Case study on the application of geophysics to a port expansion project

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SUMMARY

The first stage of a major port expansion project called for an approach to rapidly and cost effectively screen a broad area to assist with determining the most appropriate location for additional berths, turning pockets and associated channels. A combination of marine geophysical techniques were used to achieve this goal without the need for drilling which, although essential for detailed assessment and planning of the final location, would have resulted in significant delays and extra costs at this stage.
Seismic refraction and continuous seismic profiling (CSP) were used together to characterise the upper 20 m below the seafloor. Sidescan sonar, swath bathymetry and magnetometry were used to check for possible seafloor hazards.

The results showed a region with a deeper sequence of low velocity material and a high seismic velocity ridge. Since the high velocity materials represent a significant impediment to dredging the surveys highlighted the areas more and less suitable for use in the expansion.

In these surveys no unknown seafloor hazards were identified.

The results at the site demonstrate the applicability of marine geophysical surveys to efficiently provide an indication of subsurface conditions over a broad area. This ability makes them a valuable tool for port development investigations.

Key words: port, seismic, refraction, dredge, marine, sidescan, bathymetry.

INTRODUCTION

Prior to a capacity upgrade at a major Australian industrial port, a geophysical study was undertaken to assess the seafloor and sub-seafloor conditions around the existing and planned facilities. The geophysical survey served the purpose of providing a first pass evaluation of the possible expansion areas without the need for drilling. Although drilling will be essential for detailed assessment and planning of the final location, it would have resulted in significant delays and extra costs at this stage.

Several broad areas were investigated in the field program. In total, over 27 km of CSP and 23 km of refraction data were acquired. One site was near a headland and Figure 1 illustrates the survey plan for that site.

Seismic refraction and continuous seismic profiling (CSP) were used to characterise the top 20 m of the subsurface. A combined approach, using sidescan sonar, swath bathymetry and magnetometry was deployed to image the seafloor and map any potential hazards.

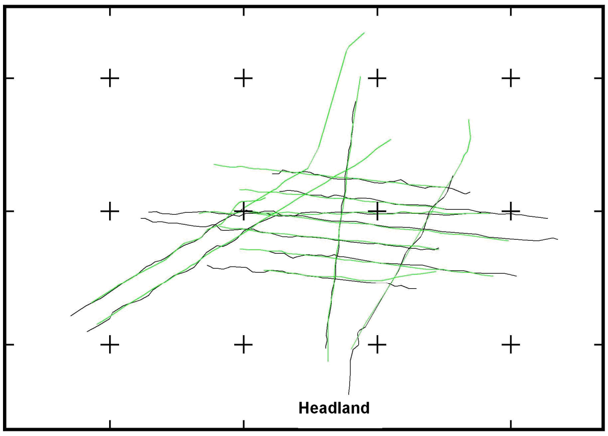

Figure 1. Line plan for a portion of the survey area, where, green lines indicate refraction and black lines CSP data, swath bathymetry and magnetometry were collected over the entire area.

METHOD

Underwater seismic refraction was conducted using a 10 – 20 cubic inch airgun and a 94m 48 channel hydrophone streamer mounted on a proprietary seafloor tracking tow sled. Seafloor shot separation equated to approximately 5 m. The refraction first arrival times were picked using a highly customisable autopicker. This autopicker considerably reduced processing time compared to more manual approaches and aided the required fast turn-around. The subsurface velocity structure was determined by using both a delay–time solution and 2D and 3D nonlinear traveltime topographic inversions.

The CSP data were acquired using an Applied Acoustic Engineering (AEE) 300 J towed catamaran boomer source coupled with an 8 element, single channel receiver using a geometrics geode seismograph recorder. Data were depth converted using velocities obtained from both the refraction data and from previous work in similar environments.

A vessel mounted GeoAcoustics Geoswath Plus coupled with a CodaOctopus F180 motion sensor was used to simultaneously acquire swath bathymetry and sidescan.

Magnetics data was collected using a Geometrics G-882 marine magnetometer, towed approximately 2 m from the seafloor. The magnetics data was processed with a 1st order background removal and horizontal gradient filter. The depth of sources associated with discrete dipolar sources were estimated using Peter's half slope method (Peters, 1949). In order to focus on the near surface, sources estimated to be deeper than 30 m were discarded.

DISCUSSION

The refraction data collected imaged seismic velocity to depths of up to approximately20 m. Figure 2 illustrates the P – wave velocities determined The plot shows the excellent line to line correlation achieved.

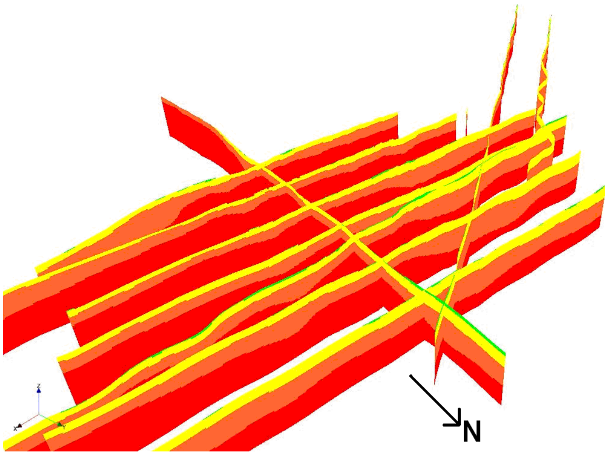

Figure 3. Seismic velocity (from refraction data) coloured according to values in table 1, view looking southwest.

The data was coloured dependant upon dredge-ability as summarised in Table 1. Two different dredging methods are typically used depending on the strength of material present. A Trailing Suction Hopper Dredger (TSHD) is mostly used for removing loose unconsolidated sediments and, when more competent material is met a Cutting Suction Dredger (CSD) is required.

P – Wave Velocity (m/s)	Dredging characteristics	Colour (on plots)
1530 – 1900	Easily dredged with a TSHD	Green
1900 – 2500	Easily dredged with a CSD	Yellow
2500 – 4000	Dredge with difficulty with a CSD	Orange
> 4000	Blasting required	Red

Table 1. Indication of the characteristics of dredging material. From Murphy (1974) and Tennyson (2011).

The sharp boundary to materials at velocities greater than approximately 4000 m/s is inferred to represent the top of bedrock and exists at depths ≥16 m below the local chart datum.

The image shows a high velocity ridge extending away from the headland at the south of the survey area. This ridge would present a significant impediment to dredging. There is a thicker sequence of lower velocity material on the western side which should be more favourable for dredging.

Three persistent reflectors were observed in the CSP data (see Figure 2). Based on their geometry and the velocity indicated by the refraction survey, these were inferred to most likely represent: unconsolidated sediments, well consolidated material and the top of bed rock The upper 2 reflectors were missing in areas that had been dredged for the current port as shown in Figure 2.

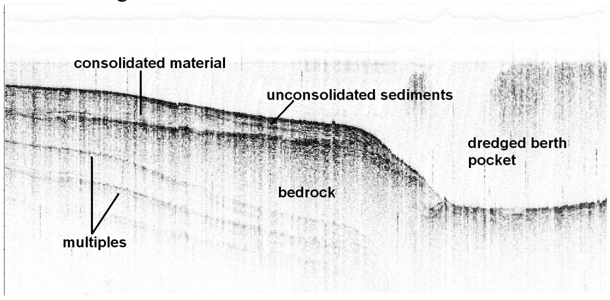

Figure 2. Partial reflection profile showing the contrast between the dredged berthing pocket and the surrounding area. Several reflectors are present. Based on their geometry and the velocity indicated by the refraction survey, these were inferred to most likely represent unconsolidated sediments, well consolidated material and the top of bed rock. On the right hand side multiples are evident.

Combining the reflection and refraction data into an integrated product greatly aids the characterisation and interpretation of the sub-seafloor units. The reflectors apparent in the CSP data correlate well with the refraction images and provide greater resolution of boundaries than it is possible to achieve from the refraction alone. In particular the lowermost of the 3 reflectors tracks along the sharp velocity gradient around 4000 m/s in the refraction data and makes it possible to more precisely define this boundary.

An example of some of the swath bathymetry data is shown in Figure 4. The image clearly shows different dredge levels and dredge scarring. Neither the bathymetry, sidescan or magnetic data at the site indicated any unknown seafloor hazards to development.

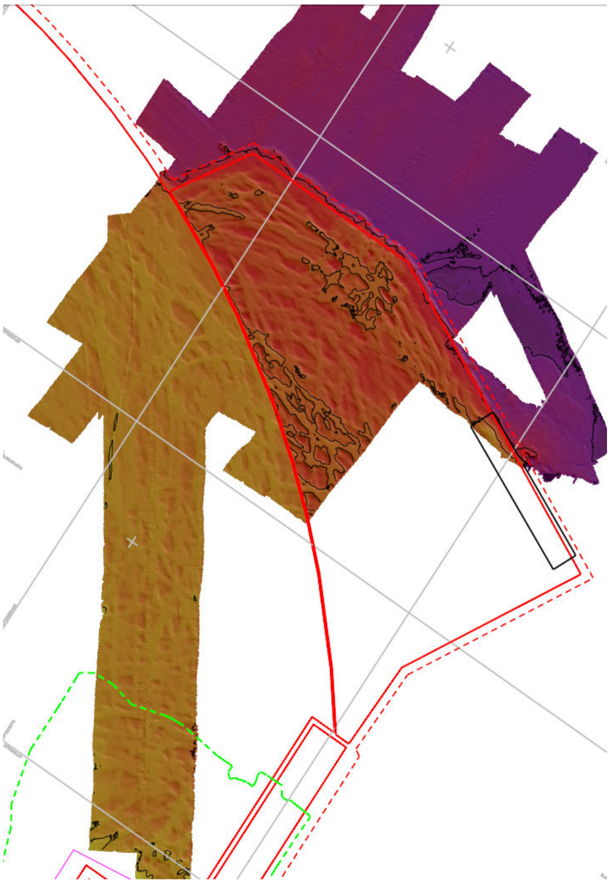

Figure 4. Shaded relief bathymetric image

CONCLUSIONS

The seismic refraction and reflection results show a high velocity ridge extending away from a headland that would present a significant impediment to dredging. Thus the surveys highlighted that the area along the ridge would not be highly suitable for further development of the port. There is however a thicker sequence of lower velocity material on the western side which should be more favourable for dredging and thus for use in the port expansion.

The bathymetry, sidescan sonar and magnetics did not indicate any hazards that might affect the further development

Overall, the geophysical data provided an excellent overview of the characteristics of the site, allowing for the concentration of efforts into the best location for port development

The results at this site demonstrate the applicability of marine geophysical surveys to port infrastructure projects. Specifically, the ability of these surveys to efficiently provide an indication of subsurface conditions over a broad area makes them a highly valuable tool for marine geotechnical work.

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