ENGEO

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Geotechnical Assessment

Dargaville

Kaipara District

Submitted to:

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1 Executive Summary

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

In general, this area is characterised by rolling hills of complex geology bisected by broad alluvial and fluvial valleys filled with young sediments. Elevations range from approximately sea level, within the Wairoa River, up to approximately 130 m above mean sea level in the hills to the north. The Wairoa River is a prominent feature that meanders along the south side of Dargaville and is responsible for much of the geomorphological features that make up the study area.

The area contains five main geological units. These are: Undifferentiated Mangakahia Complex, Undifferentiated Mélange, Hukatere Subgroup Volcanics, Awhitu Group and Tauranga Group soils.

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

2 Introduction

ENGEO was engaged by Kaipara District Council (KDC) to undertake an assessment of the engineering geology and geotechnical hazards and their associated risk for development within the growth area of Dargaville. 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 Dargaville area;
- Suitability of the ground for the disposal of effluent waste water;
- Suitability of the land for future development;
- Risks and hazards of the Dargaville 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 KDC 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 map 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, geotechnical design solutions, or mapping of overland flow paths. Additionally, our report contains no information regarding climate change and the consequential coastal erosion or related coastal hazards which may be associated with climate change. Accordingly, we have not included an 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 for future developments 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 any 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 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); and
- 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 Dargaville Growth Area is an approximately circular-shaped region with an area of approximately 6,400 hectares, located around the township of Dargaville, within the Kaipara District. The study area lies approximately 48 kilometres northwest of Maungaturoto, and 55 kilometres southwest of Whangarei along the northern Wairoa River.

The study area includes State Highway 12, State Highway 14, Hokianga Road, Waihue Road, Parore West Road, Baylys Coast Road, Mount Wesley Coast Road, Pouto Road, Arapohue Road, KiwiRail's North Auckland Line (NAL), the township of Dargaville and the commercial, industrial and residential developments within the township, large paddocks used for horticulture, and a portion of the northern Wairoa River. The vicinity of the study area is shown in Figure 1, and the Dargaville Indicative Growth Area is shown in Figure 2.

Figure 1: Site Vicinity

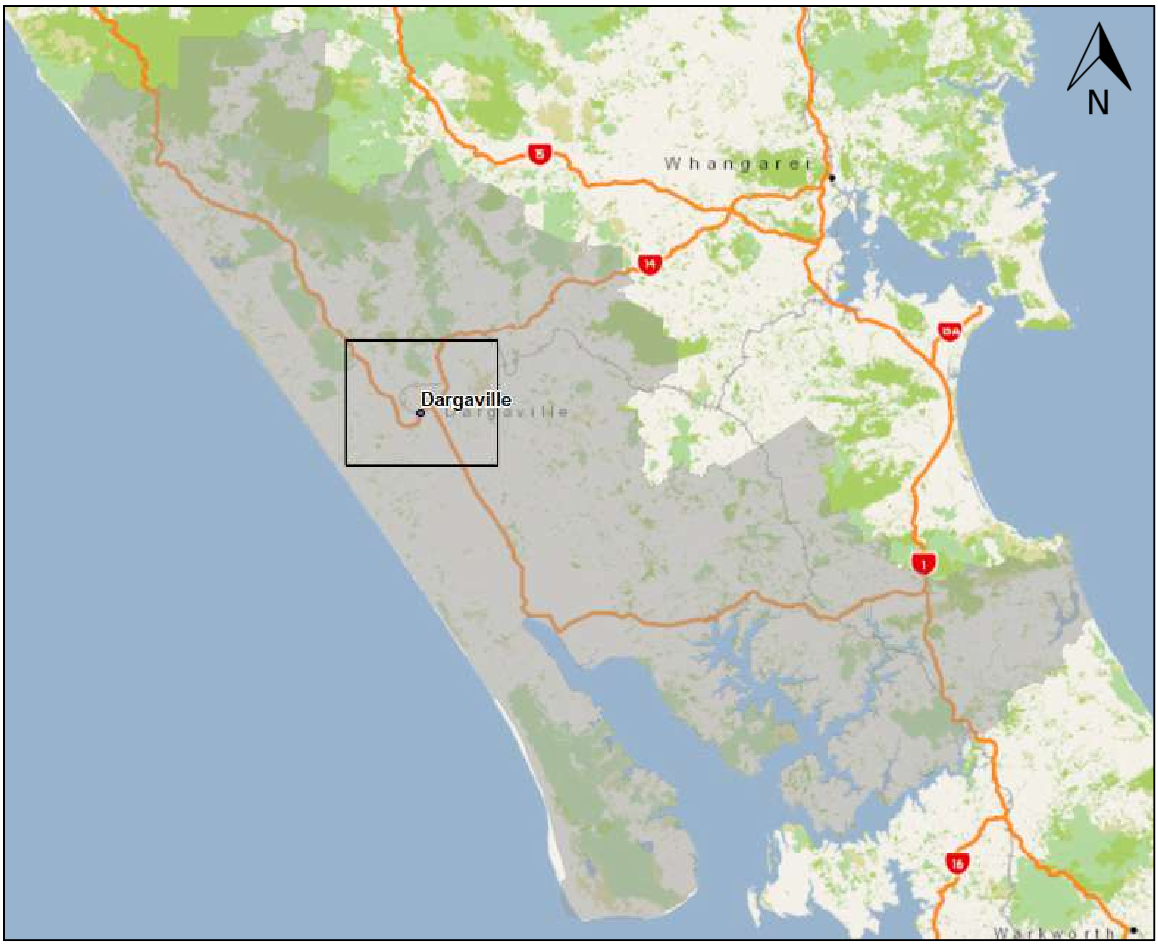


Image sourced from Land Information New Zealand, CC-BY-3.0. Not to Scale

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 Dargaville 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 Dargaville area is presented in the following sections.

7.1 Published Geology

The primary geological map reference for the Dargaville study area is the 2009 GNS 1:250000 map, “Geology of the Whangarei Area” (Edbrooke and Brook, 2009). The QMAP series are widely accepted as an accurate account of the surface expression of geological units across the country. However, at a regional 1:250000 scale, the detail and accuracy of unit boundaries and structural features are indicative only and should not be relied upon exclusively to support land use planning and geotechnical assessment.

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

Figure 3: Geology Map

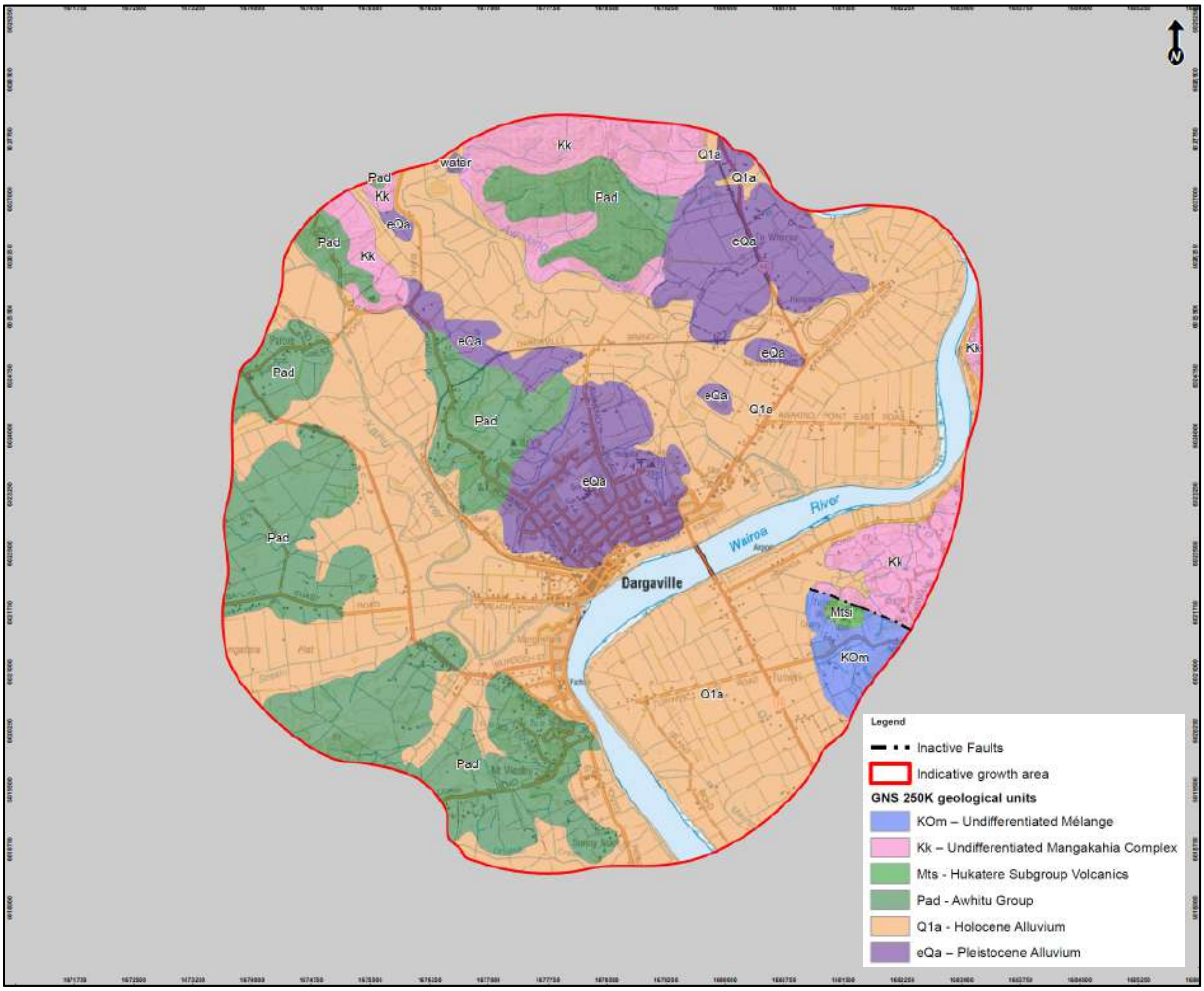


Image adapted from GNS QMAP. Not to Scale

7.2 Northland Allochthon

Much of the Northland region is underlain by Cretaceous-to Oligocene-aged rocks of the Northland Allochthon, a series of thrust sheets and mélange 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 Dargaville study area, the Northland Allochthon rocks comprise undifferentiated rocks of the Mangakahia Complex, and Undifferentiated Mélange, 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.

7.2.1 Undifferentiated Mangakahia Complex (Kk)

Undifferentiated Mangakahia Complex rock is mapped in the northern portion of the study area, west of State Highway 14 and between Opanake Road and Waihue Road on the north side of the Wairoa River, and south and east of Hoanga Road on the south and east side of the Wairoa River. This unit comprises a complex combination of Punakitere Sandstone and Whangai Formation mudstone facies that are not readily distinguished.

Whangai Formation mudstone is a thin-bedded siliceous mudstone with thin glauconitic sandstone and chert beds. It is highly shattered and sheared, and can include minor units of limestone, calcareous and non-calcareous mudstone.

7.2.2 Undifferentiated Mélange (KOm)

An isolated block of Undifferentiated Mélange, is mapped in the south-eastern corner of the Dargaville study area with a fault bound contact with the Mangakahia Complex and intruded by Hukatere Subgroup Volcanics. 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.

7.3 Hukatere Subgroup Volcanics (Mtsi)

A relatively small, approximately circular shaped andesitic plug is located at the eastern end of the site, south of the Wairoa River. Here, Hukatere Volcanics intrude Undifferentiated Mélange and are fault-bound to the northeast by Undifferentiated Mangakahia Complex. Hukatere Subgroup is composed of mainly andesite, although the overall unit includes basalt and dacite as well. Much of the intrusion has been industrially quarried for its andesite, which is locally advertised as “hard bronsite andesite”.

7.4 Awhitu Group (Pad)

Pliocene to Early Pleistocene aged fixed dune deposits of the Awhitu Group are present within the north, west and south portions of the Dargaville study area. These older dune deposits generally consist of moderately to weakly consolidated, dune-bedded cemented sand and extremely weak sandstone with undulating bounding surfaces generally with intercalated paleosols, lignite and carbonaceous mudstone and sandstone associated with estuarine and fluvial depositional environments.

7.5 Tauranga Group

Pliocene to Holocene-aged alluvium of the Tauranga Group is mapped in the low lying areas throughout the study area around Dargaville and the Wairoa River.

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.

7.5.1 Pleistocene Alluvium (eQa)

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

Organic soil and peat layers associated with decomposition of organic matter in swamp and estuarine environments are likely to be present throughout the unit.

7.5.2 Holocene Alluvium (Q1a)

Much like the Pleistocene Alluvium deposits, the Holocene Alluvium typically comprise soft and poorly consolidated mud, sand and gravel units with peat and organic soil beds. This younger alluvium underlies present day flood plains in the base of stream and gully systems.

7.6 Unmapped Units

7.6.1 Historical Fill

Historical 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 offal pits.

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

7.6.2 Colluvium

Colluvium and landslide deposits have not been separately mapped within the study area. However, colluvium and landslide deposits are present on many slopes within the greater Dargaville area. These deposits present as mobilised soil and rock that can be encountered as largely intact, but disturbed blocks of soil and rock, to 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 field mapping and have been incorporated into the Geomorphological Map presented in Figure 5.

8 Groundwater

Publicly available groundwater data for the study area is limited, with only ten groundwater bores referenced for groundwater level data.

Seven bores are located within mapped Holocene alluvial sediments of the Tauranga Group, and three bores within mapped Awhitu Group. In the Holocene alluvial sediments, stock, private water supply and monitoring wells recorded groundwater levels between 0.6 m below ground level (bgl) and 7.8 m bgl. In the Awhitu Group, two private wells located at approximately 20 m RL (one in the southern end of the study area and one in the western end of the study area), recorded groundwater to be at the surface, while one exploration well placed at approximately elevation 60 (near the center of the site) encountered groundwater at 37.5 m bgl.

In addition to publically available well data, there is also a topographic depression near the northern end of the study area, at the foot of the Mangakahia Complex hills, where overland flow paths and creeks drain to. This feature appears to hold standing water year round. The area of standing water appears to fluctuate seasonally, and is present in historic aerial photos we reviewed.

Groundwater can be expected to be close to the surface across most of the study area. This is evident by the prevalence of overland flow paths, wide-spread surface drainage patterns and creek, swampy ground near the Wairoa River margins, elevated groundwater levels in the well data we reviewed and standing water at the north end of the site.

Groundwater in the low lying flood plain areas, underlain by Holocene Alluvium, is likely to be at levels comparable to the Wairoa River levels. Within the Awhitu Group soils, groundwater levels may be lower, particularly in elevated areas where the sandy soils may be more free draining (like the exploration well near the centre of the study area).

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 study area. The nearest active fault is the Waikopua Fault located approximately 150 km southeast of the study area, to the southeast of Auckland City.

There are several unnamed, inactive faults mapped within the study area that are generally located at the contact between the different geologic units. One unnamed, inactive thrust fault is mapped at the western end of the study area, separating the Mélange from the Mangakahia Complex.

10 Ground Slope Angles

Slope steepness within the Dargaville area varies from relatively flat in the valleys and flood plains along the Wairau River and major drainages, to quite steep in the elevated hills to the north and west. Areas mapped as Mangakahia Complex (Kk) and Mahurangi Limestone (Omm) appear to support the steepest slopes within the study area, while Undifferentiated Mélange (KOm) supports a more subdued topographic relief.

A profile of existing slope angles was created using LINZ Topo50 20 m contours (vertical accuracy ≤ 10m). 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

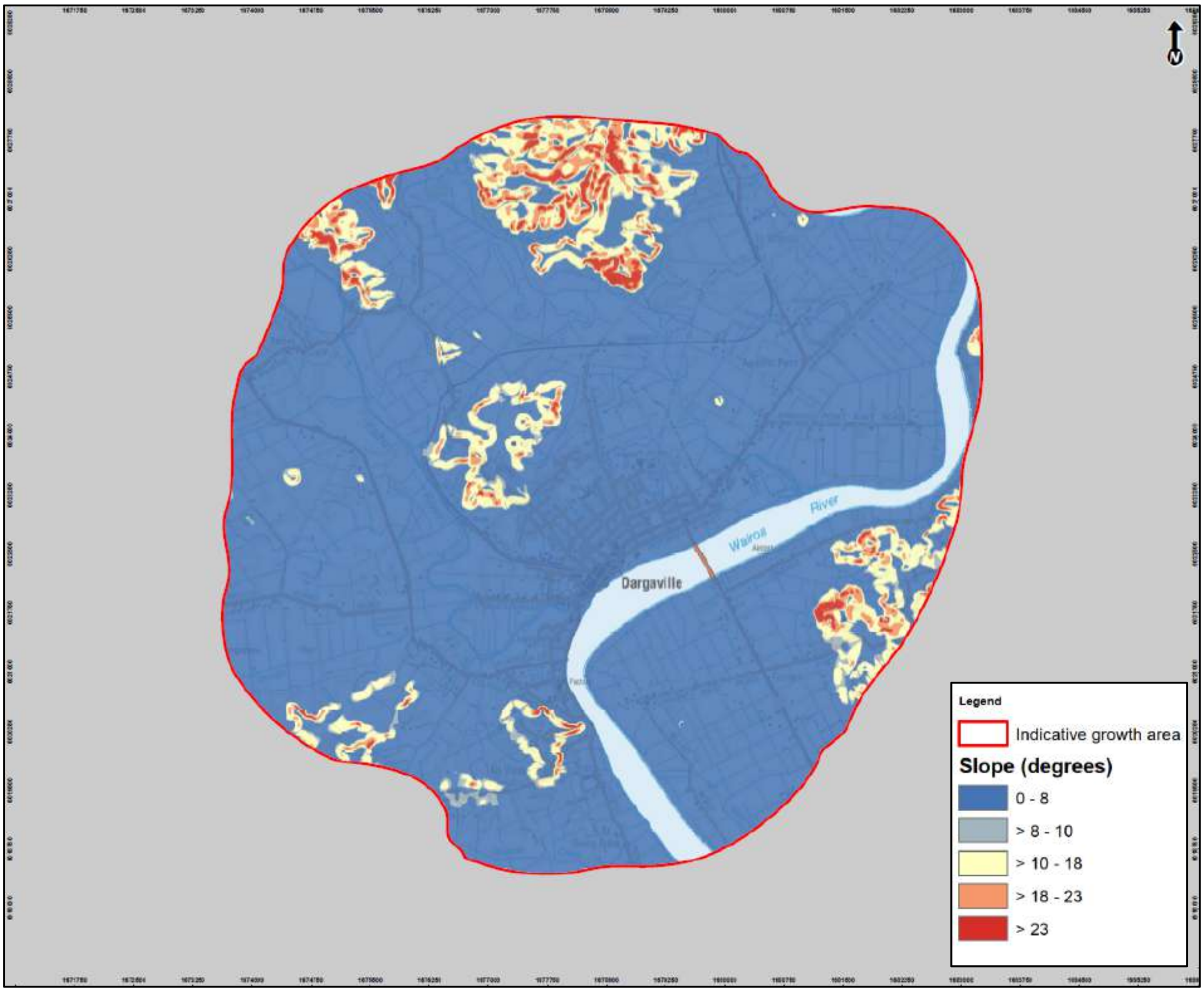


Image sourced from Land Information New Zealand, CC-BY-3.0. Not to Scale.

11 Geotechnical Hazard Discussion

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

11.1 Seismic Hazards

Potential seismic hazards resulting from moderate to major earthquakes affecting the Dargaville area 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, and may include 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; and

- 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.

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 two closest volcanos to the site (Tokatoka and Hukatere) suggests that these eruptions occurred between 16 and 19 million years ago. As such, further low-magnitude eruptions are unlikely.

11.5 Sulphate Attack on Concrete

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

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

11.6 Other Hazards

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 statured. 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 1952 to 2017. The photographs were viewed under the context of identifying general changes to the landform.

Table 1: Historic Aerial Photograph Summary

Date	Description
1952 - 1963 Retrolens Aerial Photo Series	Major roadway improvements associated with State Highway 12, State Highway 14. The town of Dargaville had been developed along State Highway 12 and 14, between the Kaihu River and the Awakino River on the north banks of the Northern Wairoa River, as well as west of the Awakino River bend along Colville and River Roads and Logan Street. The Dargaville Branch of the North Auckland Line railway track to the west of State Highway 12 was opened in 1943. Earthworks associated with the construction of Dargaville Hospital were evident in 1952. The beginnings of works at the Turiwiri Quarry were also evident in 1952.
1968 - 1996 Retrolens Aerial Photo Series	Residential and commercial densification evident within the Dargaville township and surrounding areas. The Turiwiri Quarry was formed and active in the 1979 photograph. No obvious signs of large instability.
2010 - 2017 Google Earth	Development continues in the Dargaville area, however no significant changes to the landform were observed at this scale (e.g. bulk earthworks operations).

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

13 Geomorphological Assessment

13.1 Stereo-Paired Aerial Photo Interpretation

We supplemented geologic mapping within the study area with interpretation of stereoscopic aerial photographs obtained from WSP-Opus. Photo-interpretive mapping was performed using stereo-paired aerial photos from Flight SN 5091 M/7 through M10, N/6 through N/8 flown on 10 January 1979. 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 geologic hazards (geohazards).

The geomorphic mapping performed for this study should be considered a reconnaissance level effort, and is intended to provide a generalized delineation of geohazards 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 study area generally consists of rolling hills of complex geology bisected by broad valleys with stepper hill systems located within the northern and south-eastern areas. The Wairoa River is a prominent feature that flows from the north-east past the south of Dargaville township and through the south of the study area. The Wairoa River is fed from the north by the Kaihu and Awakino Rivers as well as multiple minor tributaries.

These drainages, gullies and streams are commonly flanked by broad generally level alluvial plains with elevated, alluvial terraces within the central and north-eastern areas. Elevated, dune derived, rolling hills intercept the alluvial plains in the western and central part of the study area.

Steeper hill systems with medium to high relief are located in the northern and south-eastern parts of the study area. The hills in these areas are well vegetated and express widespread evidence of historical slope instability, as well as active slope instability. This is primarily expressed in the form of shallow rotational failures and hybrid rotational / translational failures. Mid-slope benches and arcuate head scarps were observed on several of the moderate to steep slopes, as well as widespread hummocky ground in lower slope areas. Active soil creep, particularly in the form of terracettes, was evident over much of the study area.

13.2.2 Borrow Areas

Two quarries are listed on the minedat.org website, Turiwiri Quarry, located south of the Wairoa River, within the Hukatere Subgroup Volcanics, and an unnamed Kauri gum excavation, located north of the Wairoa River, near State Highway 12, within alluvium soils. Local areas of instability may be associated with excavations at Turiwiri Quarry, while consolidation of soft soils and organics may be associated with the Kauri gum excavations. A discussion on geohazards associated with open pit quarries is in Section 15.1.

13.2.3 Rock Outcrops

Few areas were observed to have significant rock outcrop. Where exposed, we generally observed weak to extremely weak sandstone in road cuttings, particularly in areas mapped as being underlain by Awhitu Group fixed dune deposits. Although we did not gain site access the Turiwiri Quarry, we observed volcanic rock on the steep sided quarry walls.

13.2.4 Surficial Deposits

Holocene alluvial deposits are mapped throughout the study area, particularly with low-lying plains proximate to the Wairoa, Kaihu and Awakino Rivers and tributary streams. Both of the Holocene areas appear to be relatively level and no signs of slope instability were observed.

Pleistocene alluvial deposits are mapped within the central and northern parts of the study area. These areas were observed to generally form level to gently undulating terraces that are generally elevated several metres higher than the surrounding Holocene alluvial areas.

Figure 6: Photographs

Photo 1: Looking northwest across hill and gully areas in the south-eastern part of the study area.

Photo 2: Looking northeast across Dargaville township and Wairoa River from the Dargaville Museum.

Photo 3: Looking east towards where Kaihu River meets Wairoa River.

Photo 4: Elevated area of Pleistocene Alluvium (eQa) in the eastern part of the study area.

Photo 5: Elevated area of Awhitu Group dune deposits (Pad) located in the western part of the site.

Photo 6: Awhitu Group dune material exposed in a road cutting north of Parore West Road in the northwest of the study area.

Photo 7: Looking northeast from the end of Awakino Point East Road towards elevated hills in the east of the study area.

Photo 8: Looking south from Hoanga Road towards elevated hills in the south-east of the site.

Photo 9: Hummocky ground and evidence of shallow instability in Undifferentiated Mangakahia Complex in the eastern part of the study area.

Photo 10: Hummocky ground and evidence of shallow soil creep in Undifferentiated Mangakahia Complex in the northwest of the site.

14 Geotechnical Hazards Identified in Dargaville

14.1 General

Based on the findings of this high-level geotechnical assessment, we consider the primary geotechnical constraints of the Dargaville Indicative Growth Area to be slope instability, settlement due to liquefaction, and settlement due to soft, compressible soils. This report does not contain information regarding climate change and the consequential coastal erosion or coastal inundation that may be associated with climate change. 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.

The primary geotechnical constraints and likely investigation requirements for a future development are discussed as follows.

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, and will require a higher level of geotechnical investigation.

14.3 Geohazard Map

As part of this geotechnical assessment, ENGEO has compiled a Geohazard Map (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, settlement due to liquefaction and settlement due to soft compressible soils). This map may not show all areas of potential geohazards, and potential geohazards 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.

14.4 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.

14.4.1 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 Northern Wairoa River (i.e. within the active channel of the river and within some of the Holocene deposits adjacent the river) and within the depressed area at the northern end of the site, where standing water and swampy terrain exists.

14.4.2 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.

14.4.3 Liquefaction and Lateral Spread

Although there is a relatively low risk for strong seismic shaking in the Northland region, the Holocene and Pleistocene alluvial deposits, and the Pliocene to Early Pleistocene aged fixed dune deposits within the study area may contain loose sandy soils. Due to the presence of sandy soils, and in combination with assumed high groundwater levels, we consider liquefaction and lateral spread under seismic conditions to be a risk, particularly within the young Holocene alluvial deposits which generally consist of soft and poorly consolidated mud, sand and gravel. As discussed in Section 14.2, "low", "medium", and "high" liquefaction 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 Potential

Northland Allochthon rock and Hukatere Volcanics rock are not considered liquefiable. Residual soils of Northland Allochthon typically comprise moderately plastic clays and silts with variable amounts of sand. Due to the nature of these soils, we consider the liquefaction potential to be low.

Areas having a low liquefaction potential are unshaded in Figure 7.

Medium Liquefaction Potential

Awhitu Group dune deposits (Pad) comprising moderately to weakly consolidated dune-bedded sand and extremely weak sandstone may be susceptible to liquefaction is present below groundwater level.

GNS maps these deposits in the northern, western, and south-western parts of the study area. We consider these areas have the potential to liquefy under ULS conditions.

Pleistocene Alluvium (eQa), comprising poorly to moderately consolidated mud, sand and gravel form elevated terraces above surrounding Holocene alluvial deposits. GNS maps these soils in the northern and central portions of the study area. We consider these areas to have some potential to liquefy under ULS conditions.

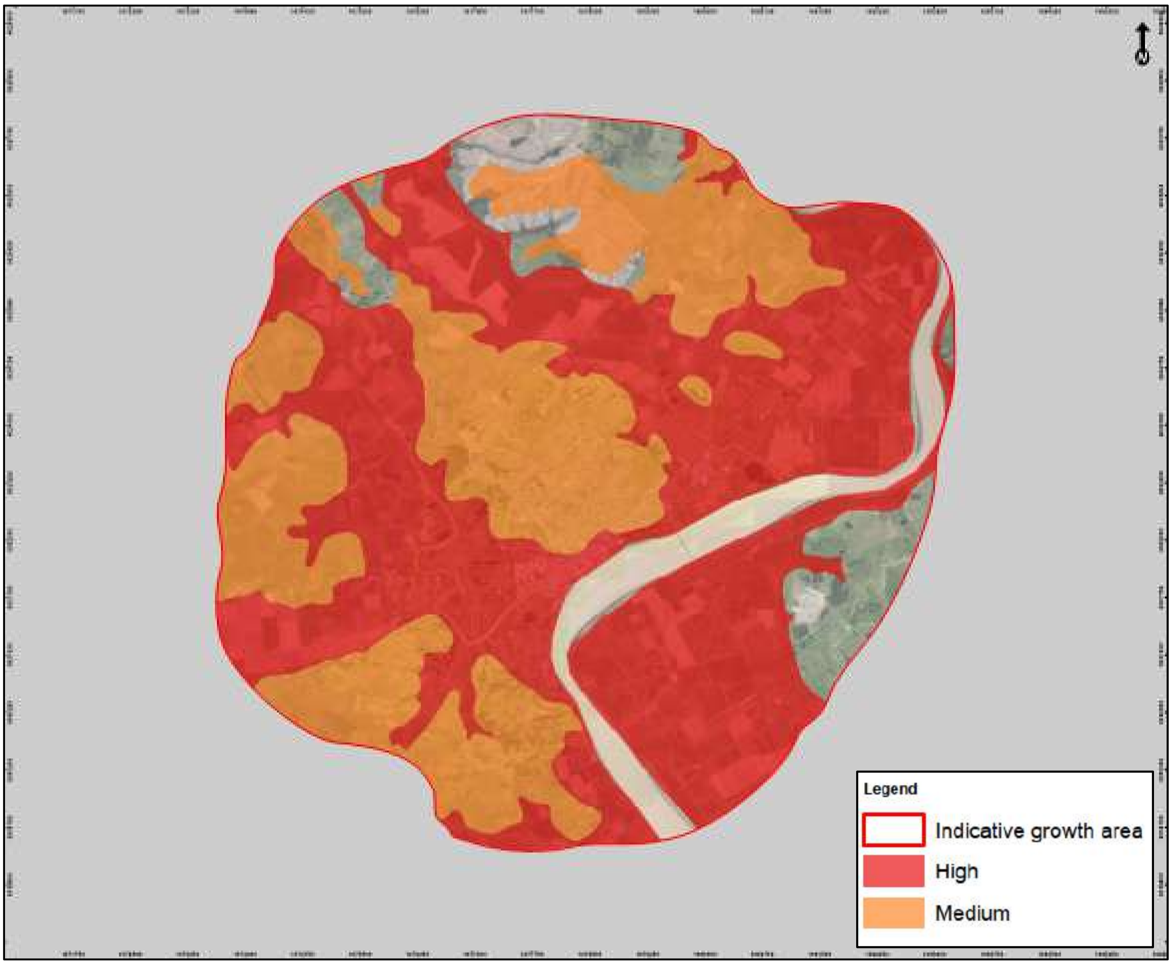
Given the potential for poorly consolidated, coarse-grained soils to be present below groundwater within the Pleistocene Alluvium, we consider liquefaction and lateral spread potential within this unit to be medium.

High Liquefaction Potential

Young Holocene alluvial deposits (Q1a) are mapped across the majority of the study area. These deposits generally consist of soft and poorly consolidated mud, sand and gravel 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 potential of the Holocene Alluvium to be high.

Figure 7: Liquefaction Susceptibility Map



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

14.4.4 Geotechnical Investigation Requirements

Areas identified as having a low liquefaction 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 potential should be further investigated by a suitably qualified geotechnical professional. Site specific investigations in these areas are expected to include:

- 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; and

- Site-specific liquefaction analysis should be performed to calculate theoretical settlement due to liquefaction, and set-backs should be established for lateral spread.

14.5 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 (which form some of the steepest terrain in the study area), 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, most commonly within the overburden soil profile, although deep seated failures within the rock mass have occurred historically in the wider Northland area.

The Hukatere Volcanics are comprised of mainly andesite is generally confined to within the Turiwiri Quarry. The rock mass within the quarry appears sufficiently strong to form near-vertical quarry walls. Quarry activities and mining techniques can lead to mechanically fractured and disturbed rock, furthermore, we can expect the rock to vary in quality, weathering, discontinuities and strength. As such, we consider this formation to have a very low potential for instability at slopes less than 18 degrees and a low to moderate potential for instability for slope angles between 18 and 45 degrees.

Pliocene to Early Pleistocene aged fixed dune deposits (Pad) were observed at slopes up to approximately 70 degrees in road cuttings. Some slopes are weakly cemented, resulting in more indurated soils that form some of the steeper slopes, while other slopes are uncemented, which resulted in the formation of flatter slopes or slopes expressing a higher degree of deformation. Evidence of historical and active slope instability affecting these steep slopes was observed during our geomorphological review. Based on the variable conditions of the sand dune deposits and our field observations, we consider these formations to have a very low potential for instability for slope angles less than 14 to 16 degrees.

Pleistocene and Holocene alluvial soils are poorly consolidated and susceptible to creep and shallow instability on slopes having angles greater than 10 degrees.

14.5.1 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°..."

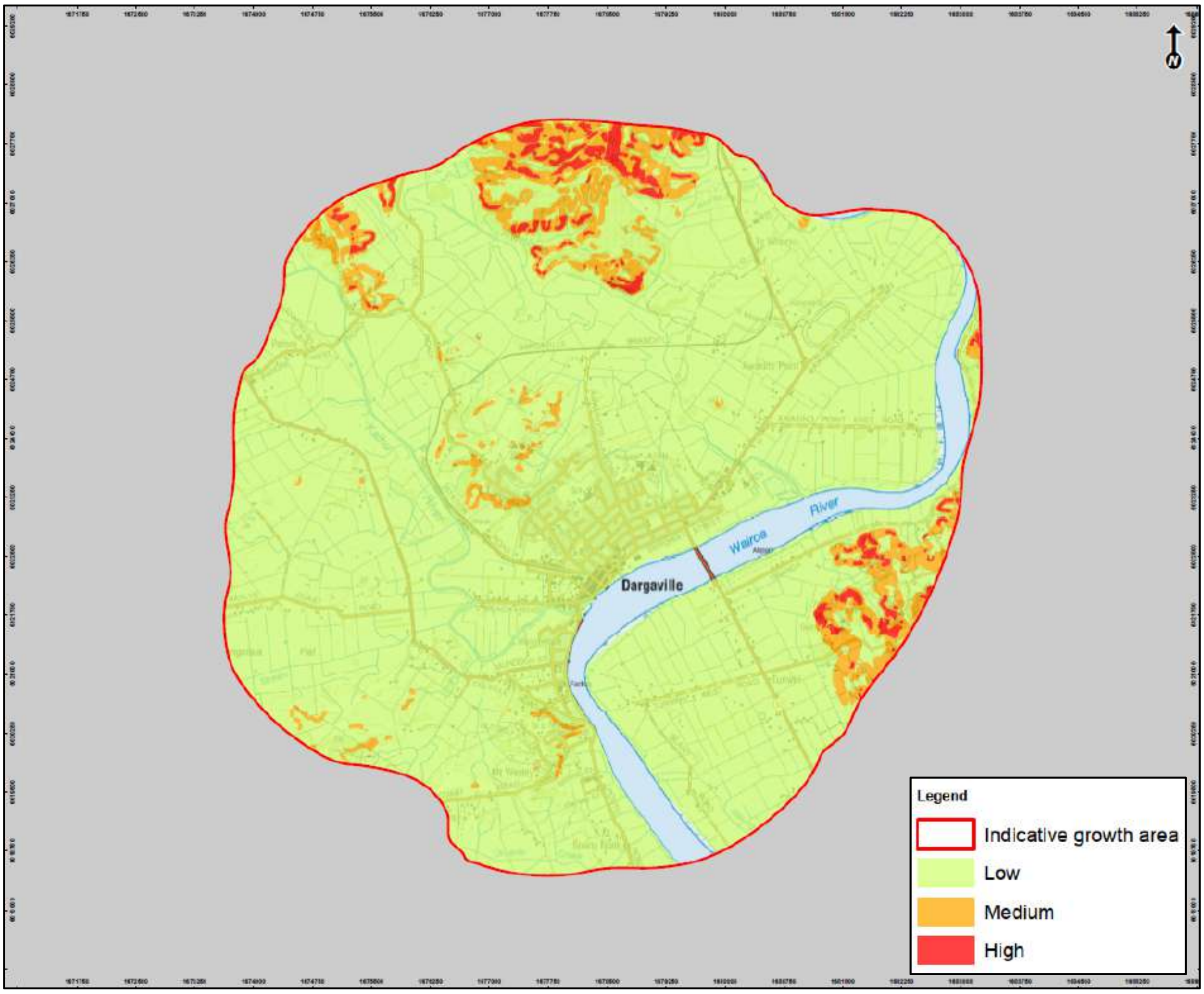
Based on GNS, Auckland Council, previous geotechnical assessments, and our experience working in Northland, we have developed slope profile ranges which are presented in Table 2. Slope profile ranges categorise the potential for instability in each geological unit as low, medium, and high, with corresponding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

Table 2: Slope Instability Profile

Geologic Unit	Slope Instability Potential based on Slope Profile Ranges		
	Low	Medium	High
Holocene Alluvium (Q1a)	<10°	10-23°	>23°
Pleistocene Alluvium (eQa)	<10°	10-23°	>23°
Awhitu Group (Pad)	<16°	16-33°	>33°
Hukatere Volcanics (Mts)	<18°	18-45°	>45°
Mélange (KOm)	<8°	8-18°	>18°
Undifferentiated Mangakahia Complex (Kk)	<8°	8-18°	>18°

The slope profile ranges have been applied to the LiDAR contour and elevation data to generate the Slope Instability Potential map 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. Rather, some of slopes may have historically failed, which has resulted in the flatter slope angles observed today. Changes to the equilibrium of a slope through some combination of land modification earthworks, fill or building loading, or introduction of water, can trigger reactivation of previous landslides on any slope.

Figure 8: Slope Instability Potential



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 instability potential are defined by slopes having angles flatter than 8° in Northland Allochthon, 18° for Hukatere Volcanics, 16° for Awhitu Dunes and 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 professional[1].

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

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; and
- 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.

14.6 Consolidation Settlement

Holocene and Pleistocene deposits within the study area (refer to Figure 3) 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.

14.6.1 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

Northland Allochthon and Hukatere Volcanic rock is not considered to be susceptible to settlement under loading. Residual soils of Northland Allochthon 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.

Pliocene to Early Pleistocene aged fixed dune deposits (Pad) are generally comprised of moderately to weakly consolidated, dune-bedded sand and extremely weak sandstone. We consider this formation to have a low consolidation settlement potential.

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

Medium Consolidation Settlement Potential

Pleistocene Alluvium (eQa) comprising poorly to moderately consolidated mud, sand and gravel, with peat and organic beds, form elevated terraces above present day flood plain levels. GNS have mapped these soils in the northern and central portions of the study area (Figure 9).

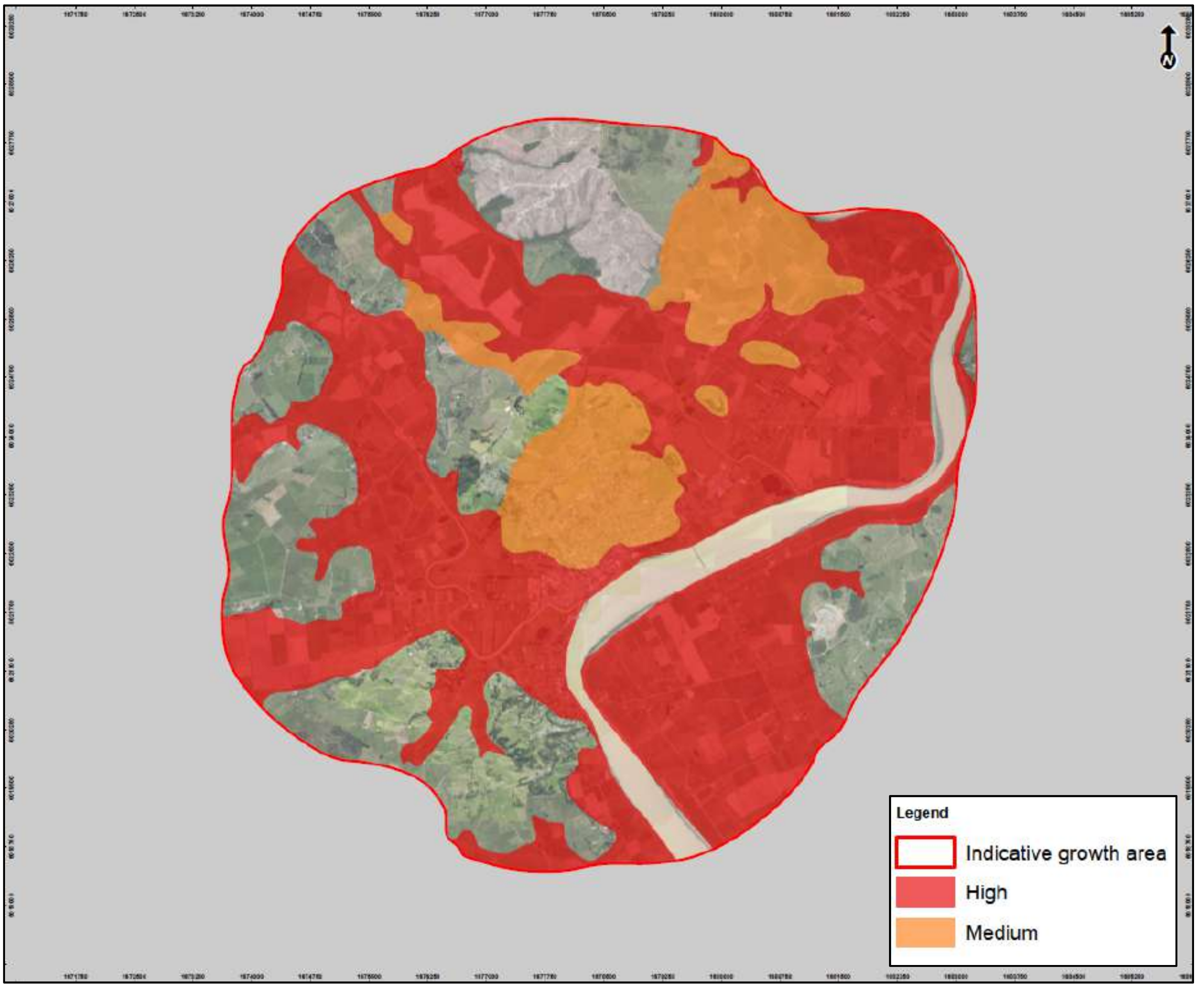
Based on the likely presence of organic material and soft clay layers, we consider these areas to have a medium potential to experience consolidation settlement under loading.

High Consolidation Settlement Potential

Young Holocene alluvial deposits (Q1a) are mapped within the low-lying areas on the map and make up more than half of the surface soils within the study area (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 Map



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

14.6.2 Geotechnical Investigation Requirements

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

Geotechnical investigations for future development areas mapped as having a medium 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; and
- Detailed settlement analyses should be performed to calculate theoretical total and differential settlements due to consolidation.

15 Combined Geohazard Assessment

ENGEO has compiled a Combined Geohazard Map (Appendix A) showing the range of expected geotechnical hazards within the Growth Area. This map 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, settlement due to liquefaction and settlement due to soft compressible soils). Areas where multiple geohazards exist are presented on the map based on the highest assessed hazard level.

As this map has been prepared using a combination of desktop-based assessments supported by limited geomorphic field mapping, it may not show all areas of potential geohazards. Further, the potential geohazards 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 geohazards 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 geohazards represented on the Combined Geohazard Map, 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 Geohazard Map Summary Table

Zone	Colour	Assessed Geohazard Risk	Geotechnical Implications
Low	Green	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. Slope instability potential is considered to be low based on prevailing slope angles and field landform observations. Locally oversteepened slopes (e.g road cuts, stream banks, etc.) may be susceptible to soil creep or small scale instability.	Site-specific assessments are required to confirm the extent to which the identified geohazards affect the land, and the suitability of the land for the intended development. Geohazards may be mitigated through local small-scale earthworks and retaining structures, or by imposing setbacks from areas identified as at risk of these geohazards.
Medium	Orange	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. 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.).	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. Geohazards 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.
High	Red	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.	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 geohazards affect the site, and the implications of the development proposals on the existing landform. 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.

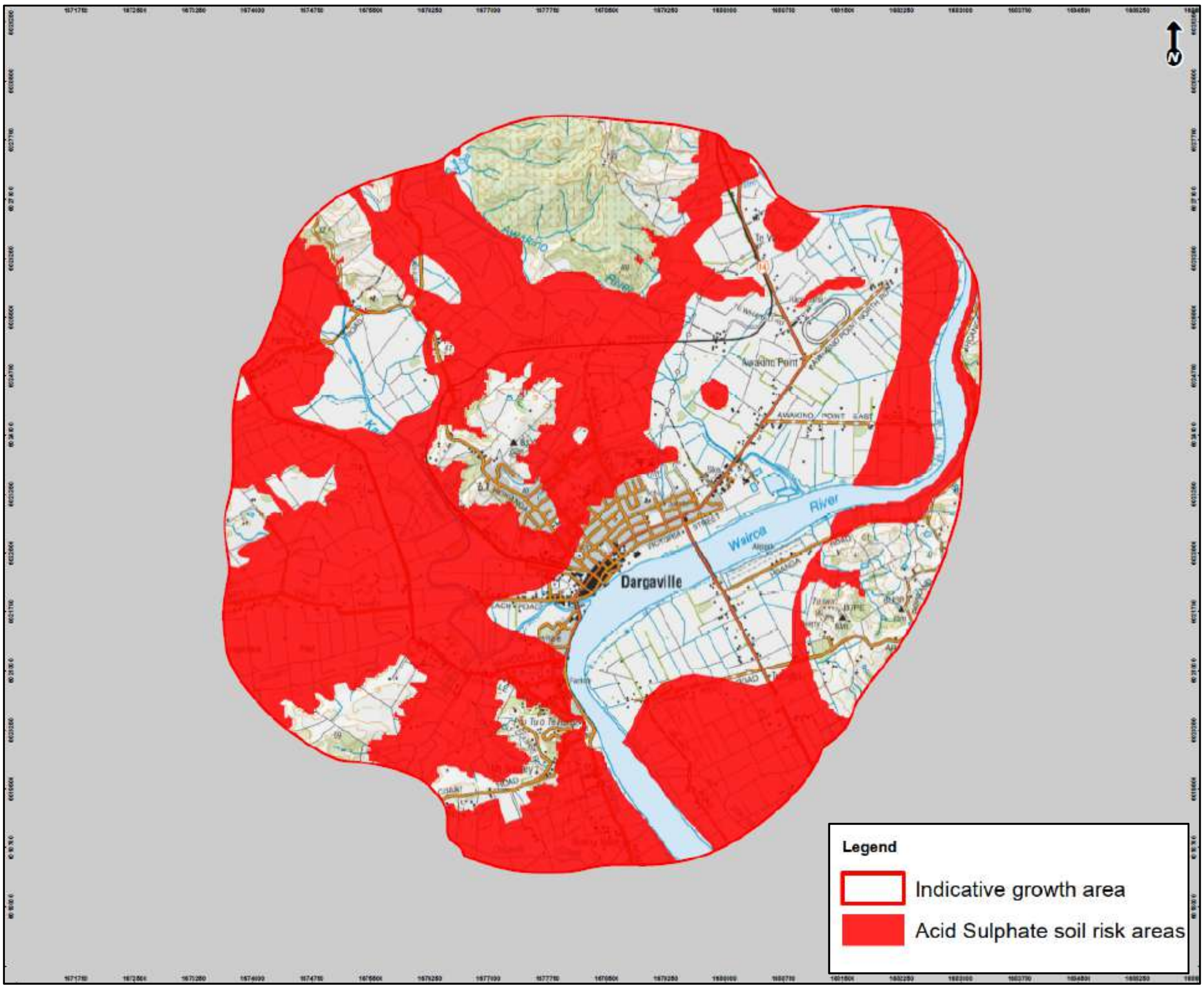
15.1 Sulphate Attack on Concrete

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 map that was developed using historic sea levels, current surface elevations and mapped sedimentary deposits. Kaipara District Council have provided zoomed in areas of the map for use in this study, which includes the Dargaville study area (Figure 10).

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

Figure 10: Acid Sulphate Soil Risk Map



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

15.2 Other Geohazards

Mines and Quarries – There are two known quarries within the Dargaville study area. The Turiwiri Quarry, is a commercially active andesite quarry located approximately 5 kilometers southeast of the town of Dargaville, and an unnamed Kauri gum excavation existed near the town of Dargaville, adjacent to State Highway 12.

Mining can lead to multiple environmental, erosional and instability hazards. Slope stability issues and deformation would be limited to the excavation batters and immediate areas adjacent to the crest of the excavation batters. Overburden soils, stockpiled soils, and uncompacted fills associated restoring excavations may be subject to differential consolidation settlement. Additionally, Kauri gum mining typically occurred in areas of historic swamp deposits. Consolidation settlement due to soft, saturated and highly organic soils may be present in the vicinity of the Kauri gum excavation.

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

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

Collapsible Soils – Unsaturated, young alluvial soils that are rapidly deposited in generally sub-arid climates can undergo a large volume change when they become statured. 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.

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 Dargaville. In the absence of a reticulated wastewater 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 Dargaville 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

A 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 Dargaville

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

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

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

This assessment is considered preliminary only and is intended to guide future developers when considering development intensity. All future developments should be supported by site-specific assessments to confirm the potential or otherwise for on-site effluent disposal.

Wastewater treatment systems will need to be designed by a suitably qualified, experienced and accredited Engineer to meet any requirements of the building code.

16.2.1 Northland Allochthon

The Northland Allochthon units within the study area typically weather to form clay-rich residual soils with relatively shallow soil profiles, and are highly susceptible to instability on gentle slopes. 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 Northland Allochthon is considered to be unlikely.

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

16.2.2 Awhitu Group

Where Pliocene to Early Pleistocene aged dune deposits are presented as residual sand soils and are elevated above flood plain levels, these can present an opportunity for successful on-site effluent disposal where the soil profile is sand- and silt-rich. Restrictions associated with consolidation of the material, depth to groundwater, and setbacks from sloping land would also be critical to placing disposal fields within this unit. Accordingly, the potential for on-site effluent disposal in areas underlain by dune sands having a low slope instability risk (refer to Section 14.5.1) 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.

16.2.3 Hukatere Subgroup Volcanics

The Hukatere Subgroup Volcanics located in the south-eastern part of the study area predominantly consists of andesite. Where Hukatere Volcanics has not weathered to form significant clay-rich soil mantles and have a low slope instability risk (refer to Section 14.5.1), 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.

16.2.4 Tauranga Group

Pleistocene Alluvium, where elevated above flood plain levels, can present an opportunity for successful on-site effluent disposal where the soil profile is sand- and silt-rich. However, the presence of relatively low permeability clay or peat layers within the alluvium can have the opposite effect, and the location and extent of such layers is unknown without subsurface investigation. Restrictions associated with depth to groundwater, and setbacks from sloping land would also be critical to placing disposal fields within this unit. Accordingly, the potential for on-site effluent disposal in areas underlain by Pleistocene Alluvium having a low slope instability risk (refer to Section 14.5.1) is considered to be possible. For areas having a medium to high slope instability risk, the potential for on-site disposal is considered to be unlikely.

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

Figure 11: On-site Effluent Disposal Potential Map

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

16.3 Geotechnical Investigation Requirements

Geotechnical investigations to support design of on-site effluent disposal systems for future developments in Dargaville 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 Auckland Council's guideline document GD2018/006 (Chen, Z. and Roberts, G. Silyn, 2018), or other relevant local guidance document 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.

18 References

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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 map, as the information is only an indication of what we consider to be the general level of the mapped geohazards.

iii. It should be appreciated that the geohazards described within this report and accompanying map 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. Geohazard 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 map should not be used as a replacement for site specific assessments.

v. This Limitation should be read in conjunction with the Engineers NZ / ACENZ Standard Terms of Engagement.

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

Report prepared by

Jacob Cornall
Engineering Geologist

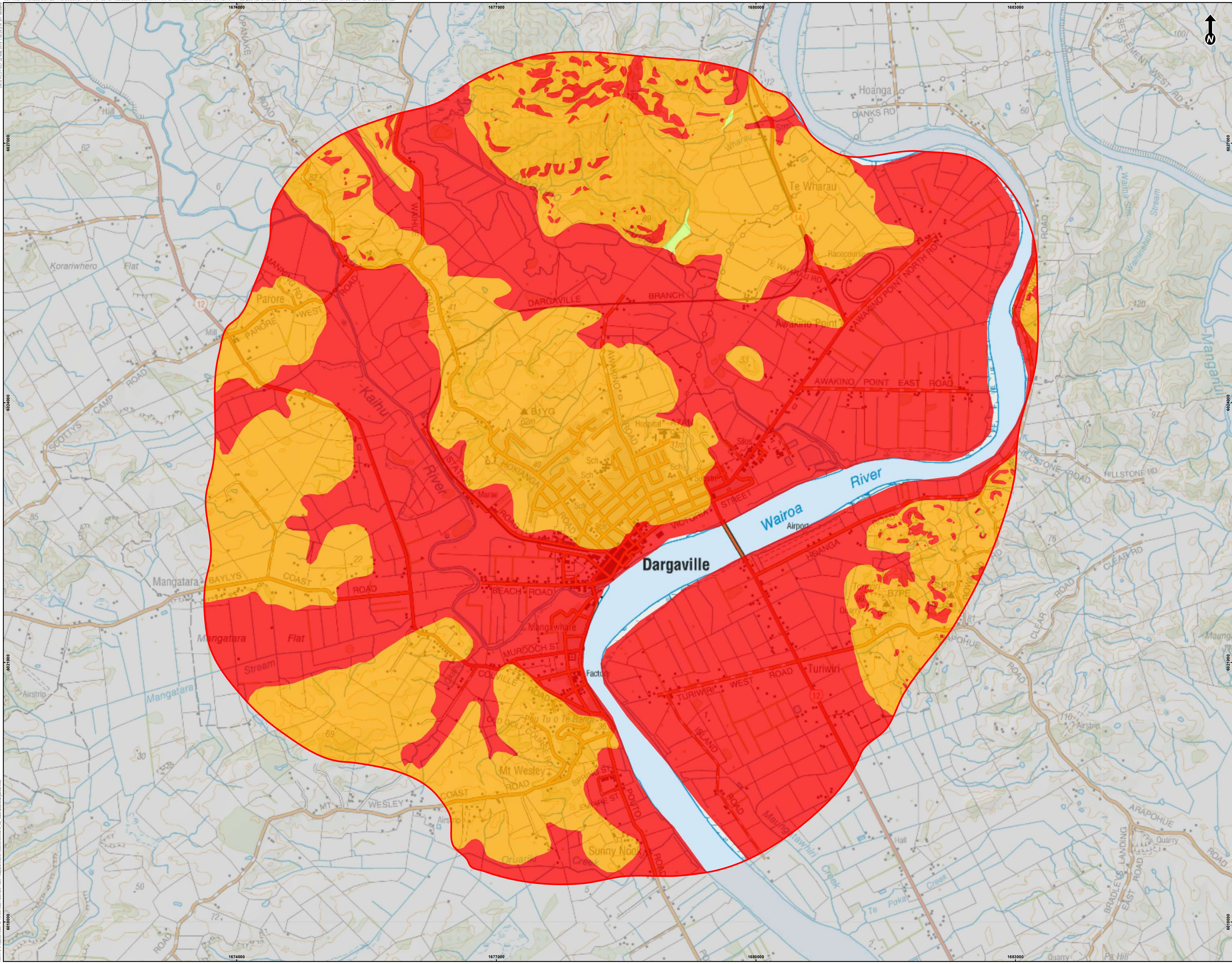
Report reviewed by

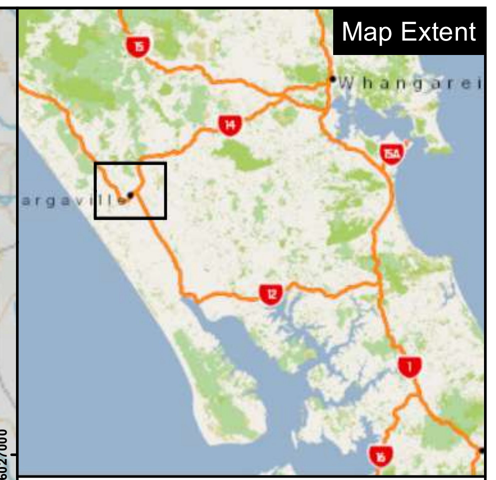
Richard Justice, CMEngNZ (PEngGeol)
Principal Engineering Geologist

Craig Wright, CMEngNZ (PEngGeol)
Associate Engineering Geologist

APPENDIX 1:

Geotechnical Hazard Map





Legend

Indicative growth area

Geohazard risk

- Low
- Medium
- High

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

0 — 1,400 Metres

PROJECTION: NZGD 2000 New Zealand Transverse Mercator

ENGEO

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Title: Combined Geohazard Plan Dargaville

Client: Kaipara District Council		Appendix: A
Project: Geotechnical survey and hazard mapping	Designed: CW Drawn: RW Checked: RJ Date: May 19	Size: A2
Proj No: 15601.000.000	Scale: 1:27,500	Revision: A

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