Chapter 14
Part G
VOLUME 2

Geotechnical Engineering and Resilience

Overview

Key geotechnical aspects of the Project include:

- Cut slopes in dune sand, including erodibility and erosion protection;
- Cut slopes in terrace alluvium;
- Embankment fills including undercut of peat and other compressive swamp deposits;
- Ground improvement and instrumentation;
- Earthworks and construction materials; and

The proposed cuttings for the Project will involve lowering the groundwater levels by up to 2m locally (across the road width) due to the installation of sub-horizontal drains at the cut slopes and sub-soil drains below the pavement. Excavations to undercut and remove peat will require lowering of the groundwater levels locally by about 3m over a period of a few days. These cuttings will have a negligible effect on the groundwater regime in the area, including on groundwater takes.

Construction and preloading of the embankments on soft ground will cause some ground settlement of the area immediately surrounding the preload areas. However, this work will be in rural areas and will be carefully managed.

The Expressway will have a good level of resilience to major earthquakes. In the event of a major earthquake, some limited subsidence of the Expressway embankments could occur due to liquefaction of isolated limited layers in the underlying ground, but the Expressway is likely to provide continued access, though with some uneven road surface which is likely to be reinstated within a few days to two weeks.

In the event of rupture of the Northern Ohariu Fault (located approximately 100m east of the Expressway), it is possible that the Expressway will be closed due to road deformation or rupture of the fault. It is possible that a fault rupture where the Expressway crosses the fault may have a distributed deformation rather than a concentrated rupture. The Northern Ohariu Fault crosses the earth ramp leading to the Te Horo overbridge over the Expressway. Any fault rupture displacement of the earth embankment is likely to disrupt access to the bridge. However, access can be quickly reinstated by earth moving machinery in the event of fault displacement.

14 Geotechnical Engineering and Resilience

14.1 Introduction

This Chapter summarises the geotechnical aspects of the Project. This includes identification and assessment of actual and potential effects relating to geotechnical engineering, including effects on groundwater, aquifers and existing abstraction bores, rivers and ground settlement, along with an assessment of significant hazards which include earthquake ground shaking, liquefaction and active fault rupture.

The report that contributes to this overall assessment is:

- Peka Peka to Ōtaki Expressway: Assessment of Environmental Effects Geotechnical Engineering and Geology (Technical Report 4).

This technical report is included in Volume 3 of this AEE report.

14.2 Existing Environment

14.2.1 General

The Expressway crosses the Ōtaki alluvial plain over a distance of approximately 13 km, from Taylors Road, just north of Ōtaki, to Te Kowhai Road, Peka Peka, in the south. The alluvial plain influences the topography significantly. Land either side of the route is generally flat or with low gradients. The foothills of the Tararua Ranges lie to the east, with waterways flowing from east to west towards the sea.

14.2.2 Geology

Field engineering geological mapping was carried out in November 2010 to confirm and map the geology and geomorphic features and the fault traces identified in the geological maps and aerial photographs. An engineering geological map was produced after the mapping and was refined after more information was gathered during the site investigations. A programme of geotechnical site investigations was developed, implemented and assessed.

Ground conditions in the Project area are summarised as follows:

- Alluvial floodplain deposits are found in the Ōtaki River floodplain and along other watercourses including the Mangaone Stream and the Waitohu Stream.
- Dune sand is located at the southern part of the proposed route (south of Mary Crest) and at the northern end (between Waitohu Stream and Rahui Road). The Expressway route crosses the old beach / dune deposits at the northern end of the alignment and to the west of the existing state highway south of Mary Crest.
- Swamp deposits (inter-dunal areas) comprising organic silt, clay, peat and sand are found north of County Road and at two locations south of Mary Crest.
- A significant length of the proposed route (from south of Ōtaki River to north of Mary Crest) is underlain by terrace alluvium.

14.2.3 Surface Water

The Expressway crosses a number of watercourses including the Mangaone Stream (at Te Horo), Ōtaki River (south of the Ōtaki township), Mangapouri Stream (near County Road, Ōtaki) and Waitohu Stream (north of Ōtaki).

14.2.4 Hydrogeology

The hydrogeology present in the Project area can be described in terms of the three groups of deposits as classified by Jones and Baker (2005) as follows:

- Glacial and inter-glacial deposits – a thick layered semi-confined to confined aquifer system of poorly sorted and stratified clay-bound gravels and sand overlying bedrock;
- Post-glacial beach and dune sand deposits – a low-yielding, unconfined aquifer which becomes semi-confined with depth towards the coast (up to 50 m depth). The aquifer system encompasses a coastal dune belt, which has resulted in the formation of a number of inter-dunal wetlands where drainage has been impeded; and
- Recent river gravel deposits – relatively high-yielding unconfined aquifers in the alluvial flood plain around the rivers. The gravels were reworked by rivers during the interglacial and postglacial period and have a direct hydraulic connection with surface water.

14.2.5 **Groundwater**

Groundwater levels were monitored in the shallow unconfined aquifers in the Project area and are summarised as follows:

- Groundwater at shallow depths of 0m to 2m in inter-dunal areas. Groundwater seepage was commonly observed at 1m to 2m depths in dry summer conditions. Some low-lying inter-dunal areas are commonly water-logged with standing water during the wet winter periods.
- Groundwater levels in the sand dune areas are generally dictated by the groundwater conditions at the inter-dunal depressions; thus the sand dunes are generally dry with reduced groundwater levels similar to that in the adjacent inter-dunal areas.
- Groundwater levels within the alluvial floodplain deposits are generally determined by the level of the adjacent watercourses such as rivers and streams, and are typically at 2m to 5m depth below ground level.
- Groundwater levels were found to be fluctuating between 5m to 10m below surface in the alluvial terrace deposits. The groundwater at the terrace south of the Ōtaki River is likely influenced by the fluctuation of the river levels.

14.2.6 **Natural Hazards**

The proposed Project is located in an area of high seismicity. Primary geo-hazards identified along the route include active faults, fault rupture, ground shaking, earthquake induced slope failure and liquefaction. The Northern Ohariu Fault and Ohariu Fault are the two active faults closest to the site. The Northern Ohariu Fault is mapped to be about 100m east of the Expressway at Te Horo. The Ohariu Fault is indicated to be about 1km away from the alignment to the southeast of Peka Peka Road. A rupture of either fault could result in between 3m and 5m of right lateral displacement at the ground surface with varied vertical displacement. It is also expected that an individual surface rupture along the Northern Ohariu Fault could generate 3m to 4m of right-lateral displacement at the ground surface, with a lesser and variable amount of vertical displacement.

There is potential for significant ground shaking during large earthquakes. The ground shaking is expected to be modified and exacerbated by the presence of deep soil deposits and soft ground in the area. The design horizontal peak ground accelerations to be used in assessing the stability of slopes and structures such as fill embankments and bridge structures have been derived according to the New Zealand Earthquake Loading Standard, NZS 1170.5: 2004 (Standards NZ, 2004) and the Bridge Manual (Transit NZ, 2003) and its Provisional Amendment in December 2004.

An importance level of 3 and a 100 year design life is assumed for bridge structures, resulting in an annual probability of exceedance of 1/2,500. For other structures (e.g. free standing walls, cuttings) which do not form an integral part of bridge structures, a return period factor of 1.5 is adopted. This is equivalent to an annual probability of exceedance of 1/1,500.

The Regional Slope Failure Hazard Map (Wellington Regional Council, 1995) indicates a generally low susceptibility to earthquake-induced slope failure along the Project route. Localised narrow bands of high susceptibility to slope failure in earthquakes exist along the abandoned sea cliff to the south of Mary Crest to Peka Peka Road and along Te Waka Road and the river terraces south of Ōtaki River, just north of Ōtaki township and along the stream opposite Te Hapua Road. There is also a high susceptibility locally at a steep portion of the railway cutting just south of the Ōtaki River crossing.

Liquefaction as a consequence of earthquakes could lead to subsidence and lateral spreading, which could affect any surface development. According to the Regional Liquefaction Hazard Map (GWRC, 1993) the majority of the proposed Expressway is situated in areas which are not susceptible to liquefaction. In areas to the north of Ōtaki River, variable potential for liquefaction from low to high may be present. There is very low or no potential for liquefaction between Ōtaki River and Mary Crest. A moderate potential for liquefaction is indicated in the areas underlain by sand dunes and inter-dunal deposits, south of Mary Crest. Results of the site investigations show that there are localised sand and silt layers within the site that could potentially liquefy.

14.3 Assessment of Environmental Effects

An engineering assessment of geotechnical aspects for the Project has been completed and is presented in Technical Report 4, Volume 3. This includes a geotechnical engineering assessment of:

- Cut slopes in dune sand, including erodibility and erosion protection;
- Cut slopes in terrace alluvium;
- Embankment fills including undercut of peat and other compressive swamp deposits;
- Ground improvement and instrumentation;
- Earthworks and construction materials; and
- Effects on groundwater regime and on groundwater takes in the area.

The report includes consequential design requirements that are incorporated into the Project design.

An AEE related to geotechnical engineering and a study of route security for the Project is also included in the report. A summary of key findings is listed below.

14.3.1 Potential Groundwater Drawdown

Groundwater drawdown would cause a reduction in bore water pressure, which might result in ground settlement and changes to groundwater flow.

Permanent Drawdown due to Cuttings

The potential of groundwater drawdown due to formation of cuttings has been reviewed. It is assessed that the excavations in dune sand areas will generally be formed above the measured groundwater level and thus would have negligible effects on the groundwater table. For excavations within terrace alluvium to the south of Ōtaki River, the measured highest groundwater level in the area is about 1m above the excavation level. In order to construct the Expressway in this location, the groundwater table would need to be drawn down about 2m locally across the road width, which can be achieved through the installation of sub-horizontal drains at the cut slopes and sub-soil drains below the pavement.

Temporary Drawdown due to Undercutting

Undercutting in the order of 3m depth is expected at some of the wet inter-dunal areas. These areas will be backfilled with well-compacted materials. During excavation, groundwater in the excavation will be drained temporarily by sumps or drains. This will lead to localised draw-down of groundwater in the surrounding area, up to about 3m depth below ground surface.

The effects of the both permanent and temporary groundwater drawdown are considered to be negligible.

14.3.2 Effects on Groundwater Flow and Direction

Groundwater in the area generally flows from the east towards the sea coast. Since the permanent groundwater drawdown is local and of a relatively small order, its effects on groundwater flow and direction are considered to be insignificant. Temporary groundwater drawdown would have negligible influence on the long-term groundwater flow and direction.

14.3.3 Effects on Groundwater Use

The long term effects of the Project on consented water takes are considered to be negligible.

There may be some minor, temporary, localised effects on existing ground water abstractions during construction, so groundwater levels and pressures will be monitored during construction, and conditions are proposed to ensure that any such effects will be remedied through provisions of an alternative water source and that there will be no effects on water abstraction in the vicinity.

14.3.4 Ground Settlement

Ground settlements can be caused by consolidation of ground due to groundwater drawdown and construction of fill embankments on compressible ground.

Consolidation of Ground due to Groundwater Drawdown

Since the permanent groundwater drawdown at the cutting areas is local and of small order (about 1m to 2m), and the ground at these areas (dense terrace alluvium) has low compressibility, the resultant ground settlement is likely to be negligible.

Temporary excavation and dewatering at some of the inter-dunal areas could potentially cause groundwater drawdown up to about 3m deep. As the groundwater drawdown is temporary, and for no more than a few days at a time, the ground settlement during this period will be small. Also these areas are generally farming areas and there will be no buildings near the Project works at risk of damage from settlement of that size. Therefore such ground settlements will have a negligible, if any, adverse effect on the environment.

Consolidation of Ground due to Fill Embankments

Soft and compressible materials such as peat in inter-dunal areas will be removed / undercut before placing of fill. There are some areas along the route, e.g. south of Mary Crest, where soft materials of more than 3m thickness are present and it becomes costly to completely undercut. In such instances partial undercutting to 3m depth followed by preloading is proposed, with extra surcharge to accelerate consolidation during construction. However, secondary consolidation is expected to continue even after construction. This will result in ground settlement within the road footprint and a short distance in the surrounding area.

The adjacent existing SH1 and railway in the area south of Mary Crest could potentially be affected. The settlement of the embankments as well as the State highway and railway will be monitored during construction. The State highway will be reinstated and the railway line re-levelled using ballast if necessary.

Interdunal deposits are found north of Rahui Road. Current investigations show that the soft materials are up to 3m thickness and thus can be removed completely before the placing of fill. However, should the soft materials be deeper and some soft materials remain below a nominal 3m depth of undercut, ground settlement due to construction of embankment on soft ground will occur.

There are no buildings in the surrounding area that may be affected by such settlements and therefore any effects will be low. However, settlement will be monitored postconstruction to ensure that any effects on adjacent facilities, such as SH1 and the NIMT south of Mary Crest, are carefully managed and remedied. Conditions are proposed to achieve this.

Minor road repair to existing roads, such as sealing of cracks, may be required during construction and the pavement may need to be reinstated on completion of the preloading and construction.

14.3.5 **Wetlands**

The temporary groundwater drawdown will not have a significant effect on the long term viability of the proposed Ōtaki Railway wetland, the Mary Crest wetland or the wetland to the west of County Road. A low embankment will be required with a weir to ensure that water is retained in the wetland and surplus water can overflow through the weir during wet weather conditions.

14.3.6 **Effects of Bridge Foundation Works**

The bridge scheme design shows that bridges will generally be founded on bored piled foundations and abutments on either reinforced soil walls or spill through embankments.

Some potential effects due to piling works are:

- Ground settlement when piles / casings are driven through loose materials (such as loose sand), which causes vibration and consolidation of the ground surrounding the piles. There are no buildings directly adjacent to the proposed bridges, and therefore any effect on adjacent structures is highly unlikely. However, where there are buildings in close proximity to new bridge structures (e.g. the former Milk Treatment Station at Rahui Road) ground settlement will be monitored.
- Spilling of concrete and grout leading to pollution of watercourses. Best practice measures will be taken when constructing piles, particularly adjacent to waterways, to prevent any spillage that could contaminate waterways.
- Change of aquifer system – such as piling into a confined aquifer and resulting in the pressurised artesian water flowing through the aquifer. The site investigations have not shown the presence of confined or artesian aquifers that may be affected within the depth of the proposed piles. Therefore any risk to the groundwater systems is considered to be low.

14.3.7 **Erosion Control at New Cuts Slopes**

The newly-formed cuttings sand dune areas will be susceptible to erosion. Adequate measures are required to protect the cuttings from erosion. Appropriate measures include:

- Re-vegetation as soon as possible after formation of cut, and maintenance of the vegetation during the early stages after construction. The type of vegetation should be carefully selected to suit the local coastal dune sand environment;
- Installing erosion protection geotextile mats; and
- Placing topsoil or peat on the slope surface.

With appropriate management and measures, the effects of proposed excavations on sand dune erosion can be kept to a minimum and adverse effects are unlikely.

14.3.8 **Route Security**

The Expressway will have good resilience against earthquakes and other natural hazards. The Expressway is likely to remain open for access in the event of a large magnitude 7.5

local earthquake in the Region, perhaps at some reduced level of service due to damage to the road associated with localised liquefaction and subsidence. These areas are generally likely to be able to be reinstated quickly (e.g. within 3 days to 2 weeks).

An objective of the Project has been to avoid crossing the Northern Ohariu Fault with structures which may be severely damaged and will take a long time to reinstate. The Project does cross the fault, namely where an earth ramp leads to the Te Horo overbridge, a location where the topography enables quick restoration of access. That aside, the Northern Ohariu Fault trace becomes indistinct in the lidar-based topography[29], and it is possible that an apparent fault rupture near to where the Expressway passes the fault is a distributed deformation rather than concentrated rupture. This will reduce the extent of any damage and disruption, and in the event of damage the Expressway is likely to be able to be opened for limited access by earthmoving machinery.

14.4 Measures to Avoid, Remedy or Mitigate Actual and Potential Adverse Effects

14.4.1 Consolidation of Ground due to Fill Embankments

Ground settlement will be closely monitored during and after the preloading period to assess the effect to settlement of the adjacent ground, especially at the current SH1 and NIMT. Any development of cracks on the seal should be recorded and monitored.

Minor road repair such as sealing of cracks may be required during construction and the pavement may need to be reinstated on completion of the preloading and construction. Short, localised sections of the NIMT may also need to be re-levelled during or soon after construction.

14.4.2 Wetlands

Installation of low embankments with a weir to ensure water is retained within the wetland and surplus water can overflow through the weir during wet weather conditions.

14.4.3 Effect of Bridge Foundation Works on the Environment

Site investigation results did not show significant thick layers of loose soil that could result in settlement due to vibration. Care will be taken during pile construction particularly adjacent to waterways to prevent spillage and contamination and ground settlement will be monitored when piling takes place adjacent to the existing railway and State highway, or in close proximity to buildings. This work will be the subject of a construction management plan which will include measures to avoid possible spillage.

In the unlikely event that any artesian water is encountered, this can be managed through raised casing above ground level.

14.4.4 Erosion Control at New Cut Slopes

Re-vegetation should occur as soon as possible after formation of cut areas, and vegetation should be maintained during the early stages after construction. The type of vegetation should be carefully selected to suit the local coastal dune sand environment. Erosion protection geotextile mats should be installed. Topsoil or peat should be placed on slope surfaces. With appropriate management and these measures, the effects of excavation on sand dune erosion can be minimised and adverse effects are unlikely.

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[29] Lidar (Light Detection And Ranging) based topography is an optical remote sensing technology that can measure the distance to, or other properties of, a target by illuminating the target with light, often using pulses from a laser.