Nelson Tasman Site Classification Study

Defining the dynamic site characteristics of the Nelson-Tasman region subsoil materials

Rebecca McMahon & Liam Wotherspoon
University of Auckland
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Project Objectives & Proposed Outcomes

The project objective is to determine and map dynamic site characteristics across the Nelson-Tasman region and therefore assess the potential seismic site response including soft-soil amplification effects.

A combination of geotechnical and geophysical methods have been implemented in a region-wide study of the developed urban areas of Nelson-Tasman. Existing sub-surface information will be utilised to constrain the processing of collected geophysical data and to identify geological trends across the region.

To achieve this, the following goals were set:

1. Collect existing geotechnical subsurface information from around the region, understand the geological and geomorphological features of the area.
2. Estimate the site period over a grid of sites across Nelson-Tasman using horizontal-to-vertical spectral ratio (HVSR).
3. Undertake Multi-Channel Analysis of Surface Waves (MASW), 2D passive arrays and circular array testing to define the shear wave velocity profile for selected sites across the region.

The primary outputs from this project include a database of collected factual sub-surface information and presentation of dynamic site parameters derived from geophysical testing. Like similar studies around New Zealand, this information will also help with future ground motion modelling, both regionally and for nation–wide studies.

Nelson-Tasman Region

The Nelson-Tasman region is a rugged mountainous area formed of very hard rocks, some of which are among the oldest in New Zealand (GNS, 2016 Geological Maps and Active Faults Database (1:250 000)). The area comprises recently deglaciated Tasman Mountains in the west and the lower Richmond Ranges and other ranges in the east separated by the low-lying Moutere Depression.

The Nelson-Tasman region is bounded by a number of faults and has been impacted by a number of large magnitude events in previous years. Deep soil and gravels deposits are present in this area which may lead to significant amplification of seismic ground shaking and possibly 'basin effects'.

Figure 1: Google Earth image of collected existing sub-surface geotechnical information (total of 550 records)

Existing sub-surface geological information has been collated and plotted spatially as shown in Figure 1. Over 500 records were gathered including borehole logs and Cone Penetration Test (CPT) logs, and a large proportion of this information has been uploaded to the New Zealand Geotechnical Database (NZGD), where permission was granted to do so.

Figure 2: Broadband 3-component seismometer

Geophysical Testing

Various geophysical testing techniques have been employed to estimate dynamic characteristics at a number of sites around the Nelson-Tasman region. The available factual geotechnical records collected were used to constrain the inversion of the geophysical data during processing.

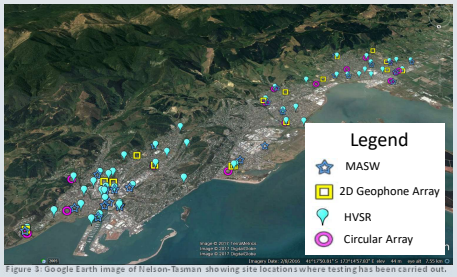

Figure 3: Google Earth image of Nelson-Tasman showing site locations where testing has been carried out.

Surface Wave Testing (MASW & 2D Geophone Arrays)

Rayleigh and Love waves are surface waves, generated when seismic body waves interact with the earths surface. To complete the surface wave testing, linear or 2D L-shaped array of geophones was set up to record either an active source of seismic waves (sledgehammer or drop-weight) or passive source (ambient long period waves generated by a number of sources, both natural and man-made). This testing was completed at a total of 29 sites with a linear array, and 17 sites with a 2D-array.

Horizontal-to-Vertical Spectral Ratio (HVSR)

HVSR measurements provide an estimate of site period by taking a ratio of the horizontal and vertical spectral data collected by a 3D seismometer. Using Broadband 3-component seismometers a total of 50 tests were undertaken at various public parks, road reserves and car-parks around Nelson and Tasman. From each of these sites the H/V ratio was then processed to obtain an estimate of the site period at that location.

Circular Arrays

Broadband seismometers were deployed in a large circular array of 50-200m diameter with at least 7 seismometers spaced equally around a central seismometer. With accurate GPS location information, the recorded data from the circular array was then analysed to generate a dispersion curve which captures longer period wave energy compared with other testing techniques. This circular array testing was completed at 13 sites and allowed deeper characterisation of the Nelson-Tasman regional deposits.

Shear Wave Velocity Profiles

Shear wave velocity is an important parameter in seismic assessment, modelling and design. It is a key input used in the assessment of NZS1170.5 seismic site classification and therefore it was an important output required from this research project. To develop shear wave velocity profiles, data from a range of geophysical testing methods were compiled, as shown in Figure 4 below.

The benefit of using multiple methods of testing is that different depths of the soil profile can be characterised more effectively by different types of geophysical tests and that comparing resulting shear wave velocity estimates from multiple methods ensured consistent results

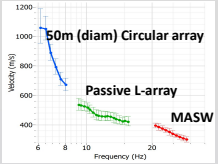

Figure 4: Example of experimental dispersion curve with various types of testing data used as inputs.

Inversion of the experimental dispersion curve was completed using available factual geotechnical information to constrain the processing. The resulting statistical spread of best-fit shear wave velocity profiles will then be compared with the regional geological model to identify trends in the shear wave velocity of various regional deposits. A selection of sites have been shown below to illustrate the type of outputs that can be generated. After processing all the sites, the regional geological units can then be assigned typical ranges of shear wave velocity.

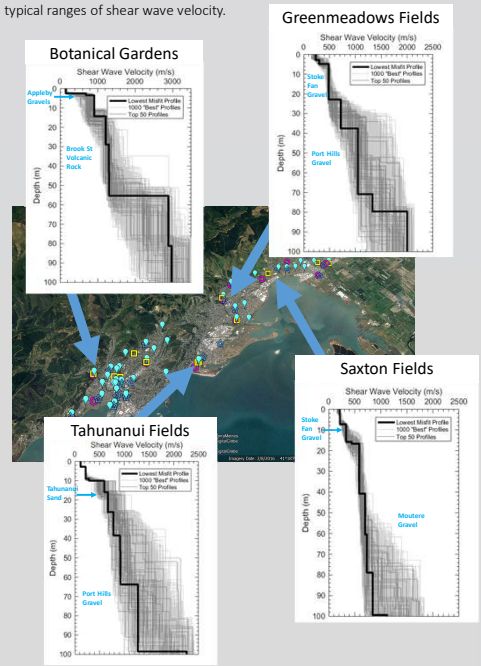

Figure 5: Selection of shear wave velocity profiles from around the region with Google Earth Image Location Map.

The Botanical Gardens site and Tahunanui Fields are know to have a weaker surficial material overlying a denser layer. The shear wave velocity significantly increases at a depth of around 4m at the Botanical site, and around 10m below ground level at Tahunanui. Greenmeadows and Saxton Fields are founded on relatively deep gravel basins with a gradually increasing stiffness. This is reflected in the Vs profiles, as shown by the relatively small incremental change of Vs with depth.

Site Period

Utilising the data recorded using the broadband seismometers, the Horizontal to Vertical Spectral Ratio (HVSR) was processed. It was identified however, a number of the Nelson-Tasman sites tested, did not exhibit clear 'peaks' in the ratio which would normally indicate the fundamental site period.

The reason for this is inferred to be the lack of strong impedance contrast. Instead of a softer soil deposit overlying much stronger bedrock, the deep gravel basins in Nelson-Tasman gradually increase in stiffness and density. As shown in Figure 6 below, this made it very difficult to estimate the fundamental site period using HVSR.

Site 4 (Tahunanui) is likely to be Tahunanui sands overlying much denser Port Hills Gravel. Site 6 (Botanical Gardens) is mapped as Appleby Gravels but with bedrock likely to be relatively shallow. Sites 1, 2, 3 and 5 are located on areas of deep gravel deposits. Particularly at Site 3 and 5, there is no clear peak identified in the HVSR, which is thought to be caused by the lack of strong impedance contrast.

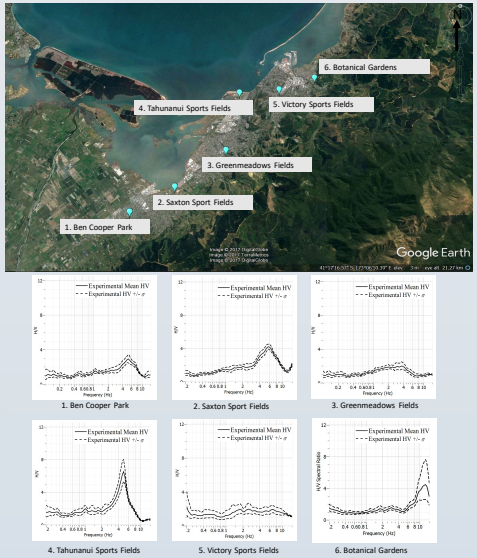

Figure 6: Examples of Horizontal to Vertical Spectral Ratio (HVSR) plots from a range of Nelson-Tasman Sites

Next Steps

Using the collected factual geotechnical and acquired geophysical testing information, the processing, interpretation and application of the data is currently underway. Processing completed to date indicates some regional trends that will be further explored and constrained. To do this, a 3D geological model focussed on capturing the interface between Moutere Gravel or Port Hills Gravel, with overlying sediments is being developed. In addition, discussions with the local geology experts are required to better understand the likely properties and characteristics of the regional deposits.

The final output for this study will be the presentation of dynamic site parameters derived from geophysical testing and assigned to the various regional deposits. This data will also be used for wider national seismic research and modelling of earthquake shaking propagation.