

Multichannel Analysis of Surface Waves (MASW) for Offshore Geotechnical Investigations

McGrath, T.¹, O'Connor, P.², Trafford, A.², Long, M.¹
¹School of Civil, Structural & Environmental Engineering, University College Dublin,
²APEX Geoservices Limited, Knockmullen Business Park, Gorey, Wexford, Ireland

Objectives

- To generate shear wave profiles from collected data
- To determine small strain shear modulus values
- To compare these results with data obtained from borehole measurements throughout the test sites
- To identify limitations for using MASW in marine environments (e.g. noise)
- To investigate the feasibility of stationary and/or mobile MASW

Site

The first stage of offshore practical work was performed in various locations in Dublin Bay (Figure 1), analysing numerous line segments, to ensure a comprehensive survey of the site and to maximise the quality of the data obtained. An arbitrary area was chosen in a shallow, sheltered area to the west of Dun Laoghaire Harbour for testing the equipment configuration and deployment/recovery procedures. Some trials were also performed in the intertidal zone at Dollymount, to be used for comparison with a traditional onshore MASW investigation. Finally the primary area for investigation consists of two lines of boreholes, both extending from South Bull Wall by the Poolbeg Generating station. The first line extends from west to east, while the second is in a more south-easterly direction. These site locations were chosen as a good variety of subsurface layers with varying soil and properties is present, determined from good pre-existing geotechnical data for the area, which has been supplied by Geological Survey Ireland.

Equipment

Numerous components were required for use in the field trials of offshore MASW. A 12cu.in MINI G air gun (Figure 4) and a 40cu.in MINI G air gun acted as pneumatic sources and later used to compare frequency ranges produced by air guns of different capacity. This was accompanied by a source controller unit which managed the triggering functions of the air guns. High pressure air was provided using dive cylinders and a regulating manifold to maintain a working pressure of 100bar. The receivers for data collection consisted of a Geometrics DHA-7 24 channel hydrophone cable (figure 5), which was laid on the sea bed to record the transmitted surface waves, and was connected to a Geode seismograph (figure 6(b)). The seismograph converted the recorded data and transferred it to a computer for on site review and processing where possible. To access the designated sites in Dublin Bay, INFOMAR agreed to hire one of their research vessels, the R.V. Geo, for the first set of trials to be conducted in Dublin Bay. With the aid of its experienced crew and their relevant knowledge, a suitable equipment setup and method of deployment/recovery was quickly determined and successfully tested. See Figure 3 for final set up.

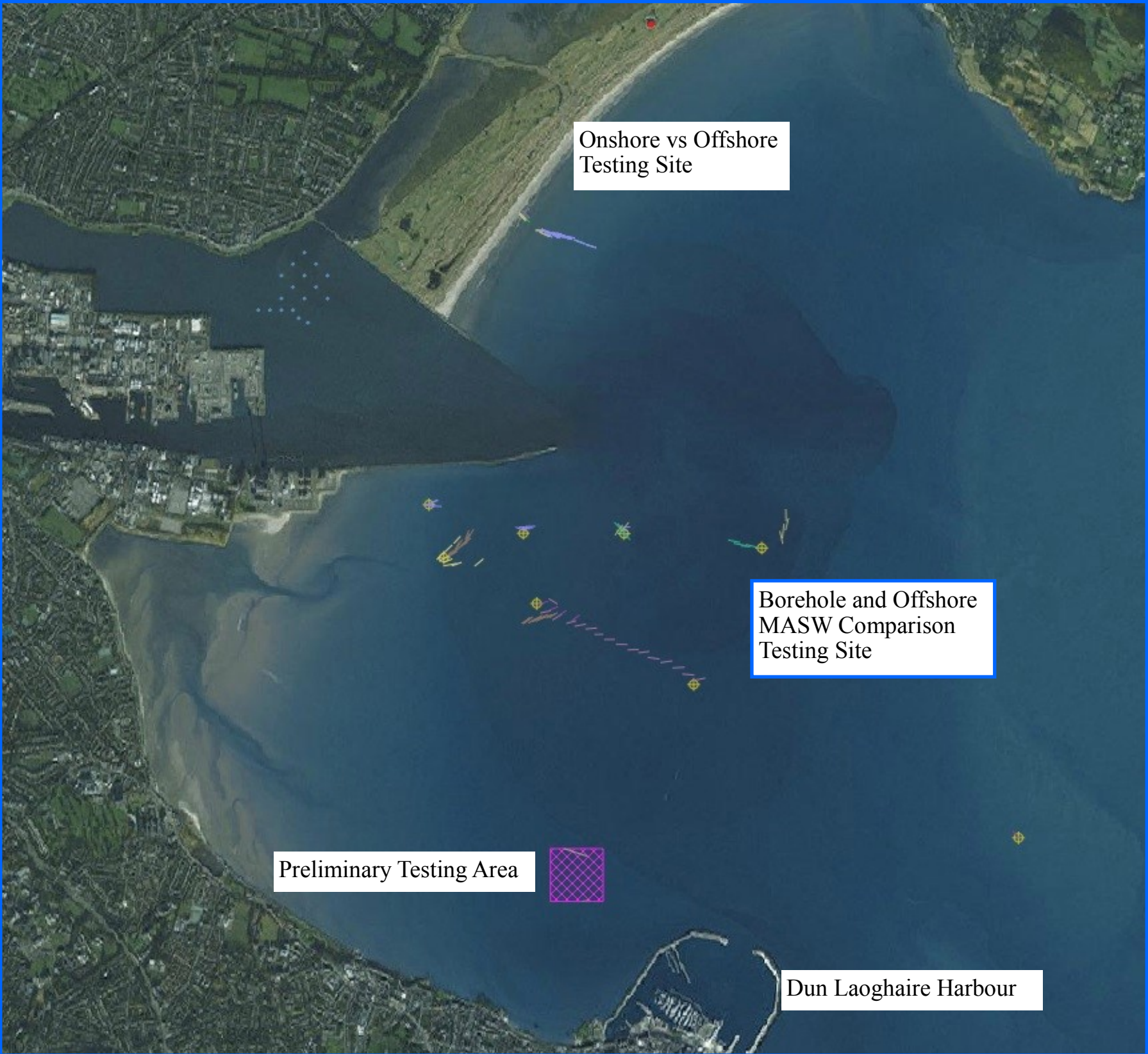


Figure 1: Dublin Bay site locations



Figure 2: INFOMAR's R.V. Geo

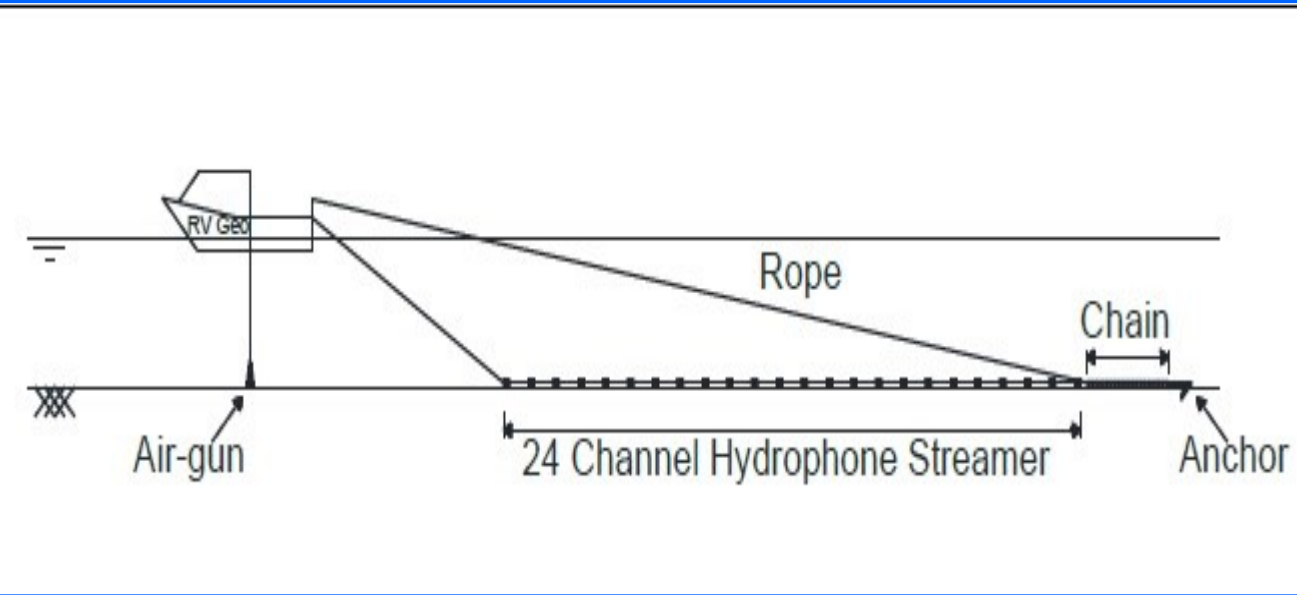


Figure 3: Stage 1 survey set up



Figure 4: 12cu.in MINI G air gun



Figure 5: Geometrics DHA-7 hydrophone cable

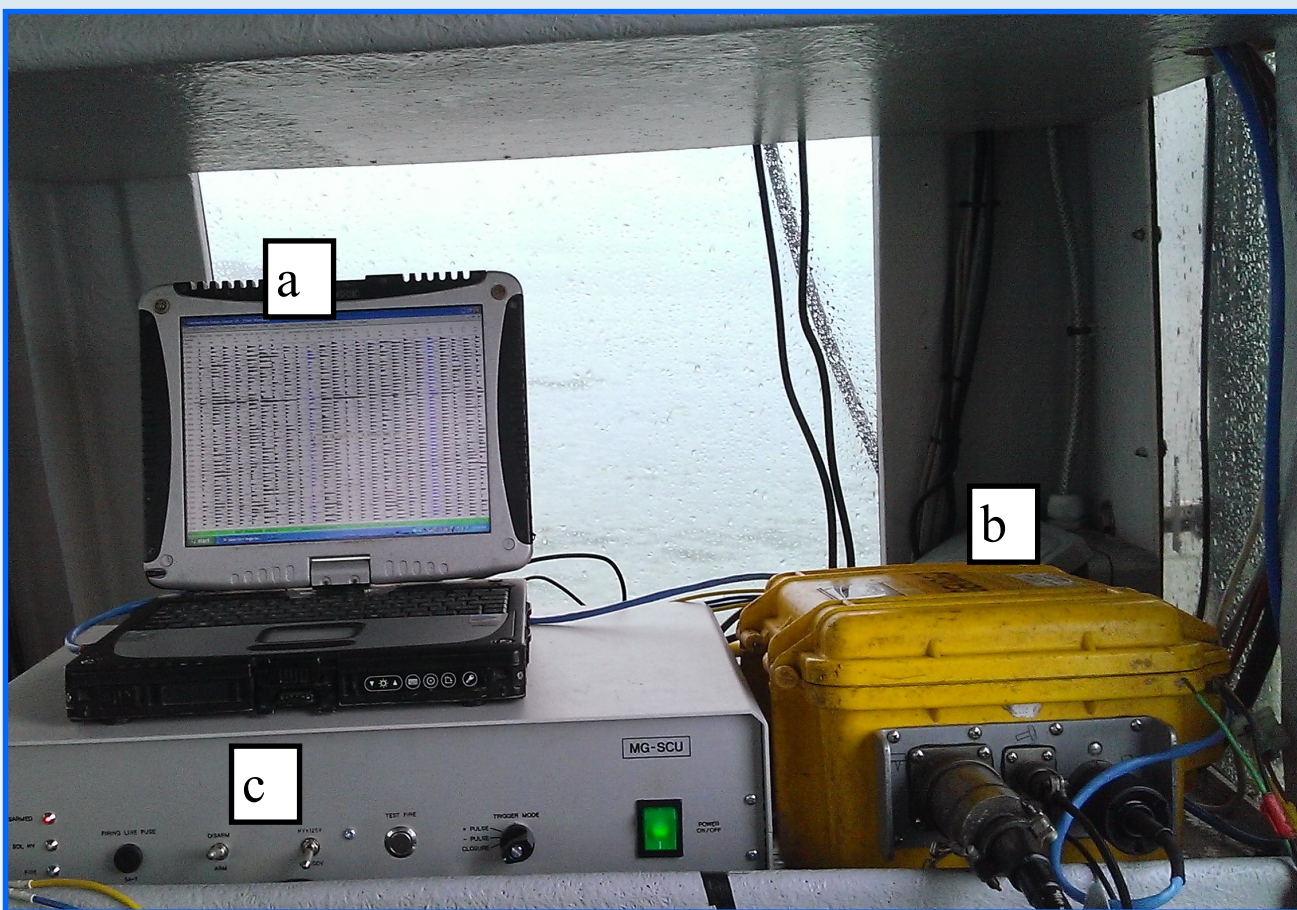


Figure 6: (a) Computer, (b) Geode Seismograph, (c) MINI G Source controller

Data Processing

Having completed the field trials, the focus of the project switched to processing the data. SurfSeis 4.0 Seismic Processing Software was required as a package capable of MASW processing. It's processes include reading seismic recordings and producing a dispersion plot. The investigator would use this plot to pick a suitable dispersion curve (usually only the fundamental curve was visible in the plot) which the software would then perform an inversion upon to produce a curve of shear wave velocity (V_s) in ms^{-1} versus depth in metres. To demonstrate the effectiveness of these curves all SPT values taken from the boreholes were converted to small strain shear modulus values (G_{max}), using curves produced by M.A. Stroud (the Penetration Test—Its Applications and Interpretation, 1989). These in turn were converted these to shear wave velocities using the formula: $G_{\text{max}} = \rho V_s^2$.

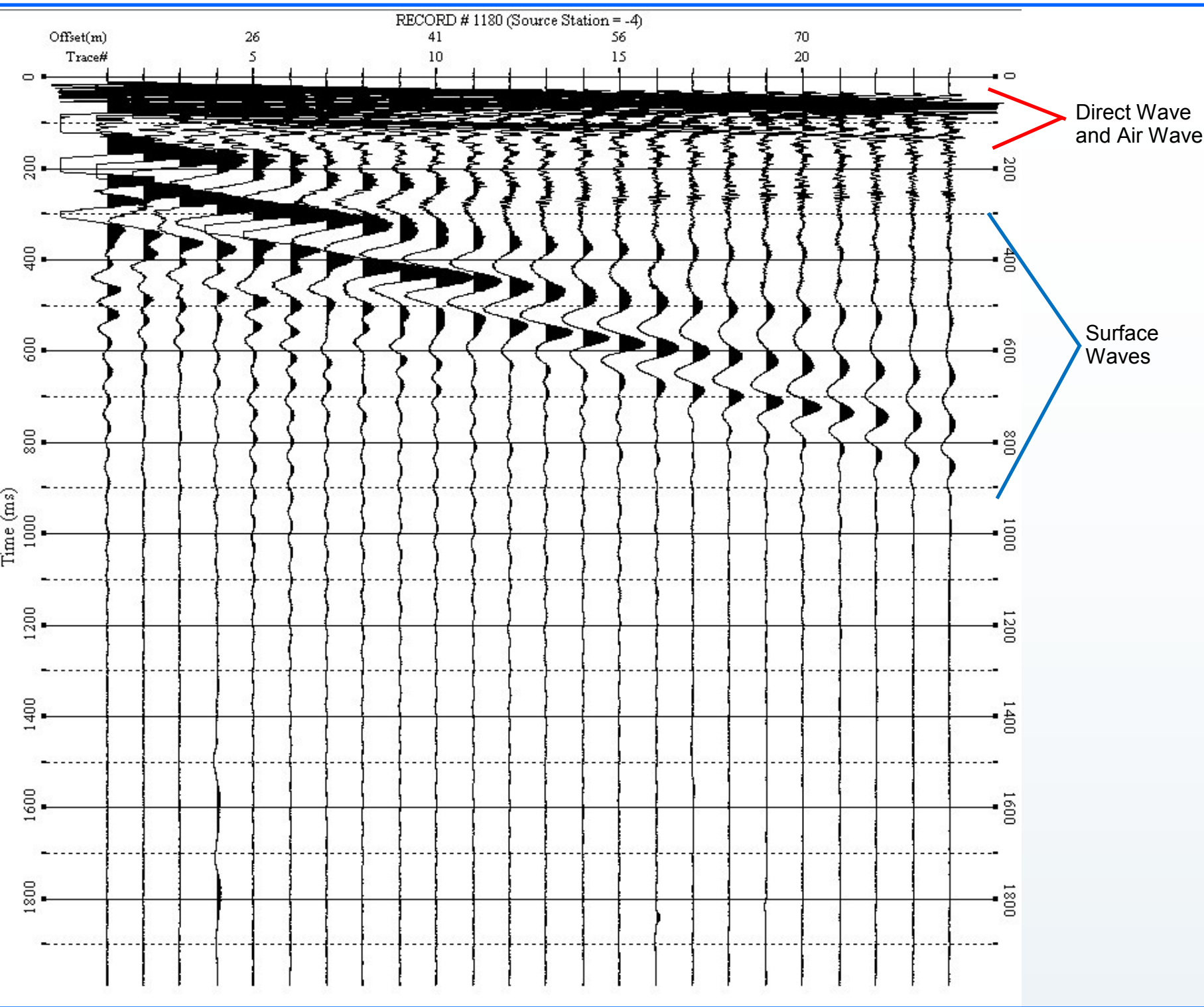


Figure 7: Seismic Recording

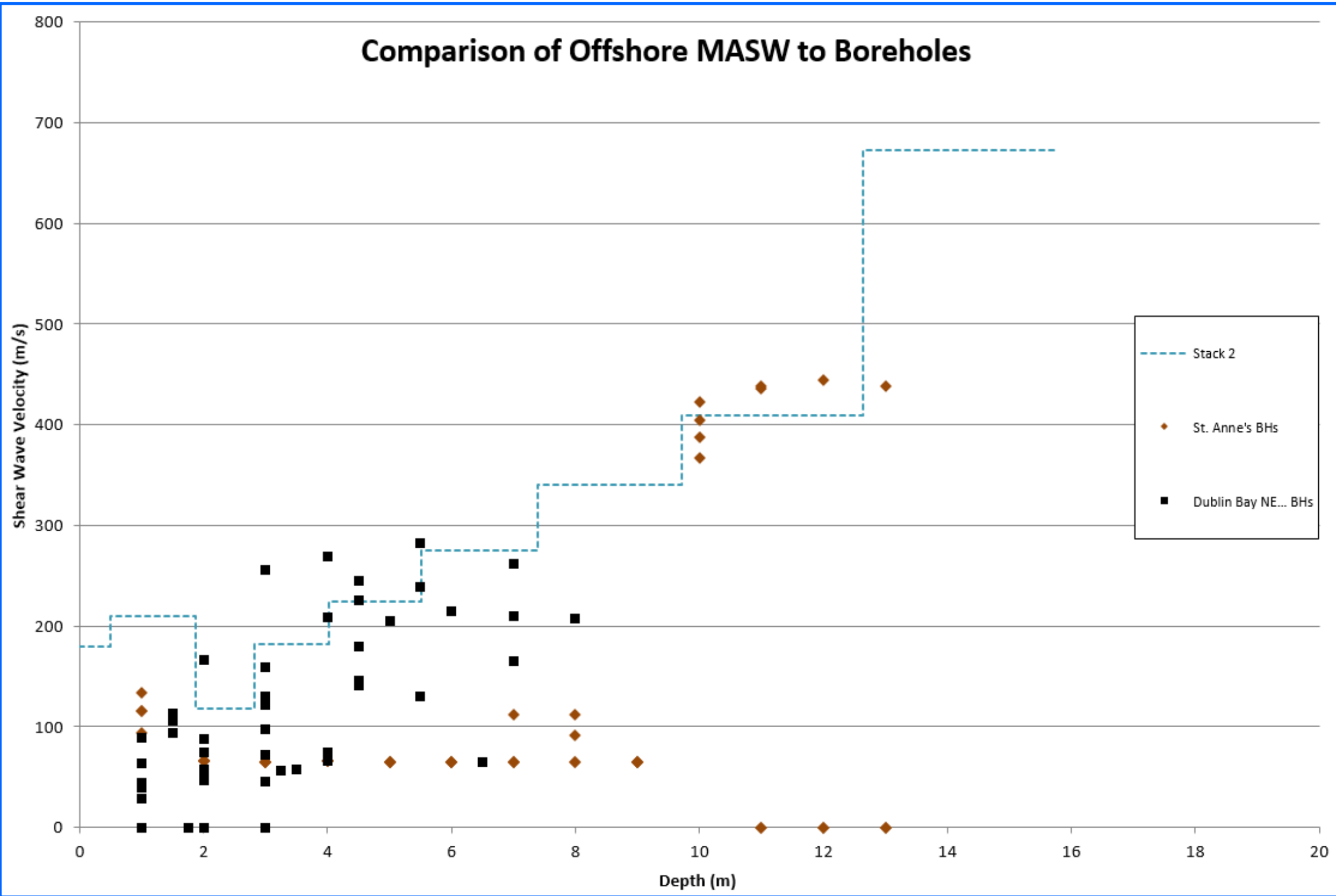


Figure 9: Offshore MASW compared with two separate sets of borehole data

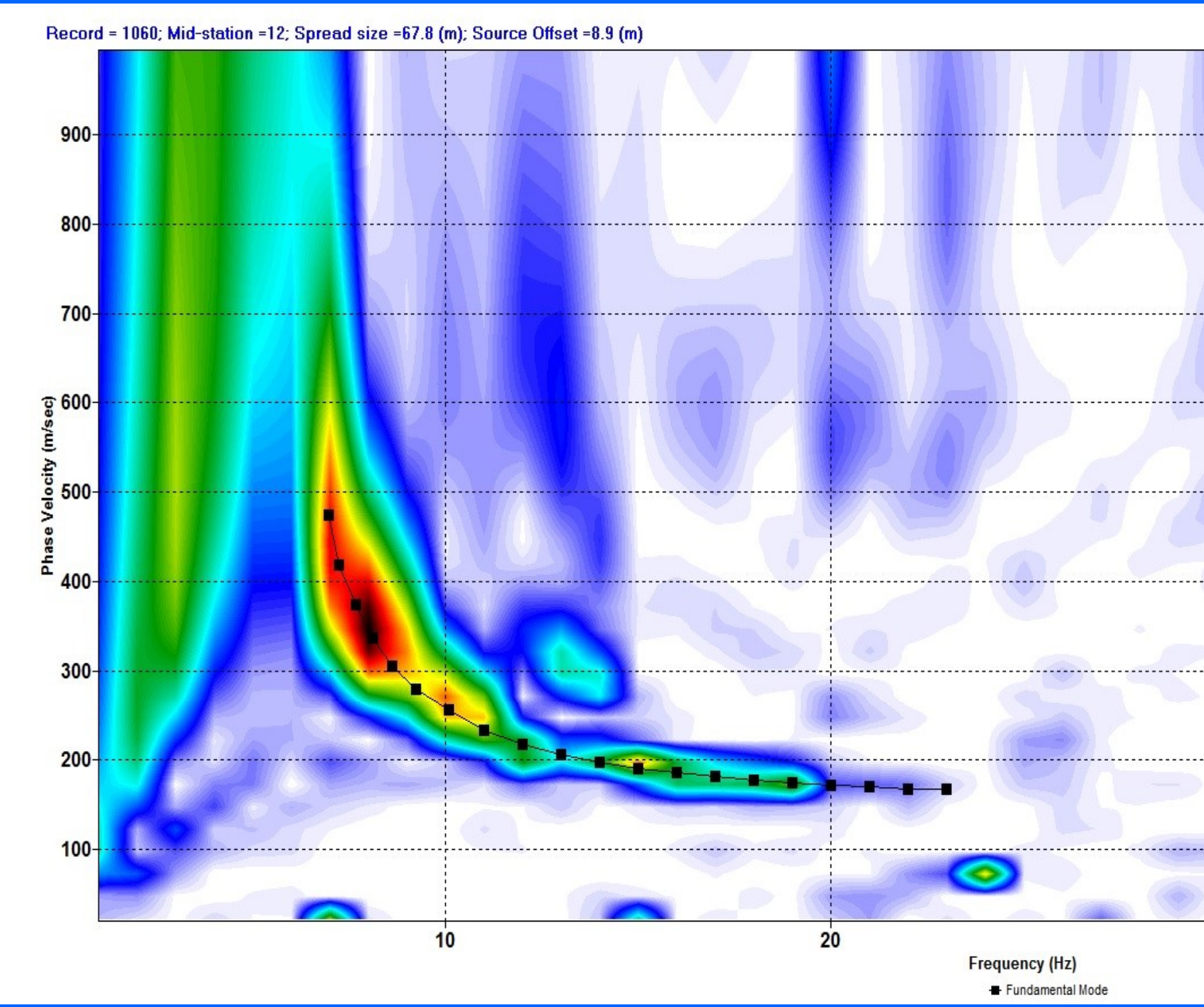


Figure 8: Dispersion Curve

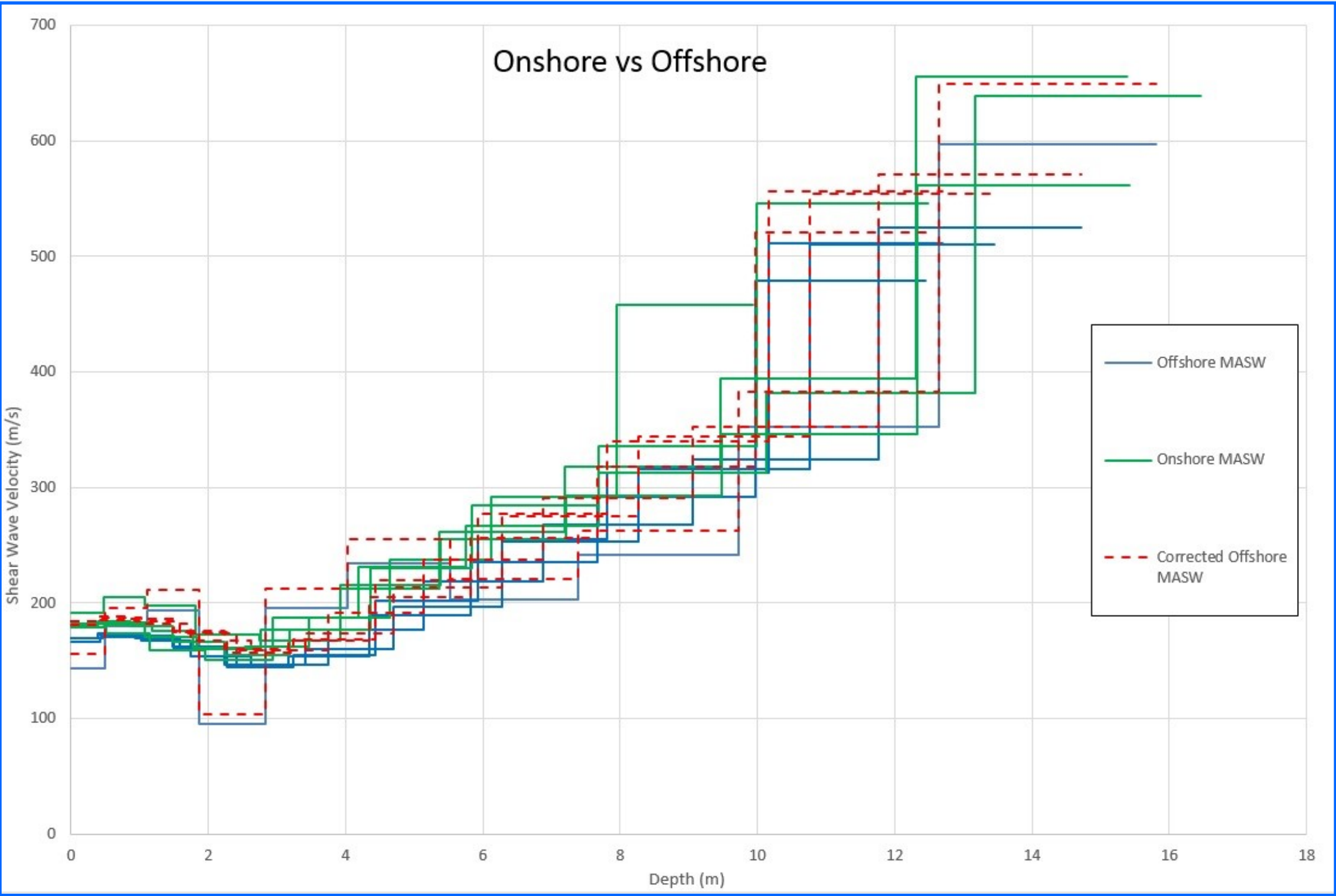


Figure 10: Offshore MASW results compared with Onshore MASW testing

Results and Conclusions

Figure 7 illustrates a seismic recording produced from offshore field trials. While this shot recording appears to have a significant amount of noise, when compared to a traditional onshore MASW shot, the surface waves are still clearly evident running through the recording. It should be noted that unlike onshore MASW there is no clear evidence of the P-wave arrivals as these have been masked by the higher amplitudes of the direct wave and air wave. Many of the dispersions curves produced look similar to that in figure 8, with good amplitude and a frequency range from as low as 6Hz to as high as 30 Hz, allowing for more confidence and penetration depth. From figure 9 depicting the graph of a comparison of Offshore MASW to two sets of nearby Boreholes we see a good agreement between the 3 sets of data. Because of the pick of the dispersion curve, and more specifically where it reaches it's highest frequency, it is accepted that the first 3m of data produced by the MASW is untrustworthy due to the software's inversion process. However this was considered a successful result otherwise. There is some scatter in the borehole data, however due to the types of soil present (sands and gravels) these may have affected the results of the SPT tests leading to this scatter. Looking to the top right hand end of the curve we see that the agreement between Offshore MASW and boreholes is maintained at an acceptable level. Figure 10 is a plot produced to compare the traditional onshore and developmental offshore techniques. The offshore curves (plotted in blue) show very good agreement with the onshore curves (green). However during the processing stage no adjustment was made for the fact that the surface waves produced in a marine environment are Scholte waves rather than Rayleigh waves. Since Scholte waves travel slower than Rayleigh waves a correction factor of 10% was added to the offshore waves, thus producing the red dotted curves seen in the graph. These red curves show even better agreement with the green onshore curves which suggests that this added factor will have to be looked at in further detail in greater depths.

Acknowledgements

This project is funded by the Irish Shelf Petroleum Studies Group (ISPSG) of the Irish Petroleum Infrastructure Programme (PIP) Group 4. The ISPSG comprises: Atlantic Petroleum (Ireland) Ltd, Cairn Energy Plc, Chrysaor E&P Ireland Ltd, Chevron North Sea Limited, ENI Ireland BV, Europa Oil and Gas (Holdings) Plc, ExxonMobil E&P Ireland (Offshore) Ltd, Kosmos Energy LLC, Maersk Oil North Sea UK Ltd, Petroleum Affairs Division of the Department of Communications, Energy and Natural Resources, Providence Resources Plc, Repsol Exploración SA, San Leon Energy Plc, Serica Energy Plc, Shell E&P Ireland Ltd, Sosina Exploration Ltd, Statoil (UK) Ltd, Tullow Oil Plc and Woodside Energy (Ireland) Pty Ltd.

