

**Gerhard Krummei**

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**From:** "Nicholas Smith" <nick@passivex.com>  
**To:** "Gerhard Krummei" <gkrummei@ozemail.com.au>  
**Sent:** Friday, 10 March 2017 3:13 PM  
**Subject:** Re: Scoping Tests- Passive Seismic  
Hi Gerhard,

Thanks for the drilling information.

I will complete my interpretation and report through next week, most likely by Wednesday.

Regarding "H/V" - this is what we are extracting from the passive seismic data. The term H/V means the horizontal to vertical ratio of motion, at the measurement location, as induced by seismic energy.

The important concepts to understand are as follows:

- Seismic motion is three-dimensional (i.e. for a given measurement point a seismic wave induces motion in the x, y, and z directions)
- Ambient seismic energy is "equipped-partitioned", meaning that all types of seismic waves exist with equal energies and propagate in all directions
- For an equipartitioned wave field, a layered geology with a soft upper layer overlying a hard bedrock induced a horizontal "resonance" in the seismic motion around a certain frequency (hence a peak in the horizontal to vertical ratio of motion)
- The frequency of horizontal resonance induced by the layered geology is proportional to the average seismic velocity and thickness of the overlying "soft" geology
  - If we know the depth of the bedrock at a given location we can calculate the average velocity,
  - or vice-versa, if we know the average velocity of the overlying material we can calculate the depth to the bedrock interface
- The amplitude and width of the measured H/V peak carries information on the characteristics of the soft rock / hard rock interface

Regarding the "frequency to depth conversion" If we can measure the H/V peak frequency at a location with known depth to bedrock we can define a relationship that converts frequency to depth and which can be applied to other measurements throughout a project area. Alternately, if we can measure the average seismic velocity of the "soft" layer overlying the bedrock we can use this information to directly calculate the bedrock depth from the measured H/V peak frequency (without using drilling for a priori depth calibration). There are several methods to estimate the seismic velocity from passive seismic data, the best of which required at least two seismometers to be deployed at the same time and employ "array processing" methods. I was able to use the data from our scoping survey from two seismometers deployed at the same time and estimate the seismic velocity profile of the geology, and the result is well constrained. All in all, there are several methods to employ to convert the H/V results to bedrock depth estimates. When the different methods give the same answer a high confidence in the result is achieved. This is the objective for next week.

Cheers,  
Nick

11/12/2017

Report for  
**PASSIVE SEISMIC SCOPING SURVEY**

At the  
**MAYDENA SANDS PROJECT**

On behalf of  
**MAYDENA SANDS PTY. LTD.  
GERHARD KRUMMEI**

Submitted by

**Nick Smith**  
Mar 16, 2017

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## 1. INTRODUCTION

On Tuesday March 7<sup>th</sup> 2017, passive seismic data were collected at seven locations on the Maydena Sands Pty. Ltd. project in Maydena, Tasmania. These data were collected at locations with ground truth established through previous drilling (Figure 1). The objectives of the survey was to trial the Horizontal to Vertical spectral ratio (H/V) passive seismic method and to establish *a*) characteristics of the ambient seismic wavefield, and *b*) the nature and acoustic properties of the bedrock contact beneath a silica sand resource, as manifested in the passive seismic data.

This report addresses the scoping survey objectives and provides a summary of the passive seismic data, acoustic properties of the geology of interest, and an interpretation of the passive seismic data in terms of cover thickness.

## 2. METHOD OVERVIEW

Passive seismic methods are a cost-effective and logistically simple geophysical method for characterising and mapping the principal sub-horizontal geological boundaries from the near-surface to 100's of metres depth. The methods use the background vertical- and horizontal-component seismic energy, recorded using high-fidelity portable broadband seismometers, and modern data processing methods.

The single-instrument H/V technique measures the frequency of ground resonance where a layered sequence (cover) overlies a hard bedrock, and an acoustic impedance contrast of several factors exists between the cover and bedrock. Where a suitable impedance contrast exists, horizontal-component seismic motion is amplified relative to vertical-component motion and a horizontal resonance is produced at a resonance frequency which is proportional to the cover thickness. The frequency of ground resonance is calibrated to thickness when the average shear-wave velocity or the thickness of the cover at calibration points (e.g. drill holes) is known. When multiple measurements are made, the H/V technique is used to map the variation in cover thickness and basement topography.

An accuracy of <10% for the cover thickness is routinely achieved for the H/V technique. Where particularly high-quality data are recorded, further qualitative inference of the nature of the cover and the cover-bedrock interface can be made.

## 3. PASSIVE SEISMIC DATA CHARACTERISTICS

Time-series of recorded data are characterised by a consistent and uniform low-amplitude signal with occasional superimposed "spikes" of high-amplitude transient signal (Figure 1). The low-amplitude signal is representative of the background ambient energy (utilised for H/V processing) and its uniformity through time indicates a high-quality wavefield. The high-amplitude transient signals are due to impulsive sources such as footsteps and tree-falls. The exact source of the transient signal cannot be determined in this case, but the low rate of occurrence and rapid decay preserves the ambient signal.

For such high-quality passive seismic data, acquisition times for a production survey can safely be reduced to the recommended minimum of 20 minutes. In practice, for a production survey using 8 instruments and a 2-person field crew, acquisition times of 1 hour are maintained due to the field crews rate of instrument deployment and uplift, therefore providing additional data redundancy.

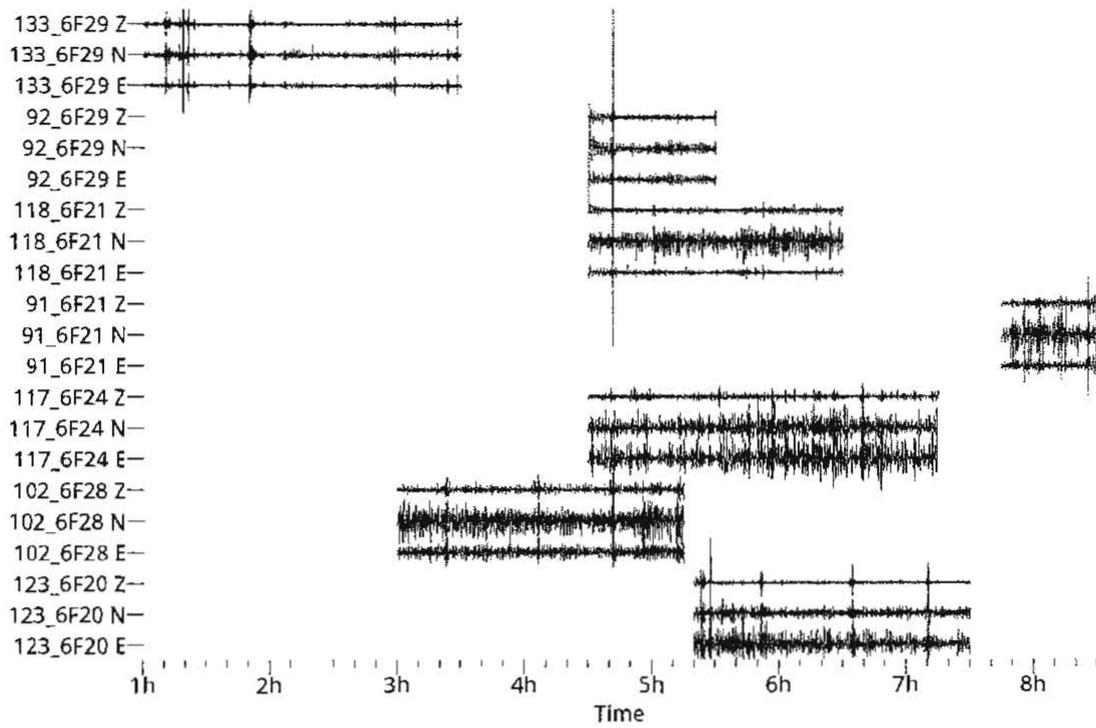


Figure 1: Seismic time-series for acquired data.

For data pre-processing, the recorded time-series were high-pass filtered above 0.1 Hz to remove the signal from the settling of the concrete seismometer plinth, and cut and tapered at the start and finish of the recording to remove the signal of deployment/uplift activities.

For computation of the H/V curves, pre-processed time-series were cut into 20 second windows and the ratios of horizontal to vertical energy estimated. The ratios for each window were then averaged to estimate the H/V curve along with the ensemble variances. Review of the H/V ratio for each window and the average H/V ratio shows a high stability through time.

Results for H/V directionality analysis, whereby directional horizontal-component energy at 5 degree increments (as opposed from the total horizontal-component energy) is used to compute the H/V curve, show a dominant resonance peak irrespective of horizontal component orientation and the emergence of low amplitude subsidiary resonance peaks for several measurement locations. The lack of strong H/V directionality phenomena indicates a relatively flat cover/bedrock contact with low aspect-ratio, and validates the isotropic and equi-partitioned wavefield assumptions fundamental to the H/V method. The emergence of subsidiary resonance peaks may qualitatively indicate an increase in geological complexity, but is inconclusive. For locations where subsidiary peaks are present, a dominant peak remains and it interpreted to represent the acoustic impedance contrast of the main cover/bedrock interface.

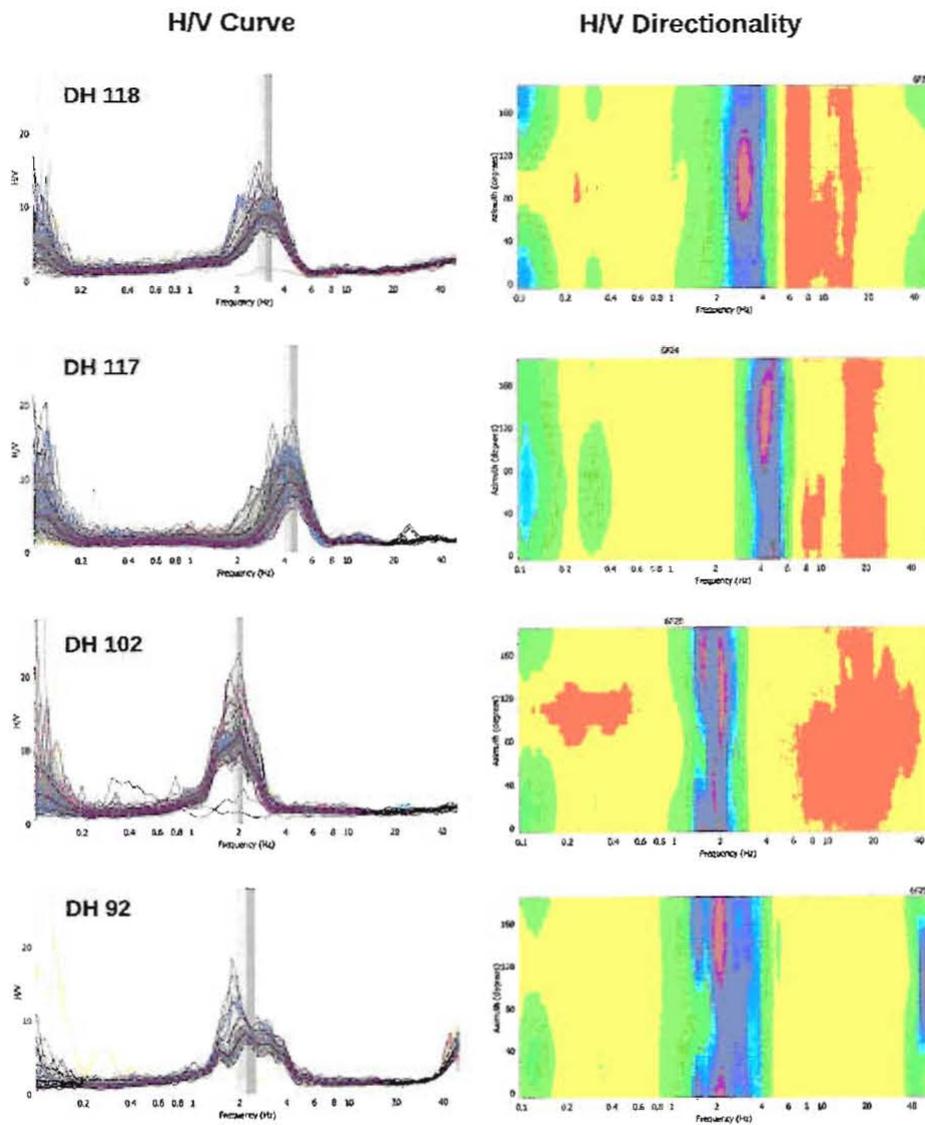


Figure 2: H/V curves and directionality analysis for representative measurement locations. The left column shows the H/V versus frequency curve, with coloured lines showing the H/V curve for successive 20 scc duration time-series windows, and black solid line showing the average H/V. The right column shows the average H/V amplitude computed with directional horizontal-component energy at 5 deg intervals.



Thicknesses estimated from drill holes 118, 117, 102, 123 and 92 were used for the thickness calibration. Thicknesses estimated from drill holes 133 and 91 were inconsistent with the data trend, and as such were not used for the frequency to thickness calibration procedure. For drill holes 133 and 91, the cover thickness predicted from the H/V resonance frequencies were under and over estimated respectively by >20%. The main reason why this has happened is likely due to a high uncertainty in the cover thickness for the drill holes used in the calibration procedure.

Geological sections showing surveyed drill holes and H/V cover thickness interpretations are included in *Appendix A* of this report.

DH #	Easting (AGD66)	Northing (AGD66)	INST #	Start (local)	End (local)	HV Frq (Hz)	HV Dpth (m)	DH Dpth (m)
133	465666	5263933	29	12:00	14:30	2.57	22.1	33
118	465654	5263892	21	12:30	14:30	3.03	17.0	20
117	465655	5263853	24	12:45	15:45	4.40	9.4	7
102	465990	5263834	28	14:00	16:15	1.98	33.6	35
123	465932	5263846	20	13:45	16:15	2.23	27.8	30
92	465926	5263790	29	15:30	16:30	2.22	28.0	23
91	465983	5263757	21	15:45	16:30	2.19	28.6	15

A = 100.17	B = -1.6	RMS = 6.8m
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**Table 1:** Frequency to thickness calibration and survey metadata. Note – Cover thicknesses estimated for drill holes 133 and 91 (red font) are inconsistent with the general data trend, and as such, are rejected from the frequency to thickness calibration procedure.

## 5. SUMMARY

A passive seismic scoping study was completed in March 2017 at the Maydena Sands Pty. Ltd. project at Maydena, Tasmania to assess the ability of the single station H/V passive seismic method to detect the bedrock beneath a silica sand deposit at the project. One day of field work was carried out, during which data were recorded at seven locations with drill hole ground truth.

Review of the collected data indicated a high-quality passive seismic wavefield and a strong acoustic impedance contrast in the earth. Processed H/V waveforms were diagnostic of a relatively simple geology with a dominant acoustic impedance contrast, and were stable over time and wavefield direction.

Interpretation of processed H/V waveform indicated cover thicknesses consistent with the depths estimated from the drill hole ground truth for five of the seven measurement locations. The two inconsistent locations are interpreted to represent a bad thickness estimate from the drill hole data.

The single station H/V passive seismic methods is well suited to the wavefield and geological conditions at the Maydena project site. Passive seismic surveys for the purpose of mapping the bedrock topography are expected to be successful if undertaken.

## APPENDIX A

### GEOLOGICAL SECTIONS WITH THICKNESS- CALIBRATED H/V MEASUREMENTS

Section 465660mE – Drill holes: 117, 118 & 133

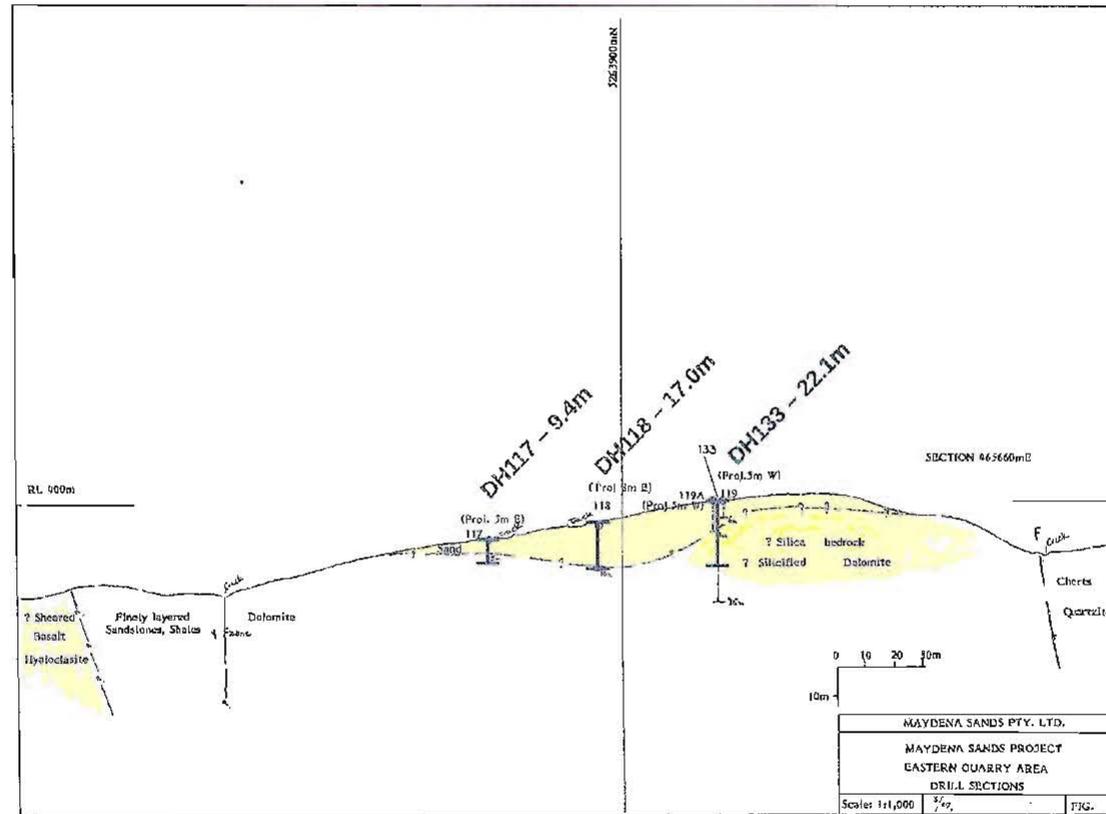


Figure A1: Geological section 465660mE. Blue lines show cover thicknesses from calibrated HV measurements.

Section 465890mE – Drill holes: 123 & 92

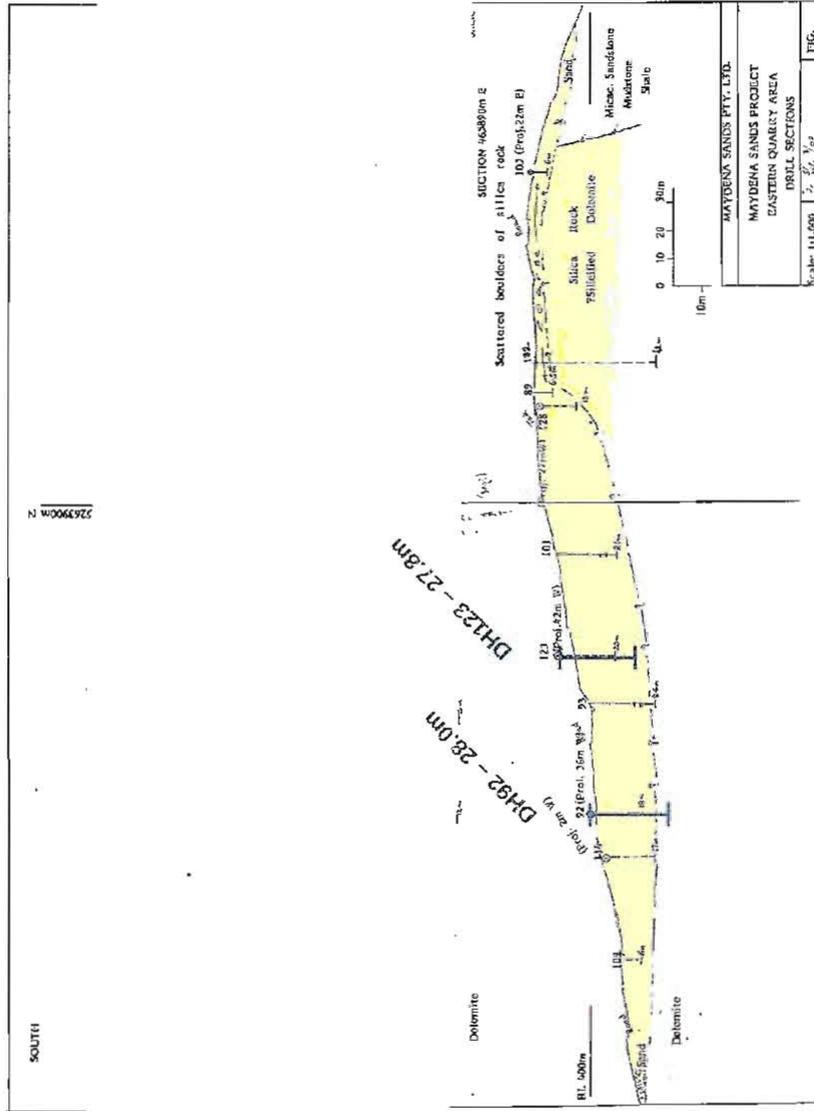


Figure A2: Geological section 465890mE. Caption as for Figure A1.



## ILLUSTRATIONS

