The Geology of Omokoroa-Te Puna Region within the Tauranga Area: A Case Study from the Geotechnical Investigation of Stage 2 of the Takitimu North Link Project

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ABSTRACT

Stage 2 of the Takitimu North Link (TNL) project involves the proposed construction of a new 7 kilometre long four-lane expressway for State Highway 2, connecting in the east to the end of Stage 1 near Loop Road, extending approximately 900m west of the existing Omokoroa Intersection. It is to include several bridges and grade separated interchanges. The geology between Te Puna and Omokoroa is highly variable and complex and includes weathered and unweathered ignimbrite deposits at depth, which are overlain by reworked aged alluvial deposits. The landform along the TNL alignment consists of several broad terraces which are underlain by volcanic tephra deposits. The terraces are bisected by deeply incised gullies with steeply graded escarpments. Geologically recent very soft alluvial deposits are present within the base of these gullies. A Geotechnical Investigation for the specimen design of Stage 2 was undertaken between March and October 2021 to develop a ground model for the site and to provide design parameters and key geotechnical recommendations for the construction of the expressway. This paper presents the geotechnical investigation techniques used during the geotechnical investigation and describes the logistical challenges associated with accessing site locations. It focuses on presenting and discussing the complex ground model that was derived from the investigations and some of the key geotechnical design issues that will require resolving due to the difficult ground conditions anticipated.

Keywords: road, geotechnical, alignment, terrace, gully, geology

1. INTRODUCTION

Stage 2 of the Takitimu North Link (TNL) project is a Waka Kotahi project that involves the proposed construction of a new 7 kilometre long four-lane expressway for State Highway 2 (SH2), that connects to the end of TNL Stage 1 near Loop Road, Te Puna, in the east and extends approximately 900m west of the existing intersection between SH2 and Omokoroa Road. The project involves the construction of eight bridges in locations where the proposed expressway alignment intersects with arterial roads and traverses streams, gullies and wetland areas. To meet the geometric requirements set out in the New Zealand Transport Agency (NZTA) Bridge Manual version 3.3 (BM3.3), earthworks involving cuts of up to 30m deep and engineered fill embankments with heights of up to 15m are anticipated.

2. INVESTIGATION SCOPE

2.1 Introduction

The geotechnical investigations that were undertaken along the TNL Stage 2 road alignment commenced in March 2021 and were completed in September 2021. The investigation locations generally targeted locations where large cuts, fills and major structures were proposed. They also involved both soil sampling techniques and in situ tests.

2.2 Investigation Techniques

2.2.1 Soil Sampling Techniques

Soil sampling techniques included hand auger boreholes, machine excavated test pits, and rotary cored machine boreholes. The material that was recovered was logged in accordance with the New Zealand Geotechnical Society (NZGS) guidelines described in NZGS (2005) and the NZTA guidelines described in NZTA (2015).

In excess of 174 hand auger boreholes were drilled using a 50mm diameter auger to depths of up to 5m below the existing ground level. In excess of 48 machine excavation test pits were undertaken using 8 to 16-tonne excavators equipped with 1.2m wide mud-buckets and were extended to depths of up to 4m below the existing ground level. In situ shear strength measurements were recorded within cohesive soils using a handheld shear vane apparatus. Dynamic cone penetrometer tests were undertaken where granular soils were encountered to determine the relative density of the soils.

In excess of 39 rotary cored machine boreholes were drilled to depths of up to 60m below the existing ground level. Rotary drilling techniques included triple tube and push tubes at selected depth intervals in the boreholes. In locations where bridge foundations have been proposed, acid sulphate samples were selected and collected from the material that was recovered from the boreholes.

In excess of 25 standpipe piezometers were installed within some of the machine boreholes using a 50mm uPVC pipe, gravel and bentonite plug, and a flush cover. Within two of the machine boreholes, nested piezometers were installed using two 32mm uPVC pipes. In locations where bridge foundations have been proposed, groundwater samples were collected to determine the sulphate and chloride concentrations.

2.2.2 In Situ Tests

In situ tests included cone penetrometer tests (CPTs), seismic penetrometer tests (sCPTs), and standard penetration tests (SPTs). In excess of 114 CPTs and 39 sCPTs were advanced to depths of up to 30m below the existing ground level using a track mounted Geoprobe rig and 36mm diameter cone. At several of the CPT investigation locations, dissipation tests were completed. During the advancement of the sCPTs, downhole seismic testing was undertaken at 1.0m interval depths, using a single geophone. The SPTs were carried out at 1.5m intervals during the advancement of the machine boreholes.

2.3 Laboratory Testing

Within some of the locations where soil sampling techniques were undertaken, undisturbed bulk samples and push tube samples were collected and selected for laboratory testing. The laboratory testing involved Atterberg limits, particle size distribution, organic content, one dimension consolidation (oedometer), dynamic triaxial tests, unconfined compressive strength, standard compaction, California bearing ratio, consolidated undrained triaxial compression, soil field density nuclear densometer direct transmission, soil core samples, and moisture content tests. The laboratory tests were undertaken in an IANZ accredited laboratory in accordance with New Zealand Standards 4402: 1986 and 4407: 2015, and British Standard 1377-7: 1990.

2.4 Logistical Challenges

The majority of investigations were undertaken during the wet and winter seasons, and also within gullies and wetland areas. Accessing investigation locations within these areas involved the mobilisation of equipment and machinery over wet, slippery, very soft and uneven terrain, sometimes with steep gradients and dense vegetation. There were several cases where excavation works were required to provide safe access tracks with gently sloping gradients that were unobstructed by vegetation, fences, or streams, and were also overlain by competent ground to prevent machinery getting stuck.

The land underlying the proposed alignment is currently occupied by rural properties and is privately owned. Accessing and undertaking investigations within these properties required obtaining permission from the property owners, which in several cases was not granted until near the end of the investigation program or was only permitted for a limited time. This resulted in piecemeal site access into properties along the road alignment. Investigations were prioritised to be completed in properties where site access was granted for a limited period, as well as properties where site access was fully granted. To minimise disruption to property owners and leaseholders, investigations were planned to be completed within a single property at a time where possible.

During August 2021, an outbreak of the COVID-19 pandemic resulted in a nationwide lockdown that lasted for two weeks within the Tauranga Area. No geotechnical investigation work was permitted during that time. After the lockdown restrictions were lifted, the investigation tests that were originally scheduled to be undertaken prior to the lockdown were prioritised to be completed. This enabled the initial geotechnical investigation testing schedule to be followed successfully.

The final investigation locations were undertaken in properties where access was not initially permitted, but eventually became granted after positive relationships between the consultants and the property owners had been developed. These remaining investigations were able to be completed. The proposed road alignment is also located along and near areas of Māori heritage, and investigations were required to not cause any destruction to Māori taonga. This was achieved by having an iwi monitor at each investigation location. Due to access restraints, seven test pit excavations and fourteen hand auger boreholes were abandoned.

3. GROUND MODEL

3.1 Geomorphology

The general landform within the Omokoroa-Te Puna region comprises a series of north-north-east trending terraces elevated at approximately between RL22m and RL62m (Moturiki Datum). The terraces are bisected by shallow gullies and deeper incised gullies that are associated with the Te Puna Stream. The gullies are located between Munro Road east and Ainsworth Road, and are also located at an inlet to the Tauranga Harbour approximately 700m to the south-east of the intersection between SH2 and Omokoroa Road. The elevations of the shallow gullies are at approximately RL8m to RL23m, and for the deeply incised gullies they are at approximately RL1m to RL18m. The transition between the gullies and terraces comprises moderately to steeply inclined escarpments that are inclined at gradients of 15 degrees to greater than 40 degrees. Relic landslide scarps are present on many of the escarpments.

3.2 Geological Setting

Omokoroa and Te Puna are located within the Tauranga basin, with the 2.09Ma Waiteariki Ignimbrite comprising the basement material (Briggs et al. 1996). The Tauranga basin has been subsequently infilled with late Pliocene and Pleistocene aged volcanic rocks and soils consisting of ignimbrites that are intercalated with estuarine and terrestrial deposits of the Matua Subgroup (Briggs et al. 1996). The Waiteariki Ignimbrite dips to the north-east as a result of uplift of the Kaimai Ranges (Briggs et al. 1996).

Within the Omokoroa-Te Puna region, the Te Puna Ignimbrite has previously been identified in locations to the east of the proposed TNL Stage 2 road alignment, where it overlies the Waiteariiki Ignimbrite and is underlain by soils of the Matua Subgroup, but it has not been identified in locations to the west of the road alignment (Briggs et al. 1996; CMW Geosciences 2021). It has a geological age of 0.93Ma, and is typically non-welded to partially welded and extremely weak (Briggs et al. 1996, 2005). The soils of the Matua Subgroup have a wide range of lithologies, and include fluvial deposits, estuarine and lacustrine muds, peats and lignites, and intercalated tephras (Briggs et al. 1996).

The peninsulas and terraces within the Omokoroa-Te Puna region are overlain by late Quaternary aged volcanic airfall deposits that originated from the Taupo Volcanic Zone, which comprise interbedded silts, sands and clays (Briggs et al. 1996). From oldest to youngest, these deposits include the Hamilton Ash, Rotoehu Ash, and Post-Rotoehu Ashes (Briggs et al. 1996). Within the gully features, the geology comprises Holocene and Late Pleistocene aged alluvial and peat deposits (Briggs et al. 1996). The current orientation of the terraces and gullies has been suggested to have been caused by a series of north-north-east striking faults that are regarded to be present in the Tauranga basin (Briggs et al. 1996).

3.3 Project Geology

The geological report created by Briggs et al. (1996) indicates that the proposed project alignment for TNL Stage 2 is underlain by units associated with the Waiteariki Ignimbrite and Matua Subgroup. This was later confirmed with the geotechnical investigations that were completed. The geological map of the area within which the road alignment comprises is presented in (Figure 1).

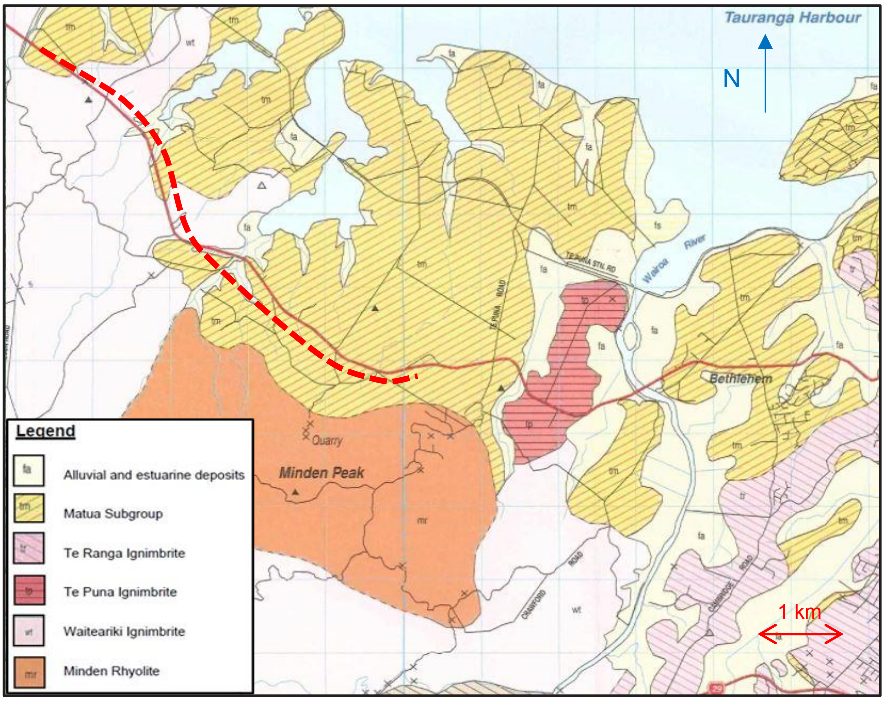

Figure 1: Geological map of the Te Puna-Omokoroa Region, with the extent of the road alignment for TNL Stage 2, modified from Briggs et al. (1996). The dashed red line indicates the approximate extent of the proposed road alignment. Units are described in the legend.

On the basis of the findings from the geotechnical investigation, the ground model for the road alignment for TNL Stage 2 includes seven geotechnical units. The units were determined based on having distinct engineering properties and are summarised in (Table 1) below:

Table 1: Summary of geotechnical units encountered underlying the road alignment for TNL Stage 2.

Geotechnical Units		Description
Unit	Name	
Holocene Alluvium	Recent Alluvium – Sands	Sand and silty sands. Light grey to grey in colour. Loose to medium dense.
	Recent Alluvium – Swamp Deposits	Interbedded alluvial silts, clayey silts, sandy silts, organic silts, and peat. Brown, grey, and bluish grey in colour. Very soft to soft in cohesive soils and very loose to loose in granular materials. Variable organic content.
Volcanic Ash	Late Quaternary Volcanic Airfall	Silt, sandy silt, silty sand, and sand layers. Orange-brown, brown, and grey in colour. Firm to very stiff. Moderately sensitive to sensitive.
Matua Subgroup	Matua Subgroup – Tephra	Interbedded silts, sandy silts, and clayey silts. Light orange, orange and brown in colour, often mottled. Firm to very stiff. Moderately sensitive to sensitive.
	Matua Subgroup – Tephra, Alluvium, and Intercalated Ignimbrite	Interbedded clayey silts, silts, sandy silts, silty sands, and sands. Wide range in colours. Firm to very stiff in cohesive soils. Loose to very dense in granular soils.
Ignimbrite	Non-welded Ignimbrite	Highly to completely weathered rock. Recovered as hard silts and medium dense to very dense sands. Consistency increases with depth.
	Partially welded, weathered Ignimbrite	Highly to completely weathered. Recovered as extremely weak to very weak rock.

3.4 Groundwater

Groundwater table depths were determined from monitoring the water levels within the piezometers that were installed within the machine boreholes during the geotechnical investigation. Within the Omokoroa-Te Puna region, the groundwater level is known to fluctuate significantly, and perched groundwater has been found to form after a heavy rainfall event due to the geological units having contrasting permeabilities.

4. GEOLOGICAL DESIGN ISSUES

4.1 Introduction

The findings from the geotechnical investigation have revealed that significant ground improvements are required to be resolved for the design and construction of Stage 2 of TNL to have grades and transitions that meet the performance criteria outlined in BM3.3. Two of the key geotechnical design issues that will need to be addressed are discussed.

4.2 Earthworking of Matua Subgroup Deposits

Earthworks associated with construction of Stage 2 of TNL are anticipated to involve cuts up to 30m deep in the elevated terraces. In the locations along the road alignment where road cuts are proposed over elevated terraces that expose the soil profile below the upper 6m, soils of the Matua Subgroup units will be encountered. These soils generally have high in situ moisture contents and very high sensitivities, and therefore can be extremely difficult to earthwork.

Previous experience has indicated that earthworking of soils from the Matua Subgroup units can be successful where there is sufficient land area for the soil to be spread, disked and then dried in thin layers. However, this can be difficult to achieve on roading construction projects, where there is limited time and space available for earthworking the soils. Therefore, the suitability of soils from the Matua Subgroup units for the use as engineered certified fill structures is considered unlikely; however, they can possibly be used for non-permanent fill structures such as pre-loads. Due to the high sensitivity, care would still be required when handling these soils, even if they are to be used in non-certifiable fill structures.

4.3 Settlement in Alluvial Deposits

Engineered earth fill embankments with heights of up to 15m have been proposed to be constructed over the base of the gullies along the road alignment. The soils within the base of the gullies comprised very soft to soft organic and estuarine silts, clays, and peat within the Recent Alluvium – Swamp Deposits unit, and were assessed for settlement induced from earth fill embankment loading.

Within the Recent Alluvium – Swamp Deposits unit, the primary consolidation settlement values were determined in accordance with 1-dimensional consolidation theory described in Terzaghi et al. (1996), and secondary creep settlement values were determined based on Mesri et al. (1994). For the earth fill embankment, a design life of 100 years and construction period of 18 months were used, and locally sourced borrow materials were assumed to be used for the earth fill. It was found that, where the thickness of the Recent Alluvium – Swamp Deposits units was greater than 1.1m, primary consolidation static settlement values exceeded the BM3.3 serviceability limit state performance criterion of 50mm over a design life of 100 years.

Ground improvement techniques are required in order for the predicted settlement values within the Recent Alluvium – Swamp Deposits units to be compliant with BM3.3 performance criteria. In some locations along the alignment, the removal and replacement of these units with engineered fill would be considered cost exorbitant, environmentally unacceptable, and/or difficult to achieve within locations below the level of the groundwater table. Alternative ground improvement options may be required that would reduce the values of post-construction settlement within the Recent Alluvium – Swamp Deposits unit. Some options for this to be achieved could be in the form of the construction of a pre-load fill embankment, the use of lightweight geofoam for the earth fill embankment construction, and/or undertaking ground improvement techniques within locations beneath where the earth fill embankment is proposed to be constructed.

Alluvial soils, such as the Recent Alluvium – Swamp Deposits units, have an inherent material composition that is influenced by the local depositional environment, that can be highly variable both laterally and at depth, and that can also be affected by the presence of sand lenses. This makes the time rates of settlement extremely difficult to estimate in alluvial soils. The settlement values that have been predicted for the Recent Alluvium – Swamp Deposits units were determined from the oedometer tests and prior back-analysis of settlement parameters from the TNL Stage 1 trial embankment, and are unlikely to account for the complete range of settlement values occurring across the entire length of the road alignment. Therefore, it is recommended that settlement monitoring instruments are installed at regular intervals along the road alignment where the earth fill embankment is proposed to be constructed, as this will enable back analysis of the resulting consolidation settlement parameters and allow for the subsequent geotechnical design to be progressively refined.

5. CONCLUSIONS

Based on the findings from the geotechnical investigation completed for TNL Stage 2, the following conclusions have been made:

- For major roading construction projects, significant challenges related to successfully completing a geotechnical investigation may arise if accessing investigation locations involves traversing difficult terrain, working within areas of archaeological significance, and/or requiring permission to enter private properties. These obstacles can be overcome with careful planning and by developing positive relationships with the stakeholders;
- Within deeper cuts along the TNL Stage 2 road alignment, soils within the Matua Subgroup unit are likely to be exposed, which are unlikely to be suitable for use as certifiable earth fill structures, and care should be used when handling those soils if they are to be used for non-permanent fill structures;
- Settlement values predicted from consolidation analysis indicates that earth fill embankment construction over the Recent Alluvium – Swamp Deposits units is likely to induce settlement that exceeds the BM3.3 performance criteria. Therefore, ground improvement in the form of construction of a pre-load fill embankment, the use of lightweight geofoam for the earth fill embankment construction, and/or undertaking ground improvement techniques within locations beneath where the earth fill embankment is proposed to be constructed, are likely to be required.

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