An onshore and offshore seismic investigation across a creek

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SUMMARY

A seismic survey across a river with refraction and multichannel analysis of surface waves (MASW) methods was carried out to investigate the ground condition for design of a bridge across Iron Creek near Hobart, Tasmania.

The survey had onshore and offshore components. Therefore it was necessary to use a hydrophone cable as well as land geophones. A sledge hammer was used as an onshore seismic source and a small airgun across the creek.

The result is presented as P-wave velocity section from the refraction analysis and S-wave velocity section from MASW. Two boreholes onshore indicated the depth of basalt with very high strength at 8 metres on west bank and 3 metres on east bank. These depths correspond to P-wave velocity about 1400 m/s and S-wave velocity about 600 m/s. The sections showed the depth of this strong basalt increases in the creek up to about 10 metres, and it is the deepest in the eastern side of the creek. With this information, necessity of expensive offshore drilling was eliminated.

Key words: geotechnical application, seismic refraction, MASW ground competence, bridge construction.

INTRODUCTION

Iron Creek is a tidal creek which runs north east of Hobart, Tasmania (Figure 1). A bridge of Arthur Highway, a main thoroughfare between Hobart and Port Arthur, crosses this creek. The project is to duplicate this bridge to increase the capacity of traffic. A seismic survey with refraction and multichannel analysis of surface waves (MASW; Park et al, 1999) methods was carried out to investigate the ground condition for design of a bridge.

For designing and construction of roads and bridges, knowledge of the competence of the ground is essential. Due to the accessibility, drilling is limited to the banks of the creek. A geophysical survey was considered to obtain the geological information between the bore holes, particularly across the creek. The seismic refraction method was used for P-wave velocity structure, and S-wave velocity structure was estimated by the MASW method. These seismic methods provided information of mechanical characteristics of the ground.

The field survey involved onshore and offshore operations. The two different kinds of data presented no problem in compatibility during data processing. The result presented comparable profiles of P- and S-wave velocity structures.

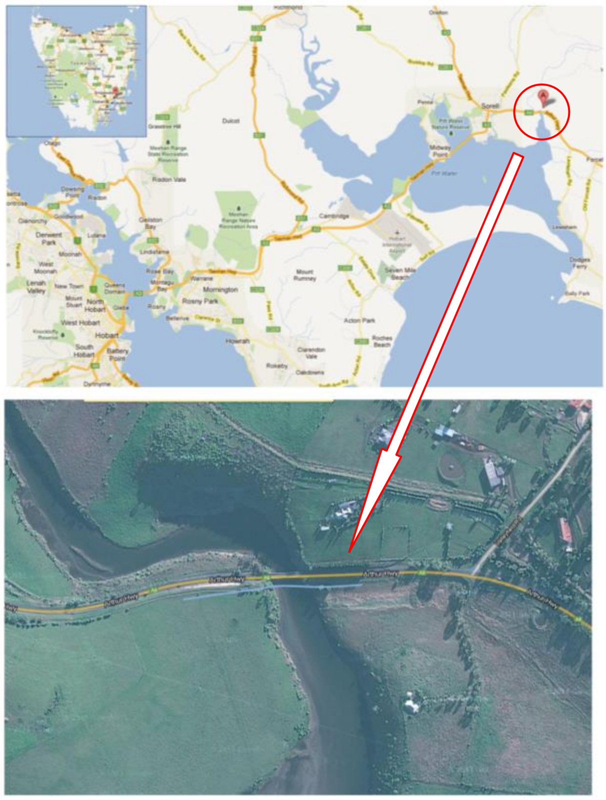

Figure 1: Area and site maps from Google Maps. Approximate location of the survey line is in blue.

DATA ACQUISITION

The survey consisted of onshore and offshore components: 135 metres on the west bank, 40 metres across the creek and 69 metres on the east bank. The conventional spiked geophones were used on land, and a water bottom cable was used across the creek. The refraction and MASW data were collected at the same time with common parameters except for record length and sampling frequency. The data acquisition parameters are summarised in Table 1.

Table 1. Data Acquisition Parameters

Seismic source:	12lb sledgehammer / Airgun
Recording system:	Geometrix StrataView; 24-bit 24-channel recorder
Recording channels:	24 per record
Sampling rate:	0.0625 ms (16000Hz) for refraction 0.5ms (2000Hz) for MASW
Record length:	128ms for refraction 2 seconds for MASW
Geophone / Hydrophone type:	Geospace GS11 7.55 Hz vertical geophones on land / PVDF Piezo Polymer Hydrophones 3-3000Hz
Geophone interval:	3m on land / 2m water bottom cable

The onshore part of the survey site is a paddock with light vegetation (Figure 2). For this part of the survey, we used spiked geophones rather than a landstreamer because of the steep slope and thick shrubs near the bank of the creek. A small dinghy was brought for the offshore part of the survey (Figure 3) to lay the water bottom cable and to operate the airgun source at shot points on the water.

Figure 2. (Left) Typical field condition onshore. (Right) Recording system.

Figure 3. (Left) Airgun and water bottom cable. (Right) Offshore deployment.

The road near the site, Arthur Highway, is a main thoroughfare between Hobart and Port Arthur, and the traffic was always busy. This caused some noise to several records of the seismic data. Figure 4 shows an example of seismic data from an onshore part of the survey.

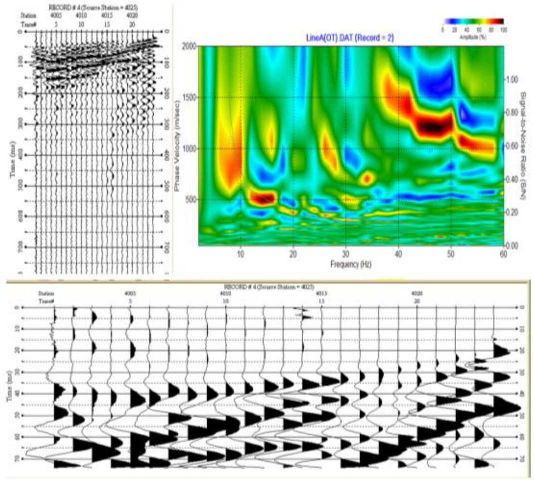

Figure 4. (Top) Records in the time-distance and the frequency-phase velocity domains (overtone analysis): Data from onshore right bank; 60Hz high-cut filter applied.
(Bottom) Enlarged record for refraction analysis.

ONSHORE AND OFFSHORE DATA

The data quality of onshore and offshore records is compared. (Figure 5 for refraction and Figure 6 for MASW.)

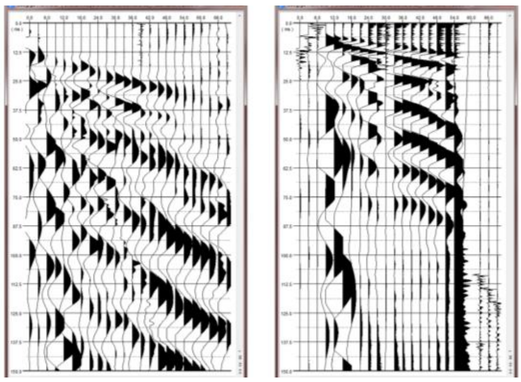

Figure 5. Seismic records for refraction survey. Full time scale is 150ms. (Left) Onshore. (Right) Offshore; Note channels at both ends are out of water and not recording signals.

Although there is some noise in the early part of the offshore data, the first breaks of the seismic signals are picked with a reasonable confidence.

The contamination by traffic noise on the onshore data was worse in the longer MASW data, as the signal needed to be amplified more for the distant late part of the data. However, the spectra of this noise are of high-frequency and the surface wave signals are recognised when it is filtered out. In practice, the overtone analysis was performed on the unfiltered data. The noise falls outside of the analysis range.

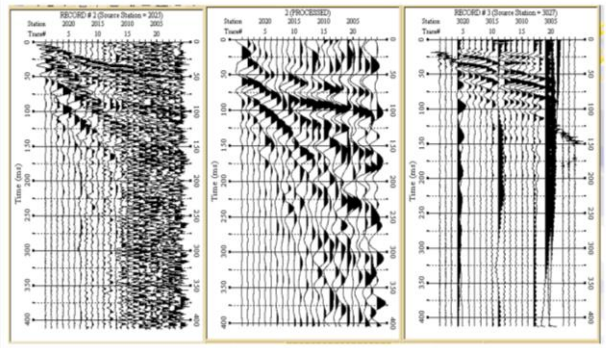

Figure 6. Seismic record for MASW analysis. Top 400ms is displayed. (Left) Original onshore record. (Middle) The same record with a 60Hz high-cut filter applied. (Right) Onshore record.

ANALYSIS AND INTERPRETATION

The refraction analysis and tomographic inversion were carried out using the SeisImager® software by Geometrics. SurfSeis® by Kansas Geological Survey was used for the MASW analysis. Figure 7 (next page) shows 2D velocity sections along the survey line. The P-wave velocity section was produced through tomographic inversion process of the first break picks while the S-wave velocity section was made by interpolating the MASW inversion between analysis points every 12 metres. Although there are several different features, these profiles are largely in agreement.

Two boreholes were drilled along the survey line: one each side of the creek. The borehole logs indicated four geological units, among which the depth of basalt is of most interest. Figure 8 shows correlation between the borehole data and S-wave velocity structure derived from MASW inversion at the nearest analysis point. The S-wave velocity changes reflect the geological boundaries reasonably well, but the absolute values of S-wave velocity do not exactly match the soil/rock type. The description "fresh basalt" corresponds to about 400m/s at BH1 and 600m/s at BH2.

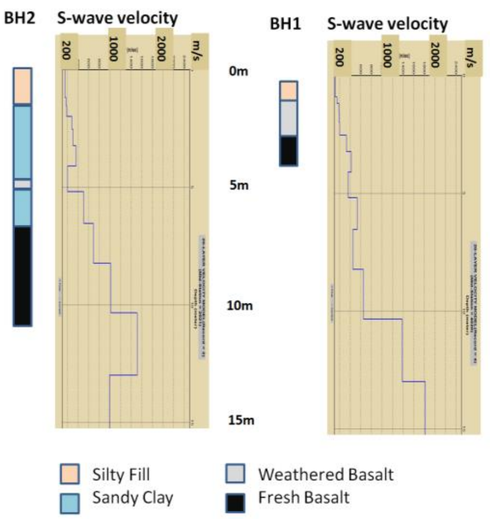

Figure 8: Comparison between lithology at boreholes and S-wave velocity by MASW inversion.

The borehole data are posted on the velocity sections (Figure 9), in which the velocities are blocked to show divisions. The P-wave velocity corresponding to the "fresh basalt" is about 1400 m/s at BH1 and 1600 m/s at BH2; the trend of discrepancy is consistent with S-wave velocity. This may be due to the range within a qualitative description of rock type of borehole data, and seismic velocities may be better representing the strength of the ground.

The velocity structures in the offshore part of the survey line are also conformable. It suggests that the MASW survey can also be applied to the offshore survey.

CONCLUSIONS

A seismic survey to investigate the ground competence for bridge foundation was carried out across Iron Creek, Tasmania. Compatibility between the onshore and offshore data is demonstrated by comparing the data. The refraction and MASW survey resulted in P- and S-wave velocity structures largely comparable, and represent the structure of the strength of the ground.

The validity of MASW survey for offshore application is demonstrated, while the refraction survey is commonly used.

The data provided valuable information across Iron Creek where borehole cannot be easily drilled. The data were used in designing the second bridge over Iron Creek.

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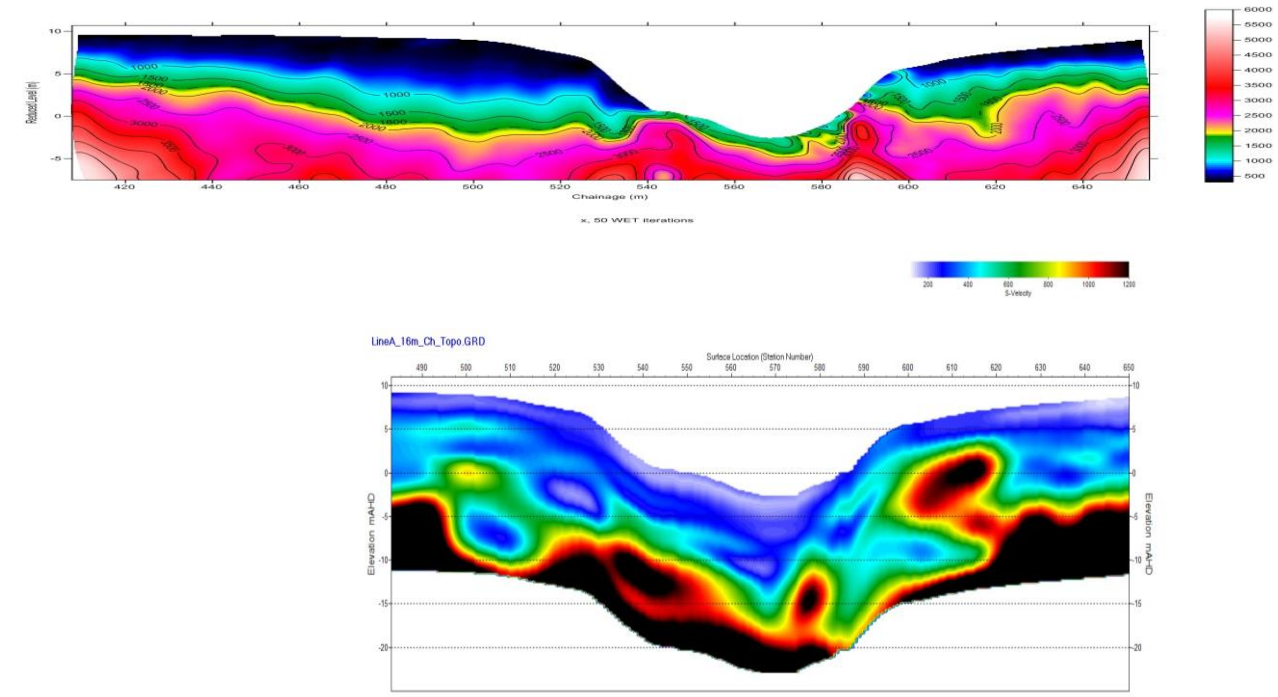

Figure 7: Seismic velocity structure across Iron Creek.
(Top) P-wave velocity structure by refraction; (Bottom) S-wave velocity structure by MASW.

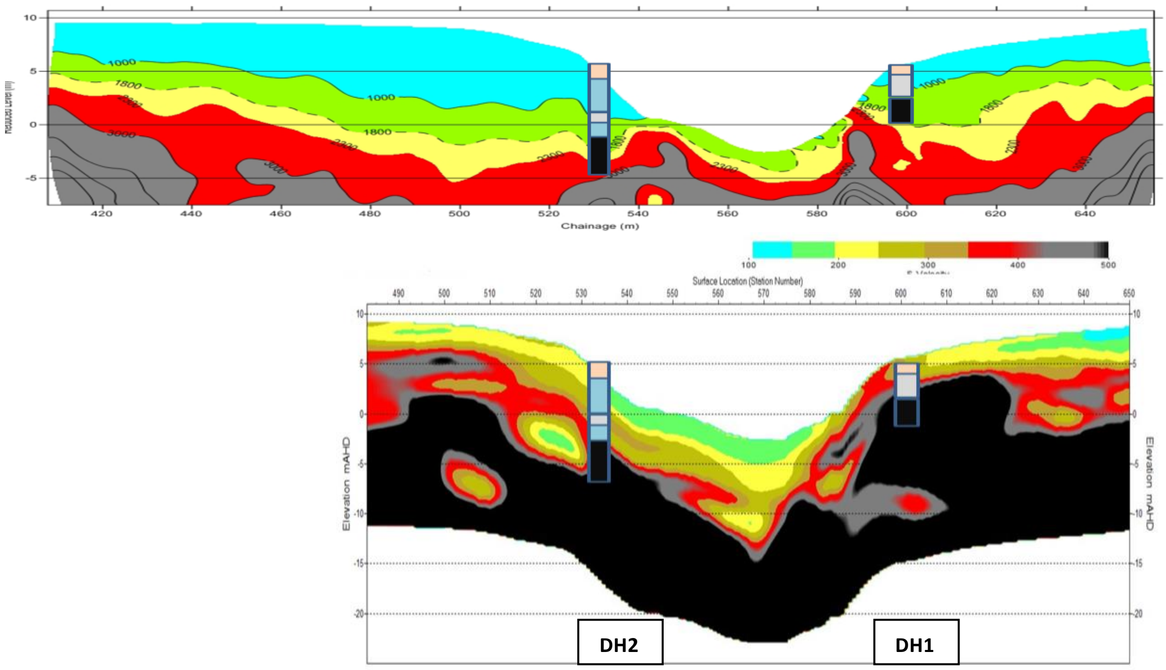

Figure 9. Velocity sections with blocked colour scheme. Borehole lithology the same as Figure 8 is superimposed.
(Top) P-wave velocity structure by refraction; (Bottom) S-wave velocity structure by MASW.