



ENGEO

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Geotechnical Assessment

Kaiwaka

Kaipara District

Submitted to:

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1 Executive Summary

This report presents our geotechnical assessment and hazard mapping for the Kaiwaka area. The purpose of this geotechnical assessment was to provide the Kaipara District Council (KDC) with information on land stability and other geotechnical hazards that could constrain developments of the area defined by KDC as 'Future Residential and Business Growth Area' and 'Greater Structure Plan Policy Area' of Kaiwaka.

In general, this area is characterised by rolling hills underlain by complex geology which are bisected by relatively poorly defined valleys and incised gullies filled with young alluvial sediments. Elevations range from essentially sea level, within the Kaiwaka River in the north-western corner of the study area, up to approximately 160 m above mean sea level in the mountains in the southern portion of the study area. The Kaiwaka River is a prominent feature that begins near downtown Kaiwaka and flows east, where it joins the Wairau River to form the Otamatea River, which drains into the Kaipara Harbour. The Kaiwaka River is fed by a series of tributaries and drainages within its catchment.

The area contains five dominant groups of geological materials. These geological materials are: Undifferentiated Mélange, Mahurangi Limestone, Punakitere Sandstone, Pakiri Formation and Tauranga Group soils.

Based on the findings of this geotechnical assessment, the primary geotechnical constraints of the Kaiwaka Indicative Growth Area are slope instability, liquefaction and lateral spread potential, and settlement due to consolidation of soft compressible soils. Additionally, development within the area may need to consider expansive soils, acid sulphate soils, and karst topography. Given the observed instability, soil and rock properties, presence of clean water sources and groundwater conditions, the potential for on-site effluent disposal should also be considered early in the planning phase.

2 Introduction

ENGEO was engaged by Kaipara District Council (KDC) to undertake an assessment of engineering geology and geotechnical hazards and their associated risk for development within the growth area of Kaiwaka. Our assessment has been largely informed by desktop-level studies and geomorphological mapping, and should not be used as a substitute for detailed geotechnical site investigations and site specific hazard assessments.

Based on the request for pricing and information, Contract Number 4107.908 and discussions with KDC, we prepared our scope to inform Council of the following:

- Extent of slope instability hazard within the Kaiwaka area;
- Suitability of the ground for the disposal of effluent waste water;
- Suitability of the land for future development;
- Risks and hazards of the Kaiwaka area;
- Provide KDC with a basis for determining the geotechnical assessment requirements to support applications for subdivision and building consents in these areas; and
- Assist Council with future planning of the areas.

3 Scope of Work

The geotechnical assessment and geotechnical hazard mapping has included the following scope of work:

- Review of published geological maps;
- Review of historical aerial photographs available in the Retrolens database, Google Earth images, New Zealand Geotechnical Database, and other publically available databases;
- Undertaking a desktop geotechnical hazard assessment;
- Production of a geotechnical hazard plan showing a three-level hazard profile (Low, Moderate and High); and
- Preparation of this report.

Our scope of work has not included site specific geotechnical investigation or geotechnical design solutions, mapping of overland flow paths, or assessment of coastal hazards related to tsunami inundation, flooding, or sea level rise, as we understand this will be provided in assessments by others. Site specific geotechnical investigations may be required by Council to address these hazards, as well as define the bearing capacity, seismic site classification, expansive site class, an assessment of natural hazards in accordance with Section 106 of the Resource Management Act (1991), and other design criteria required to develop land within this area.

4 Our Approach

This geotechnical hazard assessment has been carried out by Engineering Geologists from ENGEO Limited using a geomorphological assessment and slope profile assessment approach, in accordance with industry standard practice. Geomorphic assessments have been completed based on stereo-paired aerial photographic interpretation, review of historical aerial photos and Google Earth images, and supplemented by limited field reconnaissance mapping. Due to the limited coverage of LiDAR data over the study area, the LINZ Topo50 20 m contours (vertical accuracy ≤ 10 m) were used to create a digital elevation model (DEM), and then a slope model of the study area. All GIS assessment was executed in the New Zealand Transverse Mercator (NZTM) coordinate system.

Slope profile assessments were made by overlaying regional geology, available geotechnical and mining base maps on the slope model. Slope stability and settlement parameters were derived by applying published strength characteristics, general consolidation and liquefaction potential estimates to each geological material. A three-level hazard based geotechnical assessment has been undertaken to inform Council of the level of impact a hazard may potentially have on future developments and the level of investigation that may be necessary to develop land within these three zones.

5 Statutory Framework

The Resource Management Act 1991 and the Building Act 2004 are the primary pieces of legislation in New Zealand that define the responsibilities of the consenting authorities with regard to management of land subject to natural hazards. The geotechnical assessment of natural hazards is undertaken with due regard for the potential for future land use to mitigate, or exacerbate, identified hazards in keeping with the intent of the legislation.

5.1 Resource Management Act 1991 (RMA)

Section 106 of the RMA states that the consent authority may refuse subdivision consent in certain circumstances. As such, a site specific assessment must consider if the site is presently subject to erosion, significant subsidence (including liquefaction), falling debris, slippage or inundation by soil or rock in accordance with the provision of Section 106 of the Resource Management Act 1991.

Furthermore, in accordance with Section 106, a site-specific assessment must consider if the future planned development or land use is likely to accelerate, worsen or result in material damage to the land.

5.2 Building Act 2004

Section 71 of the Building Act 2004 requires Council to refuse the granting of a building consent for construction of a building, or major alterations to a building, if the land on which the building work is to be carried out is subject or is likely to be subject to one or more natural hazards, or if the building work is to accelerate, worsen, or result in a natural hazard on the land or other property. As such, natural hazards, including erosion (coastal erosion, bank erosion, and sheet erosion), falling debris (including soil and rock), subsidence, inundation (including flooding, overland flow, storm surge, tidal effects, and ponding), and slippage should be assessed if land use includes such building works.

However, consent may be granted under Section 71 if the building consent authority is satisfied that adequate provision has been, or will be made to protect the land, building work and other property from the natural hazard(s) or restore any damage to that land or other property arising as a result of the building work.

Further, Council may issue a Building Consent under Section 72 of the Building Act if it considers building work will not cause or make worse a natural hazard on the property.

However, it should be noted that a Building Consent granted under Section 72 must include – as a condition of consent - notification on the property title that consent was granted under Section 72 and identify the natural hazard concerned.

5.3 Intent of Current Study

The intent of the hazard assessment undertaken for this report is to provide KDC with a desktop-level geographical distribution of potential areas where the requirements of the RMA and Building Act:

- Are likely to be met with little additional geotechnical assessment (Low hazard areas).
- May be met; however, further geotechnical assessment and hazard mitigation works may be required (Medium hazard areas).
- Are unlikely to be met without significant geotechnical assessment and comprehensive hazard mitigation works (High hazard areas).

As far as has been reasonably practicable with the available site data, the high, medium and low divisions within each hazard type are considered to be broadly consistent. In other words, the hazards posed in a high slope stability hazard area have a similar potential to cause building damage and land deformation as would a high liquefaction hazard area.

6 Study Area

The Kaiwaka Growth Area is an approximately circular shaped region with an area of approximately 1,600 hectares, located around the township of Kaiwaka, within the Kaipara District. The study area lies approximately 20 kilometres north of Wellsford, 18 kilometres west of Mangawhai Heads, and 60 kilometres south of Whangarei.

The study area includes portions of State Highway 1, Gibbons Road, Kaiwaka-Mangawhai Road, Settlement Road, Greenway Road, Oneriri Road, Pukenui Road, minor tributary roadways and subdivision streets, KiwiRail's North Auckland Line (NAL), the township of Kaiwaka and the commercial, industrial and residential developments within the township, large paddocks used for farming and horticulture, and the mouth of the Kaiwaka River. The vicinity of the study area is shown in Figure 1, and the Kaiwaka Indicative Growth Area is shown in Figure 2.

Figure 1: Site Vicinity

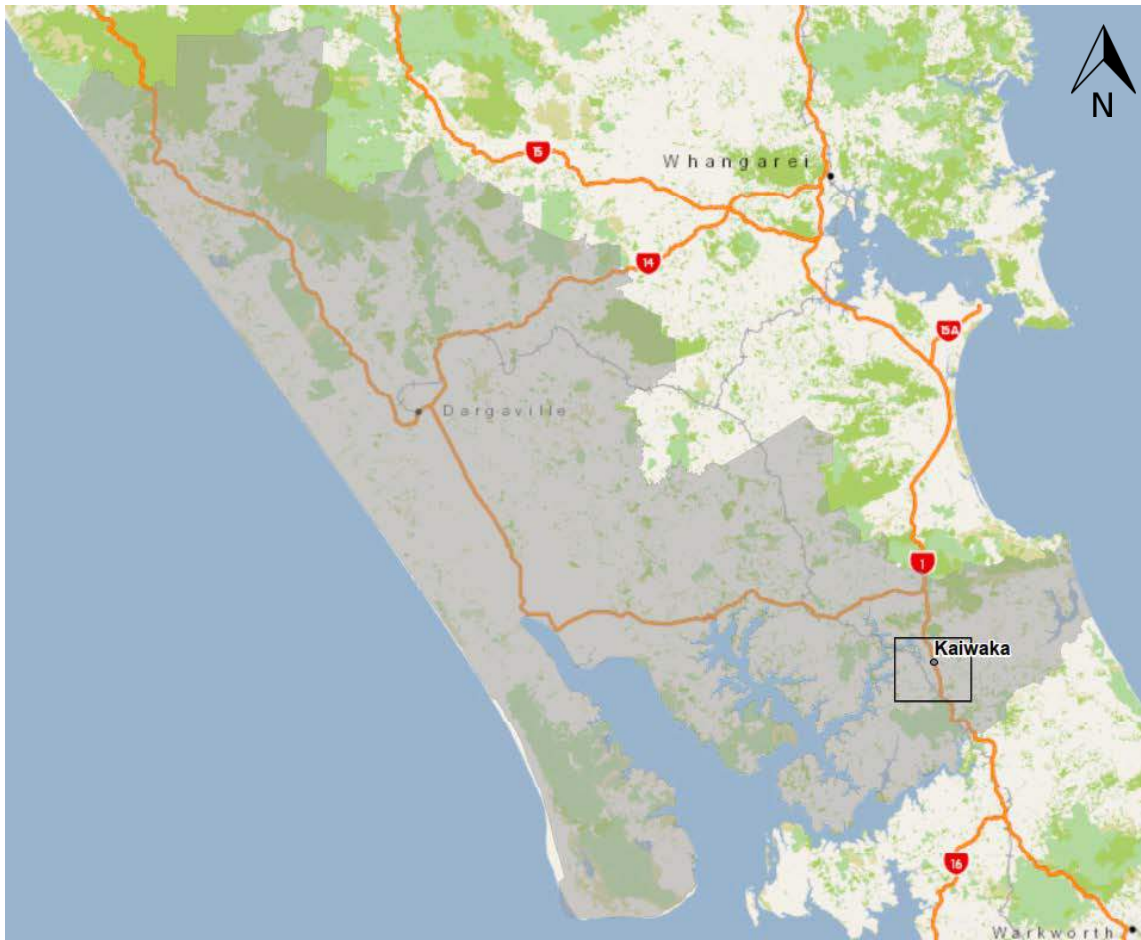


Image sourced from Land Information New Zealand, CC-BY-3.0. Not to Scale

Figure 2: Indicative Growth Area

Image sourced from Eagle Technology, CC-BY-3.0. The Indicative Growth Area boundary was provided by Kaipara District Council. Not to Scale

7 Geological Setting

The geological setting of Kaiwaka has been established through a review of published geological information for the area, principally the GNS 1:250000 map which is the prevailing map resource for New Zealand, and supplemented by a site walkover to observe the landform and outcrops, where accessible.

A summary of the mapped geology of the Kaiwaka area is presented in the following sections.

7.1 Published Geology

The primary geological map reference for the Kaiwaka study area is the 2009 GNS 1:250000 map, “Geology of the Whangarei Area” (Edbrooke and Brook, 2009). This map has been compiled using data from numerous sources including published geological maps, reports and papers, unpublished university theses, technical reports, field trip guides, and various geological databases.

A limited programme of field mapping was also undertaken between 2003 and 2008 to extend map coverage across the entire mapped area, although landslides were predominantly mapped from aerial photographs.

The QMAP series are widely accepted as an accurate account of the surface expression of geological units across the country. However, at a regional 1:250000 scale, the detail and accuracy of unit boundaries and structural features are indicative only and should not be relied upon exclusively to support land use planning and geotechnical assessment.

The map has been adapted to create Figure 3, depicting the surface expression of the geological units mapped across the study area.

Figure 3: Geology Map

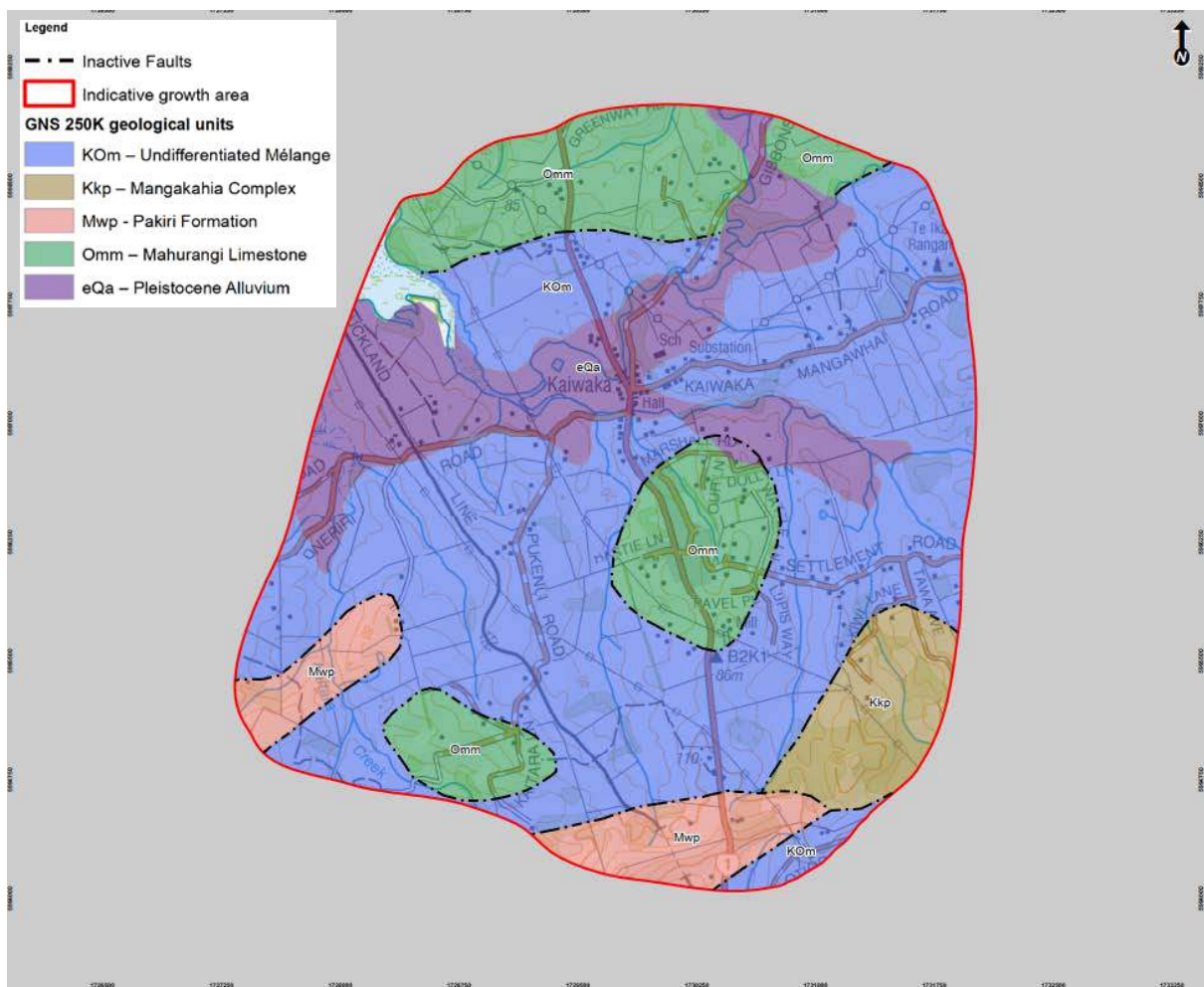


Image adapted from GNS QMAP. Not to Scale

7.2 Northland Allochthon

Much of the Northland region is underlain by Cretaceous- to Oligocene-aged rocks of the Northland Allochthon, a series of thrust sheets and mélangé containing a range of sedimentary and igneous rocks emplaced across Northland as a result of thrusting and gravity sliding into the deepening Waitemata Basin from the northeast. The allochthon was placed during the Miocene epoch, dating the unit to approximately 15 million years.

Due to the nature of their emplacement, the thrust sheets (or nappes) are faulted, folded and sheared resulting in a complex structure that makes identification of the original stratigraphic units difficult. Accordingly, four distinct lithological units have been established to describe the bulk of the Northland Allochthon, with some geologically unique outliers described as separate rock units.

In the Kaiwaka study area, the Northland Allochthon rocks comprise Mahurangi Limestone of the Motatau Complex, Punakitere Sandstone, Undifferentiated Mélangé, which comprises predominantly Mangakahia Complex mudstones with included blocks of Mangakahia Complex, Motatau Complex and Te Kuiti Group rocks, and Pakiri Formation. These units are described in the following sections.

7.2.1 Motatau Complex - Mahurangi Limestone (Omm)

Mahurangi Limestone is mapped in the northern, central and south-eastern portions of the study area. The northern-most portion of the study area is bisected by a Pleistocene alluvium deposit, and the other two areas are isolated blocks bounded by faults.

Mahurangi Limestone is described as a pale grey to white, massive- to thinly-laminated, fine grained, micritic limestone. It is moderately to well cemented, with a sheared and fractured rock fabric.

7.2.2 Mangakahia Complex - Punakitere Sandstone (Kkp)

A small area of Punakitere Sandstone is mapped in the south-eastern portion of the study area, south of Settlement Road and east of State Highway 1. Punakitere Sandstone is described as thin- to thick-bedded alternating layers of sandstone and mudstone with minor mudstone-dominated flysch. Beds of pebbly sandstone, grit, and conglomerate are also present throughout the unit.

The grey rocks weather to a yellow-brown and reddish-brown, and are commonly friable where exposed.

7.2.3 Undifferentiated Mélangé (KOM)

Much of the central, eastern and western portions of the study area are mapped as Undifferentiated Mélangé, and likely underlies much of the Tauranga Group alluvium to the north. The Undifferentiated Mélangé is a thick and laterally extensive unit mapped across much of the area south of Whangarei, comprising a matrix of sheared Mangakahia Complex red, brown, green and grey mudstones with tectonic blocks of Mangakahia Complex, Motatau Complex and Te Kuiti Group rocks.

The nature of the rock mass in this unit is variable across short distances, as the displaced blocks within the matrix can range in size from metres to kilometres.

7.2.4 Pakiri Formation (Mwp)

Two small areas of Pakiri Formation are mapped in the southern and south-western end of the study area. In this area, Pakiri Formation, part of the Waitemata Group, comprises predominantly volcanic-poor flysch sequences of thickly-bedded sandstone and grit layers alternating with laminated mudstone layers. The rock weathers locally to form a residual soil profile comprising typically grey, orange and brown clays and silts with occasional sandy layers.

7.3 Tauranga Group

Pleistocene-aged alluvium of the Tauranga Group is mapped in the low lying areas in the northern portion of the study area around Kaiwaka River and other main drainages near Oneriri Road, Gibbons Road and south of Kaiwaka-Mangawhai Road.

This unit comprises river, lake and estuarine sediments that have been deposited in river valleys prior to subsequent sea level fluctuations, resulting in sequences of alluvial terraces and flood plains. The Tauranga Group is further subdivided into Pleistocene and Holocene-age alluvium, as described in the following sections.

7.3.1 Pleistocene Alluvium (eQa)

Pleistocene Alluvium, comprising poorly to moderately consolidated mud, sand and gravel with peat and organic beds is mapped within the study area, and can form terraces above present day flood plain levels.

The alluvium is derived from erosion and weathering of *in situ* Northland Allochthon residual soils, mudstone, sandstone and limestone units. Organic soil and peat layers associated with decomposition of organic matter in swamp and estuarine environments are likely to be present throughout the unit.

7.3.2 Holocene Alluvium (Q1a)

Much like the Pleistocene Alluvium deposits, the Holocene Alluvium typically comprise soft and poorly consolidated mud, sand and gravel units with peat and organic soil beds. This younger alluvium underlies present day flood plains in the base of stream and gully systems, but has not been included in regional maps by GNS for this area.

7.4 Unmapped Units

7.4.1 Historical Fill

Pre-existing fill describes deposits of human origin that have been placed in association with historical land modification and development work. This can include reclaimed land near the river, landfills, land development structural fills, and small-scale filling associated with domestic and farming activities including culverts, earth bunds and offal pits.

No such deposits have been mapped within the study area, as only the largest and most significant fill areas have been recorded at the 1:250000 map scale. However, pre-existing fill is likely to be present within the study area at discrete locations. Unless placed under supervision and certified by an Engineer, these fills are described as 'undocumented' and should be subject to careful scrutiny where encountered.

7.4.2 Colluvium

Colluvium and landslide deposits have not been separately mapped within the study area. However, colluvium and landslide deposits are present on most slopes, typically as a result of instability within the residual soils, although deep seated landslides moving within the underlying sheared rock mass do occur in this terrain. These deposits present as mobilised soil and rock that can be encountered as largely intact, or as chaotic deposits of clay-to boulder-sized soils.

Colluvium and landslide deposits (both shallow-seated and deep-seated) were mapped as part of our photo interpretation and geomorphic field mapping and have been incorporated into the Geomorphological Map presented in Figure 5.

8 Groundwater

Publicly available groundwater data for the study area is limited, with only one groundwater bore referenced for groundwater level data. The bore, located at the Three Furlongs Hotel, near the centre of Kaiwaka, is an active monitoring well 121.1 metres deep. The bore is located within an area regionally mapped by GNS as Undifferentiated Mélange and the static water level is recorded as being at ground surface.

Groundwater is expected to be close to the surface across most of the study area. Within the Northland Allochthon geology, groundwater is typically near to the ground surface and perched at the interface between the overburden residually weathered soils and the underlying relatively low permeability rock mass. This is evident in the landform by the prevalence of overland flow paths, wide-spread surface drainage patterns, observed seeps in road and rail cuts and presence of swampy ground.

Groundwater in the low-lying flood plain areas is likely to be at levels comparable to the stream and river levels. Within the Pleistocene Alluvium, groundwater levels may be lower, particularly in elevated terraces where the sandy soils may be more free draining. However, perched groundwater surfaces can be expected at the interface with less permeable soil units, including clay and peat beds.

Accurate groundwater levels will need to be established as part of site-specific assessments for future proposed developments, as groundwater can influence slope instability, consolidation settlement, and liquefaction potential, as well as bulk earthworks and service trench excavations.

9 Active Faults

Northland is one of the lowest earthquake activity regions in New Zealand. We have reviewed the GNS New Zealand Active Faults Database, which indicates there are no known active faults in the Kaiwaka study area. The nearest active fault is the Waikopua Fault located approximately 100 km southeast of the study area, to the southeast of Auckland City.

There are several unnamed, inactive faults mapped within the study area that are generally located at the contact between the different geologic units of the Northland Allochthon. Several unnamed, inactive thrust faults are mapped at the southern end of the study area, separating the Mélange from the Pakiri Formation.

10 Ground Slope Angles

Slope steepness within the Kaiwaka area varies from relatively level in the valleys and flood plains along the Kaiwaka River, portions of the Gibbons Road corridor and major drainages throughout the area, to quite steep in the elevated hills to the north and west. Areas mapped as Mahurangi Limestone (Omm) to the northwest and Pakiri Formation (Mwp) to the south and southwest appear to support the steepest slopes (up to approximately 30 degrees on natural slopes and approximately 70 degrees in road cuts) within the study area, while Undifferentiated Mélange (KOM) and Tauranga Group alluvium support more subdued topographic relief.

A profile of existing slope angles was created using LINZ Topo50 20 m contours (vertical accuracy ≤ 10 m). From this, a digital elevation model (DEM) was generated, and then a Slope Profile (Figure 4) was produced to show relative steepness within the study area.

Figure 4: Topographic Slope Angles

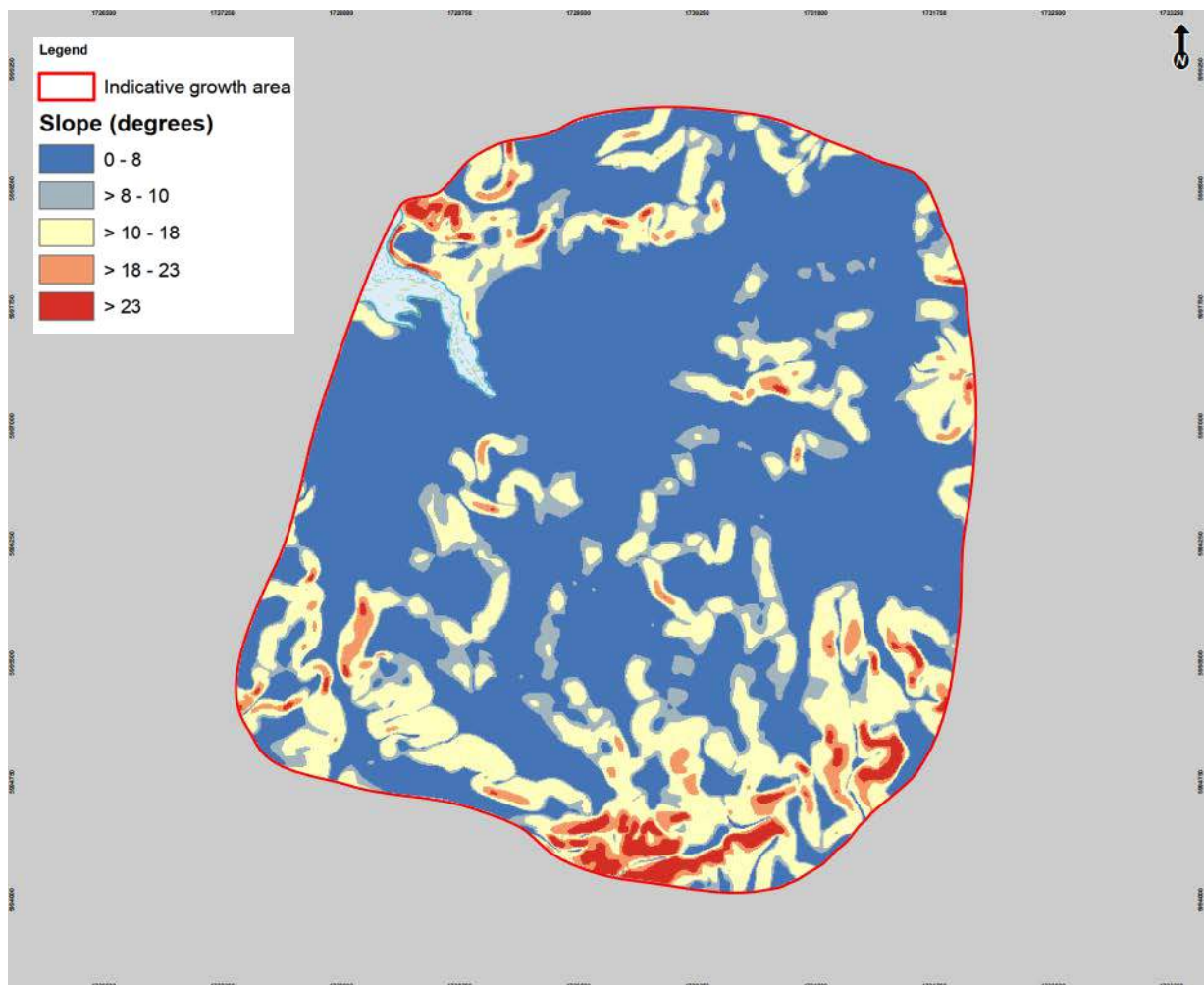


Image sourced from Land Information New Zealand, CC-BY-3.0. Not to Scale.

11 Geotechnical Hazard Discussion

The following geotechnical hazard discussion is based on available geotechnical information, geological mapping, aerial photography and our understanding of the Kaiwaka area. This section is intended to help define the specific geotechnical hazards and to describe the mechanics of triggering these conditions. Subsequent sections of this report will specifically identify where these hazards may be located, present a geotechnical hazard rating system for the key geotechnical hazards identified, and recommend geotechnical investigations required when developing within these conditions.

11.1 Seismic Hazards

Potential seismic hazards resulting from nearby moderate to major earthquakes can generally be classified as primary and secondary. The primary effect is ground rupture, also called surface faulting. The common secondary seismic hazards include ground shaking, regional subsidence or uplift, soil liquefaction, lateral spreading, landslides, tsunamis, flooding or seiches.

Soil liquefaction results from loss of strength during cyclic loading, such as imposed by earthquakes. Soils most susceptible to liquefaction are clean, loose, saturated, uniformly graded fine sands below the groundwater table. Empirical evidence indicates that loose silty sands are also potentially liquefiable.

When seismic ground shaking occurs, the soil is subjected to cyclic shear stresses that can cause excess hydrostatic pressures to develop. If excess hydrostatic pressures exceed the effective confining stress from the overlying soil, the sand may undergo deformation. If the sand undergoes virtually unlimited deformation without developing significant resistance, it is said to have liquefied, and if the sand consolidates or vents to the surface during and following liquefaction, ground settlement and surface deformation may occur.

Lateral spread involves lateral ground movement caused by gravity and seismic shaking. Lateral spread is most common in sloping ground or where a “free face” is exposed in close proximity to the site. A free face can include any near-vertical cut, but is commonly associated with riverbanks or creek terraces.

11.2 Slope Instability

Slope instability is a general term that includes landslides, as well as shallow slope movement, such as slumping and soil creep. The term “landslide” describes a wide variety of processes that result in the downward and outward movement of slopes. Slope movements may occur by falling, toppling, sliding, spreading, or flowing. The various types of landslides can be classified by the mechanics of movement and by the kinds of material involved.

These landforms can be clear and distinct immediately following episodes of movement but typically become subdued by erosion and deposition of colluvium with the passage of time. The most effective method of landslide mapping is the use of aerial photographs to identify the distinct features of slope movement. Often these features include: Concave or convex slope profiles, step-like slopes, over-steepened head scarps, mid-slope benches or depressions (graben) at the top of the slide, and back-tilting. Lobate, convex or bulging ground could indicate landslide debris, and hummocky and irregular-shaped landmass may indicate historic sliding.

Shallow slumping and soil creep are generally caused by loose, unconsolidated sediments that have failed along over-steepened slopes or have slowly moved downslope through the action of gravity.

These features are often difficult to observe on 1:25000 scale aerial photographs, and are best observed during geomorphological mapping. Features of slumping and soil creep often present as hummocky landmass and formation of terracettes (horizontal soil ridges).

11.3 Consolidation Settlement

Consolidation settlement occurs when compressible soils are subject to increased stress, such as from new structure or fill loads. Weak clay and organic soils are most prone to consolidation settlement.

Static settlements likely to occur under building and fill loads may be as a result of immediate settlement and primary consolidation. The time required for settlement to occur for each of these components is dependent on the settlement mechanisms:

- Elastic settlement generally occurs immediately after construction is complete.
- The time required to complete primary consolidation is dependent on the soil properties, layer thickness and groundwater conditions. Typically, primary consolidation occurs on a logarithmic time scale (magnitude of settlement decreasing with time), and may be as long as several decades to achieve 100% consolidation.

11.4 Volcanic Hazards

The Northland Volcanic Arc comprised two belts of volcanoes that erupted along both sides of Northland and Auckland between 23 and 15 million years ago (Hayward, Bruce, 2017). The western belt (Waitakere Group) consisted of Waitakere, Kaipara Volcano and Waipoua, as well as numerous offshore volcanoes. The eastern belt (Coromandel Group) consists of the eroded remains of at least five andesite stratovolcanoes. Three smaller volcanoes, Takatoka, Hukatere and Oruawharo are located northeast of the Kaipara Volcano near our study area. Between Kaiwaka and the Brynderwyn Junction, there are the slightly eroded remains of about ten dacite domes, including the prominent Pukekaroro dome, just north of the study area.

Volcanic activity presents a risk within the Northland region; however, the location and timing of eruptions are difficult to predict due to the monogenetic nature of the volcanic field. Hazards proximal to an eruption include pyroclastic surge, block fall and lava flows. Ash fall at a greater distance can cause large disturbance with remobilisation of ash deposits, particularly during rainfall events.

The volcanic field is generally considered to be dormant and age data from the Tokatoka and Hukatere volcanoes suggests that these eruptions occurred between 16 and 19 million years ago. As such, further low-magnitude eruptions are unlikely, as it is generally considered that the volcanic fields have a relatively low recurrence interval.

11.5 Sulphate Attack on Concrete

Water-soluble sulphates are capable of chemically reacting with the components of concrete, causing accelerated corrosion and resulting in a shortened design life. High sulphate soils and groundwater are common where excessive amounts of gypsum or other sulphate containing minerals are present. Other sources of acid sulphates can come from seawater, peat deposits and industrial waste waters.

Elevated areas of Northland Allochthon are unlikely to contain acid sulphates, due to the lack of sulphate containing minerals, influence of seawater, peat deposits and industrial uses. However, low-lying alluvial deposits may be subject to sulphate attack on concrete.

11.6 Other Hazards

Karst – Limestone and other carbonate rocks are highly soluble in rainwater due to their dissolved carbon dioxide content, and piping failures can occur resulting in subsurface drainage channels along defects within the limestone rock mass. These can form near the ground surface, may be up to several metres wide, and may collapse to form sinkholes (karst topography).

Expansive Soils – Certain cohesive soils have a tendency to shrink and swell, particularly with seasonal fluctuations of soil water content. This behaviour has implications for foundation design and the performance of surface structures. As such, expansive soil behaviour should be considered during foundation design.

Collapsible Soils – Unsaturated, young alluvial soils that are rapidly deposited in generally sub-arid climates can undergo a large volume change when they become saturated. Based on the climate and high groundwater in the Northland region, collapsible soils are considered unlikely to be found in the study area.

Dispersive Soils – Clay soils saturated with sodium ions can be sensitive to water erosion. This cation imbalance can lead to soil breakdown, resulting in piping failure and rainfall erosion. Generally, dispersive soils are associated with soils formed in arid or semi-arid climates and in areas of alkaline soils. Based on geographic and climatic factors in the Northland region, dispersive soils are considered unlikely to be found in the study area.

12 Historical Aerial Photograph Review

We have reviewed historical aerial photographs from Retrolens New Zealand, stereo-paired aerial photos, and Google Earth dating from 1961 to 2018. The photographs were viewed under the context of identifying general changes to the landform.

Table 1: Historic Aerial Photograph Summary

Date	Description
<p>1961</p> <p>Retrolens Aerial Photo Series</p>	<p>Major roadway improvements associated with State Highway 1, Gibbons Road, Kaiwaka-Mangawhai Road and Settlement Road are well established. Minor feeder roads, such as Oneriri Road, Ranganui Road, Pukenui Road, Marshall Road, Tawa Avenue and Vista Lane have also been constructed by 1961, as well as many driveways accessing large paddocks and property blocks.</p> <p>The main town of Kaiwaka has been developed along State Highway 1, with commercial buildings placed near the intersection of Gibbons Road and Kaiwaka-Mangawhai Road. Residential development is concentrated north and west of the intersection, on the west side of State Highway 1 just south of Oneriri Road, on the east side of State Highway 1, just north of Settlement Road, and near the intersection of Settlement Road to the south.</p> <p>The North Auckland Line railway track runs approximately parallel to State Highway 1, about 1.5 km to the west. It then turns east, where it meets the west side of Highway 1 just south of the study area. The railroad station was constructed in 1913 and is located in western edge of the study area, just north of Oneriri Road. The rail station has several associated buildings along the west side of the tracks and at least six dwellings along the east side of the tracks.</p> <p>An open pit borrow area or quarry exploration exists north of Gibbons Road. Unvegetated headscarps, indicative of recent slope instability, hummocky landscape, and erosional gullies are prevalent throughout the study area.</p>
<p>1972</p> <p>Retrolens Aerial Photo Series</p>	<p>Further densification within the main town of Kaiwaka is apparent near the intersection of Gibbons Road and Kaiwaka-Mangawhai Road. Further residential development is evident on the west side of State Highway 1 just south of Oneriri Road, on the east side of State Highway 1, just north of Settlement Road, and near the intersection of Settlement Road to the south. A new commercial building (where Three Furlongs now exists) has been developed and additional farm tracks and rural residences have been added.</p> <p>Instability features and erosional features do not appear to be strikingly different compared to the earlier aerial photographs.</p>
<p>1983</p> <p>1:25000 Scale Aerial Photos Series</p>	<p>Residential densification continues on both sides of State Highway 1, near the intersection of Settlement Road, and in the rural areas within the study area. A new building, now the Gateway North Motel and Café, is constructed west of State Highway 1. There appears to be less buildings associated with the railroad station. Puawai Street has been created north of Settlement Road.</p> <p>A large pond has been created in a formerly swampy area near a prominent meandering bend near the head of the Kaiwaka River, west of the Gateway North Motel.</p>
<p>2010</p> <p>Google Earth</p>	<p>Marshall Road, Our Lane and Dolly Lane are added as a northern extension of Puawai Street, Pavel Place and Lupis Way, which now extend off the southern end of Settlement Road. Numerous driveways and farm tracks have been added or changed, and further development of the Kaiwaka township continues between 1983 and 2010.</p> <p>Slope stability features, although abundant, are not significantly different to the earlier aerial photographs.</p>
<p>2017</p> <p>Google Earth</p>	<p>Development continues in the Kaiwaka area, however no significant changes to the landform were observed at this scale (e.g. bulk earthworks operations, localised slips, minor roading, etc.).</p>

Aside from the observed changes summarised in Table 1, and vegetation changes over time, no other significant or large-scale geomorphic changes were noted in the historic aerial photograph review.

13 Geomorphological Assessment

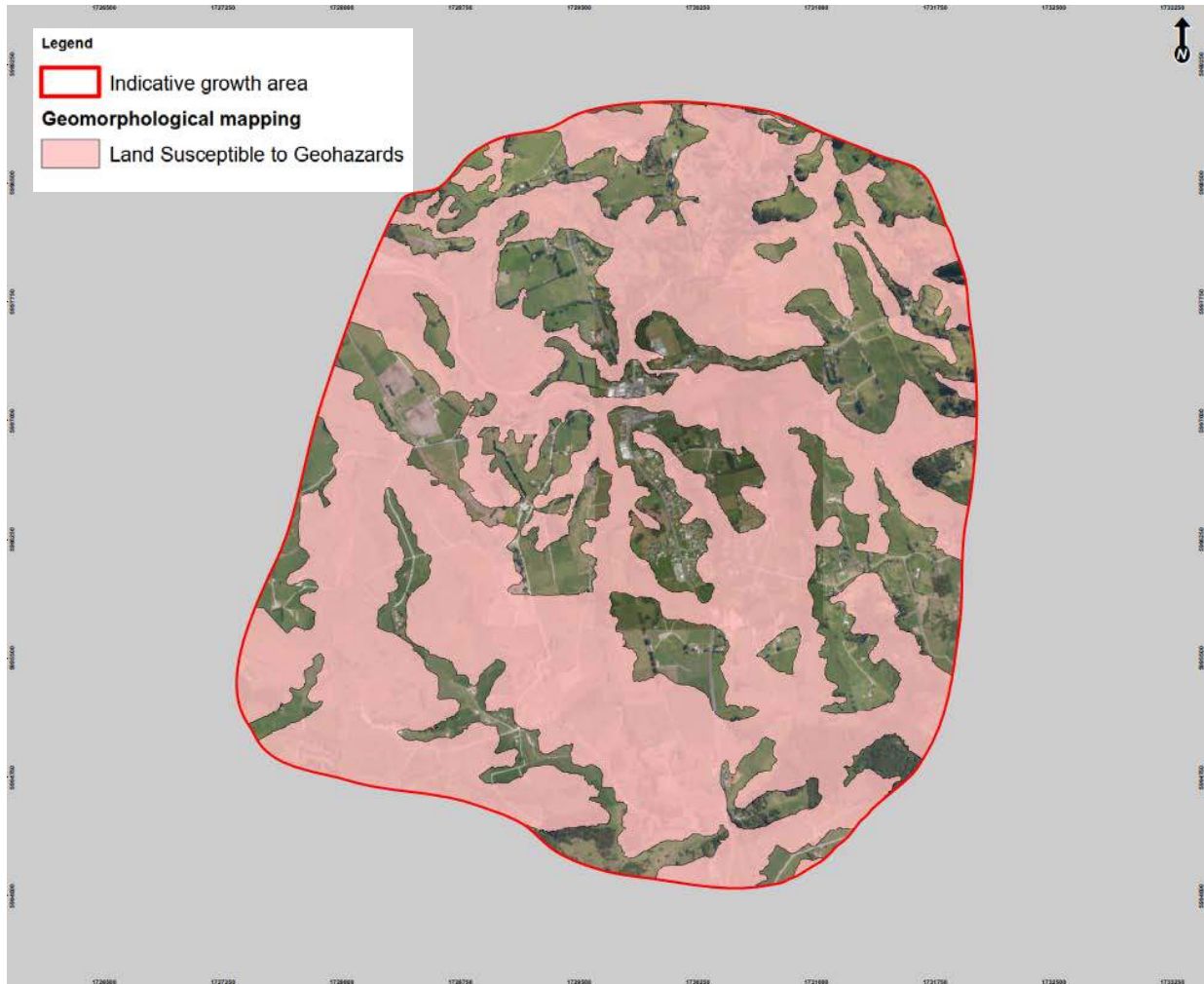
13.1 Stereo-Paired Aerial Photo Interpretation

We supplemented geologic mapping within the study area with interpretation of stereoscopic aerial photographs obtained from WSP Opus. The photo interpretive mapping was performed using stereo-paired aerial photos from Flight SN 8104 E/24, E/25, E/26, F/21, F/22 and F/23, flown on 10 January 1983. A middle-range scale of 1:25000 was selected to provide project coverage, 60% overlap and enough detail to map larger features.

We assessed the images to identify geomorphic features such as headscarps, hummocky and irregular-shaped landscapes, displaced blocks, and debris lobes that may be indicative of recent or historic landslide activity. Based on subtle inflections in topography, we mapped the approximate limits of interpreted land instability areas as depicted in Figure 5. We also mapped the approximate limits of alluvium and colluvium deposits in hillside gullies and valley areas, which are considered to be susceptible to liquefaction and consolidation settlement. Interpreted land instability (deep seated and surficial), colluvium, gully fill, and alluvial soils were not differentiated in our mapping, which was intended to identify land susceptible to geotechnical hazards.

The geomorphic mapping performed for this study should be considered a reconnaissance-level effort, and is intended to provide a generalised delineation of geotechnical hazards for planning-level site evaluations. The accuracy was limited by the scale of the aerial images and other factors such as vegetative cover, farming, and urban development. The mapping depicted on Figure 5 should be supplemented by detailed site-specific geomorphic mapping for design-level studies.

Figure 5: Geomorphological Mapping



Base image sourced from Land Information New Zealand, CC-BY-3.0. Not to Scale.

13.2 Site Walkover

After review of aerial photos and Google Earth images, ENGEO visited the growth area to observe typical ground conditions and geomorphological features of the area. Our mapping was not intended to provide a detailed geomorphic assessment of the area. The purpose of our mapping was to note general ground condition features that could not readily be interpreted from aerial photographs, and was limited to areas that could be observed from public access roadways.

13.2.1 General

The area generally consists of rolling hills bisected by broad valleys and incised gullies. The hills are generally more gentle in the middle, eastern and western portions of the site, with steeper terrain to the north and south. The Kaiwaka River is a prominent feature that begins just west of the town of Kaiwaka and is fed by tributaries and drainages within the Catchment. Pukekaroro Dome dominates the skyline to the north, but lies just outside of the Kaiwaka study area.

The drainages and gullies observed were commonly flanked by slope instability features, such as shallow rotational landslides and active soil creep within the gentle slopes above. The rolling hills within the study area are well vegetated and express widespread evidence of historical slope instability, as well as active slope instability (Photos 1, 2 and 3). This is primarily expressed in the form of shallow rotational failures and hybrid rotational / translational failures. Mid-slope benches and arcuate head scarps were observed on many of the moderate (16-30 degrees) to steep (>31 degrees) slopes. Active soil creep, particularly in the form of terracettes, was evident over much of the study area (Photo 4).

Groundwater appeared to be relatively shallow near the lower lying gullies and along the flood plains adjacent the main branches of the Kaiwaka River. Groundwater was also observed seeping out of road and rail cuts within Undifferentiated Mélange (Photos 5 and 6).

An exposed railroad cut at the southern end of the site was observed to be failure at an approximate 18-degree batter. The slope consisted of crushed claystone (Undifferentiated Mélange), had an active groundwater seep and was sliding toward the railroad tracks (Photo 5).

13.2.2 Rock Outcrops

Only limited areas were observed to have rock outcrops. Where exposed, we observed extremely weak, very thinly bedded to laminated, sheared and crushed mudstone mapped as Undifferentiated Mélange (Photos 5 and 6).

13.2.3 Borrow Areas

During our historical aerial photo review, we observed an apparent open pit borrow area or quarry exploration area north of Gibbson Road, in the northern part of the study area, that predates 1961 (Photo 7). Additionally, we understand that Parker Lime Co. currently operates a lime quarry on the west side of Gibbons Road, just north of the study area. It is likely that other localised areas used as quarry sources for farming improvements or roading works exist within the study area. If present, local areas of instability are expected where excavations have created over-steepened slopes. A discussion on geotechnical hazards associated with open pit quarries is in Section 15.1.

13.2.4 Surficial Deposits

Holocene alluvial deposits are not mapped in this area by GNS, however these deposits were observed near the mouth of the Kaiwaka River in the north-western end of the study area (Photo 8) and along tributaries near the mouth of the Kaiwaka River. Pleistocene alluvial deposits have been mapped by GNS adjacent the Holocene alluvial deposits, Kaiwaka River, creeks and tributaries in the northern third of the study area. Pleistocene alluvial deposits observed near Oneriri Road and Gibbons Road, appear to be failing on slopes steeper than 1V:3H, or about 18.4 degrees. This observation is generally consistent with our mapping in Maungaturoto, as well as slope performance reported by others (GNS 2009, T+T 2006 and 2008, and Auckland Council 2017) and supports our assessment of slope instability in Section 14.4.

Figure 6: Photos



Photo 1: Typical landscape featuring hummocky, irregular ground, inferred landslide debris and soil creep.



Photo 2: Active landslides, soil creep and failing slopes on relatively gentle slope angle.



Photo 3: Moderately steep slope exhibiting shallow slope instability.



Photo 4: Shallow instability and soil creep in the form of horizontal soil ridges.



Photo 5: Road cut on the south side of Oneriri Road. Note the water seeping from the shallow cut.



Photo 6: Railroad cut on the west side of the rail road, near the southern end of the study area. Note the water seeping from the cut and the slope failing at less than 1V:3H slope batter.



Photo 7: 1995 aerial photo of a possible open pit borrow area. This feature is present in photos dating back to 1961.



Photo 8: Young Holocene alluvial soils on the flood plain of this tributary to the Kaiwaka River near Oneriri Road.

14 Geotechnical Hazards Identified in Kaiwaka

14.1 General

Based on the findings of this geotechnical assessment, we consider the primary geotechnical constraints of the Kaiwaka Indicative Growth Area to be slope instability, liquefaction and lateral spread potential, and settlement due to soft, compressible soils. From discussions with Council and in accordance with our engagement, we understand that coastal hazards associated with flooding, tsunami inundation and sea level rise will be investigated by a Coastal Engineer, and have therefore not been considered in this geotechnical hazards assessment. We note that areas affected by sea level rise may experience increased susceptibility to the hazards already identified, due to elevated groundwater levels.

Further geotechnical investigation will be required to confirm the geological model and provide site specific engineering to support detailed design and consenting for all future development within the study area.

14.2 Geotechnical Hazard Rating

In order to quantify the geotechnical hazard potential of an area for land planning, a broad framework based on a three-level hazard profile has been developed. This system defines potential hazard areas as Low, Medium and High, relative to the level of impact they may potentially have on future development. This system not only indicates the potential for adverse effects on developments but may also be used to inform Council of the level of geotechnical investigation required to develop land within these three zones.

14.2.1 Low Hazard Potential

Areas mapped as 'Low' hazard potential, would only affect a structure in events unlikely to occur in the design life of the structure and would require a lower level of geotechnical investigation. The hazard potential of areas mapped as 'Low' may become at risk of hazard potential if subjected to land modification earthworks or natural disasters.

14.2.2 Medium Hazard Potential

Areas mapped as 'Medium' hazard potential, exhibit evidence of past slope instability or recent sediment deposits that could have significant effects on the design and construction of a structure, and would require a medium level of geotechnical investigation.

14.2.3 High Hazard Potential

Areas mapped as 'High' hazard potential, are areas that have exhibited past slope instability or are on over-steepened slopes. These areas are expected to have significant consequences for structures, could require complex mitigation, and will require a higher level of geotechnical investigation.

14.2.4 Combined Geohazard Plan

As part of this geotechnical assessment, ENGEO has compiled a Combined Geohazard Plan (Appendix A) presenting the assessed low, medium and high hazard potential areas based on a summation of the primary geotechnical constraints considered for this area (slope instability, liquefaction and lateral spread potential, and settlement due to soft compressible soils). This plan may not show all areas of potential geotechnical hazards, and potential geotechnical hazards mapped may not experience slope deformation or settlement at the levels estimated.

The assessed primary geotechnical constraints considered to be present within the study area are discussed in the following sections.

14.3 Seismic Hazards

As previously discussed, there are no known active faults located within the site and the greater Northland region is regarded as tectonically stable (GNS 2009). Based on our review of the GNS New Zealand Active Fault Database, it is our opinion that fault-related ground rupture is very unlikely within the study area.

Based on topographic and lithologic data, risk from earthquake-induced regional subsidence / uplift, and seiches is also considered negligible within the study area. We understand that coastal hazards associated with flooding, tsunami inundation and sea level rise will be addressed by a Coastal Engineer.

14.3.1 Seismic Site Classification

Seismic site classification should be assessed on a site-specific basis in accordance with NZS 1170.5.2004, however, based on our site reconnaissance and general knowledge of the study area, we consider the site classification to generally be 'Class C – Shallow Soil Sites' or 'Class D – Deep or Soft Soil Sites' for the majority of the study area, while we consider it possible to encounter 'Class E – Very Soft Soil Sites' in close proximity to Kaiwaka River (i.e. within the active channel of the river and within some of the Holocene deposits adjacent the river).

14.3.2 Ground Shaking

From discussions with Kaipara District Council, we understand the purpose of this geotechnical assessment is to provide planning-level guidance to residential development. Assuming development within the Indicative Growth Area will be limited to typical residential and low-rise commercial construction, we have assumed a Building Importance Level 2 will be typical (i.e. structures that will not contain people in crowds or contents of high value to the community). Importance Level 2 buildings with a 50-year design life are required to be designed to resist earthquake shaking with an annual probability of exceedance of 1/500 (i.e. a 500-year return period) at the Ultimate Limit State (ULS) level, and 1/25 (i.e. a 25-year return period) at the Serviceability Limit State (SLS) level.

Peak horizontal ground accelerations should be calculated in accordance with MBIE / NZGS Module 1 (2016) on a site by site basis.

14.3.3 Liquefaction and Lateral Spread

Although there is a relatively low risk for strong seismic shaking in the Northland region, the Holocene and Pleistocene deposits within the study area may contain loose sandy soils. Due to the presence of sandy soils, and in combination with assumed high groundwater levels, we consider liquefaction and lateral spread under seismic conditions to be a risk, particularly within the young Holocene alluvial deposits which generally consist of soft and poorly consolidated mud, sand and gravel. As discussed in the following sections, "low", "medium", and "high" liquefaction and lateral spread hazard areas have been developed for the study area, as they relate to Importance Level 2 (IL2) structures, with an assumed design life of 50 years.

Low Liquefaction and Lateral Spread Potential

Northland Allochthon rock is not considered liquefiable. Residual soils of Northland Allochthon and Waitemata Group typically comprise moderately plastic clays and silts with variable amounts of sand. Due to the nature of these soils, we consider the liquefaction and lateral spread potential to be low. Areas having a low liquefaction potential are unshaded in Figure 7.

Medium Liquefaction and Lateral Spread Potential

Pleistocene Alluvium (eQa) comprising poorly to moderately consolidated mud, sand and gravel, forms elevated terraces above present day flood plain levels. GNS maps these soils in the northern third of the study area near the Kaiwaka River and tributaries (Figure 3).

We consider these areas to have a potential to liquefy under ULS conditions. Given that the Pleistocene Alluvium forms steep slopes near the Kaiwaka River and associated tributaries, lateral spread is also possible during a ULS event.

Given the potential for poorly consolidated, coarse-grained soils to be present below groundwater within the Pleistocene Alluvium, we consider liquefaction and lateral spread potential within this unit to be medium (Figure 7).

High Liquefaction and Lateral Spread Potential

Young Holocene alluvial deposits are not mapped by GNS, however, these deposits were observed near the mouth of the Kaiwaka River in the north-western end of the study area and along tributaries near the mouth of the Kaiwaka River extending to the south, east and northeast. These deposits generally consist of soft and poorly consolidated mud, sand and gravel and occupy low-lying areas immediately adjacent the river and creek beds.

We consider the liquefaction and lateral spread potential of the Holocene Alluvium to be high. Due to the isolated areas which these deposits were observed, Holocene deposits have not been included on Figure 7.

Figure 7: Liquefaction and Lateral Spread Susceptibility Plan



Base image sourced from Land Information New Zealand, CC-BY-3.0. Not to Scale

14.3.4 Geotechnical Investigation Requirements

Areas identified as having a low liquefaction and lateral spread potential are underlain by soil and rock units that are not expected to liquefy under seismic loading. Geotechnical investigations to support future developments in these areas are likely to include a preliminary assessment of liquefaction potential based on site-specific subsurface investigation data confirming the nature of the underlying strata.

Geotechnical investigations for future development areas mapped as having a medium liquefaction and lateral spread potential should be further investigated by a suitably qualified geotechnical professional. Site specific investigations are expected to include, at a minimum:

- Desk based study of relevant available geotechnical and geological publications, including a review of historical aerial photographs.
- Deep cone penetration testing (CPT) and accompanying machine boreholes to confirm the nature and extent of liquefiable strata.

- Assessment of groundwater levels through installation of piezometers.
- Supporting laboratory testing (particle size distribution (PSD) and Atterberg Limits in accordance with NZS 4402:1986 Test 2.8.4 and 2.1-2.4, respectively) of the potentially liquefiable layers.
- Site-specific liquefaction analysis should be performed to calculate theoretical settlement due to liquefaction, and set-backs should be established for lateral spread.

14.4 Slope Instability

Land instability is a common and significant geological hazard in the Northland area due to the underlying geology, high groundwater, and relatively high mean annual rainfall. Groundwater is a critical factor driving instability within the Northland Allochthon stratigraphy, as water percolates through the near-surface soil profile and becomes perched at the interface with the relatively low permeability rock mass. Accordingly, the residual soil mantle typically has relatively high strength near the ground surface, becoming weaker near the transition to rock as the soil water content increases. This weaker area, between the residual soil and transition to bedrock, often becomes a plane of weakness for slope instability.

The highly sheared and fractured nature of the Mélange and Mangakahia Complex means that slope instability can occur on low angles, as gentle as 8 degrees. Instability is most common within the overburden soil profile, although deep seated failures within the rock mass have occurred historically in the wider Northland area.

The calcareous units of the Mahurangi Limestone are generally less fractured and may be cemented by calcite infill in defects, resulting in a relatively more stable rock mass. Natural slopes in this unit can stand at angles in excess of 20 degrees. However, instability within calcareous rocks can arise as a result of piping erosion and sinkhole formation (karst). Mahurangi Limestone may also be underlain by weaker Northland Allochthon rock, and are therefore prone to large translational block failures. For these reasons, the risk of instability has been modelled equal to the weaker units of the Northland Allochthon.

Waitemata Group materials, including Pakiri Formation, are generally very weak to extremely weak sedimentary rocks consisting of interbedded layers of sandstone, siltstone, mudstone and weak conglomerates. These rock units typically weather to form residual soils comprised of stiff, orange brown to grey silts and clays, with variable amounts of sand. Field observations show that the Waitemata Group rock is more resistant to erosion and can form slopes up to 45 degrees from horizontal. These rocks are more weathered and fractured near the fault bound contacts with Northland Allochthon rocks and result in more subdued slopes of 14 to 30 degrees. The less resistant residual soils can exhibit soil creep and shallow failures at or above the soil-rock contact on slopes greater than about 14 to 18 degrees.

Slopes within Pleistocene alluvial terraces are also susceptible to instability, although their lack of a sheared or fractured fabric and ability to more freely drain groundwater allows them to stand at slightly steeper angles than the Northland Allochthon units. The alluvial soils are poorly consolidated and susceptible to creep and shallow instability on slopes having angles greater than 10 degrees.

14.4.1 Slope Instability Potential

A preliminary assessment of the potential for slope instability within the study area has been undertaken using GNS geological maps, LiDAR contours and elevation data, and a slope profile range based on known angles at which instability occurs in different lithologies.

GNS state: “Late Cretaceous and Tertiary mudstones and sandstones of the Northland Allochthon generally have a high risk of failure on slopes greater than about 15°” (GNS, Geology of the Whangarei Area, 2009). Auckland Council (2017) have published geotechnical reports for the Silverdale West Dairy Flat area stating that slope instability potential typically has moderate slopes between 15° to 26° for Waitemata Group (includes Pakiri Formation and residual soils), 10° and 23° for lower strength alluvial soils, and 8° to 18° for sheared Northland Allochthon. Tonkin and Taylor published a geotechnical assessment for Whangarei (2008) and Kamo, Maunu, Onerahi, Otaika and Tikipunga (2006) stating: “Non-calcareous and non-siliceous mudstone lithologies... [of the Northland Allochthon] tend to stand between 7° and 14°...”

Based on GNS, Auckland Council, previous geotechnical assessments, and our experience working in Northland Allochthon, we have developed slope profile ranges which are presented in Table 2. Slope profile ranges categorise the potential for instability in each geological unit as low, medium, and high, with corresponding slope angles.

Table 2: Slope Instability Profile

Geologic Unit	Slope Instability Potential based on Slope Profile Ranges		
	Low	Medium	High
Holocene Alluvium (Q1a)	<10°	10-23°	>23°
Pleistocene Alluvium (eQa)	<10°	10-23°	>23°
Mahurangi Limestone (Omm)	<8°	8-18°	>18°
Punakitere Sandstone (Kkp)	<8°	8-18°	>18°
Undifferentiated Mélange (KOm)	<8°	8-18°	>18°
Pakiri Formation (Mwp)	<14°	14-26°	>26°

The slope profile ranges have been applied to the LiDAR contour and elevation data to generate the Slope Instability Potential plan presented in Figure 8. It is important to note that the “Low Instability Potential” category does not imply that instability will not occur on these slopes, particularly where underlain by Northland Allochthon strata. Rather, some of slopes may have historically failed, which has resulted in the flatter slope angles observed today. Changes to the equilibrium of a slope through some combination of land modification earthworks, fill or building loading, or introduction of water, can trigger reactivation of previous landslides on any slope.

Site specific investigations in these areas are expected to include, at a minimum:

- Desk based study of relevant available geotechnical and geological publications, including a review of historical aerial photographs.
- Subsurface investigation in the form of shallow hand augers, test pits, and/or deep machine boreholes, including determination of static groundwater levels.
- Measurement of critical cross-sections through the site and development of a comprehensive geologic model.
- Detailed slope stability analysis is likely to be required to confirm that adequate factors of safety are met for the development, with accompanying remedial design as required.

14.5 Consolidation Settlement

Holocene and Pleistocene deposits within the study area may contain soft and poorly consolidated mud, sand and gravel units, with peat and organic soil beds, that may be susceptible to consolidation settlement under future building or fill loads.

14.5.1 Consolidation Settlement Potential

Consolidation potential has been identified as one of the predominant geotechnical hazards within this study area, particularly within the young Holocene alluvial deposits which contain soft organic clays and peats that are susceptible to settlement under loading. As discussed in the following sections, “low”, “medium”, and “high” settlement hazard areas have been developed, as they relate to Importance Level 2 (IL2) structures, with an assumed design life of 50 years. The following further defines these hazards for consolidation settlement potential.

Low Consolidation Settlement Potential

Northland Allochthon rock is not considered to be susceptible to settlement under loading. Residual soils of Northland Allochthon and Waitemata Group typically comprise moderately plastic clays and silts with variable amounts of sand. Due to the nature of these soils, we consider the consolidation potential to be low.

Areas having low consolidation settlement potential are unshaded in Figure 9.

Medium Consolidation Settlement Potential

Pleistocene Alluvium (eQa) comprising poorly to moderately consolidated mud, sand and gravel, with peat and organic beds, form elevated terraces above present day flood plain levels. GNS maps these soils in the northern third of the study area near the Kaiwaka River and associated tributaries (Figure 3). Based on the likely presence of organic material and soft clay layers, we consider these areas to have a medium potential to experience consolidation settlement under loading.

High Consolidation Settlement Potential

Holocene deposits were observed near the mouth of the Kaiwaka River in the north-western end of the study area and along tributaries near the mouth of the Kaiwaka River extending to the south, east and northeast. These deposits generally consist of soft and poorly consolidated mud, sand and gravel and occupy low-lying areas immediately adjacent the river and creek beds.

We consider these areas to have a high potential to experience consolidation settlement under loading. Due to the isolated areas which these deposits were observed, we have not included Holocene deposits on Figure 9.

Figure 9: Settlement Susceptibility Plan



Base image sourced from Land Information New Zealand, CC-BY-3.0. Not to Scale

14.5.2 Geotechnical Investigation Requirements

Areas identified as having a low consolidation settlement potential are underlain by Northland Allochthon and Waitemata soil and rock units that are not expected to be significantly compressible under future building and fill loads. Geotechnical investigations to support future developments in these areas are likely to include a desktop and/or subsurface investigation designed to confirm the nature of the underlying strata, to confirm this assessment based on mapped geology.

Geotechnical investigations for future development areas mapped as having a medium consolidation settlement potential should be further investigated by a suitably qualified geotechnical professional. Site specific investigation should include, at a minimum:

- Desk based study of relevant available geotechnical and geological publications, including a review of historical aerial photographs.
- Deep machine boreholes to assess depth and nature of the compressible materials.
- An assessment of groundwater levels.
- Supporting laboratory testing (one-dimensional incremental consolidation testing in accordance with NZS 4402:1986 Test 7.1) of potentially compressible layers.
- Detailed settlement analyses should be performed to calculate theoretical total and differential settlements due to consolidation.

15 Combined Geotechnical Hazard Assessment

ENGEO has compiled a Combined Geohazard Plan (Appendix A) showing the range of expected geotechnical hazards within the Growth Area. This plan combines the areas of low, medium and high likelihood of hazard occurrence for each of the primary geotechnical constraints considered for this area (slope instability, liquefaction and lateral spread potential, and settlement due to soft compressible soils). Areas where multiple geotechnical hazards exist, are presented on the plan based on the highest assessed hazard level.

As this plan has been prepared using a combination of desktop-based assessments supported by limited geomorphic field mapping, it may not show all areas of potential geotechnical hazards. Further, the potential geotechnical hazards mapped may not be present in all locations to the risk levels estimated. Site-specific assessments are required for all proposed new developments to confirm the extent to which geotechnical hazards affect the land, and appropriate design and engineering mitigation measures are required to address the associated risk.

Table 3, below, presents a summary of the combined primary geotechnical hazards represented on the Combined Geohazard Plan, and an indication of the magnitude of geotechnical investigation and design that would be required to support future developments in these areas. Specific recommendations for future investigations have been presented in the hazard-specific discussions in this report. Additional geotechnical hazards, including expansive soils and acid sulphate soils, as well as on-site effluent disposal potential are mapped separately and are not included in Table 3 or Appendix A.

Table 3: Combined Geotechnical Hazard Plan Summary Table

Level	Colour	Assessed Geotechnical hazard Risk	Geotechnical Implications
Low	Green	<p>The potential for liquefaction or consolidation settlement in these areas is considered to be low based on the mapped underlying geological units and their geotechnical properties.</p> <p>Slope instability potential is considered to be low based on prevailing slope angles and field landform observations. Locally over-steepened slopes (e.g. road cuts, stream banks, etc.) may be susceptible to soil creep or small scale instability.</p>	<p>Site-specific assessments are required to confirm the extent to which the identified geotechnical hazards affect the land, and the suitability of the land for the intended development.</p> <p>Geotechnical hazards may be mitigated through local small-scale earthworks and retaining structures, or by imposing setbacks from areas identified as at risk of these geotechnical hazards.</p>
Medium	Orange	<p>These areas may be susceptible to liquefaction and/or lateral spread under ULS conditions, and/or be susceptible to consolidation settlement under building and development loads.</p> <p>These areas may also be susceptible to slope instability, particularly where land modification earthworks and/or building developments are proposed to modify or otherwise impact the existing landform, and/or where natural events trigger instability (e.g. rainfall events, earthquake, etc.)</p>	<p>Proposals to develop or modify land in these areas will be subject to robust site-specific assessments designed to confirm the underlying ground conditions and their geotechnical properties, and to assess the implications of the development proposals on the existing landform.</p> <p>Geotechnical hazards in these areas may be mitigated through determination of appropriate setbacks, and/or through use of specifically designed remedial earthworks, and/or retaining walls and associated structures, and/or drainage networks, to achieve acceptable long term factors of safety for the proposed development.</p>
High	Red	<p>These areas are considered likely to be susceptible to future land instability and may have undergone recent slope deformation or active slope movement.</p>	<p>Proposals to develop or modify land in these areas is subject to comprehensive geotechnical investigation and design to determine the magnitude to which the assessed geotechnical hazards affect the site, and the implications of the development proposals on the existing landform.</p> <p>Extensive geotechnical remediation measures are likely to be required to facilitate development of land in these areas, which may include large-scale land modification earthworks, and/or extensive ground improvement or retention structures.</p>

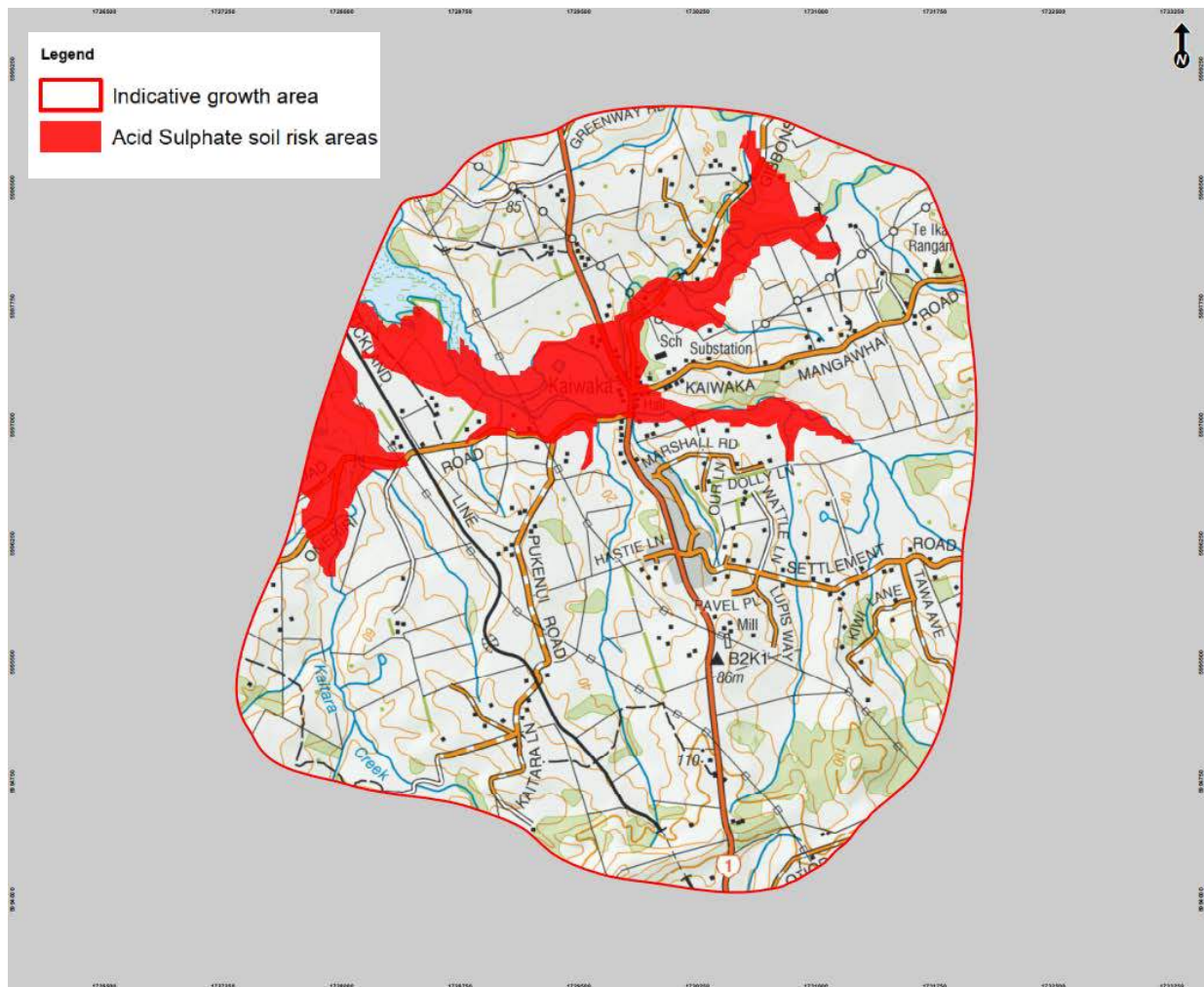
15.1 Sulphate Attack on Concrete

Tauranga Group soil deposits within the study area (refer to Figure 3) may contain organic soil and peat layers associated with decomposition of organic matter in swamp and estuarine environments. Low-lying alluvial deposits may have also been influenced by seawater during times of higher sea levels. These areas may contain sulphate and sulphide rich soils and groundwater which may present a risk to infrastructure.

A draft joint Council submission (Acid Sulphate Soils – Northland) was recently undertaken (Opus 2017). Included in this report is an Acid Sulphate Soil Risk plan that was developed using historic sea levels, current surface elevations and mapped sedimentary deposits. Kaipara District Council have provided focussed areas of the plan for use in this study, which includes the Kaiwaka study area (Figure 10).

Discussion on risk levels and investigation methodology is provided in Kaipara District Council's Acid Sulphate Soils Policy Basic Planning Guide.

Figure 10: Acid Sulphate Soil Risk Plan



Base image sourced from Land Information New Zealand, CC-BY-3.0 and WSP-Opus Whangarei Office. Not to Scale.

15.2 Other Geotechnical Hazards

Karst – Piping failures within the Mahurangi Limestone have been observed in greater Northland. However, no karstic features have been mapped within the study area, or observed as part of this assessment. Nevertheless, there is a risk that this type of rock mass erosion and subsequent instability may occur in the future within the portions of the study area underlain by limestone, and the hazard should be assessed as part of site specific assessments in the affected areas.

Mines and Quarries – Subsidence due to underground coal mining has been well documented in Northland, particularly in Kamo and Hikurangi. These hazards are present well north of the study area and there are no known commercial mine or quarry sites within the Kaiwaka study area. However, Mahurangi Limestone is quarried in Portland, south of Whangarei, for use in manufacture of cement and for agricultural lime and Parker Lime Co. currently operates a lime quarry on the west side of Gibbons Road, just north of the study area. The limestone is also used as roading aggregate on secondary roads and farm tracks and, on this basis, the presence of local small-scale quarries on farmland located within the Mahurangi Limestone stratigraphy should not be discounted.

As previously discussed in Section 13.2.3, a possible open pit ‘borrow area’ was observed within the study area. Mining can lead to multiple environmental, erosional and instability hazards. Stability issues and deformation associated with the borrow area will be limited to the excavation batters and immediate areas adjacent to the crest of the excavation batters. The batters are now well vegetated and deformation was not observed between 1961 and 2017.

Expansive Soils – Areas most susceptible to the effects of expansive soils are areas underlain by weathered mudstone, residual soils of Northland Allochthon and Waitemata Group, colluvium-filled gullies and valleys, and young mud, clay and organic soils within the Holocene alluvium adjacent to river and creek beds.

Site specific laboratory testing (shrink swell) should be performed for determination of the Expansive Site Classification in accordance with AS 2870.

16 On-Site Effluent Disposal

We understand Kaipara District Council does not plan to extend and/or upgrade their current wastewater networks. As such, reticulated systems within the district cannot be relied upon as a suitable method of disposal when submitting an application to subdivide land in Kaiwaka. In the absence of a reticulated network to support areas of new development, on-site effluent disposal is required and, subject to the nature of the system designed for the development, presents a constraint in terms of development density (in terms of lot sizing and layouts for a residential development, or occupation density for a commercial or industrial development).

Successful disposal of effluent on-site is highly contingent on the site-specific ground conditions and topography, as well as the nature of the development and the capacity of the disposal system required. The final type and location of a disposal system is controlled by the nature of the soil and the thickness of the soil profile, together with surface water and groundwater flow behaviour, slope angles, and local climate.

Site specific assessments and subsurface investigations will be required for all future on-site effluent disposal systems within the study area. However, for the purpose of this assessment, we have completed an assessment of likely ground conditions and the potential for on-site disposal relative to the mapped geological units in the Kaiwaka study area.

16.1 Factors Affecting On-Site Disposal

When designing a system for on-site effluent disposal, a number of site specific factors must be taken into account. The following is not intended to be an exhaustive list, but presents a summary of the key factors relevant to the study area.

16.1.1 Topography

Steeply sloping land, or land susceptible to instability, is sensitive to the addition of water which can trigger slope failures. Deep bore or trench disposal systems are not acceptable methods of disposal on such sloping land, with preference given to dripper lines and evapotranspiration methods of disposal.

Low lying land susceptible to flooding is also unsuitable for disposal as freely draining conditions are required.

16.1.2 Soil Properties

Soil permeability is an important factor affecting the success of on-site effluent disposal, with low permeability soils generally being unfavourable. The soil needs to be permeable enough to pass the water and yet capable of retaining the water so that treatment occurs. Therefore, optimum conditions for a slow rate system would be a hydraulic conductivity between 5 mm/h and 50 mm/h, which provides the best balance between drainage and the retention of the wastewater components (Tchobanoglous & Burton, 1991).

Depth to rock or other impermeable strata is also an important factor, as most on-site disposal systems rely on surface area exposure to the soil via trenches or pits to treat the necessary volumes.

16.1.3 Groundwater Conditions

Near-surface groundwater is not favourable for on-site disposal as the soil needs to be free draining to appropriately dispose of treated effluent. A minimum 1 m between the treatment device and groundwater is recommended, but a greater depth is usually preferred.

16.1.4 Disposal Field Setback Restrictions

Minimum setback restrictions from boundaries, buildings, and clean water sources apply to the placement of disposal fields, as well as from steeply sloping land or land otherwise susceptible to instability.

16.2 Potential for On-Site Effluent Disposal in Kaiwaka

Without site-specific assessments, the potential for on-site effluent disposal can be considered as a function of anticipated soil type, topography, and mapped geotechnical hazards for any given area. We have prepared a plan depicting the potential for on-site effluent disposal in the Kaiwaka study area (Figure 11) based on these factors, as summarised in the following sections.

Areas identified as “unlikely on-site disposal” (red) may be unsuitable for deep bore or trench disposal systems and should be considered as rural residential areas. Lot sizes less than 4,000 square metres may not be able to accommodate the area demands of large wastewater disposal systems required to support a single residential dwelling.

Areas identified as “possible on-site disposal” (orange) may be subdivided as residential lots, where on-site wastewater has been identified as the suitable method of disposal, provided the lot size is such that it can support an appropriate wastewater disposal system. This will need to be determined at the initial design phase of the subdivision.

This assessment is considered preliminary only and is intended to guide future developers when considering development intensity. All future developments should be supported by site-specific assessments to confirm the potential or otherwise for on-site effluent disposal. Wastewater treatment systems will need to be designed by a suitably qualified, experienced and accredited Engineer to meet any requirements of the building code.

16.2.1 Northland Allochthon and Waitemata Group

The Northland Allochthon units within the study area typically weather to form clay-rich residual soils with relatively shallow soil profiles, and are highly susceptible to instability on gentle slopes. Similarly, residual soils of the Waitemata Group units, including Parkiri Formation weather to clay-rich soils. The relatively low permeability of the soil profile, together with typically near-surface groundwater and sloping land constraints, mean these soils are generally unfavourable for on-site effluent disposal.

The constraints associated with soils of this nature can be mitigated at the planning stages, for example by limiting minimum lot sizes to allow for large evapotranspiration disposal fields set back from sloping land, water courses, and/or boundaries. Minimum residential lot sizes for developments in sloping terrain may require approximately 1,000 m² to allow for a house footprint and amenity areas, primary and secondary disposal fields. Approximately 2,000 m² or greater may be required where land gradients or watercourses preclude disposal field sites. Accordingly, the potential for on-site effluent disposal in areas underlain by Northland Allochthon is considered to be unlikely.

Actual soil properties and depth to rock and/or groundwater data can be obtained through site-specific subsurface investigation, which will confirm the most appropriate methods of disposal at the development level.

16.2.2 Tauranga Group

Pleistocene Alluvium, where elevated above flood plain levels, can present an opportunity for successful on-site effluent disposal where the soil profile is sand- and silt-rich. However, the presence of relatively low permeability clay or peat layers within the alluvium can have the opposite effect, and the location and extent of such layers is unknown without subsurface investigation. Restrictions associated with depth to groundwater, and setbacks from sloping land would also be critical to placing disposal fields within this unit. Accordingly, the potential for on-site effluent disposal in areas underlain by Pleistocene Alluvium having a low slope instability risk (refer to Section 14.4.1) is considered to be possible. For areas having a medium to high slope instability risk, the potential for on-site disposal is considered to be unlikely.

Due to its low-lying topography, typically near-surface groundwater table, and mandatory setback requirements from clean water sources, effluent disposal potential within Holocene Alluvium should be considered unlikely.

Figure 11: On-Site Effluent Disposal Potential Plan



Base image sourced from Land Information New Zealand, CC-BY-3.0. Not to Scale

16.3 Geotechnical Investigation Requirements

The potential for successful on-site effluent disposal at a given site should be assessed as part of the initial geotechnical investigation at Resource Consent stage, such that the development can be designed with due regard to the appropriate method of disposal. Geotechnical investigations to support design of on-site effluent disposal systems for future developments in Kaiwaka will need to include a site-specific geomorphic assessment to assess the risk of active and historical instability that may have occurred at the site, which will need to be supported by a site-specific survey to map land gradients and watercourses across the development area.

A subsurface investigation undertaken by a suitably qualified and experienced geotechnical professional should comprise hand augers or test pits to determine the soil category in accordance with AS/NZS 1547:2012, TP58, A Guide to On-site Wastewater Design Reporting for Building Consent Applications to the Kaipara District Council (December 2018), or other relevant local guidance documents, if available. Design of on-site effluent disposal systems should be undertaken by a suitably qualified and experienced party.

17 On-Site Stormwater Disposal

With increasing development and intensification comes increasing demand on the reticulated stormwater systems serving the wider community, and a requirement for specifically designed on-site stormwater disposal systems in areas not serviced by the reticulated network.

It is important that the specifically designed stormwater disposal systems are designed to collect all runoff from sealed areas, roofs and driveway areas (including water tank overflows) and are connected directly to specifically designed and constructed energy dissipation structures, such as level spreaders located on approved portions of the lower reaches of the slopes, and below any on-site wastewater disposal fields. Discharge structures should be located near the base of the gullies wherever practical.

Under no circumstances should soakage pits or uncontrolled flows be permitted to discharge onto or into sloping ground, as this has the potential to trigger slope instability.

All developments intending to utilise an on-site stormwater management and disposal system will be subject to site-specific assessments by suitably qualified and experienced civil and geotechnical professionals to support detailed design of appropriate systems to accommodate the development proposal and site-specific constraints.

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19 Limitations

- i. We have prepared this report in accordance with the brief as provided. This report has been prepared for the use of our client, Kaipara District Council, their professional advisers and the relevant Territorial Authorities in relation to the specified project brief described in this report. No liability is accepted for the use of any part of the report for any other purpose or by any other person or entity.
- ii. The recommendations in this report are based on the ground conditions indicated from published sources, site assessments and aerial photograph analysis described in this report based on accepted normal methods of site investigations. Only a limited amount of information has been collected to meet the specific financial and technical requirements of the client's brief and this report does not purport to completely describe all the site characteristics and properties. No liability is accepted for any of the information presented in this report or appended geohazard plan, as the information is only an indication of what we consider to be the general level of the mapped geotechnical hazards.
- iii. It should be appreciated that the geotechnical hazards described within this report and accompanying plan have gradational contacts between low, moderate and high-risk. Properties that straddle two zones or are in the proximity to a different zone, should be investigated based on the higher geotechnical assessment level category.
- iv. Geotechnical hazard conditions relevant to development and construction works should be assessed by professionals who can make their own interpretation of the factual data provided. They should perform any additional testing and investigation as necessary for their own purposes, and the geohazard plan should not be used as a replacement for site specific assessments.
- v. This Limitation should be read in conjunction with the Engineers NZ / ACENZ Standard Terms of Engagement.

We trust that this information meets your current requirements. Please do not hesitate to contact the undersigned on (09) 972 2205 if you require any further information.

Report prepared by



Craig Wright, CMEngNZ (PEngGeol)

Associate Engineering Geologist

Report reviewed by



Richard Justice, CMEngNZ (PEngGeol)

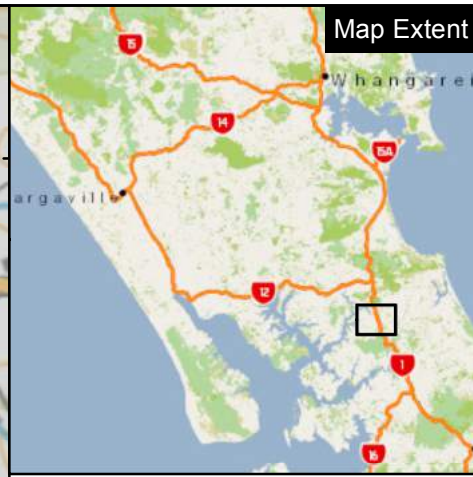
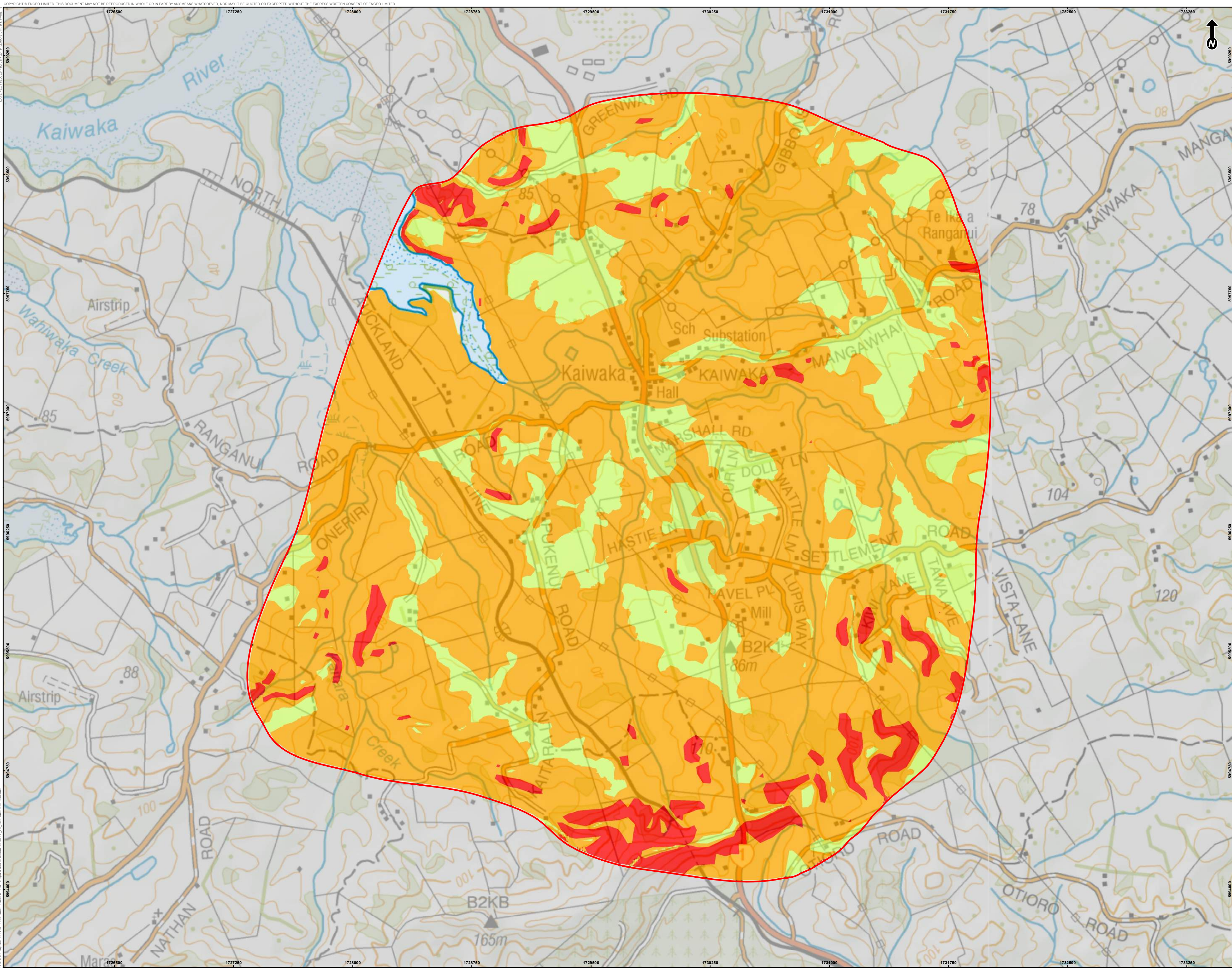
Principal Engineering Geologist



Heather Lyons

Associate Engineering Geologist

APPENDIX A:
Geotechnical Hazard Map



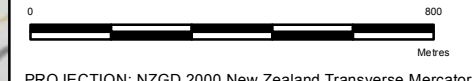
Legend

- Indicative growth area

Geohazard risk

- Low
- Medium
- High

Aerial: LINZ and Eagle Technology, CC-BY-3.0-NZ.
 Map image: Eagle Technology, CC-BY-3.0-NZ.
 Geology Data: GNS Science CC-BY-3.0-NZ.



PROJECTION: NZGD 2000 New Zealand Transverse Mercator



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Title: **Combined Geohazard Plan
 Kaiwaka**

Client: Kaipara District Council		Appendix:
Project:	Designed: CW	A
Geotechnical survey and hazard mapping	Drawn: RW	
	Checked: RJ	
Proj No:	Date: Feb 19	Size: A2
15601.000.001	Scale: 1:15,000	Revision: A

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