Dynamic Site Characterisation and Site Response in Auckland, New Zealand

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Introduction:

The Auckland region has been targeted by local government to accommodate a large portion of the city's future urban and commercial expansion. The area has highly variable geology; in terms of dynamic site characterisation, the areas with thick organic soil, alluvium, and where basalt has been deposited over soft soils provide particularly challenging characteristics.

Auckland is assumed to have a low seismic hazard because of its tectonic setting away from plate margins and major known fault systems. Seismic sources with potential to cause significant shaking in Auckland are associated with the Hikurangi Subduction zone and the Taupo Volcanic Zone. Nearby seismic sources (E.g. Wairoa North Fault, 60 km away) have low activity rates, thus pose less of a hazard. There is also potential for a significant earthquake along an unidentified or off-shore fault, as there may also be large faults in close vicinity to the city whose seismic potential are unknown.

The initial stages of this research involved geotechnical and geophysical field investigations to characterise the shear wave velocity (Vs) of the dominant surficial deposits in the Manukau Lowlands region of Auckland (Figure 1). This poster provides an overview of the typical deposits in this region and the surface wave testing methodology.

Field testing methodology:

Both active and passive source surface wave testing techniques were used to develop realistic shear wave velocity (Vs) profiles at a number of sites across the city, with borehole and cone penetration testing data used to constrain layering during surface wave inversion. Vs profiles representative of the region were used to carry out site response analyses to investigate potential earthquake ground motion amplification effects across the region. The results of the investigation are compared to the framework of the current New Zealand seismic design standards.

1. Tauranga Group

Undifferentiated Alluvium

Variability
Deposits in the flat low-lying parts of the region are large swamp deposits and peat bogs.

Deposit thickness
Can be greater than 10 m.

Puketoka Formation

Variability
Widespread alluvial deposits, comprised of silt, mud and clay with local gravel. Forming in valleys across the region.

Deposit thickness
Can be greater than 20 m.

2. East Coast Bays Formation

Variability
Interbedded sandstone and mudstone deposits which are usually highly weathered near their interface with overlying materials.

Deposit thickness
Can be greater than 20 m.

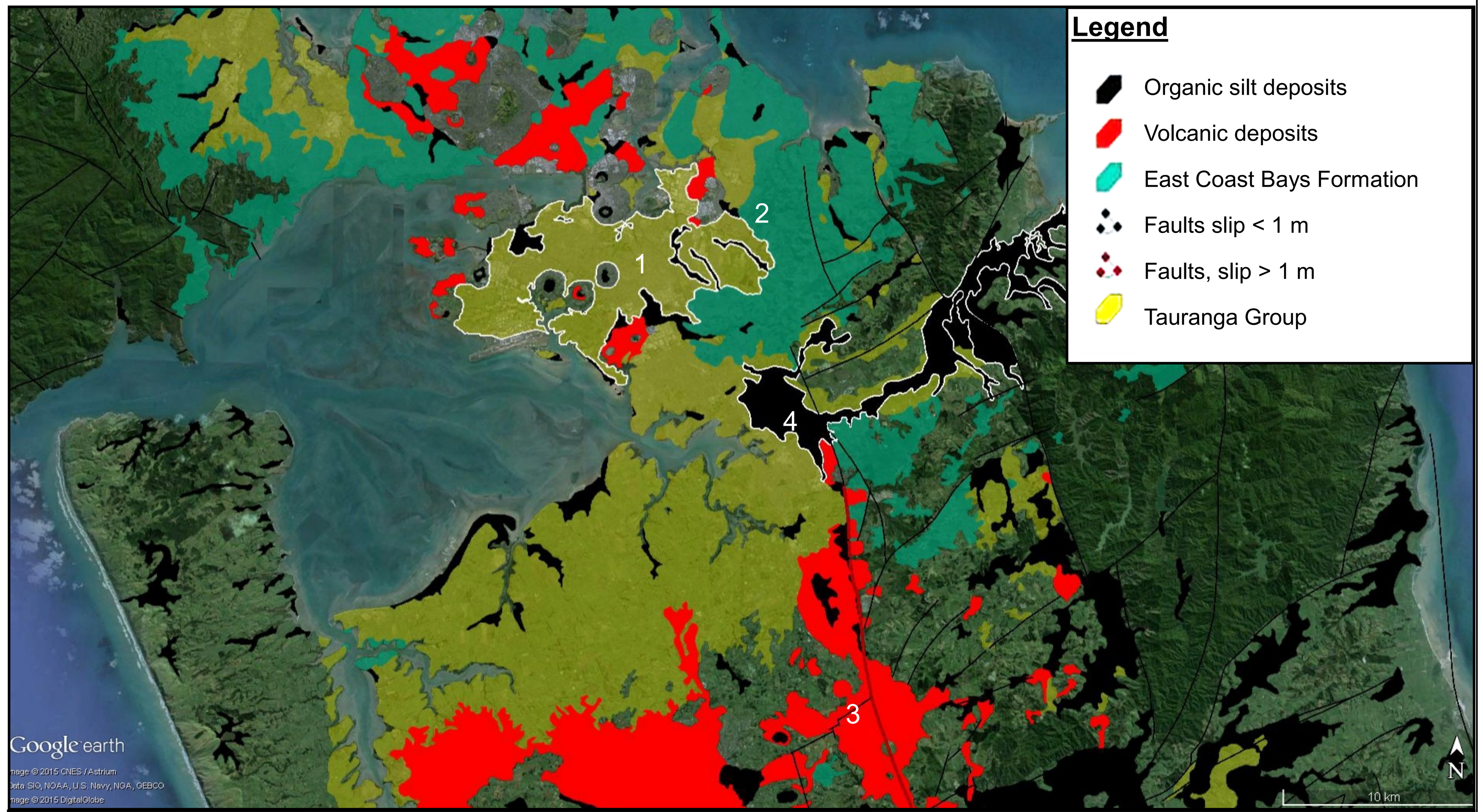

Figure 1. Plan view of the Manukau region with dominant surficial deposits. Numbers indicate deposit types discussed below.

Results:

Unit	Vs	Site Period
Organic silt deposits	60 m/s - 90 m/s. Minimal increase in Vs with depth (Figure 2b).	The site period (0.95 s; Figure 3, label A) marked is to a depth of 21.5 m. First sign of impedance contrast is at boundary of underlying ECBF.
Undifferentiated Alluvium	115 m/s -130 m/s. Minimal increase in Vs with depth	Estimated Vs average = 90 m/s. Vs = 4h/T. Where h is depth to bedrock or in this case a response at shallower depths and T is site period. The Vs profile (Figure 2b) was collected approximately 2 km north of the marked location and likely to have a similar soil column to this location.
Puketoka Formation	150 m/s - 350 m/s. Rapid increase in Vs with depth (Figure 2a).	Site period in this area increase away from the hills towards the centre of Organic silt deposit in the south and north, corresponding to site subsoil Class D or E (E, when active source Vs testing profiles are incorporated).
East Coast Bays	400 m/s - 500 m/s in the highly weathered profile. Gradual increase in Vs with depth.	Impedance contrast have been found between layers above bedrock.
Volcanic deposits	800 m/s - 2000 m/s. Vs is affected by weathering, fracture density and vesicularity.	Pending results.

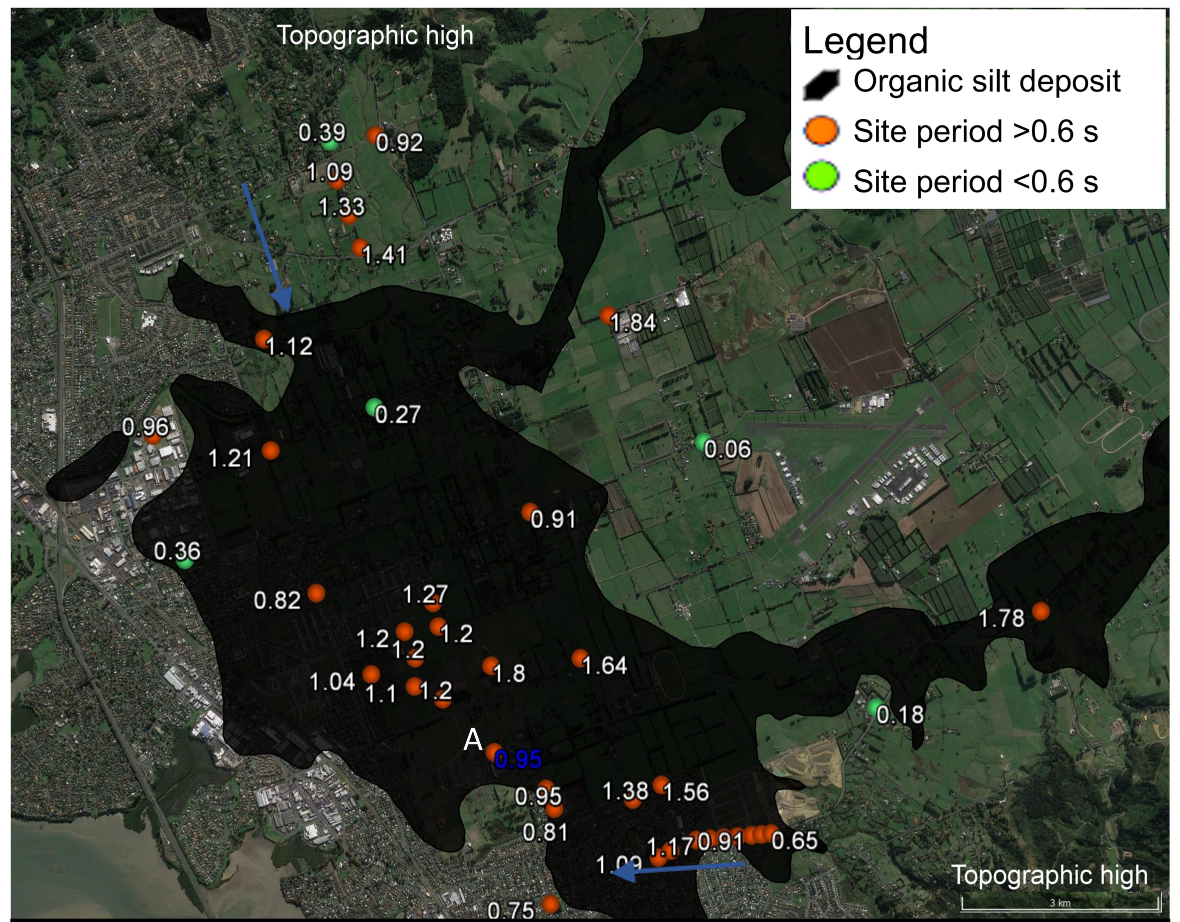

Figure 3. Organic Silt HSVR testing. A represents site period to average Vs comparison location. Arrows represent increasing site period away from

3. Volcanic surface deposits

Variability
Lava flows from volcanic eruptions in the area deposited highly variable basaltic deposits over original strata, with infilled valley areas of the most interest for site response.

Deposit thickness
Can be greater than 20 m.

4. Organic silt deposits

Variability
Subsurface investigation data shows that these silt deposits have a high organic content.

Deposit thickness
Can be greater than 20 m in some infilled valleys

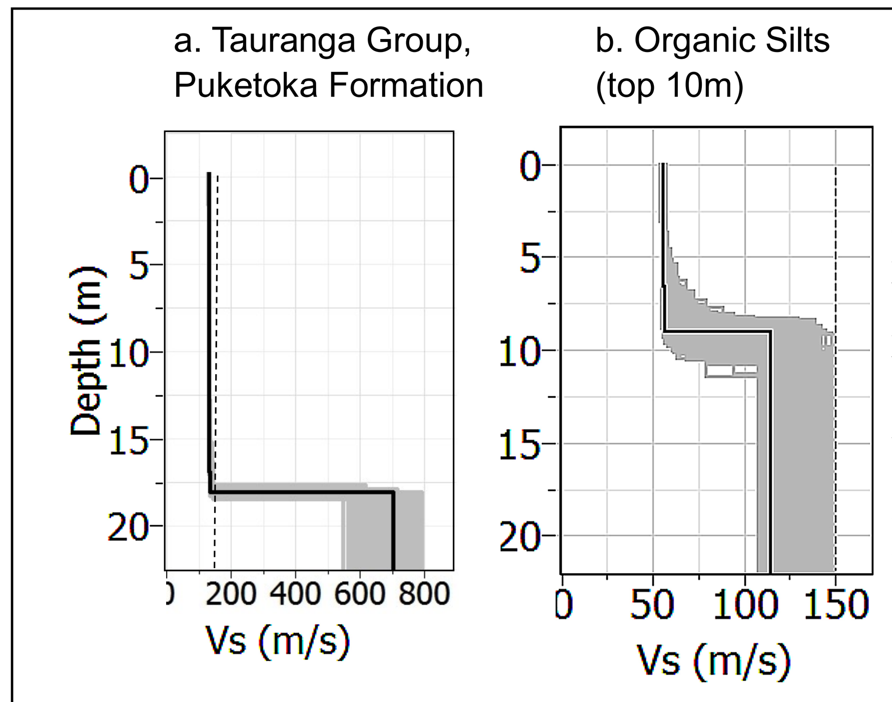

Figure 2. Vs profiles characteristic of deposits in locations marked on Figure 1 (labels , 1 and 4). Black line represents profile with lowest misfit (>1), grey lines represent profiles modelled within 20% of lowest misfit. Dashed line shows boundary for a Site class E classification (More than 10 m depth of soils with shear wave velocities of 150 m/s or less).

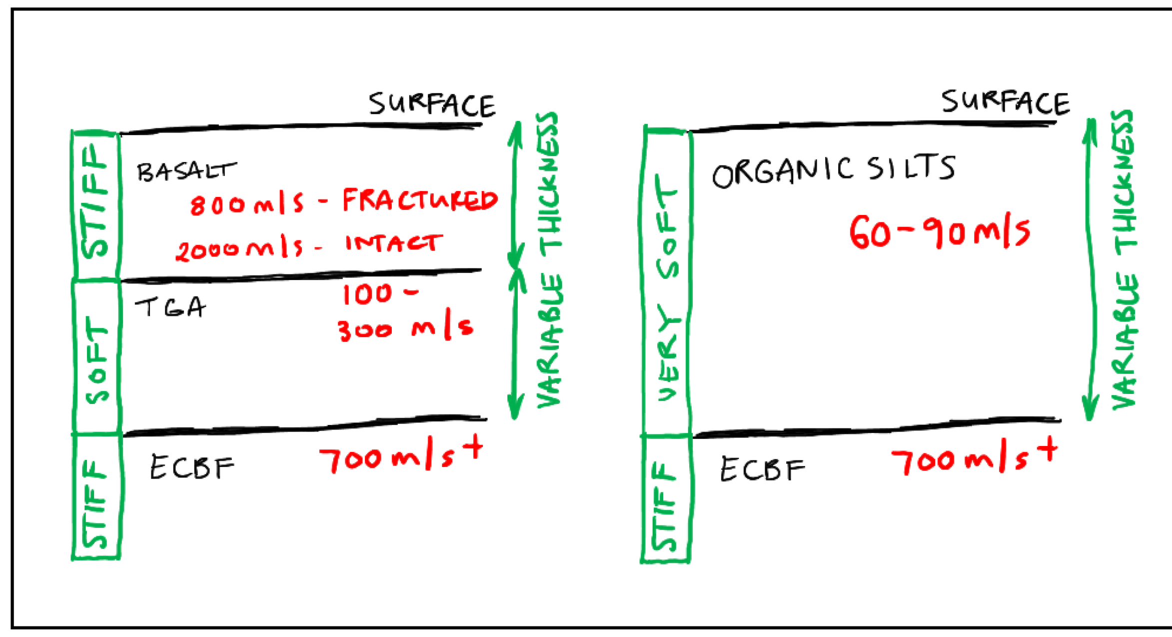

Figure 4. Annotation showing typical layering of deposits in the Auckland region. a. 'Stiff over soft' layering, where basalts have been deposited over alluvium and unwelded tuff deposits b. Organic Silts with variable thickness overlaying East Coast Bays Formation.

Discussion:

Volcanic Deposits

The stratigraphy in Auckland is very complex in many locations, and does not easily fit into the NZS1170.5 site classification framework. Basalt at the surface is often a Class B rock site, especially if sufficient subsurface investigations are not present to identify underlying alluvial material. The effect of the 'stiff over soft' layering, where basalts have been deposited over alluvium and unwelded tuff deposits (Figure 4a), will influence the dynamic response characteristics at these sites, even if the underlying materials have a Vs greater than the 300 m/s limit set in NZS1170.5 for site subsoil Class B.

Analysis has shown that this stiff over soft characteristic, has a significant effect, with the combination of layer thickness and Vs of the stiff and soft deposits meaning that site class will also be dependent on the fundamental period of the structure being designed at a location. A combination of these factors that will determine whether site subsoil Class B or C is appropriate, and it is possible that at a particular location a different site subsoil class may be appropriate for different structures.

Organic Silt and Peat Deposits

Vs survey results indicate that the surface peaty silt soils, which extend to ~10 m depth, should be classified as site class E (Figure 2b). These deposits have a thickness greater than the site class E limit of 10 m, and Vs significantly below the site class E limit of 150 m/s. If the underlying soft alluvium is also taken into account at this site (Figure 4b), the shear wave velocity for the top 20 m is well below the site class E limits in both Vs and thickness.

Deposits in this area are likely to exhibit strong amplification of ground motions from the underlying rock to the ground surface and may not be adequately captured by the NZS1170.5 framework because their properties are so far below the site class E limiting criteria. Even at locations that have 5 m thick or organic silt and peat deposits, the site response potential would be similar to the site class E limiting criteria (i.e. 5 m of material with a Vs = 75 m/s is equivalent to 10 m of material with a Vs = 150 m/s in terms of nonlinear site response).

Future Work:

This research is part of an ongoing PhD project and will increase the coverage of surface wave testing and other site investigations across the region. This information will be used to inform site response analyses of representative site profiles. Future work will focus on the soft highly organic silts and peats in the Manukau region to better understand the amplification effects of these deposits, and the effect of the stiff over soft layering due to the presence of surface volcanic deposits that have been deposited in valleys. This work will provide a better indication as to how these profiles fit into the current New Zealand Standards framework.