APPENDIX I2 – MARINE GEOPHYSICAL REPORT

Survey Objectives and Equipment

Although the survey was designed to meet the requirements of the engineering site investigation the data was sufficiently detailed to be re-used for the archaeological assessment.

The following equipment was mobilised onboard the commercially licensed survey vessel and speedboat/sampan for the echo sounding survey over the shallower water areas:

- C-Nav GcGPS;
- The EGS computerised navigation package v1.2 and PC;
- Knudsen echo sounder;
- The Reson 8125 multibeam system;
- Swath PC;
- Seismic profiler;
- Hydrophone;
- EGS TVG console;
- Waverley recorder;
- DF1000 side scan sonar system with digital tow fish;
- TSS Gyro compass;
- Valeport velocity profiler;
- TSS DMS 3-05 heave motion compensator;
- Seaspy magnetometer;
- TSS HS50 heave motion compensator (SBES); and
- KVH Azimuth 1000

The survey vessel was located with a globally corrected Global Positioning System (GcGPS) unit called C-Nav, for which no shore based differential correction transmitter is required. The system provides corrected positions to an accuracy of +/- 0.3m without the need for a shore-based transmitting system. The EGS computerized navigation system was added to the positioning system to control the steering of the boat along the traverses specified, and to log all horizontal and vertical control data. This system provides the user with a dynamic analogue and digital screen display on which the following are continuously updated:

- Skewed grid set parallel to the desired line direction;
- Boat position;
- Water depth;
- Date and Time; and
- GcGPS diagnostics enabling quality control.

The positioning system was calibrated by checking the co-ordinates displayed by the navigation system at the previously co-ordinated point located at the Tuen Mun typhoon shelter. Carrying out the above quality assurance checking procedure ensured an accuracy of +/-1m or better.

Tidal levels were recorded at Tung Chung and tidal data collected were used to reduce all echo sounding data to Principal Datum, Hong Kong (PD).

The survey was carried out relative to Hong Kong Principal Datum. For reference, Chart Datum is 0.15m below Principal Datum (Reference: Hydrographic Office, Marine Department, Government of the HKSAR, 2005, Charts for Local Vessels).

A C-View operating and interpretation software package was applied and this system was installed on survey vessels. The system provided screen displays on up to three monitors for seismic profiling and side scan systems. Full operating systems coverage was provided, to enable the best survey records to be obtained and all raw data was logged digitally. Side Scan Sonar interpretation was carried out through on screen interpretation and was then directed straight to Autocad without the need for further re-digitizing. Seismic data interpretation was carried out from the paper records.

Field Procedures

The swath (multibeam echo sounding), seismic, side scan sonar and magnetic surveys were carried out from a Class IV survey vessel, M V Wing Hung 2 and a sampan used for the echo sounding survey. The vessels are shown in Plate 1 and 2 below.

Plate 1: Wing Hung 2, Class IV commercially licensed survey vessel

Plate 2: The sampan used for the echo sounding survey

Main traverses for the swath, seismic and side scan sonar surveys were set at 40m intervals with cross lines at 200m intervals. Infill lines for swath data were defined on site to ensure the full coverage. The line spacing for echo sounding measurements by echo sounder were set at 10m intervals with cross lines at 50m intervals.

Swath (Multibeam) Bathymetry (MBES): Seabed level observations were made with a multibeam echo sounder system with the transducers mounted over the starboard side of the survey vessel. The GcGPS antenna was mounted directly above the transducers and as such the swath transducer acted as the datum for the survey vessel. The swath system is a multibeam echo sounder. Instead of transmitting a single vertical pulse, which provides a record of water column thickness beneath the vessel track, the swath measures the same type of data over a 'fan' on both sides of the vessel.

For errors to be avoided, the MBES system requires careful calibrations. A potential source of error relates to the speed of sound in water; the MBES system requires the speed of sound be measured through the water column, and for these data to be entered into a file which is accessed by the MBES acquisition and processing software. On the west side of Hong Kong near the Pearl Estuary the speed of sound can vary significantly near the sea surface; therefore a speed velocity probe was installed at MBES transducer so that measurements are recorded at all times during the survey and the corresponding corrections can be made within the MBES system in real-time. In addition, a patch test is required to calibrate system components, as follows:

- Navigation Delay: A survey line is set exactly over a well-defined feature, such as a rock outcrop, a significant slope or a man-made structure. The line is run twice in the same direction, once at the slowest possible speed and once at the highest speed.
- Pitch Offset: A survey line is set exactly over a well-defined feature. The line is run in opposite directions at the same speed.

- Roll Offset: A survey line is set over an area with a flat and featureless seabed. The line is run in opposite direction at the same speed.
- Yaw (Heading) Offset: Two parallel lines are set to either side of a well-defined feature with the feature positioned in the middle of the two lines. The off-track distance between the feature and the lines are selected according to water depth and the fan width of the MBES system, so that the feature will be detected at the outer part of sounding "fan". The lines are run in the same direction at the same speed; once passing the feature to Port and once to Starboard.

  By applying appropriate algorithms to match the apparent differences in the positions of the selected feature and the seabed topography measured in the individual calibration line, these calibration factors can be determined and are entered into the acquisition system to correct the seabed level measurements.

Side Scan Sonar Survey: Prior to the commencement of the survey, the side scan sonar system was tested to ensure the system was working correctly. The side scan sonar tow fish was towed from the stern of the survey vessel, at a depth of around 5m beneath the sea surface, depending on the water depth. The equipment used in the side scan sonar survey is shown in Plate 3 below.

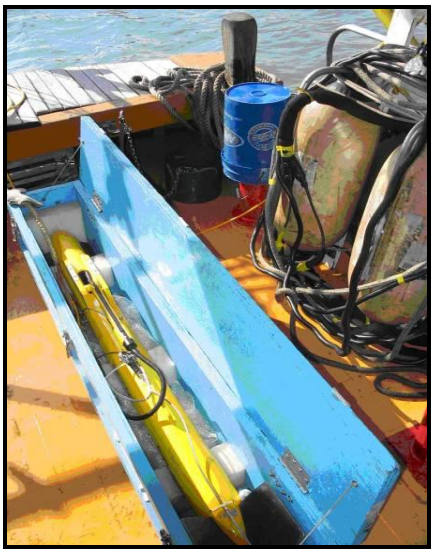


Plate 3: The DF-1000 used in the side scan sonar survey

The recording parameters for the side scan survey were as follows:

- Vessel speed: 1.5 – 1.8 m/sec
- Fix interval: 10 seconds
- Source frequency: 100 kHz and 500 kHz
- Pulse length: 25 us
- Gain setting: Manually controlled

- Slant range: 75m

All data were logged on the C-view SDMP where four channels (100kHz port and starboard; 500kHz port and starboard) were simultaneously recorded with navigation, fix, vessel heading, cable out angle and length, fish heading, water depth. Detailed log sheets were recorded with unique survey line numbers, start fix and end fix for each survey line, roll number, range, frequency and cable out value and angle. The corresponding C-View data file name was also recorded in these log sheets.

Seismic Reflection Survey: Prior to the commencement of survey the EGS boomer was tested to ensure the system was working correctly. The EGS boomer was towed from the stern of the survey vessel, at a distance of 20m such that noise from the survey vessel was kept to a minimum. The recording parameters for the seismic reflection survey were as follows:

- Vessel Speed: 1.5 – 1.8 m/sec
- Fix Interval: 10 seconds
- Out put power: +/- 500 volts
- Sweep: 80ms (paper)
- Delay: 0ms
- Gain setting: Manually controlled

The Seismic acquisition and printing system and boomer are shown in Plates 4 and 5 below.

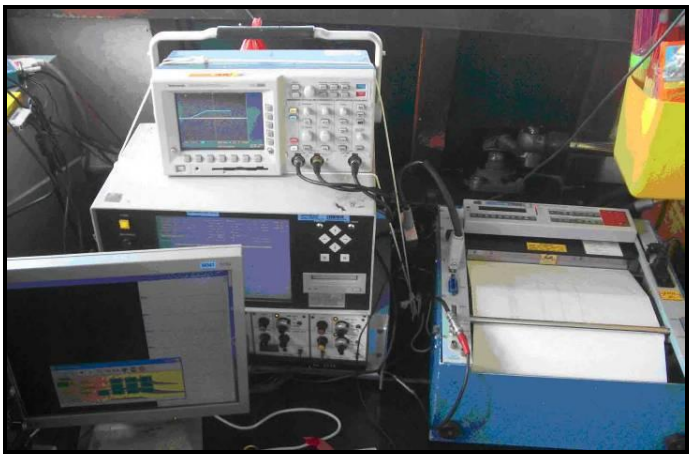


Plate 4: Seismic acquisition and printing system

Plate 5: The EGS boomer was towed astern of the vessel for sub-bottom seismic profiling

Site Safety

Safety was generally in accordance with the 'Marine Geophysical Operations Safety Manual' (International Association of Geophysical Contractors, Ninth Edition, 2004).

Quality Assurance

Quality was assured by adopting the measures set out in the EGS ISO9001 Quality Handbook.

Reduction of Observations and Interpretation

Sounding and Swath (Multibeam) Data: For sounding readings, the influence of wave action was corrected in real time by the heave motion compensator. The smoothed sounding data was then reduced to levels below Principal Datum (PD) using the measured tide levels. Tidal correction and filters were applied before the swath data sets were edited manually. Gridded sounding selection was used for engineering purposes. These gridded data were then plotted at a spacing of 6mm at the charting scale, to provide a sounding plan for the whole area surveyed This gridded plot was contoured using the 2m spacing dataset and coloured using processing and charting software to provide the sounding plans.

Side Scan Sonar Data: Processing and interpretation of side scan sonar data was carried out using the C-View interpretation software. All features were individually marked or grouped into regions using on- screen digitising. All offsets and laybacks were applied to the C-View system. The subsequently generated interpretation files were then imported to the Auto CAD environment on a line by line basis where the interpretation was reconciled and a detailed check was performed. The interpretation of the side scan sonar records in this area had sought to quantify the following elements and features on the seabed:

- Indicators for the presence of intact or broken up shipwrecks;
- Isolated objects which could have archaeological potential;

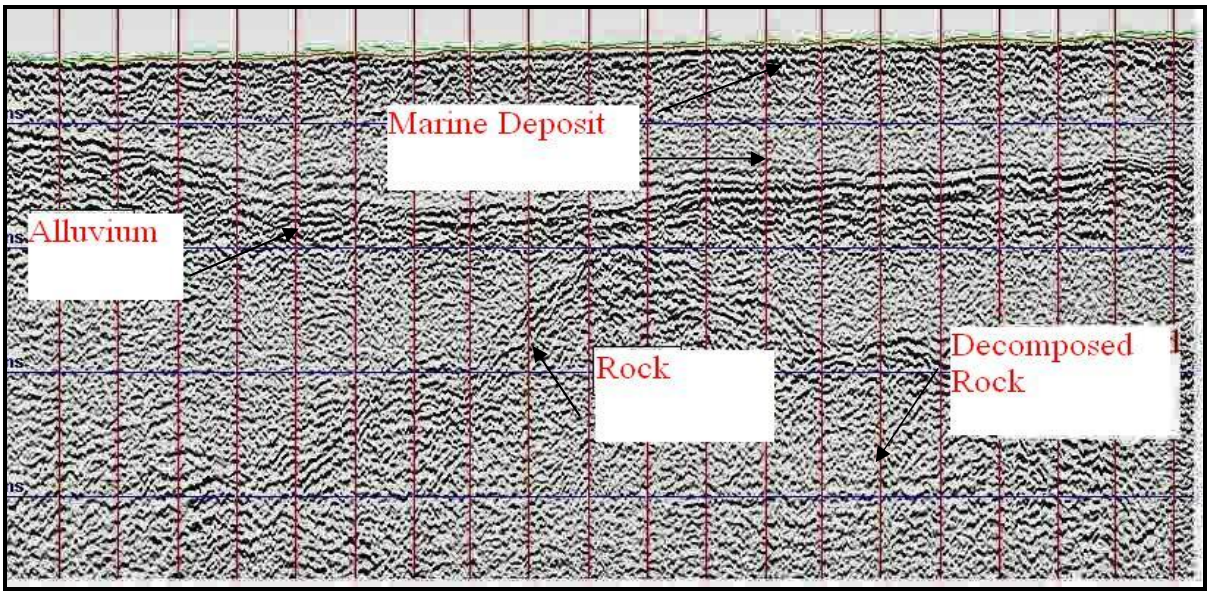
- Areas of disturbed seabed attributed to anchoring or trawling;
- Large area of debris, dumped materials or concrete slabs;
- Seafloor with pipeline/cable related scars;
- Higher reflectivity areas attributed to gravel or sandy materials and rocks;
- Lower reflectivity areas attributed to relatively clean or undisturbed marine sediments; and
- Any other significant sonar contacts.

Seismic Data: Although there are large masked zones over the north boundary and south portion of the survey area, the quality of the seismic records was good and acceptable. The interpretation of the seismic records sought to quantify the elements of the offshore geological succession detailed in Table AI.1 below and shown in Figure AI.1

Table AI.1 Elements of Offshore Geological Succession for Seismic Interpretation

Formation	Event
Marine Deposits of Holocene age (Hang Hau Formation)	The base of these deposits occurred during the last ice age
Alluvium (Chek Lap Kok Formation; mainly coarse sediments with gravels)	Up to four ice ages occurred during the Pleistocene

Figure AI.1 The Main Components of the Seabed Stratigraphy



Marine deposits are generally soft or very soft clays or silts, and as such are readily identifiable on seismic records as a clear conformable horizon sometimes with an unconformity represented by a desiccated layer or by local re-working of deposits by ancient river systems.

Near The Brothers, only an intermittent veneer of marine and alluvium sediments was observed over the rock. The sediment layer was very thin and irregular. A rock outcrop was recorded to the

south of The Brothers. Interpretation was carried out whereby the seismic horizons were selected for interpretation in accordance with the list above, and drawn on copies of the seismic records during preliminary interpretation. All traverse crossing points were then calculated, and marked on the seismic records. The records were then physically correlated at all of these points and the horizons digitized, plotted and contoured.

Seismic data interpretation has revealed two major masked areas within the survey boundary:

- a large masked area on the south; and
- a small masked area on the north coast

Record quality was affected by masking. This is probably caused by the presence of organic materials on the seabed (e.g. discharge from dockyards and the airport) and anaerobic bacteria feeding on decaying organic material at depth. The gas bubbles so generated absorb the seismic energy, thereby preventing reflections from deeper horizons.

Survey Results

The results have been recorded in summary charts extracted from the Contractors Survey Report as follows and presented at the back of this Appendix.

- Charts 1.1-1.5 Echo Sounding and Swath Bathymetry Track Plots
- Charts 2.1-2.5 Seismic and Side Scan Sonar Track Plots
- Charts 3.1-3.3 Magnetic Survey Track Plots
- Charts 4.1-4.5 Colour Contoured Swath Bathymetry Plans
- Charts 5.1-5.5 Contoured Levels at the Base of Marine Deposits
- Charts 6.1-6.5 Contoured Levels on Top of Rock in Any State of Decomposition
- Charts 7.1-7.5 Contoured Levels on Top of Presumed Moderately Decomposed Rock
- Charts 8.1-8.5 Isopachs of Marine Deposits
- Charts 9.1-9.5 Isopachs of Alluvium
- Charts 10.1-10.5 Isopachs of Rock in Any State of Decomposition
- Charts 11.1-11.5 Sea Bed Features and Cable Alignments

In addition, the seabed features from the 2004 survey are also provided as Charts 12.1 to 12.3.

Data Coverage (Charts 1.1-1.5, 2.1-2.5 and 3.1-3.3). The charts show the exact area of seabed covered by each piece of equipment and the tracks are defined as described in Table AI.2 below:

Table AI.2 Track Definitions

Position/Track Type	Definition
Echo sounding and swath bathymetry track	This is the track of the echo sounder and swath system, used to define sea bed levels.
Seismic and side scan track	Seismic and side scan surveys were conducted simultaneously, hence tracks of seismic data are presented here for presentation purposes.
Magnetic survey track	Layback corrected magnetometer positions are shown on the plots.

Colour Contoured Bathymetry Plan (Charts 4.1- 4.5): Seabed level readings are presented in the drawings at 15m grids (6mm in chart scale). Bathymetric data collected by swath system are shown in colour contoured format, while seabed levels from the echo sounder are shown in non-colour lines. The most obvious features on the seabed bathymetry plans are (1) the fairway channel at the north side of The Brothers, (2) the shallow rocky area close to The Brothers, (3) the northeast-wards drainage channel from Lantau, and (4) the flat and shallow area at the south portion. The seabed varies between –2m PD and –22m PD within the survey area.

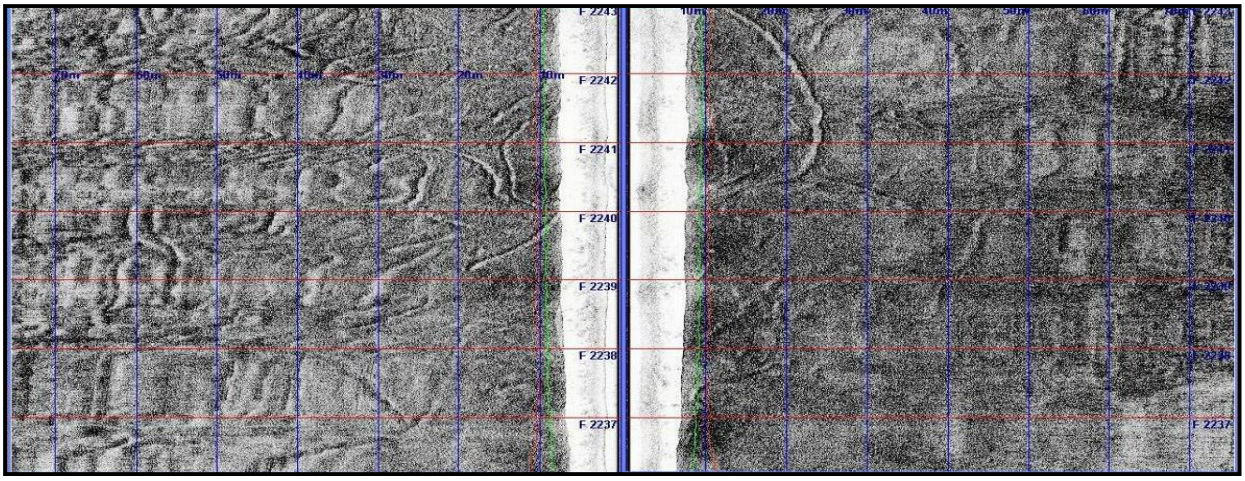
Marine Deposits (Charts 5.1-5.5 and 8.1-8.5): The drawings illustrate the general topographic levels at the base of the Marine Deposits. The thickness of Marine Deposits is generally thin over the north coast area, the dredged Urmston Road, and around the rock outcrop south of The Brothers. Marine deposits reach to a maximum thickness of 22m at west and southwest of The Brothers. Fast currents of over 0.65m/s will have removed Marine Deposits.

Alluvium (Charts 6.1-6.5 and 9.1-9.5): Charts 6.1 to 6.5 show the level on the top of rock in any state of decomposition, equivalent to the base of Alluvium where present. The surface is varying and reaches to about -60m below PD to the southwest of The Brothers. Isopachs of Alluvium are presented on Charts 9.1 to 9.5. The survey results show that alluvium over the survey area is mostly more than 6m thick and becomes thicker (up to 40m) in the vicinity of the fault zone. The only exceptions are the north coast area and the rock outcrop offshore south of The Brothers.

Rock in Any State of Decomposition and Grade III Rocks (Charts 7.1-7.5 and 10.1-10.5): The topographic variation of the base of rock in any state of decomposition corresponds to the top of moderately decomposed rock. This horizon is presented in Charts 7.1 to 7.5. As expected, rockhead levels are shallow close to the shores and The Brothers, and deep at the Fairway Channel and close to the fault zone. In places, grade III rock was too deep to be recorded.

Sea bed Features (Charts 11.1-11.5): As shown on the charts and in Figure AI.2, sandy clays and silts are common features on the seabed, with numerous trawl marks, anchor scars, and scattered modern debris.

Figure AI.2 Seabed Heavily Disturbed by Anchoring of Vessels



Cable Alignments (Charts 11.1 to 11.5): Four submarine cables run through the study area. These are important for the MAI as they represent areas of previous disturbance as shown in Figures AI.3 and AI.4 below

Figure AI.3 Seabed Disturbance caused by Submarine Cables

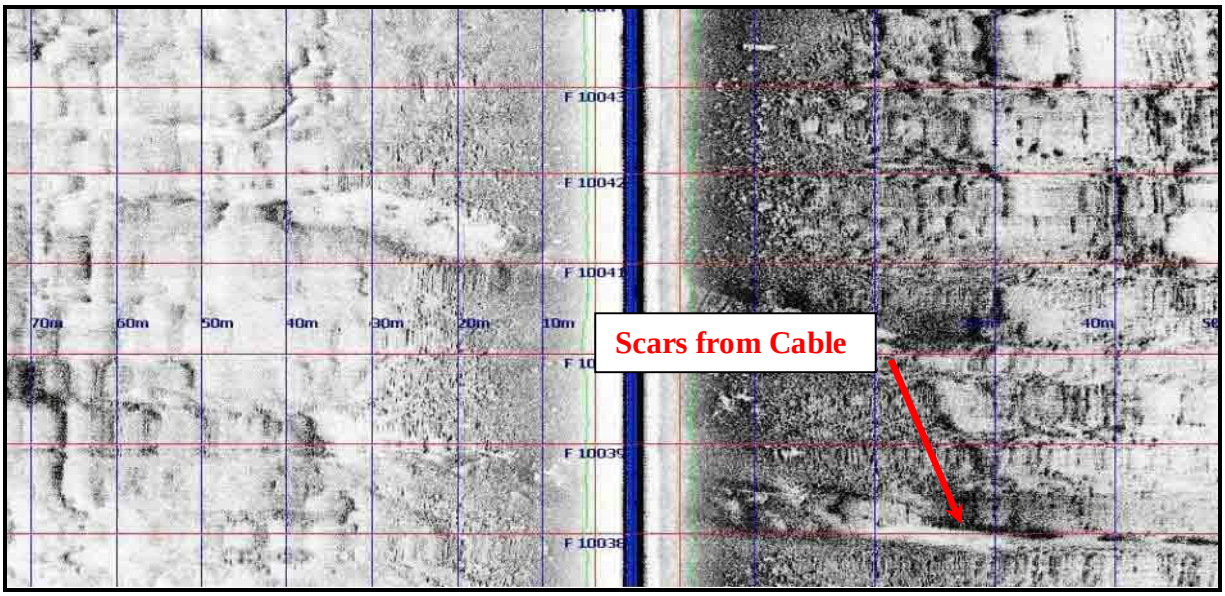
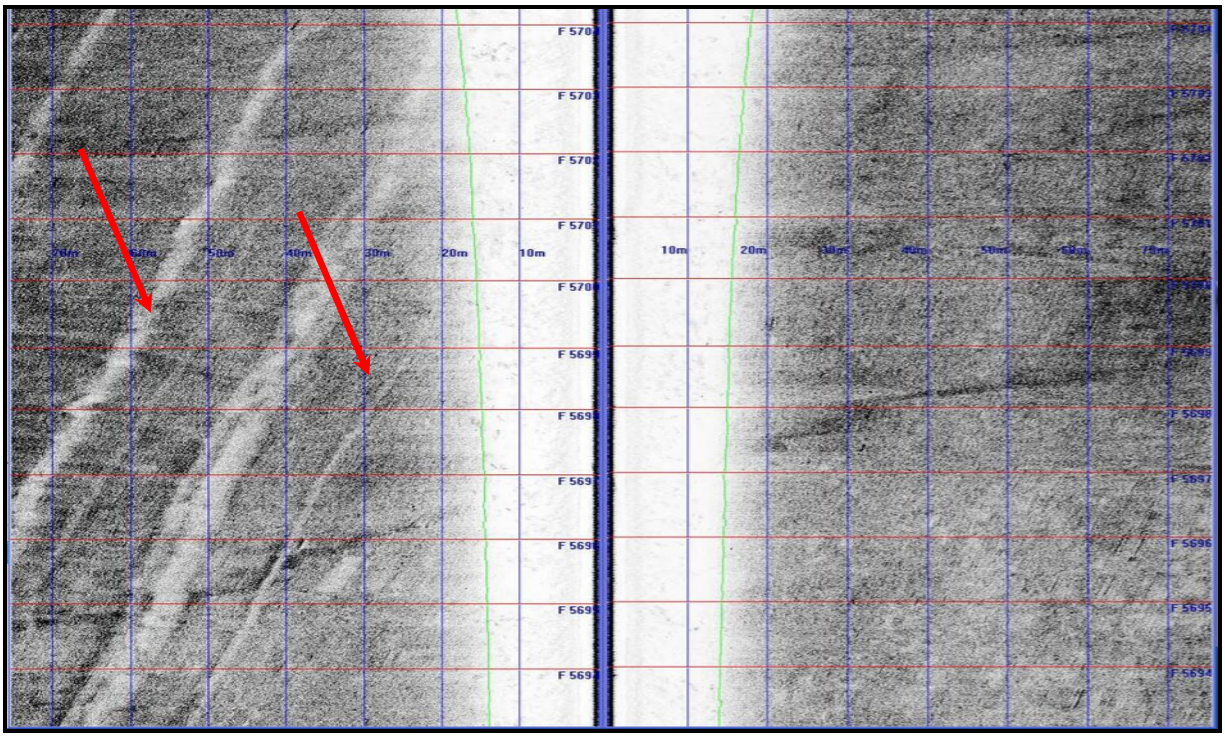


Figure AI.4 Scars from the Existing Buried Utility Cables



<u>Sonar Contacts with Archaeological Potential</u>

In total 12 sonar contacts with archaeological potential were identified from the survey data. On the Seabed Features Charts 11.1-11.5, 8 of the sonar contacts have been classified as debris, 2 as depressions, 1 as a man made object and 1 as a rectangular object. Within a busy shipping area with evidence of recent seabed disturbance, the survey classification of *debris* by the surveyors is understandable and logical. However, from an archaeological perspective these targets could be contemporary debris from modern vessels or artefacts of historical significance. An accurate description and evaluation can only be made once a diver inspection is completed.

The location of each contact is presented in Table AI.3 below. Contacts SC001 to SC005 are relatively close to the northern reclamation works and could potentially be affected. However, SC001 and SC002 are more than 200m away and therefore, outside the buffer area where impacts could be predicted to occur. Therefore, only SC003, 4 and 5 have been identified as potentially being subject to impacts and requiring further survey. Contacts SC006, SC010 and SC011 are closer to the proposed Boundary Crossing Facilities but too far away (approximately 770m to 1200m away) from the TM-CLKL to be affected. Contacts SC007, SC008, SC009 and SC0012 are close to the tunnel alignment but as the tunnel is proposed to be constructed using Tunnel Boring Machine (TBM) at deep depth, there will be no disturbance to the seabed and, therefore, these contacts will also not be affected by the project works.

Table AI.3 Sonar Contacts

Contact Number	Easting Northing	Dimensions (m)	Distance from Alignment
SC001	812966.1E 825342.7N	0.4x0.9x0.4	294.1
SC002	812963.0E 825122.1N	3.5x3.3x1.2	228.6
SC003	812736.4E 824639.9N	4.3x0.9x0.9	107.1
SC004	812731.2E 824632.3N	2.4x0.5x0.9	92.8
SC005	812728.0E 824626.5N	0.8x0.5x0.9	101.3
SC006	812594.0E 819664.9N	1.7x1.3xnmh*	1215.4
SC007	813541.2E 821884.9N	2.1x1.5xnmh	197.9
SC008	813566.2E 821663.3N	1.2x1.7xnmh	243.4
SC009	813528.8E 821626.4N	6.9x2.8xnmh	198.5
SC010	813205.2E 820466.6N	1.4x0.8x0.4	777.4
SC011	812981.7E 820426.6N	1.4x2.0x0.3	938.9
SC012	813419.7E 822676.3N	15.4x11.2x1.1	106.9

Note: nmh = no measurable height

The Figures AI.5 to AI.13 below present the data showing each of the sonar contacts.

Figure AI.5: Side Scan sonar data showing Sonar Contact SC001.

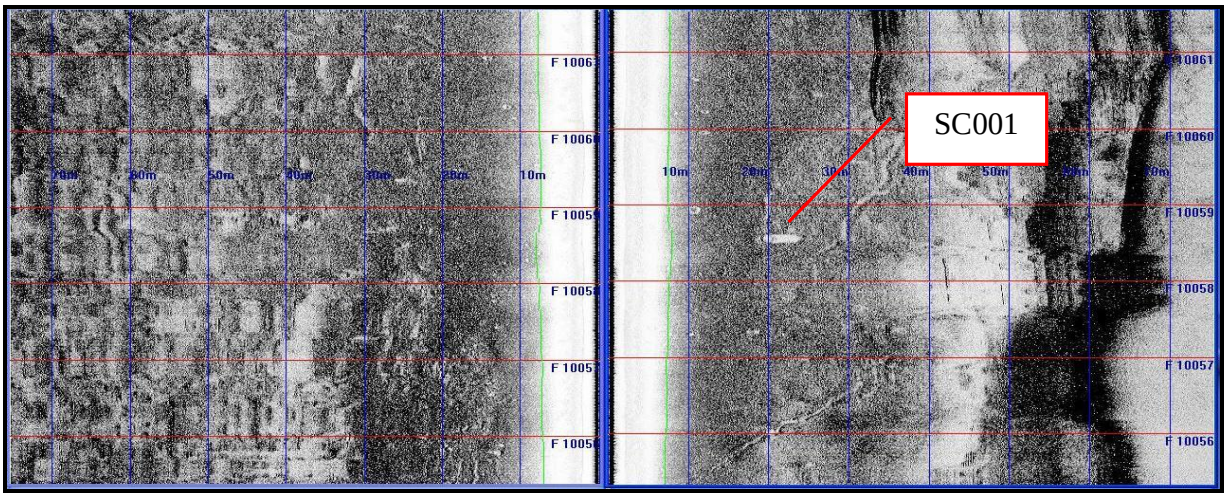


Figure AI.6: Side Scan sonar data showing Sonar Contact SC002.

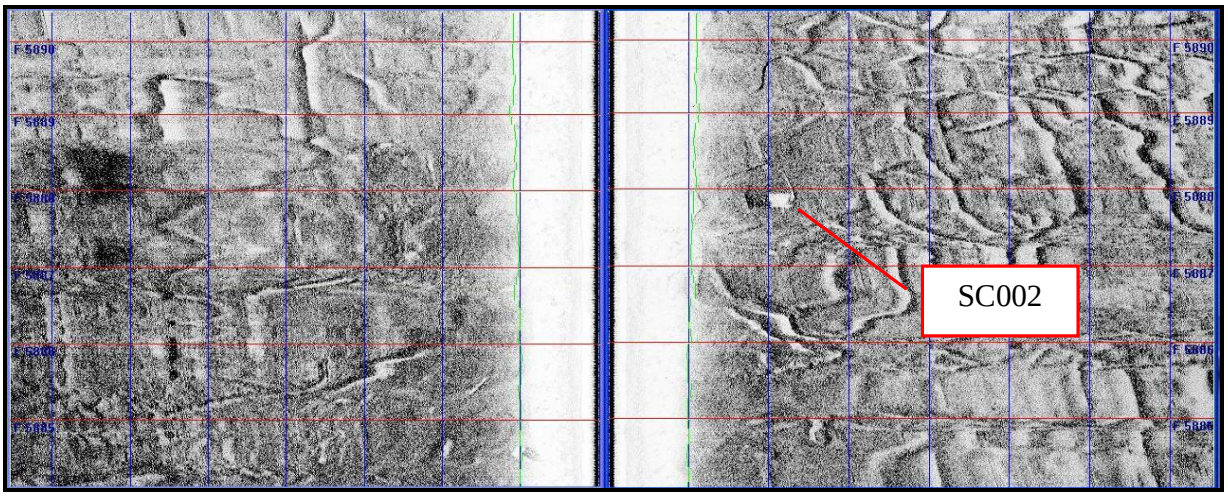


Figure AI.7: Side Scan sonar data showing Sonar Contact SC003, SC004 & SC005.

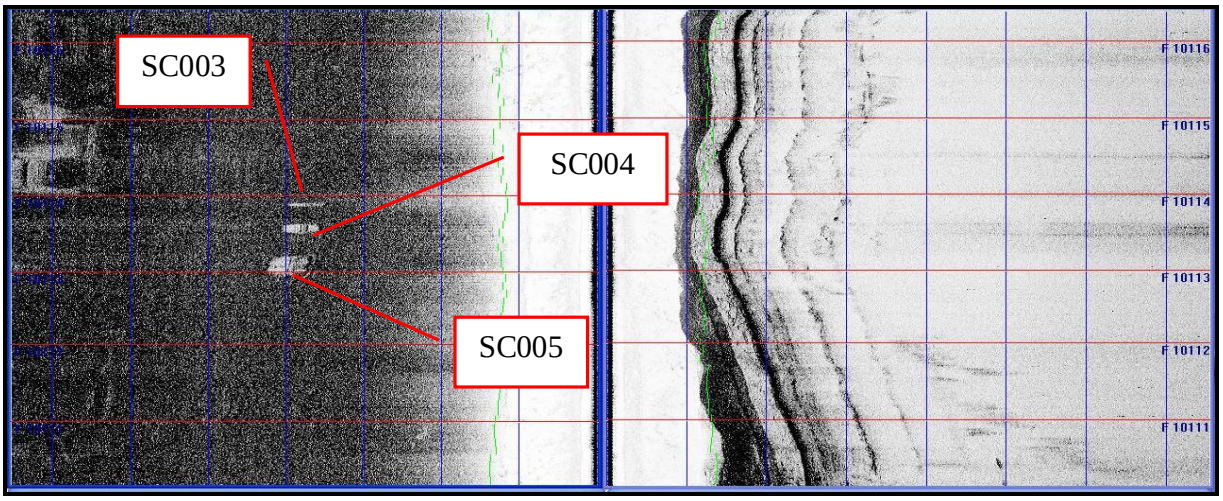


Figure AI.8: Side Scan sonar data showing Sonar Contact SC006.

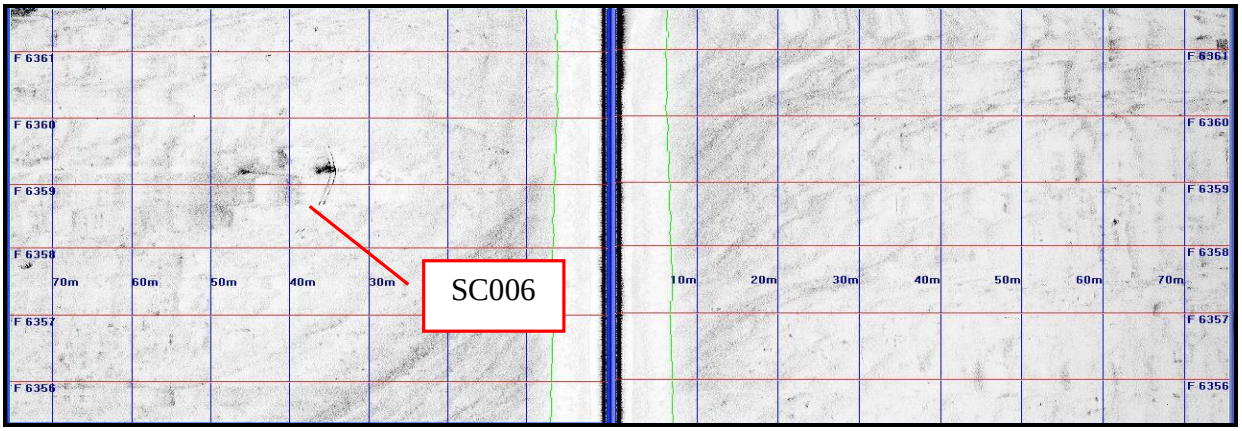


Figure AI.9: Side Scan sonar data showing Sonar Contact SC007.

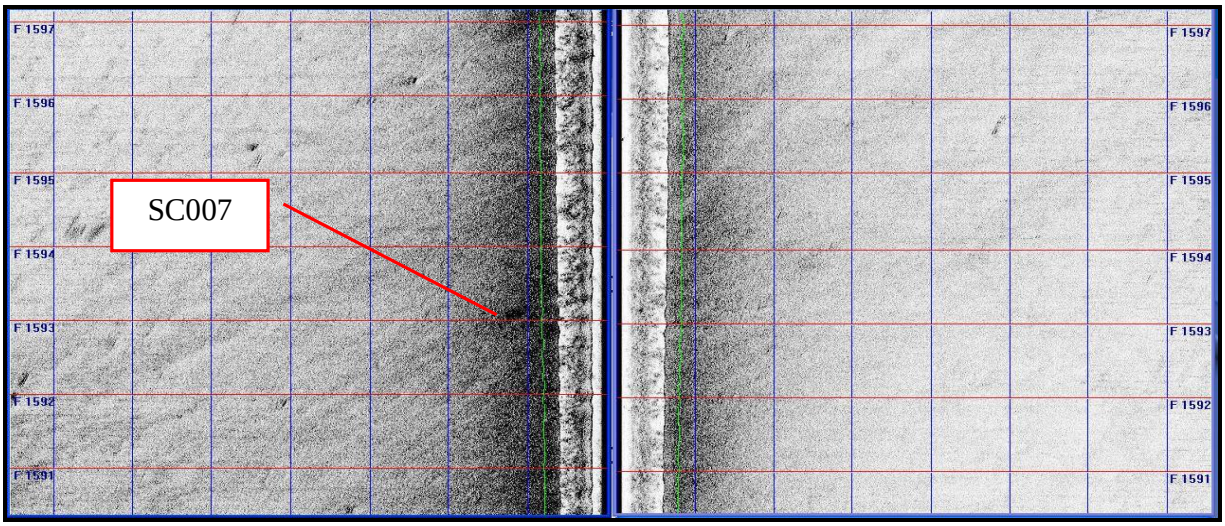


Figure AI.10: Side Scan sonar data showing Sonar Contacts SC008 & SC009

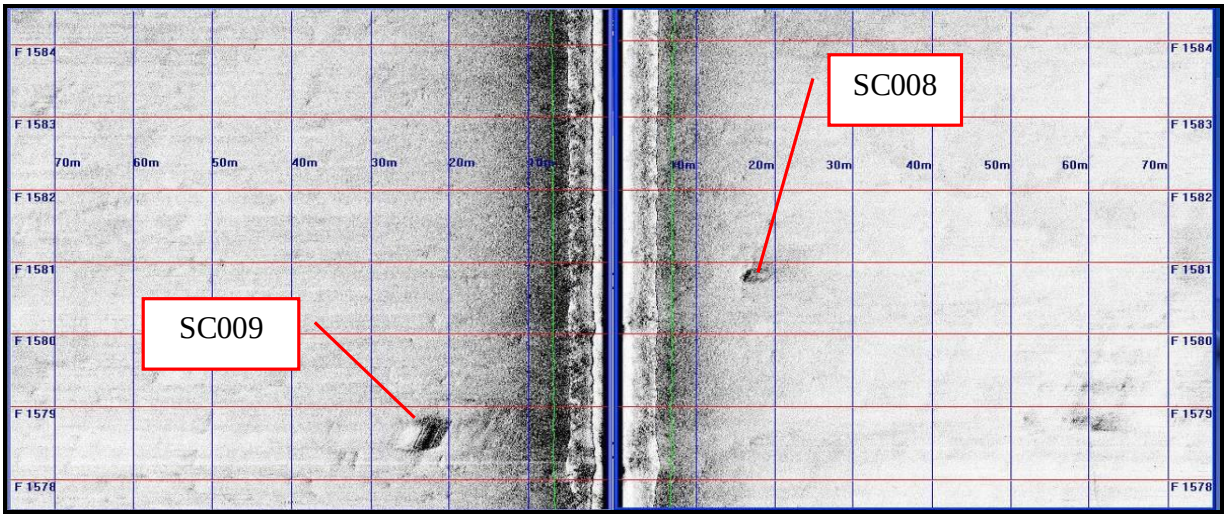


Figure AI.11: Side Scan sonar data showing Sonar Contact SC0010.

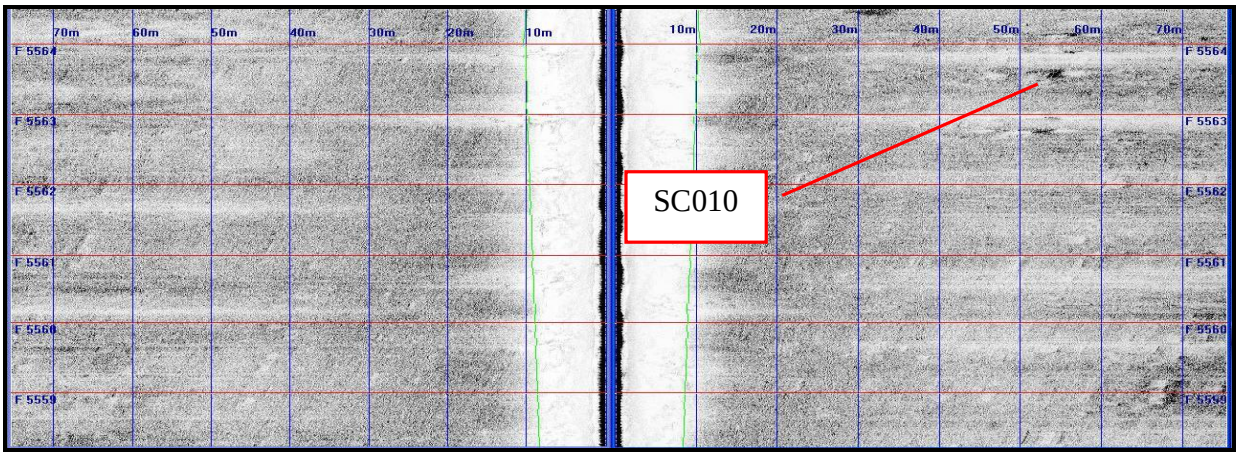


Figure AI.12: Side Scan sonar data showing Sonar Contact SC0011.

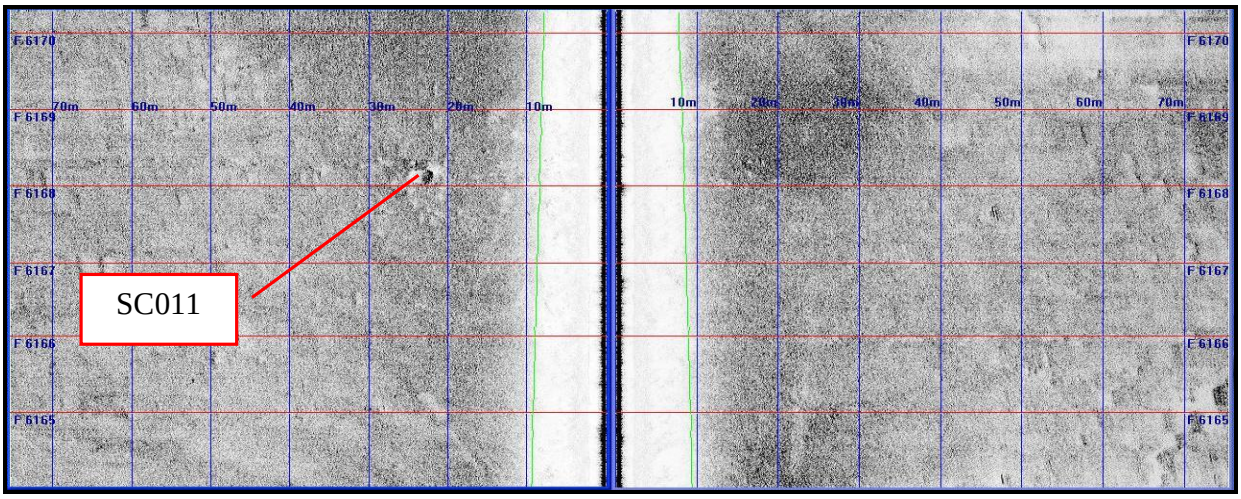
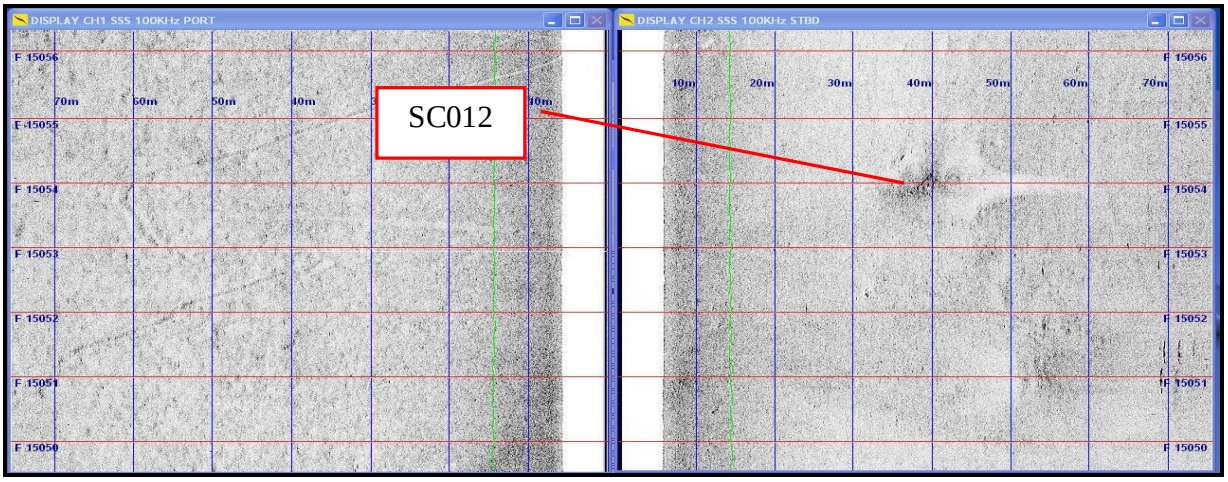


Figure AI.13: Side Scan sonar data showing Sonar Contact SC0012.



The side scan sonar contacts have been plotted in relation to the alignment of TM-CLK and it showed that there are five contacts which may be impacted by the development. These will undergo diver inspection to establish their archaeological value.