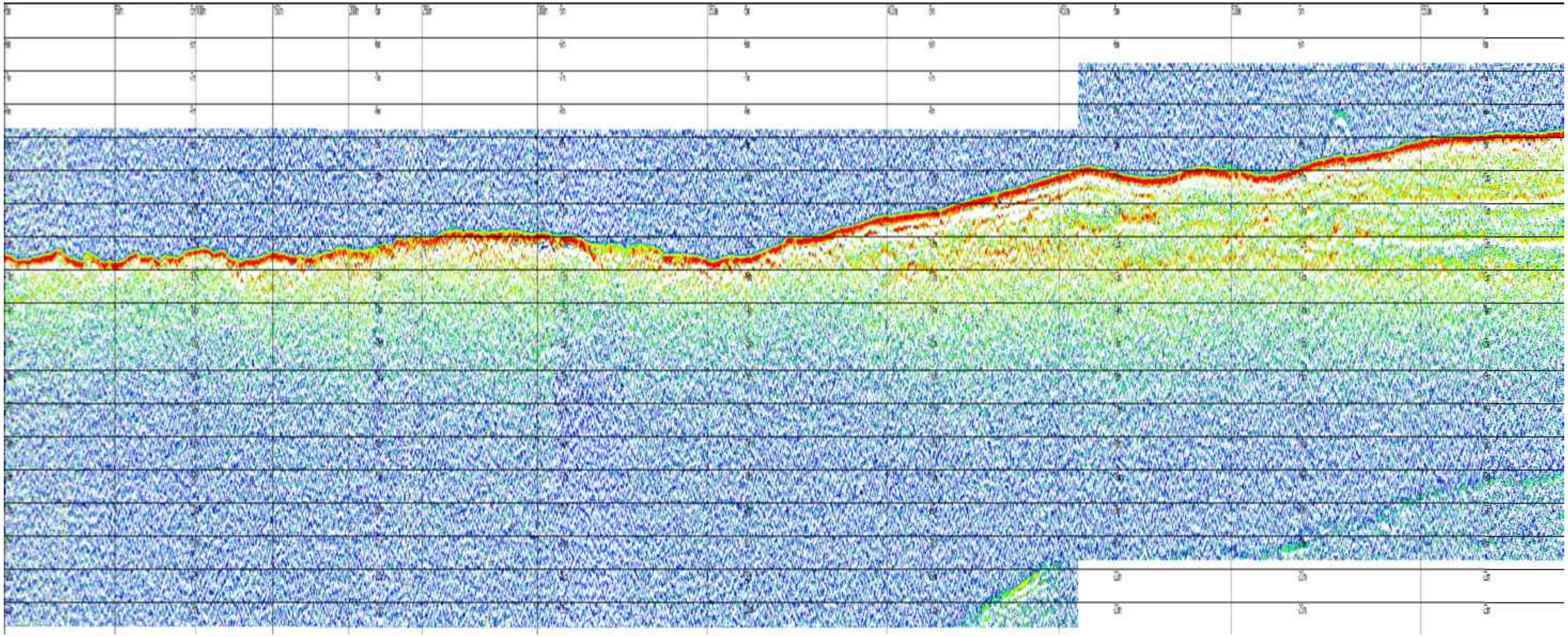

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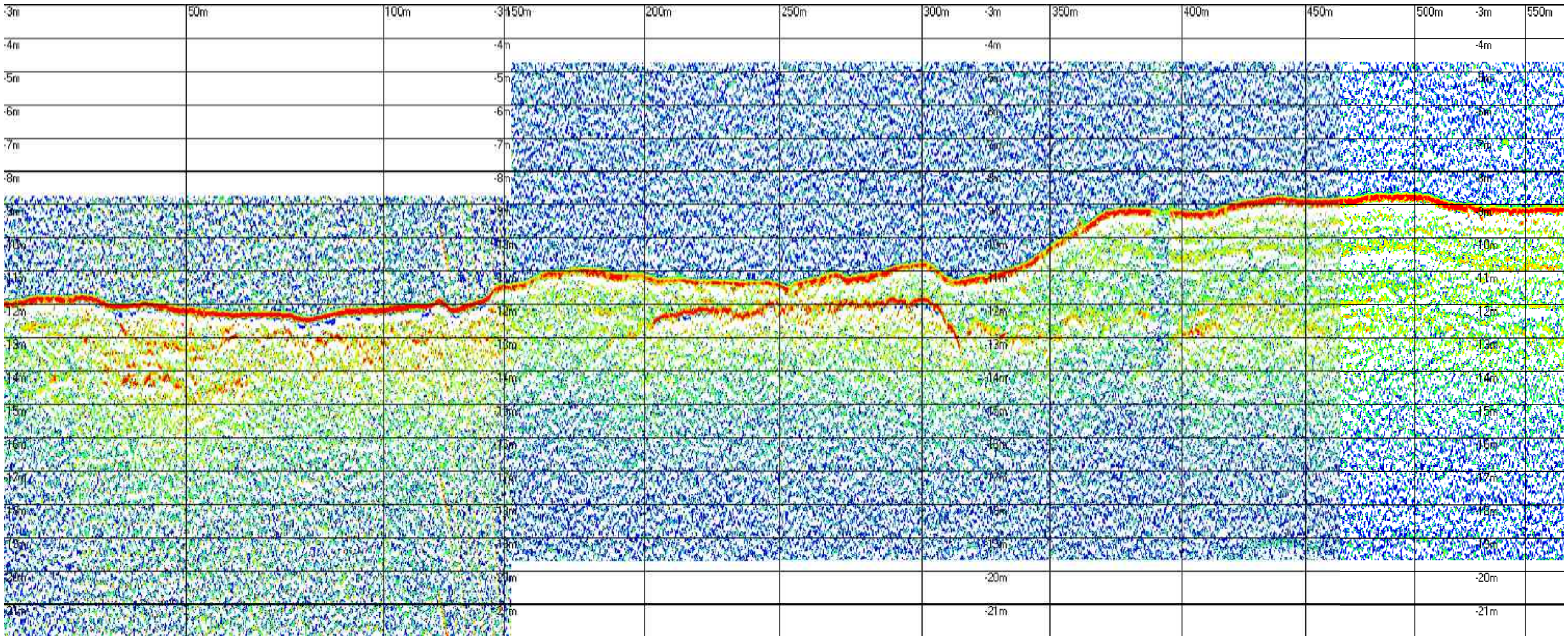
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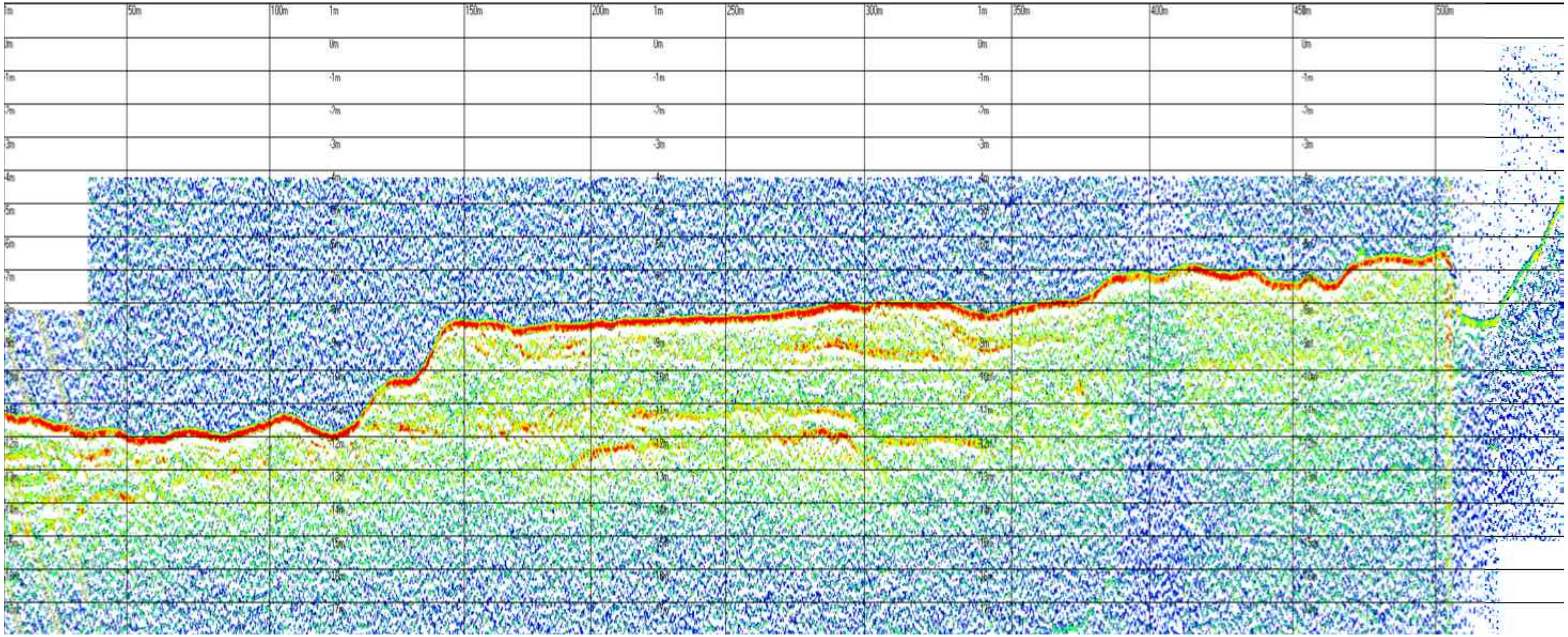
LINE EW 7



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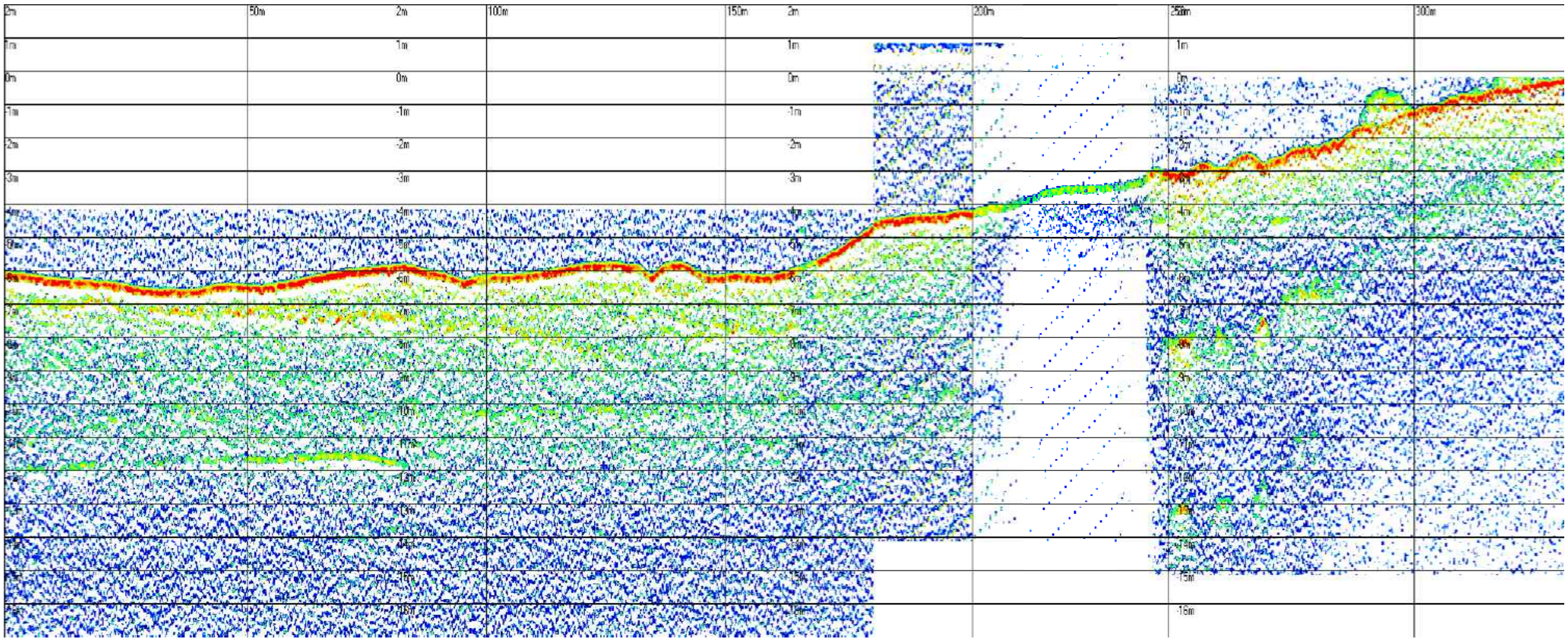

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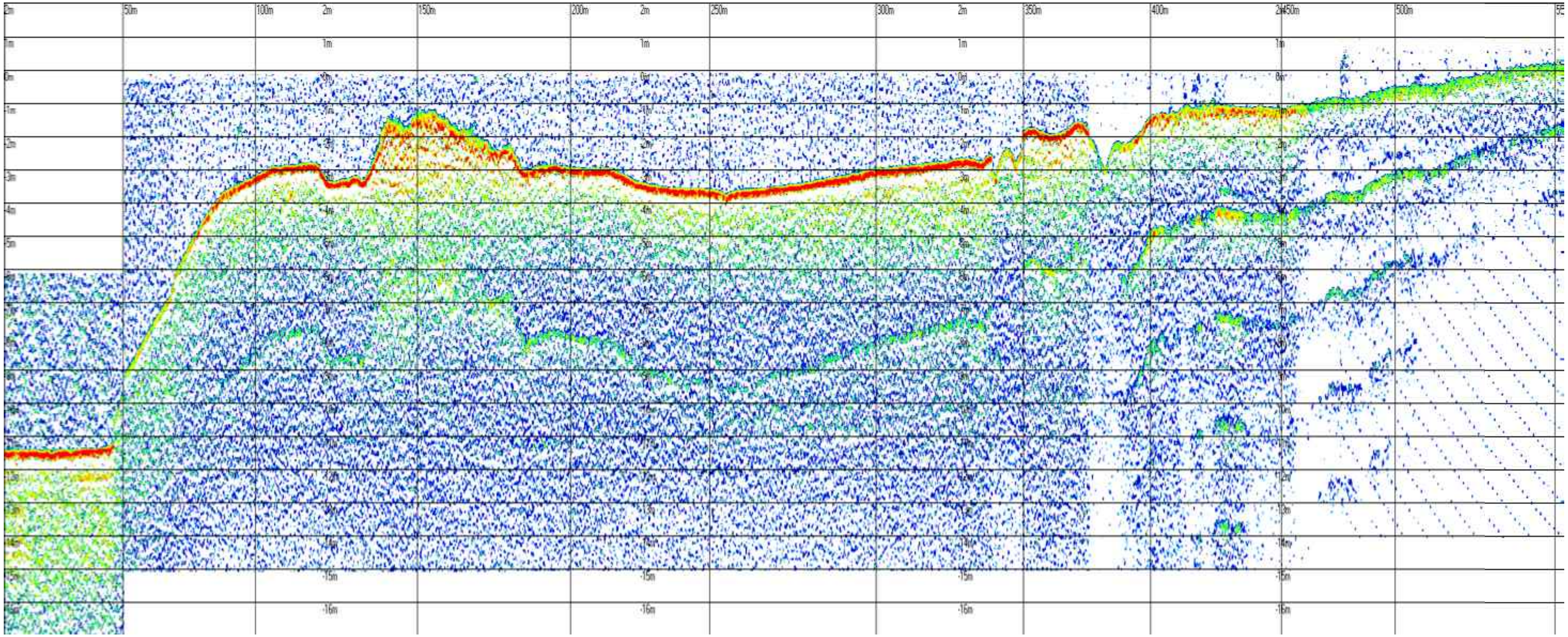

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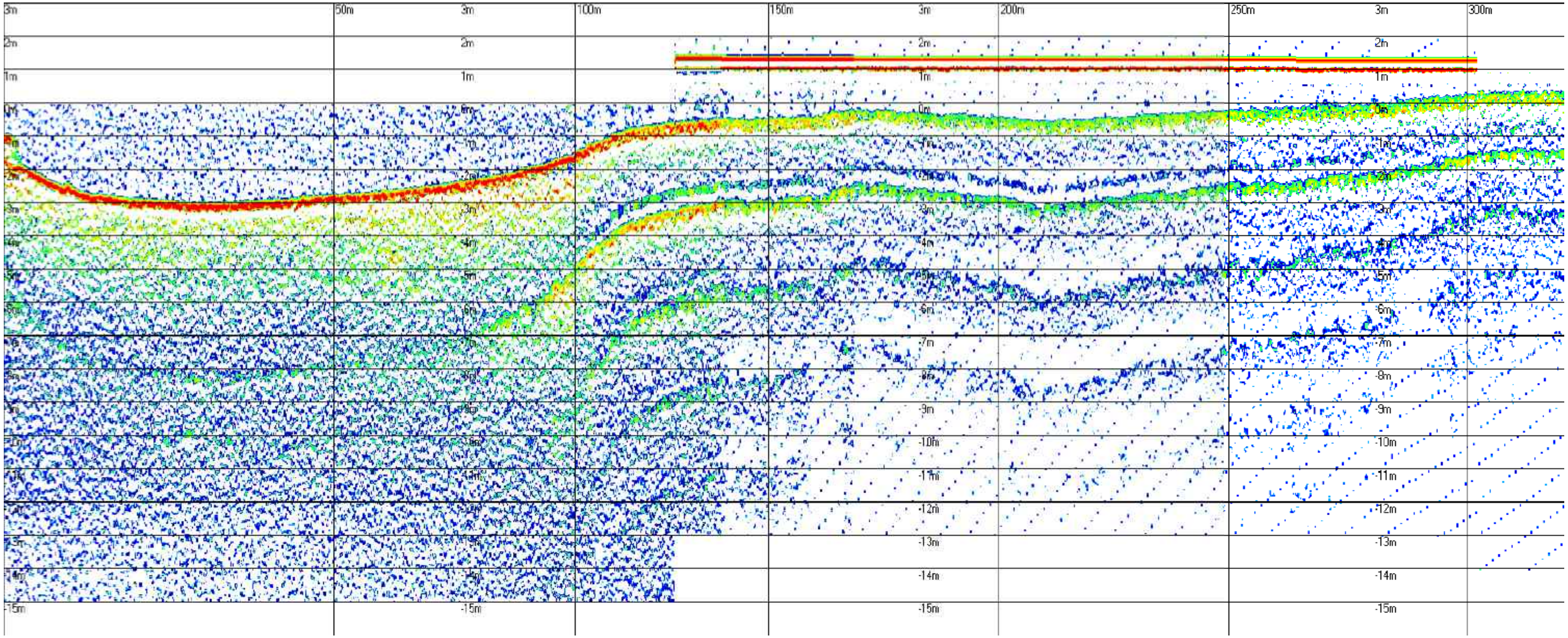

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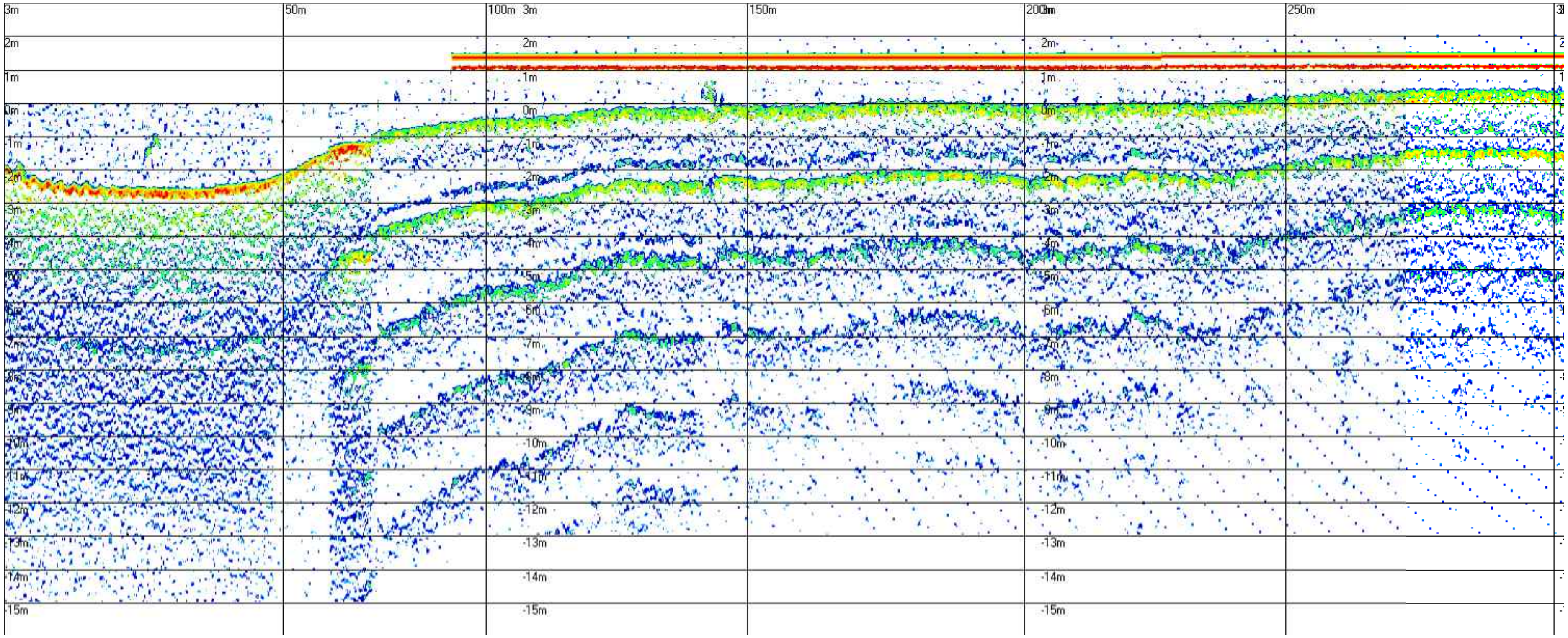
LINE EW 11



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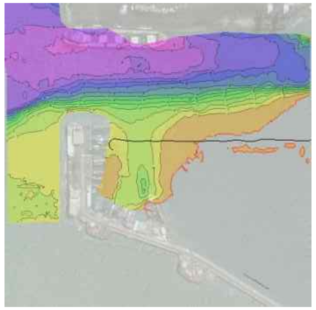
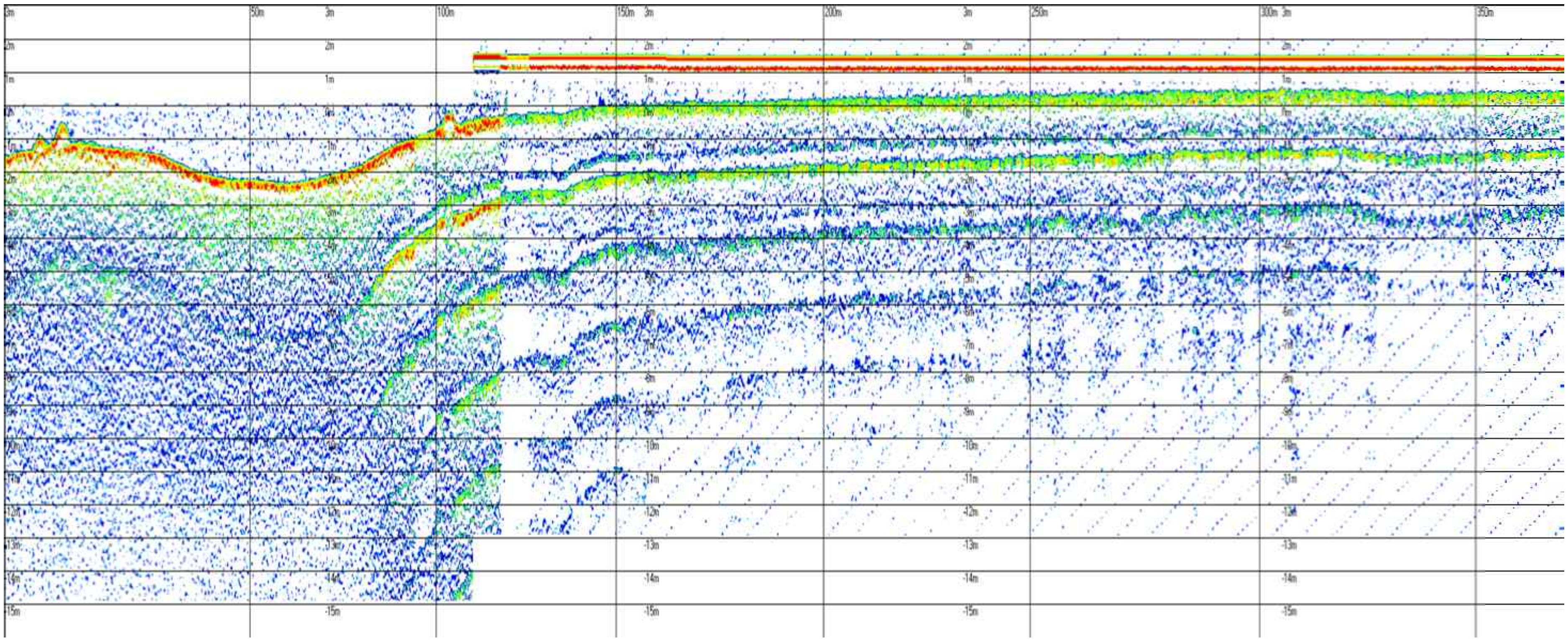
LINE EW 12





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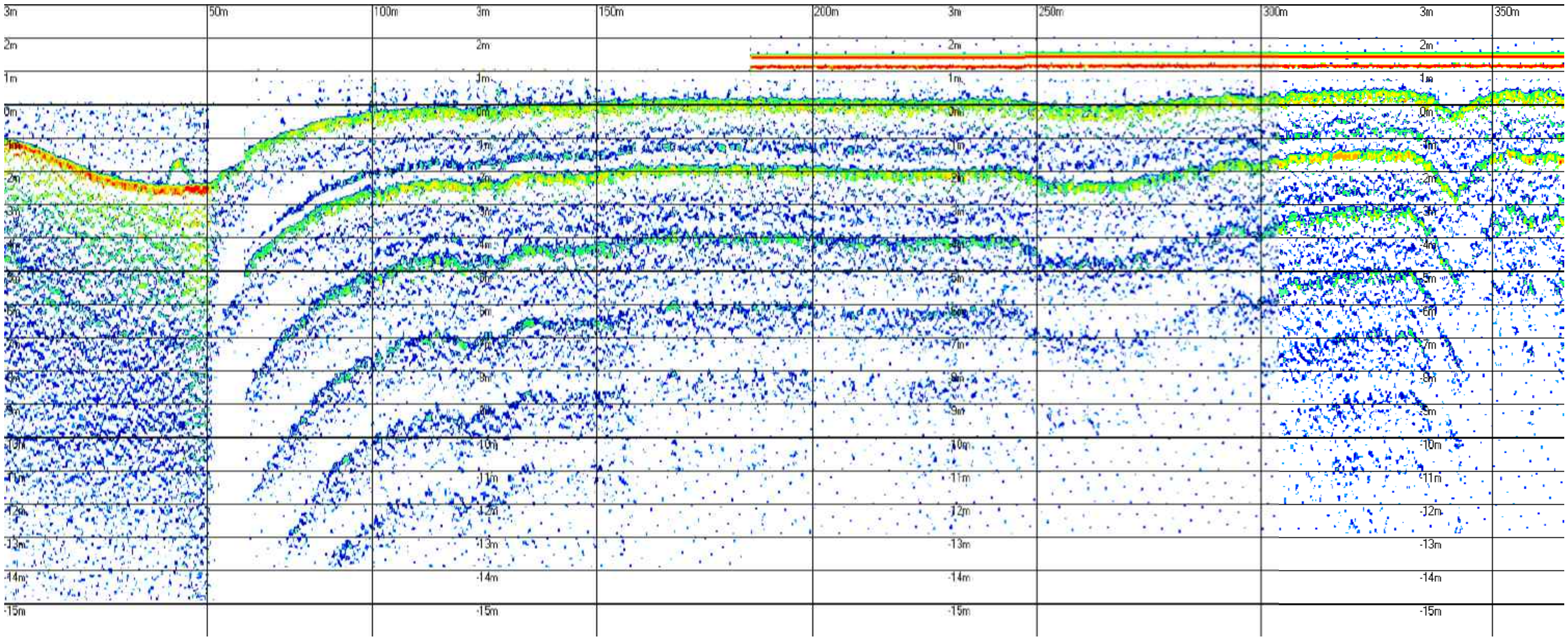

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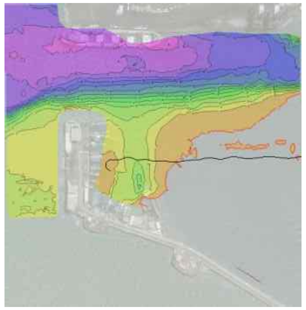

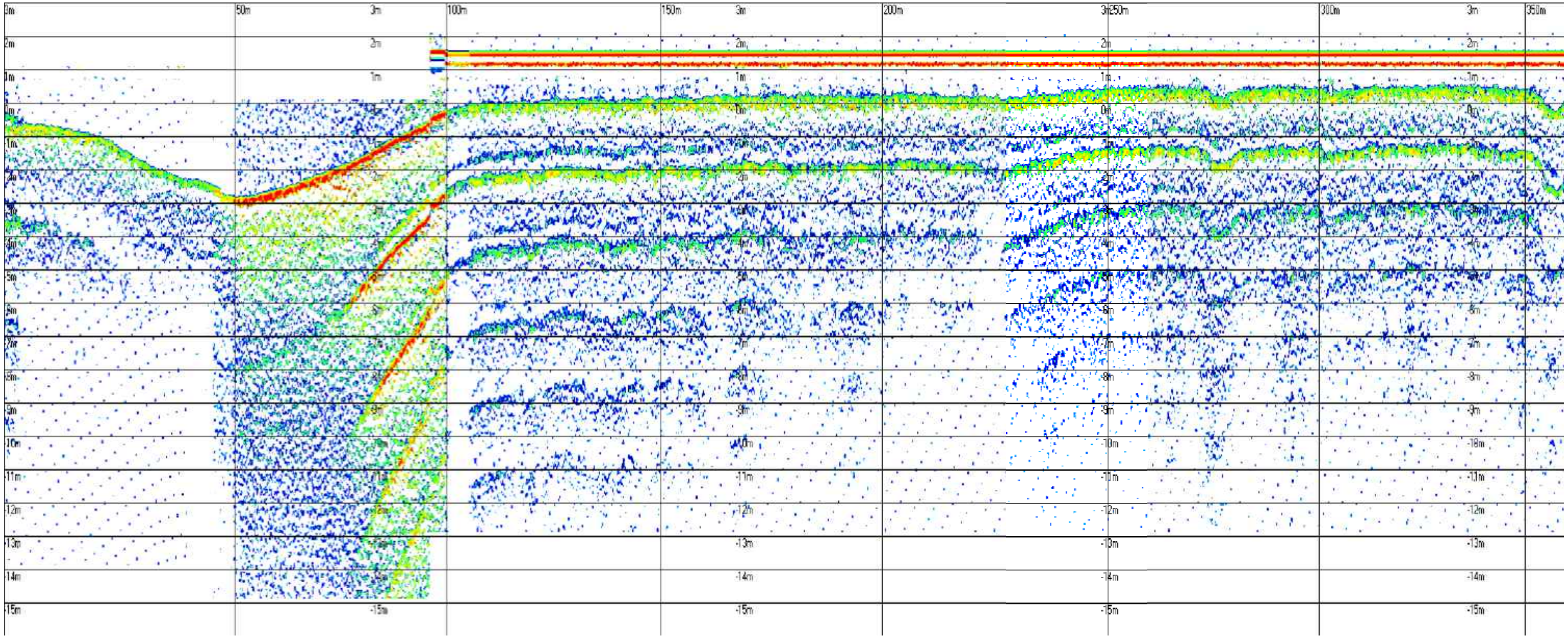

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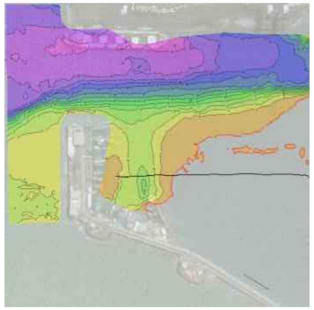
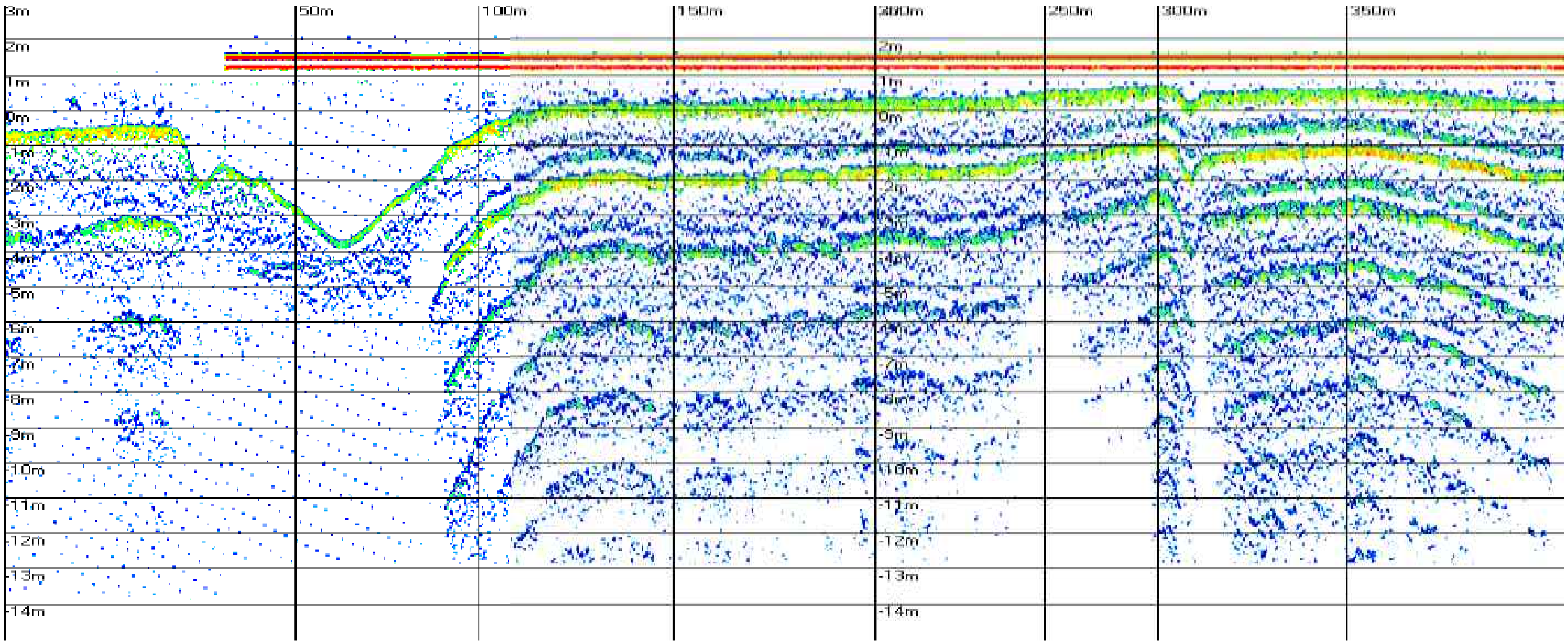
LINE EW 15





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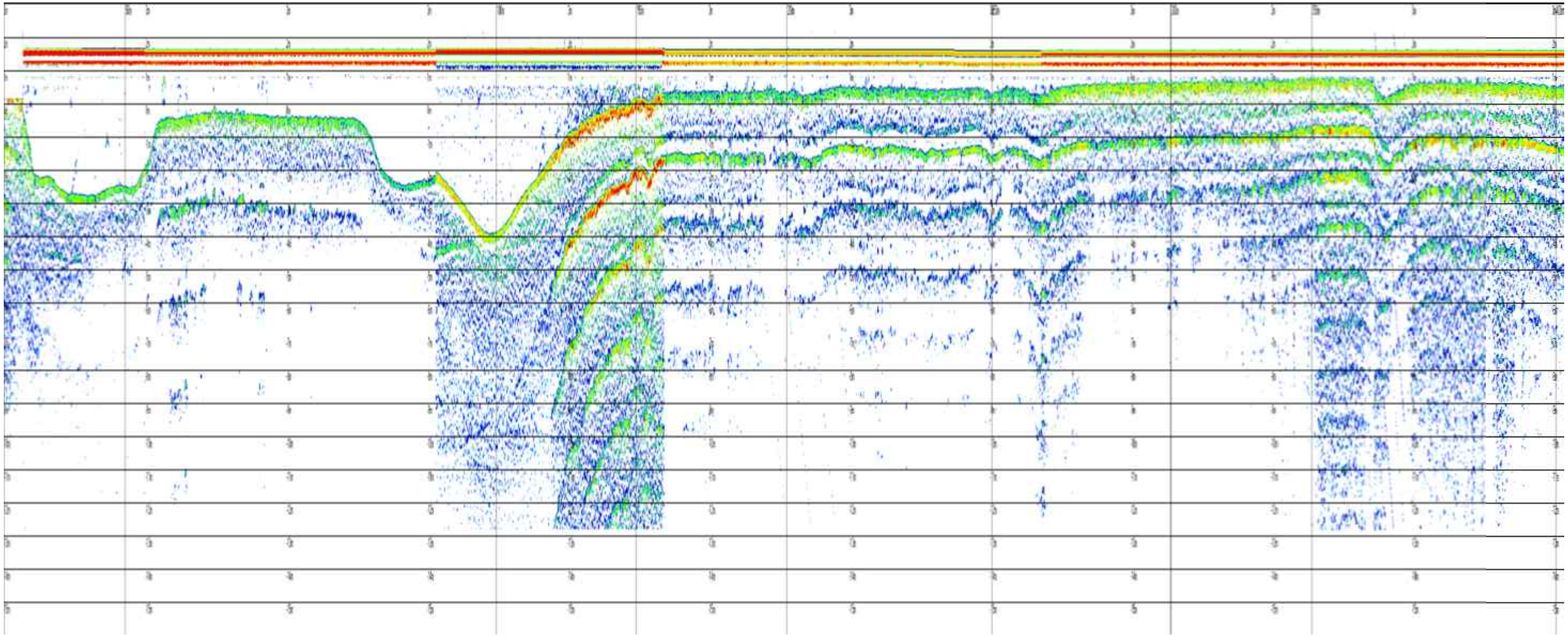
LINE EW 16



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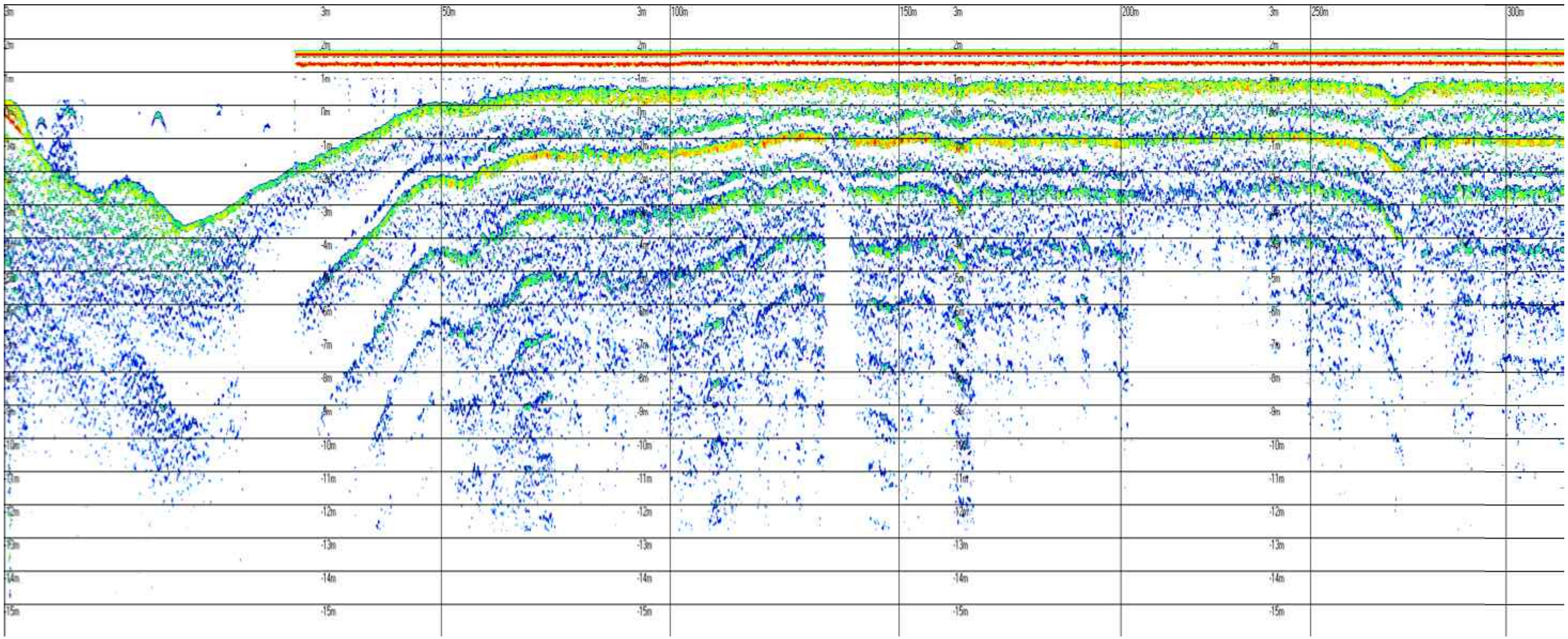

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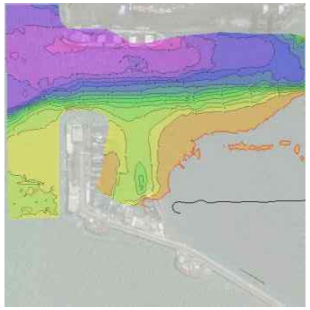

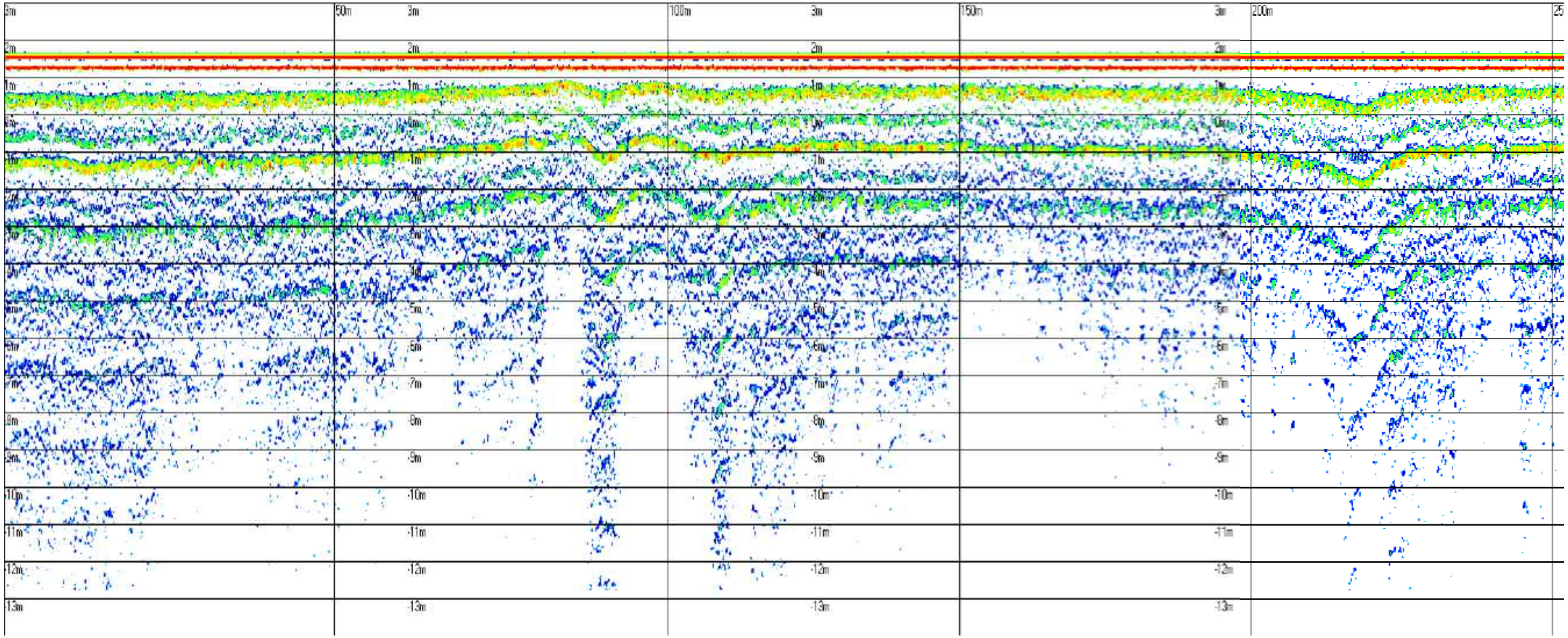

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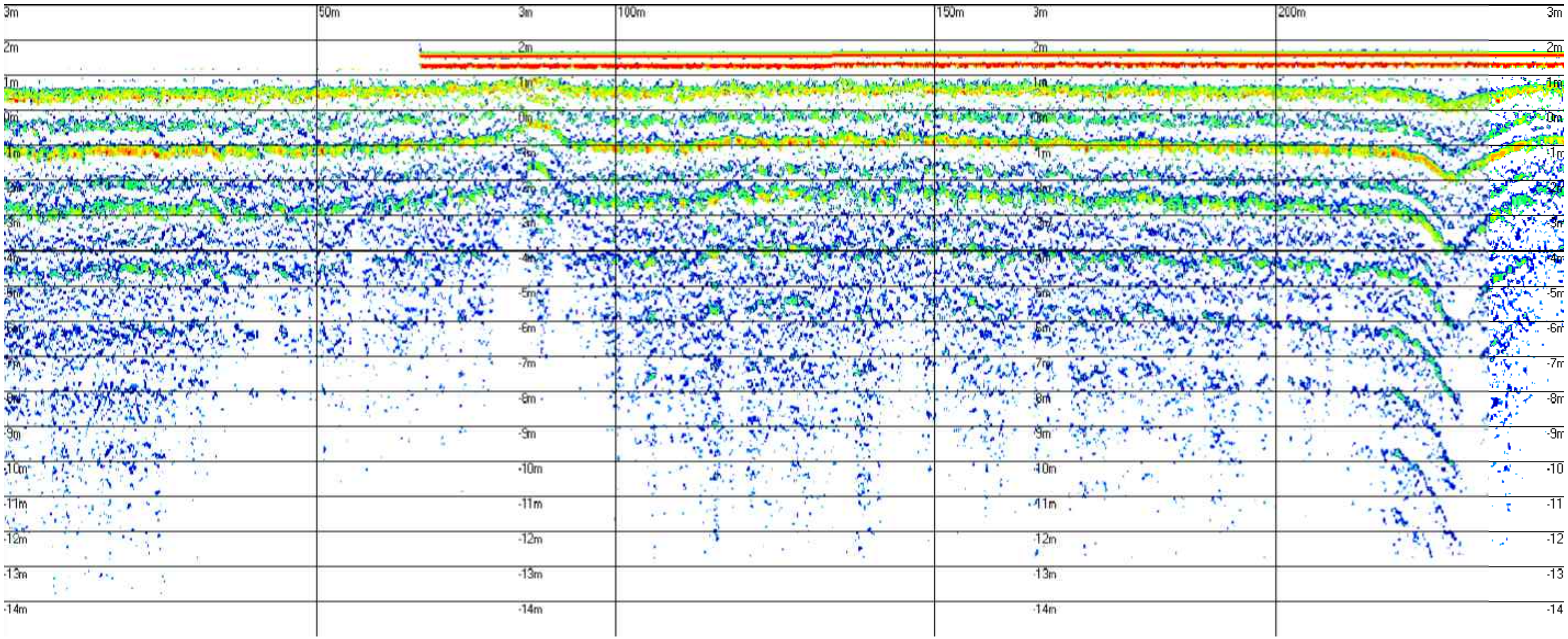
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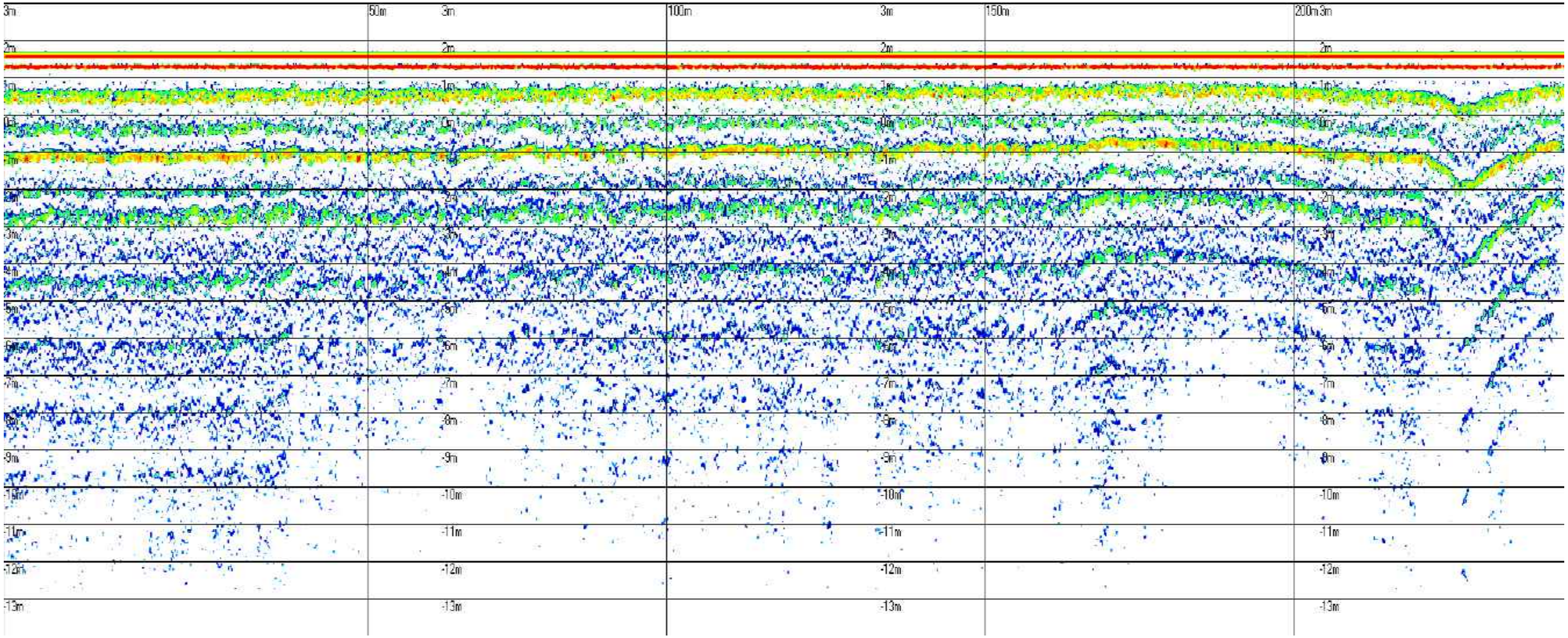
LINE EW 20



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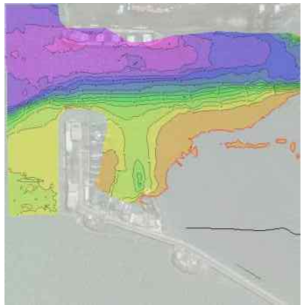
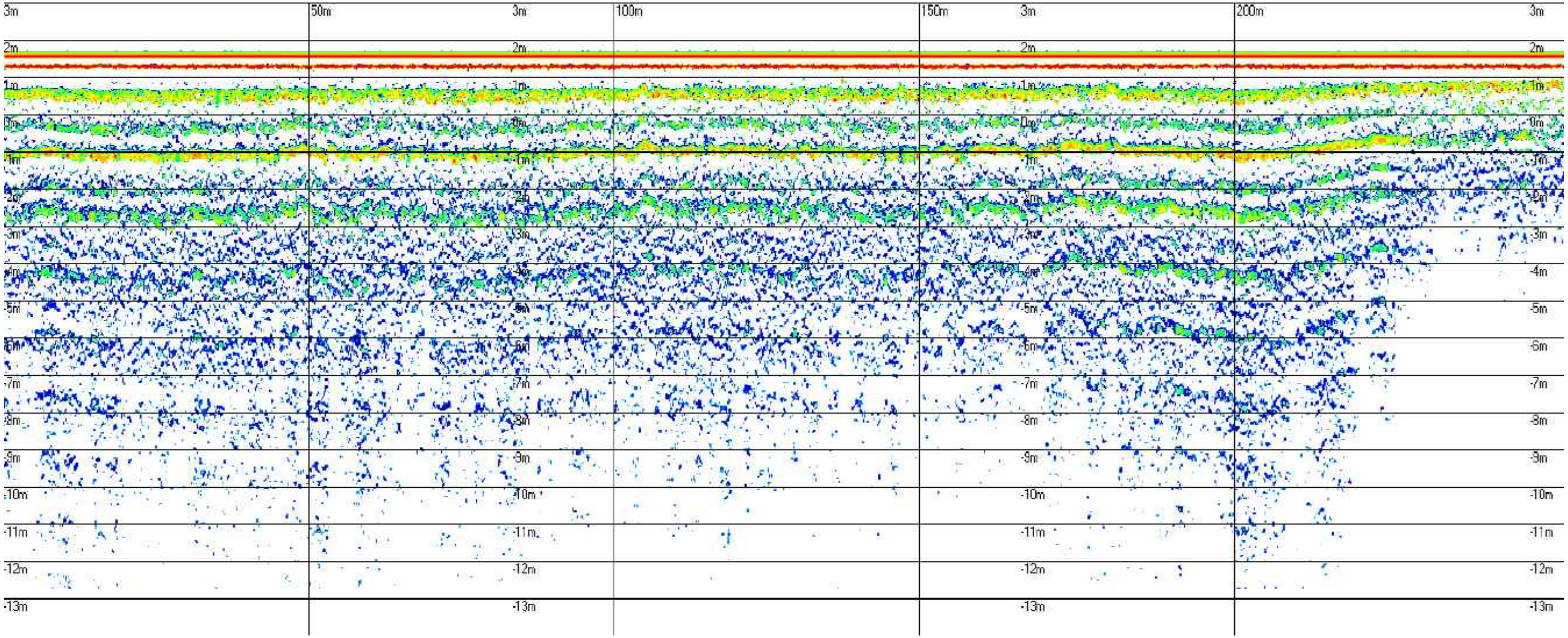
LINE EW 21





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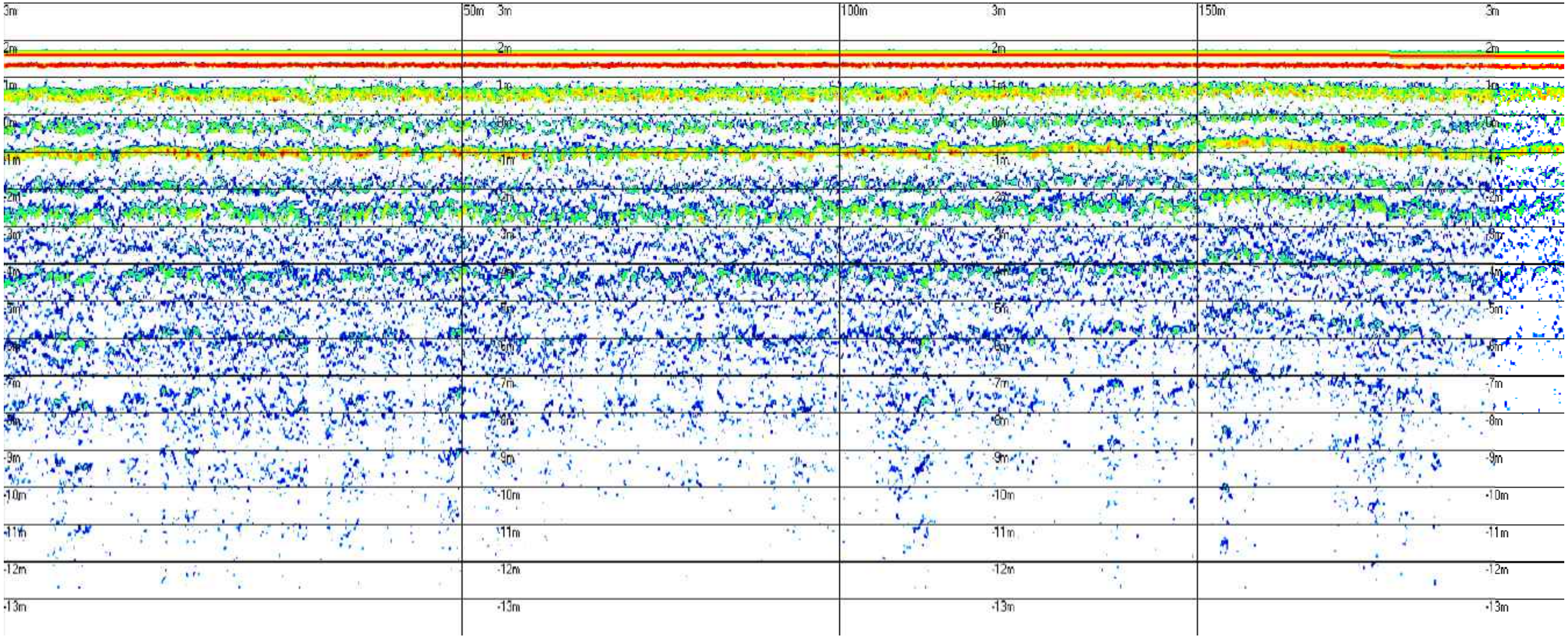
LINE EW 22



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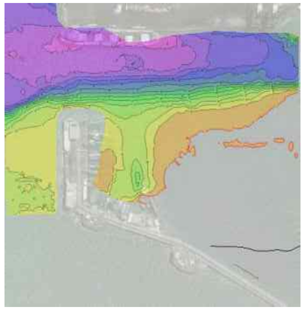

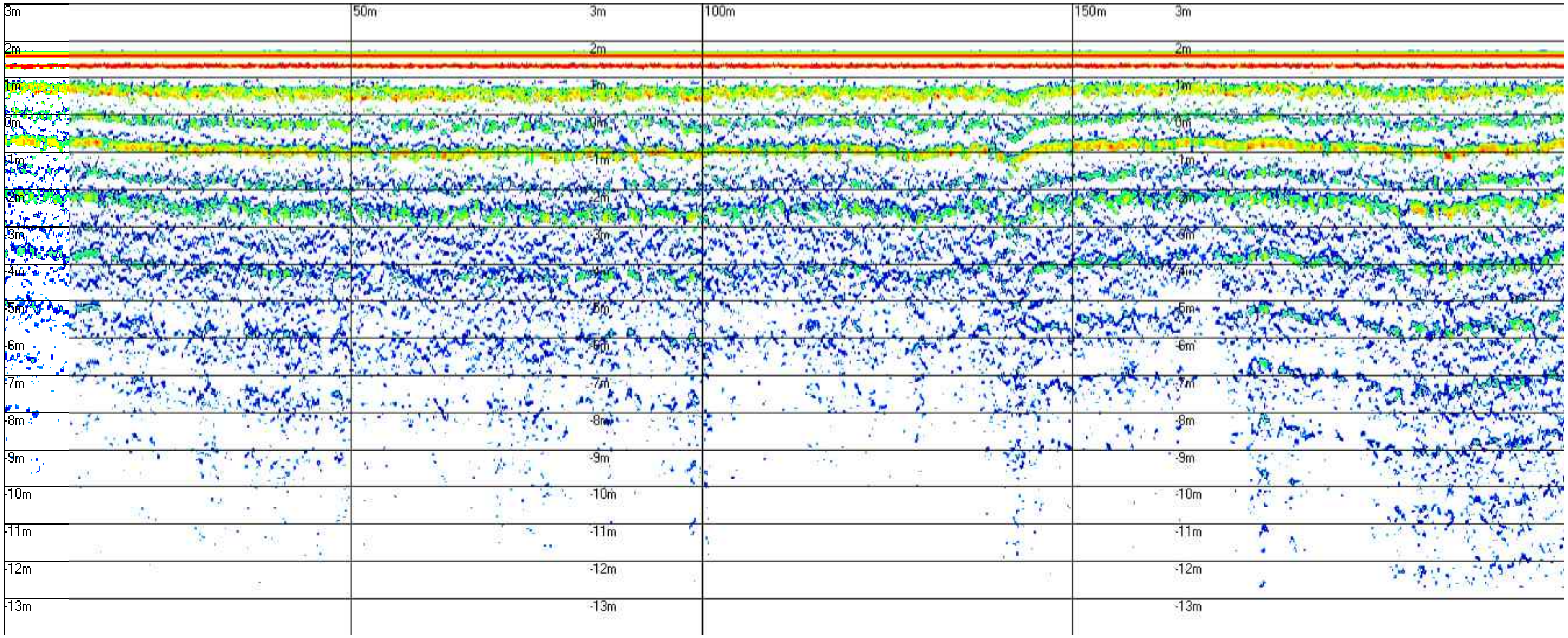

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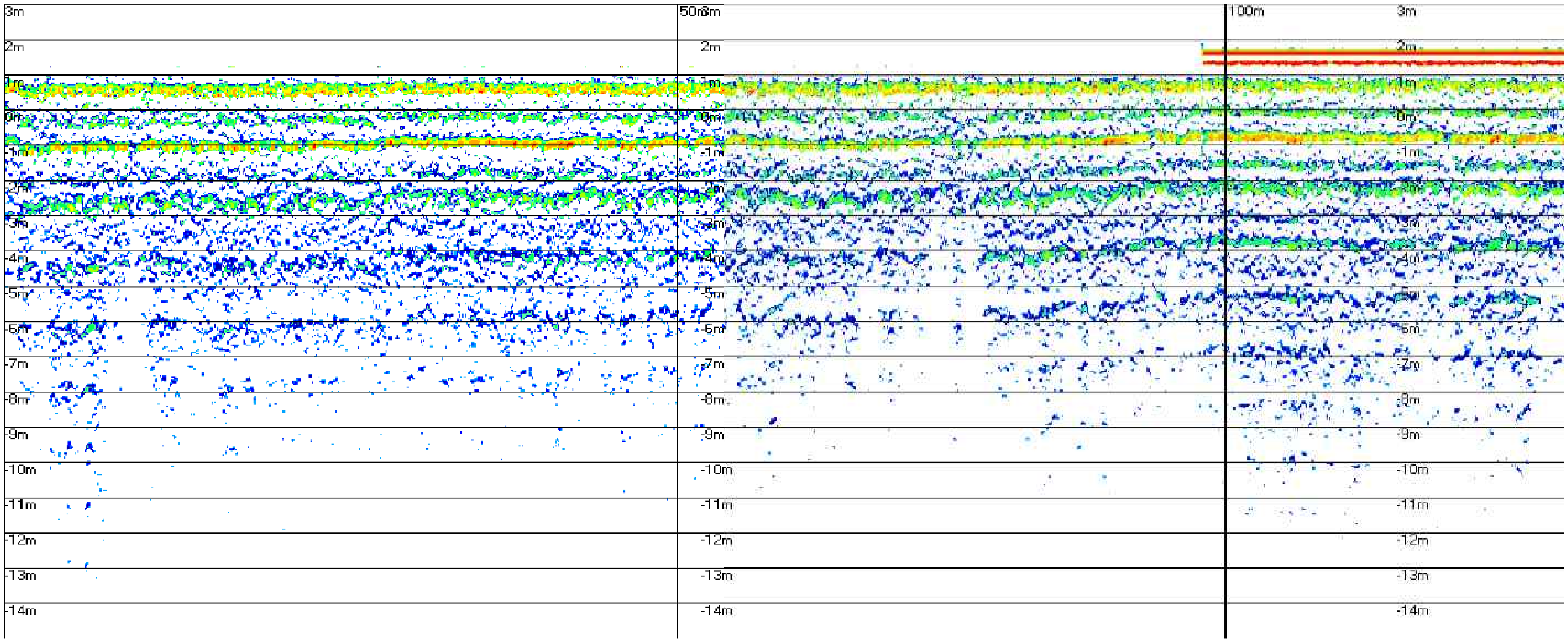

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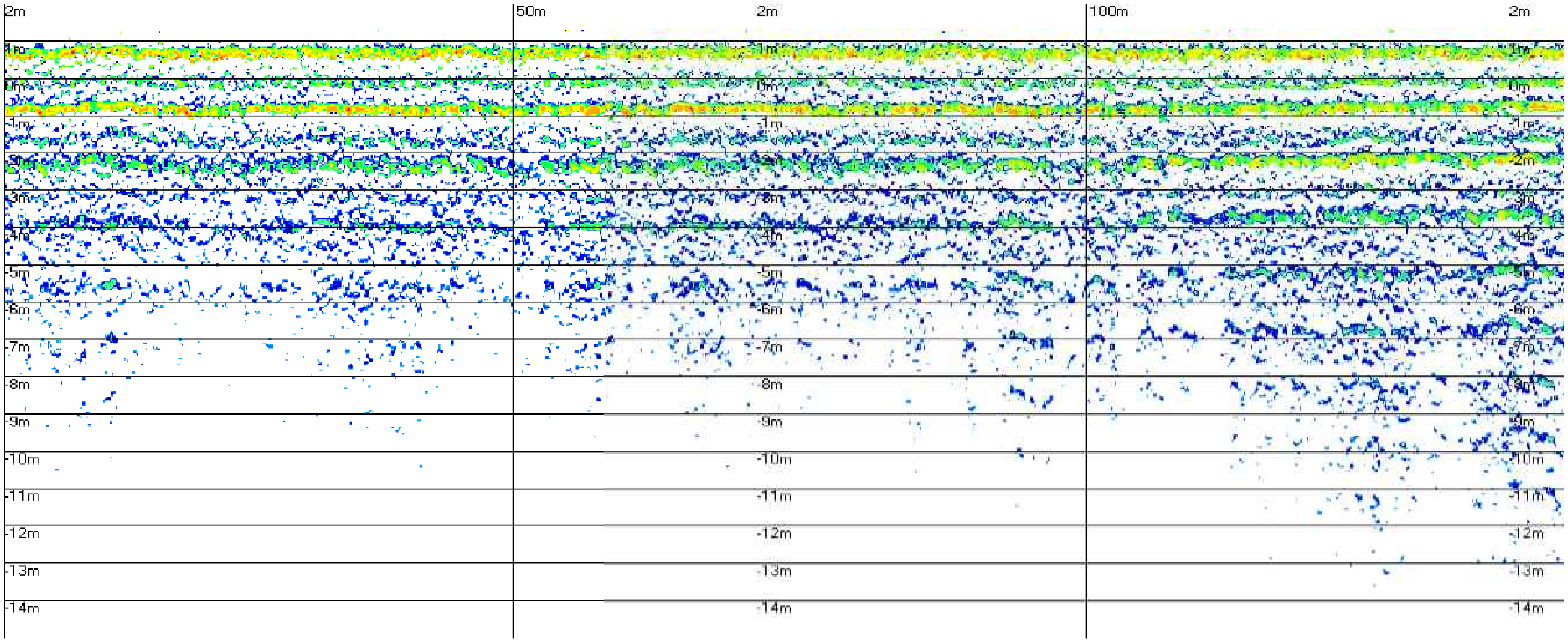
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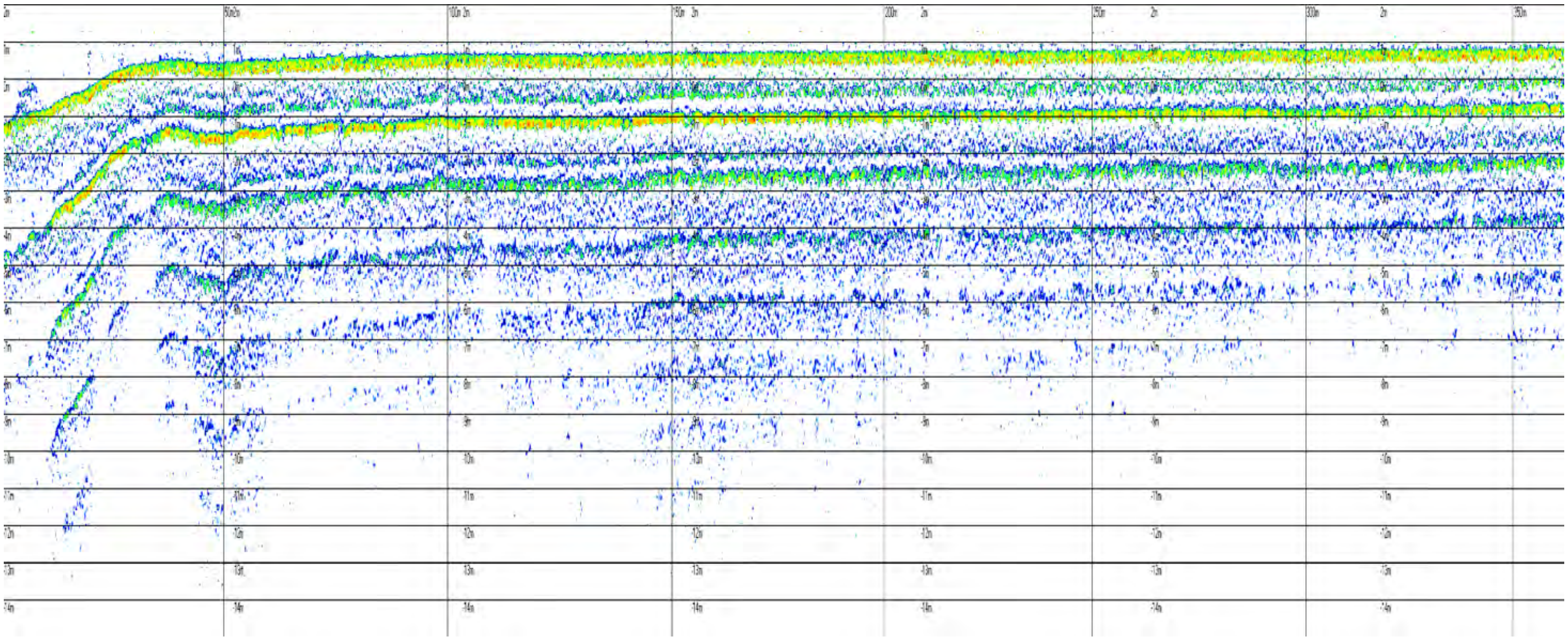
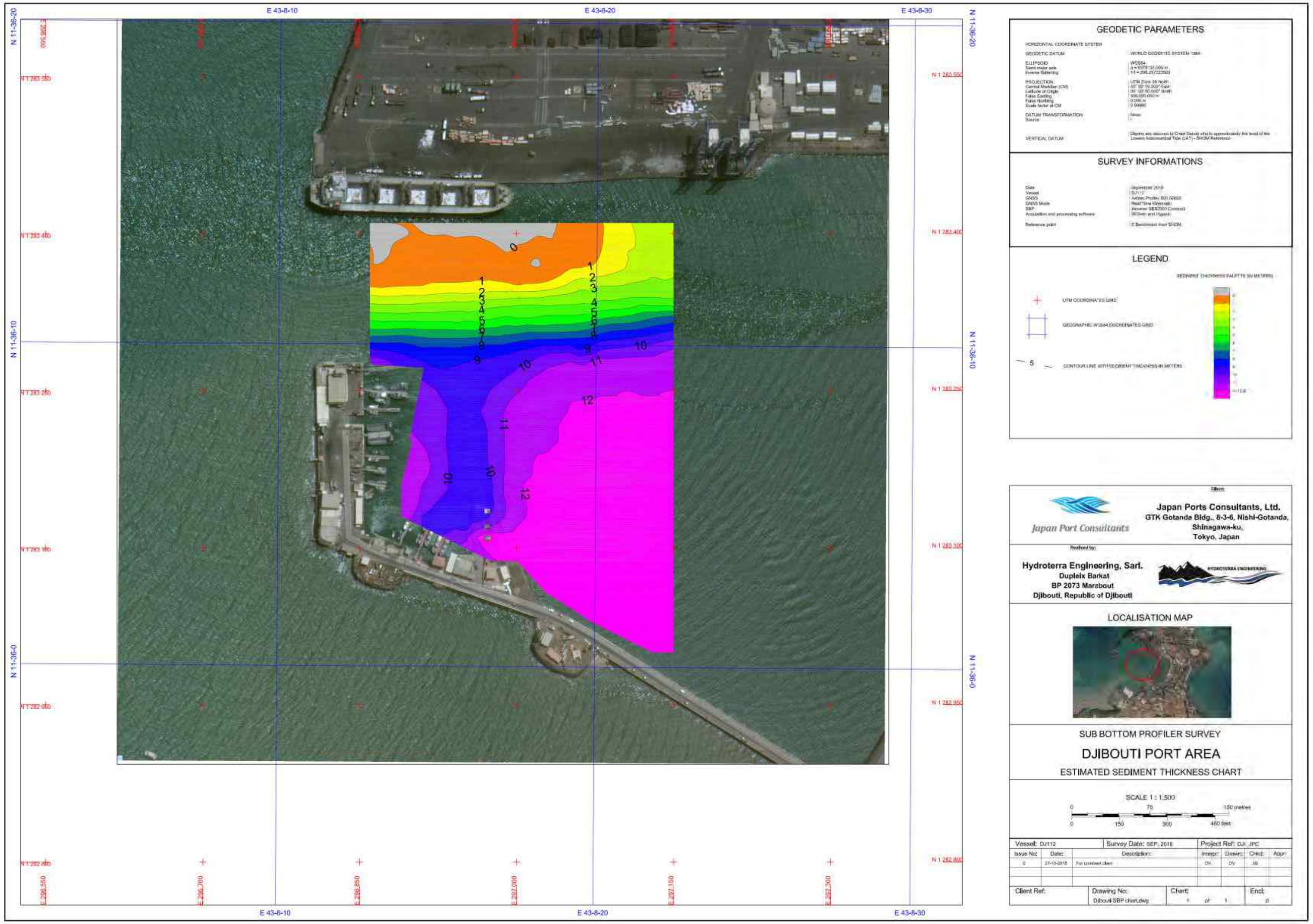
LINE EW 26



10.3 Appendix B - SBP chart of Djibouti area

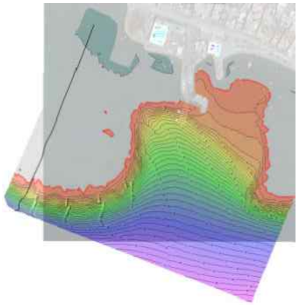


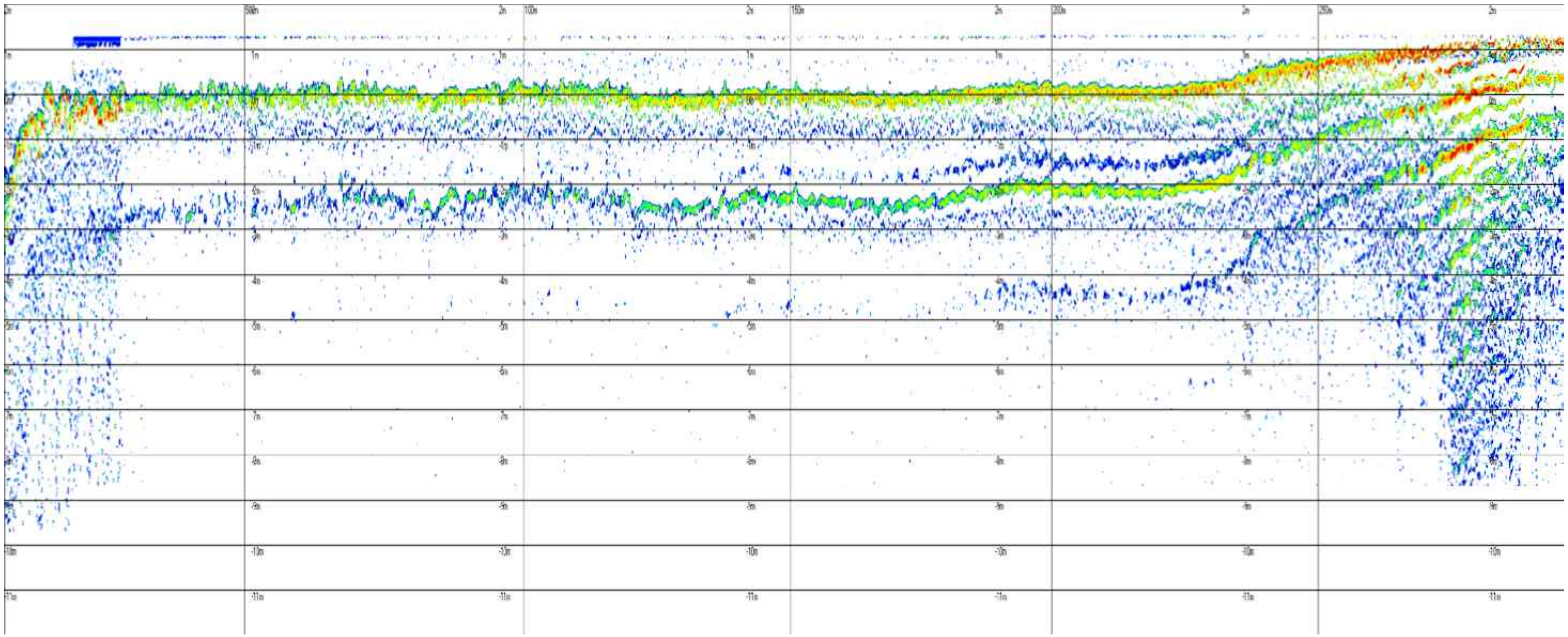
10.4 Appendix C- SBP lines of Tadjourah area

The SBP lines presented for Tadjourah area are shown on figure 38.

Figure 15 : Tadjourah SPB lines presented in appendix C

LINE SW-NE 2





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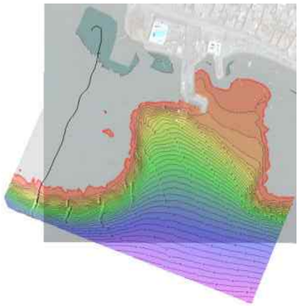
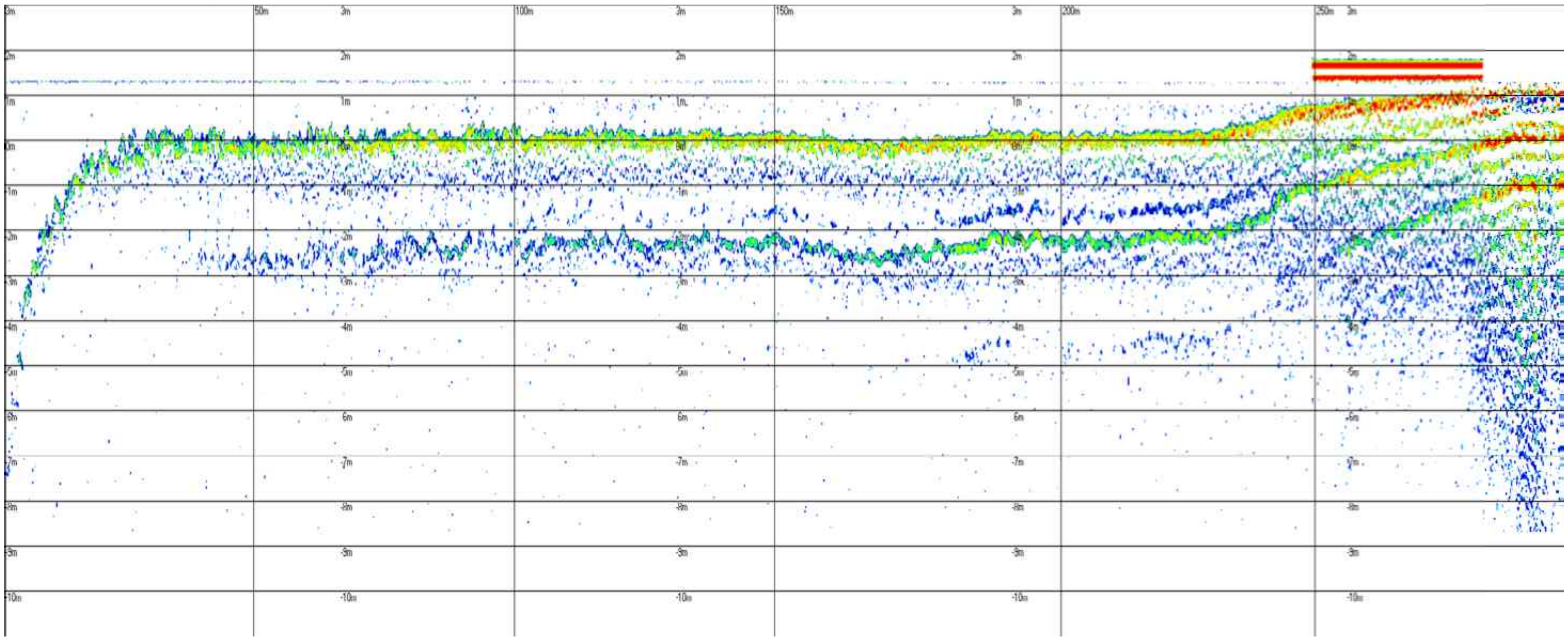
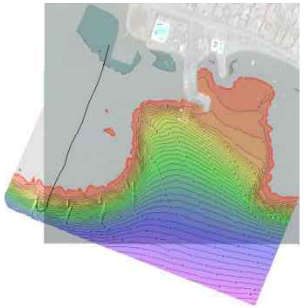
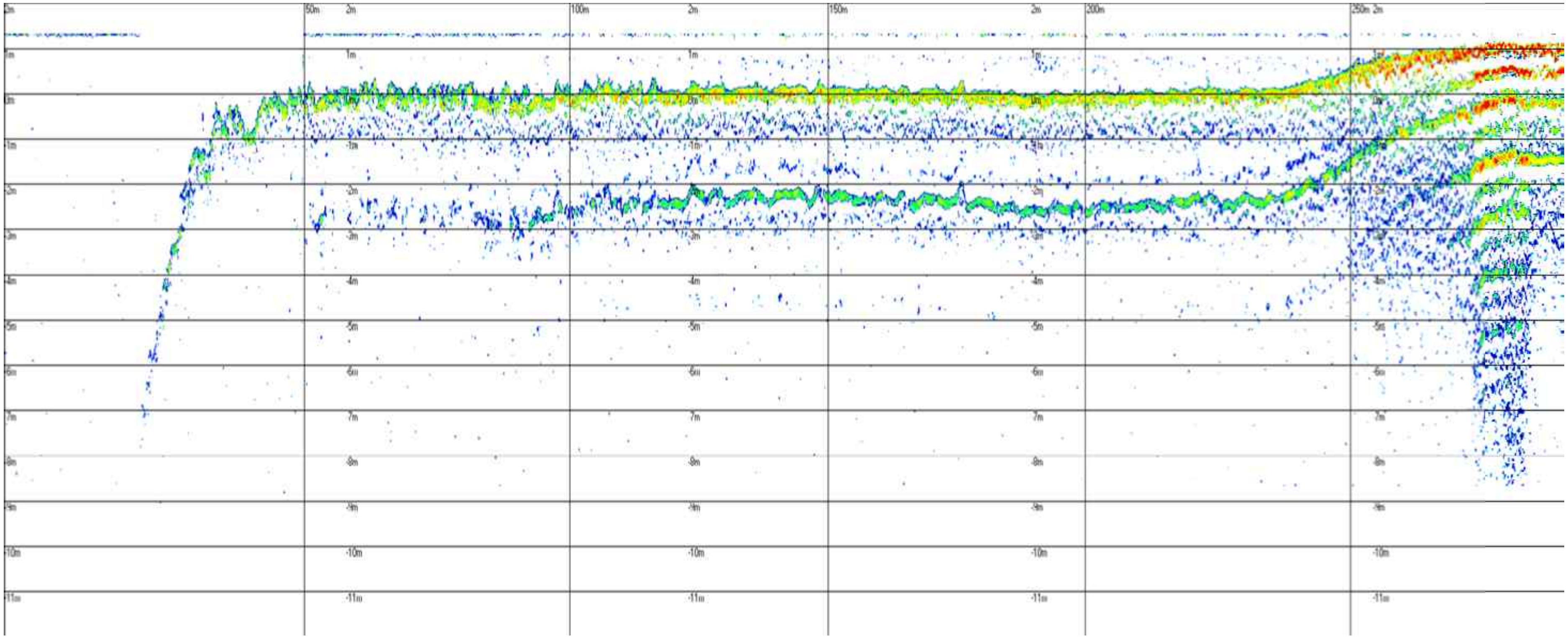



0m
50m
100m
150m
200m
250m
3m
2m
1m
0m
-1m
-2m
-3m
-4m
-5m
-6m
-7m
-8m
-9m
-10m

LINE SW-NE 4





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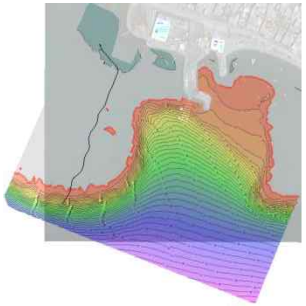

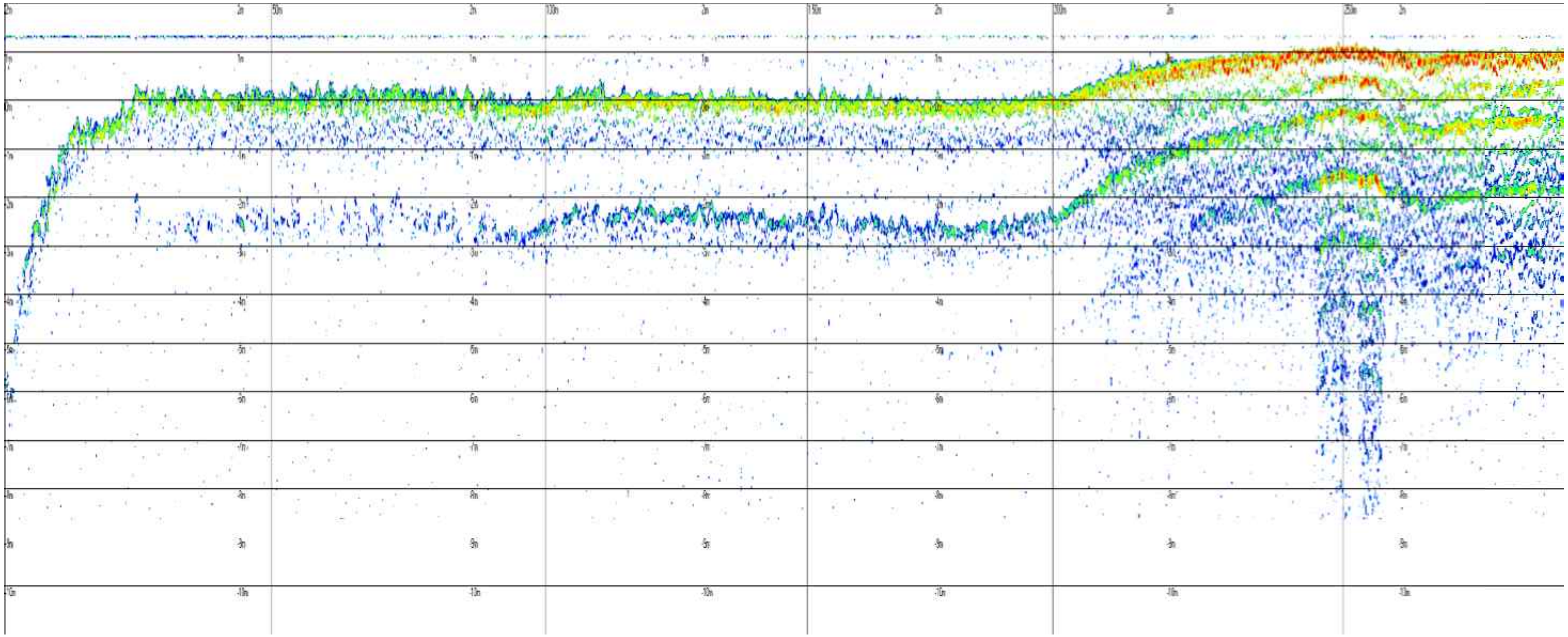

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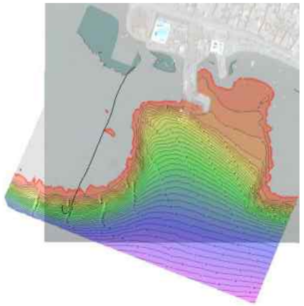

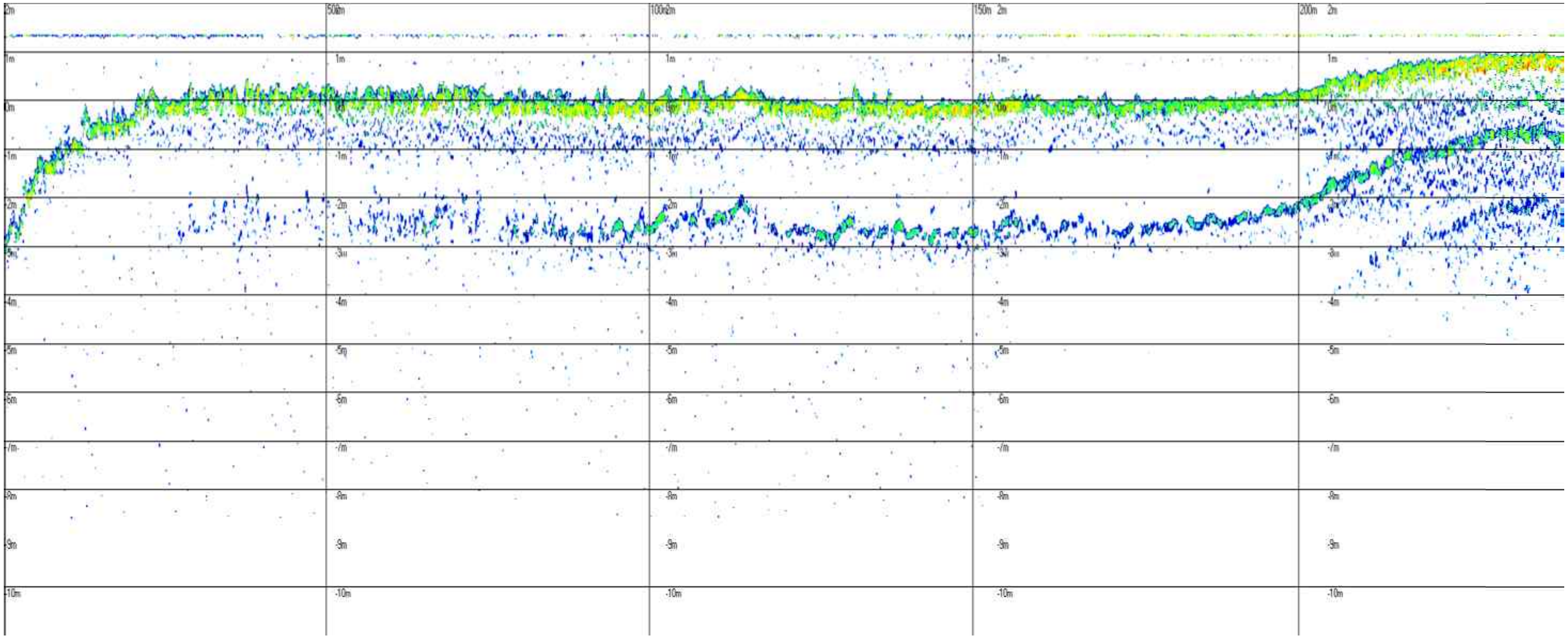

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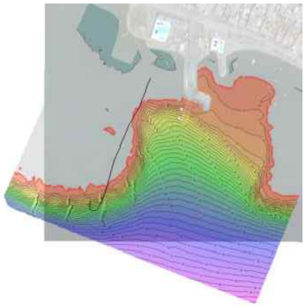

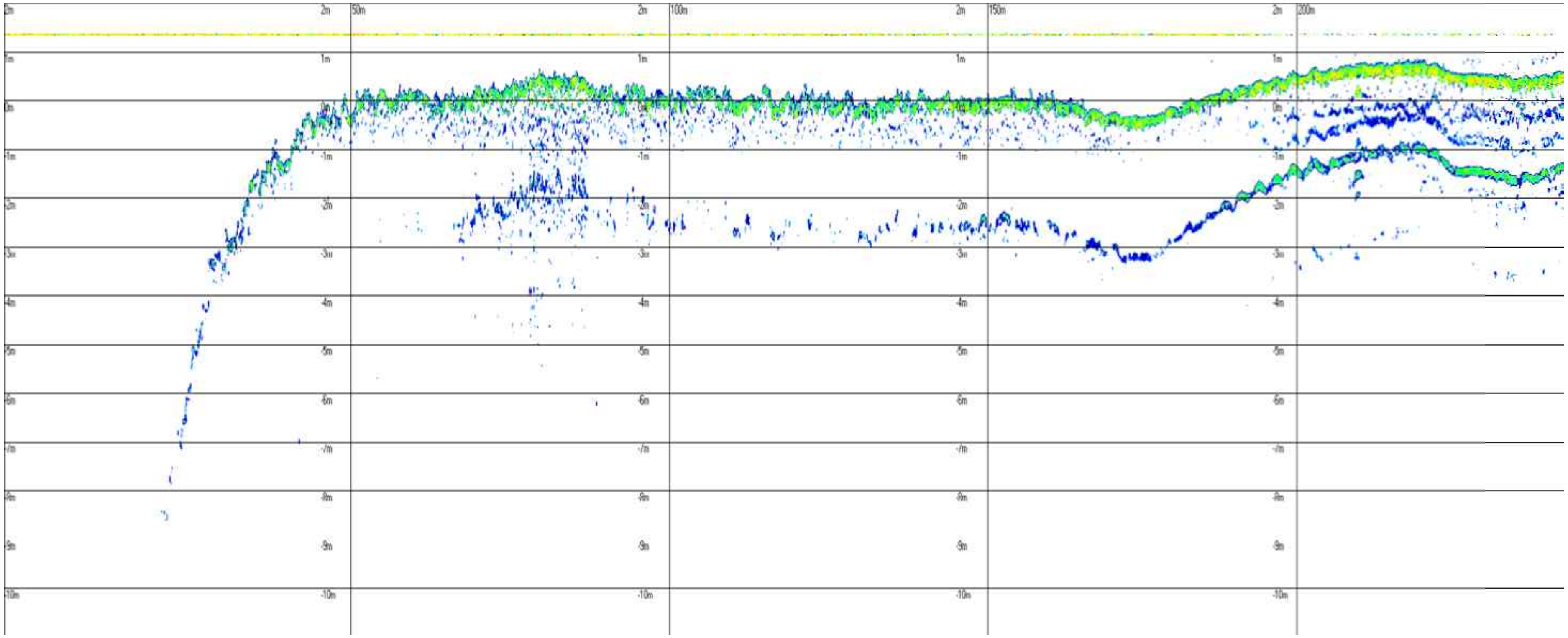

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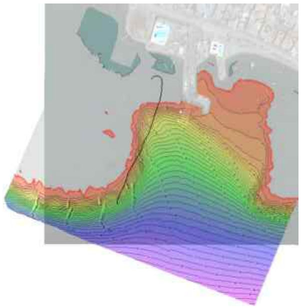

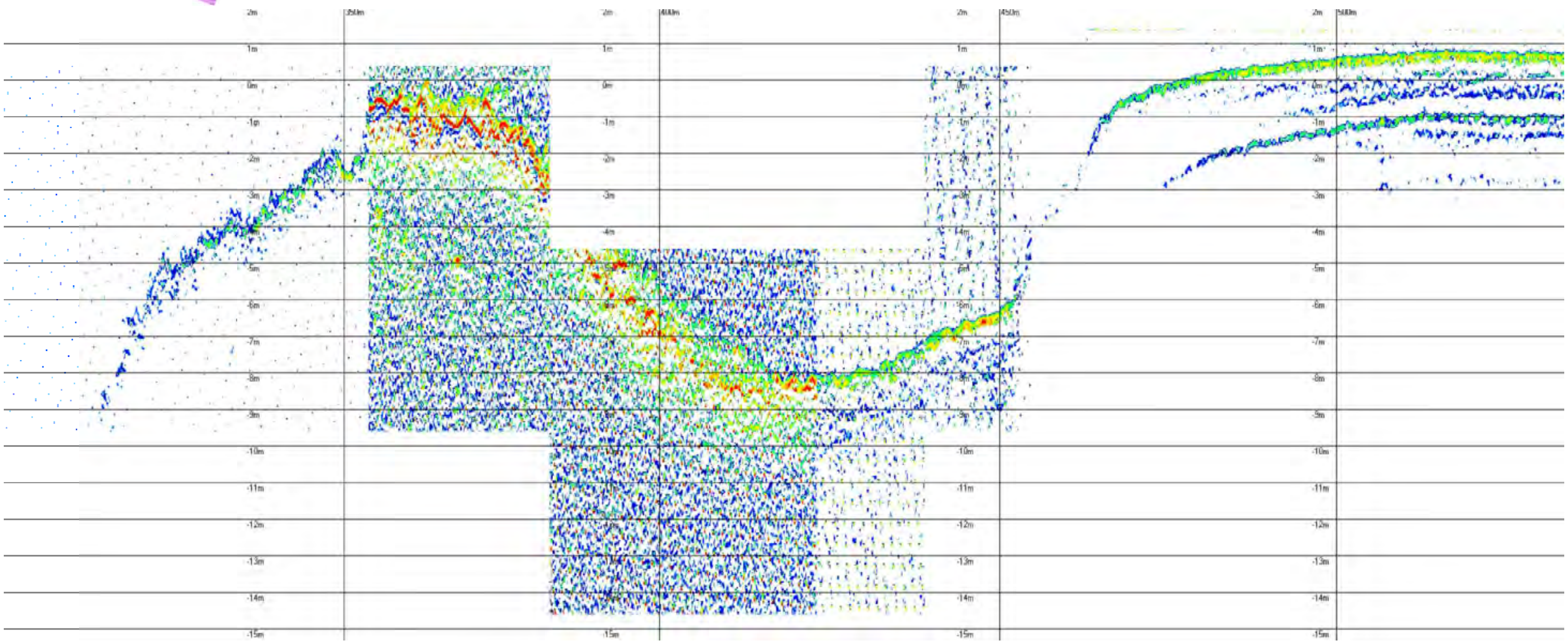

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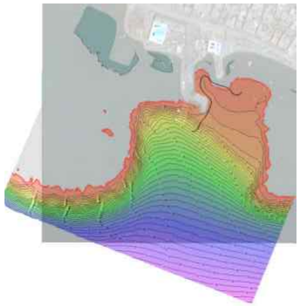

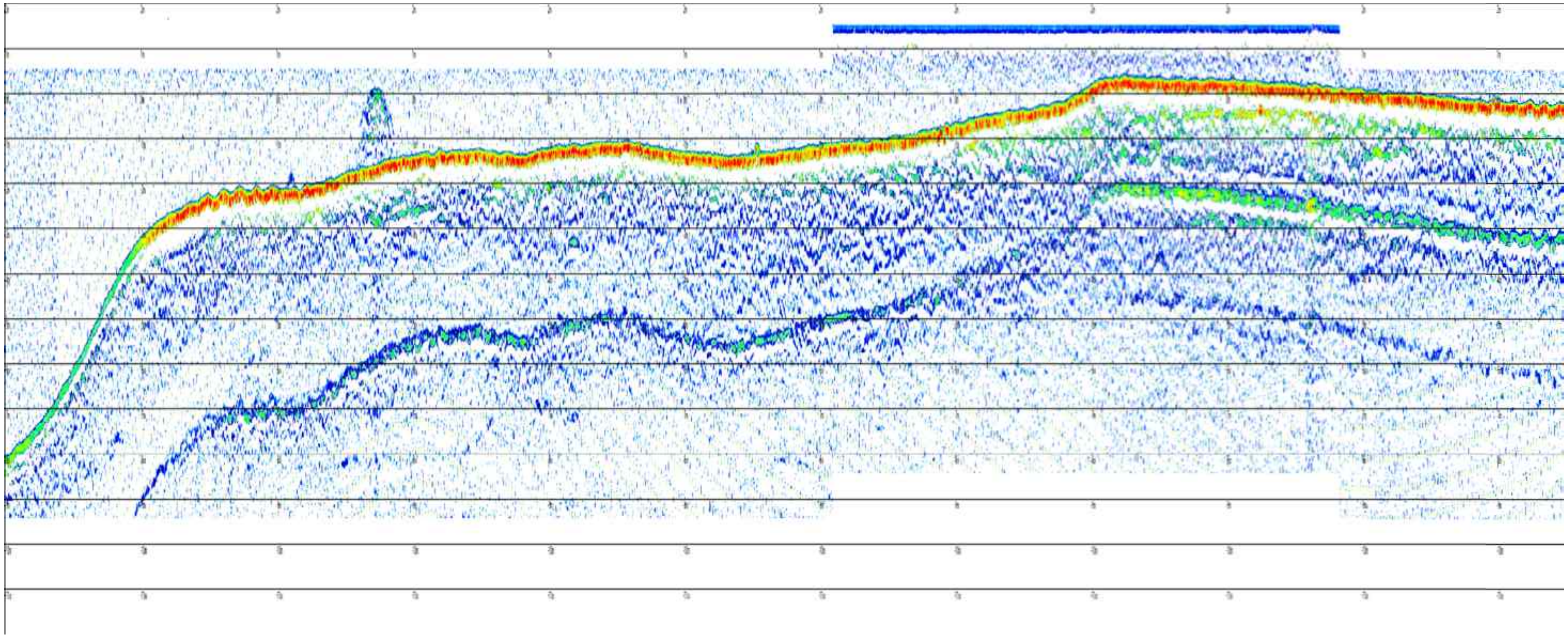

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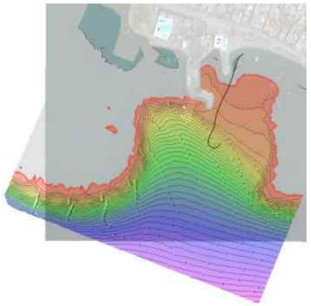

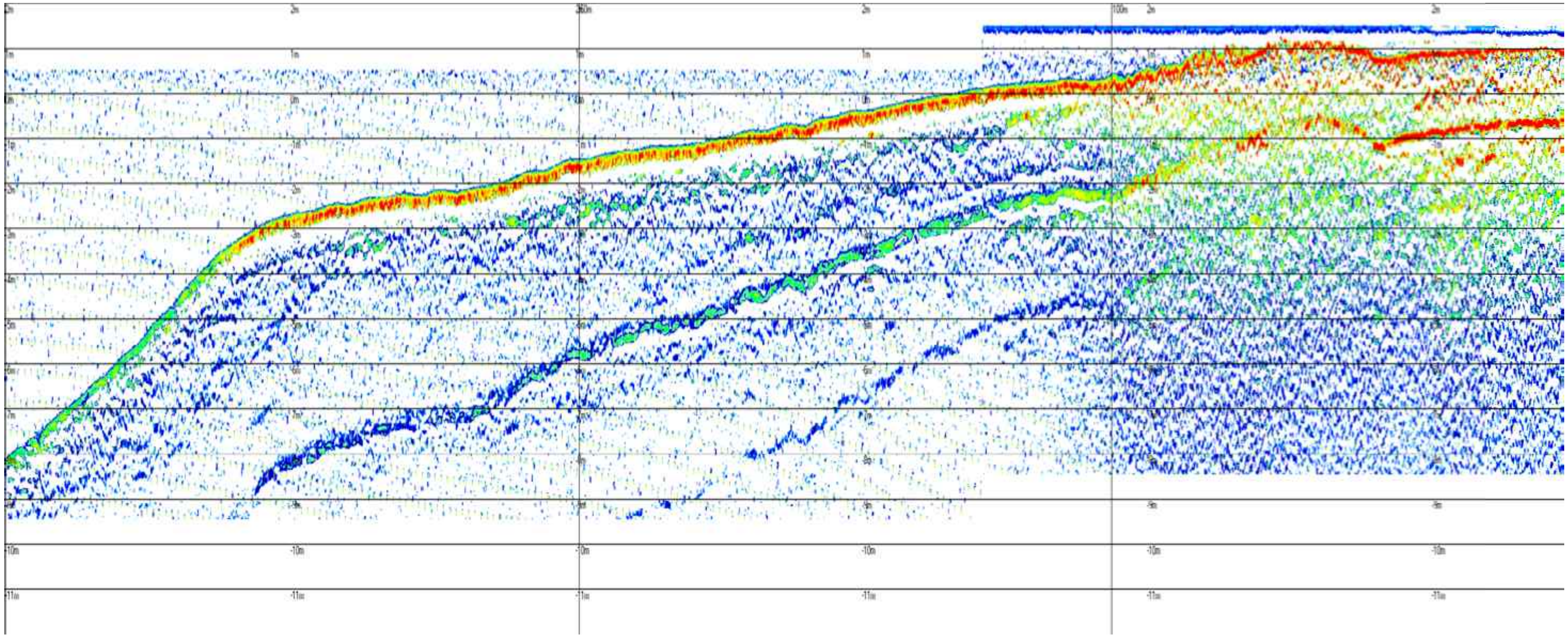

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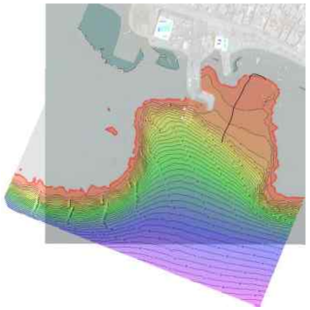

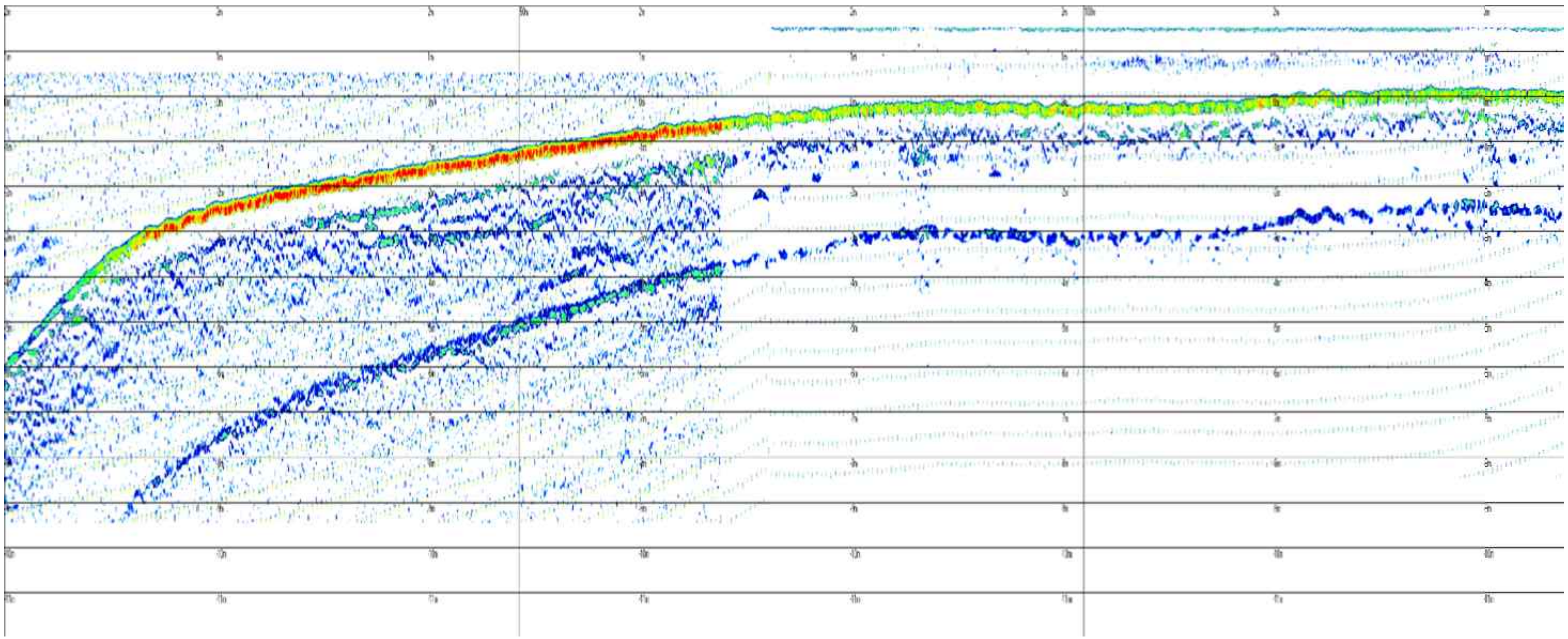

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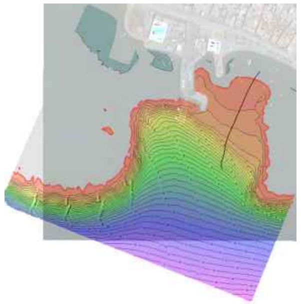

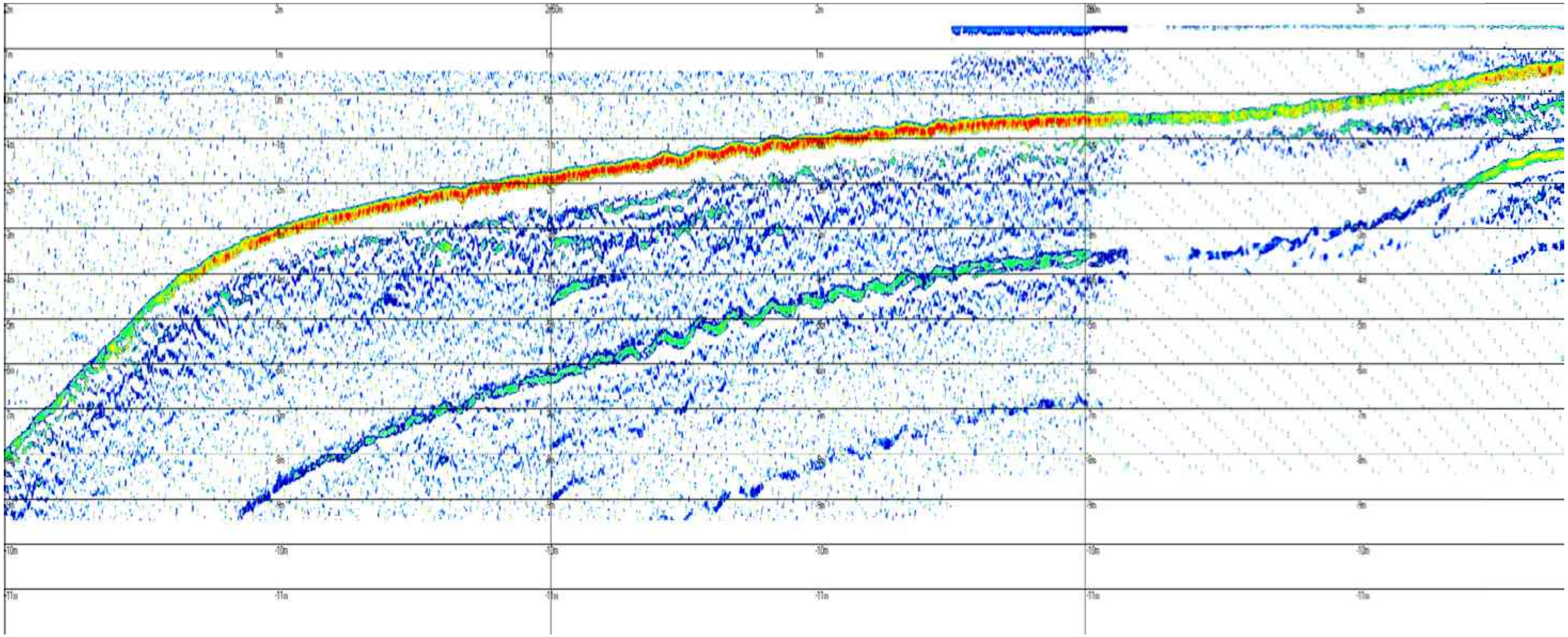

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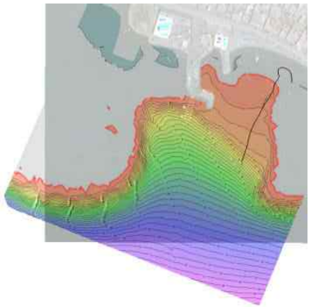

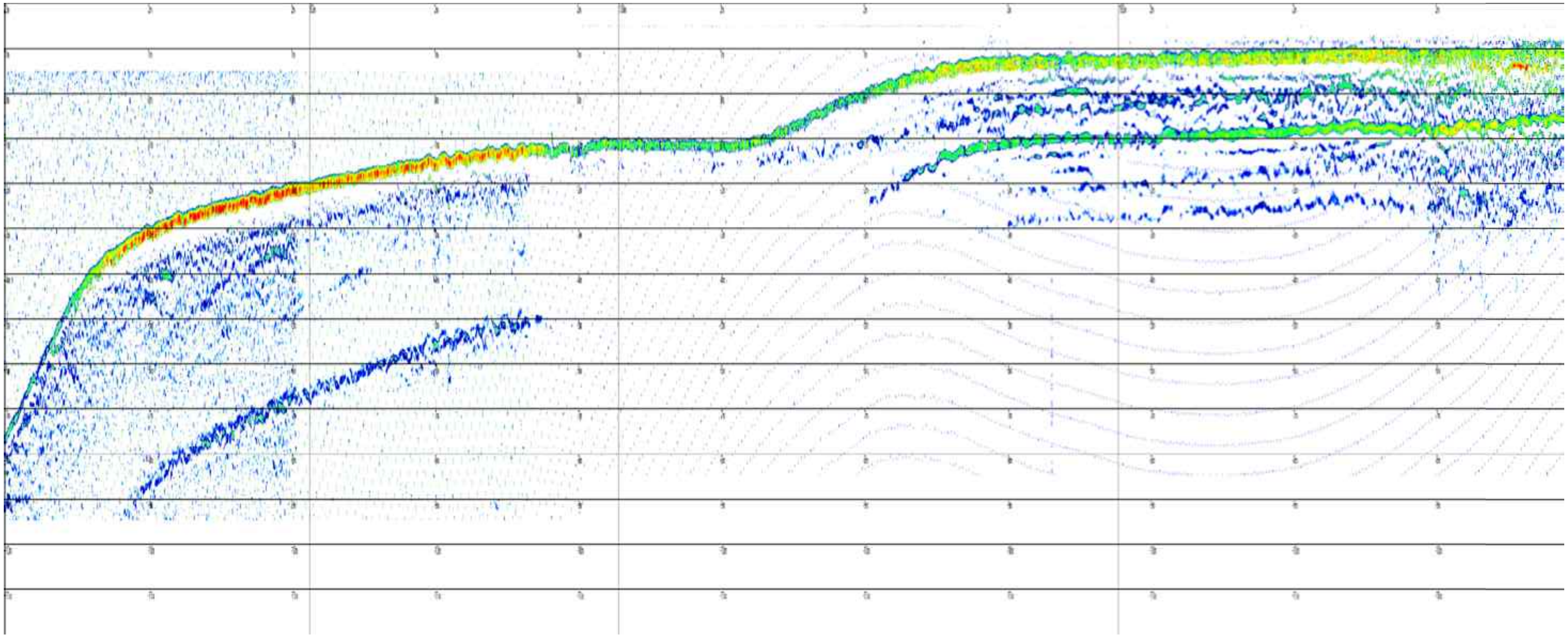

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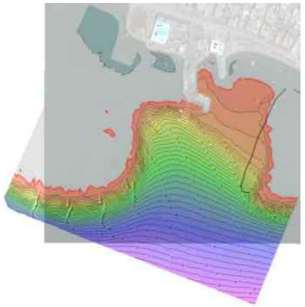

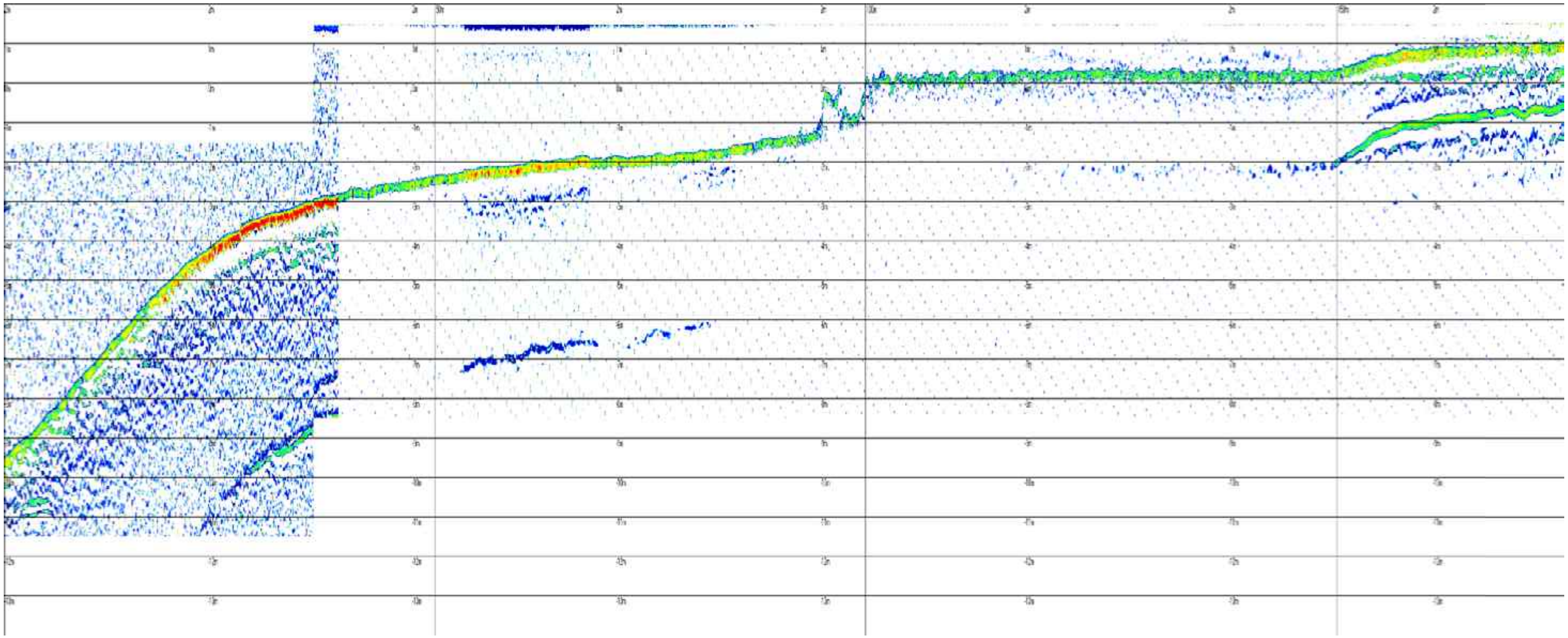

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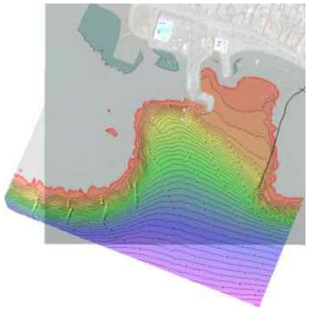

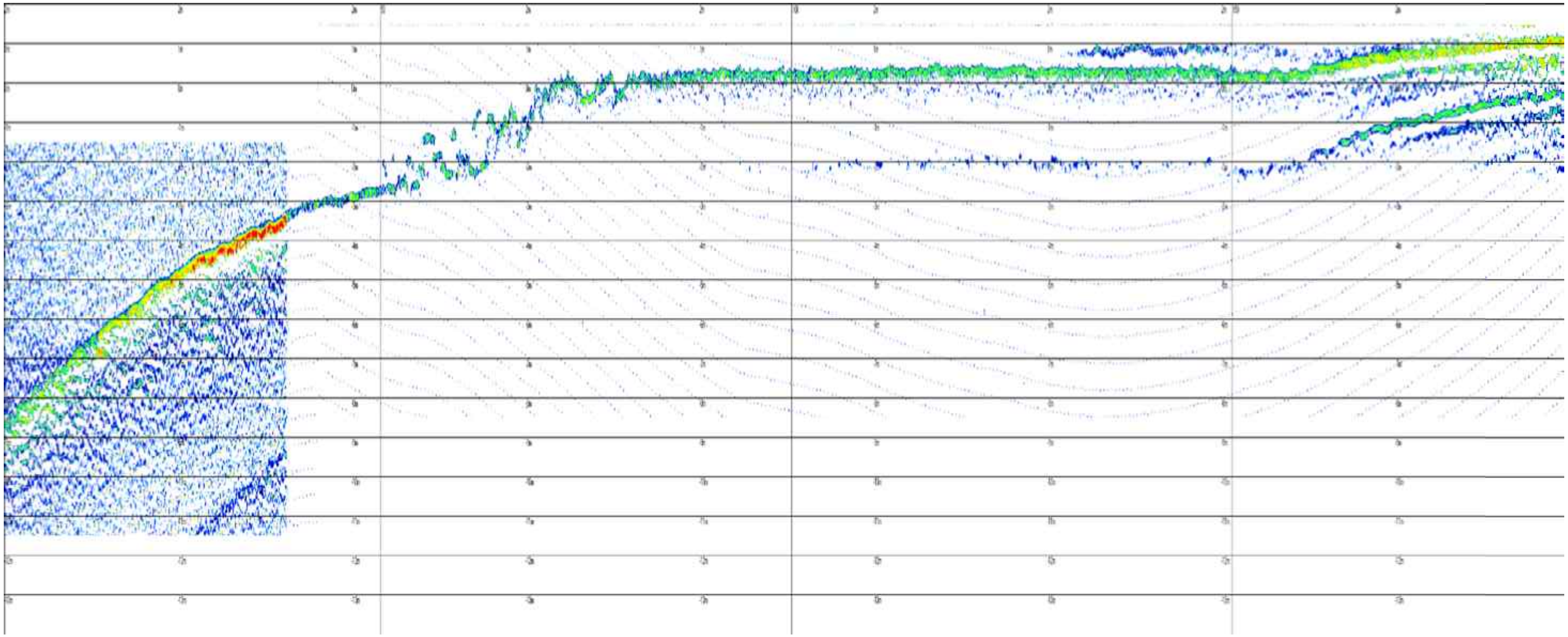

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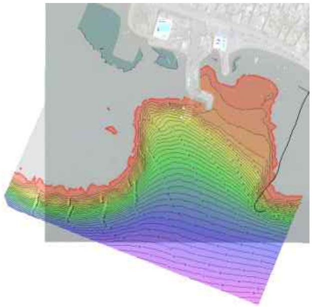

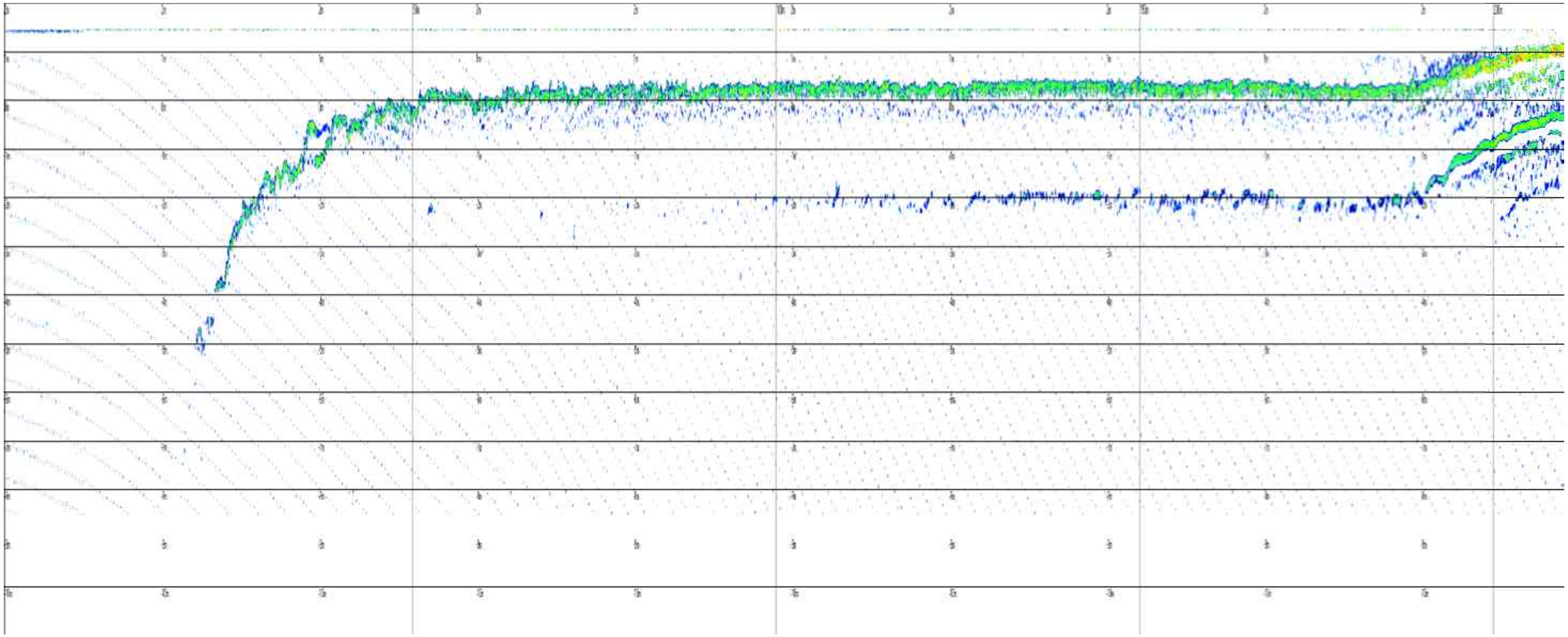

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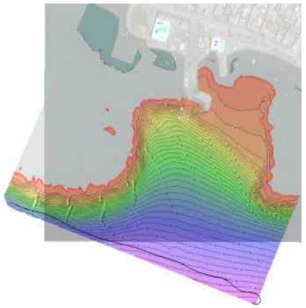

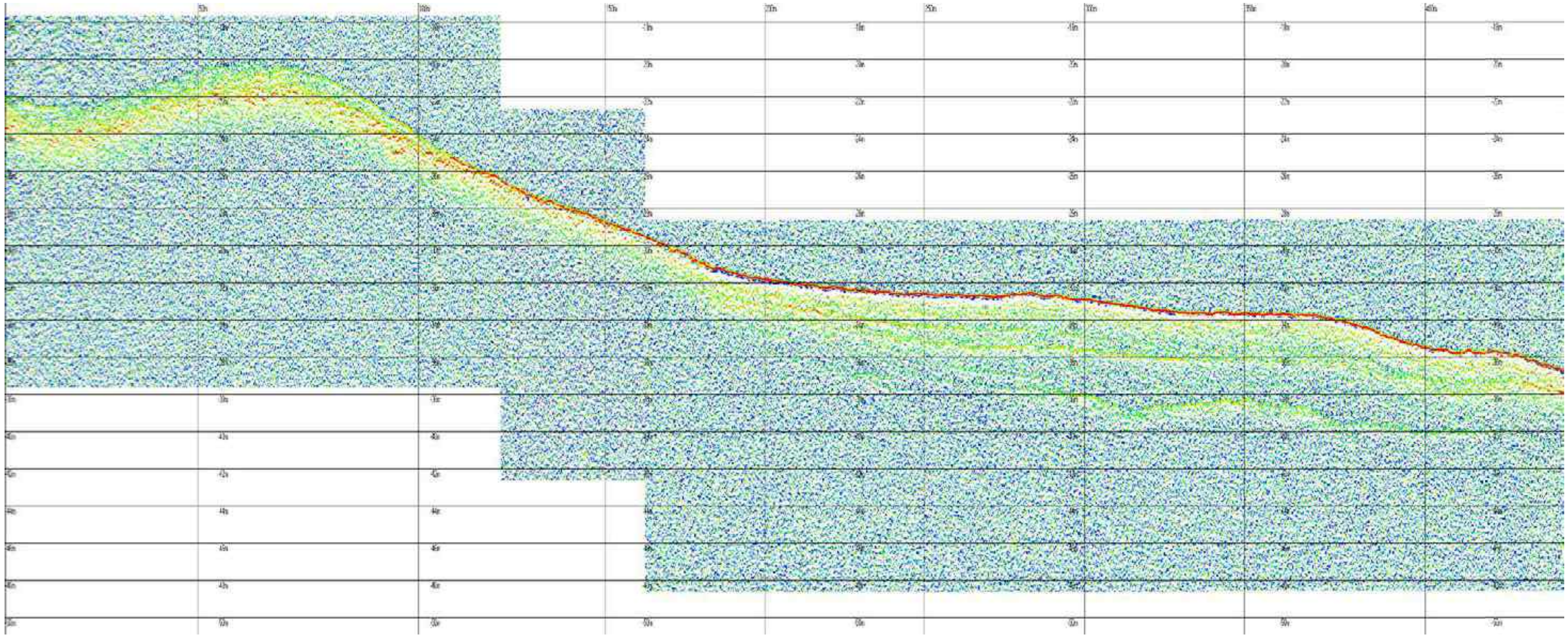

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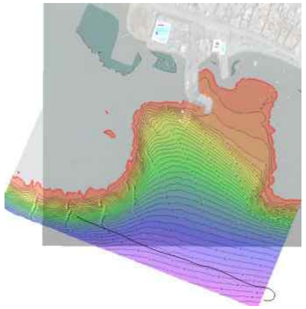

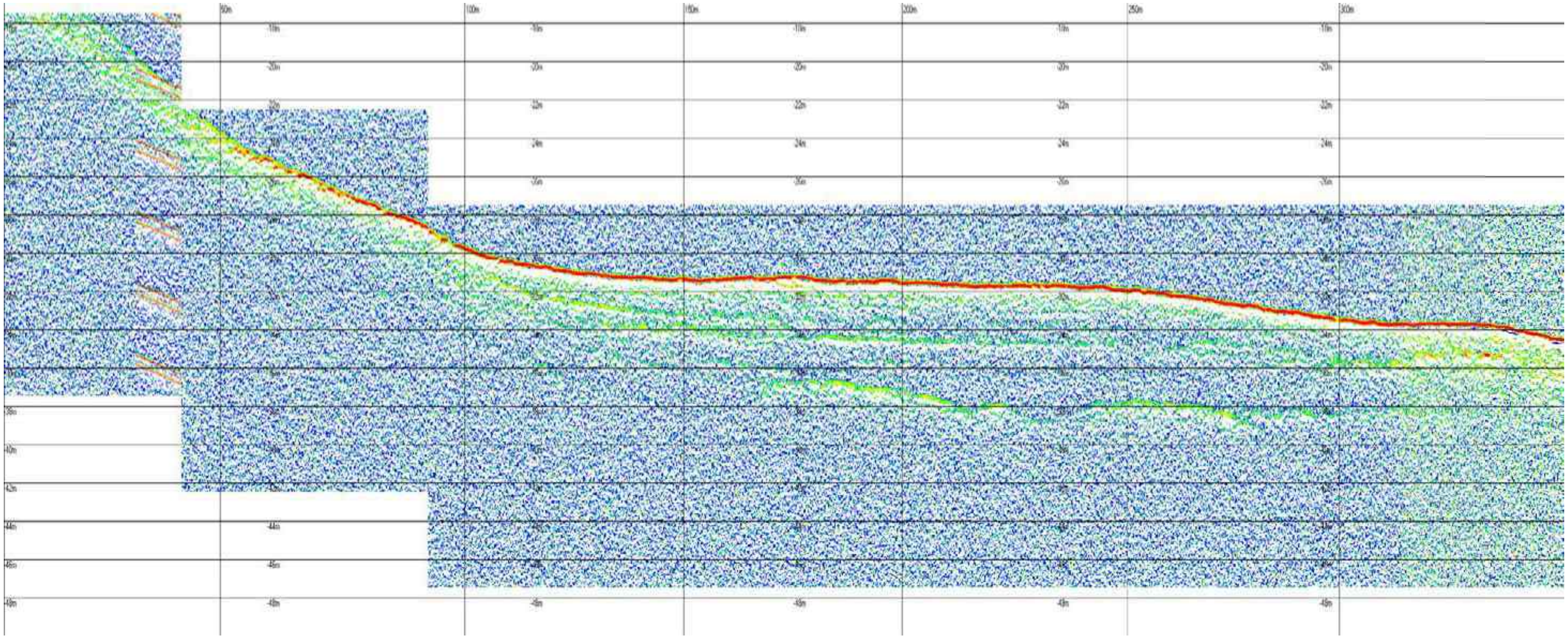

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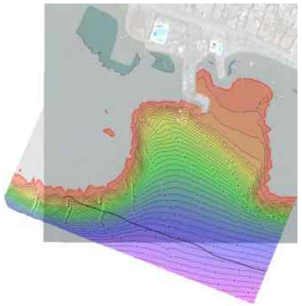

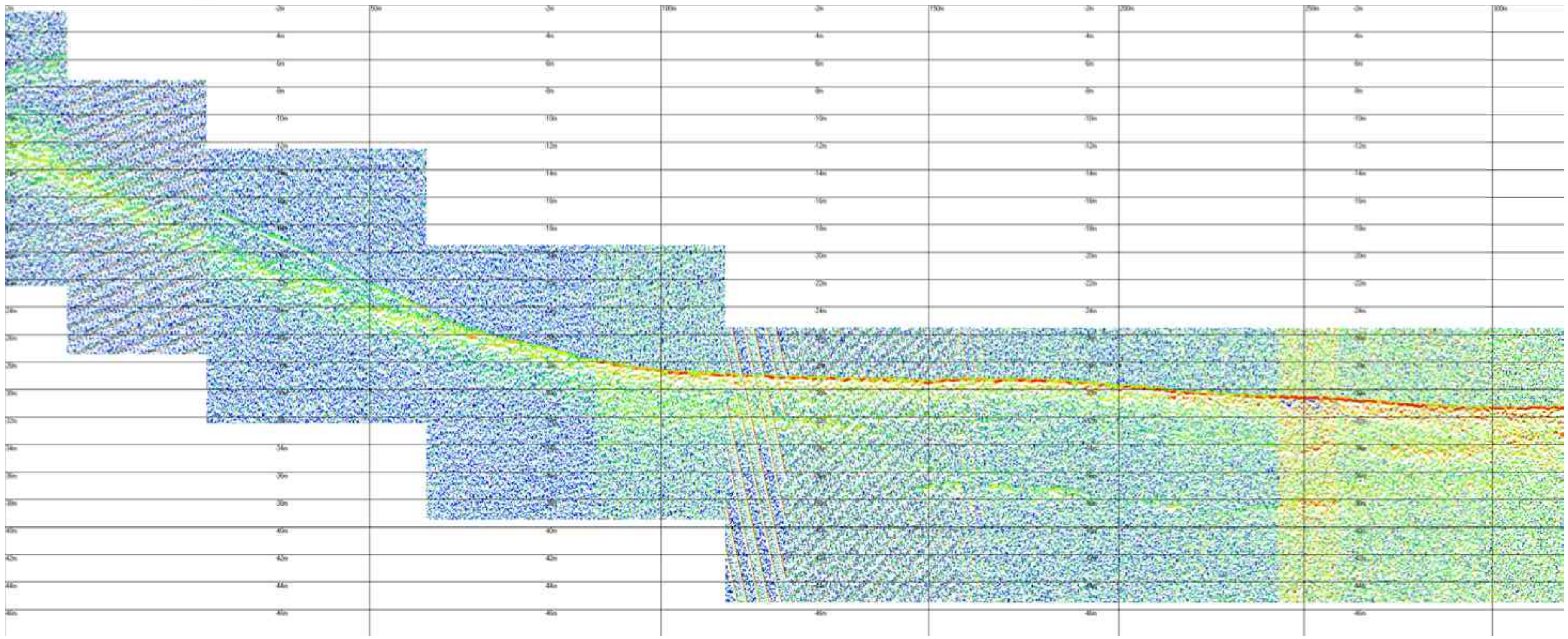

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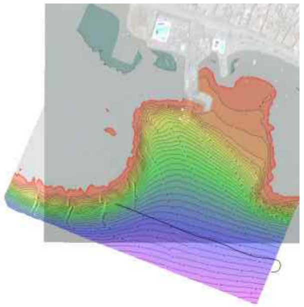

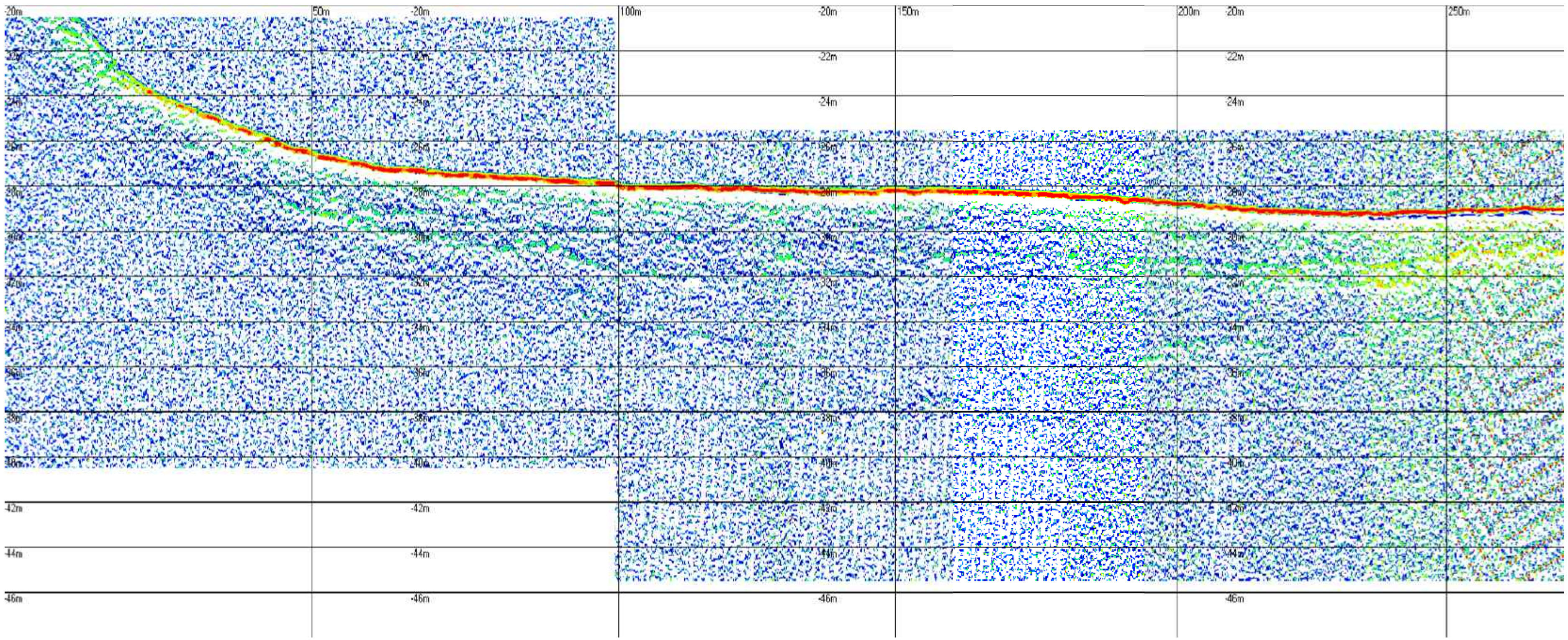

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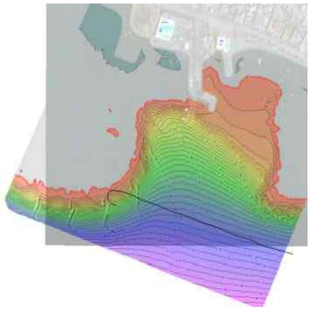

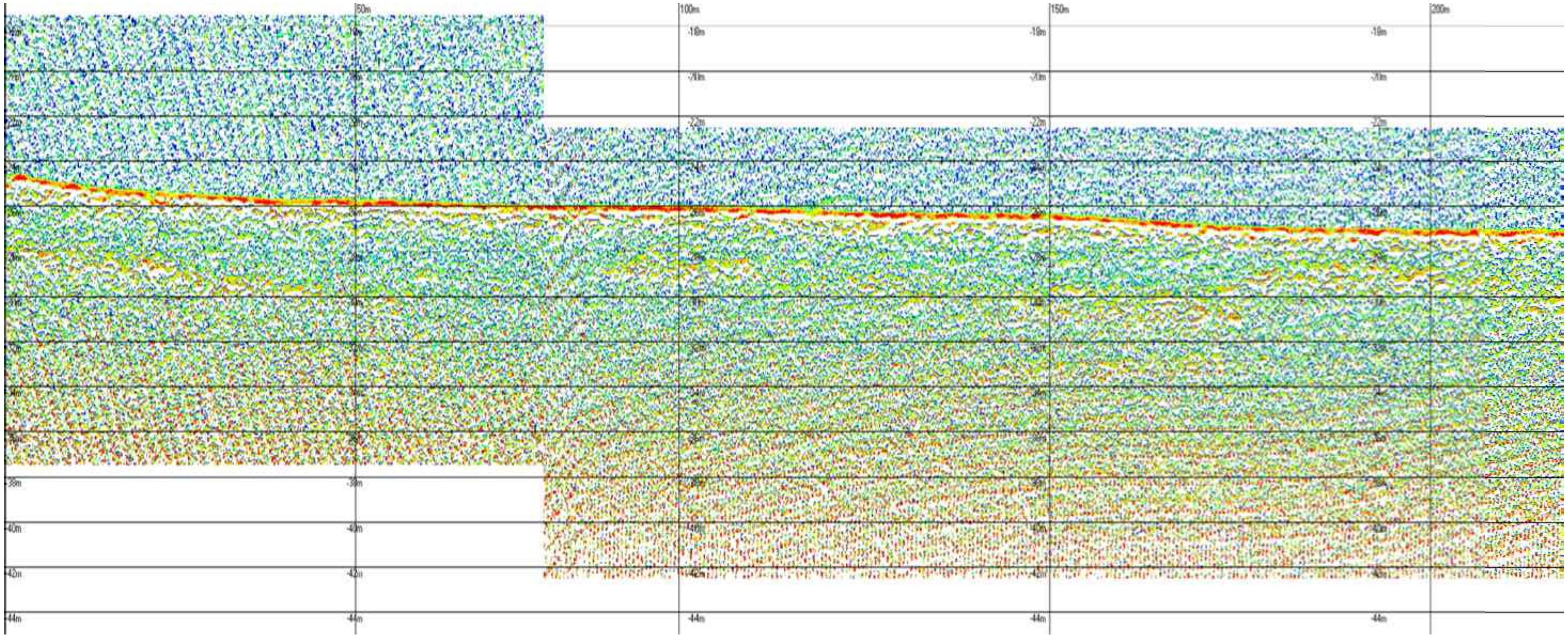

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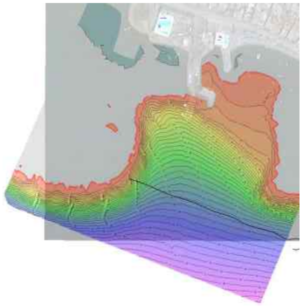

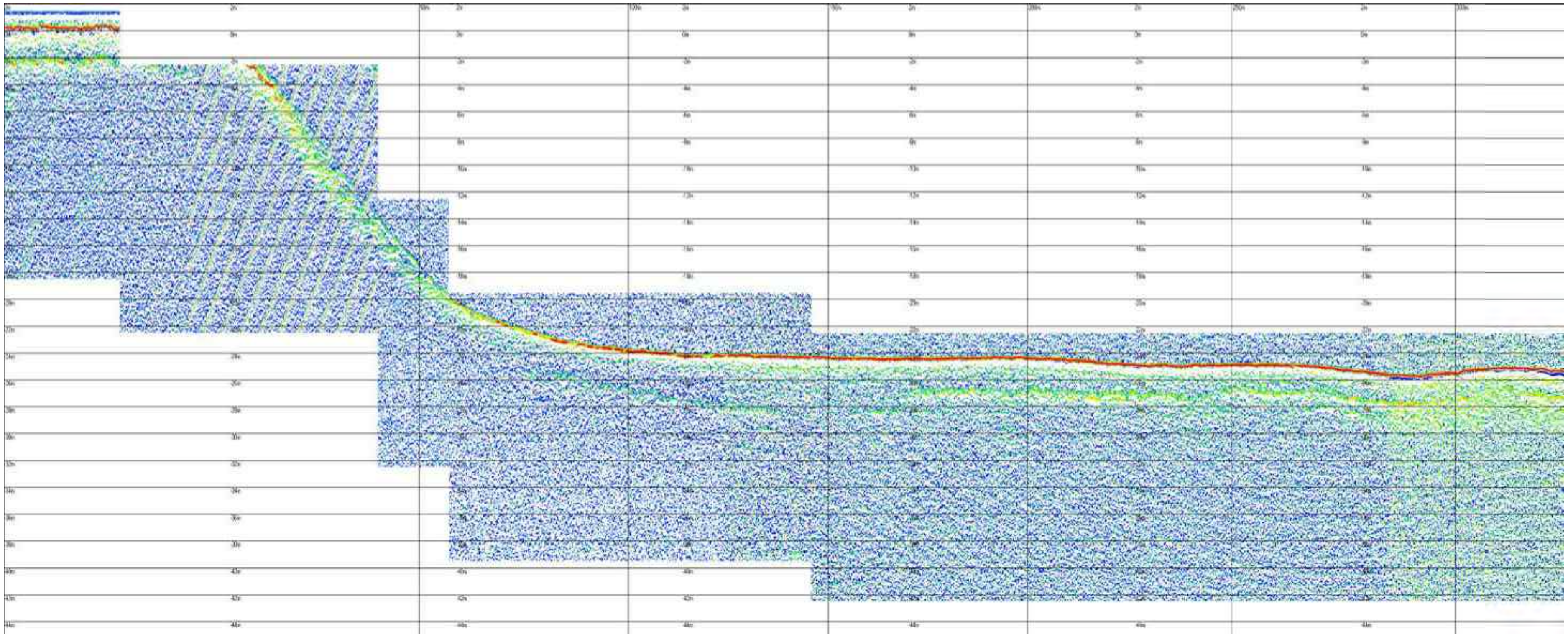

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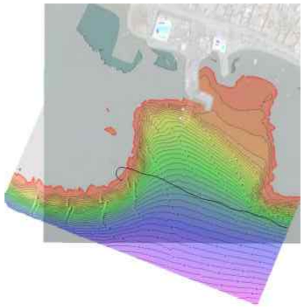
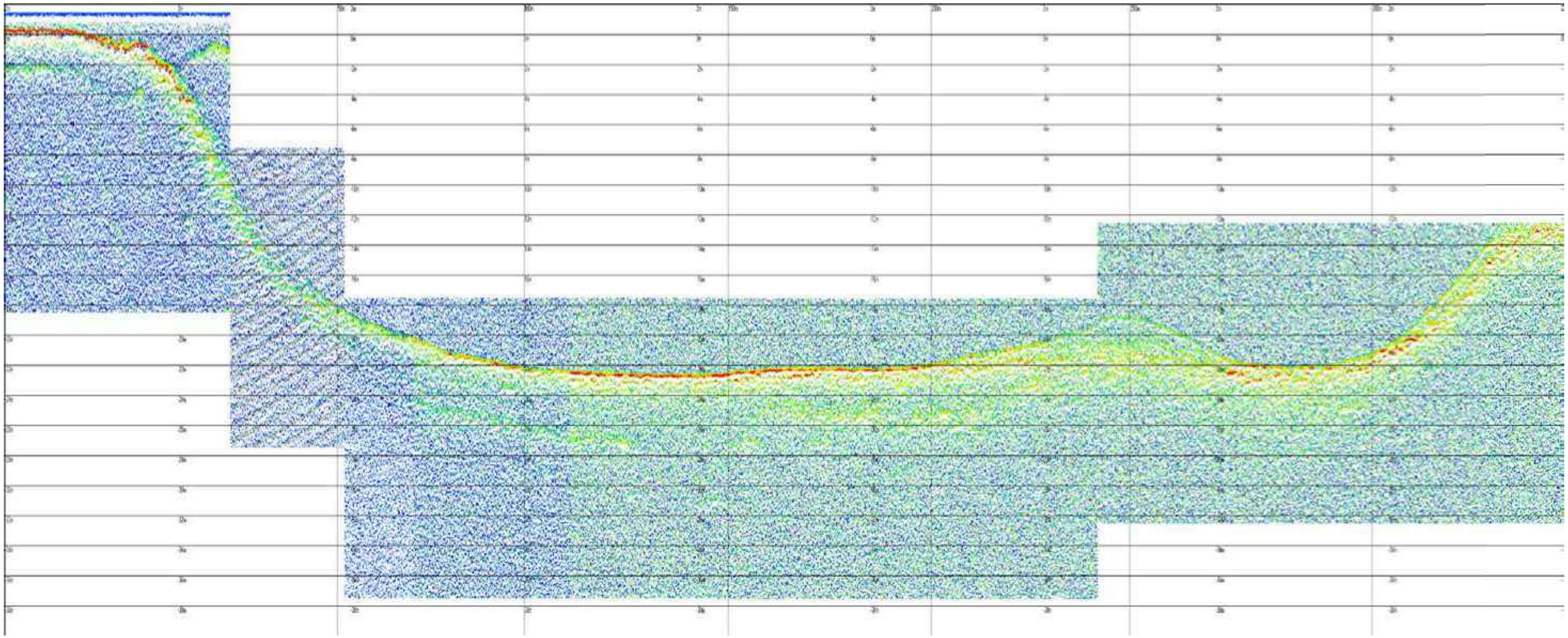

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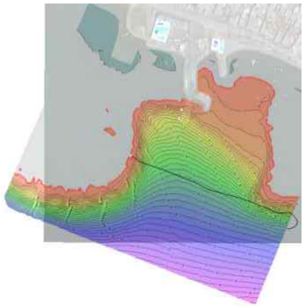

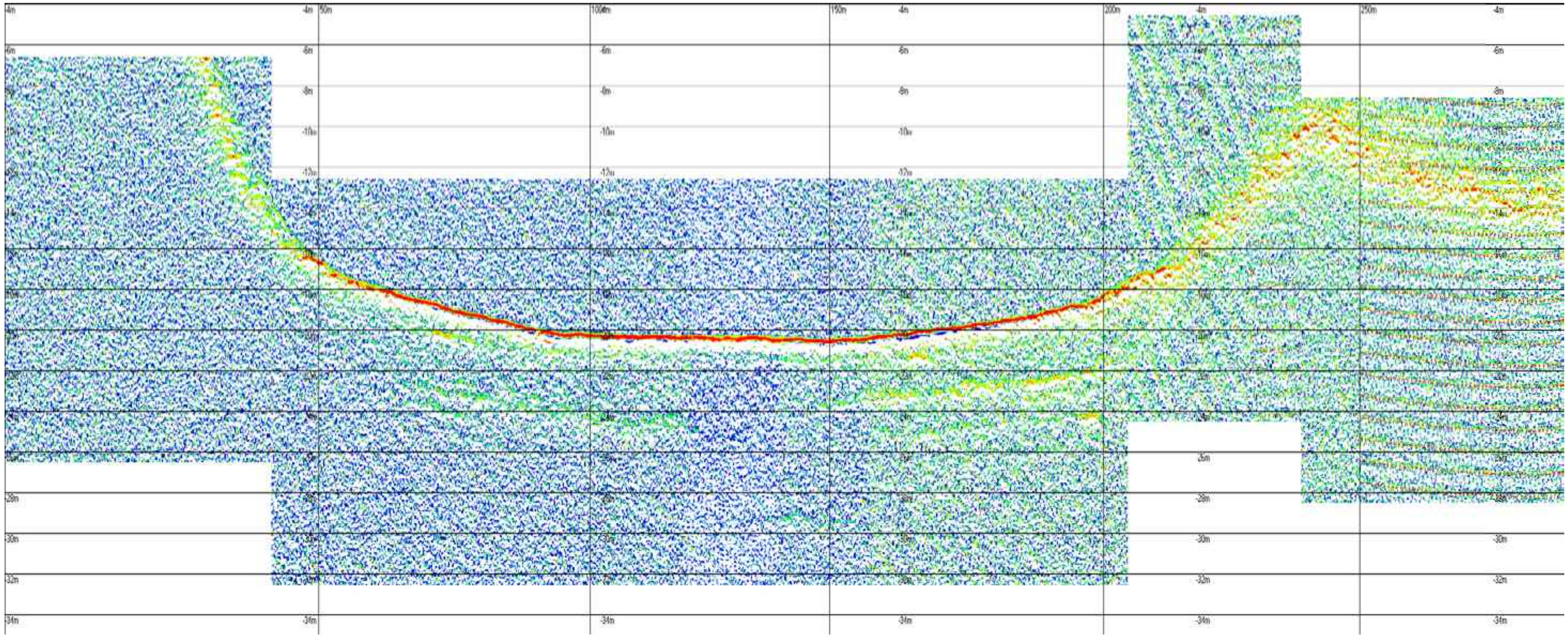

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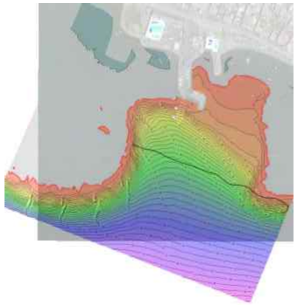

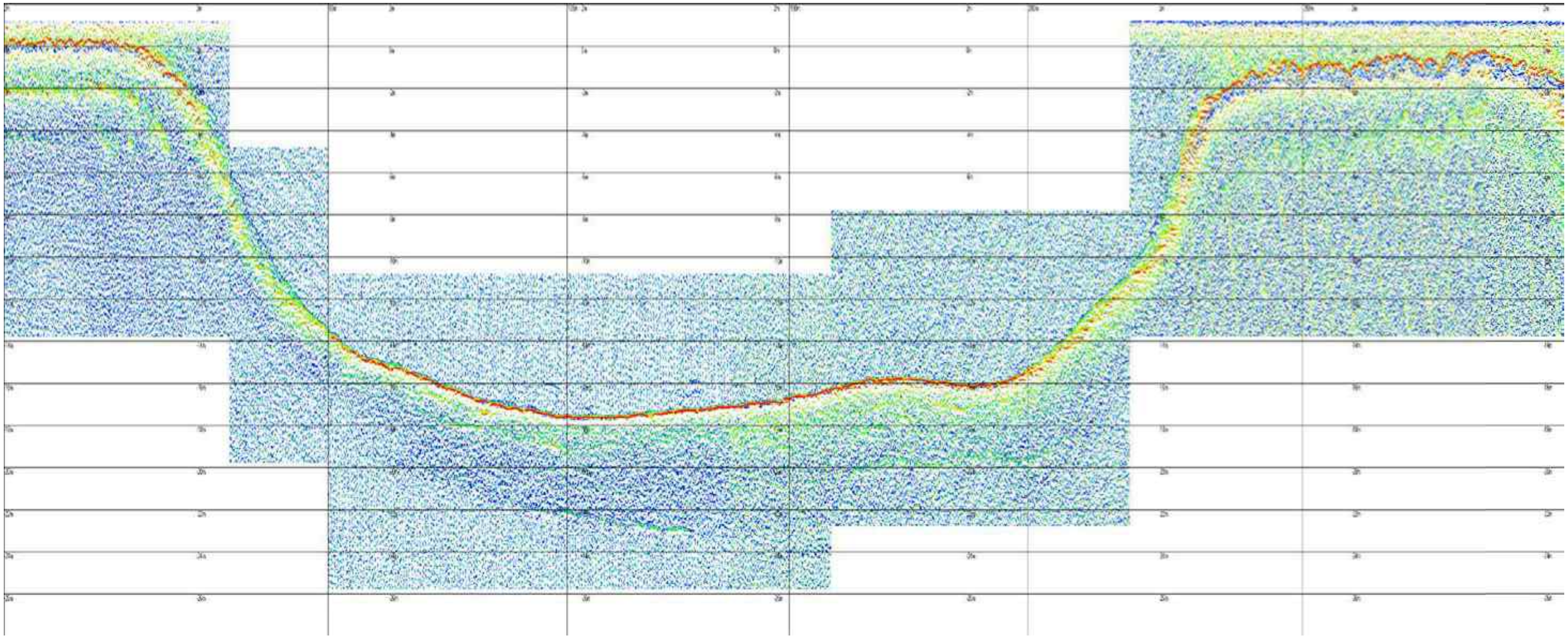

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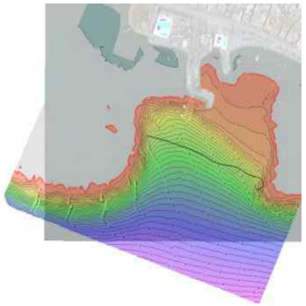

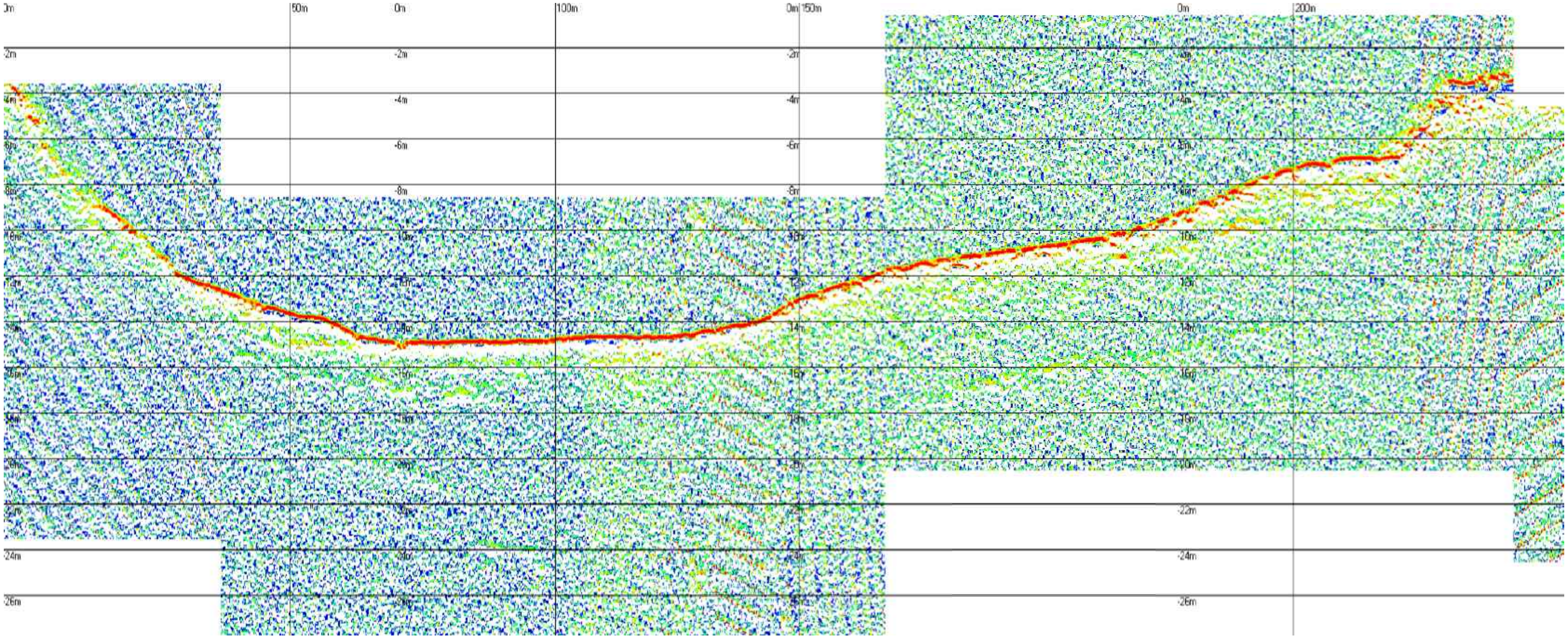

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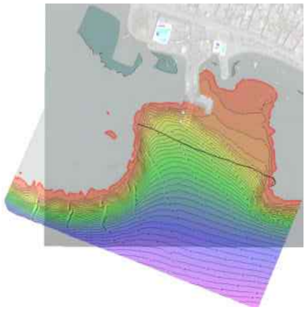

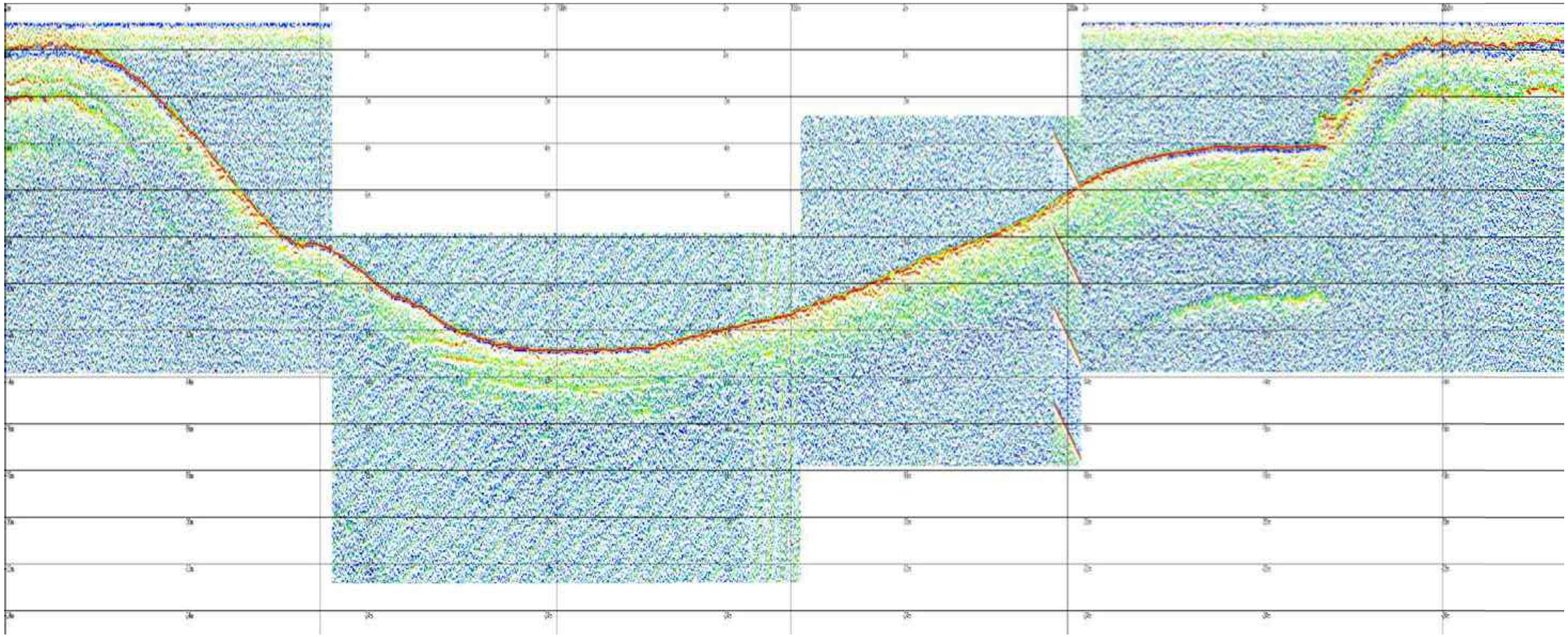

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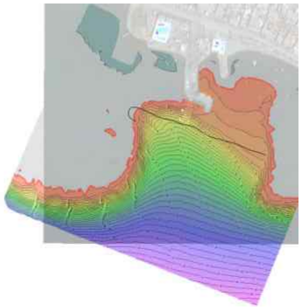

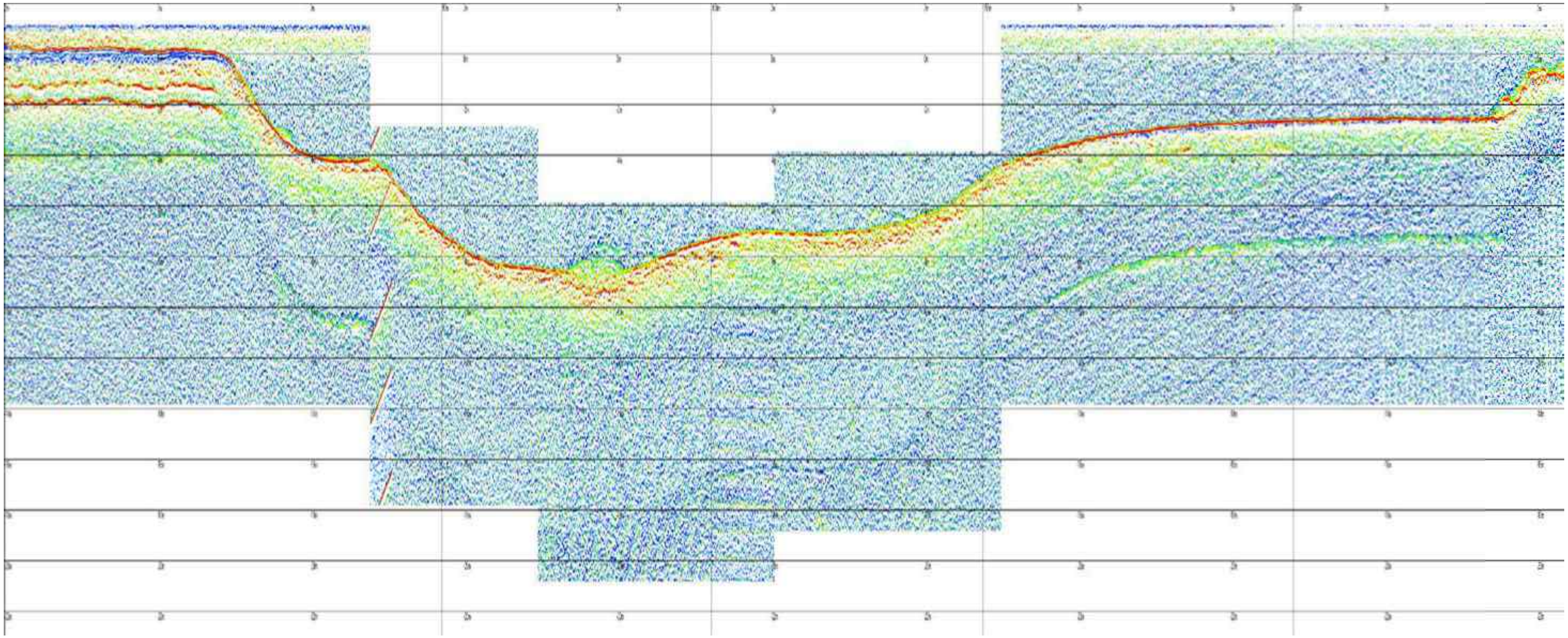

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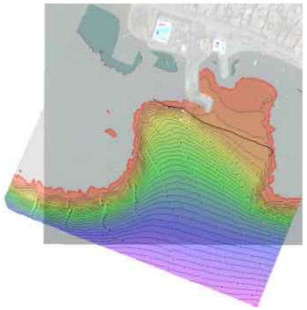

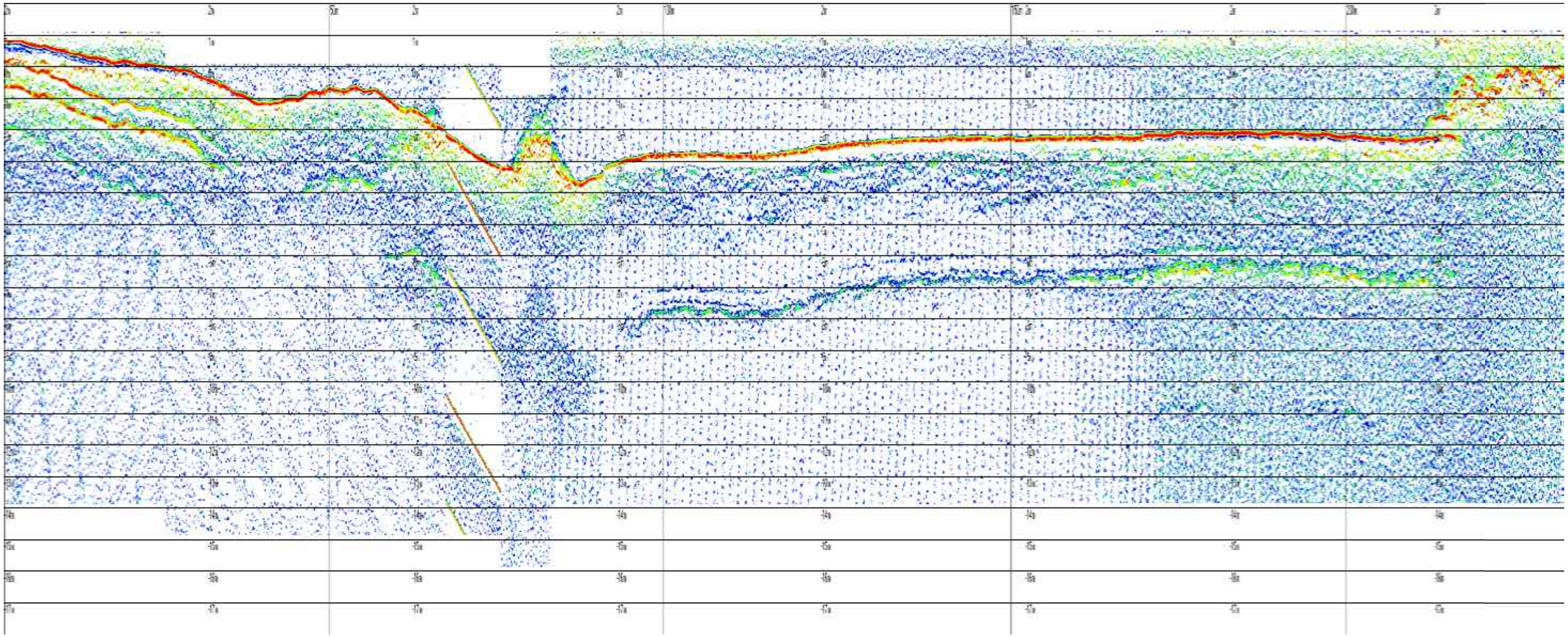

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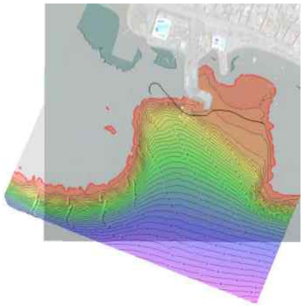

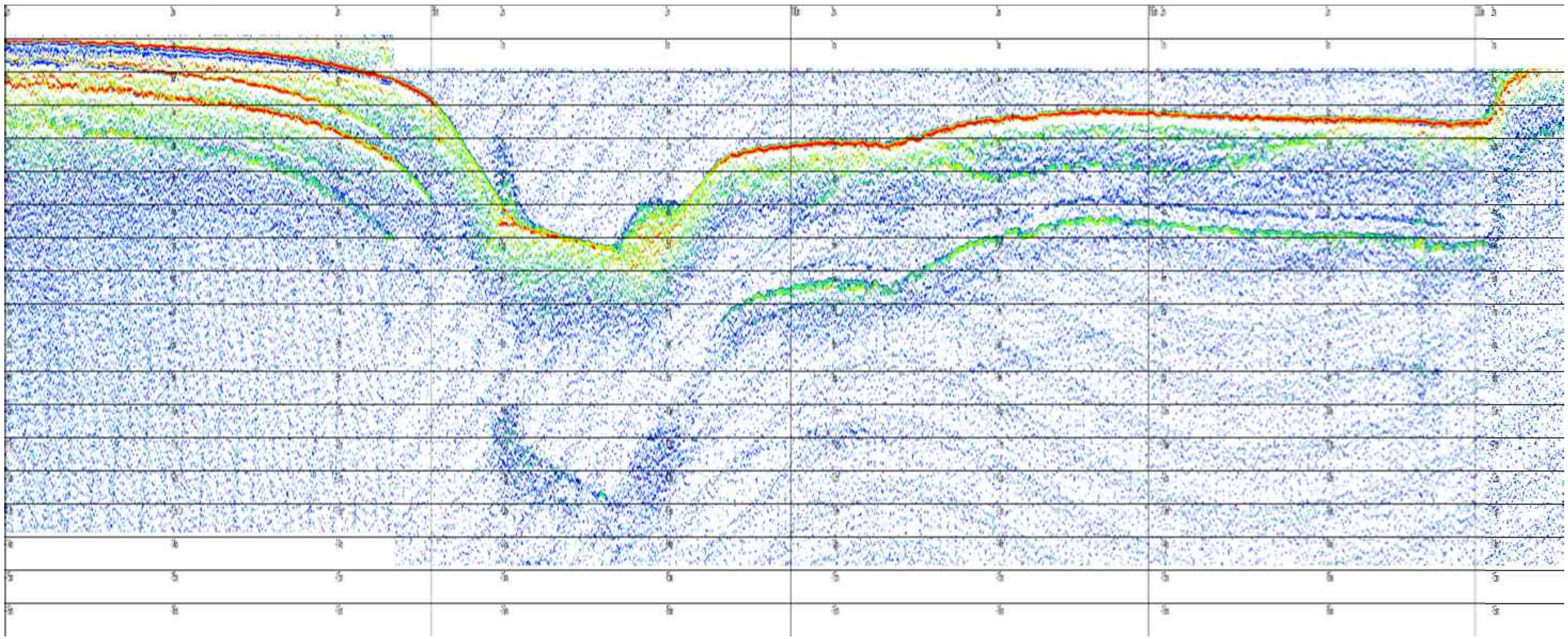

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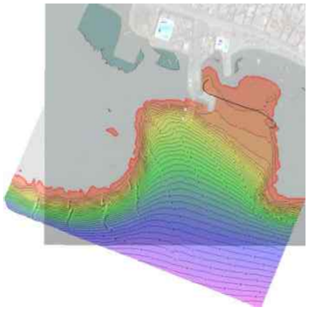

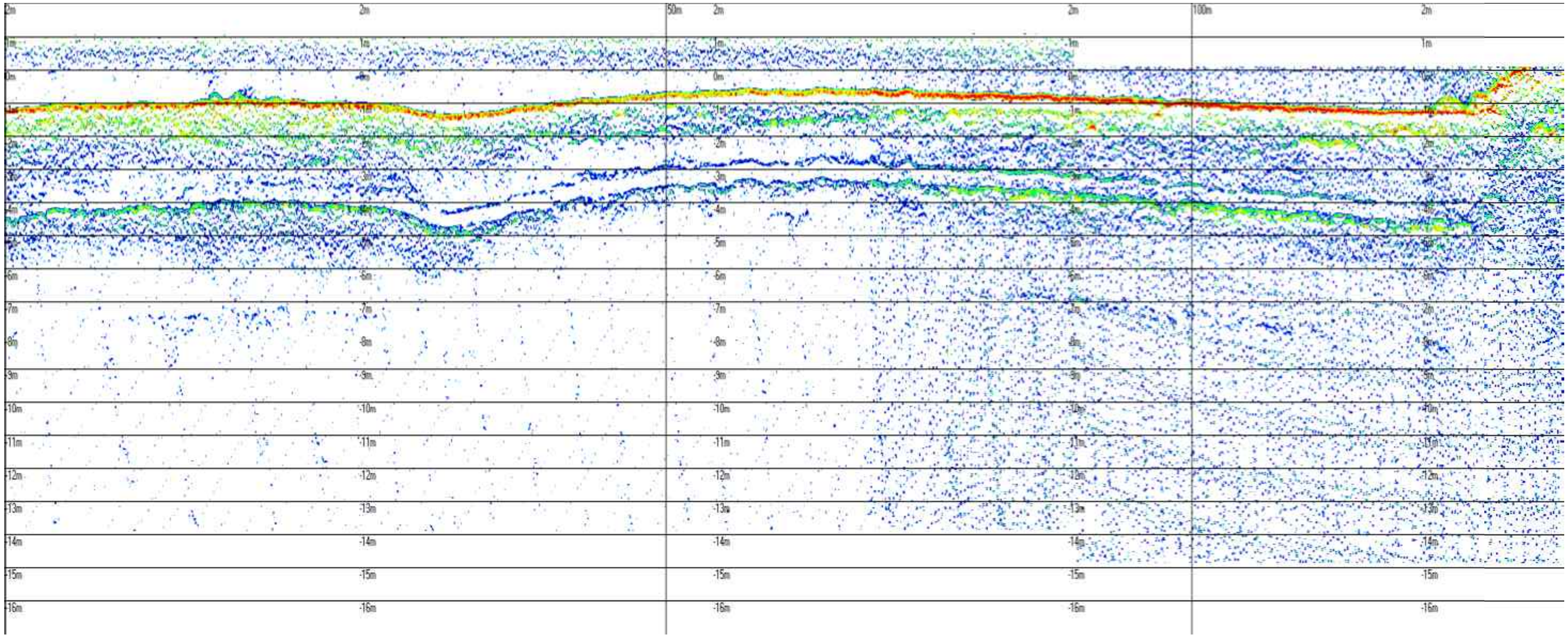

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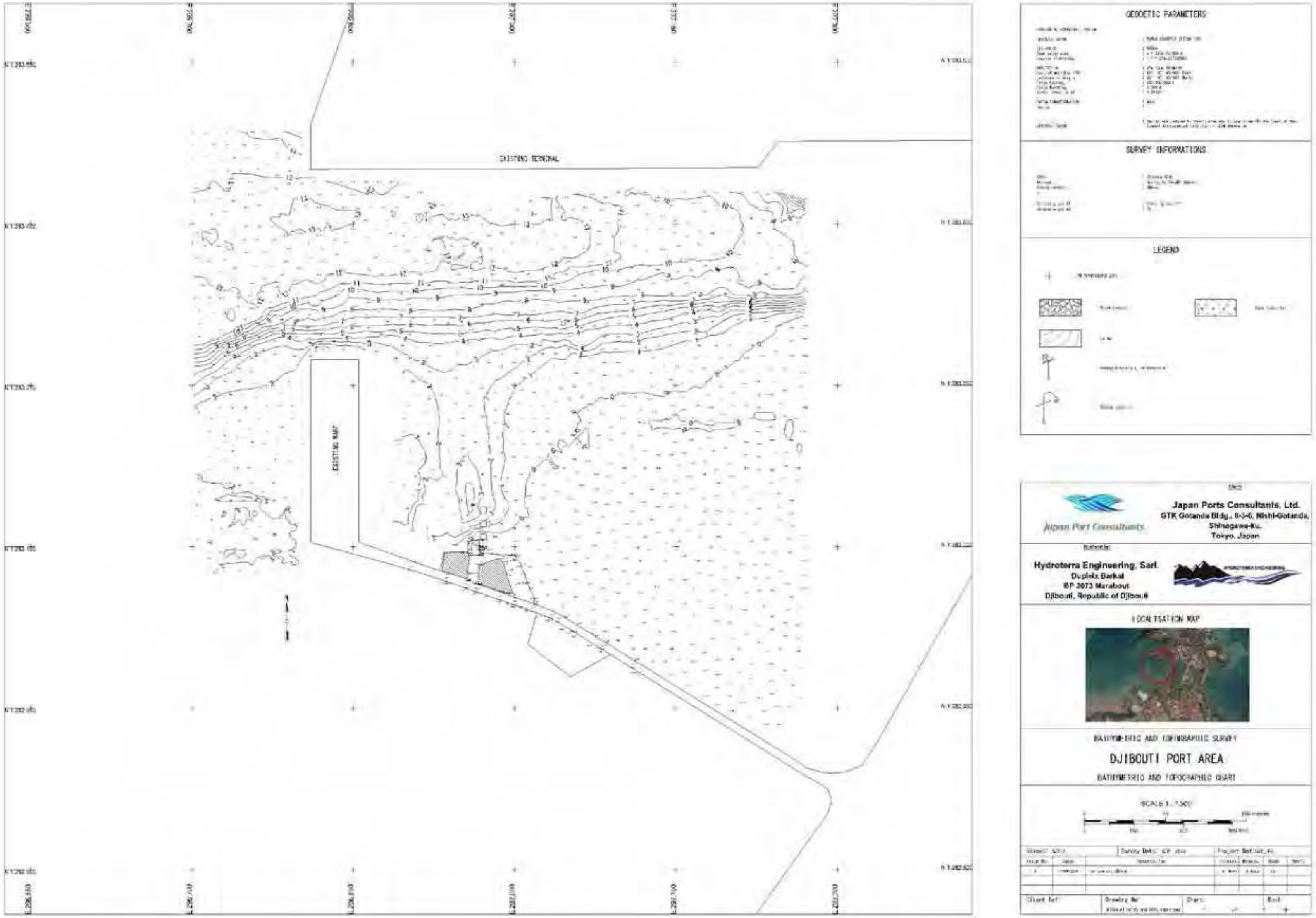
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EXISTING WHARF
GEODETIC PARAMETERS
SURVEY INFORMATIONS
LEGEND
Japan Port Consultants
Japan Ports Consultants, Ltd.
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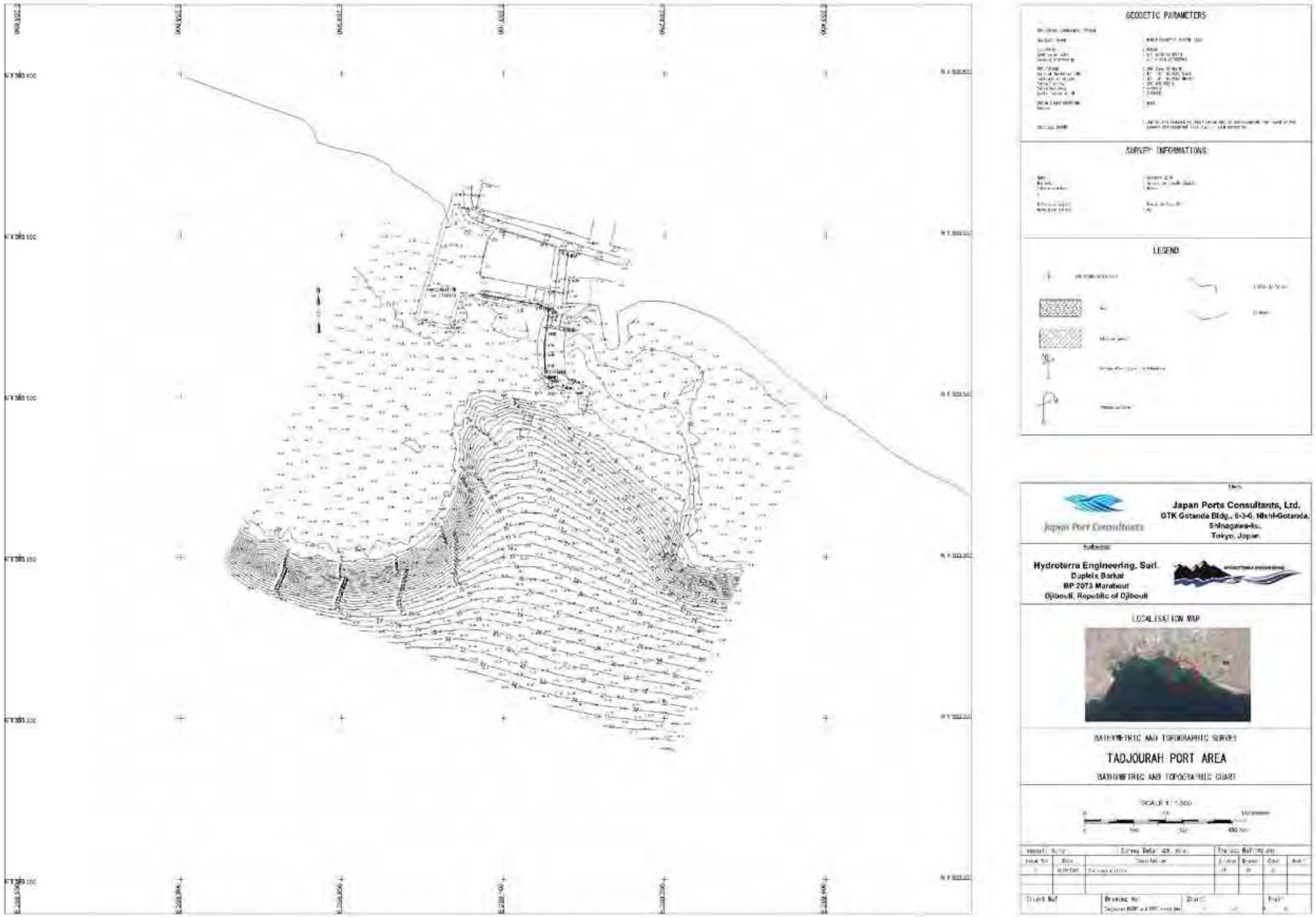
Shinagawa-ku,
Tokyo, Japan
Hydroterra Engineering, Sarl.
Duplex Barkat
BP 2073 Marabout
Djibouti, Republic of Djibouti
LOCALISATION MAP
BATHYMETRIC AND TOPOGRAPHIC SURVEY
DJIBOUTI PORT AREA
BATHYMETRIC AND TOPOGRAPHIC CHART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Duplex Barkat
BP 2073 Marabout
Djibouti, Republic of Djibouti
LOCALISATION MAP
BATHYMETRIC AND TOPOGRAPHIC SURVEY
TADJOURAH PORT AREA
BATHYMETRIC AND TOPOGRAPHIC CHART

5. Package étude environnementale (Amendement-2)

- Etudes des sédiments des fonds marins, bruits, vibrations, air, qualité de l'eau et des coraux
- Etudes détailles de la qualité des eaux et des coraux

INSUCO
Local understanding for sustainable solutions

Japan Port Consultants

ERM

January 2019

Reinforcement of Maritime Transport Capacity in the Gulf of Tadjourah – Environmental Survey including a prospective coral survey

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Djibouti

Environmental Survey including a prospective coral survey

Preparatory study on marine transport capacity enhancement project in Tadjourah bay

Final report

January 2019

Team: Jean Gassani, Geotechnician, hydrolician
Omar Moussa Youssouf, Biomarine specialist
Insuco Djibouti team

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1 Introduction

The Government of Djibouti, in partnership with Japan, is conducting a project to strengthen the capacity of maritime transport in Tadjourah Bay. The objective of this project is to provide the Tadjourah region with a new ferry with a greater capacity (200 to 250 pers.) and adapted to the harsh conditions of the sea in order to be able to navigate all year long. This new ferry will insure more regular transport from Djibouti to Tadjourah (every day of the week), increase trade and goods transportation between the two regions.

The project is part of a new economic perspective characterized by the opening of the new port of Tadjourah and the Tadjourah / Balho road linking the regional capital to the city of Mekeleh (Ethiopia).

However, despite its multiple benefits, the project is likely to have potentially negative impacts on the marine environment. In order to anticipate and mitigate these potential impacts and in a perspective of sustainable development associating the preservation of the environment, the economic and social development, the Japan International Cooperation Agency (JICA) that is supervising the whole project has recommended the realization of an environmental and social impact study (ESIS hereinafter). The state of Djibouti is in charge of the proper ESIA realization, whereas the realization of social and environmental baseline was assigned to ERM Japan in collaboration with INSUCO Djibouti Sarl. Most of the physical environment surveys are supervised by JPC with the support of ERM Japan and the mobilization of various local actors in Djibouti.

The work ambitioned in the framework of the project are located in the port of Djibouti and in the port of Tadjourah, the figures 1 and 2, below, present the existing infrastructures as well as the new one to be built.

Figure 1: Existing and new infrastructures to be built in Djibouti Port

Figure 2: Existing and new infrastructures to be built in the port of Tadjourah

2 Objective of the study

The objective of the environmental survey is to obtain a complete understanding of the biological and physical environment that will be found underwater and above water in the two ports.
Therefore, measures of air and noise were taken for the above ground information and samples of water and sediments were collected in both ports in order to produce a qualitative underwater environmental.

The samples were collected after the Khamzin season in late October. All the sediments and water collection were done under the supervision of a geotechnical surveyor who has been in close contact with the different experts mobilized for the studies. A report of the geotechnical surveyor will document the collection process and come as complement of this report.
The results obtained from the analyses of the samples collected are presented in this report.

Along those studies and analysis, a first prospective coral survey was done in order to identify and validate the need for an in-depth coral study. The result of the prospective study, presented in this report, confirmed the need of further study and experts got mobilized in December to proceed with a quantitative and qualitative study. The results of the indepth coral survey will be presented in an independant report.

3 Environmental survey

The scope of the environmental survey is limited to:

- Analyze seawater and seabed sediment quality around the project sites (Tadjourah and at Djibouti). Altogether, 5 samples of sediment and 3 samples of seawater were collected in each site (figure 6),
- Measure Air quality,
- Measure Noise and vibration.

Collection of samples

The sampling points are precisely located using a GPS. At each point, sampling date, weather conditions and environmental parameters of seawater (temperature and salinity) were registered.

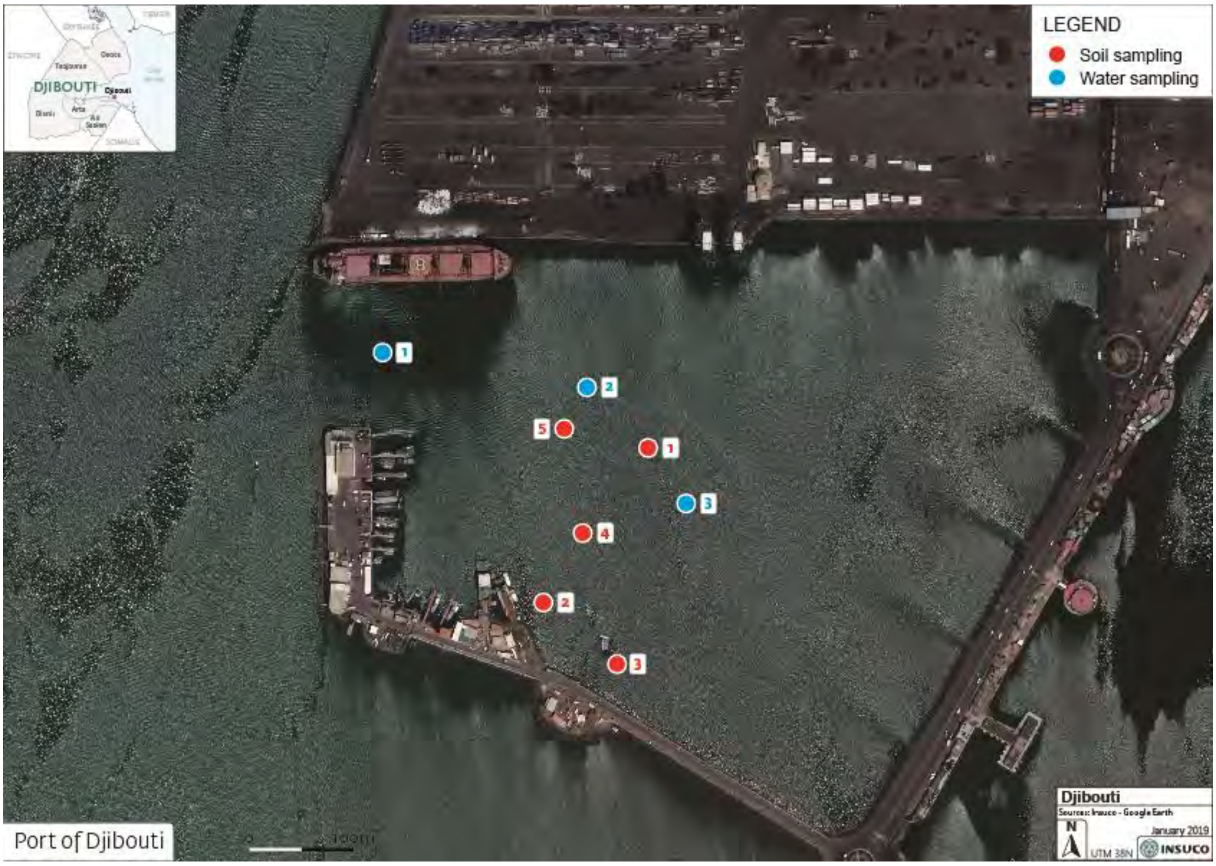

Figure 3: Sampling sites locations in Djibouti Port

Figure 4: Sampling sites in Tadjourah

Table 1: Coordinates and references of the different points of measure

Sample	Name	X	Y	Temperature	Day of collection	Day of test
18/302/2A	Eau de Djib 1	296868	1283349	12,8	18/10/18	29/10/18
18/302/2B	Eau de Djib 2	297063	1283314	12,8	18/10/18	29/10/18
18/302/2C	Eau de Djib 3	297157	1283201	12,8	18/10/18	29/10/18
18/302/2D	Eau de Tadj1	268958	1303474	12,8	20/10/18	29/10/18
18/302/2E	Eau de Tadj2	268963	1303395	12,8	20/10/18	29/10/18
18/302/2F	Eau de Tadj3	269152	1303402	12,8	20/10/18	29/10/18
18/302/2G	Sésiment Djib 1	297121	1283255	12,3	18/10/18	29/10/18
18/302/2H	Sésiment Djib 2	297020	1283106	12,3	18/10/18	29/10/18
18/302/2I	Sésiment Djib 3	297090	1283046	12,3	18/10/18	29/10/18
18/302/2J	Sésiment Djib 4	297058	1283173	12,3	18/10/18	29/10/18
18/302/2K	Sésiment Djib 5	297041	1283274	12,3	18/10/18	29/10/18
18/302/2L	Sesiment TADJ1	269030	1303557	12,3	20/10/18	29/10/18
18/302/2M	Sesiment TADJ2	269091	1303544	12,3	20/10/18	29/10/18
18/302/2N	Sesiment TADJ3	269050	1303400	12,3	20/10/18	29/10/18
18/302/2O	Sesiment TADJ4	269084	1303483	12,3	20/10/18	29/10/18
18/302/2P	Sesiment TADJ5	269033	1303461	12,3	20/10/18	29/10/18

3.1 Seabed sediment survey

3.1.1 Methodology

3.1.1.1 Sampling Methodology

The sediment samples were taken using a pipe (galvanized pipe ∅ = 63 cm, length L = 4 m) connected by joints (Figure 7). The number of pipes is equal to the depth at the sampling point. The pipes are lowered from surface to the seabed and pushed into the sediment by turning the T-handle. The pipe containing the sediment is detached to extract the sample. Before putting in the plastic bottle, all sediment samples were dried.

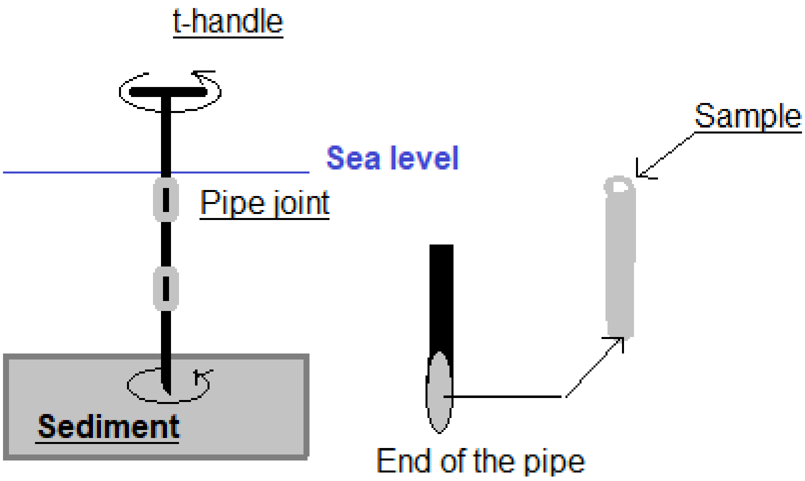

Figure 5: Scheme showing used method for sediment sample collection

The dry samples were divided into two portions. The first portion was used for grain size distribution by dry sieving. The second portion was used for chemical analysis.

More precisely the following elements were to be tested:

- Dry matter
- Organic content
- Chromium
- Nickel
- Copper
- Zinc
- Cadmium
- Mercury
- Lead
- Arsenic
- Grain Size Analysis (sieve and hydrometer test)
- Pesticides

3.1.1.2 *Granulometry analysis*

3.1.1.2.1 Principle

The methodology used in this study is based on sieving granulometric analysis[1234]. According to this methodology, the analytical process is in two phases: dispersion and separation followed by the weight determination of the various fractions. Indeed, the dispersion of the sample consists of determining the apparent texture. The separation of the various fractions (except coarse sand recovered by sieving) is carried out taking into account the different falling speeds of the particles in suspension. For the determination and separation of fractions, the pipette method is generally used.

3.1.1.2.2 Materials and reagents

- A large test tube (according to Esenwein): it is a cylinder with a capacity of 500 ml,
- A tamis with mesh of 0,2 mm;
- A mechanical stirrer,
- Sodium hexametaphosphate $(NaPO_3)_6$: 35.7 g of $(NaPO_3)_6$ dissolved in a tared flask containing 750 ml of water, 8 g of anhydrous sodium carbonate ($NaPO_3$) are added before being added to the line by the distilled water.

3.1.1.2.3 Experimental protocol

The determinations are made on 10 g of soil air-dried and sieved to 2 mm.

3.1.1.2.4 Process of Determination of the apparent texture

- In a plastic bottle containing 10g of soil, 10ml of the sodium hexametophosphate solution and 200 ml of distilled water are added.
- Stirred for two hours.
- The suspension is poured into the lever through a 0.2 mm mesh sieve where the coarse sand is collected.
- It is then washed thoroughly.
- The coarse sand, transferred from the sieve to a tared capsule, is dried in an oven at 105 ° C and weighed on the analytical balance (5 g).
- The torpid suspension and the washing water collected in the levator are brought to volume with distilled water (total volume).
- The mixture is agitated so as to obtain a homogeneous suspension. The sedimentation times should be evaluated from the moment when the stirring stops:

[1] ASTM C285-88 (Re-approved 1994) Standard test method for sieve analysis of wet milled and dry milled porcelain enamel, for determination of the fineness of frit in wet-or dry-milled porcelain enamels and other ceramic coatings on metals by use of the number 200 or No 325 mesh, 212

[2] ASTM C925-79 (Re-approved 1995) Standard test method for precision electroformed wet sieve analysis of non-plastic ceramic powders, for particle size distribution determination of pulverized alumina and quartz for particle sizes from 45 pm to 5 pm by wet sieving, 212, 230

[3] ASTM C1921 -96 Standard test method for particle size (sieve analysis) of plastic materials, applicable to particle size determination of plastic materials in powdered, granular or pelleted forms by dry sieving with a lower limit of measurement of about 38 pm, 212

[4] ISO 8130-1 (1992) Coating Powders-Part 1, Determination of particle size distribution by sieving, 212 27 ISO 6274 (1982), Concrete - Sieve analysis of aggregates, 212

- For a height of 25 cm (sedimentation liquid) and for a temperature of 20°C: One operates according to the following mode:

  - 1st sample: after 2 minutes: coarse silt grain + fine silt + clay (A)
  - 2nd sample: after 12 minutes: fine silt + clay (B)
  - 3rd sample: after 20 hours: clay (C)

Each fraction (Vp) is collected in a tared capsule after drying for weighing. For each determination series, it is necessary to weigh the dispersant (D) present in the volume taken for the single fractions by weighing.

Table 2: Definition of the different categories

Coarse Sand	particles with a diameter comprised between	0,2 mm	2mm
Fine Sand	particles with a diameter comprised between	0,05 mm	0,2 mm
Coarse Silt	particles with a diameter comprised between	0,02 mm	0,05 mm
Fine/Medium silt	particles with a diameter comprised between	0,002 mm	0,02 mm
Clay	particles with a diameter comprised between	< 0,002 mm	

- **Formula**

  - **Coarse sand (CSa) in %** = CSa * 100 / P
  - **Coarse silt (CSi) in %** = (A-B) * 100 * Vt / Vp * P
  - **Fine silt (FSi) in %** = (B-C) * 100 * Vt / Vp * P
  - **Clay (Cl) in %** = (C-D) * Vt * 100 / Vp * P
  - **Fine Sand (FSa) in %** = 100 - (CSa + CSi + FSi + Cl)

Vt= volume total, P = weight of the sample, Vp = volume taken, D = weight of dispersant

3.1.1.3 Heavy metal analysis

Table 3: Methods used for the identification of heavy metals

Parameters	Method
Arsenic (As)	NF EN ISO 11885
Cadmium (Cd)	NF EN ISO 11885
Chromium (Cr)	NF EN ISO 11885
Copper (Cu)	NF EN ISO 11885
Nickel (Ni)	NF EN ISO 11885
Lead (Pb)	NF EN ISO 11885
Zinc (Zn)	NF EN ISO 11885
Mercury (Hg)	NF EN ISO 17852

The laboratory results will be evaluated in comparison with international standards[5] in order to appreciate the quality of the waters found in the two ports. Two value of reference identified as ERL and ERM were established by Edward Long[6] in 1990 in order to establish and evaluate the potential impact of the values identified. More precisely[7]:

ERL- Effects Range Low: corresponds to the lower tenth percentile of the effects data.
ERM – Effects range median: corresponds to the median (or fiftieth percentile) of the effects data.

The evaluation will be done according to the following principles[8]:

- Concentrations below the ERL value represent a minimal-effects range, a range intended to estimate conditions in which effects would be rarely observed.
- Concentrations equal to and above the ERL but below the ERM represent a possible-effects range within which effects would occasionally occur.
- Concentrations equivalent to and above the ERM value represent a probable-effects range within which effects would frequently occur

3.1.1.4 Organochlorine Pesticides

Organochlorine were also tested. For those tests, the raw material was injected after a step of purification done with florisil.

[5] Compilation of Sediment and Soil Standards, critera and guidelines, February 1995, The Resources Agencu, Department of Water Resources, State of California, p39
[6] Long et al, Incidence of Adverse Biological Effects within Ranges of Chemical Concentrations in Marine and Estuarine Sediments.
[7] Compilation of Sediment and Soil Standards, critera and guidelines, February 1995, The Resources Agencu, Department of Water Resources, State of California, p.39
[8] *Idem*

3.1.2 Results

Photo 1: Seabed sediment: Top 5: samples (Djibouti Site) Down: 5 samples (Tadjourah Site)

3.1.2.1 Djibouti

Conditions of the period of collection of the samples:

Date	18/10/2018; 14-15h
Location	Djibouti
Tide	1.9 m
Wind direction	East
Temperature	28.9 °C
Humidity	63%

Table 4: Granulometry, dried and organic matter and heavy metals presence for samples in Djibouti

Source: Results produced by Qualio Laboratory (See Annex 1)

Sample Name	Unit	Sediment Djib 1	Sediment Djib 2	Sediment Djib 3	Sediment Djib 4	Sediment Djib 5
Sample Number		**18/302/2G**	**18/302/2H**	**18/302/2I**	**18/302/2J**	**18/302/2K**
Dried matter	g/kg	786	771	751	726	716
Organic matter	% of DM	3,7	3,3	3,2	3,2	3,9
% Coarse Silt (CSi)	%	12,15	16,35	17,25	19	19,1
% Fine Silt (FSi)	%	3,45	7,1	3,1	4,15	6,85
% Clay (Cl)	%	2,7	4,05	3,25	4,6	6,65
% Coarse sand (CSa)	%	6,86	0,86	2,89	1,52	2,53
% Fine sand (FSa)	%	74,84	71,64	73,51	70,73	64,87
Arsenic (As)	Mg/kg DM	13,6	10,4	12,9	10,8	10,1
Cadmium (Cd)	Mg/kg DM	<0,5	<0,5	<0,5	<0,5	<0,5
Chromium (Cr)	Mg/kg DM	25	29,9	26,3	28,8	27,1
Copper (Cu)	Mg/kg DM	31,1	39,9	34,2	38,4	35,8
Nickel (Ni)	Mg/kg DM	17,7	22,8	20,4	22	21,1
Lead (Pb)	Mg/kg DM	2,6	6	5,8	5	4,4
Zinc (Zn)	Mg/kg DM	72	84,7	74,3	78,4	146
Mercury (Hg)	Mg/kg DM	0,01	0,02	0,02	0,02	0,02

The values that are higher than the ERL value for the metals are highlighted. The appreciation of those results is given hereunder.

3.1.2.2 Tadjourah

Conditions of the period of collection of the samples:

Date	20 october
Location	Tadjourah
Tide	2,2 m
Wind direction	East
Temperature	32,8 °C
Humidity	67%

Table 5: Granulometry, dried and organic matter and heavy metals presence for samples in Tadjourahi

Source: Results produced by Qualio Laboratory (See Annex 1)

Sample Name	Unit	Sediment Tadj 1	Sediment Tadj 2	Sediment Tadj 3	Sediment Tadj 4	Sediment Tadj 5
Sample Number		**18/302/2L**	**18/302/2M**	**18/302/2N**	**18/302/2O**	**18/302/2P**
Dried matter	g/kg	787	793	734	773	764
Organic matter	% of DM	2,9	2,3	4,4	2,8	4
% Coarse Silt Grain (CSG)	%	0,5	0,05	0,9	0,32	0,95
% Fine Silt (FS)	%	1,7	0,45	0,65	0,25	0,4
% Clay	%	0,5	0,1	1,1	1,25	0,4
% Coarse sand (CS)	%	74	28,02	30,7	90,42	76,69
% Fine sand (FS)	%	23,3	71,38	66,65	7,75	21,37
Arsenic (As)	Mg/kg DM	2,7	3,5	1,7	3,4	1,7
Cadmium (Cd)	Mg/kg DM	<0,5	<0,5	<0,5	<0,5	<0,5
Chromium (Cr)	Mg/kg DM	4,9	19,8	2	8,3	2,1
Copper (Cu)	Mg/kg DM	5,1	20,5	<1,5	8,2	<1,5
Nickel (Ni)	Mg/kg DM	2,8	9,1	<1	4,9	<1
Lead (Pb)	Mg/kg DM	2,4	4,7	<1	3,5	<1
Zinc (Zn)	Mg/kg DM	19,9	66,7	2,2	32,7	2,7
Mercury (Hg)	Mg/kg DM	0,01	<0,01	<0,01	<0,01	<0,01

The values that are higher than the ERL value for the metals are highlighted. The appreciation of those results is given hereunder.

3.1.2.3 *Analysis of the data*

3.1.2.3.1 Granulometry

The results of particle size analysis show that the seabed has different textures in the port of Djibouti and Tadjourah. At the Port of Tadjourah, the seabed is mainly composed of coarse sand (SG) and fine silt (LF) which represent respectively 60% and 38.09%. While at the port of Djibouti, the marine soils consist of fine silt (71.12%) and coarse silt (16.77%).

3.1.2.3.2 Heavy metals

As mentioned before, in order to evaluate the marine sediment pollution by heavy metals, the comparison with the ERL and ERM values established by Long et Al 1990, were used[9].

Table 6: Sediments quality guidelines, Long et Al, 1990

Source : Quality Assurance Technical Document 7, feb 1995

Elements	Unity	Sediment reference value (mg/kg, dry weight)	
		ERL	**ERM**
As	mg/kg MS	8,2	70
Cd	mg/kg MS	1,2	9,6
Cr	mg/kg MS	81	370
Cu	mg/kg MS	34	270
Ni	mg/kg MS	20,9	51,6
Pb	mg/kg MS	46,7	218
Zn	mg/kg MS	150	410
Hg	mg/kg MS	0,15	0,71

- The results show a significant difference in the heavy metal concentration in marine sediments between the port of Djibouti and that of Tadjourah.
- On average, the values obtained at the port of Djibouti are 10 times higher than those obtained at the port of Tadjourah. This observation is normal according to the maritime traffic and the location of the sites.
- The concentrations of heavy metal are lower than the values in ordinary sediment concentrations in both sites, except for Arsenic and copper (Cu) in the sediments of the port of Djibouti, which is higher than the standard values. The moderately high copper value represents a small ecotoxicological risk. The arsenic values are higher than the ERL value but remain quite low.

3.1.2.3.3 Organochlorine Pesticides

See table below. All tested pesticides are present in less than 10 μg/kg of Dry matter.

[9]Compilation of Sediment and Soil Standards, critera and guidelines, February 1995, The Resources Agencu, Department of Water Resources, State of California

Analyses de 19 composés organochlorés sur 10 échantillons 18/302/2 sédiments marins

Les échantillons ont été extraits par le laboratoire QUALIO.

Les échantillons ont été injectés bruts après étape de purification sur florisil.

Conc finale en µg/kg MS nom de l'echantillon

nom du composés	18/302/2G	18/302/2H	18/302/2I	18/302/2G	18/302/2K	18/302/2L	18/302/2M	18/302/2N	18/302/2O	18/302/2P
alpha-HCH	<10	<10	<10	<10	<10	<10	<10	<10	<10	<10
Lindane	<10	<10	<10	<10	<10	<10	<10	<10	<10	<10
beta-HCH	<10	<10	<10	<10	<10	<10	<10	<10	<10	<10
delta-HCH	<10	<10	<10	<10	<10	<10	<10	<10	<10	<10
Heptaclor	<10	<10	<10	<10	<10	<10	<10	<10	<10	<10
Aldrine	<10	<10	<10	<10	<10	<10	<10	<10	<10	<10
Heptachlorepoxide-1	<10	<10	<10	<10	<10	<10	<10	<10	<10	<10
Heptachlorepoxide-2	<10	<10	<10	<10	<10	<10	<10	<10	<10	<10
2,4'-DDE	<10	<10	<10	<10	<10	<10	<10	<10	<10	<10
Endosulfan	<10	<10	<10	<10	<10	<10	<10	<10	<10	<10
4,4'-DDE	<10	<10	<10	<10	<10	<10	<10	<10	<10	<10
Dieldrine	<10	<10	<10	<10	<10	<10	<10	<10	<10	<10
2,4'-DDD	<10	<10	<10	<10	<10	<10	<10	<10	<10	<10
2,4'-DDT	<10	<10	<10	<10	<10	<10	<10	<10	<10	<10
4,4'-DDD	<10	<10	<10	<10	<10	<10	<10	<10	<10	<10
beta-Endosulfan	<10	<10	<10	<10	<10	<10	<10	<10	<10	<10
Endrine	<10	<10	<10	<10	<10	<10	<10	<10	<10	<10
4,4'-DDT	<10	<10	<10	<10	<10	<10	<10	<10	<10	<10
Methoxychlor	<10	<10	<10	<10	<10	<10	<10	<10	<10	<10

SC / QUALIO

3.2 *Water quality survey*

3.2.1 Methodology

The sample of seawater were taken at the surface, approximatively 50 cm from the seasurface. The closed container (bottle of 1 L) is immersed in water. At about 50 cm below the surface, the bottle is open, filled and brought to the surface. Then the sample is kept in a cooler box until analyzed in the lab.

Photo 2: Seawater samples: 3 samples from Tadjourah Site & 3 samples from Djibouti Site

The following elements were to be tested:

- ST-DCO
- Turbidity
- Dry residue
- Bicarbonates
- Chlorides
- Nitrates
- Sulphates
- Dissolved oxygen

3.2.2 Results

3.2.2.1 Djibouti

Conditions of the period of collection of the samples:

Date	18/10/2018; 14-15h
Location	Djibouti
Tide	1.9 m
Wind direction	East
Temperature	28.9 °C
Humidity	63%

Table 7: Parameters of the sample taken at 25 °c in lab on the day of collection (18th October)

Samples	Sample ref	Temperature (°C)	pH (25°C)	Conductivity
Eau Djib 1	18/302/2A	25	8.29	53.8
Eau Djib 2	18/302/2B	25	8.28	55.0
Eau Djib 3	18/302/2C	25	7.42	55.2

Table 8: Example of the table and presentation of the methods and results - correspondance with french words

Sample Reference	18/302/2A		**Name**	Eau de Djib 1			
Collected on	18/10/18		Received	29/10/18			
Parameters	**Method**	**Resuts**	**Unit**	**Quality Limit**	**Reference quality**	**Start of analysis**	
ST-DCO	ISO 15705		mg/l of O2				
Turbidity	NF EN ISO 7021-1		FNU				
Dry residue	NF T 90-029		mg/l				
Bicarbonates	NF EN ISO 9963-1		mg/l				
Chlorides	NF EN ISO 10304-1		mg/l				
Nitrates	NF EN ISO 10304-1		mg/l				
Sulphates	NF EN ISO 10304-1		mg/l				
Dissolevd oxygen	NF EN 25814		mg/l of O2				

Table 9: Table of results for sample Eau de Djib 1

Echantillon: 18/302/2A — ***EAU DE DJIB 1*** — **EAU DE MER**

Commentaires :

Prélevé le : 18/10/2018 À NC — Réceptionné le : 29/10/2018 — Température: 12,8 °C

Analyse Physico-chimique réalisée par Qualio

Paramètre	Méthode	Résultat	Unité	Limite Qualité	Référence Qualité	Début Analyse
ST-DCO	ISO 15705	90	mg/l d'O2			30/10/2018
Turbidité	NF EN ISO 7027-1	0,43	FNU			29/10/2018
Résidu Sec	NF T 90-029	42829	mg/l			29/10/2018
Bicarbonates	NF EN ISO 9963-1	186	mg/L			29/10/2018
Chlorures	NF EN ISO 10304-1	21000	mg/l			30/10/2018
Nitrates	NF EN ISO 10304-1	73	mg/l			30/10/2018
Sulfates	NF EN ISO 10304-1	2900	mg/l			30/10/2018
Oxygène dissous	NF EN 25814	8,0	mg/l d'O2			29/10/2018

Table 10: Table of results for sample Eau de Djib 2

Echantillon: 18/302/2B	EAU DE DJIB 2					EAU DE MER
Commentaires :						
Prélevé le : 18/10/2018 À NC	Réceptionné le : 29/10/2018				Température: 12,8 °C	
Analyse Physico-chimique réalisée par Qualio						
Paramètre	Méthode	Résultat	Unité	Limite Qualité	Référence Qualité	Début Analyse
ST-DCO	ISO 15705	60	mg/l			30/10/2018
Turbidité	NF EN ISO 7027-1	0,44	FNU			29/10/2018
Résidu Sec	NF T 90-029	64804	mg/l			29/10/2018
Bicarbonates	NF EN ISO 9963-1	164	mg/L			29/10/2018
Chlorures	NF EN ISO 10304-1	20000	mg/l			30/10/2018
Nitrates	NF EN ISO 10304-1	72	mg/l			30/10/2018
Sulfates	NF EN ISO 10304-1	2800	mg/l			30/10/2018
Oxygène dissous	NF EN 25814	7,6	mg/l d'O2			29/10/2018

Table 11: Table of results for sample Eau de Djib 3

Echantillon: 18/302/2C	EAU DE DJIB 3					EAU DE MER
Commentaires :						
Prélevé le : 18/10/2018 À NC	Réceptionné le : 29/10/2018				Température: 12,8 °C	
Analyse Physico-chimique réalisée par Qualio						
Paramètre	Méthode	Résultat	Unité	Limite Qualité	Référence Qualité	Début Analyse
ST-DCO	ISO 15705	60	mg/l			30/10/2018
Turbidité	NF EN ISO 7027-1	0,65	FNU			29/10/2018
Résidu Sec	NF T 90-029	49069	mg/l			29/10/2018
Bicarbonates	NF EN ISO 9963-1	159	mg/L			29/10/2018
Chlorures	NF EN ISO 10304-1	20000	mg/l			30/10/2018
Nitrates	NF EN ISO 10304-1	72	mg/l			30/10/2018
Sulfates	NF EN ISO 10304-1	2700	mg/l			30/10/2018
Oxygène dissous	NF EN 25814	7,0	mg/l d'O2			29/10/2018

3.2.2.2 Tadjourah

Conditions of the period of collection of the samples:

Date	20 october
Location	Tadjourah
Tide	2,2 m
Wind direction	East
Temperature	32,8 °C
Humidity	67%

Table 12: Parameters of the sample taken at 25 °c in lab on the day of collection (20th October)

Samples	Temperature °C	pH (25°C)	Conductivity (Ms/cm)
Eau Tadj 1	25	8.41	56.7
Eau Tadj 2	25	8.23	56.6
Eau Tadj 3	25	8.39	56.5

Table 13: Table of results for sample Eau de Tadj 1

Echantillon: 18/302/2D		***EAU DE TADJ 1***				**EAU DE MER**
Commentaires :						
Prélevé le : 20/10/2018 À NC		Réceptionné le : 29/10/2018				Température: 12,8 °C
Analyse Physico-chimique réalisée par Qualio						
Paramètre	Méthode	Résultat	Unité	Limite Qualité	Référence Qualité	Début Analyse
ST-DCO	ISO 15705	50	mg/l			30/10/2018
Turbidité	NF EN ISO 7027-1	0,49	FNU			29/10/2018
Résidu Sec	NF T 90-029	69730	mg/l			29/10/2018
Bicarbonates	NF EN ISO 9963-1	161	mg/L			29/10/2018
Chlorures	NF EN ISO 10304-1	20000	mg/l			30/10/2018
Nitrates	NF EN ISO 10304-1	71	mg/l			30/10/2018
Sulfates	NF EN ISO 10304-1	2800	mg/l			30/10/2018
Oxygène dissous	NF EN 25814	8,7	mg/l d'O2			29/10/2018

Table 14: Table of results for sample Eau de Tadj2

Echantillon: 18/302/2E		***EAU DE TADJ 2***				**EAU DE MER**
Commentaires :						
Prélevé le : 20/10/2018 À NC		Réceptionné le : 29/10/2018				Température: 12,8 °C
Analyse Physico-chimique réalisée par Qualio						
Paramètre	Méthode	Résultat	Unité	Limite Qualité	Référence Qualité	Début Analyse
ST-DCO	ISO 15705	60	mg/l			30/10/2018
Turbidité	NF EN ISO 7027-1	0,12	FNU			29/10/2018
Résidu Sec	NF T 90-029	54819	mg/l			29/10/2018
Bicarbonates	NF EN ISO 9963-1	149	mg/L			29/10/2018
Chlorures	NF EN ISO 10304-1	20000	mg/l			30/10/2018
Nitrates	NF EN ISO 10304-1	72	mg/l			31/10/2018
Sulfates	NF EN ISO 10304-1	2800	mg/l			30/10/2018
Oxygène dissous	NF EN 25814	8,2	mg/l d'O2			29/10/2018

Table 15: Table of results for sample Eau de Tadj 3

Echantillon: 18/302/2F		EAU DE TADJ 3				EAU DE MER
Commentaires :						
Prélevé le : 20/10/2018 À NC		Réceptionné le : 29/10/2018				Température: 12,8 °C
Analyse Physico-chimique réalisée par Qualio						
Paramètre	Méthode	Résultat	Unité	Limite Qualité	Référence Qualité	Début Analyse
ST-DCO	ISO 15705	70	mg/l			30/10/2018
Turbidité	NF EN ISO 7027-1	0,29	FNU			29/10/2018
Résidu Sec	NF T 90-029	73077	mg/l			29/10/2018
Bicarbonates	NF EN ISO 9963-1	148	mg/L			29/10/2018
Chlorures	NF EN ISO 10304-1	20000	mg/l			30/10/2018
Nitrates	NF EN ISO 10304-1	71	mg/l			31/10/2018
Sulfates	NF EN ISO 10304-1	2700	mg/l			30/10/2018
Oxygène dissous	NF EN 25814	9,0	mg/l d'O2			29/10/2018

3.2.2.3 Analysis of the data

The physical parameters of seawater measured on-site present homogenous characteristics and qualitative and quantitative data.

- **pH**

The hydrogen ion concentration (pH) values are clustered in the normal range value and vary from 7.42 to 8.41 but, the pH values of Tadjourah sea remain higher than the values measured for Djibouti site.

- **Conductivity / Salinity**

The electrical conductivity which express the salinity of seawater are in the range of 53,000µS/cm-56,000 µS/cm but the higher value of salinity is also recorded for Tadjourah site. (highest: 56,7 µS/cm).

- **Turbidity**

The light penetration in the seawater which is vital for coral reef is quantified by the turbidity.
The turbidity is a measure of the amount of cloudiness or haziness in sea water caused by suspended particles. On both sites, the turbidity values of seawater are normal.
During the survey, at the three measuring points in Tadjourah, the turbidity values of seawater were respectively 0.49 NFU, 0.12 NFU et 0.29 NFU (1 NFU = 1 NTU). These values are below the standard threshold value for Class I coastal waters (see table 3). However, there was significant difference between the three points:

- Turbidity was higher at point 1 (Eau/Tadj 1) located on the shallow coral reef,
- while at points Eau/Tadj 2 and Eau/Tadj 3 located respectively on the reef slope and the downfall, the turbidity values are the weakest and reflecting clearer waters.

- **Dissolved oxygen**

The dissolved oxygen is slightly higher than the minimal recommended value of 8.0mg/l except for 2 samples of Djibouti (DJIB2, DJIB3)[10]. Dissolved oxygen content of seawater was about 8.2 – 9 mg/L in Tadjourah, which is greater than the standard value of 4 mg/L recommended for protection of aquatic lives.

[10] Canadian Water Quality Guidelines for the Protection of Aquatic Life: Dissolved oxygen(DO),1999, Canadian Council of Ministers of the Environment, Winnipeg.

The ammonium nitrate concentration of seawater which is a good indicator of water pollution in general is higher than the standard maximum value associated with drinkable water (50mg/l)[11] and ranges around 71-72 mg/l.

The concentration of chemical oxygen demand (COD- STDCO in French)) which highlights the organic matters pollution varies between 50 mg/l and 90 mg/l in Djibouti (Eau de Djib1)

The hydrogenocarbonate, chloride and sulfate concentrations for all samples are under the standard value of Djibouti seawater[12].

Table 16 : Water quality criteria for class SW-1 Water (Source: International Journal of Innovative Research in Science, Engineering and Technology (An ISO 3297: 2007 Certified Organization) Vol. 4, Issue 12, December 2015)

Parameter	Standards	Rationale / Remarks
pH range	6.5 – 8.5	Range does not cause skin or eye irritation and is also conducive for propagation of aquatic life
Dissolved oxygen	4.0 mg/l or 50 percent saturation value, which ever is higher.	Not less than 3.5 mg/l at any time of the year for protection of aquatic lives
Odor or Colour	No noticeable colour or offensive odour.	Specially caused by chemical compounds like creosols, phenols, naptha, pyridine, benzene, toluene etc. causing visible colouration of salt crystal and tainting of fish flesh.
Turbidity	30 NTU (Nephelo Tur- bidity Unit : 1 NFU = 1 NTU)	Measured at 0.9 depth.
Fecal Coliform	100/100 ml (MPN)	The average value not exceeding 200/100 ml. in 20 percent of samples in the year and in 3 consecutive samples in monsoon months.
Biochemical Oxygen Demand (BOD) (3 days at 27°C)	3 mg/l	Restricted for bathing (aesthetic quality of water).

[11] WHO: Guidelines for drinking water quality, 2003
[12] Sanjuan, B., Michard, G., & Michard, A. (1990). Origine des substances dissoutes dans les eaux des sources thermales et des forages de la région Asal-Ghoubbet (République de Djibouti). Journal of Volcanology and Geothermal Research, Volume 43, Issues 1–4, 333–352.

3.3 Environmental Noise

The objective of the noise measurements was to determine outdoor ambient noise levels (dBA) around the proposed study site.

3.3.1 Djibouti

3.3.1.1 Methodology

Noise measurements were recorded on November 9 and 10, 2018, at the port of call in Djibouti for 24 hours.

- **Measuring instruments**

A decibelmeter was used to perform the noise study.
The maximum wind speed was recorded simultaneously using data from the airport weather station.

Figure 6: Sound level meter Instrument

- **Atmospheric conditions**

The sky was clear and it was generally warm (temperatures ranging from 31 ° C to 14h at 27 ° C to 4h) with average wind speeds not exceeding 5 m / s throughout the measurement period.

- **Measurement procedure**

The sound level meter (decibelmeter) was placed at a height of 1.3 m above the ground surface and continuous equivalent noise levels each (1 minute) were recorded.

3.3.1.2 Results

The measurements recorded during the evaluation are presented below.

Table 17: Results of noise measurements in Djibouti

Measuring time	Wind speed (m/s)	[dB(A)]
13:00-14:00	4	51.1
14:00-15:00	5	48.1
15:00-16:00	5	48.19
16:00-17:00	5	48.4
17:00-18:00	3	48.8
18:00-19:00	3	47
19:00-20:00	3	46.55
20:00-21:00	3	47.2
21:00-22:00	3	46.5
22:00-23:00	3	45.4
23:00-24:00	2	47
24:00-01:00	3	47.03
01:00-02:00	3	49.3
02:00-03:00	3	46.8
03:00-04:00	3	48.2
04:00-05:00	3	48.9
05:00-06:00	3	48.5
06:00-07:00	3	46.3
07:00-08:00	3	45.3
08:00-09:00	3	45
09:00-10:00	4	44.6
10:00-11:00	4	45.6
11:00-12:00	3	46.4
12:00-13:00	5	45.9
13:00-14:00	5	47

- **Standard level of noise**

Noise in the environment is defined as noise from all sources. They include air traffic, road traffic, rail traffic, industry, construction and public works (Summary of WHO Guidelines).
According to the WHO, the general fixation of noise outside and during the day is recommended at less **than 55 dB (A) and at night at 45 dB (A).**

Observations of the mean of the measurement point observed are 47 dB (A), therefore below the limits of the WHO standard.

3.3.2 Tadjourah

3.3.2.1 Methodology

Noise measurements were recorded at two proposed locations for 24 hours.

- **Measurement tools**

A decibelmeter was used to perform the noise study.
The maximum wind speed was recorded simultaneously using data from the Tadjourah weather station.

- **Atmospheric conditions**

The sky was clear and it was generally warm (temperatures ranging from 30 ° C to 14h at 25 ° C to 4h) with light winds not exceeding 4 m / s throughout the measurement period. Quieter wind speeds were recorded during the night compared to the day.

- **Measurement procedure**

The sound level meter was placed at a height of 1.3 m above the ground surface and continuous equivalent noise levels each (1 minute) were recorded.

3.3.2.2 Results

The measurements recorded during the evaluation are presented below.

Table 18: Results of noise measurements in Mosque

Measuring time (Tadjourah)	Wind speed (m/s)	[dB(A)]
10:00-11:00	2.7	58
11:00-12:00	3.5	59.9
12:00-13.00	4	57
13:00-14:00	3.9	54,8
14:00-15:00	4	53.8
15:00-16:00	4.2	54.6
16:00-17:00	3.1	57.6
17:00-18:00	2.7	59
18:00-19:00	1.8	57.78
19:00-20:00	1.5	59.65
20:00-21:00	1.8	59.49
21:00-22:00	2.45	58.41
22:00-23:00	1.3	56.48
23:00-24:00	0.95	52.17
24:00-01:00	0.95	50.96
01:00-02:00	1.1	50.97
02:00-03:00	1.2	49.96
03:00-04:00	1.16	49.89
04:00-05:00	1.16	52.06
05:00-06:00	1.1	53.26
06:00-07:00	1.4	54.87
07:00-08:00	2	58.3
08:00-09:00	2.6	58.45
09:00-10:00	3.8	59.9

Table 19: Results of noise measurements in Port

Measuring time	Wind speed (m/s)	[dB(A)]
10:00-11:00	3.95	58
11:00-12:00	4	58
12:00-13.00	4.1	54
13:00-14:00	4.4	53
14:00-15:00	4.1	48.9
15:00-16:00	4.1	49
16:00-17:00	3.28	48.8
17:00-18:00	2.76	50.45
18:00-19:00	2.2	54
19:00-20:00	1.3	54.6
20:00-21:00	0.4	55
21:00-22:00	1.3	55.29
22:00-23:00	1.4	53.12
23:00-24:00	1.3	49.63
24:00-01:00	1.3	48.08
01:00-02:00	1.5	48.6
02:00-03:00	1.4	47.93
03:00-04:00	1.16	48.22
04:00-05:00	1.1	48.9
05:00-06:00	1.16	49.7
06:00-07:00	1.48	51.25
07:00-08:00	1.4	53.72
08:00-09:00	2.3	55.36
09:00-10:00	3	58.8

- **Standard level of noise**

Noise in the environment is defined as noise from all sources. They include air traffic, road traffic, rail traffic, industry, construction and public works (Summary of WHO Guidelines).

According to the WHO, the general fixation of noise outside and during the day is recommended at less than 55 dB (A) and at night at 45 dB (A).

Observations of the mean on the two measurement points observed are 52 dB (A) for the port and 55 dB (A) for the mosque, therefore below the limits of the WHO standard.

3.4 *Air quality survey*

3.4.1 Djibouti

3.4.1.1 Methodology

The DT particle counter was used to measure mass concentrations of PM 2.5 and 10. We used climate data collected at the Djibouti aerodrome station (See Annex2).

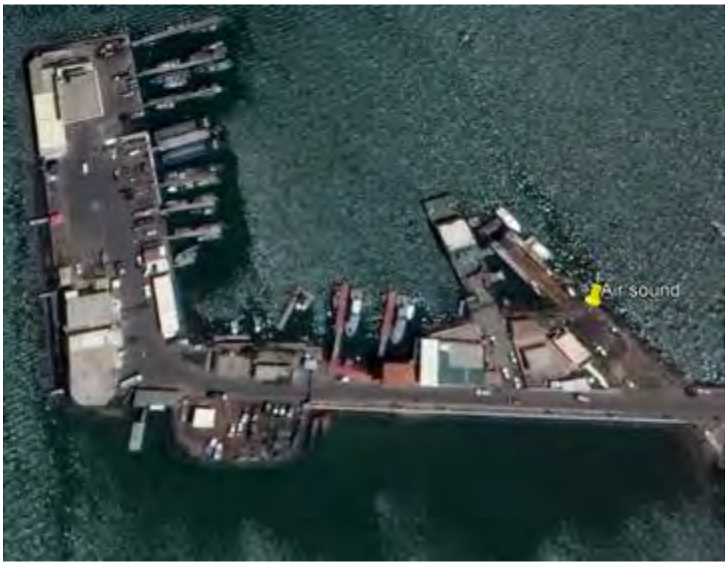

Figure 7: Study area, measurements air sound

- **Measurement methods**

The mass concentration of the particles was recorded on November 17, 2018, by operating the reader for five minutes each hour. The procedure was repeated hourly during the whole day or in total 24 hours on the site.

3.4.1.2 Results

PM 10 Concentration (µg/m³) by hours																										
Points	**Coordinate**	**Hours**																								
	Wgs 84 z38	13	14	15	16	17	18	19	20	21	22	23	24	1	2	3	4	5	6	7	8	9	10	11	12	13
Port	269099/ 1303585	4	6	7	8	7	13	14	13	10	11	10	13	11	15	13	14	11	11	8	7	4	8	6	6	6

PM 2.5 Concentrations (µg/m³) by hours																										
Points	**Coordinates**	**Hours**																								
	Wgs 84 z38	13	14	15	16	17	18	19	20	21	22	23	24	1	2	3	4	5	6	7	8	9	10	11	12	13
Port	269099/ 1303585	2	3	3	5	3	8	8	7	6	6	7	8	6	9	8	7	6	6	4	3	2	3	3	3	3

- **Standard quality of air**

Air quality standards are defined according to the different levels of danger that pollutants pose depending on the exposure period.
In the absence of air quality standards in Djibouti, we will take into account the air quality standards of the World Health Organization. The table presents the guidelines defined by WHO (2005) applicable to the project. WHO provides intermediate objectives (IT) in recognition of the need for a phased approach to achieve the recommended guidelines (GL).

Table 20: Guidelines defined by WHO (2005) for Pm10

Pollutant	Period	Air Quality Standards (µg/m3)
PM10	24 hours	150 (IT1)
		100 (IT2)
		75 (IT3)
		50 (GL)
	1 year	70 (IT1)
		50 (IT2)
		30 (IT3)
		20 (GL)

On average, the study site has a concentration rate of 5 µg / m3 PM2.5 and 9 µg / m3 PM10. The results show that the GL for 24h is respected for 24 hours.

2.1.1. Tadjourah

2.1.1.1. Methodology

A DT particle counter was used to measure the mass concentrations of PM 2.5 and 10. For wind and temperature measurements we relied on the automatic station installed during the Adcp measurements located about 200 meters from the test sites. measures. (Annex3).

Figure 8 : Location of 2 points of noise and Air measurement (Harbor/port and Mosque/mosquee) with the particle counter

- **Measurement methods**

Mass concentration of the particles was recorded at two sites on November 11 and 12, 2018, operating the reader for five minutes each hour. The procedure was repeated hourly during the whole day so a total of 48 hours at both sites.

2.1.1.2. Results

PM 10 Concentration (µg/m³) by hours																									
Points	Coordinates	Hours																							
	Wgs 84 z38	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	1	2	3	4	5	6	7	8	9
Mosque 11/11	269160/ 1303644	15	10	17	9	9	8	7	14	8	6	15	13	7	6	13	10	12	15	5	9	13	7	8	20
Port 12/11	269099/ 1303585	11	15	13	11	11	13	15	17	33	26	30	26	24	29	36	19	16	15	14	14	11	22	13	4

PM 2.5 Concentration (µg/m³) by hours																									
Points	Coordinates	Hours																							
	Wgs 84 z38	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	1	2	3	4	5	6	7	8	9
Mosque 11/11	269160/ 1303644	9	6	9	5	5	4	3	8	5	3	9	6	8	7	8	9	10	9	7	11	7	5	9	12
Port 12/11	269099/ 1303585	7	9	8	6	6	7	9	10	2	15	19	16	15	18	17	12	9	9	8	9	6	11	8	3

- **Standard quality of air**

Air quality standards are defined according to the different levels of danger that pollutants pose depending on the exposure period. For a daily concentration of PM, the United States Environmental Protection Agency analyzes the health effects of these levels of concentration.

Table 21: US EPA Air Quality Index (AQI), associated 24-hour PM10 (µg m−3) concentration, and health effects (US-EPA, 1999)

AQI category	AQI values	PM_{10} ($\mu g\ m^{-3}$)	Health effects
Good	0–50	0–54	None
Moderate	51–100	55–154	None
Unhealthy for sensitive groups	101–150	155–254	Increasing likelihood of respiratory symptoms and aggravation of lung disease, such as asthma
Unhealthy	151–200	255–354	Increasing likelihood of respiratory symptoms and aggravation of lung disease, such as asthma; possible respiratory effects in general population
Very unhealthy	201–300	355–424	Significant increase in respiratory symptoms and aggravation of lung disease, such as asthma; increasing likelihood of respiratory effects in general population
Hazardous	>300	>424	Serious risk of respiratory symptoms and aggravation of lung disease, such as asthma; respiratory effects likely in general population

In the absence of air quality standards in Djibouti, we will take into account the air quality standards of the World Health Organization. The table presents the guidelines defined by WHO (2005) applicable to the project. WHO provides intermediate objectives (IT) in recognition of the need for a phased approach to achieve the recommended guidelines (GL).

Table 22: Guidelines defined by WHO (2005) for Pm10

Pollutant	Period	Air Quality Standards (µg/m3)
PM 10	24 hours	150 (IT1)
		100 (IT2)
		75 (IT3)
		50 (GL)
	1 year	70 (IT1)
		50 (IT2)
		30 (IT3)
		20 (GL)

On average, the 2 study sites have a concentration rate of 10.75 µg / m3 (mosque) and 17 µg / m3 (harbor) PM10 µg / m3 (mean 24 hours).

Table 23: Guidelines defined by WHO (2005) for Pm2.5

Pollutant	Period	Air Quality Standards (µg/m3)
PM 2.5	24 hours	75 (IT1)
		50 (IT2)
		37.5 (IT3)
		25 (GL)
	1 year	35 (IT1)
		25 (IT2)
		15 (IT3)
		10 (GL)

On average, the 2 study sites have a concentration rate of 7.25 µg / m3 (mosque) and 10.75 µg / m3 (port) PM2.5 (average of 24 hours).
The results show that the GL for 24h is respected on the 2 points of PM10 and PM 2.5 for 24 hours.

4 Prospective coral survey

4.1 Localization

The prospective coral survey has been done along the path of the future breakwater.

Figure 9: Indication (line) for the prospective survey

4.2 Methodology

4.2.1 Delineation of the area to be scanned

The points were localized using a high precision Garmin GPS (±1 m). Floating buoys were placed at each of these three points (table 1). Underwater, a 200 m long rope was placed on the bottom between three points below and vertically to the landmarks on the surface of the sea.

Table 24: Position of the three points at the surface

	Longitude	Latitude
Point 1	42°52′48.93″E	11°47′3.25″N
Point 2	42°52′47.92″E	11°46′59.86″N
Point 3	42°52′49.63″E	11°46′57.55″N

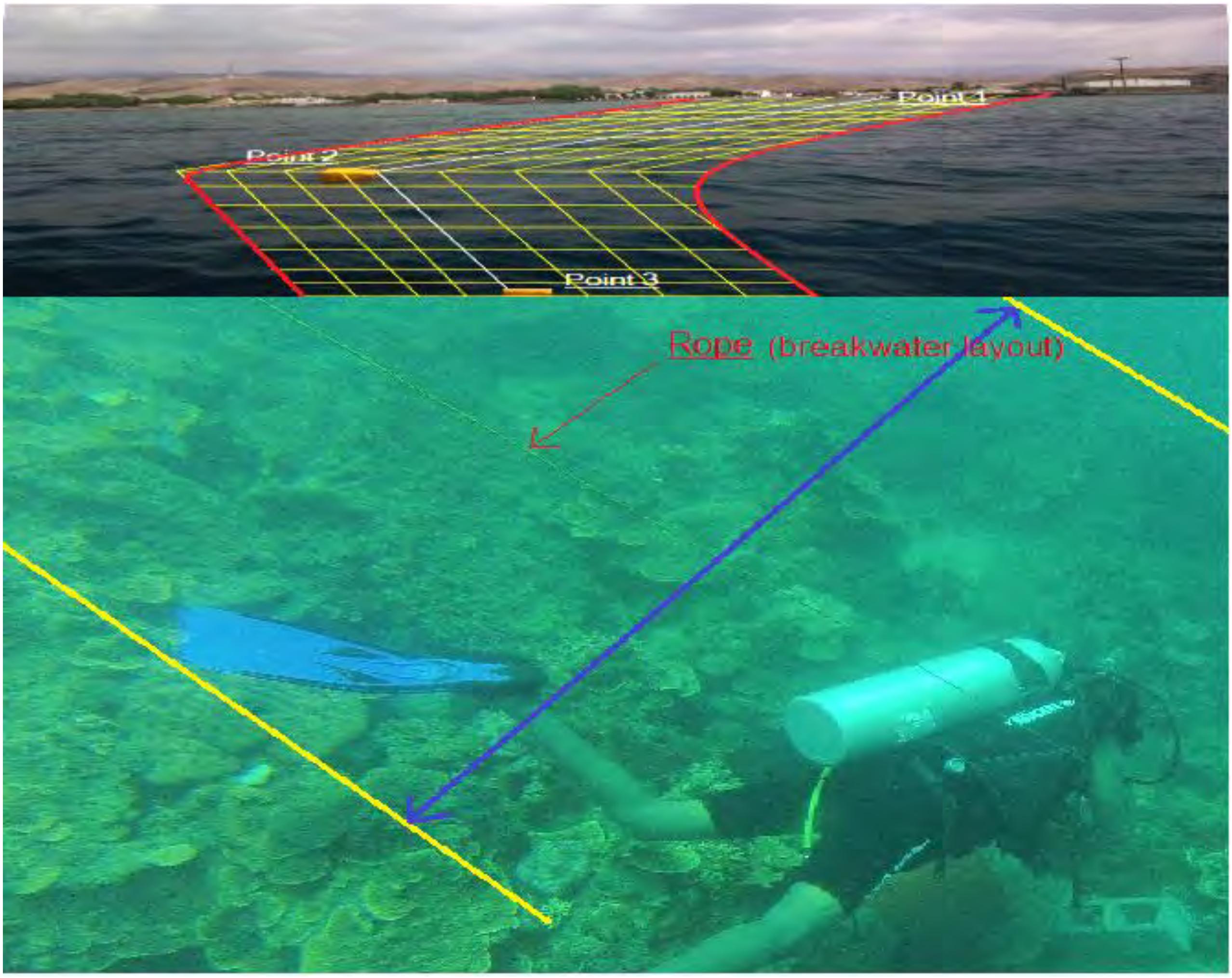

Figure 10: Top : landmarks on the seasurface : scanned zone and floating buoys
Down : layout of the breakwater (rope on the seabed in yellow thin line), limits of the scanned area (yellow thick line)

4.2.2 Materials

- Garmin GPS,
- Camera type,
- Slate and waterproof pencil,
- 200 m rope.

4.2.3 Methods

- Visual observation under scuba diving along the line connecting the two points and about 5 m wide on both sides of the line of the route. Along this line materialized by a rope, the presence or not of the corals, their condition as well as the nature of the bottoms are carefully noted on a waterproof plastic slate.
- Photographic and videos shots were taking for later analysis

4.3 Results

The study area is located on a fringing reef. This coral reef has no flat. At north, a large part is backfilled by the rocks. From the coast, the reef sinks progressively in the ocean. Visual observation in scuba diving revealed the presence of several types of seabed along the breakwater layout. This section describes by reef zonation the different types of substrates and coral populations.

4.3.1 Vicinity of the coastline

4.3.1.1 Coral rubble

The first type of substrates encountered near the coastline consists of mainly of coral rubble, sand and stone blocks. Live corals are sparse and represented by massive isolated forms and branching shapes hanging on the stone blocks (Photo 1). Some species of small fish (*Lutjanus sp.*) and giant clams (*Tridacne gigas*) were observed during the survey.

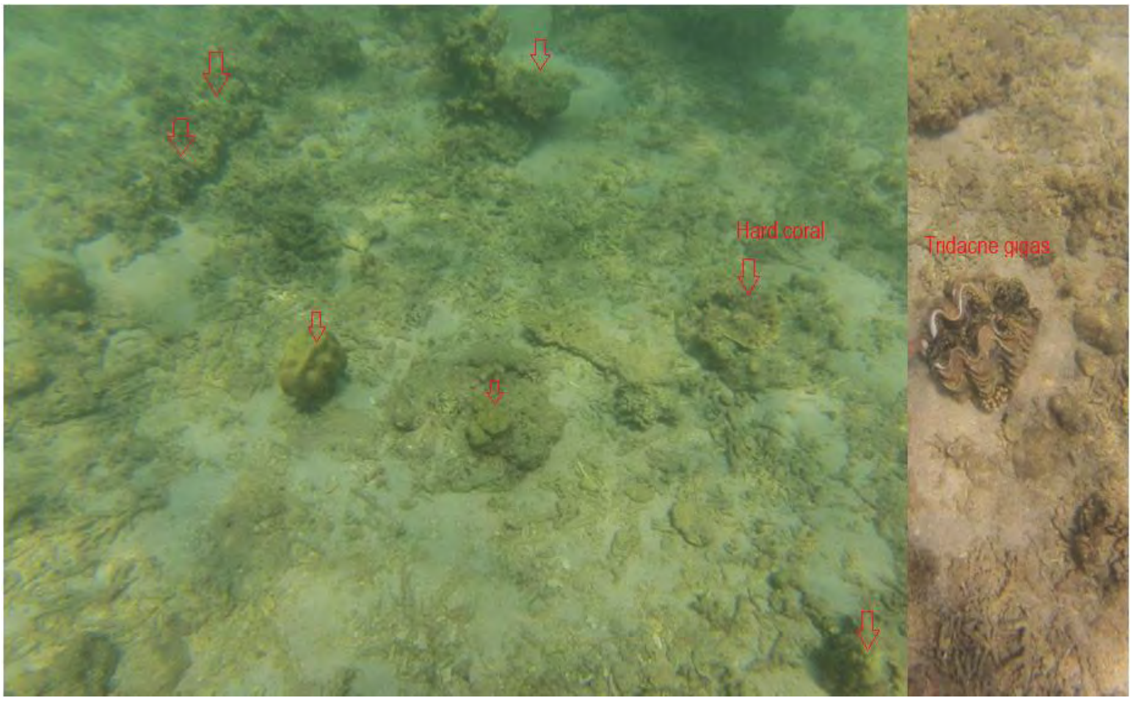

Photo 3: Seabed covered by coral bioclasts and some live corals (indicated by red arrows). On the left the giant tridances

4.3.1.2 *Exclusive settlement area of massive corals*

The ground is then covered by massive hard corals whose coverage density has been estimated at over 80%. The rest of the area is covered by sand. To the east, this area is bordered by a conglomerate of basalt stone blocks on which some corals develop.

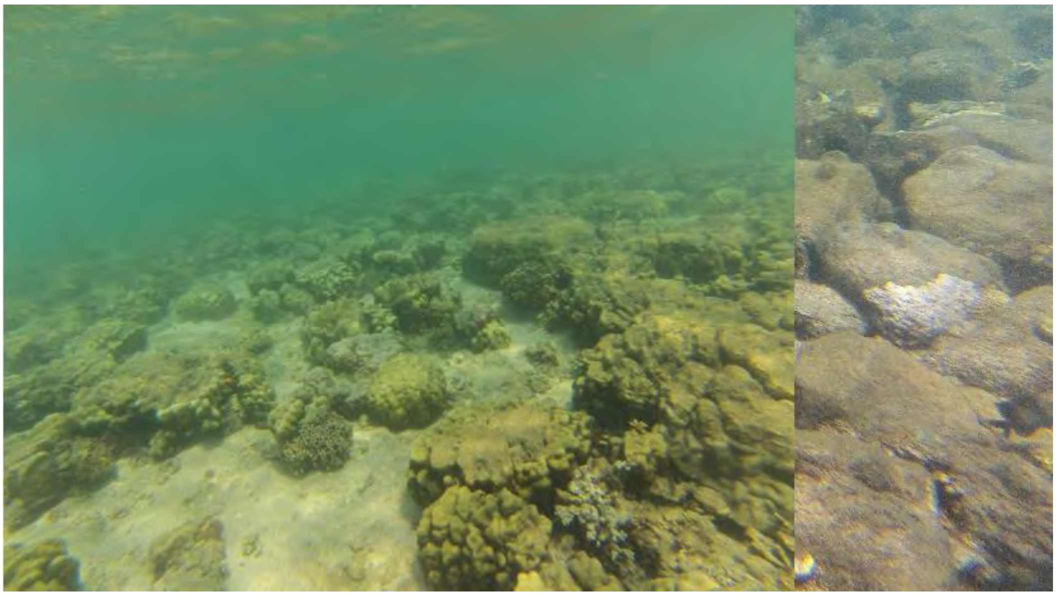

Photo 4: Seabed covered mainly by massive hard corals and stone blocks with some live corals

4.3.2 Reef Crest Zone

The reef ridge is distinguished from the massive coral zone by the diversity of coral forms and species (Photo 3).

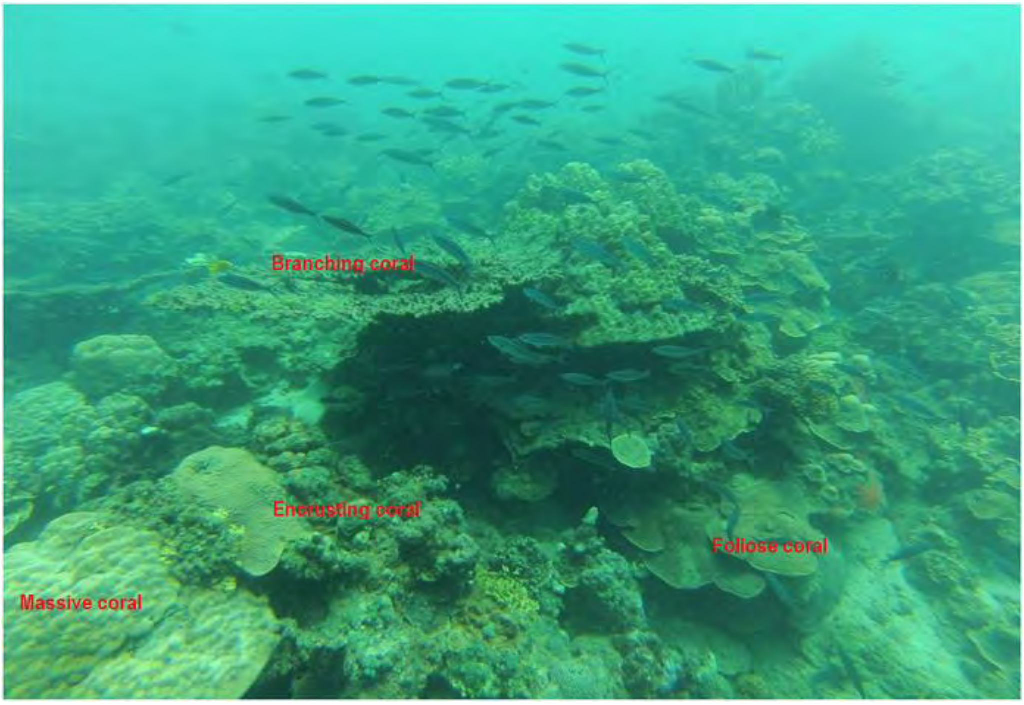

Photo 5: The reef crest covered by massive corals, encrusting, covering and branched

4.3.3 Reef Slope Area

The bottom consists of flourishing living corals of various shapes. The coral cover is high and the encrusting forms dominate the upper part of the slope while the branched and tabular forms develop in the deeper areas.

Table 25: Summary of coral presence, abundance and disposal

Zonation	Coral type	Layout and abundance
Near the coast	Coral rubbles Porites	++++ +
Back reef	Porites Sand	++++ +
Reef ridge	Massive forms Encrusting Branched forms	++++ ++
Reef slope	Massive coral Encrusting coral Branching coral	++++ ++++ ++++

4.4 Conclusion

At the end of the underwater scuba observations and snapshots, the study revealed the abundance of corals along the path of the future breakwater. The density and diversity of corals vary spatially according to the reef zonation (near the coast, back reef, reef ridge, reef slope).

- Corals are present but scanty near the coastline. In this zone, substrates consist mainly of coral rubbles and some scattered live corals.
- This area follows a shallow area with a high coral density exclusively composed of massive forms (Porites sp).
- The ridge of the reef includes large blocks of massive porites and encrusting forms that remain exposed to the waves during low tides.
- The reef slope is by far the part of the fringing reef that contains the greatest diversity of species and coral forms. The upper part of the slope is covered by massive and encrusting corals adapted to hydrodynamics. Branched and tabular corals, more sensitive to wave surges, develop in the lower part of the reef slope.
- The presence of corals on the slope is limited to a depth of about 15 m. Beyond this, the corals become scarce and the slope sinks abruptly.
- Overall, with the exception of the area near the coastline, the condition of the corals was considered good. This brief study has highlighted an unsuspected coral diversity of the fringing reef, particularly at the reef slope.

This reef is a natural barrier that protects the city of Tadjourah against large waves. Destroyed, he could no longer play this protective role. It also plays a major ecological and socio-economic role. It is a habitat and a breeding ground for multitudes of fish species and invertebrates exploited by artisanal fishing which is one of the main economic activities of the city of Tadjourah. All this justifies that this coral reef and the species it contains deserve special protection.

In this perspective, a more in-depth study should be conducted on this coral reef. This study will make an inventory of all coral species that make up the reef, their vulnerability and coral cover. It is only after this investigation and on the basis of the scientific data that a real plan for the construction of breakwaters and other infrastructures will have to be put in place. In this new plan, the breakwater layout should be such that the coral crossing portion is minimized, so that the corals will be spared.

5 Annexes

5.1 Annex 1: Laboratory results

UNIVERSITé DE FRANCHE-COMTé

QUALIO
analyses & environnement

RAPPORT D'ESSAI N° 18/302/2

Édité le 05/12/2018

N° Commande Client :
Passée par : IBRAHIM BEDAL
Affaire : EAU ET SÉDIMENTS MARINS
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SALINES OUEST
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Ce rapport d'essai, qui comporte 6 pages, ne concerne que les échantillons soumis à l'essai. Il ne peut être reproduit, que dans son intégralité, et uniquement avec l'accord préalable du laboratoire.
Analyses effectuées par un laboratoire agréé par le ministère chargé de l'environnement dans les conditions de l'arreté du 27 octobre 2011, identifiées par *. Et par le Ministère chargé de la santé;
"Laboratoire agréé pour la réalisation des analyses des paramètres du contrôle sanitaire des eaux - portée détaillée de l'agrément disponible sur demande"
Laboratoire accrédité N°1-6283 par la Section Laboratoire-Secteur Essais du COFRAC. Seules les prestations identifiées par le symbole (1) rapportées dans ce document sont couvertes par l'accréditation.
Pour déclarer, ou non, la conformité à la spécification, il n'a pas été tenu compte des incertitudes.
Hormis les essais réalisés in-situ, les autres ont été réalisés au sein des laboratoires concernés. Les données fournies par le client sont identifiées en italique.

Echantillon: 18/302/2A ***EAU DE DJIB 1*** **EAU DE MER**

Commentaires :

Prélevé le : 18/10/2018 À NC Réceptionné le : 29/10/2018 Température: 12,8 °C

Analyse Physico-chimique réalisée par Qualio

Paramètre	Méthode	Résultat	Unité	Limite Qualité	Référence Qualité	Début Analyse
ST-DCO	ISO 15705	90	mg/l d'O2			30/10/2018
Turbidité	NF EN ISO 7027-1	0,43	FNU			29/10/2018
Résidu Sec	NF T 90-029	42829	mg/l			29/10/2018
Bicarbonates	NF EN ISO 9963-1	186	mg/L			29/10/2018
Chlorures	NF EN ISO 10304-1	21000	mg/l			30/10/2018
Nitrates	NF EN ISO 10304-1	73	mg/l			30/10/2018
Sulfates	NF EN ISO 10304-1	2900	mg/l			30/10/2018
Oxygène dissous	NF EN 25814	8,0	mg/l d'O2			29/10/2018

Echantillon: 18/302/2B ***EAU DE DJIB 2*** **EAU DE MER**

Commentaires :

Prélevé le : 18/10/2018 À NC Réceptionné le : 29/10/2018 Température: 12,8 °C

Analyse Physico-chimique réalisée par Qualio

Paramètre	Méthode	Résultat	Unité	Limite Qualité	Référence Qualité	Début Analyse
ST-DCO	ISO 15705	60	mg/l			30/10/2018
Turbidité	NF EN ISO 7027-1	0,44	FNU			29/10/2018
Résidu Sec	NF T 90-029	64804	mg/l			29/10/2018
Bicarbonates	NF EN ISO 9963-1	164	mg/L			29/10/2018
Chlorures	NF EN ISO 10304-1	20000	mg/l			30/10/2018
Nitrates	NF EN ISO 10304-1	72	mg/l			30/10/2018
Sulfates	NF EN ISO 10304-1	2800	mg/l			30/10/2018
Oxygène dissous	NF EN 25814	7,6	mg/l d'O2			29/10/2018

Echantillon: 18/302/2C ***EAU DE DJIB 3*** **EAU DE MER**

Commentaires :

Prélevé le : 18/10/2018 À NC Réceptionné le : 29/10/2018 Température: 12,8 °C

Analyse Physico-chimique réalisée par Qualio

Paramètre	Méthode	Résultat	Unité	Limite Qualité	Référence Qualité	Début Analyse
ST-DCO	ISO 15705	60	mg/l			30/10/2018
Turbidité	NF EN ISO 7027-1	0,65	FNU			29/10/2018
Résidu Sec	NF T 90-029	49069	mg/l			29/10/2018
Bicarbonates	NF EN ISO 9963-1	159	mg/L			29/10/2018

Chlorures	NF EN ISO 10304-1	20000	mg/l			30/10/2018
Nitrates	NF EN ISO 10304-1	72	mg/l			30/10/2018
Sulfates	NF EN ISO 10304-1	2700	mg/l			30/10/2018
Oxygène dissous	NF EN 25814	7,0	mg/l d'O2			29/10/2018

Echantillon: 18/302/2D ***EAU DE TADJ 1*** **EAU DE MER**

Commentaires :

Prélevé le : 20/10/2018 À NC Réceptionné le : 29/10/2018 Température: 12,8 °C

Analyse Physico-chimique réalisée par Qualio

Paramètre	Méthode	Résultat	Unité	Limite Qualité	Référence Qualité	Début Analyse
ST-DCO	ISO 15705	50	mg/l			30/10/2018
Turbidité	NF EN ISO 7027-1	0,49	FNU			29/10/2018
Résidu Sec	NF T 90-029	69730	mg/l			29/10/2018
Bicarbonates	NF EN ISO 9963-1	161	mg/L			29/10/2018
Chlorures	NF EN ISO 10304-1	20000	mg/l			30/10/2018
Nitrates	NF EN ISO 10304-1	71	mg/l			30/10/2018
Sulfates	NF EN ISO 10304-1	2800	mg/l			30/10/2018
Oxygène dissous	NF EN 25814	8,7	mg/l d'O2			29/10/2018

Echantillon: 18/302/2E ***EAU DE TADJ 2*** **EAU DE MER**

Commentaires :

Prélevé le : 20/10/2018 À NC Réceptionné le : 29/10/2018 Température: 12,8 °C

Analyse Physico-chimique réalisée par Qualio

Paramètre	Méthode	Résultat	Unité	Limite Qualité	Référence Qualité	Début Analyse
ST-DCO	ISO 15705	60	mg/l			30/10/2018
Turbidité	NF EN ISO 7027-1	0,12	FNU			29/10/2018
Résidu Sec	NF T 90-029	54819	mg/l			29/10/2018
Bicarbonates	NF EN ISO 9963-1	149	mg/L			29/10/2018
Chlorures	NF EN ISO 10304-1	20000	mg/l			30/10/2018
Nitrates	NF EN ISO 10304-1	72	mg/l			31/10/2018
Sulfates	NF EN ISO 10304-1	2800	mg/l			30/10/2018
Oxygène dissous	NF EN 25814	8,2	mg/l d'O2			29/10/2018

Echantillon: 18/302/2F ***EAU DE TADJ 3*** **EAU DE MER**

Commentaires :

Prélevé le : 20/10/2018 À NC Réceptionné le : 29/10/2018 Température: 12,8 °C

Analyse Physico-chimique réalisée par Qualio

Paramètre	Méthode	Résultat	Unité	Limite Qualité	Référence Qualité	Début Analyse
ST-DCO	ISO 15705	70	mg/l			30/10/2018
Turbidité	NF EN ISO 7027-1	0,29	FNU			29/10/2018
Résidu Sec	NF T 90-029	73077	mg/l			29/10/2018
Bicarbonates	NF EN ISO 9963-1	148	mg/L			29/10/2018
Chlorures	NF EN ISO 10304-1	20000	mg/l			30/10/2018
Nitrates	NF EN ISO 10304-1	71	mg/l			31/10/2018
Sulfates	NF EN ISO 10304-1	2700	mg/l			30/10/2018
Oxygène dissous	NF EN 25814	9,0	mg/l d'O2			29/10/2018

Echantillon: 18/302/2G ***SEDIMENT DJIB 1*** **Sédiment - Solide**

Commentaires :

Prélevé le : 18/10/2018 À NC Réceptionné le : 29/10/2018 Température: 12,3 °C

Analyse Physico-chimique réalisée par Qualio

Paramètre	Méthode	Résultat	Unité	Limite Qualité	Référence Qualité	Début Analyse
Matières Sèches	NF EN 12880	786	g/kg			29/10/2018
Matières Organiques	NF EN 12879	3,7	% de MS			30/10/2018
Arsenic	NF EN ISO 11885	13,6	mg/kg MS			15/11/2018

Cadmium	NF EN ISO 11885	<0,5	mg/kg MS			15/11/2018
Chrome	NF EN ISO 11885	25,0	mg/kg MS			15/11/2018
Cuivre	NF EN ISO 11885	31,1	mg/kg MS			15/11/2018
Nickel	NF EN ISO 11885	17,7	mg/kg MS			15/11/2018
Plomb	NF EN ISO 11885	2,6	mg/kg MS			15/11/2018
Zinc	NF EN ISO 11885	72,0	mg/kg MS			15/11/2018
Mercure	NF EN ISO 17852	0,01	mg/kg MS			14/11/2018
Pesticides Organochlorés sur solides		feuille jointe	mg/kg de...			
Minéralisation	NF EN 13346	-				13/11/2018
Prétraitement (lyophilisation)	méthode interne P19...	-	-			29/10/2018

Echantillon: 18/302/2H ***SEDIMENT DJIB 2*** **Sédiment - Solide**

Commentaires :

Prélevé le : 18/10/2018 À NC Réceptionné le : 29/10/2018 Température: 12,3 °C

Analyse Physico-chimique réalisée par Qualio

Paramètre	Méthode	Résultat	Unité	Limite Qualité	Référence Qualité	Début Analyse
Matières Sèches	NF EN 12880	771	g/kg			29/10/2018
Matières Organiques	NF EN 12879	3,3	% de MS			30/10/2018
Arsenic	NF EN ISO 11885	10,4	mg/kg MS			15/11/2018
Cadmium	NF EN ISO 11885	<0,5	mg/kg MS			15/11/2018
Chrome	NF EN ISO 11885	29,9	mg/kg MS			15/11/2018
Cuivre	NF EN ISO 11885	39,9	mg/kg MS			15/11/2018
Nickel	NF EN ISO 11885	22,8	mg/kg MS			15/11/2018
Plomb	NF EN ISO 11885	6,0	mg/kg MS			15/11/2018
Zinc	NF EN ISO 11885	84,7	mg/kg MS			15/11/2018
Mercure	NF EN ISO 17852	0,02	mg/kg MS			14/11/2018
Pesticides Organochlorés sur solides		feuille jointe	mg/kg de...			
Minéralisation	NF EN 13346	-				13/11/2018
Prétraitement (lyophilisation)	méthode interne P19...	-	-			29/10/2018

Echantillon: 18/302/2I ***SEDIMENT DJIB 3*** **Sédiment - Solide**

Commentaires :

Prélevé le : 18/10/2018 À NC Réceptionné le : 29/10/2018 Température: 12,3 °C

Analyse Physico-chimique réalisée par Qualio

Paramètre	Méthode	Résultat	Unité	Limite Qualité	Référence Qualité	Début Analyse
Matières Sèches	NF EN 12880	751	g/kg			29/10/2018
Matières Organiques	NF EN 12879	3,2	% de MS			30/10/2018
Arsenic	NF EN ISO 11885	12,9	mg/kg MS			15/11/2018
Cadmium	NF EN ISO 11885	<0,5	mg/kg MS			15/11/2018
Chrome	NF EN ISO 11885	26,3	mg/kg MS			15/11/2018
Cuivre	NF EN ISO 11885	34,2	mg/kg MS			15/11/2018
Nickel	NF EN ISO 11885	20,4	mg/kg MS			15/11/2018
Plomb	NF EN ISO 11885	5,8	mg/kg MS			15/11/2018
Zinc	NF EN ISO 11885	74,3	mg/kg MS			15/11/2018
Mercure	NF EN ISO 17852	0,02	mg/kg MS			14/11/2018
Pesticides Organochlorés sur solides		feuille jointe	mg/kg de...			
Minéralisation	NF EN 13346	-				13/11/2018
Prétraitement (lyophilisation)	méthode interne P19...	-	-			29/10/2018

Echantillon: 18/302/2J ***SEDIMENT DJIB 4*** **Sédiment - Solide**

Commentaires :

Prélevé le : 18/10/2018 À NC Réceptionné le : 29/10/2018 Température: 12,3 °C

Analyse Physico-chimique réalisée par Qualio

Paramètre	Méthode	Résultat	Unité	Limite Qualité	Référence Qualité	Début Analyse
Matières Sèches	NF EN 12880	726	g/kg			29/10/2018
Matières Organiques	NF EN 12879	3,2	% de MS			30/10/2018
Arsenic	NF EN ISO 11885	10,8	mg/kg MS			15/11/2018
Cadmium	NF EN ISO 11885	<0,5	mg/kg MS			15/11/2018
Chrome	NF EN ISO 11885	28,8	mg/kg MS			15/11/2018
Cuivre	NF EN ISO 11885	38,4	mg/kg MS			15/11/2018

Nickel	NF EN ISO 11885	22,0	mg/kg MS			15/11/2018
Plomb	NF EN ISO 11885	5,0	mg/kg MS			15/11/2018
Zinc	NF EN ISO 11885	78,4	mg/kg MS			15/11/2018
Mercure	NF EN ISO 17852	0,02	mg/kg MS			14/11/2018
Pesticides Organochlorés sur solides		feuille jointe	mg/kg de...			
Minéralisation	NF EN 13346	-				13/11/2018
Prétraitement (lyophilisation)	méthode interne P19...	-	-			29/10/2018

Echantillon: 18/302/2K ***SEDIMENT DJIB 5*** **Sédiment - Solide**

Commentaires :

Prélevé le : 18/10/2018 À NC Réceptionné le : 29/10/2018 Température: 12,3 °C

Analyse Physico-chimique réalisée par Qualio

Paramètre	Méthode	Résultat	Unité	Limite Qualité	Référence Qualité	Début Analyse
Matières Sèches	NF EN 12880	716	g/kg			29/10/2018
Matières Organiques	NF EN 12879	3,9	% de MS			30/10/2018
Arsenic	NF EN ISO 11885	10,1	mg/kg MS			15/11/2018
Cadmium	NF EN ISO 11885	<0,5	mg/kg MS			15/11/2018
Chrome	NF EN ISO 11885	27,1	mg/kg MS			15/11/2018
Cuivre	NF EN ISO 11885	35,8	mg/kg MS			15/11/2018
Nickel	NF EN ISO 11885	21,1	mg/kg MS			15/11/2018
Plomb	NF EN ISO 11885	4,4	mg/kg MS			15/11/2018
Zinc	NF EN ISO 11885	146	mg/kg MS			15/11/2018
Mercure	NF EN ISO 17852	0,02	mg/kg MS			14/11/2018
Pesticides Organochlorés sur solides		feuille jointe	mg/kg de...			
Minéralisation	NF EN 13346	-				13/11/2018
Prétraitement (lyophilisation)	méthode interne P19...	-	-			29/10/2018

Echantillon: 18/302/2L ***SEDIMENT TADJ 1*** **Sédiment - Solide**

Commentaires :

Prélevé le : 18/10/2018 À NC Réceptionné le : 29/10/2018 Température: 12,3 °C

Analyse Physico-chimique réalisée par Qualio

Paramètre	Méthode	Résultat	Unité	Limite Qualité	Référence Qualité	Début Analyse
Matières Sèches	NF EN 12880	787	g/kg			29/10/2018
Matières Organiques	NF EN 12879	2,9	% de MS			30/10/2018
Arsenic	NF EN ISO 11885	2,7	mg/kg MS			15/11/2018
Cadmium	NF EN ISO 11885	<0,5	mg/kg MS			15/11/2018
Chrome	NF EN ISO 11885	4,9	mg/kg MS			15/11/2018
Cuivre	NF EN ISO 11885	5,1	mg/kg MS			15/11/2018
Nickel	NF EN ISO 11885	2,6	mg/kg MS			15/11/2018
Plomb	NF EN ISO 11885	2,4	mg/kg MS			15/11/2018
Zinc	NF EN ISO 11885	19,9	mg/kg MS			15/11/2018
Mercure	NF EN ISO 17852	<0,01	mg/kg MS			14/11/2018
Pesticides Organochlorés sur solides		feuille jointe	mg/kg de...			
Minéralisation	NF EN 13346	-				13/11/2018
Prétraitement (lyophilisation)	méthode interne P19...	-	-			29/10/2018

Echantillon: 18/302/2M ***SEDIMENT TADJ 2*** **Sédiment - Solide**

Commentaires :

Prélevé le : 18/10/2018 À NC Réceptionné le : 29/10/2018 Température: 12,3 °C

Analyse Physico-chimique réalisée par Qualio

Paramètre	Méthode	Résultat	Unité	Limite Qualité	Référence Qualité	Début Analyse
Matières Sèches	NF EN 12880	793	g/kg			29/10/2018
Matières Organiques	NF EN 12879	2,3	% de MS			30/10/2018
Arsenic	NF EN ISO 11885	3,5	mg/kg MS			15/11/2018
Cadmium	NF EN ISO 11885	<0,5	mg/kg MS			15/11/2018
Chrome	NF EN ISO 11885	19,8	mg/kg MS			15/11/2018
Cuivre	NF EN ISO 11885	20,6	mg/kg MS			15/11/2018
Nickel	NF EN ISO 11885	9,1	mg/kg MS			15/11/2018
Plomb	NF EN ISO 11885	4,7	mg/kg MS			15/11/2018
Zinc	NF EN ISO 11885	66,7	mg/kg MS			15/11/2018

Mercure	NF EN ISO 17852	<0,01	mg/kg MS			14/11/2018
Pesticides Organochlorés sur solides		feuille jointe	mg/kg de...			
Minéralisation	NF EN 13346	-				13/11/2018
Prétraitement (lyophilisation)	méthode interne P19...	-	-			29/10/2018

Echantillon: 18/302/2N — *SEDIMENT TADJ 3* — Sédiment - Solide

Commentaires :

Prélevé le : 18/10/2018 À NC Réceptionné le : 29/10/2018 Température: 12,3 °C

Analyse Physico-chimique réalisée par Qualio

Paramètre	Méthode	Résultat	Unité	Limite Qualité	Référence Qualité	Début Analyse
Matières Sèches	NF EN 12880	734	g/kg			29/10/2018
Matières Organiques	NF EN 12879	4,4	% de MS			30/10/2018
Arsenic	NF EN ISO 11885	1,7	mg/kg MS			15/11/2018
Cadmium	NF EN ISO 11885	<0,5	mg/kg MS			15/11/2018
Chrome	NF EN ISO 11885	2,0	mg/kg MS			15/11/2018
Cuivre	NF EN ISO 11885	<1,5	mg/kg MS			15/11/2018
Nickel	NF EN ISO 11885	<1	mg/kg MS			15/11/2018
Plomb	NF EN ISO 11885	<1	mg/kg MS			15/11/2018
Zinc	NF EN ISO 11885	2,2	mg/kg MS			15/11/2018
Mercure	NF EN ISO 17852	<0,01	mg/kg MS			14/11/2018
Pesticides Organochlorés sur solides		feuille jointe	mg/kg de...			
Minéralisation	NF EN 13346	-				13/11/2018
Prétraitement (lyophilisation)	méthode interne P19...	-	-			29/10/2018

Echantillon: 18/302/2O — *SEDIMENT TADJ 4* — Sédiment - Solide

Commentaires :

Prélevé le : 18/10/2018 À NC Réceptionné le : 29/10/2018 Température: 12,3 °C

Analyse Physico-chimique réalisée par Qualio

Paramètre	Méthode	Résultat	Unité	Limite Qualité	Référence Qualité	Début Analyse
Matières Sèches	NF EN 12880	773	g/kg			29/10/2018
Matières Organiques	NF EN 12879	2,8	% de MS			30/10/2018
Arsenic	NF EN ISO 11885	3,4	mg/kg MS			15/11/2018
Cadmium	NF EN ISO 11885	<0,5	mg/kg MS			15/11/2018
Chrome	NF EN ISO 11885	8,3	mg/kg MS			15/11/2018
Cuivre	NF EN ISO 11885	8,2	mg/kg MS			15/11/2018
Nickel	NF EN ISO 11885	4,9	mg/kg MS			15/11/2018
Plomb	NF EN ISO 11885	3,5	mg/kg MS			15/11/2018
Zinc	NF EN ISO 11885	32,7	mg/kg MS			15/11/2018
Mercure	NF EN ISO 17852	<0,01	mg/kg MS			14/11/2018
Pesticides Organochlorés sur solides		feuille jointe	mg/kg de...			
Minéralisation	NF EN 13346	-				13/11/2018
Prétraitement (lyophilisation)	méthode interne P19...	-	-			29/10/2018

Echantillon: 18/302/2P — *SEDIMENT TADJ 5* — Sédiment - Solide

Commentaires :

Prélevé le : 18/10/2018 À NC Réceptionné le : 29/10/2018 Température: 12,3 °C

Analyse Physico-chimique réalisée par Qualio

Paramètre	Méthode	Résultat	Unité	Limite Qualité	Référence Qualité	Début Analyse
Matières Sèches	NF EN 12880	764	g/kg			29/10/2018
Matières Organiques	NF EN 12879	4	% de MS			30/10/2018
Arsenic	NF EN ISO 11885	1,7	mg/kg MS			15/11/2018
Cadmium	NF EN ISO 11885	<0,5	mg/kg MS			15/11/2018
Chrome	NF EN ISO 11885	2,1	mg/kg MS			15/11/2018
Cuivre	NF EN ISO 11885	<1,5	mg/kg MS			15/11/2018
Nickel	NF EN ISO 11885	<1	mg/kg MS			15/11/2018
Plomb	NF EN ISO 11885	<1	mg/kg MS			15/11/2018
Zinc	NF EN ISO 11885	2,7	mg/kg MS			15/11/2018
Mercure	NF EN ISO 17852	<0,01	mg/kg MS			14/11/2018
Pesticides Organochlorés sur solides		feuille jointe	mg/kg de...			
Minéralisation	NF EN 13346	-				13/11/2018

Prétraitement (lyophilisation)	méthode interne P19...	-	-			29/10/2018

Les filtres Millipore AP40 047 05 sont utilisés pour le dosage des matières en suspension. Les résultats sont rendus en prenant en compte les matières en suspension sauf quand la filtration est indiquée dans les normes analytiques. Si l'heure de prélèvement n'est pas précisée pour la mesure du pH, ou si le délai entre le prélèvement et la réception au laboratoire dépasse 24h, des reserves sont appliquées. Le résultat de la mesure de la conductivité a été ramené à 25°C par un dispositif de correction de température. Les DBO sont réalisées avec suppression de la nitrification. Les résultats s'appliquent à l'échantillon, tel qu'il a été reçu.

Observations :

--- FIN DU RAPPORT ---

Le 05/12/2018, validé par :

DRUART Coline, Responsable de laboratoire

QUALIO - 16, Route de Gray - 25030 BESANÇON Cedex - Téléphone : 03 81 66 60 85 - Télécopie : 03 81 66 60 86 - email :qualio@univ-fcomte.fr

5.2 Annex 2: Air quality measures in Djibouti

16 & 17 November 2018				
Hours	Pm 2,5	Pm 10	Temperature	Wind Speed m/s
13	2	4	31,4	4
14	3	6	31,5	5
15	3	7	32,3	5
16	5	8	30	5
17	3	7	29,5	3
18	8	13	29	3
19	8	14	28,5	3
20	7	13	28,5	3
21	6	10	28,3	3
22	6	11	28	3
23	7	10	27,8	2
24	8	13	27,5	3
1	6	11	27,3	3
2	9	15	27	3
3	8	13	27,2	3
4	7	14	27	3
5	6	11	27,4	3
6	6	11	27,5	3
7	4	8	28,2	3
8	3	7	29,5	3
9	2	4	30,5	4
10	3	8	31	4
11	3	6	31	3
12	3	6	31,5	5
13	3	6	31,5	5

5.3 Annex 3: Air quality measures in Tadjourah

11/11/2018	Mosque				
Hours	**Pm 2,5**	**Pm 10**	**Temperature**	**Wind Speed m/s**	**Direction**
10	9	15	30,1	2,7	E
11	6	10	30,5	3,5	E
12	9	17	30,9	4	SE
13	5	9	30,5	3,9	ESE
14	5	9	30,2	4	E
15	4	8	29,8	4,2	E
16	3	7	29,5	3,1	ESE
17	8	14	28,2	2,7	E
18	5	8	27,9	1,8	E
19	3	6	27,5	1,5	ENE
20	9	15	27,7	1,8	E
21	6	13	28,1	2,45	E
22	8	7	27,9	1,3	ENE
23	7	6	27,6	0,95	NE
24	8	13	27,5	0,95	NE
1	9	10	27,5	1,1	NE
2	10	12	27,6	1,2	NNE
3	9	15	27,7	1,16	NE
4	7	5	27,6	1,16	NE
5	11	9	27,5	1,1	NE
6	7	13	27,6	1,4	NE
7	5	7	28,9	2	ESE
8	9	8	29,3	2,6	ESE
9	12	20	29,7	3,8	SE

12/11/2018Tadjourah port

Hours	Pm 2,5	Pm 10	Temperature	Wind Speed m/s	Direction
10	7	11	30,1	3,95	SE
11	9	15	30,5	4	ESE
12	8	13	30,9	4,1	SE
13	6	11	30,7	4,4	ESE
14	6	11	30,4	4,1	SE
15	7	13	29,8	4,1	ESE
16	9	15	29,4	3,28	ESE
17	10	17	28,4	2,76	ESE
18	21	33	27,8	2,2	E
19	15	26	27,6	1,3	E
20	19	30	27,3	0,4	NE
21	16	26	27,2	1,3	ENE
22	15	24	27,1	1,4	NE
23	18	29	26,8	1,3	NNE
24	17	26	26,4	1,3	N
1	12	19	26,2	1,5	N
2	9	16	26	1,4	N
3	9	15	25,8	1,16	N
4	8	14	25,5	1,1	N
5	9	14	25,48	1,16	N
6	6	11	25,95	1,48	N
7	11	22	27,32	1,4	N
8	8	13	28,6	2,3	SE
9	3	4	29,17	3	SE

5.4 Annex 4: Photos of the corals

5.5 Annex 5: Photos of the Dolphins

It was asked to seize the opportunity of the diving, to get some photos of the two dolphins in Tadjourah Port (photos hereunder provided by JPC). The diving team went around them and collected some photographs in order to identify their current state.

Photo 6: Two dolphins in Tadjourah (above water photos)

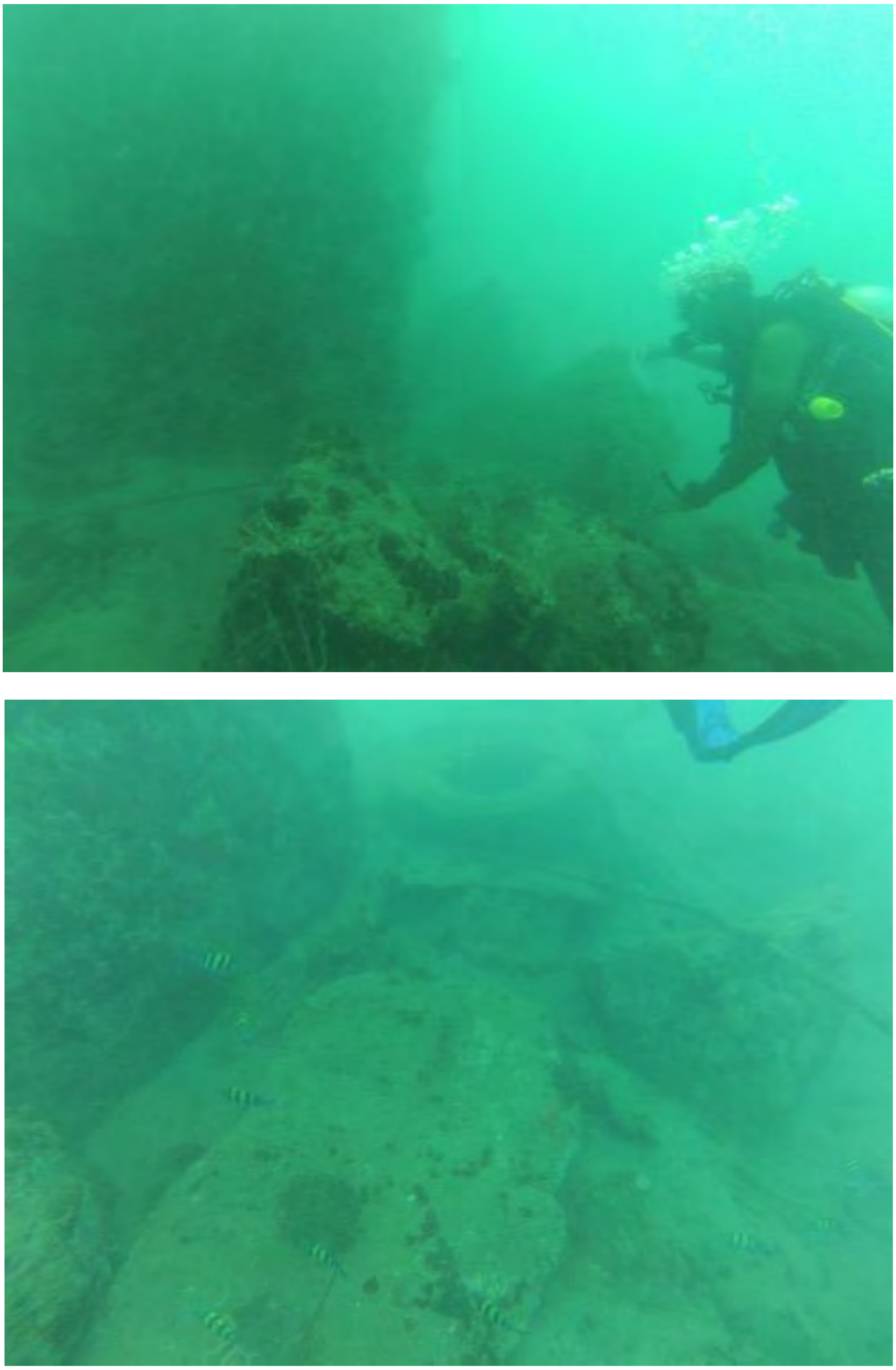

Photo 7: Structure of the two dolphins in Tadjourah port (underwater photos)

Photo 8: Structure and surrounding of the two dolphins in Tadjourah (underwater photography)

April 2019

Reinforcement of maritime transport capacity in the Gulf of Tadjourah - Water measurements & Coral survey and coral environment impact assessment

INSUCO
Local understanding for sustainable solutions

ERM

Japan Port Consultants

Reinforcement of Maritime Transport Capacity in the Gulf of Tadjourah

- **PART 1: Water measurements**
- **PART 2: Coral survey and coral environment impact assessment**

Final version

April 2019

Team:

- Moussa Omar Youssouf, Marine Biology expert
- Insuco Djibouti, quality control

Reinforcement of Maritime Transport Capacity in the Gulf of Tadjourah
Water Measurement and Coral survey and coral environment impact assessment

Client(s) : Japan Port Consultants – ERM Japan

Consultants :

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INSUCO
Local understanding for sustainable solutions

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Japan Port Consultants

April 2019

Reinforcement of maritime transport capacity in the Gulf of Tadjourah - Water measurements

Water measurements - Physico-chemical characterization of coastal water around the proposed project site (Tadjoura port)

Strengthening maritime transport in the golf of Tadjoura

Final Report

April 2019

Team:

- Dr Moussa Omar Youssouf, Biomarine specialist
- Insuco Djibouti team for quality control

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1. Introduction

In collaboration with Japan, Djibouti government is conducting a project to strengthen the maritime transport in the gulf of Tadjoura. The objective of this project is to provide the Tadjoura region a new ferry with greater capacity and adapted to the harsh conditions of the sea and able to navigate all year long.

A prospective coral survey conducted around the proposed project site at Tadjoura port of call, has revealed the existence of the corals in this area. This brief survey could not characterize this coral habitat and determine coral species and their ecological importance. These parameters are essentials to the assessment of impacts caused by the project activities.

In order to characterize this coral habitat, a first study focused on the quantitative evaluation of coral reef. This study revealed an abundant unexpected coral cover (75 - 80%) especially in the reef flat and reef slope.

In addition, the study identified 40 species of corals which include 14 species were classified as Near Threatened (NT), 17 as Least Concern (LC) and 1 as Vulnerable (VU).

The abundance of corals and especially the presence of threatened species (IUCN, Red List, 2008), led to conduct impact assessment of the project. To this perspective, the preliminary impact identification revealed that particles suspension which would be induced by project activities (construction of breakwater, land reclamation, jetties and dredging) could impact deeply the survival of coral species. To reduce this potential impact, an appropriate management plan for the activities was proposed. As the spread and extent of particle deposition are associated to the environmental conditions, it appeared crucial to study the physic-chemical parameters and hydrodynamics of the area.

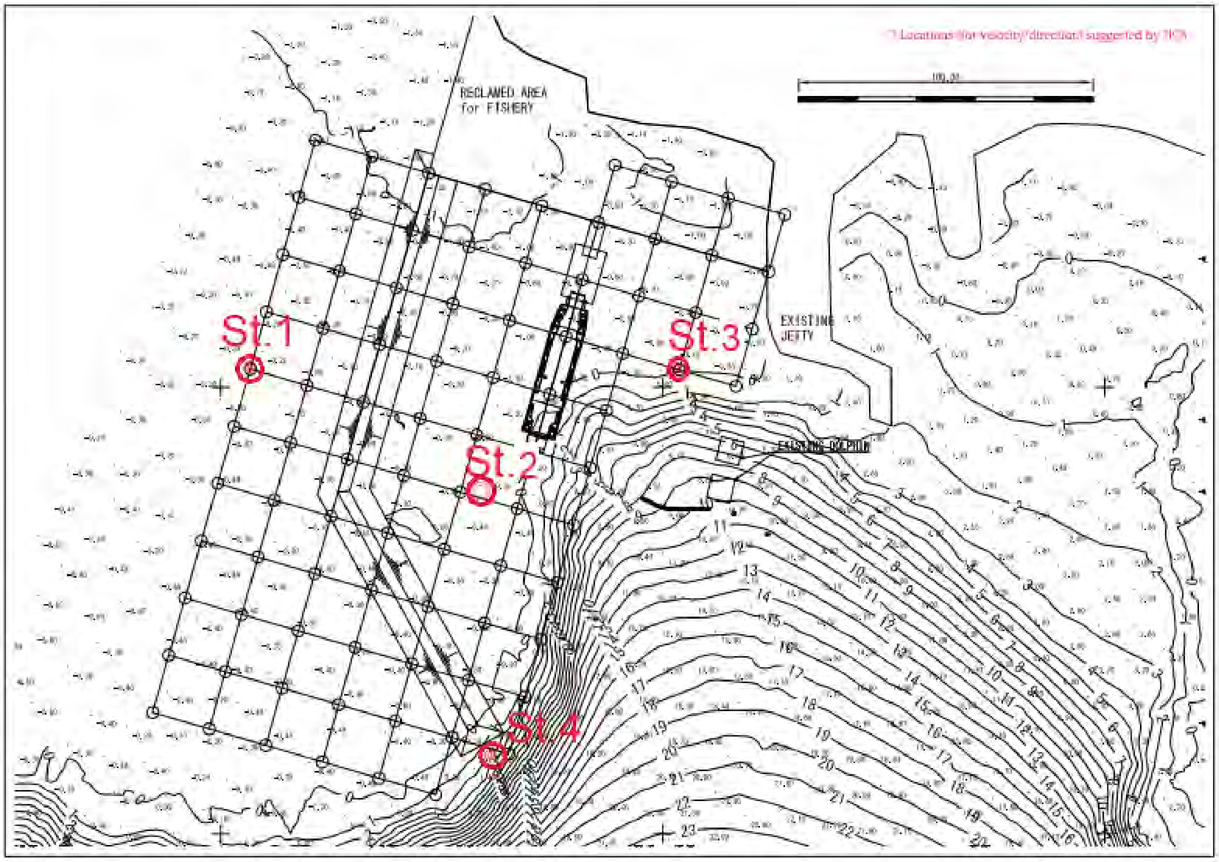
2. Objectives

The objective of this study is to determine the physic-chemical characteristics of coastal waters and its dynamics around the proposed project area. The newly collected data and the results of their analysis should be used for management of project activities to mitigate the potential impacts on coral habitat.

3. Methodology

3.1. Sampling stations

In advance of the field surveys INSUCO and ALIEL CONSULTING team, in collaboration with the ERM Japan, had discussed on the sampling stations (number, position, localization, etc.). In addition to the three sampling stations initially proposed, JICA suggested a fourth station (St. 2 in Figure 1). Thus, a total of four sampling station were selected based on bathymetry/topography and coral reef position relative to the planned project activities (Figure 1).



Stations	Latitude	Longitude
St. 1	11°47'01.93"	42°52'48.38"
St. 2	11°47'01.00"	42°52'50.45"
St. 3	11°47'01.33"	42°52'52.12"
St. 4	11°46'56.36"	42°52'49.77"

Figure 1: Localization of the sampling stations around the proposed project site. Notice bathymetric features and the planned project activities.

3.2. Methods

Firstly, the sampling stations were localized on the sea surface using a GPS (Garmin) and marked by floating buoys. During the sampling at each station, the boat was moored to the floating buoy. The measurement instruments were suspended to the fastening system specially prepared for the survey.

To characterize the coastal water around the project site, the following parameters were measured:

- Temperature, conductivity/salinity and Dissolved O2 (DO) were measured *in-situ*, using the portable probe: EXO multi-parameter
- The current direction and velocity were measured using acoustic Doppler current meter (Seaguard I).
- Turbidity/transparency was evaluated using a Secchi disk.

At each station, the probes were launched using an EXO Handheld. The frequency of recording was set up at 30 minutes for physic-chemical parameters (fig. 2) and every 10 min for the currentmeter.

After 24 hours of continuous recordings, the probe is brought to the surface and the data is transferred directly to a laptop. For current measurement, given the sensitivity of the acoustic current profiler, and poor environmental conditions during the mission, the measurement sessions (3-4 hours) were conducted during quieter periods. These measurement sessions were spread out over 24 hours. The following section describes the measurement methods for each parameter.

Figure 2 : Calibration of the EXO multiparameter

- **Current velocity and direction**

The velocity and direction of current were measured using the Seaguard current meter, which operates according to the Doppler effect. The received signals are transformed into zonal u (east-west velocity) and meridional v (north-south) components. The current vector is determined from these two components.

w: current vector

w = $\sqrt{u^2 + v^2}$

$\underset{w}{\rightarrow}$ (x, y, t); z = cte ≈ 2 m ; at each t = 10 min, the current vector ($\underset{w}{\rightarrow}$) is performed using u et v values.

The direction of current depends to the signs of u and v values. Four cases could be encountered:

u > 0 ; v > 0 NE current φ [0, 90°]

u > 0 ; v < 0 SE current φ [90°, 180°]

u < 0 ; v < 0 SW current φ [180°, 270°]

u < 0 ; v > 0 NW current φ [270°, 360°]

<u>Representation of the current vector</u>

To represent current vector ($\underset{w}{\rightarrow}$), oceanographic convention was used:

(180/3.14) x Atn2([u],[v]) ; Atn : Arctangent (Matlab function used : quiver3).

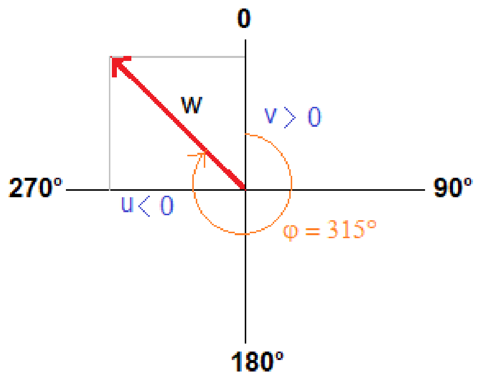


Figure 3 : Current vector from the zonal (u) and meridional (v) component.

- **Physico-chemical parameters (temperature, conductivity/salinity and Dissolved oxygen)**

These physico-chemical parameters were recorded continuously using an EXO2 multiparameter probe equipped with temperature, conductivity and dissolved oxygen sensors. Beforehand, the three sensors were tested with the "CONFIDENCE" solution and calibrated using the standard solutions. The measurement frequency was set up to 30 min.

- **Turbidity/Transparency**

Turbidity or transparency is the optical property of seawater that makes the incident light to diffuse or be absorbed by the various suspended solids (SESD operating procedure, 2017). In this study, Secchi Disk was used for measuring transparency. This is the only method that considers altogether the optical characteristics of water (particle content), the penetration of daylight, the contrast and the perception of the eye.

The transparency is measured in meters (m). It corresponds to the exact depth at which the Secchi disk disappears from the view of the observer.

3.3. Materials

- Seaguard 1 (sensor of current: velocity and direction);
- EXO 2 multiparameter with EXO handheld, rope, PC;
- Secchi disk, graduated rope and a decameter;
- GPS Garmin.

3.4. Calendar of measures and data collection

The various measures took place from March 13th until March 15th. See table below for the detail of measurement's timing.

Table 1: Calendar of measurements and data collection

DATES	Timeline	Duration
13/03/2019 **MONITORING STATION 4**		
Location and marking of the monitoring stations (St. 1, 2, 3, 4)[1] (Geolocation with GPS coordinats)	**7h00 - 8h00**	
Measurements:		
Turbidity / Opacity: Secchi Disk (1 measurement every 2 hours)	8h00 - 17h00	8h00 10h00 12h00 14h00 16h00 18h00
Continuous measurements at St. 4 (installation and lunch of dataloggers)	8h00 (3/12 - 8h00 (24 h)	Every 30 min and continuous logging for physic-chemical parameters and 3-4 measurement sessions for current
14/03/2019 **MONITORING STATION 1**		
Measurements:		
Turbidity / Opacity: Secchi Disk (1 measurement every 2 hours)	8h00 - 17h00	8h00 10h00 12h00 14h00 16h00 18h00
Continuous measurements at St. 1 (installation and lunch of dataloggers)	9h00 - 9h00 (24 h)	Every 30 min and continuous logging for physic-chemical parameters and 3-4 measurement sessions forcurrents
15/03/2019 **MONITORING STATION 2**	**11h00-12h00**	
Measurements:		
Turbidity / Opacity: Secchi Disk (1 measurement every 2 hours)		8h00 10h00 12h00 14h00 16h00 18h00
Continuous measurements at St. 2 (installation and lunch of dataloggers)	10h00 - 10h00 (24 h)	Every 30 min and continuous logging for physic-chemical parameters and 3-4 measurement sessions for current
16/03/2019 **MONITORING STATION 3**	**13h00-14h00**	
Measurements:		
Turbidity / Opacity: Secchi Disk (1 measurement every 2 hours)		8h00 10h00 12h00 14h00 16h00 18h00
Continuous measurements at St. 3 (installation and lunch of dataloggers)		Every 30 min and continuous logging for physic-chemical parameters and 3-4 measurement sessions for currents

[1]All the measuring stations were located and marked by buoys

4. Results analysis

The data were inspected for quality control and pre-processing before analyzed. Matlab codes were used for the treatment and graphical representation. The results are presented below.

4.1. Temperature

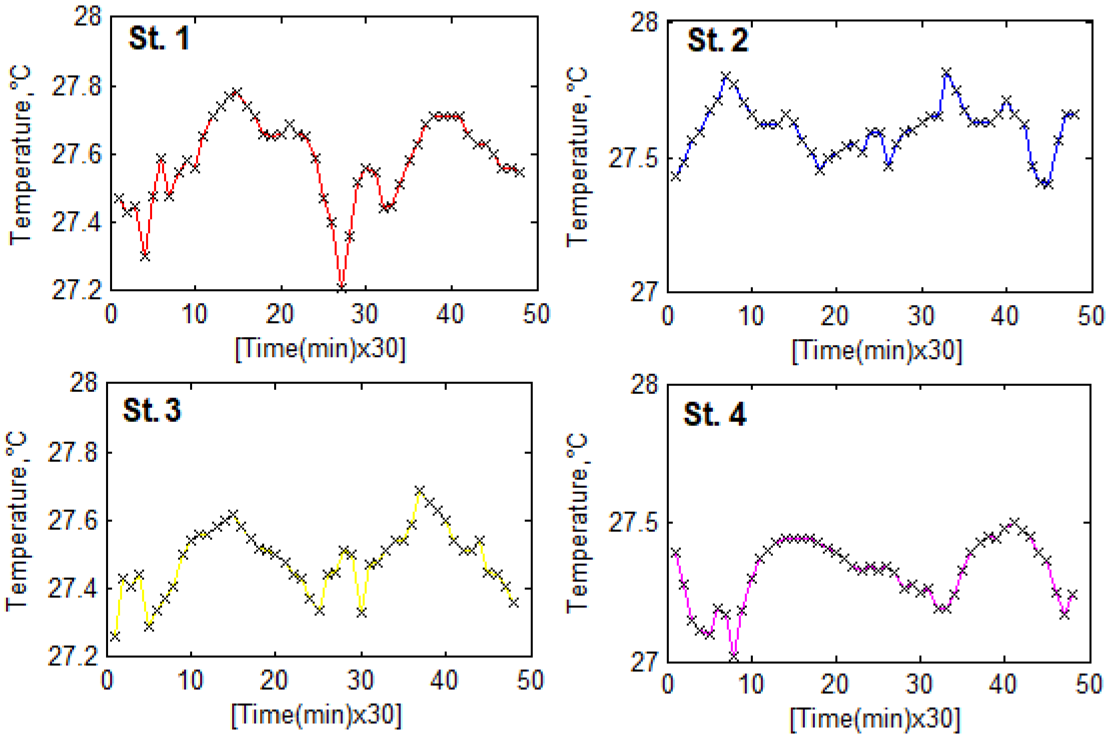


Figure 4 :Temperature evolution at 4 sampling station in the project area

The temperature of seawater has a similar profile in the four sampling stations. It increases to reach a first maximum, then decreases. This pattern is repeated during the second phase t= [30 – 48]. Furthermore, some differences could be observed between the stations (Table 1). High temperatures were recorded at stations 1 and 2 and the lowest at station 4. At this station, the temperature drops at the beginning, this trend is not observed in the other stations.

These variations in sea water temperature could be related to the air temperature and the climate in the gulf of Tadjoura where the marine environment responds to the variations in weather conditions (Youssouf et al. 2016). The recorded temperature at all stations range from 27°C to 27.78 °C, these values are consistent with the cold season conditions. Moreover, the differences between stations could be associated to the local environment characteristics: tidal variation and bathymetry/topography. Thus, the highest temperatures at stations 1 and 2 could be explained by the shallow water during low tide while the lower temperature at station 4 by the deep-water column. The thin water column warms up more than the thick one (Segar, 1997).

Table 2 : Maximums and minimums temperatures at 4 sampling statiosn

Station	*Max*	*Min*	*Mean*
St. 1	27.78	27.21	27.58
St. 2	27.62	27.34	27.48
St. 3	27.80	27.45	27.60
St. 4	27.50	27.02	27.32

4.2. Conductivity/salinity

Salinity shows the same pattern in 4 sampling stations (Figure 5). The measured values indicate low salinity (37 – 37.2 ppt) at the beginning and increase to reach a maximum of 37.20 at t = 450 min (afternoon). This increasing could be linked directly to the evaporation induced by solar heating.

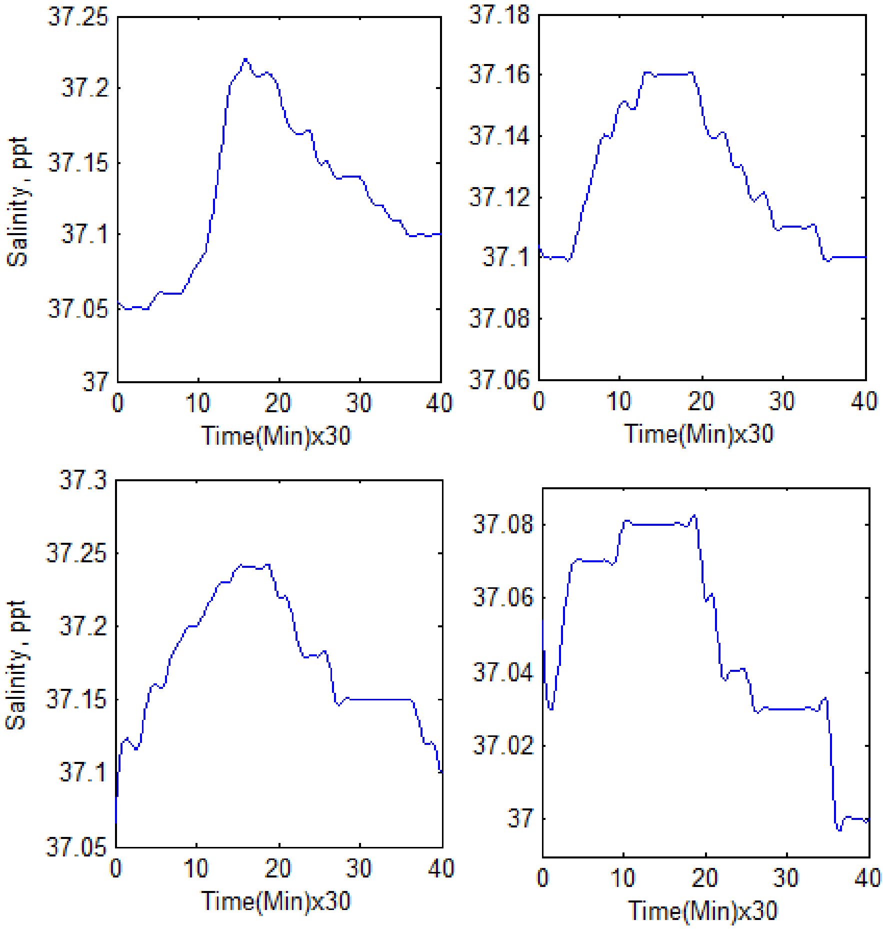


Figure 5 : Evolution of salinity in seawater at the 4 sampling statiosn in the project area

4.3. Dissolved oxygen

The dissolved oxygen data show a similar variation pattern at 4 stations. As Salinity profil, DO indicates stepped variations. DO increases at beginning and is followed by a decrease. The high values were recorded in the middle of the day (t = 300) at stations 1 and 2 and the lowest values at station 4. These variations could be linked to the local impact of local event or specificities like the presence of the urban waste decharge.

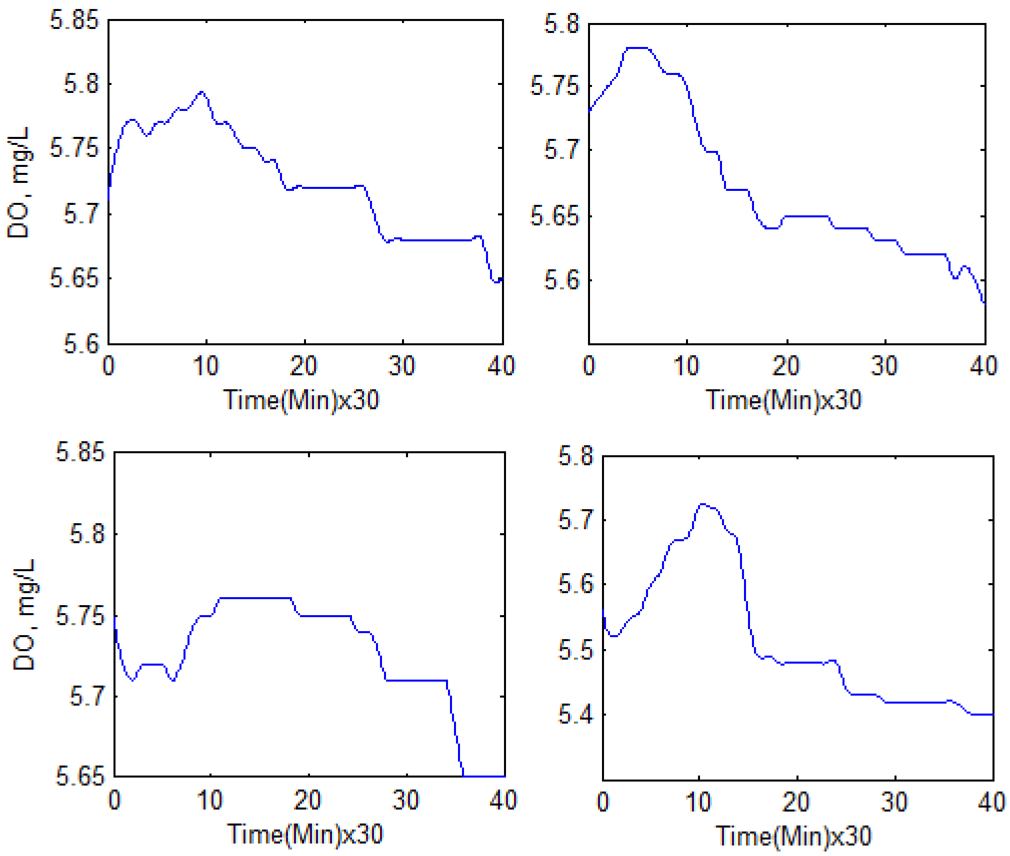


Figure 6 : Evolution of dissolved oxygen in seawater at sampling station around the project area (Tadjoura port)

4.4. Turbidity/transparency

As shown in table 2, the transparency was low at station 1 and 2 where the measured values range from 2.15 m to 2.5 m. Transparency was not measured at station 3 because of low tide (<1m). The low transparency at these stations could be associated to the sandy sea bed and shallow water.

At station 4, the transparency of sea water was significantly higher compared to the other stations. The measured values at this station range from 6.27 m to 9.5 m. During the sampling, transparency varied over time between morning and afternoon. Transparency was high early in the morning and dropped in the afternoon.

Figure 7 :Evolution of transparency in seawater at 3 sampling station around the project area (Tadjoura port)

Table 3 : Measured values of transparancy

Station	St. 1	St. 2	St. 3	St. 4
Turbidity (m)	2.50	2.57	-	9.30
	2.45	2.20	-	9.20
	2.47	2.13	-	9.50
	2.25	2.17	-	9.00
	2.20	2.21	-	8.00
	2.34	2.25	-	9.00
	2.37	2.19	-	8.13
	2.41	2.30	-	8.27
	2.47	2.26	-	9.60
	2.45	2.28	-	6.70
	2.50	2.15	-	6.40
	2.38	2.22	-	7.20
	2.36	2.43	-	7.00
	2.44	2.50	-	7.00
	2.50	2.46	-	6.27

4.5. Current velocity/direction

4.5.1. Direction

The structure of the current pattern appeared similar in all station except in St. 3. The projection of the current vector on (x,y), gives the direction of the current.

Station 1 : $u < 0$; $v > 0$ ⇔ current toward the Northwest

Station 2 : $u < 0$; $v > 0$ ⇔ current toward the Northwest

Station 3 : u and v : current does not have a precise direction

Station 4 : $u < 0$; $v > 0$ ⇔ current are toward the Northwest (predominant current)
$u < 0$; $v < 0$ ⇔ current toward the Southwest (minor current)
$u > 0$; $v > 0$ ⇔ current toward the Northeast (minor current)

The predominant current was toward the west (northwest and southwest). At station 1, 2 and 4, the eastward current is minor compared to the westward. The predominant current direction is directly linked to the predominant wind which blows all the cold season from the Northeast. The station 3 is protected from this wind, the current direction seems induced by tidal current.

4.5.2. Velocity

The velocity calculated from the zonal and meridional component rang from 2 cm/s to 70 cm/s. The high values are recorded at station 4 (60 – 70 cm/s). As this station is exposed, the high current could be related to the strong NE wind. For the other stations, the maximum velocity does not exceed 25 cm/s.

4.5.3. Results

Method: The recording time for current measurements was 10 min for 3-4 hours: 3 sessions of measurement at each station (see methodology)

Station 1: On Thursday March 14th, the sun rose in Djibouti at 6:15 h and sunset was at 18:18h. In the high tide and low tide chart, we can see that **the first low tide was at 7.26 h** and **the next low tide at 18.03. The only high tide was at 14:29h**.[2]

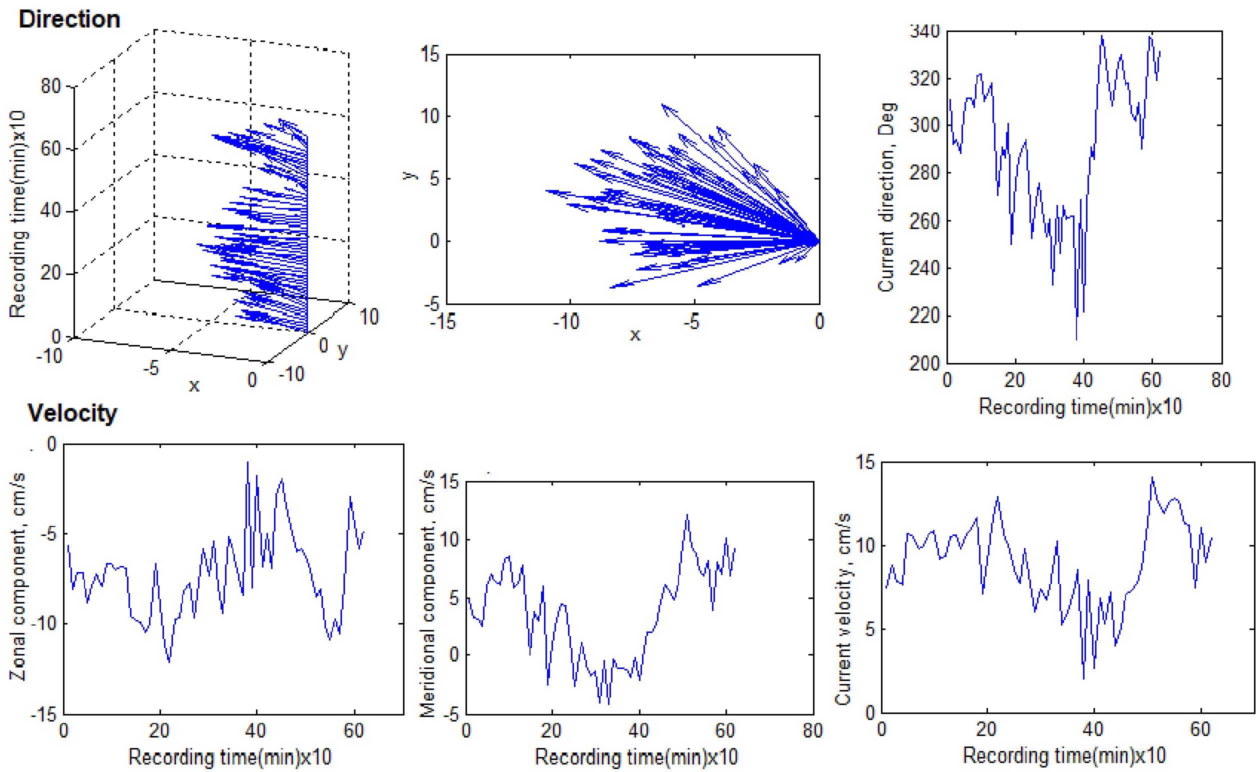


Figure 8 : Current velocity and direction at station 1. Top: current direction vector top 3D, 2D and direction in deg. (angle φ, see figure 2)

[2] https://www.tide-forecast.com/locations/Tadjoura/tides/latest

Station 2: On Friday March 15th, the sun rose in Djibouti at 6:14 h and sunset was at 18:18h. In the high tide and low tide chart, we can see that the **first high tide was at 0:35h** and **the next high tide at 16:41 h**. The **first low tide was at 8:57h** and **the next low tide at 20:39 h**.[3]

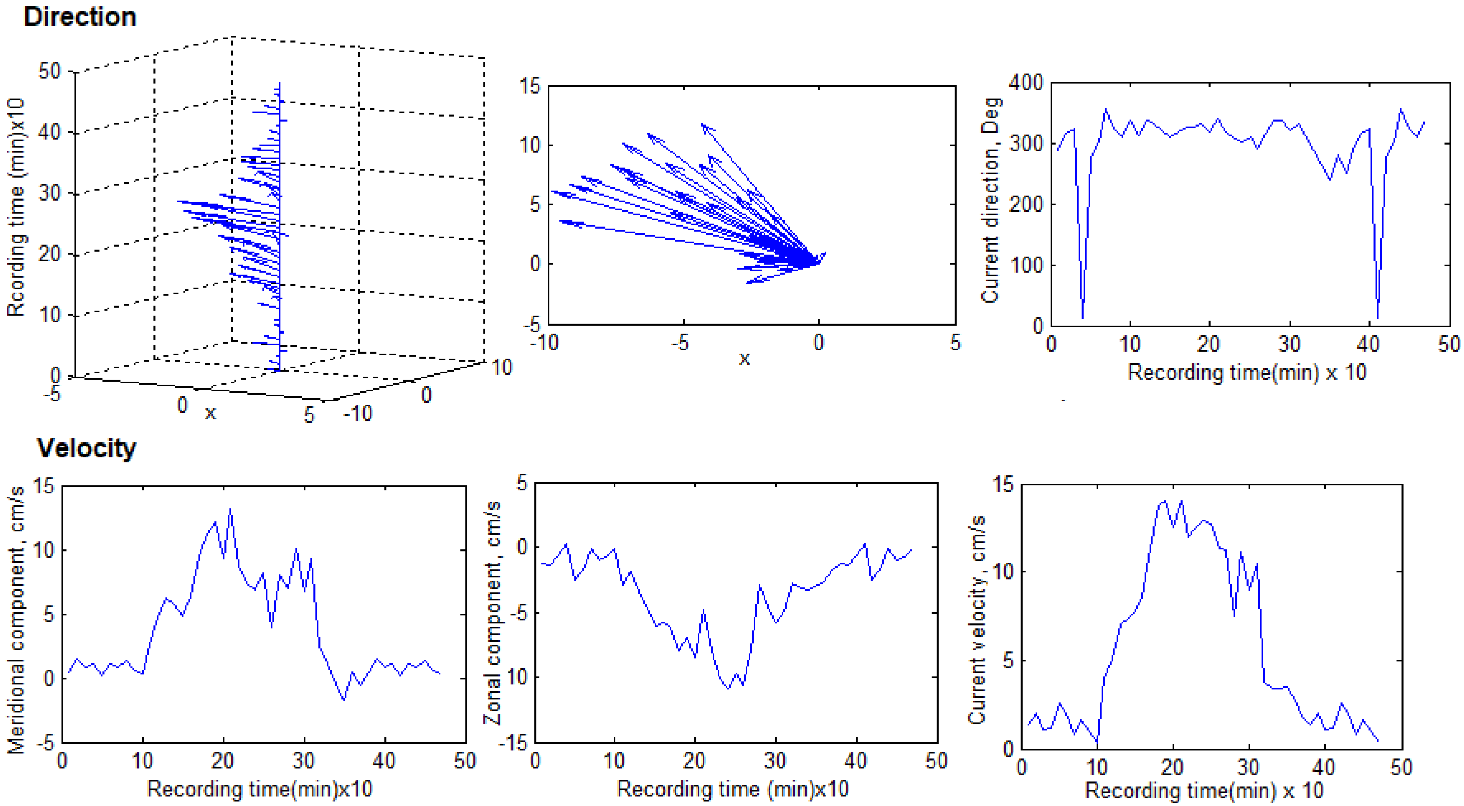


Figure 9 : Current velocity and direction at station 2. Top: current direction vector (en) 3D, 2D and direction in deg. (angle φ, see figure 3)

[3] https://www.tide-forecast.com/locations/Tadjoura/tides/latest

Station 3: On Saturday March 16th, the sun rose in Djibouti at 6:14 h and sunset was at 18:18h. In the high tide and low tide chart, we can see that the **first high tide was at 2:08 h** and **the next high tide at 17:41 h**. The **first low tide was at 10:20h** and the **next low tide at 22:47 h**.[4]

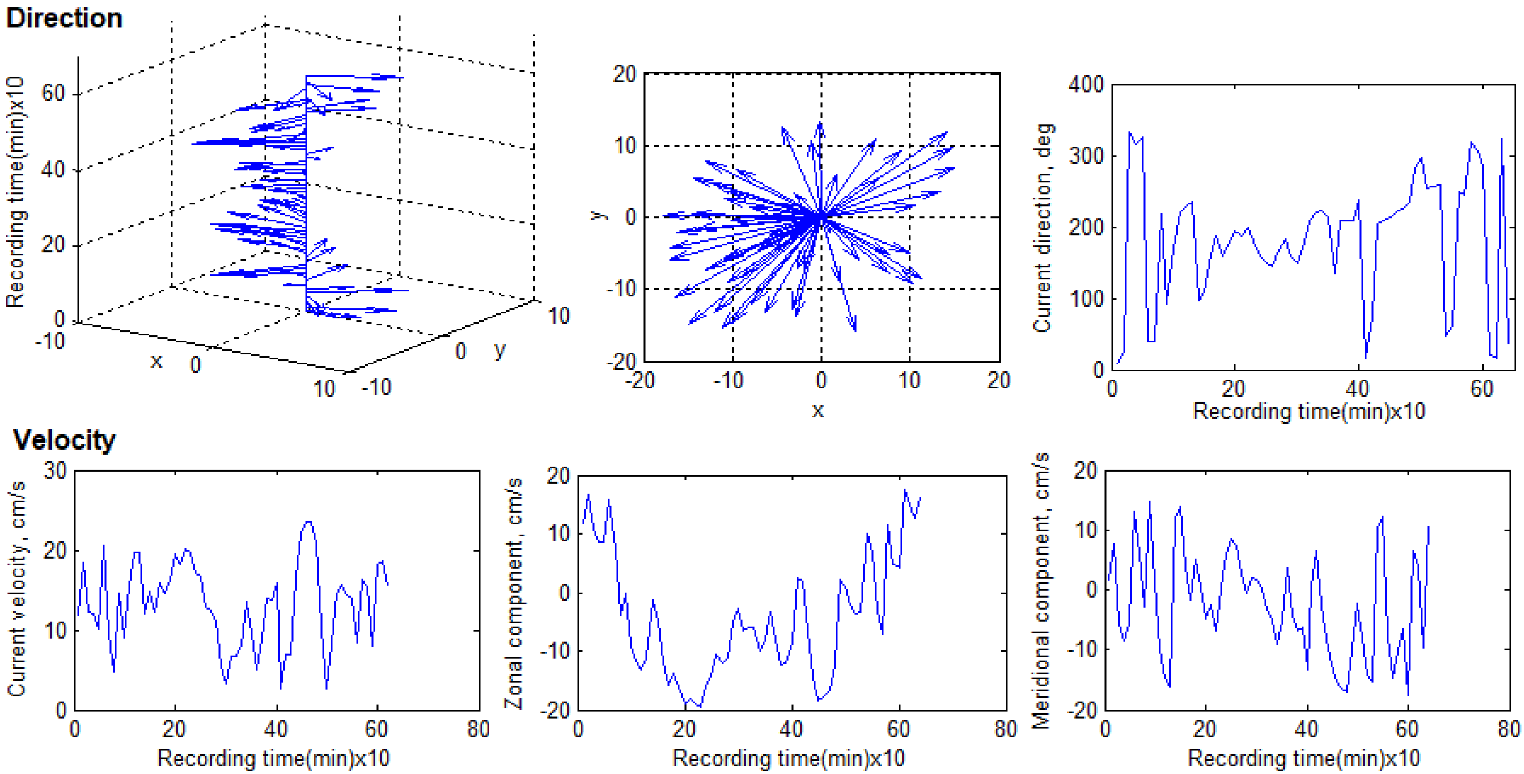


Figure 10 : Current velocity and direction at station 3. Top: current direction vector (en) 3D, 2D and direction in deg. (angle φ, see figure 3)

[4] https://www.tide-forecast.com/locations/Tadjoura/tides/latest

Station 4: On Wednesday March 13th, the sun rose in Djibouti at 6:16 h and sunset was at 18:18h. In the high tide and low tide chart, we can see that **the first low tide** was at **6:12h** and the next low tide at **17:08 h.** The **first high tide** was at **12:37h** and the next **high tide at 23:35 h[5].**

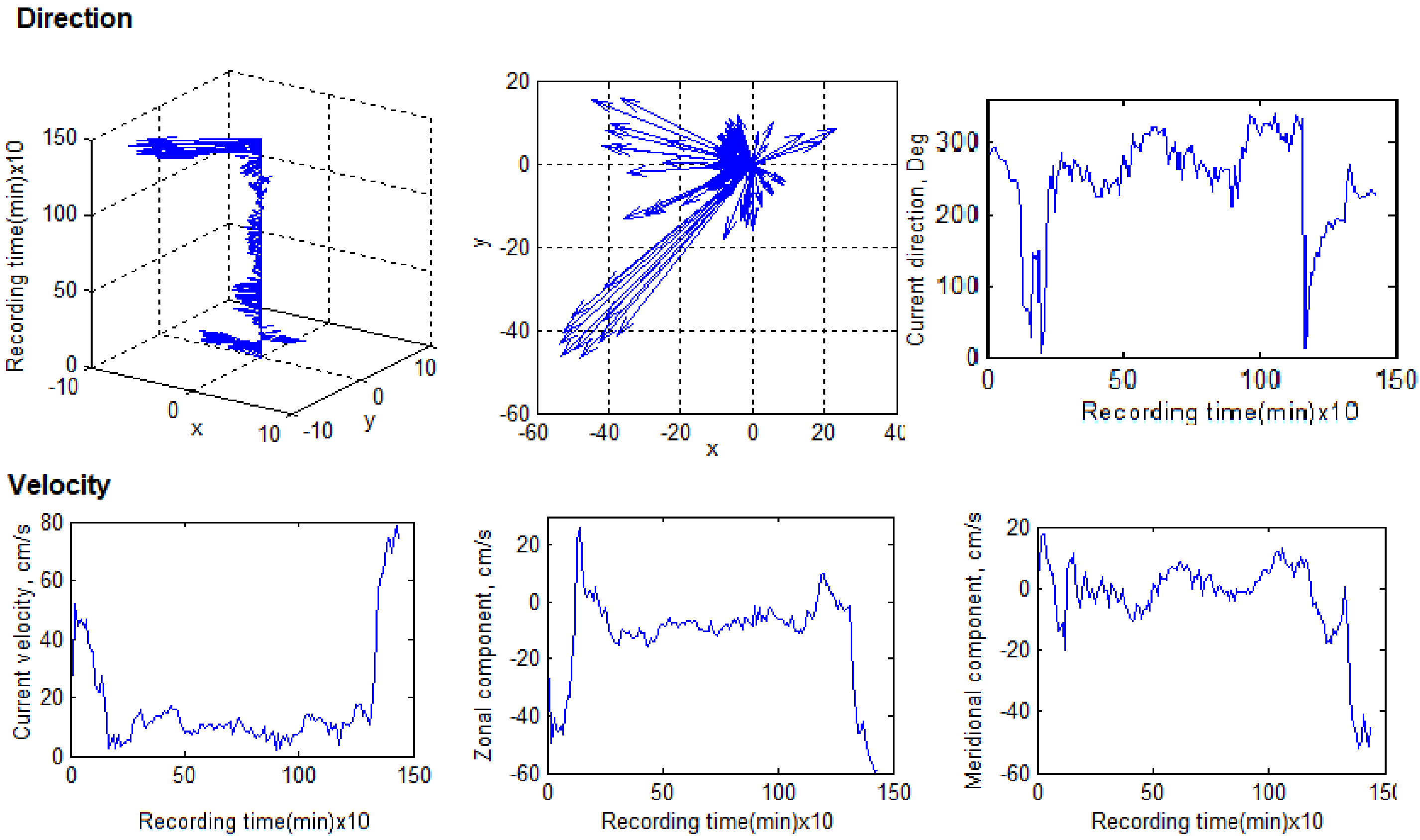


Figure 11 :Current velocity and direction at station 4. Top: current direction vector (en) 3D, 2D and direction in deg. (angle φ, see figure 3)

[5] https://www.tide-forecast.com/locations/Tadjoura/tides/latest

5. Conclusions

The study undertaken on the coastal waters around the project site in the vicinity of the Tadjoura port, allowed better understanding of the characteristics and hydrodynamics in this area. The study reveals that these parameters were mainly influenced by monsoon winds acting on a global scale. This explains the similarity of the variation profiles in all sampling stations. The results showed notable differences between the sampling stations. These differences are rather associated with local factors.

Two main results emerged clearly from the newly collected data:

1- At the south station (St. 4) located in the off-shore, the water had distinct and specific characteristics: colder, more transparent, less salty and slightly lower dissolved oxygen. These properties are identical to the water mass of the Gulf of Aden during the cold season [T = 26 – 27°, S = 37, σ = 24 - 26] (Bower and Furey, 2011). The velocity was higher (40 - 70 cm/s) than the other stations and the current was toward the southwest. The thickness of the water layer and the presence of the rocky bottom could explain the greater transparency of the water at this station.

2- In the vicinity of the coast (station 1, 2 and 3), the influence of the North-East wind seems to be attenuated by the coast effects. In this area, the shallow water and the sandy bottom lead to the high turbidity (less transparency). At station 3, because of the protection by the existing jetty from the northeast wind, the dynamics seems to be governed essentially by the currents generated by the tide. This explains why current does not have a precise direction at this station.

Stations 1 and 2 located further west on the coral reef do not benefit from jetty protection. They are directly affected by NE wind. The high temperatures recorded at these stations are related to the solar heating, which increases during the weak winds.

The physic-chemical properties and dynamics of the study area appears to be mainly influenced by the NE wind and but also by tidal fluctuations whose effects are sensitive close to the coast. The bathymetry / topography modulates the effects of these factors. The NE wind generates the westward currents and influences all studied parameters through the mixing and turbulence process. These parameters influence the transport and sedimentation of suspended particles.

At the end of this study, the wind and tide currents appear to be key determining factors that will have to be taken in consideration during the construction phase of the project (land reclamation, breakwater and jetty). The proposed management plan of the project activities should include real-time or forecast data with high temporal and spatial resolution.

The proposed management plan should include real-time and high-resolution weather forecast data on wind and tides. The project activities should be planned considering these data.

February 2019

Reinforcement of Maritime transport capacity in the Gulf of Tadjourah - Coral survey and coral environment impact assessment

PART 2: Coral survey and coral environment impact assessment in the Port of Tadjourah

Preparatory study on marine transport capacity enhancement project in Tadjourah bay

Final report

February 2019

Team: Moussa Omar Youssouf

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1. Introduction

The Government of Djibouti, in partnership withJapan, is conducting a project to strengthen the maritime transport in the gulf of Tadjourah. The objective of this project is to provide the Tadjourah region with a new ferry with greater capacity (200 to 250 pers.) and adapted to the harsh conditions of the sea in order to be able to navigate all year long. The new ferry will make shipping more regular and will increase trade of goods and services to the region. The project is part of a new economic perspective characterized by the opening of the new port of Tadjourah and the Tadjourah / Balho road linking the regional capital to the city of Mekeleh (Ethiopia).

However, despite its socio-economic benefits, the project is likely to have potential negative impacts on the marine environment. In order to anticipate and mitigate these potential impacts and in a perspective of sustainabledevelopment, the government of Djibouti has recommended conducting an environmental impact study (EIS).

In line with this, the ERM-Japan (Environmental Resources Management) in charge of the project, called on the company INSUCO Sarl Djibouti for collecting environmental data for the preparation of the EIS. A primary study on marine biological environment inthe Gulf of Tadjourah revealed the scarcity of data around the project area. The second prospective study has revealed abundant coral dominated communities at the west part of the Tadjourah port where the project will be implemented.

The goal of this survey is to complete and deepens the previous prospective survey. More specifically, this survey should cover different activities:

- Conduct a quantitative assessment of the coral reef;
- Determine the main corals pecies, their spatial distribution and threat status;
- Based on newly collected data, make recommendations to mitigate the impact of the project on the cora lcommunities in particular the vulnerable species.

This report is organized in two main parts. The first part presents the quantitative assessment of coral reef. The second part deals with the identification of corals species living in the project area and their conservation statuts.

2. Part 1: Coral reef assessment

2.1. Methodology

In advance of the field surveys INSUCO and ALIEL Consulting team, in collaboration with the ERM japan, prepared the survey plan, equipment needed for the coral survey, as per the budget allocation, procured detailed proposal on the field survey methods and prepared maps for ground-truthing (Figure 1).

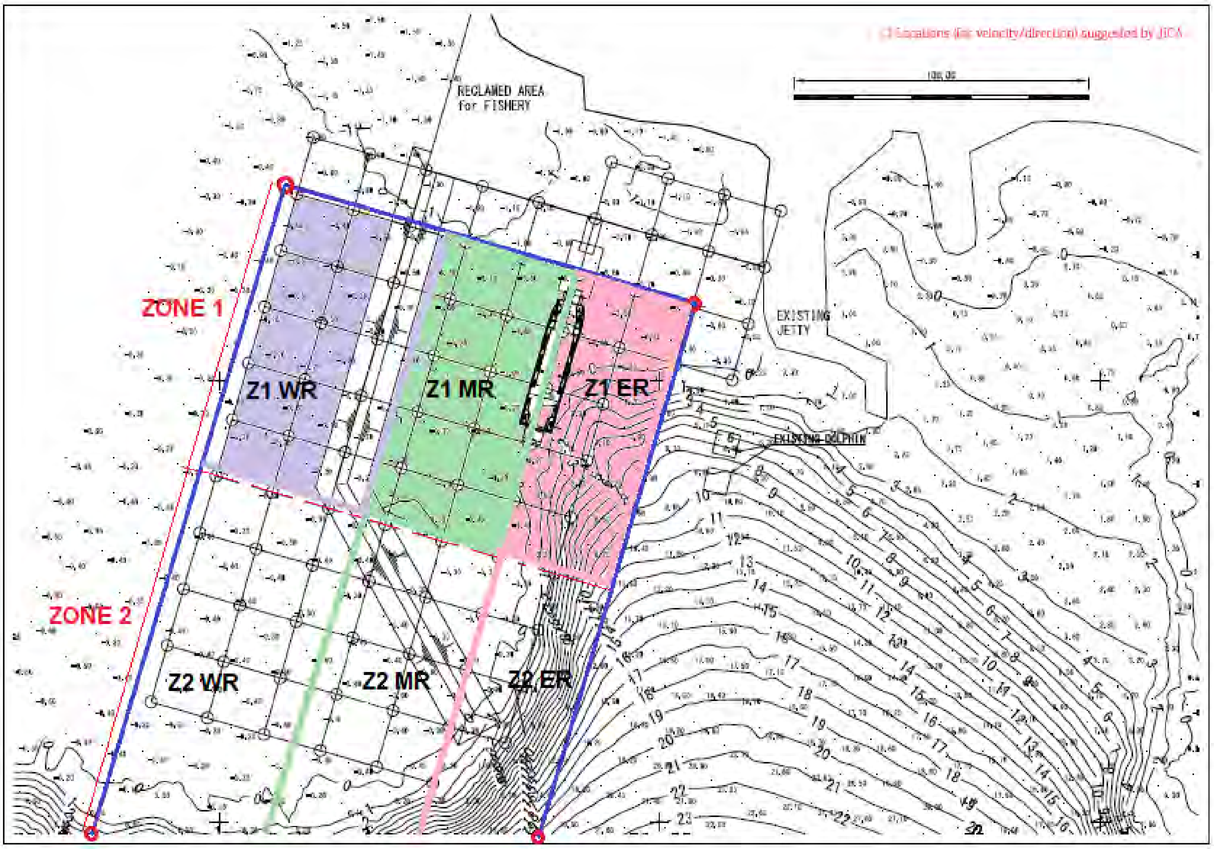


Figure1: Background, the pre-prepared bathymetric map showing the area that should be covered by the survey. The demarcation of the study area in blue line and the red circles with specification of the survey zones..

2.1.1. Delineation of the study area

After identifying the proposed limits on the pre-prepared map and ground truthing, the survey area was delineated by four points located using a GPS and marked by floating buoys (Figure 1, red circles, table 1). For the convenience of the survey, this area has been divided into two sub-areas (Z1 and Z2 hereinafter). **Z1 (ABEF)** starts at the point A located at about 20 m from the coast and extends 100 m to the south. It includes the reef flat and the back reef (Figure 2, a).

Z2 (BCDE) starts at the point B located at about 120 m from the coast and extends100 m to the reef slope. It contains the reef crest and the reef slope (Fig. 2)

Table 1: Bounderies of Z1 and Z2

Points	Latitude	Longitude
A	11°47'03.71"N	42°52'49.00"E
C	11°46'.55.45"N	42°52'45.68"E
D	11°46'.55.40"N	42°52'48.97"E
F	11°47'.02.80"N	42°52'52.13"E

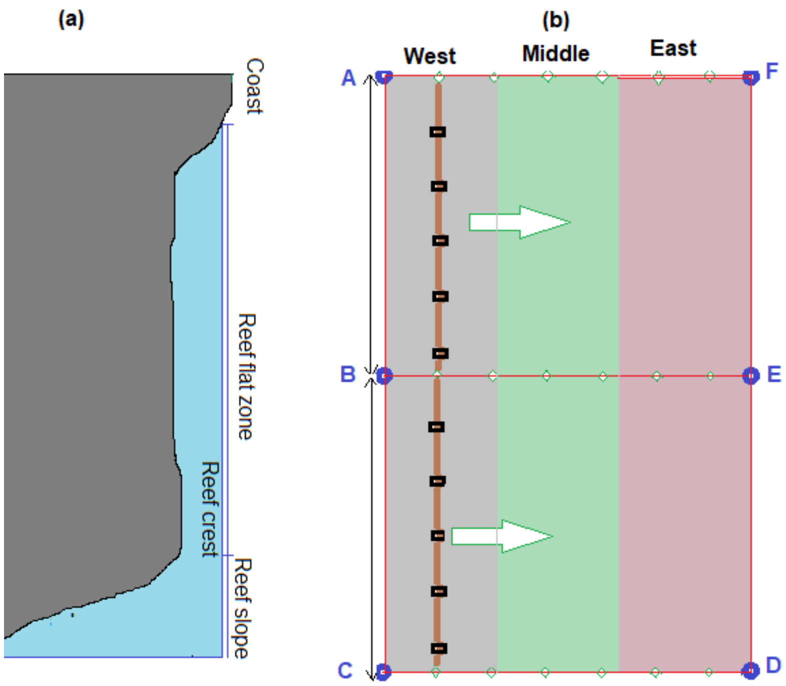


Figure 2: Scheme showing: (a) fringing reef zonation (b) sub ZONES 1 & 2 and sections (West, middle and East)

The delineated area is about 100 m wide. From the west to the east, the area was divided into three main section: west, middle and east. In each section, markings (white stake) were placed every 10 m (symbolized by green diamonds in Figure 2). The linear transects were installed along North-South between these marked points with the stakes (brown line, figure 2). Data collection on different substrates was done every 0.5 m along these transects (see data sheet in appendix 1)

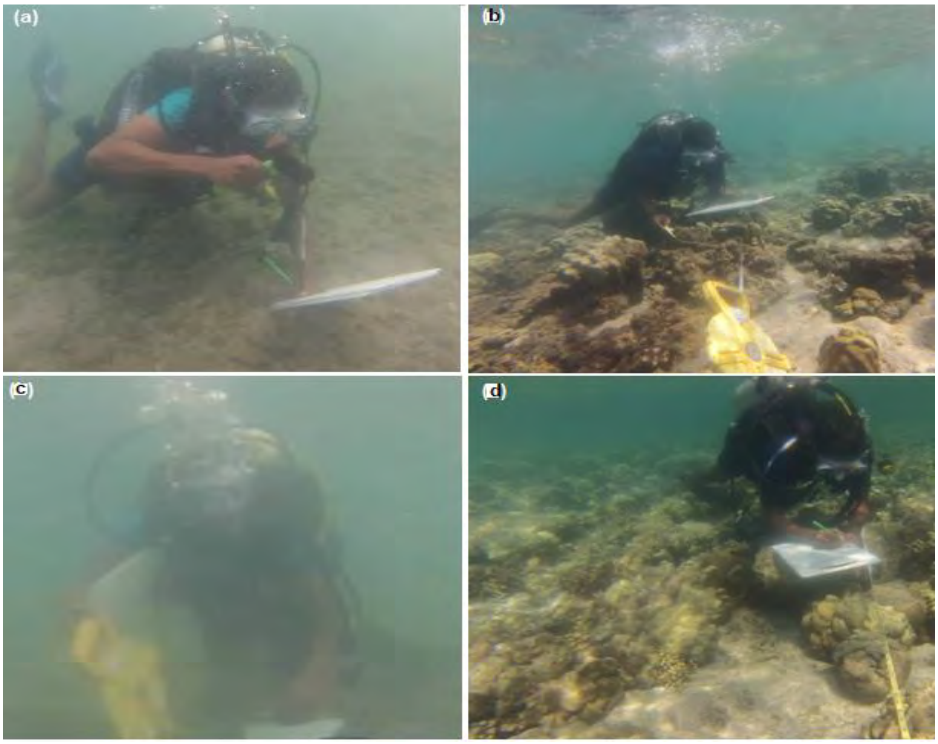
2.1.2. Coral survey method

There are many coral survey methods that can be used to collect field data and to characterize shallow marine habitats. The suitability of each method varies depending on the spatial and/or temporal scale of the sampling objective. As the purpose of the present field survey was to quantify coral cover and identify the main living coral species, linear transect methods and photo-quadrats were selected. These methods included:

- Rapid assessment methods to collect quantitative data,
- Detailed site assessment methods to better characterize corals communities (photo-quadrats and species records).

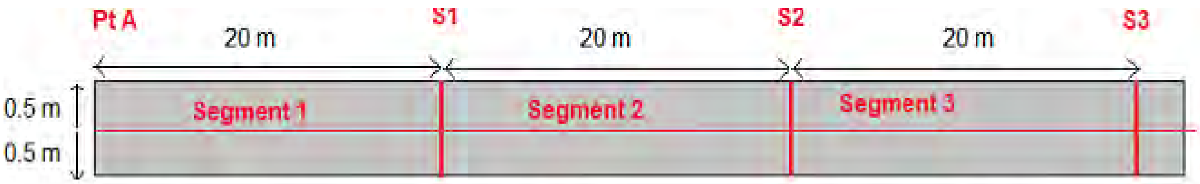
2.1.2.1. *Rapid assessment method*

The belt transect method is suitable to collect quantitative data. The transect is materialized by a double decameter and subdivided into a segment of 20 m. The zero of the transect is hooked to a stake and the ruban tape meter is unrolled to the other end located at 100 m.



Photography 1: Positioning of the transect line (a, b, c) and (d) data record along the transect

The different types of substrates encountered (every 0.5 m) are recorded in the corresponding segment (20 m x 1 m = 20m^2) on the dive slate (Figure 3).



Record locations	Substrates	Observations
0	HC	Bleached coral
0.5	HC	
1.0	RB	
.1.5	.	

Figure 3: Schemes showing the dimension of the transect and recorded locations

2.1.2.2. *Detailed sites survey method*

Photo-quadrats: Upon arrival at the survey site, the surveyors entered the water with the 0.5 m by 0.5 m photo-quadrat frame and Gopro camera. The surveyors descended to the maximum survey depth before starting to record photo-quadrats. The diver placed the frame on the line transect and took photographs of the living corals. Following each dive, a Detailed Site Survey form was completed which included:

- a description of the physical environment and site structure,
- an estimate of the physicalsubstrate and biological cover, and
- the number of photo-quadrats taken within diffent transect.

2.1.3. Equipment used

- Scuba diving equipments,
- Photo-frame,
- Dive slate,
- 50 cm x 50 cm photo-quadrat frame,
- GoPro Underwater Camera (Gopro),
- Detailed Site Survey Sheet,
- Pencil.

2.2. Data analysis

Day to day, after each dive, the observational field data has been entered from the dive slate into excel spread sheets. Images extracted from GOPRO and photographs taken during the dive were catalogued together with the associated recorded data. The images were reviewed and used to identify coral species in each transect. The graduation indicated the position of the image on the transect.

2.3. Results: Coral cover data

2.3.1. ZONE 1

2.3.1.1. Zone 1 West Reef (Z1-WR)

As shown in Figure 4, the dominant substrates in the Z1-WR are rubbles which represent 43.12% of the seabed cover. This substrate is found throughout the transect but heavy accumulations are present in segments 3 and 4, about 40 and 60 m from the coast. The silts occupy the second place with 28.75%. The rest of the seabed is covered by hard corals (15.62%) and rocks (11.87%). There is a high proportion of non-living substrates (rubble, silt, rock: 84%) compared to living corals.

Substrate Code					
HC	Hard coral	**SC**	Soft coral	**RKC**	Recentlykilledcoral
NIA	Nutrientindicatoralgae	**SP**	Sponge	**RC**	Rock
RB	Rubble	**SD**	Sand	**SI**	Silt/clay
OT	Other				

Table 2: Spatial distribution of the substrates

Total S1		**Total S2**		**Total S3**		**Total S4**		**Grand total**	
HC	0	HC	7	HC	5	HC	13	HC	25
SC	0	SC	0	SC	0	SC	0	SC	0
RKC	0	RKC	1	RKC	0	RKC	0	RKC	1
NIA	0	NIA	0	NIA	0	NIA	0	NIA	0
SP	0	SP	0	SP	0	SP	0	SP	0
RC	10	RC	4	RC	3	RC	2	RC	19
RB	16	RB	17	RB	23	RB	13	RB	69
SD	0	SD	0	SD	0	SD	0	SD	0
SI	14	SI	11	SI	9	SI	12	SI	46
OT	0	OT	0	OT	0	OT	0	OT	0
#	40	#	40	#	40	#	40		160

Substrates	**%**	**SE**
HC	15.625	2.688711
SC	0	0
RKC	0.625	0.25
NIA	0	0
SP	0	0
RC	11.875	1.796988
RB	43.125	2.096624
SD	0	0
SI	28.75	1.040833
OT	0	0
SP	0	0
OT	0	0

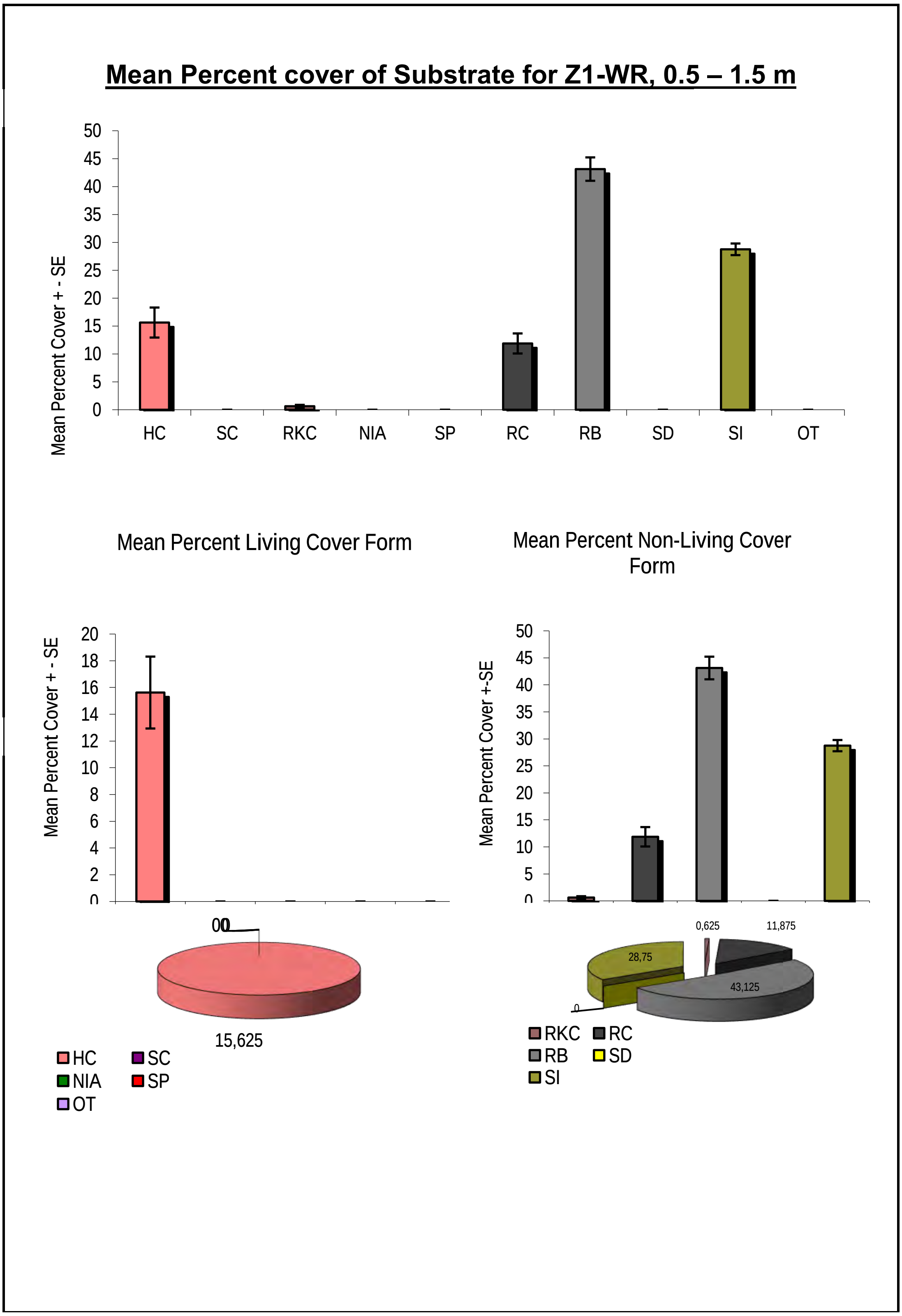


Figure 4: Mean percentage cover of substrate in the Z1-ZR, percent living and non living cover form

2.3.1.2. Zone 1 Middle Reef (Z1-MR)

Z1-MR is characterized by a higher hard corals cover (51.25%) compared to rubbles (24.37%). This middle reef is also distinguished by the presence of algae (15.62%) which are abundant on the back crest. Dead corals are relatively higher (6.25%) than in the Z1-WR. Live substrates (hard corals and algae) represent 66.87% of reef cover while non-living substrates (rubble, deadcorals and sand) occupy only 32.5%.

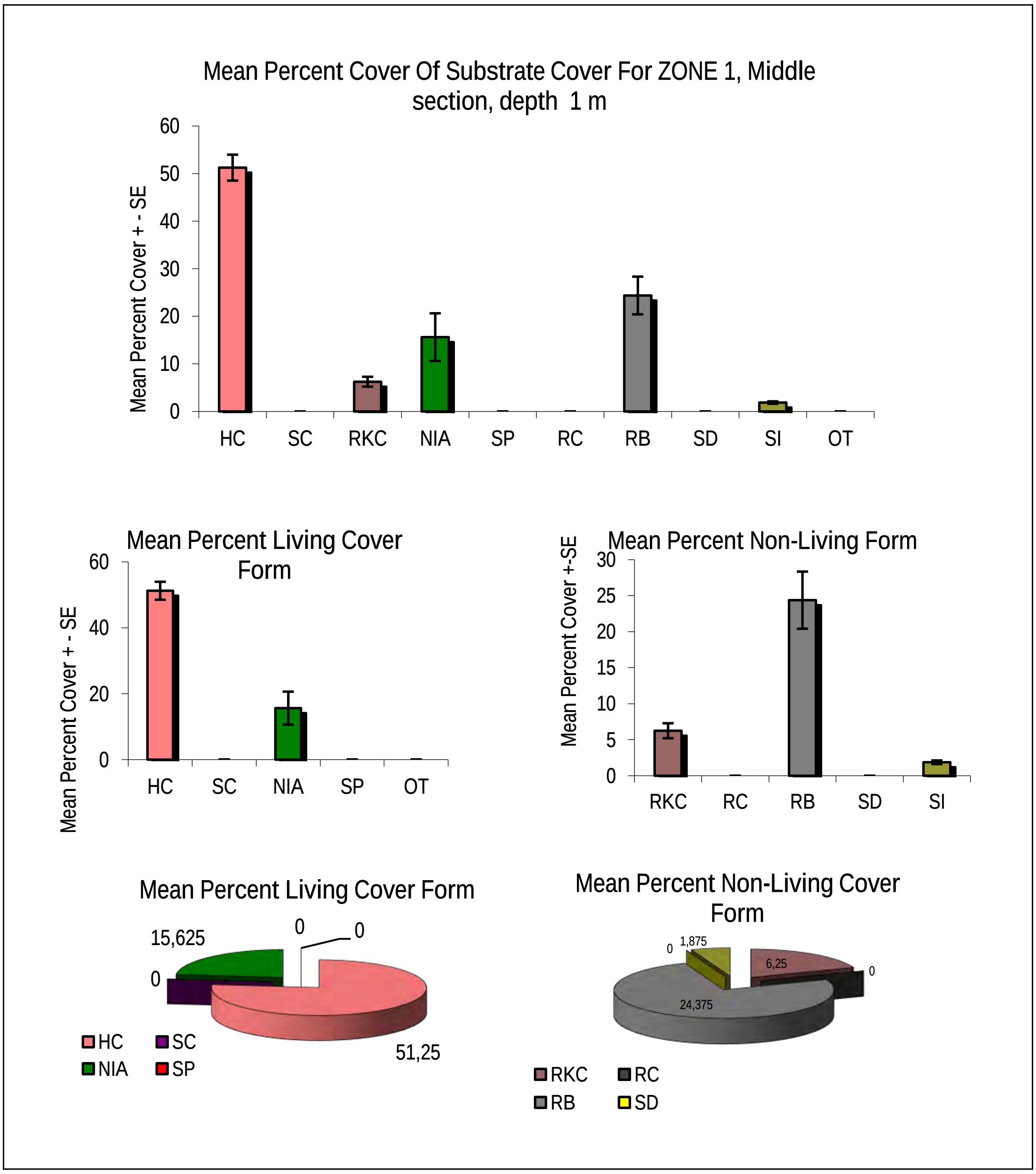
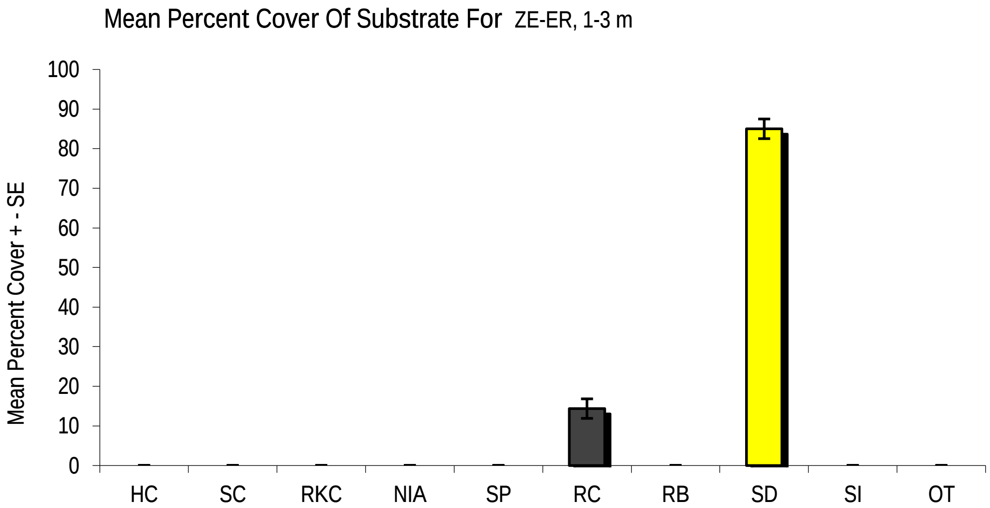


Figure 5: Mean percentage cover of substrate in the Z1-MR, percent living and non living cover form

2.3.1.3. Zone 1 East Reef (Z1-ER)

The Z1-ER is mainly covered by fine sands which represent more than 85% and some rock (14.5%). This area does not contain live corals.



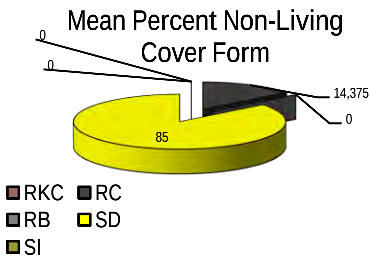


Figure 6: Mean percentage cover of substrate in the Z1-ER, percent living and non-living cover form

2.3.2. ZONE 2

ZONE 2 includes Reef crest and part of the reef slope. This zone is characterized by higher percentages of hard corals compared to ZONE 1. However, from west to east, spatial variations of different substrates are observed (Figures 8 to 10). The recorded data are presented in three sections:

- West reef (Z2-WR),
- Middle reef (Z2-MR) and
- East reef (Z2-ER).

Z2-MR has the highest percentage of hard corals reaching 85% of the reefcover (Fig. 8).

Other substrates, including dead corals and rocks, represent only 8.75% and 4.37%. The Z2-WR shows a similar structure with a high percentage of coverage by living hard corals (76.2%), dead corals (13.75%) and rocks (7.5%).

The Z2-ER has a relatively lower percentage (60.62) of hard coral compared to Z2-WR and Z2-MR. It has also a high algal coverage of 17.5%. Non-living substrates consist of silt (9.37%), rocks (6.87%) and coral debris (5.62%).

2.3.2.1. Zone2 West reef (Z2-WR)

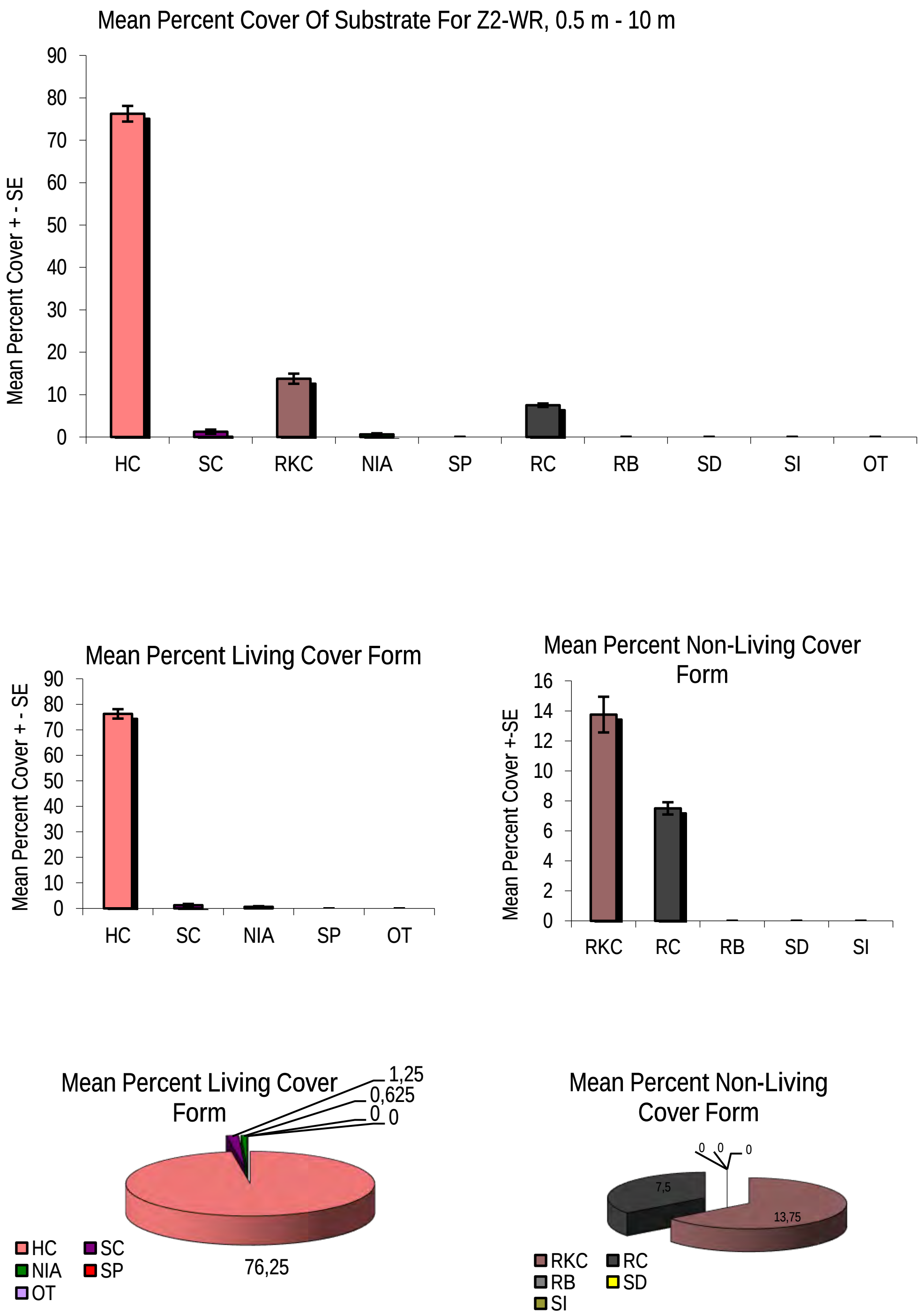


Figure 7: Mean percentage cover of substrate in the Z2-WR, percent living and non living cover form

2.3.2.2. Zone 2 Middle Rief (Z2 MR)

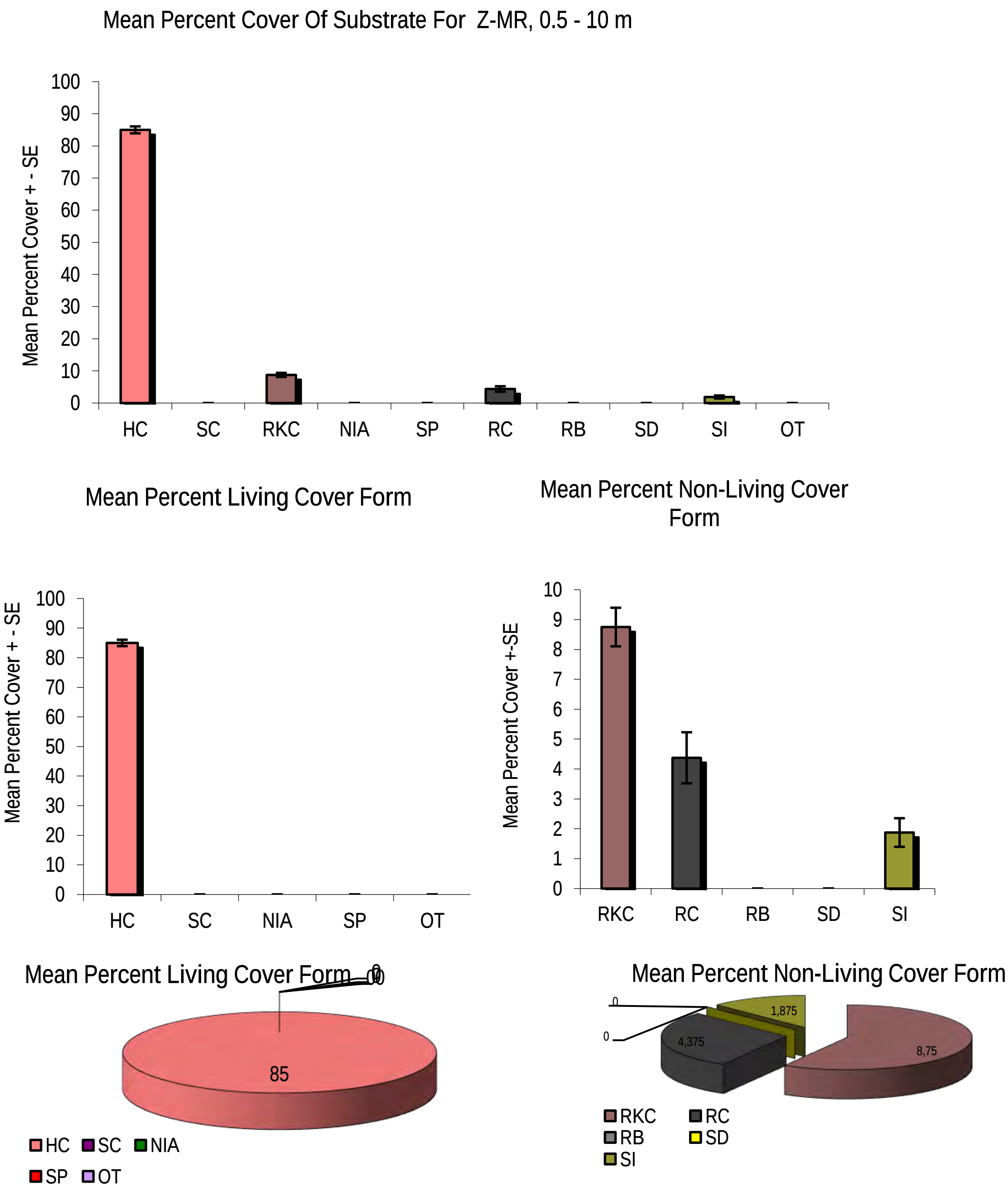


Figure 8: Mean percentage cover of substrate in the Z2-MR, percent living and non living form

2.3.2.3. Zone 2 East Reef (Z2ER)

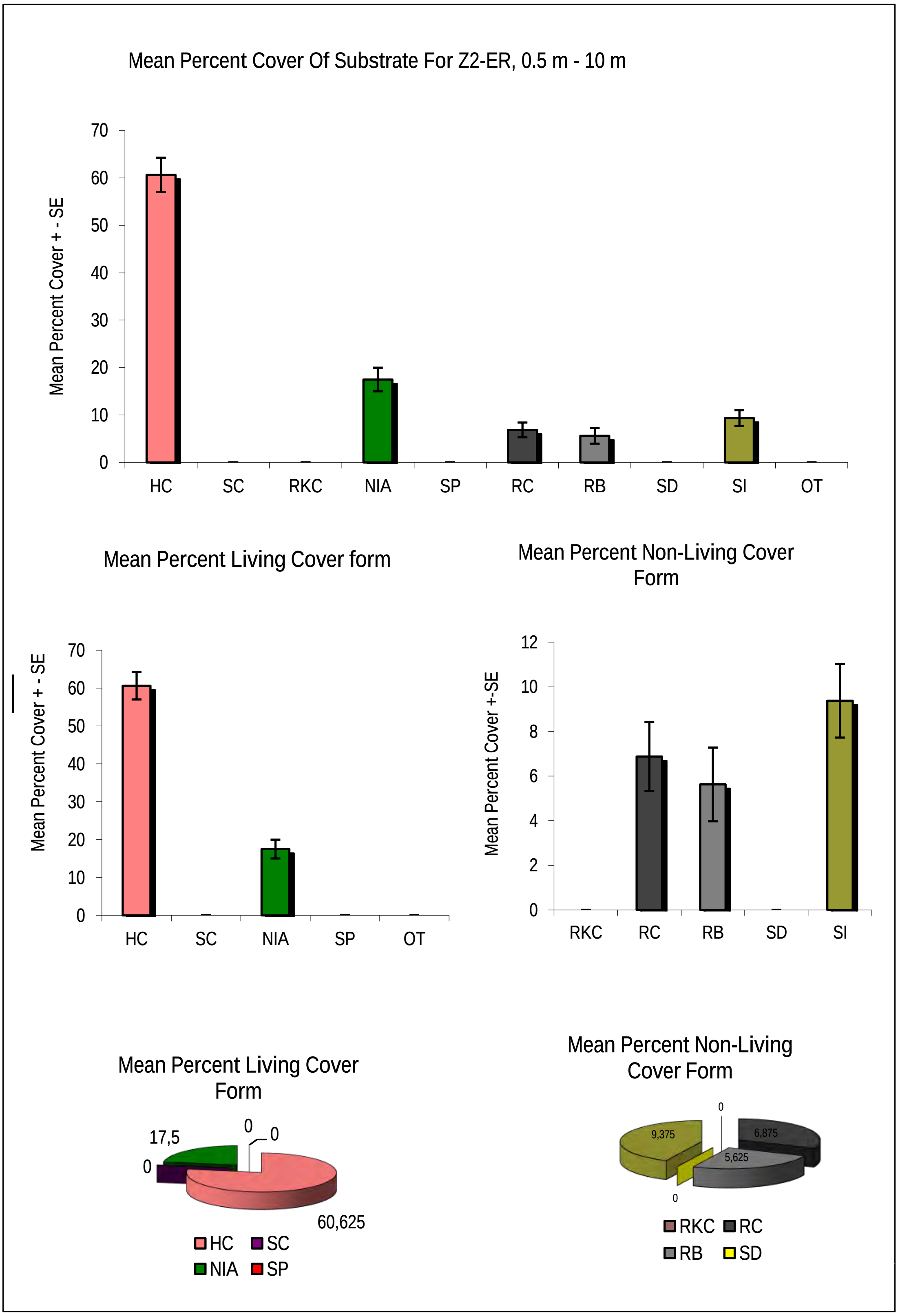


Figure 9: Mean percentage cover of substrate in the Z2-ER, percent living and non living substrates

2.3.3. Conclusion – Zone 1 & 2

Zone 1

Depending on the reef zonation and the nature of the substrates, ZONE 1 can be classified into three eco-zones:

- **The intertidal zone** exposed to tidal variations and characterized by the absence of living substrates. The seabed is covered by sands and rocks.
- **The reef flat area** dominated by rubbles with a few rare living corals. Rubbles occupies large areas and seems resulting from a destroyed reef
- **The back reef area** dominated by massive corals (genus porites) and rocks. In the east and in the middle, this area is particularly affected by the algaes.
- **The almost deserts sandy area** located between the existing jetty and coral reef. This zone ends in a drop off near the two dolphins.

Photography 2: Different types of seabed found in ZONE 1, a) intertidal zone, b) reef flat with a high proportion of rubbles c) sandy area (d) the back reef dominated by massive corals (porites).

Zone 2

Zone 2 is the part of the reef that has the highest coral density. The average hard coral cover is estimated at about 74%. The quantitative assessment has shown that:

- The western and middle parts of the reef contain **a high proportion of live hard corals** and a smaller proportion of non-living substrates. This is a good indicator of the state of health of the coral reef,
- The eastern part has the lowest percentage of cover by living corals, with a fairly high colonization by algae. The development of these algae, which affects only the eastern part of the reef, seems to be linked to a nitrification of water by urban discharges.

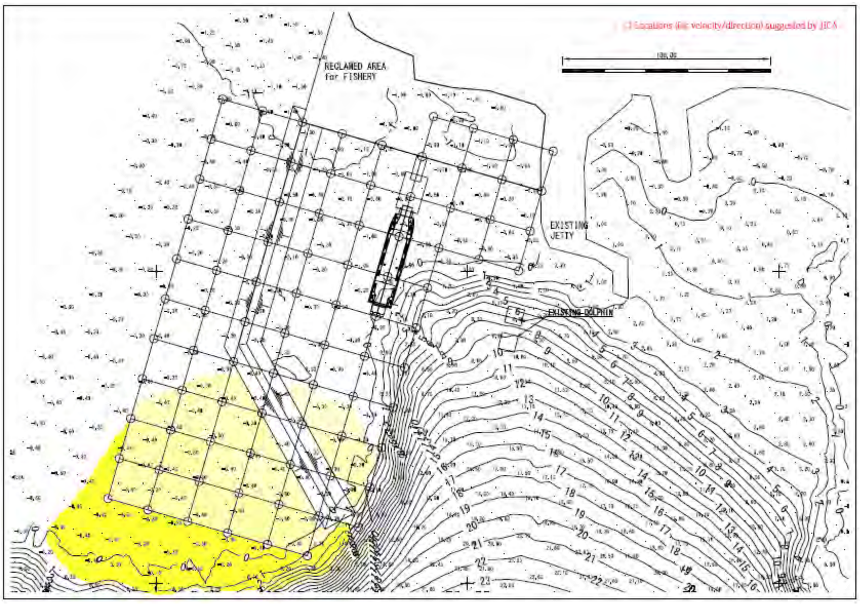


Figure 10: Map showing area with high density and diversity of living corals

Throughout the study area including ZONE 1 and ZONE 2 the coral cover is variable. The lowest percentages of coral cover were observed in the near-coastal area and in the east (Z 1 ER). The coral reef also contains particularly damaged areas dominated by coral rubbles (indicating the widespread mortality), recently dead corals and algae (photography3). These impacts are likely due to possible increase of temperature and low water quality due to proximity to the town of Tadjourah and past port activities. The presence of coral disease is also indicative of the latter. All these impacts are localized ZONE 1 and along the eastern wall in ZONE 2.

Photography 3 : Bleached coral (Left), Acanthater planci (Right)

3. Part 2: Coral species identification

3.1. Background

Coral reef surveys conducted around the proposed port development site at Tadjourah, were conducted in december 2018. GoPro images for coral identification were collected by the field team and used for identification. This report provides the list of species obtained from these sources.

3.2. Objectives

- **Objectives**

The objective of the study is to identify all corals species living in the project area.

- Inventory of coral species identified in the study area,
- Evaluation of ecological importance of coral species in the study area (referred to IUCN Red List etc.),

3.3. Methodology

In the two zones, quantitative data (percentage of cover of substrates) were collected using the belt transect method (part I). During this survey, photo-quadrats and video were taken along the transects for identification. These photos and videos were used for visual identification. After identification, the threat status was indicated for each species.

Overall, 178 images were used, in the following habitats:
- Reef Flat-Back Reef (74),
- Reef crest-Reef slope (104 images).
- In addition, 17 GoPro video clips, 17 varying between 10 seconds to 1 min length, in .mp4 format, for the reef flat location, extending down the top of the slope were used.

3.4. Results and discussion

Corals identified in the still photos are listed in Table 1. A total of 40 species were identified:
- 29 from the reef crest/slope,
- 16 in the reef flat/back reef and
- 8 from the reef flat.

Several species visible in the images could not be reliably identified even to genus level due to the conditions of turbidity and light under water found during the dives as well as the blurring from motion, and a large number of cryptic and generally brown species (such as encrusting Pavona species) are not visible at all, though undoubtedly present. The videos provided some confirmation of species identified from the still images, but the resolution and movement in the videos does not allow for certain identification of any new species.

Table 3 : Coral species identified from still photos collected on the Reef crest/slope, Reef Flat-Back Reef, Reef Flat1 and Reef Flat2 samples. The √indicate the location where the specie was observed.

Genus	Species	Status	Reef Crest/Reef slope	ReefFlat	Reef Flat1	Reef Flat2
Acropora	cytherea	LC				
Acropora	digitifera	NT	√			
Acropora	downingi	LC	√	√		√
Acropora	sp	XX	√	√		√
Acropora	sp	XX		√		
Echinopora	forskaliana	NT	√			
Echinopora	fruticulosa	NT	√			
Echinopora	gemmacea	NT	√			
Echinopora	hirsutissima	NT	√			
Favia	spA	XX		√		
Favia	spB	XX		√		√
Fungia	granulosa	LC		√		
Fungia	sp	XX	√			
Galaxea	fascicularis	NT	√			
Goniastrea	edwardsi	LC		√		
Goniastrea	pectinata	LC	√			
Goniopora	lobata	NT	√			
Herpolitha	limax	LC	√			
Hydnophora	pilosa	LC		√		
Lobophyllia	hemprichi	LC	√	√		
Lobophyllia	robusta	LC	√			
Millepora	platyphylla	LC		√		
Montipora	saudii	NT	√			
Montipora	sp A	XX	√			
Montipora	sp B	XX		√		
Montipora	spongodes	LC		√		
Pavona	decussata	VU	√	√		√
Platygyra	acuta	NT	√			
Platygyra	lamellosa	NT	√			
Platygyra	pini	NT	√			
Platygyra	sinensis	LC	√	√		
Pocillopora	damicornis	LC	√			
Pocillopora	verrucosa	LC	√	√	√	√
Porites	fontanesi	XX		√		
Porites	lobata	NT	√	√		√
Porites	lutea	LC	√	√		√
Porites	monticulosa	LC	√			
Porites	nodifera	LC		√		
Psammocora	contigua	NT	√			
Stylophora	pistillata	NT	√	√	√	√
Count of species:	**40**		**29**	**16**	**2**	**8**

Compared to dedicated species surveys conducted in 2014 (CORDIO 2015), and informed by prior surveys in 2010 and 1998, 68 and 73 species were documented in sites nearby to Tadjourah part – at Ras Douan and at Sable Blanc, respectively, for a total of 96 species for that part of the Djibouti coastline. A total of 235 coral species were identified for the whole of Djibouti's coast (except for the Sept Freres islands, Appendix 1).

The 40 species identified here belong to 18 genera, comprising many of the common shallow water genera for Djiboutian reefs. Comparing the genera identified during the survey of December (Table 2), to those identified previously, more than 80% of species recorded for the area were identified in this study, for *Echinopora, Galaxea, Hydnophora, Lobophyllia, Montipora, Platygyra* and *Stylophora*. However, for several of the speciose and important genera (e.g. *Acropora, Porites* and others), it was not possible to identify many species.

Table 4: Number of species in genera identified in this study, compared to the 90 species identified for the coastline adjacent to Tadjourah, in CORDIO 2015.

Genera	Obura 2014	This study	Proportion
Acropora	14	5	36%
Echinopora	5	4	80%
Favia	5	2	40%
Fungia	5	2	40%
Galaxea	1	1	100%
Goniastrea	3	2	67%
Goniopora		1	>>
Herpolitha	2	1	50%
Hydnophora	1	1	100%
Lobophyllia	2	2	100%
Millepora		1	>>
Montipora	5	4	80%
Pavona	5	1	20%
Platygyra	5	4	80%
Pocillopora	3	2	67%
Porites	7	5	71%
Psammocora	3	1	33%
Stylophora	1	1	100%

Thirty-two of the species identified have been assessed for the Red List of Threatened species for reef-building corals (Carpenter et al. 2008)[1] (Table 3).
Out of these 32, 14 were classified as Near Threatened and 17 as Least Concern and 1 as Vulnerable (see location of the Vulnerable on fig 11).

[1] The eight remaining ones have not yet been assessed by IUCN on their vulnerability status.

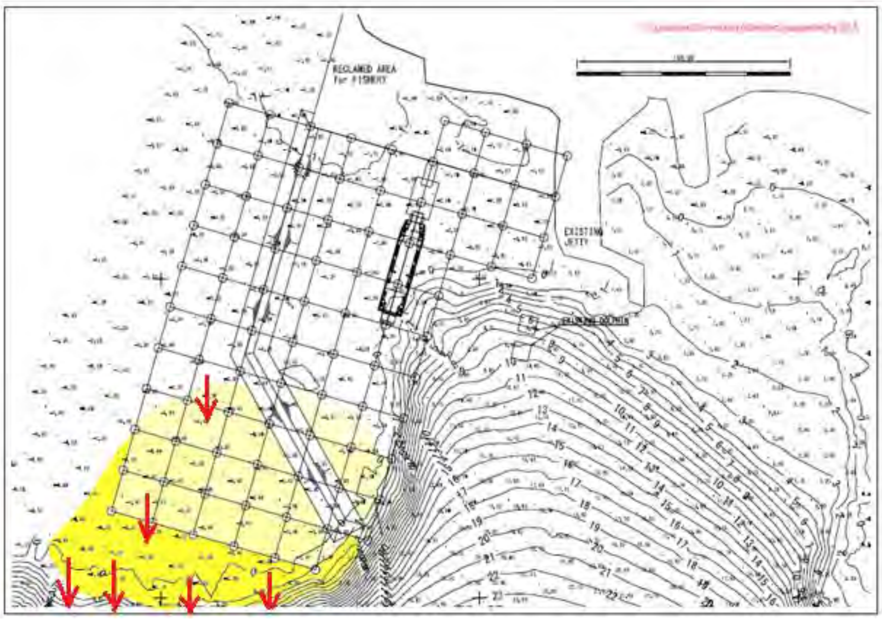


Figure 11: Localization of the vulnerable species

Table 5 : Red List status of species identified in this study. 'Not assessed' – species that were not included in the Red List of corals (Carpenter et al. 2008) and unidentified species listed a 'sp'

CATEGORY	This study
Least Concern	17
Near Threatened	14
Vulnerable	1
Data Deficient	
Not Assessed	8
Grand Total	40

The species diversity of the study site is quite typical of the fringing reefs of the north coast of the Gulf of Tadjourah. Forty species were identified, compared to approximately 70 species per site and 96 species for the general area around Tadjourah (CORDIO 2015). Of these, none were assessed as threatened with extinction by the global IUCN Red List assessment (Carpenter at al. 2008), though nine Vulnerable species documented in the reefs around the project area could well be present.

3.5. Conclusions

This coral survey allowed a better understanding of the structure and the species composition of the coral reef located in the western area of the port of Tadjourah. The main results of this survey are summarized as follows:

1. Reef zonation is typical of a fringing reef which contain two main parts.

   a- the reef flat including the intertidal area, the reef back and the reef crest.
   b- the reef slope which goes down to the south in a deep drop

2. These two areas are distinguished by the nature of seabed, the abundance and the diversity of corals species.

   c- The reef flat area near the coast (first 100 m) which corresponds to Zone 1 (figure2) is characterized by sand/gravel and strong proportion of coral rubbles. Live corals represent only a small proportion (**33.44%)** and consist mainly of massive forms (porites).
   d- The area comprising the reef back, reef crest and the reef slope is characterized by the higher proportion of live corals (**73.95%)**, high diversity of species.

Forty (40) species of coral have been identified throughout the study area. This shows that despite the small size (100 m x 200 m) and undergoing multiple impacts due to its proximity to the city of Tadjourah, the study area has a large coral diversity. Among the identified species, **14 were classified as Near Threatened (NT) and 17 as Least Concern (LC) and 1 as Vulnerable (VU).** These species were located mainly in the reef crest and the reef slope. Among these species, **11 were classified as Near Threatened (NT) and 21 as Least Concern (LC).** These species were mainly located in the reef crest and the reef slope.

4. Part 3: Coral environment impact assessment

4.1. Project site conditions

4.1.1. General meteorological conditions

Being of tropical desert climate, Djibouti is featured with high temperature and low precipitation all year round. Djibouti has a cool season and a hot season respectively from October to April and from May to September. Annual precipitation is rather uneven and the annual average precipitation over years is about 150 mm. The wind speed is low in general and destructive storm weather is rare.

Djibouti is one of the hottest countries in the world. The annual average temperature over years is higher than 30°C and the highest temperature in August may even reach 50°C. Figure 1 shows the monthly maximum and minimum temperature. Annual average relative humidity in Djibouti is around 65%. See Figure 1-(b) for the distribution.

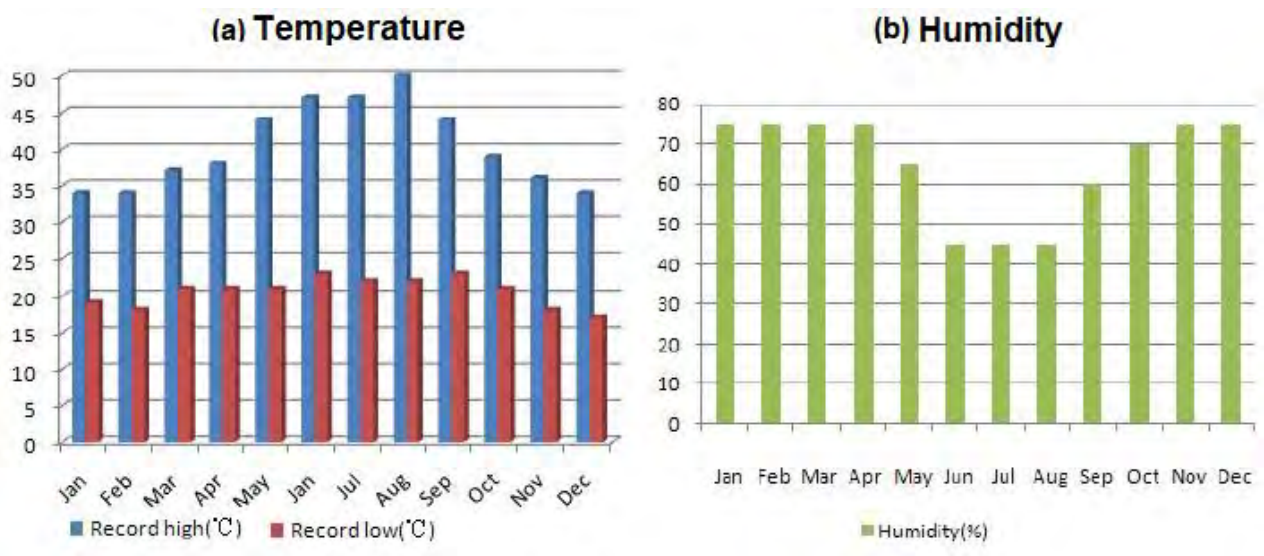


Figure 12 : Monthly maximum and minimum temperature (a) and humidity (b)

4.1.2. Local weather conditions

The weather conditions vary according to seasons and regions. The data collected on the Tadjourah site (Port of Tadjourah) during the survey are presented below.

- **Atmospheric condition**

Table 6: Conditions of the period of collection of the samples:

Date	20 october
Location	Tadjourah
Tide	2,2 m
Wind direction	East
Temperature	32,8 °C

- **Table 2: Wind speed variation**

Measuring time	Wind speed (m/s)
13:00-14:00	4
14:00-15:00	5
15:00-16:00	5
16:00-17:00	5
17:00-18:00	3
18:00-19:00	3
19:00-20:00	3
20:00-21:00	3
21:00-22:00	3
22:00-23:00	3
23:00-24:00	2
24:00-01:00	3
01:00-02:00	3
02:00-03:00	3
03:00-04:00	3
04:00-05:00	3
05:00-06:00	3
06:00-07:00	3
07:00-08:00	3
08:00-09:00	3
09:00-10:00	4
10:00-11:00	4
11:00-12:00	3
12:00-13:00	5
13:00-14:00	5

4.1.3. Ocean conditions

During the cool season, the average sea surface temperature is around 26 – 27 °C. The column of water is not stratified, and the salinity is about 37 ppt. The prevailing wind blows from the Northeast.

4.1.4. Seawater characteristic during the survey period

In order to evaluate seawater quality in the project site, 5 samples of water were collected and analyzed. The mean results are described hereunder.

- **Turbidity**

The turbidity is a measure of the amount of cloudiness or haziness in sea water caused by suspended particles. During the survey, at the three measuring points, the turbidity values of seawater were respectively 0.49 NFU, 0.12 NFU et 0.29 NFU (1 NFU = 1 NTU). These values are below the standard threshold value for Class I coastal waters (see table 3). However, there was significant difference between the three points:

- Turbidity was higher at point 1 (Eau/Tadj 1) located on the shallow coral reef,
- while at points Eau/Tadj 2 and Eau/Tadj 3 located respectively on the reef slope and the downfall, the turbidity values are the weakest and reflecting clearer waters.

- **pH**

The hydrogen ion concentration (pH) values were varying from 8.23 to 8.41 (The seawater are slightly basic; pH **7.0** is neutral). These values are clustered in the standards values (table 3).

- **Conductivity / Salinity**

The electrical conductivity which express the salinity of seawater were 56500µS/cm-to 56,700µS/cm (salinity: 37.7 ppt to 37.6 ppt). These values characterize the less saline waters which predominate during the cool season (water mass from Gulf of Aden).

- **Dissolved oxygen**

Dissolved oxygen content of seawater was about 8.2 – 9 mg/L, which is greater than the standard value of 4 mg/L recommended for protection of aquatic lives.

Table 7 : Water quality criteria for class SW-1 Water (Source: International Journal of Innovative Research in Science, Engineering and Technology (An ISO 3297: 2007 Certified Organization) Vol. 4, Issue 12, December 2015)

Parameter	Standards	Rationale / Remarks
pH range	6.5 – 8.5	Range does not cause skin or eye irritation and is also conducive for propagation of aquatic life
Dissolved oxygen	4.0 mg/l or 50 percent saturation value, which ever is higher.	Not less than 3.5 mg/l at any time of the year for protection of aquatic lives
Odor or Colour	No noticeable colour or offensive odour.	Specially caused by chemical compounds like creosols, phenols, naptha, pyridine, benzene, toluene etc. causing visible colouration of salt crystal and tainting of fish flesh.
Floating Matters	Nothing obnoxious or detrimental for use purpose.	None in concentration that would impair usages specially assigned to this class.
Turbidity	30 NTU (Nephelo Tur- bidity Unit : 1 NFU = 1 NTU)	Measured at 0.9 depth.
Fecal Coliform	100/100 ml (MPN)	The average value not exceeding 200/100 ml. in 20 percent of samples in the year and in 3 consecutive samples in monsoon months.
Biochemical Oxygen Demand (BOD) (3 days at 27°C)	3 mg/l	Restricted for bathing (aesthetic quality of water).
Nitrate	3.7 mg/L	For nitrate (as N), the 30-d average concentration to protect marine aquatic life

4.1.5. Requirement environmental condition for corals growth

To growth, corals need five following conditions:

Sunlight: Corals need to grow in shallow water where sunlight can reach them. Corals depend on the *zooxanthellae* (algae) that grow inside of them for oxygen and other things, and since these algae needs sunlight to survive, corals also need sunlight to survive. Corals rarely develop in water deeper than 165 feet (50 meters).

Clear water: Corals need clear water that lets sunlight through; they don't thrive well when the water is opaque. Sediment and plankton can cloud water, which decreases the amount of sunlight that reaches the zooxanthellae.

Warm water temperature: Reef-building corals require warm water conditions to survive. Different corals living in different regions can withstand various temperature fluctuations. However, corals generally live in water temperatures of 68–90° F or 20–32° C.

Clean water: Corals are sensitive to pollution and sediments. Sediment can create cloudy water and be deposited on corals, blocking out the sun and harming the polyps. Wastewater discharged into the ocean near the reef can contain too many nutrients that cause seaweeds to overgrow the reef.

Saltwater: Corals need saltwater to survive and require a certain balance in the ratio of salt to water. This explains why corals don't live in areas where rivers drain fresh water into the ocean ("estuaries").

Oxygen: Corals in order to grow also need plentiful supply of plankton and enough oxygen. This is important because like any other living organism corals polyps need food and oxygen in order to grow and to be able to reproduce

The water quality at all three sampling points arount the Port of Tadjourah, is good and all the measured parameter are within coastal water standards.

4.2. Project Details

4.2.1. Overall planning

The project plans to rehabilitate the former port of Tadjourah and build berthing infrastructures for the new ferry. These facilities include land reclamation, new jetty and breakwater. The planned area is located west of the former port and covers an area of 31 270 m² (figure 13, red rectangle).

Figure 13 : Map showing Project area (red rectangle), planned area for breakwater (blue thick line), Land reclamation (orange rectangle), Jetty (green) and dredging area (yellow)

According to the overall planning, the breakwater will be constructed in the west part of the project site, the land reclamation and new jetty in the northern part. The area that will be dredged is located in the south and east of the new jetty *(figure 13).*

Detailed plan of the facilities and technical specification of the project activities will be needed for further assessment of the projects impacts on the environment.

4.3. Impact assessment methodology

First, for each planned activity, all sources of impacts were identified. Then, all the identified sources of potential impacts on the physical and biological environment were evaluated. The impact significance was determined according (i) the nature and duration of the activity (ii) the sensitivity of the environment components in the vicinity of the project area (see our previous report). Mitigation measures to reduce any identified negative impacts on seawater quality and specifically on coral reef communities were then determined.

4.3.1. Impacts identification

4.3.1.1. Land reclamation and new jetty construction

- Planned activities: backfilling, compaction, dredging/excavation
- Materials used: sand, gravel and cement
- Identified impacts:
    - Emission of dust causing air pollution and particules transfert to the ocean
    - Increase in suspended solid (SS) concentrations in the coastal water

- **Emission of dust causing air pollution and particules transfert to the ocean**

Dust emission to the atmosphere could significantly impact marine ecosystem. Indeed, substances present in particles, such as most mineral, will generally have relatively short residence times and their removal, either by wet or dry deposition to the ocean surface, will generally be on a local scale, particularly close to coastlines (Jickells et al., 2005). Minerals present in the aerosol (iron, nitrogen and phosphorus) react in the **ocean as** nutrient in ocean, resulting in increased marine biological productivity (Boyd, P.W., T. Jickells et al., 2007; Jickells and Spokes, 2007; Doney et al. (2007)**.**

- **Increase in suspended solid (SS) concentrations in the coastal water**

Land reclamation and jetty construction at the coastal area involves dredging/excavation of marine sediment. This could disturb the marine bottom sediment, causing an increase in suspended solid (SS) concentrations in the water column and forming sediment plume along the tidal flows. In addition, the discharges during the work, construction runoff and drainage, with effluents potentially contaminated with silt, oil and grease.

4.3.1.2. Breakwater construction

A breakwater is a structure constructed for the purpose of forming an artificial harbour with a basin so protected from the effect of waves as to provide safe berthing for fishing boats. There are many different types of breakwaters; natural rock and concrete, or a combination of the two, are the materials which form 95 percent or more of all the breakwaters constructed (Anonyme,)

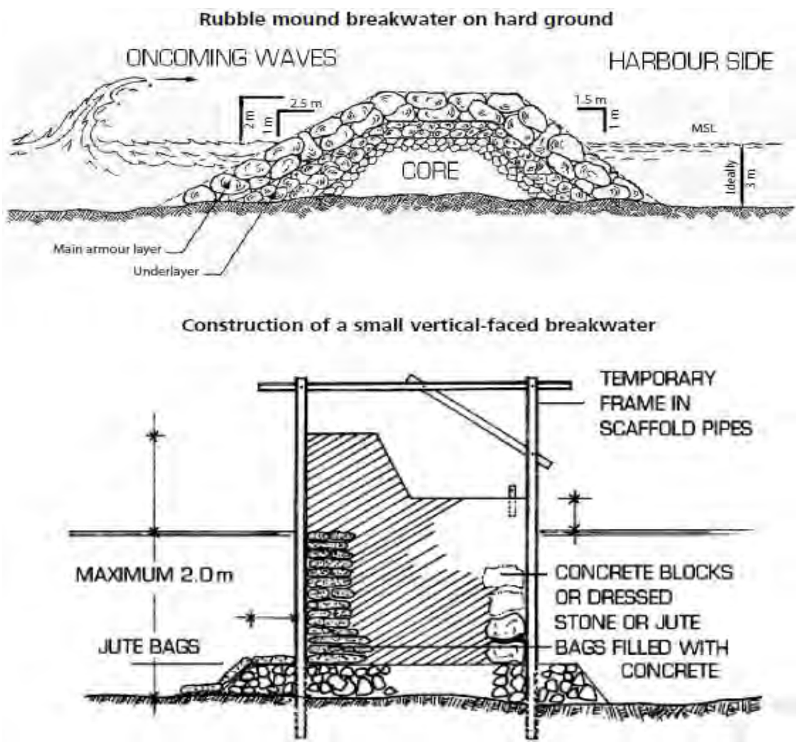


Figure 14: Solid breakwater construction (source FAO)

Whatever the typology and design of breakwater, underwater construction involves (i) Dredging / excavation, (ii) Foundation, (iii) Deposit of Stone rubble, rocks and sand. These activities could impact the seabed and surrounding marine environment.

The main identified impacts are:

- Seabed deterioration
- Seawater pollution
- Modification of coastal water circulation

- **Seabed deterioration**

Dredging/excavation of marine sediment will cause disturbance to the seabed.

- **Seawater pollution**

The release of marine mud and contaminants may affect the water quality. Seawall modification will involve excavation and placement of rocks and gravels which may also affect the water quality. Runoff from the construction works areas may contain increased loads of sediments, other suspended solids (SS) and contaminants. Potential sources of pollution from site drainage include:

- Runoff from and erosion from site surfaces, drainage channels, earth working areas and stockpiles
- Release of any bentonite slurries, concrete washings and other grouting materials with construction runoff and storm water
- Fuel, oil, solvents and lubricants from maintenance of construction vehicles and mechanical equipment

- **Modification of coastal water circulation**

The presence of the concrete blocks would create forces on the tidal flow which result in energy loss of the flow and eventually impact the flushing capacity within the vicinity of the barging point. According to the orientation of the piles and their sizes, potential impacts will need to be assessed.

4.3.1.3. Dredging

The project plans to dredge an important area around the new jetty *(see figures 13 & 15)*. Dredging/Excavation will cause disturbance of the marine bottom sediment. The excavation will also modify bathymetric feature and consequently the current system. Both dredging and excavation will increase the suspended solid (SS) concentrations in the water column which could spread over long distances.

Depending on the weather conditions (current velocity) and the spread of suspended particles, the area of influence was delineated at about 500 m around the project site *(Figure 15)*.

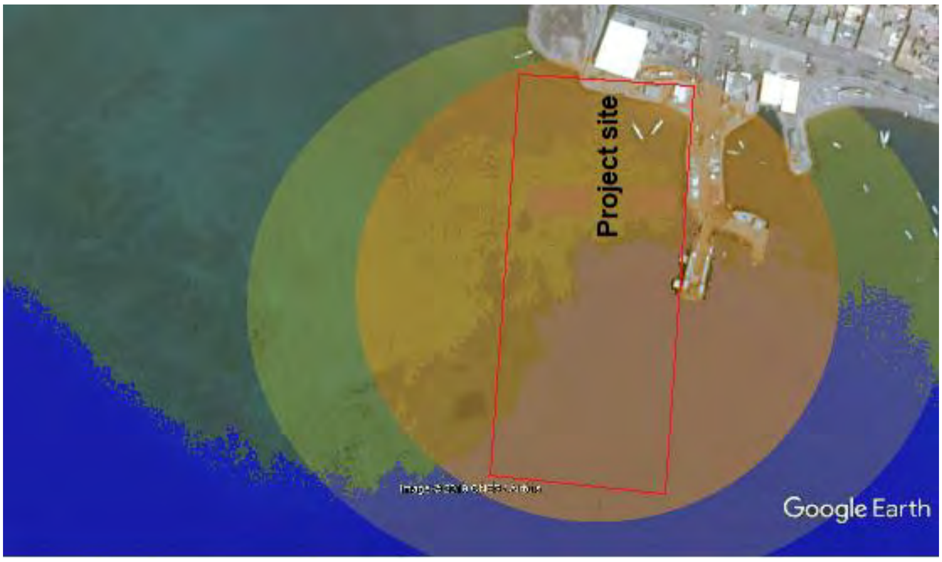


Figure 15 : Project site and project area of influence

4.3.2. Specific impacts on corals

All the above described activities (land reclamation, beakwater construction and dredging) could significantly impact corals species located in the vicinity of the work area. Based on the nature of the project activities, two main potentials impact on coral reef were identified:

- mechanical deterioration of corals and,
- their environment disturbance.

Benthic organisms, including corals, may be damaged by sediment deposition that block the respiratory and feeding organs of corals. Also, suspended solids in seawater reduce the amount of light reaching coral reefs and other shallow benthic systems; and as the sediment settles, it can bury corals or cause them to expend a large amount of energy keeping their surfaces clean. According to Hawker and Connell, the sedimentation rate higher than 0.1 kg/m² per day would introduce moderate to severe impact upon corals. Many other studies (Bak, 1978; Dodge and Brass, 1984) have showed decreases in coral growth rates with increased sediment stress, usually from disturbance such as dredging (Risk and Edinger, 2011).

4.3.3. Analysis of the impacts

The magnitude of the identified impacts on marine and coastal environment will depend on:

- the duration,
- the nature and the extend
- the sensitivity of the physical and biological components (detailed in section 4.1)

The impact analysis considers those three parameters (tables 8 and 10).

Table 8 : Project activites, impacts and receiving environment characterization

Activities	Extent (Area : m²)	Identified impacts	Target environment	Sensitivity
Land reclamation backfilling, compaction, dredging/excavation	2500	- Increased dust in air - Coastal profile modification - Suspended solid concentration in water column - Contamination by pollutants	Air Soil Water quality Seawater	Weak Average High Average
Breakwater construction	1500	- Deterioration of seabed - Seawater pollution - Modification of water circulation - Corals destruction	Seabed Seawater Water column Coral reef	Average High High High
Dredging/excavation	5400	- Deterioration of seabed - Seawater pollution - Current system disturbance - Corals environment disturbance	Seabed Seawater Water column Coral reef	High High Weak High
Navigation	Path: Djibout/Tadjourah	- Pollution by engine oils - Pollution by organic discharges - Vibration	Water column Coral reef Coral reef	High High High

Sensitivity of the receiving environment	Value of the affected element	The value of the impact corresponds to the importance given vy the population to that impacted element. The value of the impact will be appreciated as high, average or weak.
	Sensitivity of the environment	The sensitivity of the environment corresponds to the fragilty of the impacted environment according to its characteristics. The sensitivity is high, average or weak.
Severity of the impact	Extent of the impact	The extent of the impact corresponds to the spatial extent of the effects that can be produced by an intervention on the environment. The extent refers to a distance, or a specific space wherein an environment or element of this environment is going to undergo some changes. The extent of the impact can be regional, local or occasional.
	Duration of the impact	The duration of the impact corresponds to a certain amount of time during which an element of the environment or the environment itself will undergo some changes. The duration can be evaluated as long, average or short.
Importance of the impact		The interaction between the value, the sensitivity, the extent and the duration, corresponds to the importance of the impact. The importance is characterized as major, average, minor.

Table 9: Definition of sensitivity and severity of the impacts

Activities	Components of the affected environment			Nature of the impact	Matrix of impacts evaluation				
	Physical	Biological	Sensitivity		Value	Intensity	Extent	Duration	Importance of the impact
Land reclamation zone	Air	-	Low	Emission of dust Emission of gas from engines	Low	Low	local	short	+
	Soil (coast)	-	Low	Coastal profile modification	Average	Low	local	permanent	++
	Seawater in the vicinity of the coast	-	High	Suspended solid concentration in water column	High	Medium	local	Short	+
Dredging	Seabed	Benthic species	Low	habitat loss	High	Low	Local	Permanent	++
	seawater	fish	Low	Seawater quality degradation Current system disturbance	High Low	High Medium	Local Local	Short Permanent	++ ++
	Coral reef	Coral species	High	Increase of suspended solids (impact on coral growth)	high	High	Local	Short	++
Breakwater	Seabed	Benthic species	High	Seabed disturbance	Average	High	Local	Permanent	+++
	Seawater	fish	Low	Suspended solid concentration in water column Current system disturbance	High	High Medium	Local Permanent	Short Short	++ ++
	Coral reef	corals	High	Coral degradation	High	High	local	Permanent	+++
Operation phase	Water column	Fish		Habitat degradation	Medium	Medium	Permanent	Long	++
	Coral reef	corals		Reduce of light penetration	Medium	Medium	Permanent	Long	++

Table 10: Matrix of impact evaluation

Low impact (+) : low intensity, short duration and low extend ;
Medium impact (++) : Medium intensity, short duration and low extend
High impact (+++) : High intensity, long duration and high extend

5. Conclusion

This study showed that project activities can potentially have significant impact on physical and biological environment within 500 m around the project site. The mains impacts are classified in 3 groups:

1. **Pollution impacts during the construction phase** associated with gas emissions by vehicles, releases of oils and greases and effluents.
2. **Impacts related to project activities** including land reclamation, dredging / excavation and the installation of jetties and the breakwater in the submerged area. The negative effects evaluated as significant are the deterioration of the coral habitat notably by the suspension of the solid particles and the mechanical degradation of the corals during the work.
3. **Post-project impacts with long-term effect**: jety and breakwater could modify the current pattern and subsequently ecological characteristics of the area. Water pollution related to the navigation of the ferry.

The coral reef within the planned area will be particularly exposed to the negative effects of the project. This coral reef is characterized by a high coral cover and contains some threatened species classified as Neat Threatened (NT), Least Concern (LC) and Vulnerable (VU). Specific measures should be taken to preserve this biotope and its fragile components.

5.1. Impact Mitigation Measures

Appropriate management and scrupulously applied mitigation measures would eliminate or reduce the importance of the identified impacts. For each project activity, the most relevant measures to implement are summarized in table below.

Activity	Identified impacts	Mitigation measure
Land reclamation	Air, Soil and seawater pollution	Before the works, the project promoter will have to prepare an organizational scheme for the sorting, selective collection and disposal of waste. Non-recyclable waste should be taken to a landfill near the site;
		Used oils will be recovered on site (provide 1 tank of storage).
		Recovery of used oils and reduction of fuel spills to a minimum
		Sealing of fixed areas for the handling of fuels and lubricants:
		Compliance with Djiboutian requirements regarding good environmental practices, by the companies implementing the project;
		Sensitization of site staff to the environment protection
		Use of dust suppressant
		Use of the machinery engines certified according to the international standards
		Regular maintenance of machinery engines and vehicles to minimize gaz emissions;
		Watering areas exposed to the wind in dry and windy weather, especially during khamsin (June-August)
Dredging	Seawater quality degradation	Dredge during periods of calm seas and following a tide and sea state schedule. Do not discard sands dredged into the sea. Beforehand, measure turbidity and marine currents
Breakwater	Coral degradation	Dredge during periods of calm seas and following a tide and sea state schedule. Do not discard sands dredged into the sea.
	Seawater quality degradation	Beforehand, measure turbidity and marine currents (see figure below)
Operation phase	Water column pollution	Passengers awareness Set up rubbish bins in the ferry

Table 11: Mitigation measures

5.2. Sites for water measurement

Further study should be done in order to precise the potential impacts and potential measures. A proposition of the points and type of measure is indicated hereunder.

- Current velocity and direction (red),
- Turbidity, salt content, temperature and dissolved oxygen (yellow)

Figure 16 : Proposed location for water measurements

6. Recommendations

In addition to ecological importance revealed by the abundance and the diversity of coral species, this coral reef is of major socio-economic importance. Its role for the development of the artisanal fisheries will be growing with the construction of a new fishing port close to the mooring port of the new ferry. **Hence, the importance to preserve this coral ecosystem.**

The impact assessment study (IAS) carried out in the project area (Part III) shows that the project activies (land reclamation/new jetties, breakwater construction and dredging/excavation) will have a significant impact on the marine environment and specifically on the coral reefs located in the vicinity of the project site. Based on the results of the IAS, the mean recommendations are as follow:

(i) Establish a management plan for liquid, solid and gaseous discharges during the construction phase (see details of these mitigation measures in Table 7).

(ii) Underwater work (breakwater, dredging, excavation) should be undertaken in such a way as to limit the suspension of solid particles and their propagation. To this purpose, in addition to the analyze of seawater and sediment samples, more detailed measurements of turbidity, silt and especially currents (velocity and direction) should be carried out in the areas to be dredged. Dredging has to be done during the period with calm wind and smooth sea, this will prevent the spread of solid particles to the coral reef.

(iii) The breakwater **should avoid as much as possible the areas of high coral cover including the back reef, the reef crest and the reef slope**. In order to achieve this, the breakwater should be constructed in the eastern part of the reef (see figure 16 for new mapping).

(iv) The construction of the breakwater should precede all the other activities; this breakwater will be a barrier against all the rejections, in particular from the sand sedimentation; suspended particles and possible contamination by dredging activities.

(v) A grid fence should be constructed on the breakwater to mitigate solid waste pollution

(vi) The hydrological conditions measured in the project site are within the standard values which correspond to the required conditions for corals growth. These conditions should be preserved during the project implementation.

(vii) Reduce pollution during the travels between Djibouti and Tadjourah, this should be done by raising awareness of the passengers and setting up rubbish bins in the ferry

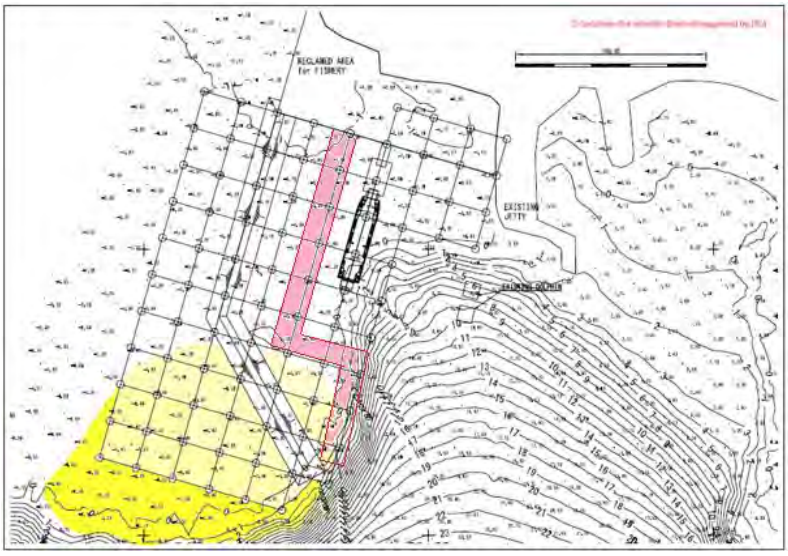


Figure 17: Alternative scenario

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7. Appendix1: Field Data Sheet used for data collection

Depth: 1 m

TS/TL:

Time: 10 h00

Date:

Data recordedby: Dr Moussa Omar

Substrate Code

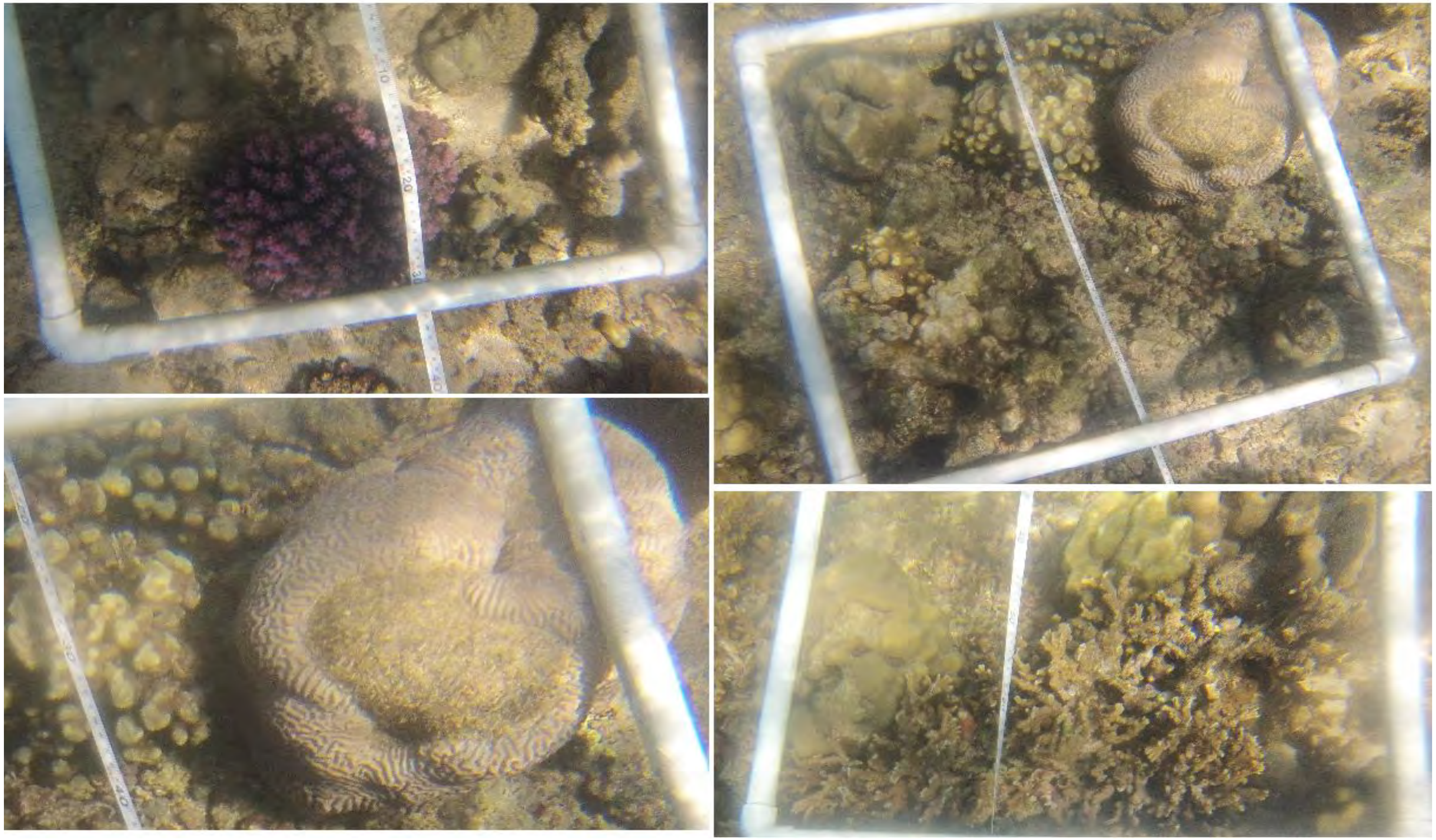
HC	**hard coral**	**SC**	**soft coral**	**RKC**	**recentlykilledcoral**
NIA	**nutrientindicatoralgae**	**SP**	**sponge**	**RC**	**rock**
RB	**rubble**	**SD**	**sand**	**SI**	**silt/clay**
OT	**other**				

SEGMENT 1				SEGMENT 2				SEGMENT 3				SEGMENT 4			
0 - 19.5 m				25 - 44.5 m				50 - 69.5 m				75 - 94.5 m			
0		10		25		35		50		60		75		85	
0.5		10.5		25.5		35.5		50.5		60.5		75.5		85.5	
1		11		26		36		51		61		76		86	
1.5		11.5		26.5		36.5		51.5		61.5		76.5		86.5	
2		12		27		37		52		62		77		87	
2.5		12.5		27.5		37.5		52.5		62.5		77.5		87.5	
3		13		28		38		53		63		78		88	
3.5		13.5		28.5		38.5		53.5		63.5		78.5		88.5	
4		14		29		39		54		64		79		89	
4.5		14.5		29.5		39.5		54.5		64.5		79.5		89.5	
5		15		30		40		55		65		80		90	
5.5		15.5		30.5		40.5		55.5		65.5		80.5		90.5	
6		16		31		41		56		66		81		91	
6.5		16.5		31.5		41.5		56.5		66.5		81.5		91.5	
7		17		32		42		57		67		82		92	
7.5		17.5		32.5		42.5		57.5		67.5		82.5		92.5	
8		18		33		43		58		68		83		93	
8.5		18.5		33.5		43.5		58.5		68.5		83.5		93.5	
9		19		34		44		59		69		84		94	
9.5		19.5		34.5		44.5		59.5		69.5		84.5		94.5	

Whatpercentage of recorded RKC is a result of bleaching?

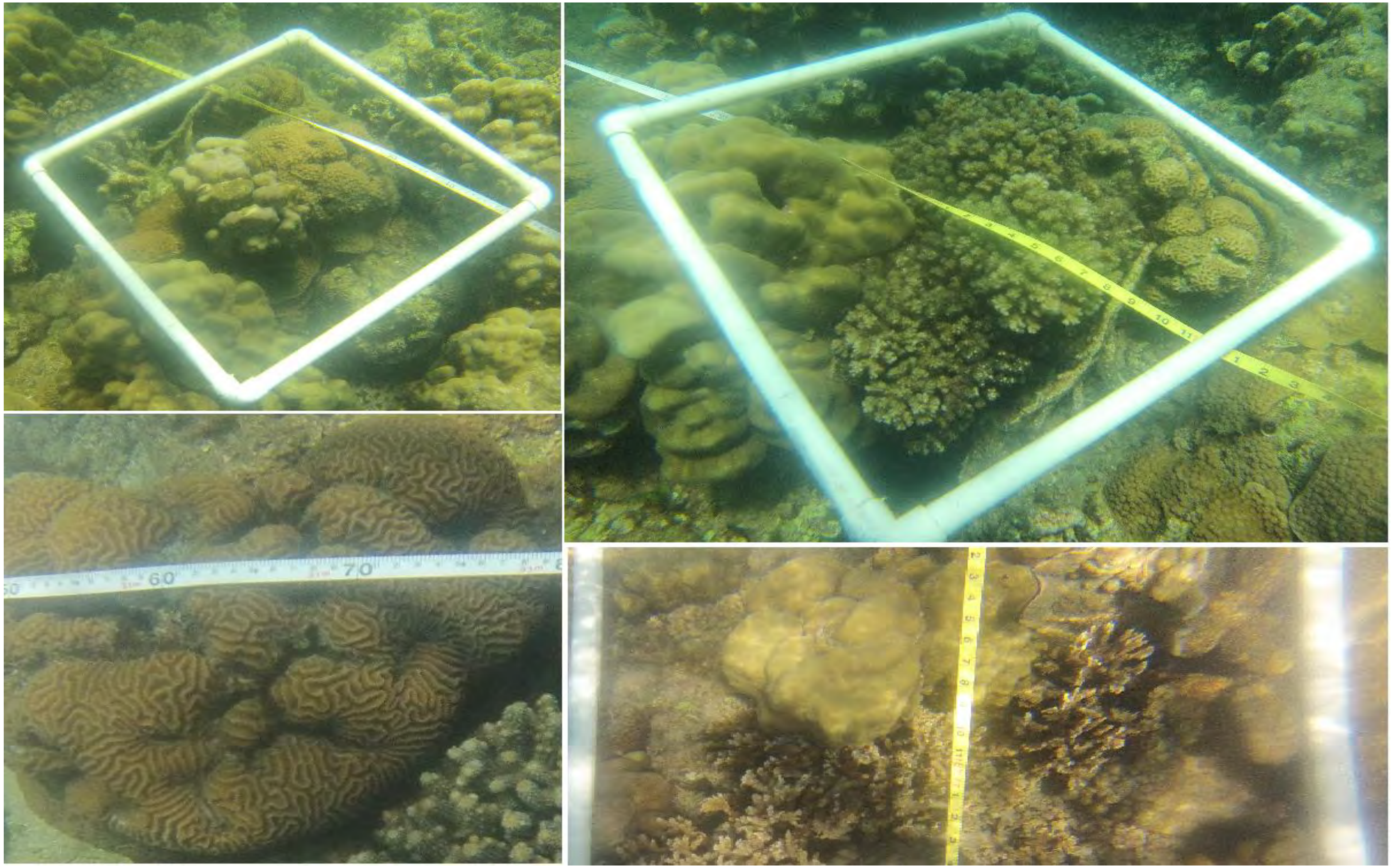
Comments:

8. Appendix2: Somes photos of living corals in ZONE 1



Photography 4 : Photos of living coral found in Zone 1

9. Appendix 3: Some photos of living corals in ZONE 2



Photography 5: Photos of living coral in Zone 2

10. Appendix 4: Some photos of living corals in Reef slope

Photography 6: Living coral in reef slope

11. Appendix 5: List of coral species from CORDIO 2015.

Note, the species and genera names listed here are not updated to current taxonomy. The Red List status is listed for each species, XX = not assessed.

	Count of species:		68	73	96	235
Genus	***Species***	***RedList***	***Ras Douan***	***Sable Blanc***	***Study area***	***Djibouti***
Acropora	cytherea	LC	1	1	1	1
Acropora	digitifera	NT		1	1	1
Acropora	divaricata	NT		1	1	1
Acropora	downingi	LC	1	1	1	1
Acropora	granulosa	NT		1	1	1
Acropora	microclados	VU		1	1	1
Acropora	pharaonis	VU	1	1	1	1
Acropora	polystoma	VU	1		1	1
Acropora	rosaria	DD	1	1	1	1
Acropora	samoensis	LC	1		1	1
Acropora	squarrosa	LC		1	1	1
Acropora	subulata	LC	1	1	1	1
Acropora	valida	LC		1	1	1
Acropora	variolosa	VU	1	1	1	1
Coscinaraea	exesa	XX	1		1	1
Coscinaraea	monile	LC	1	1	1	1
Ctenactis	echinata	LC	1		1	1
Cycloseris	wellsi	LC	1		1	1
Cyphastrea	microphthalma	LC		1	1	1
Cyphastrea	serailia	LC		1	1	1
Diploastrea	heliopora	NT	1		1	1
Echinophyllia	aspera	LC	1		1	1
Echinopora	forskaliana	NT	1	1	1	1
Echinopora	fruticulosa	NT	1	1	1	1
Echinopora	gemmacea	LC	1	1	1	1
Echinopora	hirsutissima	LC	1	1	1	1
Echinopora	lamellosa	LC	1		1	1
Favia	favus	LC	1	1	1	1
Favia	laxa	NT		1	1	1
Favia	lizardensis	NT	1	1	1	1
Favia	maritima	NT	1		1	1
Favia	rosaria		1	1	1	1
Favites	abdita	NT	1		1	1
Favites	flexuosa	NT		1	1	1
Fungia	concina	LC	1	1	1	1
Fungia	danai	XX		1	1	1
Fungia	granulosa	LC	1	1	1	1
Fungia	paumotensis	LC	1	1	1	1

Fungia	repanda	LC	1		1	1
Galaxea	fasicularis	NT	1	1	1	1
Gardineroseris	planulata	LC	1	1	1	1
Goniastrea	edwardsi	LC	1	1	1	1
Goniastrea	pectinata	LC	1	1	1	1
Goniastrea	peresi	NT		1	1	1
Herpolitha	limax	LC	1	1	1	1
Herpolitha	weberi	XX		1	1	1
Hydnophora	pilosa	LC		1	1	1
Leptastrea	aequalis	VU	1	1	1	1
Leptastrea	bottae	NT	1	1	1	1
Leptastrea	purpurea	LC	1		1	1
Leptoseris	glabra	LC	1		1	1
Lithophyllon	mokai		1	1	1	1
Lithophyllon	undulatum			1	1	1
Lobophyllia	corymbosa	LC	1	1	1	1
Lobophyllia	hemprichii	LC	1	1	1	1
Merulina	scheeri		1	1	1	1
Montastrea	valenciennesi	NT	1		1	1
Montipora	informis	LC	1	1	1	1
Montipora	meandrina	VU		1	1	1
Montipora	monasteriata	LC	1		1	1
Montipora	saudii	NT		1	1	1
Montipora	verrucosa	LC		1	1	1
Mycedium	elephantotus	LC	1		1	1
Mycedium	umbra	LC	1		1	1
Oulophyllia	levis		1		1	1
Oxypora	glabra		1	1	1	1
Oxypora	lacera	LC	1		1	1
Pachyseris	speciosa	LC		1	1	1
Pavona	cactus	VU		1	1	1
Pavona	explanulata	LC	1		1	1
Pavona	frondifera	LC		1	1	1
Pavona	varians	LC	1	1	1	1
Pavona	venosa	VU	1		1	1
Platygyra	acuta	NT	1	1	1	1
Platygyra	contorta	LC	1	1	1	1
Platygyra	daedalea	LC		1	1	1
Platygyra	lamellina	NT		1	1	1
Platygyra	sinensis	LC	1	1	1	1
Pocillopora	damicornis	LC	1	1	1	1
Pocillopora	eydouxi	NT		1	1	1
Pocillopora	verrucosa	LC		1	1	1
Podabacia	crustacea	LC	1		1	1
Porites	annae	NT		1	1	1
Porites	fontanesi	XX	1	1	1	1

Porites	lobata	NT	1	1	1	1
Porites	lutea	LC	1	1	1	1
Porites	monticulosa	LC	1	1	1	1
Porites	nodifera	LC		1	1	1
Porites	zpA (butterfly)	XX	1	1	1	1
Psammocora	contigua	NT		1	1	1
Psammocora	niestraazi	LC	1	1	1	1
Psammocora	profundacella	LC	1	1	1	1
Seriatopora	guttatus	LC	1	1	1	1
Stylophora	pistillata	NT	1	1	1	1
Symphyllia	valenciennesi	LC	1		1	1
Turbinaria	reniformis	VU	1	1	1	1

Species recorded in other parts of Djibouti

Acropora	appressa	NT				1
Acropora	aspera	VU				1
Acropora	austera	NT				1
Acropora	cerealis	LC				1
Acropora	clathrata	LC				1
Acropora	copiosa	DD				1
Acropora	elseyi	LC				1
Acropora	eurystoma	XX				1
Acropora	gemmifera	LC				1
Acropora	hemprichi	VU				1
Acropora	humilis	NT				1
Acropora	hyacinthus	NT				1
Acropora	latistella	LC				1
Acropora	loripes	NT				1
Acropora	microphthalma	LC				1
Acropora	muricata	NT				1
Acropora	nasuta	NT				1
Acropora	pulchra	LC				1
Acropora	retusa	VU				1
Acropora	secale	NT				1
Acropora	variabilis	DD				1
Acropora	verweyi	VU				1
Alveopora	spongiosa	NT				1
Astreopora	gracilis					1
Astreopora	myriophthalma	LC				1
Astreopora	suggesta	LC				1
Montipora	aequituberculata	LC				1
Montipora	crassituberculata	VU				1
Montipora	digitata	LC				1
Montipora	efflorescens	NT				1
Montipora	nodosa	NT				1

Montipora	spongodes	LC	1
Montipora	stilosa	VU	1
Montipora	tuberculosa	LC	1
Montipora	undata	NT	1
Leptoseris	foliosa	LC	1
Leptoseris	incrustans	VU	1
Pavona	chiriquiensis		1
Pavona	danai	VU	1
Pavona	decussata	VU	1
Pavona	maldivensis	LC	1
Stylocoeniella	armata	LC	1
Anomastrea	irregularis	VU	1
Coscinaraea	columna	LC	1
Horastrea	indica	VU	1
Turbinaria	frondens	LC	1
Turbinaria	irregularis	XX	1
Turbinaria	mesenterina	VU	1
Turbinaria	stellulata	VU	1
Plerogyra	sinuosa	NT	1
Barabattoia	amicorum	LC	1
Caulastrea	connata	VU	1
Cyphastrea	chalcidicum	LC	1
Cyphastrea	hexagonalis		1
Echinopora	cf.tiranensis		1
Echinopora	pacificus		1
Favia	danae	LC	1
Favia	lacuna	NT	1
Favia	matthai	NT	1
Favia	pallida	LC	1
Favia	speciosa	LC	1
Favia	stelligera	NT	1
Favia	veroni	NT	1
Favites	acuticolis	NT	1
Favites	chinensis	NT	1
Favites	complanata	NT	1
Favites	halicora	NT	1
Favites	pentagona	LC	1
Favites	russelli	NT	1
Favites	vasta	NT	1
Goniastrea	australensis	LC	1
Goniastrea	columella	NT	1
Goniastrea	retiformis	LC	1
Goniastrea	thecata	NT	1
Leptastrea	pruinosa	LC	1
Leptastrea	transversa	LC	1
Leptoria	phrygia	NT	1

Montastrea	annuligera	NT	1
Montastrea	curta	LC	1
Montastrea	magnistellata	NT	1
Oulophyllia	crispa	NT	1
Platygyra	crosslandi	NT	1
Platygyra	pini	LC	1
Platygyra	ryukyuensis	NT	1
Platygyra	verweyi	NT	1
Plesiastrea	devantieri	NT	1
Plesiastrea	versipora	LC	1
Cycloseris	costulata	LC	1
Cycloseris	cyclolytes	LC	1
Cycloseris	explanulata	LC	1
Cycloseris	patelliformis	XX	1
Cycloseris	tenuis		1
Fungia	corona	XX	1
Fungia	fungites	NT	1
Fungia	klunzingeri	XX	1
Fungia	scabra	LC	1
Fungia	scruposa	LC	1
Fungia	scutaria	LC	1
Sandalolitha	africana		1
Millepora	dichotoma	LC	1
Millepora	exesa	LC	1
Millepora	platyphylla	LC	1
Millepora	tenaera	XX	1
Hydnophora	exesa	NT	1
Acanthastrea	echinata	LC	1
Acanthastrea	hemprichii	VU	1
Acanthastrea	rotundoflora	NT	1
Blastomussa	merletti	LC	1
Blastomussa	omanensis	EN	1
Lobophyllia	hataii	LC	1
Lobophyllia	robusta	LC	1
Symphyllia	agaricia	LC	1
Symphyllia	erythraea	LC	1
Galaxea	astreata	VU	1
Pectinia	africana	VU	1
Pocillopora	indiania	VU	1
Pocillopora	ligulata	LC	1
Seriatopora	caliendrum	NT	1
Seriatopora	dentritica	VU	1
Seriatopora	hystrix	LC	1
Stylophora	madagascarensis	EN	1
Goniopora	columna	NT	1
Goniopora	djiboutiensis	LC	1

Goniopora	lobata	NT	1
Goniopora	minor	NT	1
Goniopora	planulata	VU	1
Goniopora	somaliensis	LC	1
Goniopora	stokesi	NT	1
Goniopora	tenuidens	LC	1
Goniopora	zp.	XX	1
Porites	aranetai		1
Porites	australensis	LC	1
Porites	harrisoni	NT	1
Porites	lichen	LC	1
Porites	solida	LC	1
Porites	stephensoni		1
Psammocora	albopicta	DD	1
Psammocora	stellata	VU	1
Siderastrea	savignyana	LC	1

5.6 Autres documents et informations

Liste des autres documents et informations

No.	Intitulé de données, documents et informations	Langue	Source	Date d'obtention	Format	Aperçu
1	Loi n°74/AN/14/7ème portant organisation du Ministère de l'Equipement et des Transports	Français avec traduction en japonais	Direction des Affaires Maritimes (DAM) Djibouti	01/07/2018	Imprimé	Loi portant l'organigramme du ministère de l'Equipement et des Transport
2	Décret N°2006-0202/PR/MET	Français avec traduction en japonais	DAM	01/07/2018	Imprimé	Décret confiant à la Direction des Affaires maritimes la gestion et l'exploitation de tout navire d'Etat destiné aux transports des passagers et des marchandises dans la limite des eaux territoriales
3	Arrêté N°2012-0328/PR/MET	Français avec traduction en japonais	DAM	01/07/2018	Imprimé	Arrêté fixant les barèmes tarifaires de transport des passagers et des marchandises en vue de l'exploitation du ferryboat « Med Bourhan Kassim »
4	Entreprise Dawaleh Construction (EDC) BATISSONS POUR L'AVENIR	Français	EDC	12/07/2018	Brochure	Contenu des activités de l'Entreprise EDC
5	ANNUAIRE STATISTIQUE EDITION 2017	Français avec traduction en japonais	DISED	17/07/2018	Livre	Données statistiques de la DISED
6	CONVENTION COLLECTIVE du 26 Décembre 2011	Français avec traduction en japonais	DAM	25/07/2018	Brochure	Convention de travail applicable aux personnels contractuels des établissements administratifs et publics de la République de Djibouti (avec tableau des salaires par catégorie des personnels contractuels de 2011)
7	CHAMBRE DE COMMERCE DE DJIBOUTI SERVICE INFORMATION ET ETUDES ECONOMIQUE	Français	DAM	25/07/2018	Imprimé	Liste des sociétés de construction djiboutiennes enregistrées à la Chambre de Commerce
8	QUOTATION OF : FERRY MED BOURHAN KASIM	Anglais	DAM	25/07/2018	Imprimé	Devis estimatif de la réparation en dock du ferryboat « Med Bourhan Kassim »
9	Planning des Travaux 2018	Français	DAM	25/07/2018	Imprimé	Conditions et mesures nécessaires des pièces confirmées en 2018
10	Planning des Travaux 2017	Français	DAM	25/07/2018	Imprimé	Conditions et mesures nécessaires des pièces confirmées en 2017
11	Planning des Travaux 2016	Français	DAM	25/07/2018	Imprimé	Conditions et mesures nécessaires des pièces confirmées en 2016

Liste des autres documents et informations

No.	Intitulé de données, documents et informations	Langue	Source	Date d'obtention	Format	Aperçu
12	Planning des Travaux 2010, 2012, 2014	Français	DAM	25/07/2018	Imprimé	Conditions et mesures nécessaires des pièces confirmées en 2010, 2012, et 2014
13	Cout d'exploitation du ferry (2017) Cout d'exploitation du ferry (2018)	Français	DAM	25/07/2018	Imprimé	Couts d'exploitation du ferry des 2017 et 2018
14	BC Description de l'Acheteur ; sans titre	Français avec traduction en japonais	DAM	25/07/2018	Imprimé	Dépenses de carburant du ferryboat des 2010 à 2017
15	Statistique du ferryboat de l'année 2017 (Tadjourah –Djibouti)	Français	DAM	25/07/2018	Imprimé	Statistique annuelle du nombre de passagers, du nombre de véhicules, et du nombre de marchandises (tonnes) du ferryboat de l'année 2017 entre Djibouti et Tadjourah
16	Statistique du ferryboat de l'année 2017 (Obock-Djibouti)	Français	DAM	25/07/2018	Imprimé	Statistique annuelle du nombre de passagers, du nombre de véhicules, et du nombre de marchandises (tonnes) du ferryboat de l'année 2017 entre Djibouti et Obock
17	Données d'observation météorologiques	Français avec traduction en japonais	Bureau du Météorologie	23/07/2018	Imprimé	Précipitation, température, vent, humidité et niveau de marée
18	Tarifs des ports de Djibouti 2018	Anglais	Ports de Djibouti	26/07/2018	Imprimé	Tarifs des services du port de Djibouti