# WA Array Site Characterisation – Enhanced Shear Wave Velocity Profiling from Passive Seismic Data


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## SUMMARY

The WA Array project, launched in late 2022 by the Government of Western Australia, is a seismic imaging initiative deploying 165 seismometers at 40 km intervals. Over ten years, it will cover the state of Western Australia (over 2.5 million square kilometres), focusing on mapping crustal and lithospheric structures and aiding mineral exploration, energy studies, seismic risk assessments, and green energy planning. One of the anticipated products from the project include a local site characterisation including a site-specific near surface shear wave velocity profile, the time-averaged shear-wave velocity in the top 30 meters of the ground, $V_{S30}$, and bedrock depth determinations, all of which are essential for characterizing local site conditions.



**Key words:** WA Array, site classification, shear wave velocity, inversion, dispersion curve.


## WA Array – Site characterisation

Characterizing the near surface response at seismic stations can help benchmark the recorded data to a reference site condition. This supports the assessment and selection of ground-motion models (GMMs) to be used in seismic hazard assessments. However, near surface shear velocity measurements are unavailable for most earthquake-recording stations in Australia, including WA Array stations. This lack of data makes it challenging to benchmark amplification effects to a reference site condition. Passive seismic methods offer an inexpensive and efficient solution to derive these results. The measurements were made at ad-hoc WA Array locations during Phase 1 and more systematically at every second station during Phase 2 (Murdie et al., 2024a, 2024b).

At each location, we employed three-component geophones to measure and characterize near-surface site conditions. Analysing surface waves from ambient vibrations provides well-constrained information on shear-wave velocity to a few hundred meters depth. We processed the data by combining modified spatially averaged coherency (MSPAC) (Bettig et al., 2001) and frequency-wavenumber (FK) (Wathelet et al., 2018; Fäh et al., 2009) array signal processing techniques to retrieve multimode Rayleigh and Love phase velocity dispersion curves and Rayleigh wave ellipticity. Including Love wave dispersion in the ambient wavefield better constrains the inversion of the uppermost shear-wave velocity structure. The results of all analyses converged to the definition of a set of best-representative 1-D shear wave velocity profiles for each site, achieved through joint inversion of multimode dispersion (Love and Rayleigh) and ellipticity curves.

The S-wave velocity structure and $V_{S30}$ results derived from the inversion process provide an inexpensive technique to measure $V_{S30}$ and bedrock depth for site classification. This data will be integrated into the national map of $V_{S30}$, enhancing Australia's Ground-Motion Characterisation Models for future updates of the National Seismic Hazard Assessment. Additionally, it will contribute to a national repository of earthquake ground-motion data and site metadata for engineering applications. WA Array results will be published on a strict schedule, one year after data collection for each phase is completed. The first report, Phase 1, with detailed maps and models, will be published via the GSWA eBookshop eBookshop (dmp.wa.gov.au) in December 2024, but we will preview the results in this meeting. The study results for each station will be available through the GSWA geophysical data server, MAGIX MAGIX (dmirs.wa.gov.au), and published concurrently with the rest of the data from that phase.

An example of the type of results that can be expected can be seen in Figure 1. We followed the procedure suggested by Vantassel and Cox (2020) for the inversion approach. Figure 1a-c displays the inversion results for station WBW08, showing the minimum misfit shear wave velocity profiles obtained from each parametrisation. The variability in the accepted lowest misfit profiles illustrates the interparametrisation uncertainty, which is quantified in Figure 1d using the lognormal standard deviation of Vs ($\sigma_{ln,Vs}$). Figure 1b presents the 10-lowest misfit profiles from each accepted parametrisation, along with their corresponding $\sigma_{ln,Vs}$ displayed in Figure 1d. Further exploration involves showcasing the 100-lowest misfit profiles from each accepted parametrisation in Figure 1c, alongside their corresponding $\sigma_{ln,Vs}$ values in Figure 1d. Collectively, Figures 1a-c offer a qualitative understanding of the most uncertain sections of the profile (half-space velocity and layer boundaries) and the well-constrained parts (near-surface velocity and velocity increase with depth). These observations align quantitatively in Figure 1d, where $\sigma_{ln,Vs}$ is smallest near the surface and gradually increases with depth. The evident bulges in $\sigma_{ln,Vs}$ correspond to the layer boundary locations, providing quantitative evidence of their lower certainty.

While it may seem that layer boundaries exhibit high uncertainty due to increased $\sigma_{ln,Vs}$ values, this perception is a result of the typical calculation of $\sigma_{ln,Vs}$, which mixes layer boundary uncertainty with that of Vs, thereby exaggerating the uncertainty of these model regions.

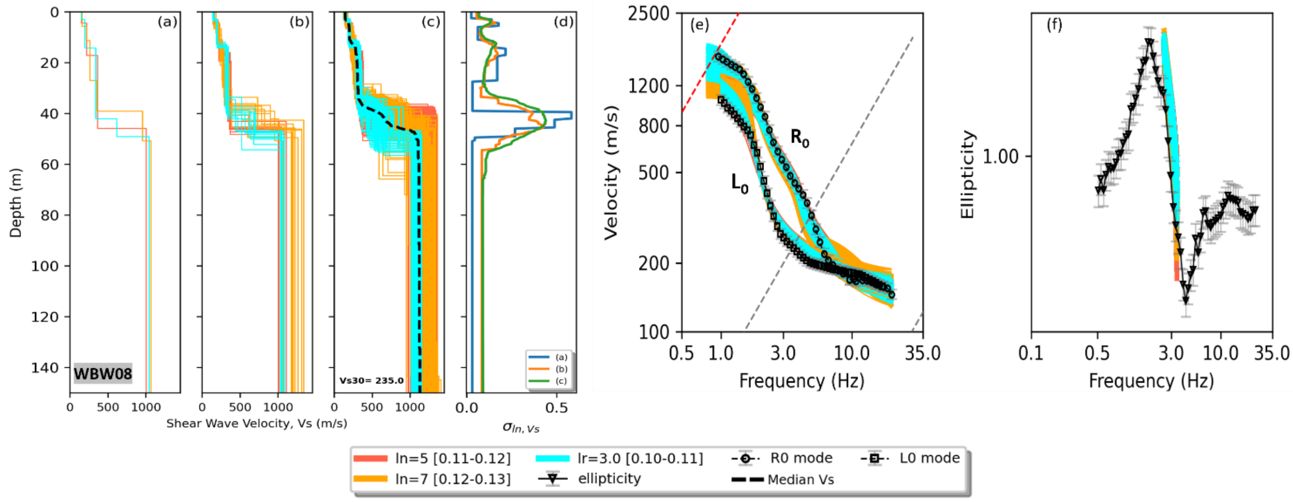


**Figure 1. Inversion results for station WBW08 are presented to address shear wave velocity profile for this station using three approaches: (a) considering the best model from each accepted inversion parametrisation, (b) considering the 10 lowest misfit models from each accepted inversion parametrisation, and (c) considering the 100 lowest misfit models from each accepted inversion parametrisation. Panel (d) shows the corresponding uncertainties ($\sigma_{ln,Vs}$) for each previously mentioned panel; the black dashed line showing the median of the accepted 100 lowest misfit models; the range of the misfit values are also mentioned in the square brackets. (e) Example of fitting the best inversion solutions to the observed fundamental mode of Love and Rayleigh dispersion curves (f) Example of fitting observed ellipticity curve with the best inversion solutions.**

## ACKNOWLEDGMENTS

This work is supported by the Government of Western Australia. We are very grateful to the landowners in Western Australia. The authors publish with the permission of the Executive Director, Geological Survey of Western Australia.

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