Recent site characterisation work in New Zealand

Andrew Stolte

QuakeCoRE TP2 Field Research Engineer

Non-invasive Seismic Geophysical Testing

Horizontal/Vertical Spectral Ratio (HVSR)
- Evaluate site period using ambient vibrations measurements
  - ~1 hour recordings
- Single station test (3-component sensor)
  - Allows rapid deployment and testing across a large geographical area

Surface Wave Testing
1) Field measurements of waveforms
2) 2D Transform to develop surface wave dispersion curves
3) Inversions to develop 1D V_S profiles

Multichannel Analysis of Surface Waves (MASW)
- Active source → sledgehammer, drop weight, vibroseis
- Linear array of geophones
- Maximum depth of V_S profile is typically less than 30 meters

Microtremor Array Measurements (MAM)
- Passive source → ambient vibrations
- 2D array (e.g., circle, triangle, "L") of sensors (e.g., broadband seismometers or geophones)
- Maximum depth is limited by array geometry and wavelengths of surface waves

Goal: Improve sedimentary basin models across NZ

Recent Projects:
- Marlborough
  - HVSR Testing
  - QuakeCoRE TP2
- South Dunedin
  - HVSR, MASW, MAM, and more
  - U. Otago – Catherine Sangster
- Hauraki Plains
  - HVSR
  - U. Auckland – Zaid Rana
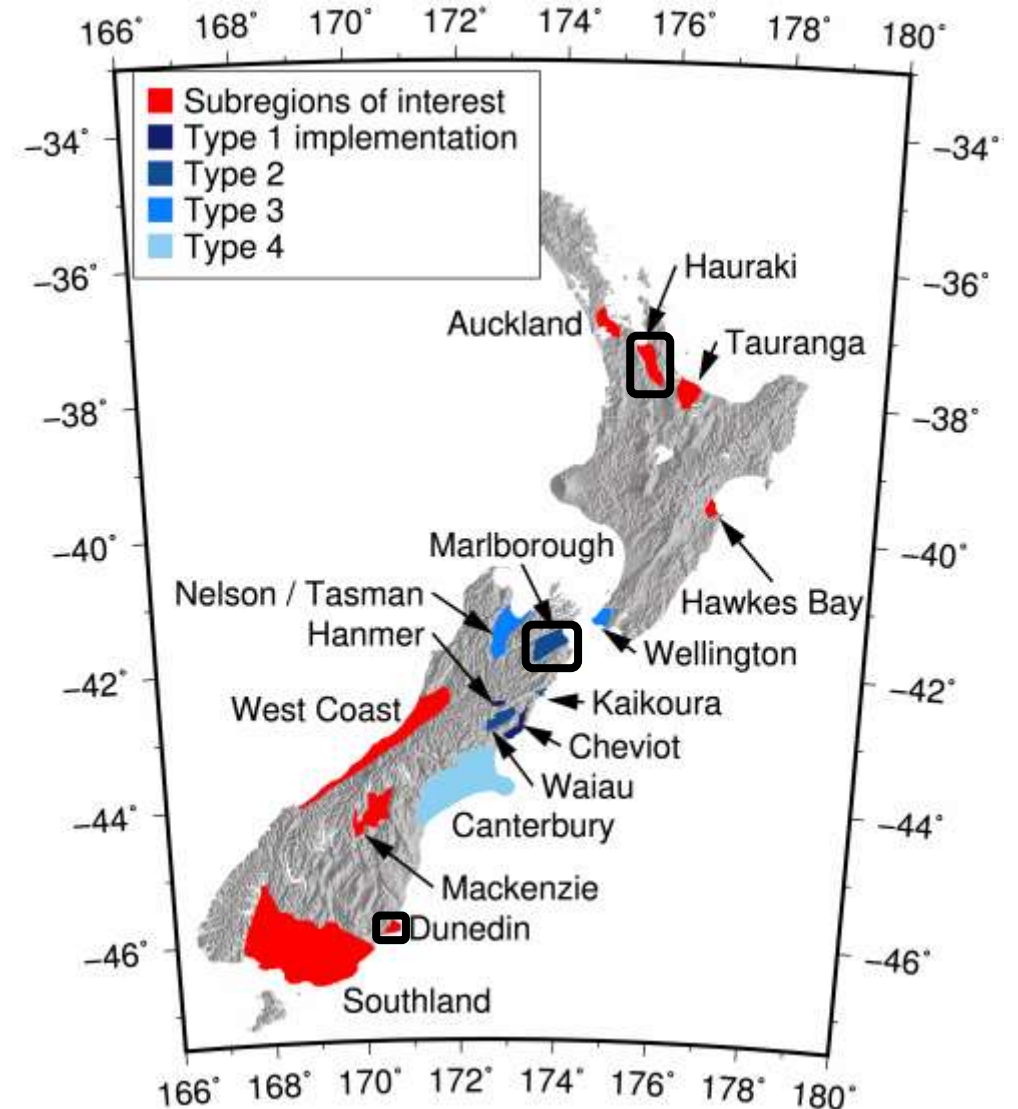
Marlborough Sedimentary Basin

March 2018

- 12 HVSR Test Sites
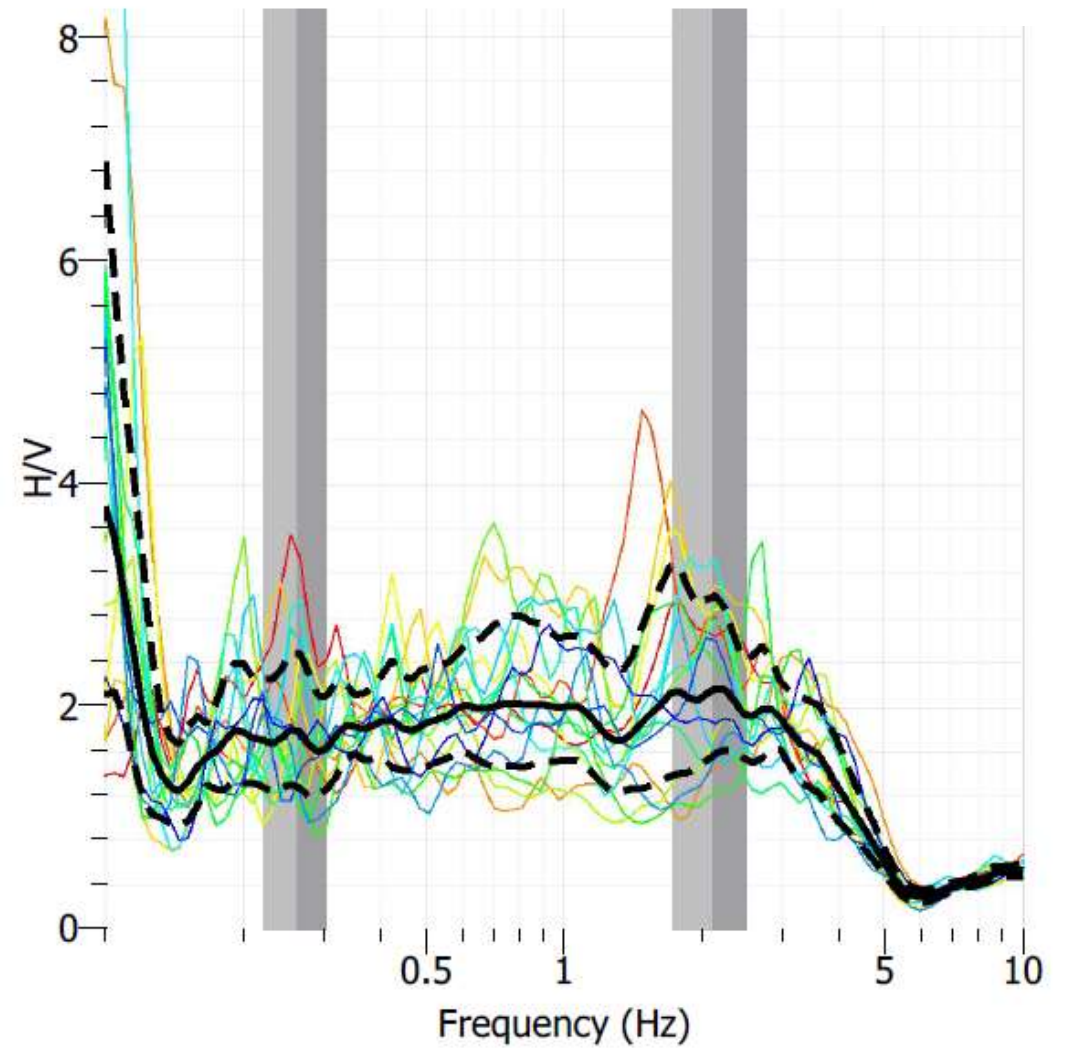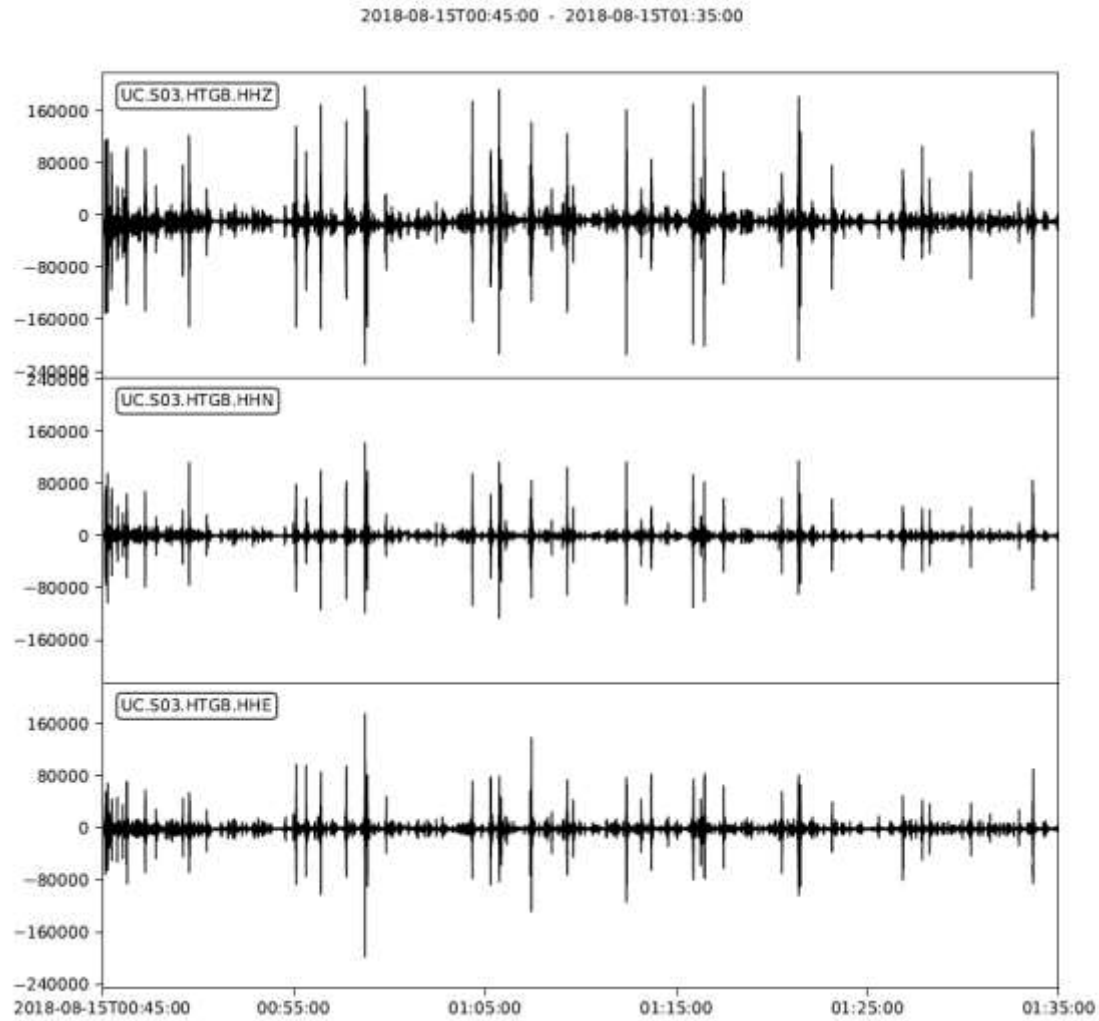- Focused on sites in Blenheim

August 2018

- 17 HVSR Test Sites
- Revisited old sites with poor data
- New sites outside of Blenheim

Results

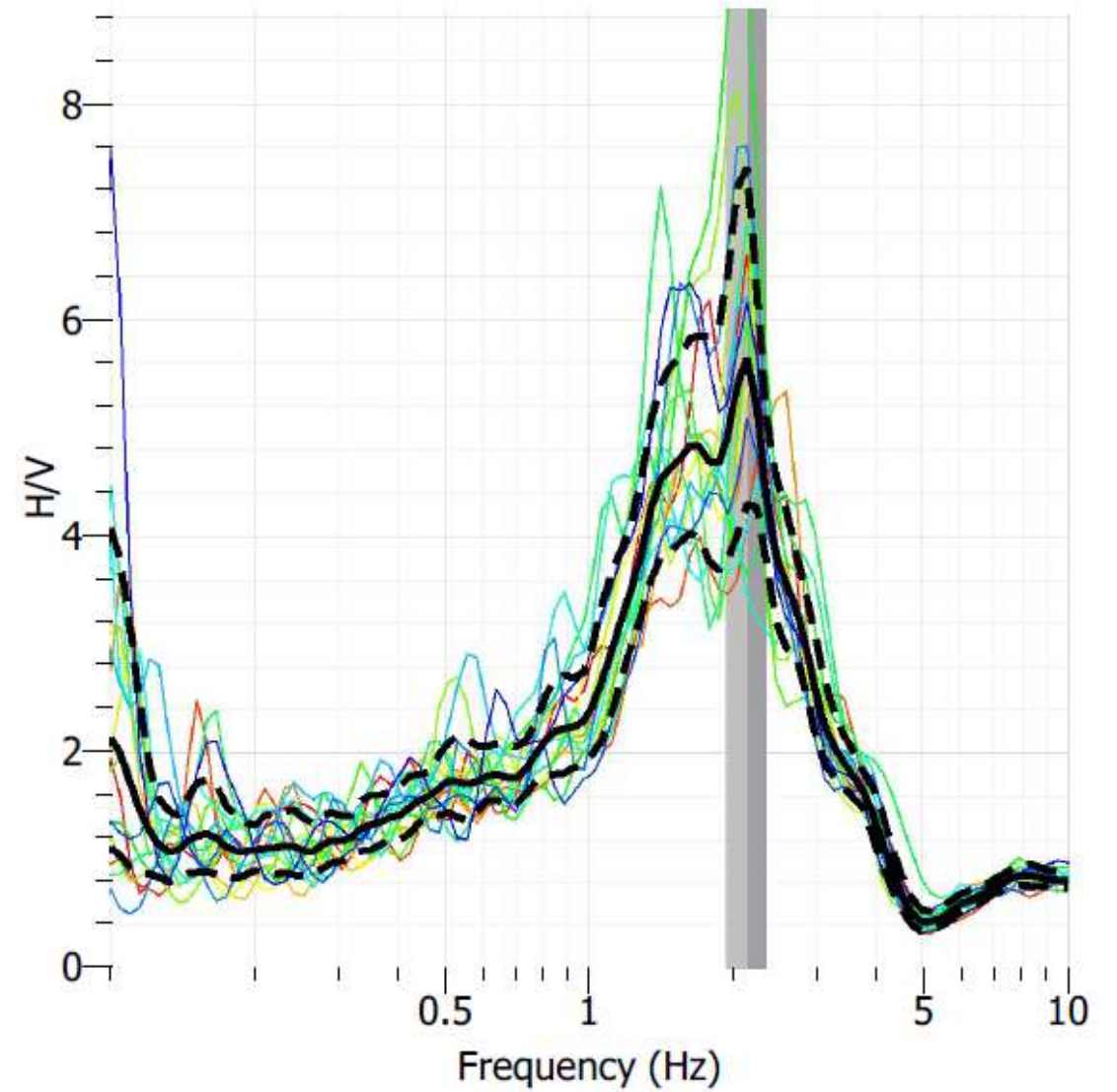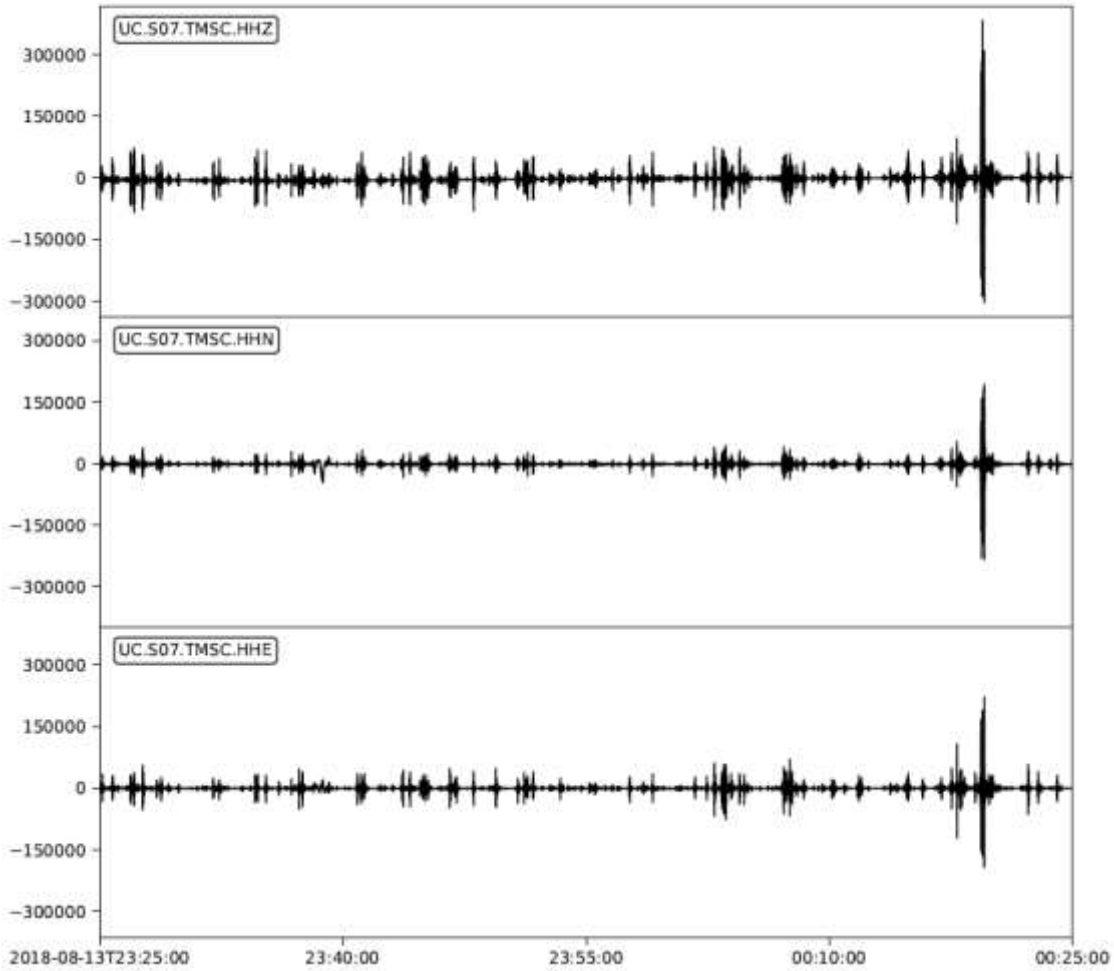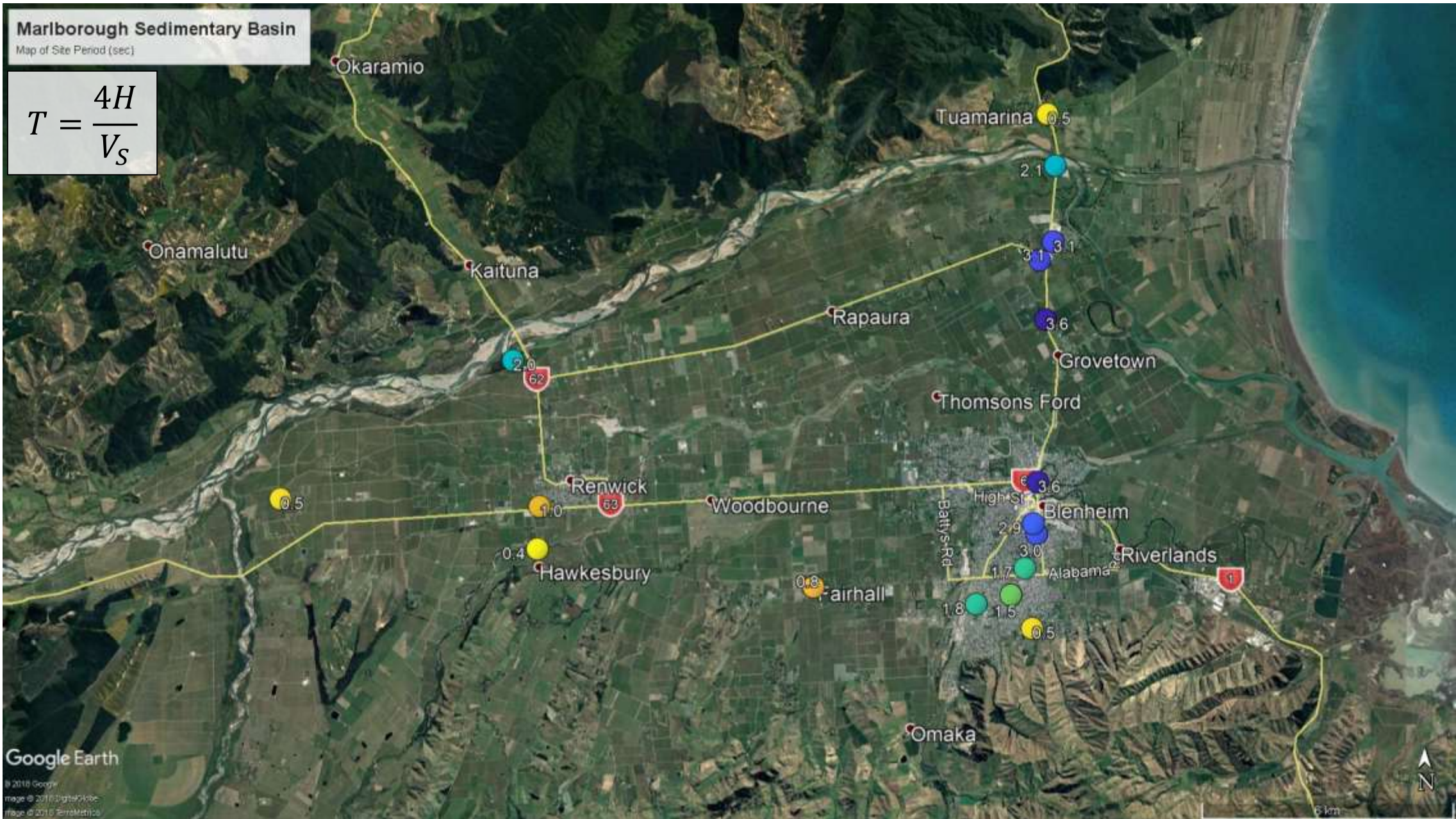- ~19 sites with clear peaks → site periods estimates

Heritage Bakery

Tua Marina School

$$T = \frac{4H}{V_S}$$

Hauraki Plains Sedimentary Basin

University of Auckland
- Zaid Rana → Develop basin model (MS project)

Previous Field Testing:
- Seismic reflection(?) lines in 1970's

Field Testing (Sept. 2018 – present)
- HVSR
  - Field testing programme is ongoing (awaiting site permissions at ~20 sites)
  - 65 sites tested as of 12 October 2018
  - Develop map of site period (estimates of depth to bedrock)
- Potential for surface wave testing to refine velocity model

A.C. Stolte - Recent Site Characterisation in NZ
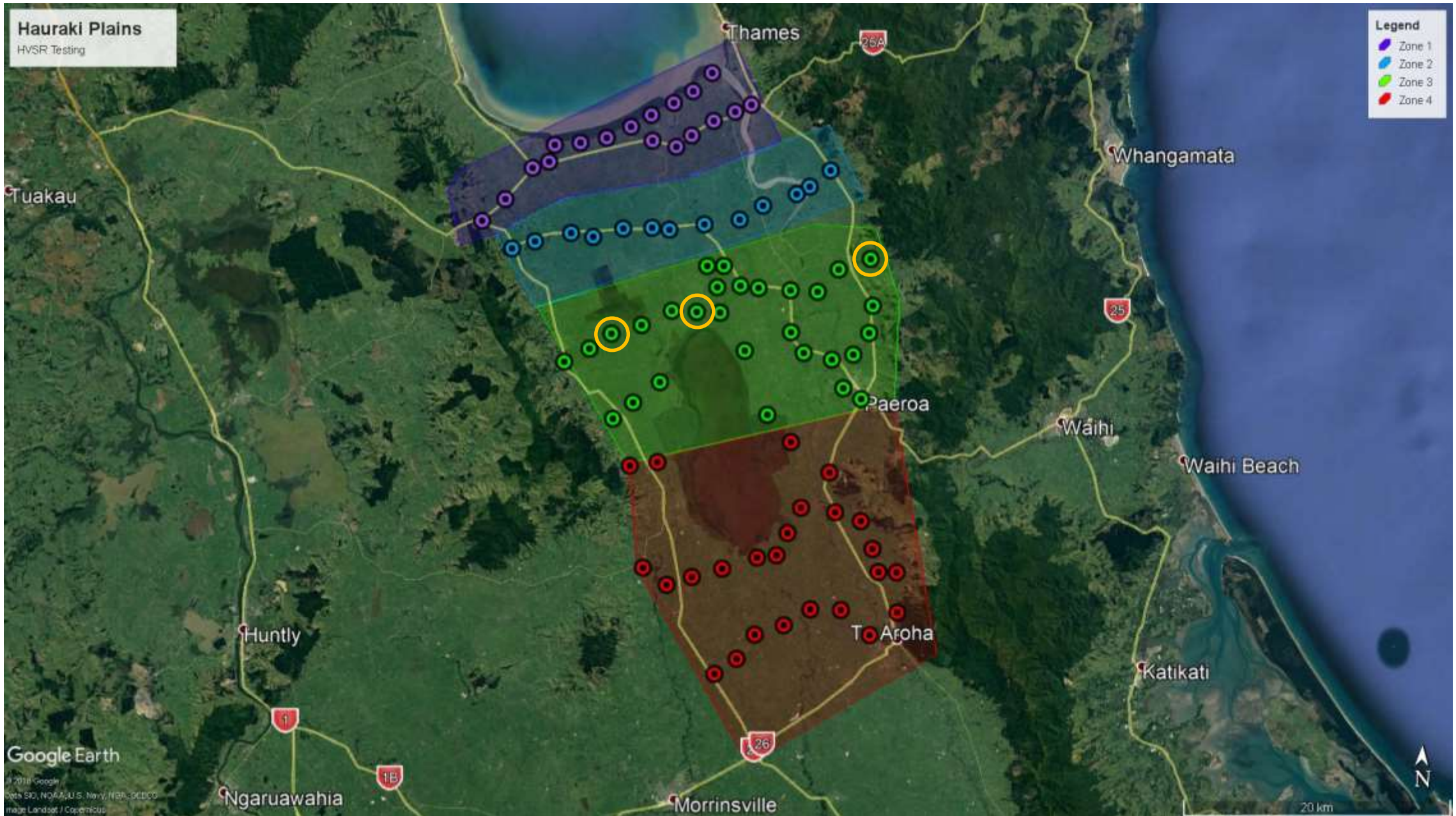
Hauraki Plains Example HVSR Curves
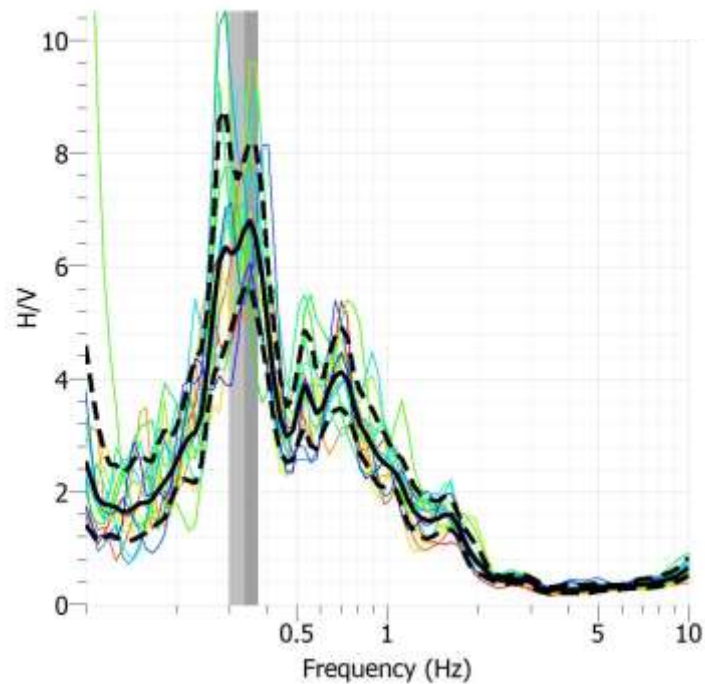
Peak Frequency: 0.336 Hz
Site Period: 2.976 sec
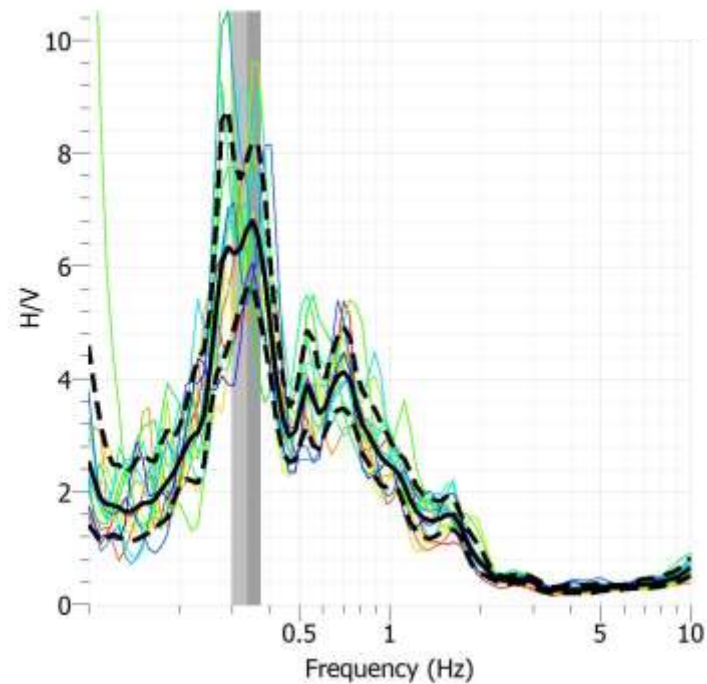
Peak Frequency: 0.204 Hz
Site Period: 4.901 sec

Peak Frequency: 2.121 Hz
Site Period: 0.471 sec

TP2 Field Testing Data Archival

Archive of TP2 field data + metadata
- Organized by project
- Field data to include:
  - Raw Data (e.g., waveforms)
  - Processed/Interpreted Data (e.g., site period and V_S profiles)
- Metadata (XML File)to include:
  - Project Information (e.g., general location, description)
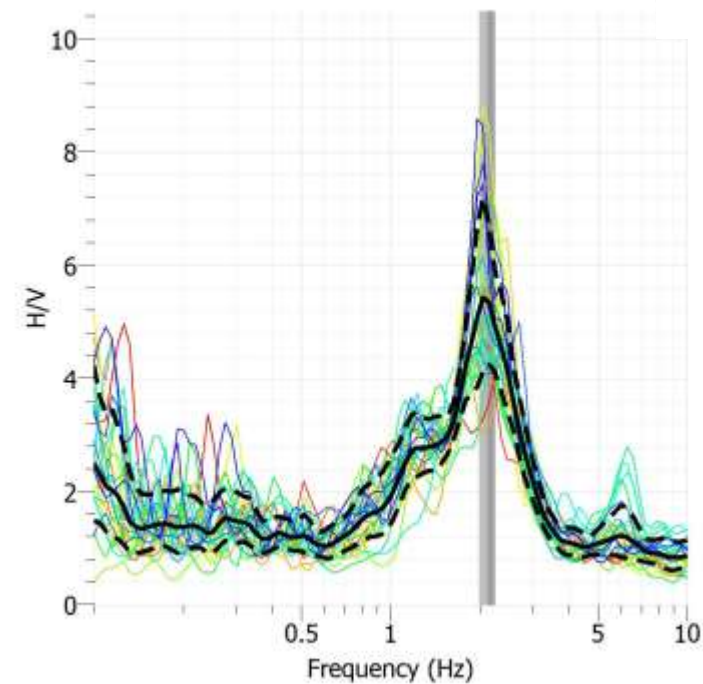 - Test Information (e.g., test type, location, date, time, personnel)
    - Optional: Results Summary (e.g., site period, V_{S30}, etc.)
  - Sensor/Station Information (e.g., location, geometry, serial number)

Data + Metadata will be stored on DesignSafe-CI
- https://www.designsafe-ci.org/
- Plan develop interactive map using metadata → link to design safe archive

Example Metadata for Blenheim HVSR

XML Files

- Collapsible Tree Organisation
  - Trunk (Project)
  - Branches (Individual Tests)
  - Limbs (Results, Stations)
- Use of Tags
  - Allows programmatic parsing
  - Easily readable by human
  - Individual tags are optional and adaptable to project/test/station

```xml
<?xml version="1.0" encoding="UTF-8"?>
<Project>
    <!-- Each Project Root Element should have a single ProjectHeader Element -->
    <ProjectHeader>
        <ProjectID>BlenheimHVSR</ProjectID>
        <ProjectName>Blenheim HVSR</ProjectName>
        <ProjectLocation>Blenheim, NZ</ProjectLocation>
        <ProjectDescription>HVSR testing for characterisation of Blenheim sedimentary basin</ProjectDescription>
        <ProjectGeologicInformation>N/A</ProjectGeologicInformation>
    </ProjectHeader>
    <!-- Each Project Root Element, may have one or more Test Element(s) -->
    <Test ID="B01" Type="HVSR">
        <!-- The following Test Element sub-elements are recommended -->
        <Type>HVSR</Type>
        <ID>B01</ID>
        <Name>Toll 27 Gouland Rd, Spring Creek</Name>
        <Operator>Chris de la Torre</Operator>
        <Date>22 March 2018</Date>
        <StartTimeUTC>20180322211900</StartTimeUTC>
        <EndTimeUTC>20180323033300</EndTimeUTC>
        <!-- Each Test Element may have one or more Station Element(s), this allows single station HVSR to multistation MAM -->
        <Station>
            <InstrumentType>Centaur/Trillium Station</InstrumentType>
            <InstrumentID>UC.S09</InstrumentID>
            <Location>
                <CordinateDatum>WGS84</CordinateDatum>
                <Latitude>-41.457156</Latitude>
                <Longitude>173.964018</Longitude>
            </Location>
            <InstallationMethod>Cradle on Surface</InstallationMethod>
            <GroundConditon>N/A</GroundConditon>
        </Station>
        <!-- Each Test should have one Results Element that will vary by test type-->
        <Results>
            <MedianPeriodT0>3.13</MedianPeriodT0>
            <MedianFreqT0>0.320</MedianFreqT0>
            <StdFreqT0>0.063</StdFreqT0>
            <MedianAmplitudeT0>1.859</MedianAmplitudeT0>
            <MedianPeriod2ndPeak>0.641</MedianPeriod2ndPeak>
            <MedianFreq2ndPeak>1.560</MedianFreq2ndPeak>
            <StdFreq2ndPeak>0.242</StdFreq2ndPeak>
            <MedianAmplitude2ndPeak>3.734</MedianAmplitude2ndPeak>
        </Results>
    </Test>
    <Test ID="B02" Type="HVSR">
        <!-- The following Test Element sub-elements are recommended -->
        <Type>HVSR</Type>
```

Upcoming Projects

Hawkes Bay: HVSR and Surface Wave Testing
- University of Auckland (Liam Wotherspoon & students)
- Summer 2019

Waikato: HVSR and Surface Wave Testing
- University of Waikato (Seokho Jeong & students)
- Initial study (Summer 2018)
- Expanded study (2019 – 2020)

Future Site Characterisation?
- Non-invasive testing well suited to basin model development for ground motion simulation
- Also, opportunities for near-surface invasive testing for liquefaction studies