



ENGEO

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Geotechnical Assessment

Mangawhai
Kaipara District

Submitted to:
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16.04.2019
15601.000.003_02



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ENGEO Document Control:

Report Title	Geotechnical Assessment - Mangawhai, Kaipara District			
Project No.	15601.000.003	Doc ID	02	
Client	Kaipara District Council	Client Contact	Mr Paul Waanders	
Distribution (PDF)	Kaipara District Council			
Date	Revision Details/Status	WP	Author	Reviewer
28/03/2019	Issued to Client as Draft	BK	CSW/HL	RJ
16/04/2019	Issued to Client	BK	CSW/HL	RJ

1 Executive Summary

This report presents our geotechnical assessment and hazard mapping for the Mangawhai 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 Mangawhai.

In general, this area is characterised by mountainous terrain to the north, steep slopes and narrow ridges to the south, with rolling hills of complex geology bisected by broad valleys and incised gullies filled with young alluvial sediments through the centre of the study area. Dune sands and alluvium dominate the coastal areas to the east and south. Elevations range from approximately sea level within the Mangawhai Estuary, up to 397 m above mean sea level in the mountainous terrain to the north. The Mangawhai Harbour and Estuary is a prominent feature that begins east of the towns of Mangawhai and Mangawhai Heads, and is fed by a series of tributaries and drainages within its catchment.

The area contains eight main geological units; these are: Waipapa Group Greywacke, Whangarei Limestone, Northland Allochthon, Waitemata Group sandstones and mudstones, Coromandel Group volcanics, Kerikeri Volcanic Group, Kariotahi Group dunes and Tauranga Group alluvial soils.

Based on the findings of this geotechnical assessment, the primary geotechnical constraints of the Mangawhai 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 and acid sulphate soils. 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 Mangawhai. 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 Mangawhai area;
- Suitability of the ground for the disposal of effluent wastewater;
- Suitability of the land for future development;
- Risks and hazards of the Mangawhai 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. Geomorphological 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 Mangawhai Growth Area is an irregularly shaped region with an area of approximately 10,400 hectares, located around the townships of Mangawhai, Mangawhai Heads, Hakaru and Tara, within the Kaipara District.

The study area includes the main roads Cove Road (approximately north-south) and Mangawhai Kaiwaka Road (approximately east-west), and minor roads Molesworth Drive, Mangawhai Heads Road, Insley Street, Lawrence Road, and Settlement Road. A number of smaller local and dirt roads are also captured within the study area. Mangawhai Harbour in the east continues inland to form the Mangawhai Estuary, which is fed by Tara Creek and Bob Creek, and a number of smaller tributaries. Hakuru River is located in the south-western portion of the study area, and flows towards the southwest to feed into the Topuni River beyond the extent of the study area.

The vicinity of the study area is shown in Figure 1, and the Mangawhai Indicative Growth Area is shown in Figure 2.

Figure 1: Site Vicinity

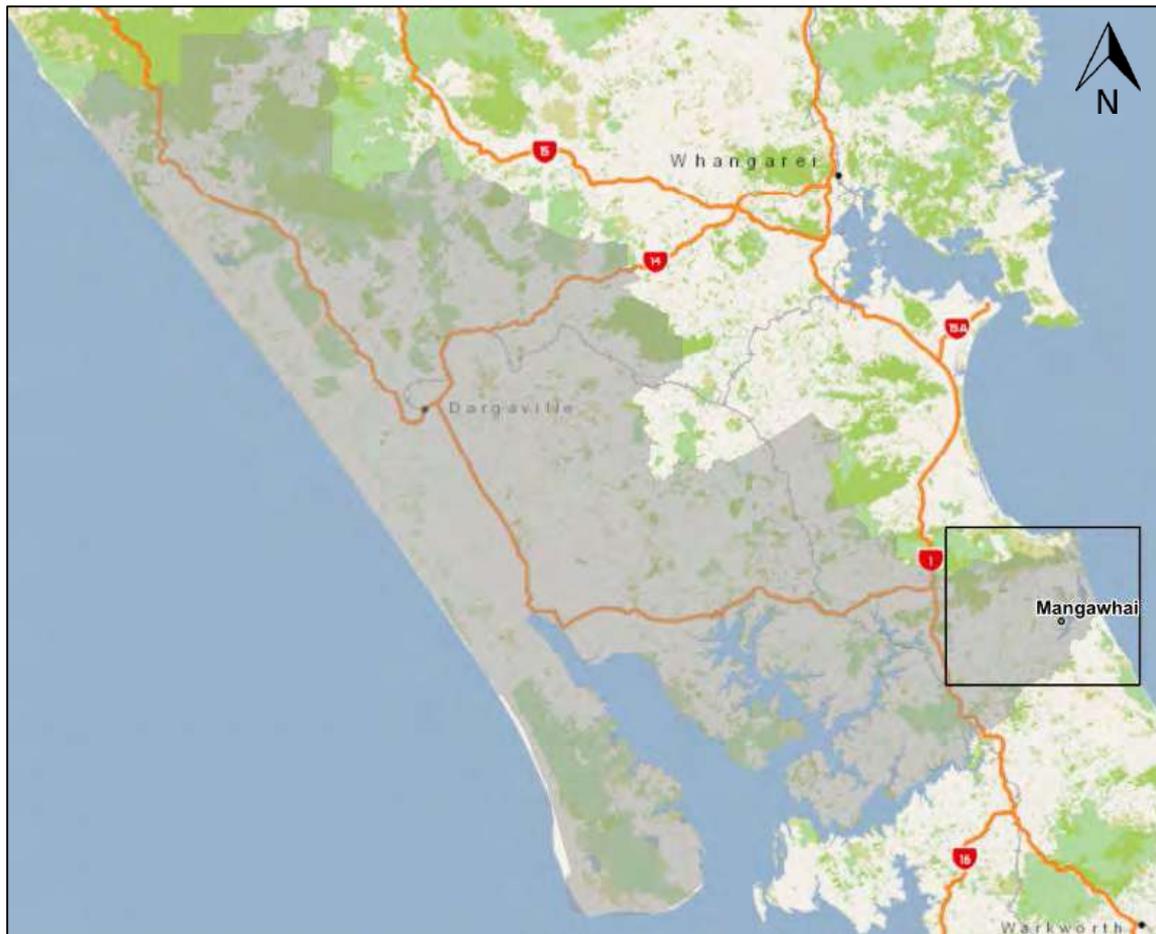


Image sourced from Land Information New Zealand, CC-BY-3.0. Not to Scale

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 Mangawhai has been established through a comprehensive 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 Mangawhai area is presented in the following sections.

7.1 Published Geology

The primary geological map reference for the Mangawhai 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

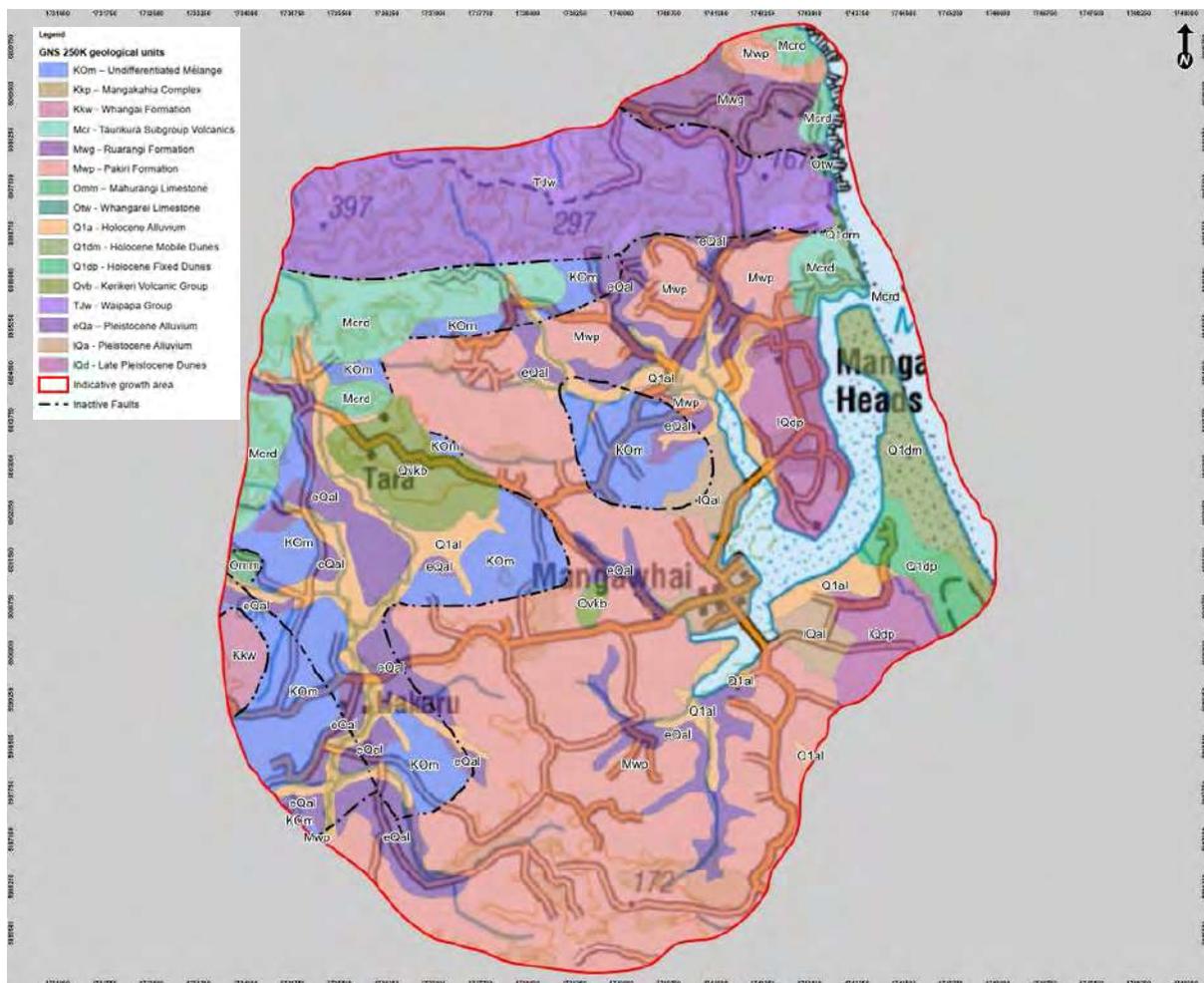


Image adapted from GNS QMAP. Not to Scale

7.2 Waipapa Group (TJw)

The northern portion of the Mangawhai study area is underlain by Permian- to Jurassic-aged metamorphosed sedimentary rocks comprising thinly bedded, fine grained sandstone and argillite, massive, poorly bedded or laminated argillite, and massive “Greywacke”.

The rocks are typically strong to very strong and closely fractured, with veins of calcite, phrenite, quartz, chlorite and zeolites throughout. The unit is bound to the south by the Waipu Boundary Fault, an inactive normal fault with a near-vertical dip which forms the base of the sheer ridgeline that defines the northern extent of the wider Mangawhai area.

Waipapa Group rocks form sheer craggy cliffs in coastal exposures, and spiny mountainous terrain inland. They weather to form white to yellow-brown clays and silts where exposed.

7.3 Whangarei Limestone (Otw)

Oligocene-aged Whangarei Limestone of the Te Kuiti Group is exposed in a small coastal outcrop in the north-eastern portion of the Mangawhai study area. The limestone is described as white to pink, stylolitic, bioclastic limestone with some interbedded conglomerate and pebble horizons. It ranges in thickness from 1 m to 120 m throughout the greater Northland area, however this unit has limited exposures within the study area.

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

7.4.1 Mangakahia Complex – Whangai Formation (Kkw)

A small pocket of Whangai Formation mudstone is mapped in the south-western portion of the Mangawhai study area, west of Hakaru. In this area the Whangai Formation comprises thin-bedded, grey, siliceous mudstone, locally with thin glauconitic or chert beds, micritic limestone, and both calcareous and non-calcareous mudstone beds. This unit is typically shattered and sheared.

7.4.2 Motatau Complex - Mahurangi Limestone (Omm)

A very small pocket of Mahurangi Limestone is mapped in the western portion of the study area, northwest of Hakaru.

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.

7.4.3 Undifferentiated Mélange (K0m)

Pockets of the central and western portions of the study area are mapped as Undifferentiated Mélange, bounded by thrust faults displacing the surrounding units. The Undifferentiated Mélange 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.

7.5 Waitemata Group

Waitemata Group rocks comprise interbedded sandstone and mudstone units of Miocene age that overlie the Mesozoic basement and Northland Allochthon units. Waitemata Group formations are incorporated within the Northland Allochthon as a result of the later emplacement via thrusting and gravity sliding into the Waitemata Basin.

In the Mangawhai study area, the Waitemata Group rocks include the Ruarangi Formation of the Bream Subgroup, and the Pakiri Formation of the Warkworth Subgroup. These units are described in the following sections.

7.5.1 Ruarangi Formation (Mwg)

The Ruarangi Formation is mapped in the north-eastern corner of the Mangawhai study area, overlying Waipapa Group terrain and separated by an inferred thrust fault. The unit is dominated by mudstone with local intercalated sandstone beds and turbidite units, with siltstone and mudstone layers. It weathers locally to form orange and brown, high plasticity clays and silts.

7.5.2 Pakiri Formation (Mwp)

Pakiri Formation is mapped across much of the central and southern areas of the Mangawhai study area, forming steep and narrow ridges at the southern extent and more low-angle slopes and broad ridges through the central and northern areas.

Pakiri Formation typically 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.

7.6 Coromandel Group – Taikura Subgroup (Mcr)

The Coromandel Group includes the remnants of volcanoes across Northland, with the Taikura Subgroup comprising predominantly andesitic volcanoclastic deposits and flows, with dacite domes, and andesite, diorite and granodiorite intrusions. Subaerial dacite domes and associated altered tuff forms the Pukekaroro Hills between Maungaturoto and Mangawhai.

In the Mangawhai study area, dacite outcrops (Mcrd) are mapped in the northwest adjacent to the Waipu Boundary Fault, and on the coast in the northeast forming steep, craggy cliffs and ridges.

7.7 Kerikeri Volcanic Group (Qvb)

The Kerikeri Volcanic Group is a Late Miocene to Quaternary-aged volcanic group that includes a number of monogenetic (single eruption) basaltic volcanoes across Northland, with an isolated flow remnant outcropping in Mangawhai.

A large basalt flow outcrop is mapped to the northwest of Mangawhai town, with a smaller peak-like outcrop immediately west of the town adjacent to Kaiwaka-Mangawhai Road. In the larger mapped area to the northwest, basalt has historically been quarried in association with development of the land (presumably for agricultural purposes), and the basalt rock has been used to construct low stone walls across the area.

7.8 Kariotahi Group

The Kariotahi Group encompasses Early Pleistocene to Holocene-aged coastal sand deposits including shallow marine, beach and dune sands. In the Mangawhai study area, fixed and mobile (or active) dune deposits are mapped in the east at the Mangawhai Heads. The Kariotahi Group is further subdivided into Pleistocene and Holocene-age dune units, as described in the following sections.

7.8.1 Pleistocene Fixed Dunes (IQd)

Pleistocene fixed dune deposits within the study typically comprise weakly cemented sands with preserved interdune swamp deposits forming lignite layers and often containing fossil remains. These deposits are mapped forming most of the peninsula on which Mangawhai Heads township has been constructed, inside the Mangawhai Harbour, as well as in the south-eastern portion of the study area forming vegetated rolling hills above the estuary.

7.8.2 Holocene Fixed Dunes (Q1dp)

The younger Holocene-aged fixed dune deposits are mapped in the south-eastern portion of the study area, south of Mangawhai Heads. They are located immediately behind the active dune deposits on the coast, and are typically stabilised by variable vegetation growth. The sands are typically weakly cemented to uncemented.

7.8.3 Holocene Mobile Dunes (Q1dm)

Holocene-aged mobile dunes form the coastal peninsula at the eastern extent of the study area, south of Mangawhai heads and are the youngest of the dune deposits. The unit comprises bare sand dunes with sparse vegetation, and changes to the distribution and formation of these deposits are ongoing as a result of coastal weathering and deposition processes.

7.9 Tauranga Group

Pliocene-to Holocene-aged alluvium of the Tauranga Group is mapped in the low lying valley and gully areas across the study area.

These units comprise river, lake and estuarine sediments that have been deposited in river valleys prior to subsequent sea-level rises and falls, 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.

7.9.1 Early to Middle Pleistocene Alluvium (eQa)

Early to Middle 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 elevated terraces above present day flood plain levels.

The alluvium is derived from erosion and weathering of *in situ* soil and rock units surrounding the gullies. Organic soil and peat layers, associated with decomposition of organic matter in swamp and estuarine environments, are likely to be present throughout the unit.

7.9.2 Late Pleistocene Alluvium (IQa)

Late Pleistocene alluvium forms broad, level terraces up to 3 m above sea level around the Mangawhai Harbour, underlying the low-lying areas of Mangawhai town. The deposits typically comprise sand, peat and mud layers of alluvial, swamp, and estuarine origin.

Although not detailed on the geological maps, a hard iron pan is known to be present across the low lying areas of Mangawhai. This hard pan consists of chemically altered soils that form a dense and relatively impermeable layer of weakly cemented soil typically within 1 to 2 m of the ground surface. The thickness of the hard pan varies, based on ENGEO's site specific experience, and is typically between 0.5 m and 2 m thick. Groundwater is normally encountered perched at the surface of the hard pan layer.

7.9.3 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 plans in the base of stream and gully systems.

7.10 Unmapped Units

7.10.1 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 in harbour areas, landfills, land development structural fills, and small-scale filling associated with domestic and farming activities including culverts, earth bunds and ofal 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.

7.10.2 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

Extensive water bore data is available for the Mangawhai area through Northland Regional Council (NRC), who have provided us with records for more than 100 bores across the Mangawhai study area. We have also been provided with a report prepared by Sinclair Knight Mertz (2005) presenting a preliminary study in to the Mangawhai aquifer from a perspective of groundwater resources to service the growing community. The report details data collected from approximately 80 water bores across Mangawhai, and notes that most of them are installed into the Waitemata Group sediments at an average termination depth of approximately 65 m. Water bores have also been installed into the coastal dune sands with termination depths between 4.5 m and 33.5 m, however the limited extent and depth of the sand aquifer and its poor water quality has resulted in fewer installations.

Based on the reported groundwater bore records, depth to groundwater within the sand aquifer ranges from above ground level (artesian conditions) to 19 m below the ground surface. Depth to groundwater within the Waitemata Group aquifer ranges from above groundwater (artesian conditions) to 45 m below the ground surface. The artesian pressures are typically associated with deep bores, which indicates that groundwater pressures increase with depth at a rate greater than hydrostatic.

It is important to note that the groundwater aquifer studies target deep, long term groundwater aquifers and do not identify or address perched groundwater tables that occur near to the surface within the overburden soil layers. It is these perched groundwater surfaces that are typically encountered during land investigation and development work, and that also are the critical contributing factors affecting slope instability and liquefaction.

Groundwater can be expected to be close to the surface across most of the study area. Within the Waipapa Group, Waitemata Group and 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 and swampy ground with wide spread surface drainage patterns across much of the sloping land underlain by these units.

Groundwater in the low lying flood plain areas and gully areas, underlain by Holocene alluvium, is likely to be at levels comparable to the stream and river levels and, in some cases, may be artesian as observed in some of the NRC water bores. Within the Pleistocene alluvium and dune sand deposits, 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.

Groundwater levels in mapped volcanic areas (Coromandel Group and Kerikeri Volcanic Group) are likely complex.

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 within the Mangawhai Growth Area. The nearest active fault is the Waikopua Fault located approximately 110 km southeast of the study area, to the southeast of Auckland City.

The Waipu Boundary Fault is mapped extending approximately east-west across the northern portion of the Mangawhai study area, forming the boundary between the steep, mountainous terrain of the Waipapa Group in the north, and the lower-lying varied geology of the rest of the study area. The fault is mapped as an inactive normal fault with a near-vertical dip.

There are several unnamed, inactive thrust faults within the study area that separate the Pakiri Formation and the Whangai Formation from Undifferentiated Mélange.

10 Ground Slope Angles

Slope steepness across the Mangawhai study area is highly variable. The northern portion of the study area, underlain by Waipapa Group rock (TJw), presents the greatest relief with rugged terrain defined by narrow ridges and sheer, steep slopes. The southern portion of the study area, underlain by Pakiri Formation (Mwp) also features narrow ridges with steep ridge flanks, and this terrain extends towards the north through the study area with gradually decreasing relief.

Taurikura Subgroup (Mcr) dacite outcrops in the north-western portion of the study are also associated with steep slopes, as is the Late Pleistocene-aged dune deposit forming the peninsula into Mangawhai Harbour on which Mangawhai Heads township has been constructed.

Undifferentiated Mélange (KOm) and Tauranga Group alluvium through the central and western portions of the study area support lower lying relief, with broad slopes and wide valley floors. The flattest terrain extends to the east on the southern side of the Mangawhai Harbour, where Tauranga Group alluvium and low lying Kariotahi Group dunes have created a very subdued landform. To the south, the landform rises into older fixed dune deposits and Pakiri Formation hills, resulting in steeper slopes extending beyond the study area boundary.

A profile of existing slope angles was created using LINZ Topo50 20 m contours (vertical accuracy $\leq 10\text{m}$). 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

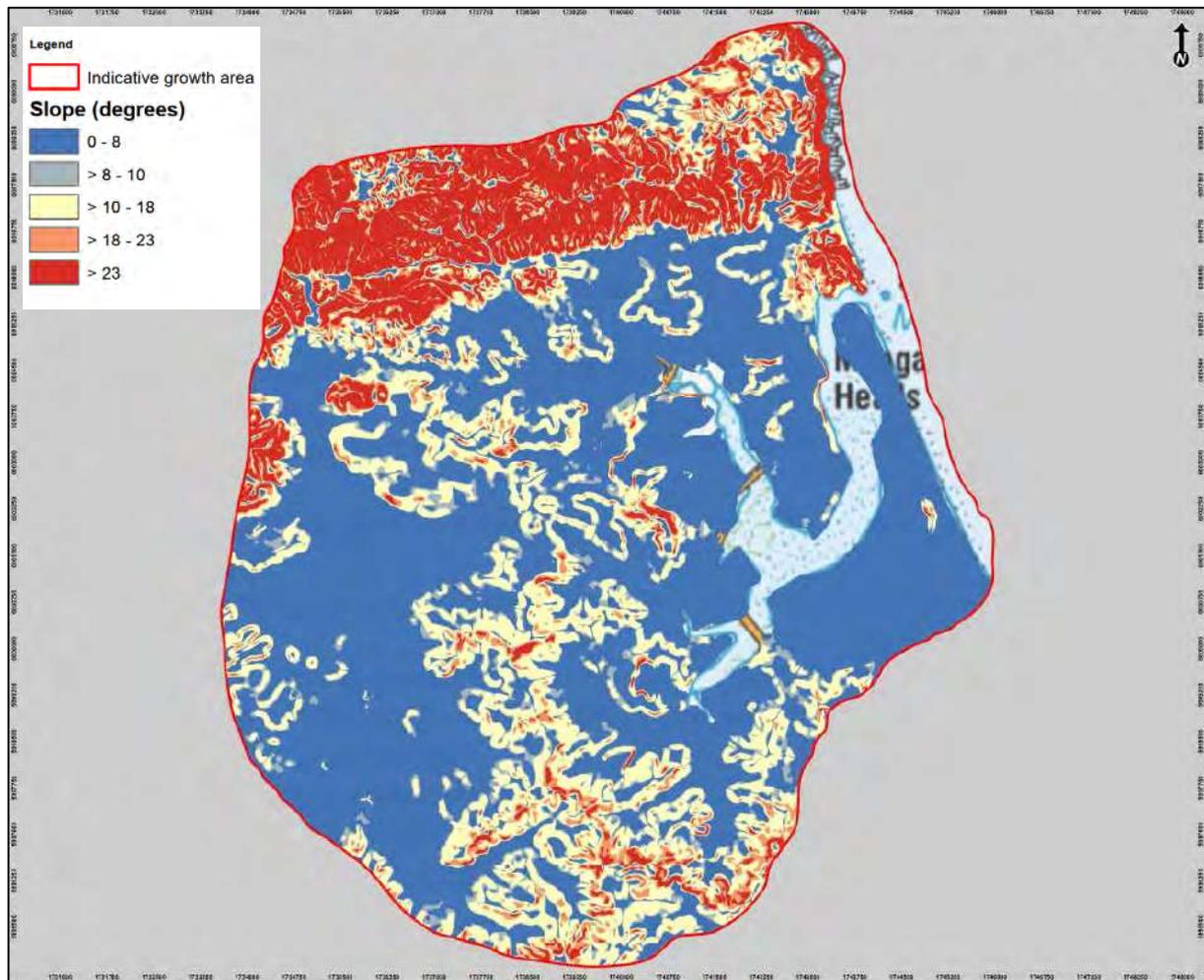


Image sourced from Land Information New Zealand, CC-BY-3.0. Not to Scale.

11 Geotechnical Hazard Discussion

The following geotechnical hazard discussion is based on available geotechnical information, geological mapping, aerial photography and our understanding of the Mangawhai 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 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 at 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. Dacite outcrops are mapped in the northwest, adjacent to the Waipu Boundary Fault, along the coast in the north-eastern portion of the study area and continues north to Bream Tail. Between Kaiwaka and the Brynderwyn Junction, to the west of the site, and between Maungaturoto and Mangawhai, there are many subaerial dacite domes, including the prominent Pukekaroro dome and Bald Rock.

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 wastewaters.

Elevated areas of sedimentary rock and residual soils 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 2017. The photographs were viewed under the context of identifying general changes to the landform.

Table 1: Historic Aerial Photograph Summary

Date	Description
<p>1961 - 63</p> <p>Retrolens Aerial Photo Series</p>	<p>Early residential development of the eastern part of Mangawhai Heads with dirt roads and sparse housing is present. The central and western areas of the Mangawhai Heads Peninsula is largely undeveloped. Molesworth Drive is present. There is evidence of slope instability along the eastern coast of Mangawhai Heads near the eastern ends of Findlay Street and the now present Evelin Street (eastern instability area).</p> <p>Areas to the south of the estuary appear to be developed with agricultural pasture land. The Inslay Street estuary crossing has been constructed at this time.</p> <p>Mangawhai township is sparsely populated with residential and rural properties at this time with less than approximately 30 houses located on Moir Street, Tara Road, Molesworth Drive and Pearson Street.</p> <p>The majority of the current major roads in the area (Kaiwaka-Mangawhai Road, Lawrence Road, Mangawhai Road, Cove Road, Grabolino Road, Hilltop Road, Brown Road, Devich Road, Tomarata Road) were present, however the majority of the roads appear to be unpaved.</p> <p>Tara and Hakaru were generally utilised for agriculture with limited isolated residential structures.</p>
<p>1977</p> <p>Retrolens Aerial Photo Series</p>	<p>Residential densification in Mangawhai Heads with further formation of dirt roads within the township. Molesworth Drive bridge has been constructed, linking up the Molesworth Drive loop. No observed change in the eastern instability area.</p> <p>Limited densification of Mangawhai township, and the Hakaru and Tara areas remain predominantly rural with limited, isolated residential structures.</p> <p>King Road and its associated tributary roads are present at this time, however the surrounding area is predominantly rural with limited, isolated residential structures.</p>

Date	Description
<p>1982 – 86</p> <p>Retrolens Aerial Photo Series</p>	<p>Ongoing residential intensification of Mangawhai Heads. Majority of the roads within the township appear to be generally paved. Residential development appears within the potential eastern instability area.</p> <p>Evidence of instability (hummocky ground and potential scarps) southwest of the Kaiwaka-Mangawhai Road and Lawrence Road intersection.</p> <p>Ongoing establishment of the agricultural crop land surrounding Tara.</p> <p>Several established agricultural crop developments were present south of the estuary inlet.</p>
<p>1993 – 96</p> <p>Retrolens Aerial Photo Series</p>	<p>Significant residential densification of the eastern half of Mangawhai Heads. The golf course and an area utilised for agricultural purposes is present in the central-western part of the peninsula.</p> <p>Significant residential densification in Mangawhai township on Molesworth Drive, Pearson Street, Moir Street, and Kaiwaka-Mangawhai Road.</p> <p>Ongoing establishment of the agricultural crop land surrounding Tara and Hakaru.</p>
<p>2004 – 2017</p> <p>Google Earth</p>	<p>Residential densification of Mangawhai Heads. Residential development of the southern part of the peninsula (south of Molesworth Drive). No observed movement of the eastern instability area.</p> <p>Residential densification of Mangawhai and development north along Old Waipu Road, east along Dune View Drive and northeast along Tara Road.</p> <p>Residential development south and southeast along Devich Road, Coal Hill Road and Tern Point.</p> <p>Development north along Pebblebrooke Road and King Road.</p> <p>Small residential and rural densification in Tara and Hakaru.</p> <p>Ongoing evidence of instability southwest of the Kaiwaka-Mangawhai Road and Lawrence Road intersection.</p>

Aside from the observed changes summarised in Table 1, general residential intensification 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 numbered C/32 through C/34, D/30 through D/32, and E/27 through E/29, 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 Mangawhai study area is underlain by a complex geological regime, and is broadly defined by steep mountainous terrain to the north, broad, rolling hills and ridges with moderately steep flanks through the central and western areas, narrow resilient ridges with steep flanks to the south, and low-lying alluvium and sand dunes to the southeast.

The northern portion of the study area is largely inaccessible, and is dominated by densely vegetated mountainous terrain with isolated residential properties located on narrow, resilient ridges. The north-eastern portion of this area is less densely vegetated, and is underlain by Waitemata Group sandstones and mudstones, with Coromandel Group dacite outcrops at the coast. The landform in this area slopes more gently, and is incised by a series of gully features with numerous tributaries extending up the flanks of the broad ridges. Instability features are common adjacent to the gully features, as elevated groundwater levels coupled with a loss of toe support contribute to episodic slips on steep slopes.

A large Coromandel Group dacite outcrop stands at the head of Mangawhai Harbour, and has been developed with residential properties perched on the steep slopes (Photo 1). The high strength and relative resilience of the dacite rock allows for hard engineering measures, such as rock anchors and piles to support building development. To the west of the dacite outcrop, low rolling hills underlain by Pakiri Formation support low-intensity residential properties and farming. A series of gully systems bisect the landform, and evidence of shallow rotational landslides and active soil creep is visible on the gully flanks (Photo 2). Further west, elevated Pleistocene alluvial terraces form broad, approximately level land on which farming and residential development has taken place (Photo 3), before rising into steep Waipapa Group terrain to the north, and Coromandel Group dacite terrain extending to beyond the study area boundary to the west.

The central and western portions of the study area are underlain by a combination of Pakiri Formation and Undifferentiated Mélange forming low, rolling hills bisected by gullies that have been infilled with Holocene-age alluvial sediments, and flanked by Pleistocene-age alluvial terraces (Photos 4 through 6). Evidence of historical slope instability was observed across much of this portion of the study area, forming hummocky ground and mid-slope benches on moderate to steep slopes (>14 degrees) (Photo 4). Basalt and dacite outcrops are exposed in the north-western portion of the study area, with the basalt forming a broad, low-angle dome and the dacite outcrops forming steep, densely vegetated slopes.

Although Pakiri Formation (and other Waitemata Group members) are known to typically stand stable at slope angles greater than that of the Northland Allochthon units, the resilience of the slopes in the central and northern portions of the site, where in close proximity to thrust faults and Northland Allochthon outcrops, was observed to be poor. Significant areas of instability were observed and are attributed to historical deformation associated with emplacement of the Northland Allochthon, and subsequent episodic instability associated primarily with active gully and groundwater processes, and instability within the adjacent and underlying Undifferentiated Mélange units.

The southern portion of the study area is predominantly underlain by Pakiri Formation rock and residual soil, forming steep, resilient ridgelines with Pleistocene and Holocene alluvium infilling the gully systems. Residential development has been limited to low density clusters on wide ridge crests, with evidence of significant shallow and deep-seated instability on the steep ridge flanks where slope angles exceed 14 degrees (Photos 7 and 8). The instability features include hummocky ground, mid-slope benches, arcuate headscarps and debris lobes on most slopes, with active gully regression extending to the crest of ridges in some cases.

Holocene and Pleistocene alluvial deposits form low-lying, broadly-level terraces in the south-eastern portion of the study area on the southern side of the Mangawhai Estuary (Photos 9 and 10). The dune deposits to the south and east adjoin the level terraces as low rolling hills, increasing in relief to the south and beyond the study area boundary. Little evidence of historical slope instability was observed in this portion of the site due to access constraints, however soil creep was observed on dune slopes having angles of approximate 14 degrees.

The peninsula on which Mangawhai Heads township is constructed predominantly comprises Pleistocene fixed dune deposits, which include a low lying terrace approximately 3 m above sea level on the estuary frontage, rising to approximately 53 m above sea level at the centre of the peninsula (Photos 11 and 12). The landform slopes steeply (up to 70 degrees), and where exposed, weakly cemented sands were observed in cut faces. Evidence of historical slope instability affecting these steep slopes was observed at Eveline Street, on the eastern side of the peninsula, where a recent slip has affected infrastructure and pedestrian access to properties on the waterfront.

Figure 6: Photographs



Photo 1: View north from Mangawhai Beach access towards Taurikura Subgroup dacite outcrop, with typical steep slopes and dense vegetation.



Photo 2: View north across Pakiri Formation low-angle rolling hills, with steep Waipapa Group terrain at rear.



Photo 3: View north across Pleistocene alluvial terraces, with steep Waipapa Group terrain at rear.



Photo 4: View south across Pakiri Formation hills in northern study area, showing mid-slope instability feature on the moderately steep ridge flanks.



Photo 5: View east across low-lying alluvium in western study area, with Undifferentiated Mélange low-angle slopes at rear.



Photo 6: Undifferentiated Mélange in central study area, forming low-angle slopes bisected by wide gully features infilled with alluvium.



Photo 7: Pakiri Formation slopes in southern study area, note hummocky ground and extensive gully regression across slopes.



Photo 8: Pakiri Formation narrow ridgelines with steep flanks showing evidence of historical instability.



Photo 9: Holocene alluvium in south-eastern study area forming broad, flat areas currently in use for farming.



Photo 10: View south in south-eastern study area from low-lying Pleistocene dune deposits towards rising inland dunes.



Photo 11: View south from low-lying Pleistocene dune deposits to the Holocene active dunes across Mangawhai Harbour.



Photo 12: View south from atop the Pleistocene dune deposits forming the peninsula in Mangawhai Harbour, with flat Holocene alluvium deposits at rear.

14 Geotechnical Hazards Identified in Mangawhai

14.1 General

Based on the findings of this geotechnical assessment, we consider the primary geotechnical constraints of the Mangawhai 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, are on over-steepened slopes, or have been identified with Holocene Alluvium susceptible to liquefaction and consolidation settlement. These areas are expected to have significant consequences for structures, could require complex mitigation or setbacks, 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 Mangawhai Estuary (i.e. within the active channel of the estuary and within some of the adjacent Holocene deposits).

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 and dune deposits, which generally consist of soft and poorly consolidated mud, sand and gravel, to unvegetated mobile sand. As discussed in Section 14.2, "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

Waipapa Group, Whangarei Limestone, Northland Allochthon, Waitemata Group, Coromandel Group and Kerikeri Volcanic Group rocks and their associated residual soils are not considered liquefiable. Due to the nature of these units, we consider their 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 Dunes (IQd) comprising weakly cemented dune sands, and Alluvium (IQa/eQa) comprising poorly to moderately consolidated mud, sand and gravel, forms terraces up to 30 m high above present day flood plain levels. GNS maps these soils adjacent to the Mangawhai Harbour and Estuary, and in the bases of gullies further inland (Figure 7). We consider these areas to have a potential to liquefy under ULS conditions. Given that the Pleistocene Alluvium forms steep slopes near the Mangawhai Estuary, lateral spread is also possible during a ULS event.

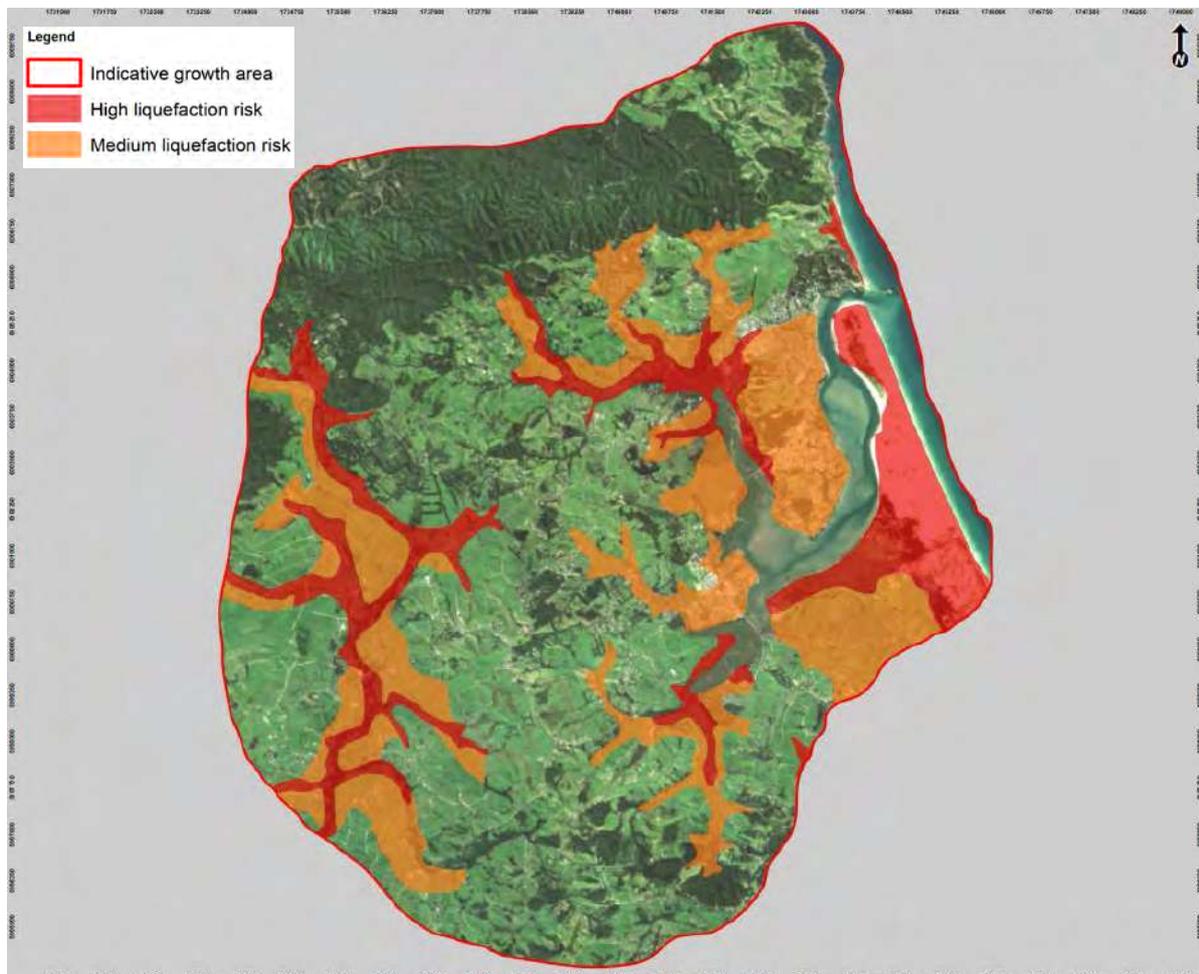
Given the potential for poorly consolidated, coarse-grained soils to be present below groundwater within the Pleistocene Alluvium units in particular, we consider liquefaction and lateral spread potential within this unit to be medium.

High Liquefaction and Lateral Spread Potential

Young Holocene Dunes (Q1d) and Alluvium (Q1a) are mapped around Mangawhai Heads, on the margins of Mangawhai Harbour and the Mangawhai Estuary. Alluvium is also mapped inland in the base of stream and gully features (Figure 7). These deposits generally consist of unconsolidated sands, or soft and poorly consolidated mud, sands and gravels, and occupy low-lying areas associated with elevated groundwater.

We consider these areas to have a potential to experience liquefaction under SLS conditions. Due to the granular nature of these soils and expected high groundwater, we consider the liquefaction and lateral spread potential of the Holocene deposits to be high.

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 to high 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, relatively 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. This most commonly occurs 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 and the Whangarei Limestone are generally less fractured and may be cemented by calcite infill in fractures, resulting in a more stable rock mass. Natural slopes in these units can stand at angles well 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 and Ruarangi Formations, 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.

Waipapa comprises alternating fine-grained sandstone and argillite beds and massive jointed Greywacke sandstone. The rock is generally well indurated and can form very steep slopes in Mangawhai. Taikura Subgroup and Kerikeri Volcanic Group consist of andesitic volcanoclastics, andesitic flows and dacite domes or large basalt flows. These formations, like Waipapa Group rocks, form some of the steepest slopes in Mangawhai.

Pleistocene-Aged fixed sand dune deposits were observed at slopes up to approximately 70 degrees. However, evidence of historical and active slope instability affecting these steep slopes was observed during our geomorphological review. Unvegetated mobile dune deposits are mapped near the perimeter of the Mangawhai Harbour. These deposits, such as Mangawhai spit, may be listed as Outstanding Natural Features and subject to restrictions to land use and development. However, their engineering properties are expected to perform similar to uncemented Holocene- and Pleistocene-aged fixed dune deposits.

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. 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 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°...".

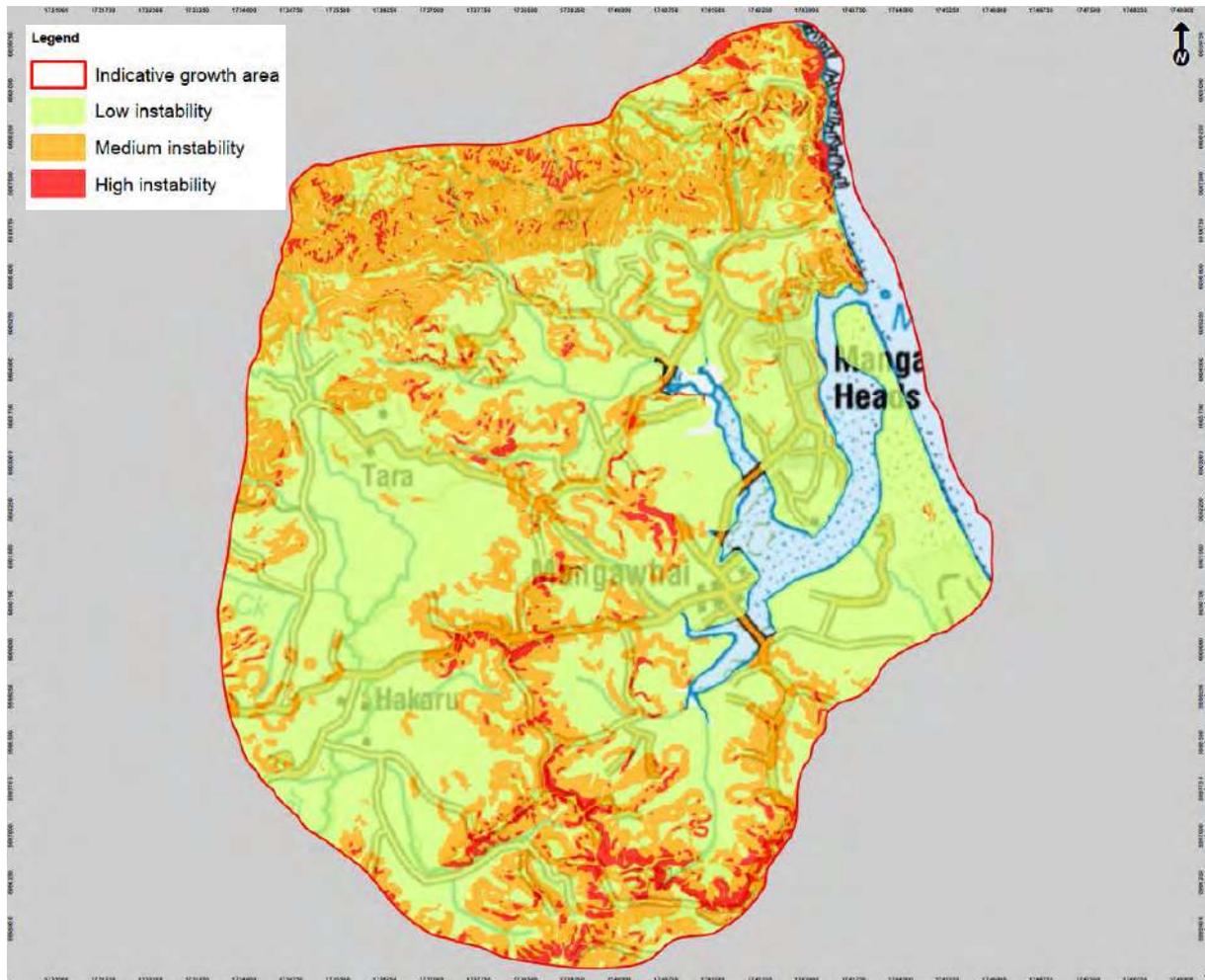
Based on GNS, Auckland Council, previous geotechnical assessments, and our experience, we have developed slope profile ranges which are presented in Table 2. Slope profile ranges categorise the potential for instability in each geological unit as low, medium, and high, with corresponding slope angles.

Table 2: Slope Instability Profile

Geologic Unit	Slope Instability Potential based on Slope Profile Ranges		
	Low	Medium	High
Tauranga Group Alluvium	<10°	10-23°	>23°
Kariotahi Group dunes	<14°	14-26°	>26°
Kerikeri Volcanic Group	<18°	18-45°	>45°
Taikura Subgroup	<18°	18-45°	>45°
Waitemata Group (includes Pakiri Formation and Ruarangi Formation)	<14°	14-26°	>26°
Northland Allochthon (includes Undifferentiated Mélange, Mahurangi Limestone, Whangai Formation)	<8°	8-18°	>18°
Whangarei Limestone	<8°	8-18°	>18°
Waipapa Group	<18°	18-45°	>45°

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 the 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.

Figure 8: Slope Instability Potential



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

14.4.2 Geotechnical Investigation Requirements

Areas identified as having a low instability potential are defined by slopes having angles flatter than 8° in Northland Allochthon, 18° in Waipapa Group, Taikura Subgroup, and Kirikiri Volcanics Group, 14° in Waitemata Group and fixed dune deposits, or 10° in Tauranga Group Alluvium. Geotechnical investigations to support future developments in these areas will need to include a site-specific geomorphic assessment to assess the risk of historical instability that may have occurred at the site, which may include subsurface investigations to substantiate a ground model to satisfy the requirements of the investigation scope.

Geotechnical investigations for future development areas mapped as having a medium to high slope instability potential should be further investigated by a suitably qualified and experienced geotechnical professional¹.

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 of the Tauranga Group (Figure 3: Geology Map) 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 Section 14.2, “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

Waipapa Group, Whangarei Limestone, Northland Allochthon, Waitemata Group, Taikura Subgroup and Kerikeri Volcanic Group rock is not considered to be susceptible to settlement under loading. Residual soils of Northland Allochthon, Waipapa Group 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.

Pleistocene fixed dunes (IQd and Q1d on Figure 3) are generally comprised of weakly cemented and uncemented sands and typically lack a well-developed soil. As such, we consider them to have a low consolidation settlement potential. However, these deposits can include a preserved interdune swamp deposit, which may be susceptible to consolidation. If interdune swamp deposits are encountered during site investigation, then consolidation settlement should be considered.

We expect that this individual would be accredited with Engineering New Zealand as either a Chartered Professional Engineer (CPEng) or Professional Engineering Geologist (PEngGeol)

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

Medium Consolidation Settlement Potential

Pleistocene Alluvium (eQa and IQa) comprising poorly to moderately consolidated mud, sand and gravel, with peat and organic beds, form elevated terraces above present day flood plain levels (Figure 9).

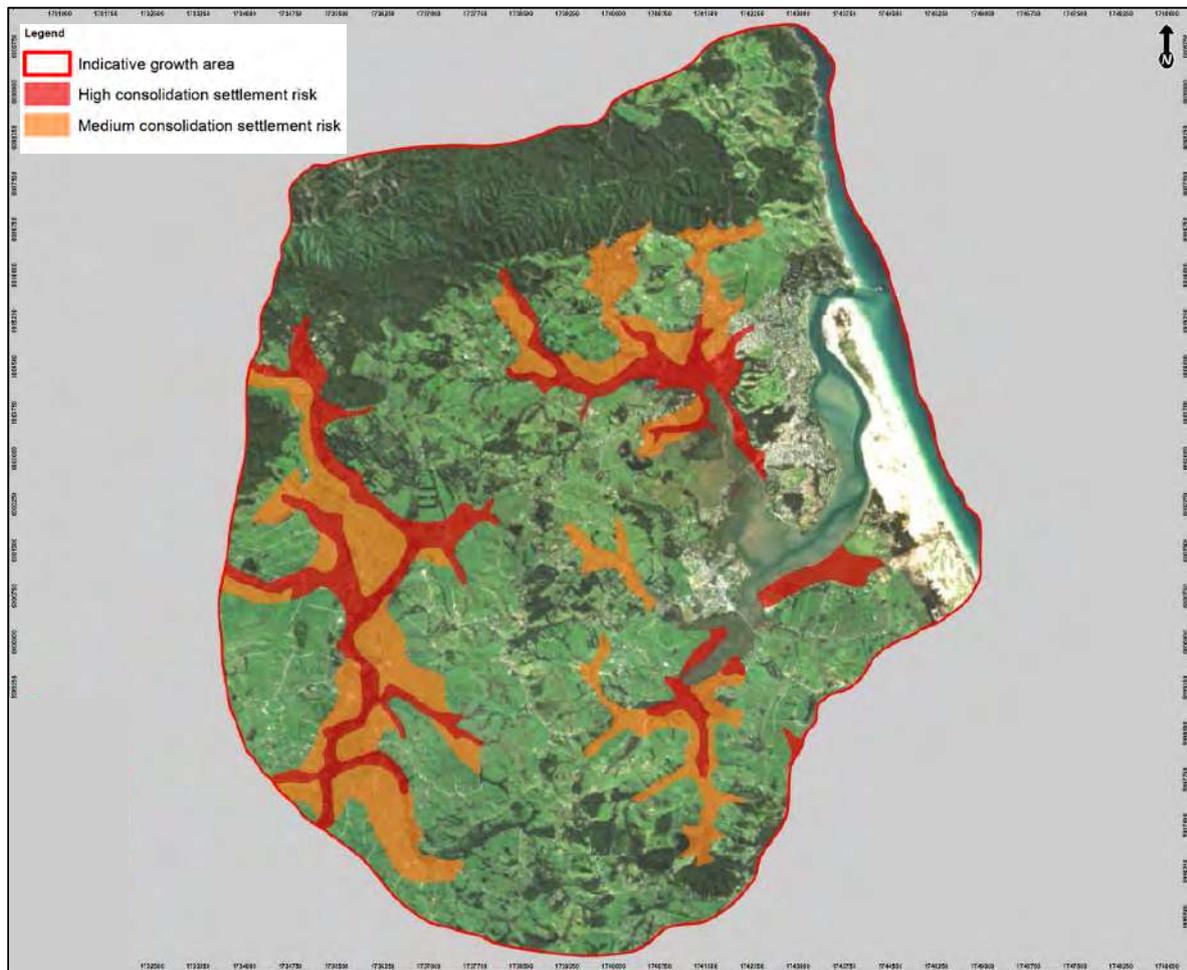
Based on the likely presence of organic material and soft clay layers, we consider these areas to have a medium potential to experience consolidation settlement under loading.

High Consolidation Settlement Potential

Young Holocene alluvial deposits (Q1a) are mapped along the Tara Creek, south of Mangawhai Harbour, and within the north-south trending stream valleys in the western portion of the study area and near the Wairau Rive (Figure 9). Similar to the Pleistocene Alluvium, these deposits comprise mud, sand and gravel, with peat and organic beds. These soils, however, are considered to be soft and poorly consolidated.

Given the likely presence of organic material and soft clay layers, we consider these areas to have a high potential to experience consolidation settlement under loading.

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 relatively strong residual 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.

Geotechnical investigations for future development areas, mapped as having a medium to high 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 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 liquefaction and/or lateral spread under ULS conditions, and/or be susceptible to consolidation settlement under building and development loads, and/or be subject to recent or active slope instability.</p>	<p>Proposals to develop or modify land in these areas are 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>

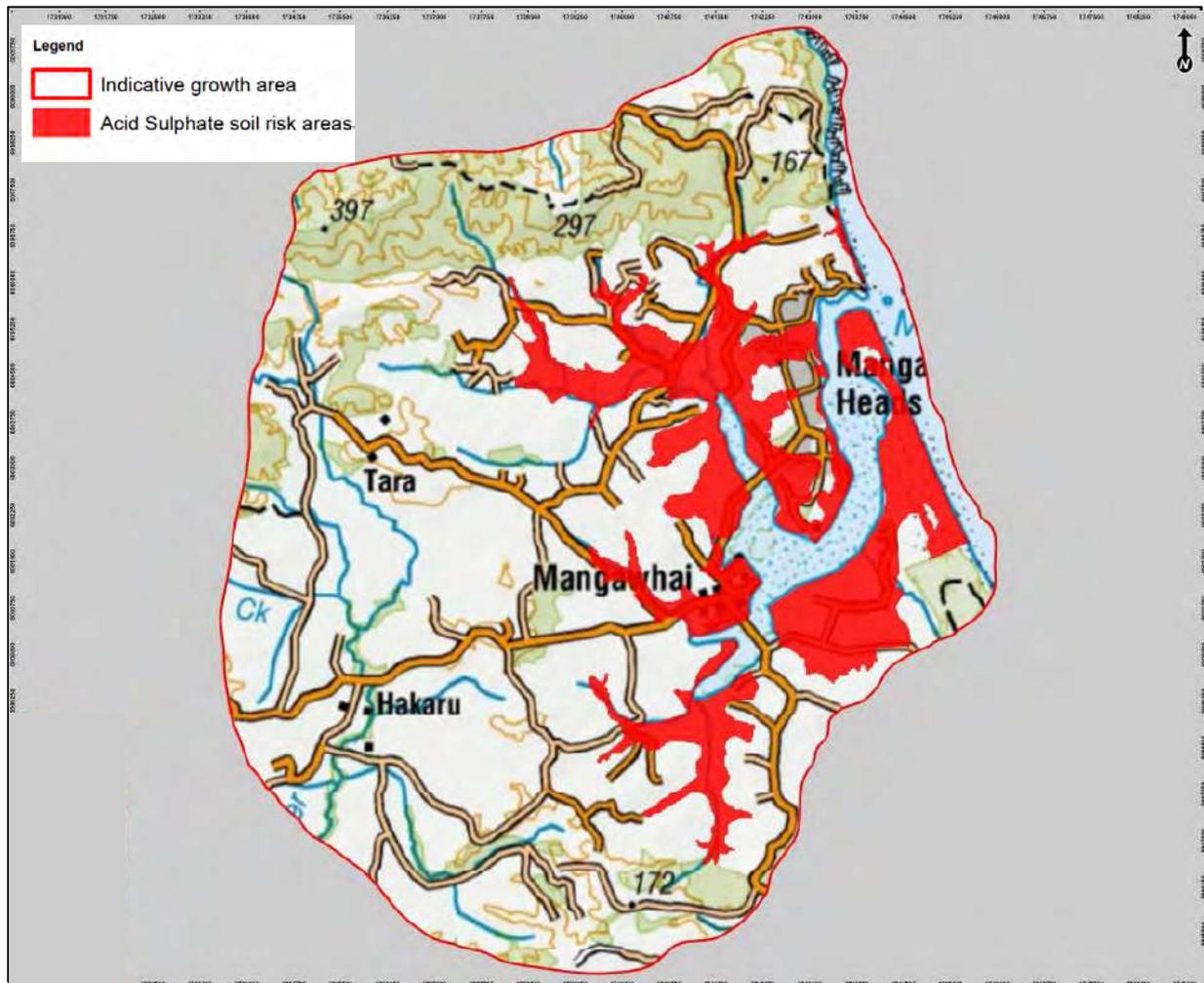
15.1 Sulphate Attack on Concrete

Some Holocene and Pleistocene 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 zoomed in areas of the plan for use in this study, which includes the Mangawhai 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 – The extent of limestone deposits within the Mangawhai study area is limited to two isolated pockets in the western-most portion on the coast. 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 Mangawhai study area. Further, no open pit 'borrow areas' were observed within the study area during our site walkover. Any such features that do exist within the study area are likely to be limited to small-scale operations on private property and if present, should be addressed as part of a future site-specific assessment prior to any land redevelopment.

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

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 Mangawhai. 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 Mangawhai 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 Mangawhai

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 Mangawhai 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 Waipapa Group, Whangarei Limestone, Northland Allochthon and Waitemata Group

The Waipapa Group, Whangarei Limestone, Northland Allochthon and Waitemata Group units within the study area typically weather to form clay-rich residual soils with relatively shallow soil profiles, and can be highly susceptible to instability on gentle slopes. 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. Accordingly, the potential for on-site effluent disposal in areas underlain by Waipapa Group, Northland Allochthon and Waitemata Group 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 Taikura Subgroup and Kerikeri Volcanic Group

The Taikura Subgroup generally consists of andesitic volcanoclastics, andesitic flows and dacite domes. Given the high feldspar mineral content of the subgroup, exposed rock can chemically weather to form halloysitic clays. Where Taikura Subgroup has not weathered to form significant clay-rich soil mantles and have a low slope instability risk (refer to Section 14.4.1), the potential for on-site effluent disposal is considered to be possible.

The Kerikeri Volcanic Group presents as a large basalt flow northwest of the town of Mangawhai, with a smaller peak-like outcrop immediately west of the town. Basalt rock is a highly variable material and competency of this rock often varies widely over short distances. Fractured basalt blocks and gravels are common near the surface, while scoria banding, voids and fractured zones can exist at depth. The interconnected pore space associated with these features can allow water to move vertically through the basalt. Where basalt has a low slope instability risk (refer to Section 14.4.1), the potential for on-site effluent disposal 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.

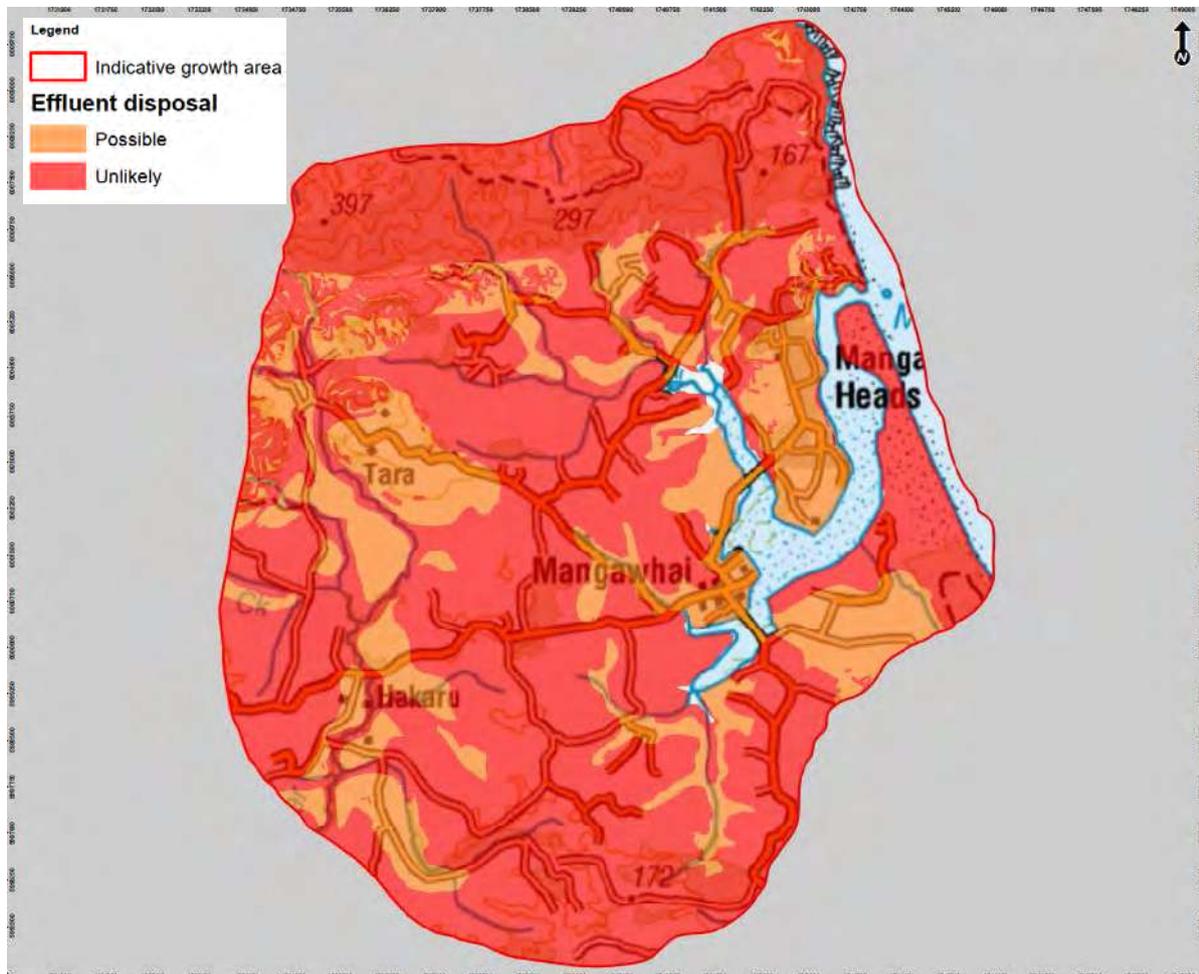
16.2.3 Tauranga Group and Kariotahi Group

Pleistocene alluvium and dune sands, 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 units can have the opposite effect, and the location and extent of such layers is unknown without subsurface investigation. Restrictions associated with depth to groundwater, proximity to clean water sources, 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 their low-lying topography, typically near-surface groundwater table, and mandatory setback requirements from clean water sources, Holocene alluvium and dune sand units have low effluent disposal potential.

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 Mangawhai 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 system 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 the 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 Engineering 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.

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APPENDIX A:
Geotechnical Hazard Plan

