ENGEO

Expect Excellence

Geotechnical Assessment

West Coast Sites

Kaipara District

Submitted to:

Mr Paul Waanders

Kaipara District Council

42 Hokianga Road

Dargaville 0310

ENGEO Limited

8 Greydene Place, Takapuna, Auckland 0622

PO Box 33-1527, Takapuna, Auckland 0740

Tel +64 9 972 2205   Fax +64 3 328 9013

www.engeo.co.nz

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1 Executive Summary

This report presents our geotechnical assessment and hazard mapping for the Omamari, Baylys Beach, Glinks Gully, and Te Kopuru areas, located on the West Coast of the Kaipara District. 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 developments of the area defined by KDC as 'Future Residential and Business Growth Area' and 'Greater Structure Plan Policy Area' of Omamari, Baylys Beach, Glinks Gully, and Te Kopuru.

In general, the West Coast areas are characterised by rolling hills of dune sands bisected by broad valleys and incised gullies filled with young alluvial sediments. Elevations range from approximately sea level, within the Wairoa River and on the coast, up to over 60 m above mean sea level within the dune systems.

The area contains four dominant groups of geological materials. These materials are: Pliecene to Pleistocene-aged dunes of the Awhitu Group, Pleistocene and Holocene-aged dunes of the Kariotahi Group, and Holocene-aged alluvial soils of the Tauranga Group.

Based on the findings of this geotechnical assessment, we consider the primary geotechnical constraints of the study areas to be 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 four West Coast Sites (WCS) within the Kaipara District. 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 have prepared our scope to inform Council of the following:

- Extent of slope instability hazard within the West Coast site areas;
- Suitability of the ground for the disposal of effluent waste water;
- Suitability of the land for future development;
- Risks and hazards of the WCS 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 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 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 Ltd 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 a slope model of the study area. All GIS assessment used 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 study areas of the WCS are focused around the townships of Baylys Beach, Glinks Gully, Omamari and Te Kopuru within the west coast of the Kaipara District. The Indicative Growth Areas account for a total of approximately 620 hectares across the four sites.

The study areas include main access roads (i.e. Omamari Beach Road, Baylys Coast Road, Glinks Road, Pouto Road and West Coast Road), the commercial, industrial and residential developments within the townships, large paddocks utilised for farming and horticulture, the south-western bank of the Wairoa River (near Te Kopuru), and the coastal areas of Baylys Beach, Glinks Gully and Omamari.

The vicinities of the study areas are shown in Figure 1, and the WCS Indicative Growth Areas are shown in Figures 2 to 5.

Figure 1: WCS Vicinity

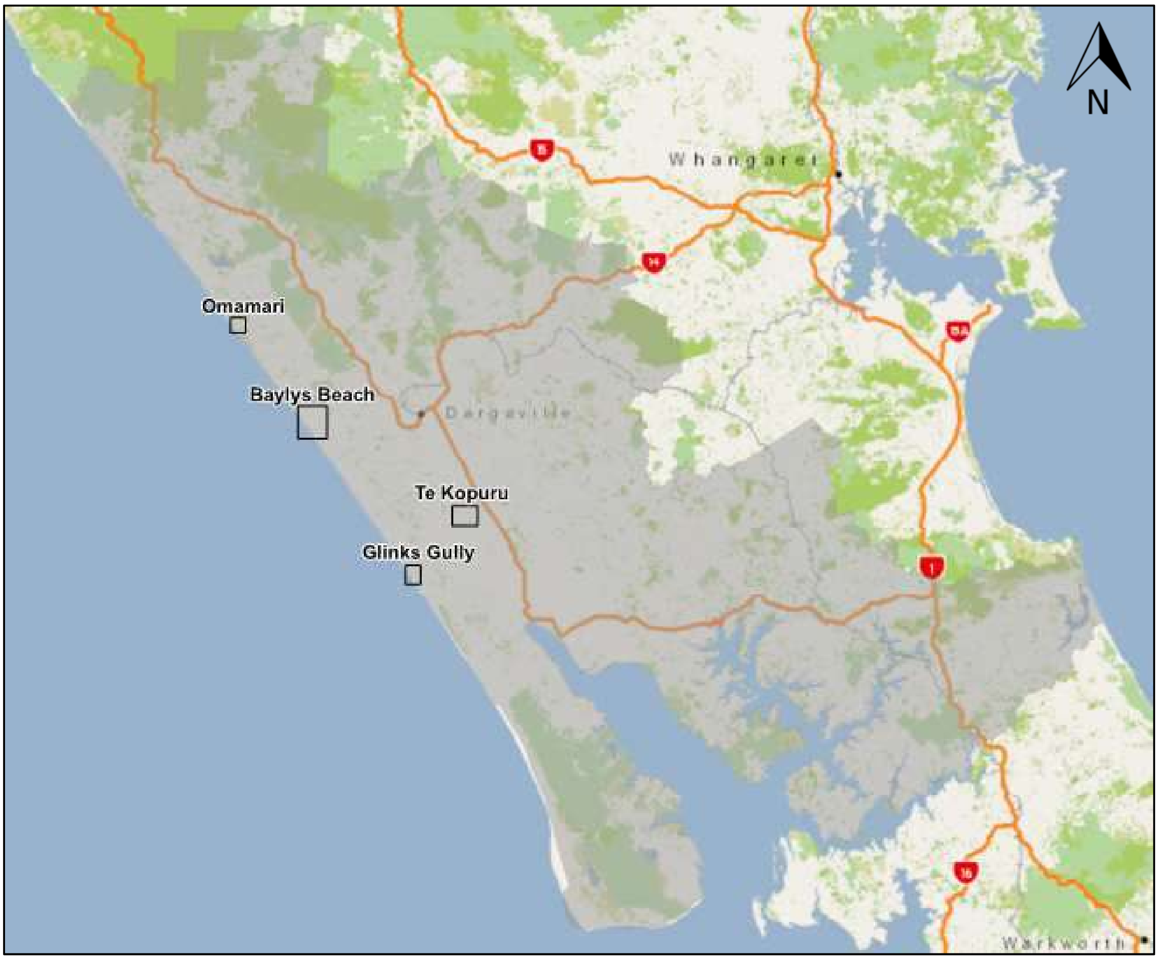


Image sourced from Land Information New Zealand, CC-BY-3.0. Not to Scale

Figure 2: Indicative Growth Area – Omamari

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

Figure 3: Indicative Growth Area – Baylys Beach

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

Figure 4: Indicative Growth Area – Glinks Gully

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

Figure 5: Indicative Growth Area – Te Kopuru

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 the WCS has been established through a comprehensive review of published geological information for the area, principally the GNS 1:250,000 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 site areas is presented in the following sections.

7.1 Published Geology

The primary geological map reference for the WCS study area is the 2009 GNS 1:250,000 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 program 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 1:250,000 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 Figures 6 through 9, depicting the surface expression of the geological units mapped across the study area. Unshaded areas of the figures are outside of the QMAP dataset.

Figure 6: Geology Map – Omamari

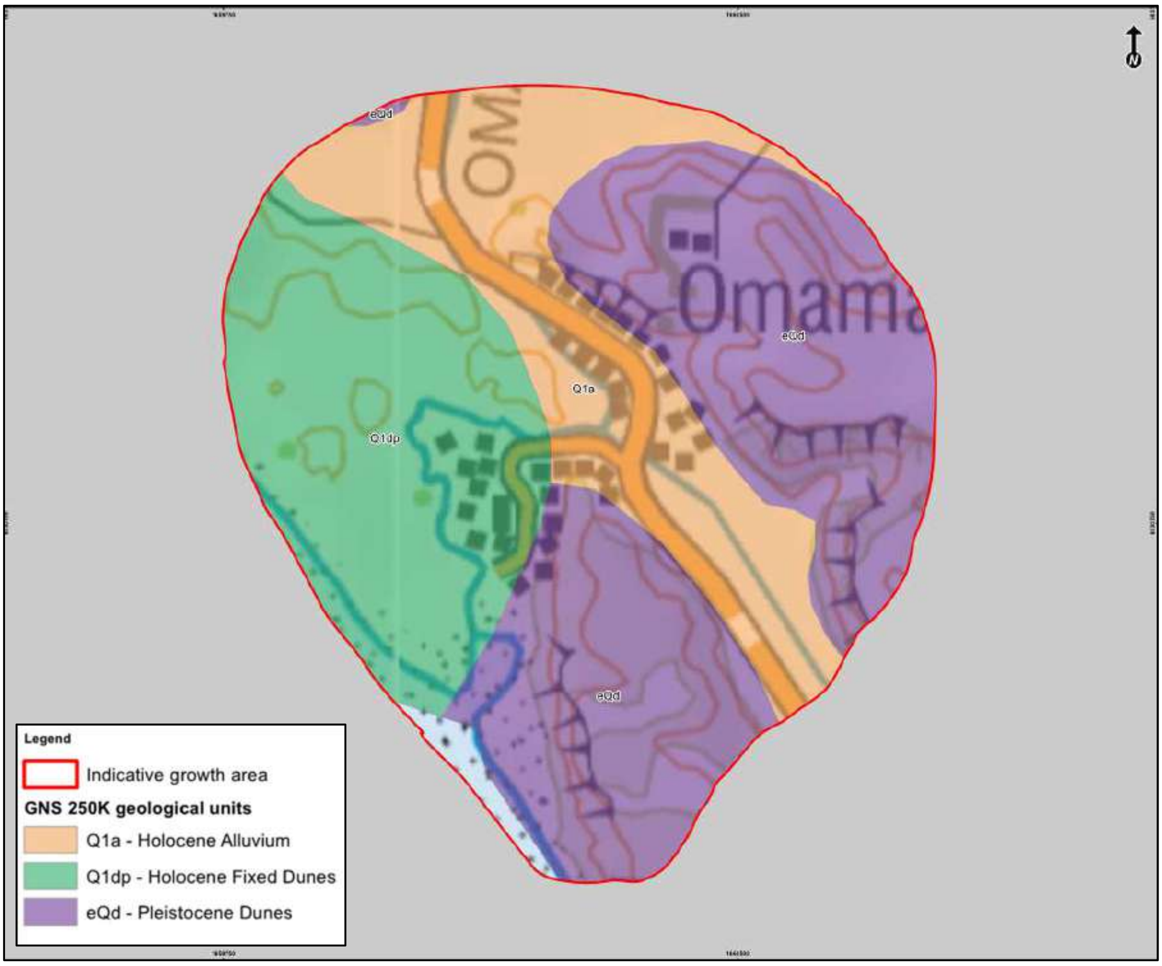


Image adapted from GNS QMAP. Not to Scale.

Figure 7: Geology Map – Baylys Beach

Image adapted from GNS QMAP. Not to Scale.

Figure 8: Geology Map – Glinks Gully

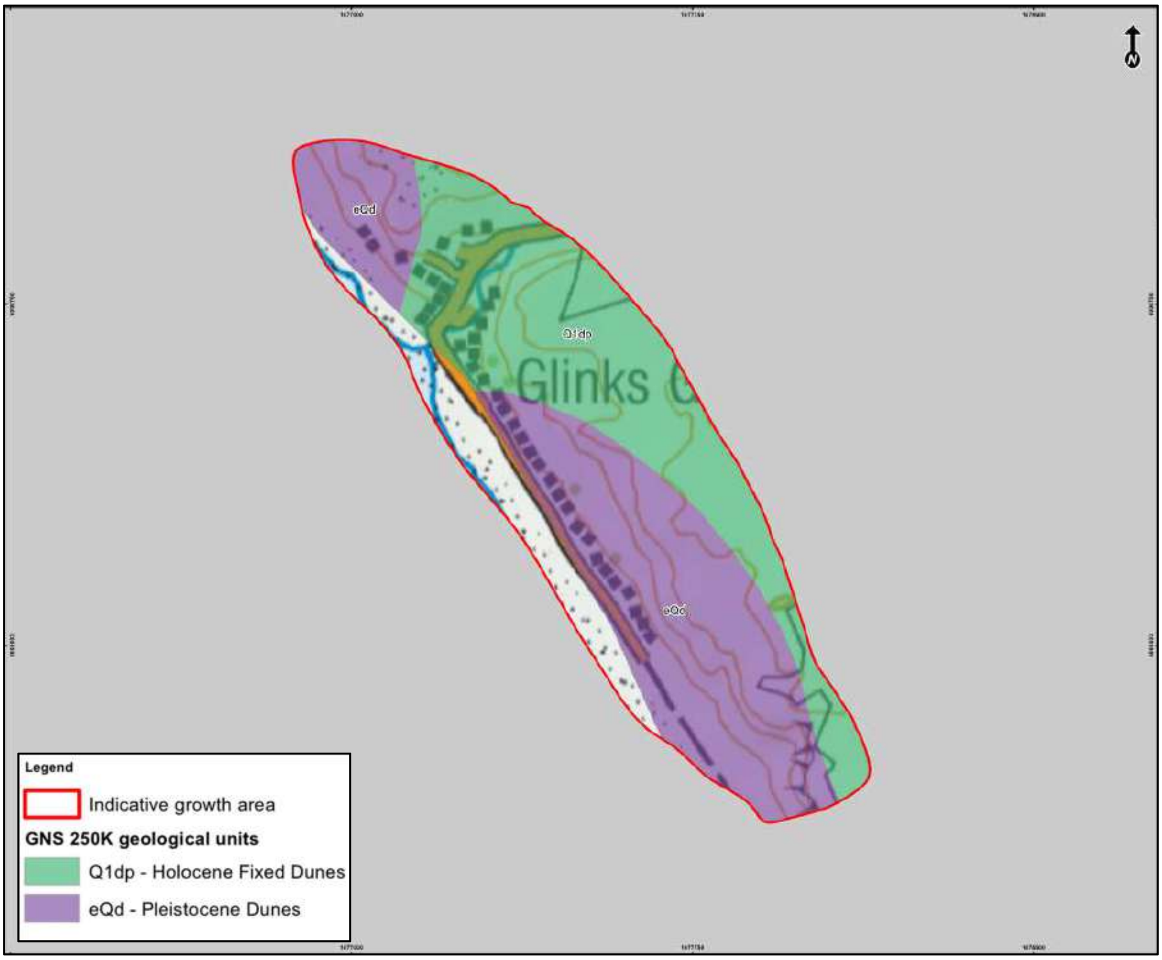


Image adapted from GNS QMAP. Not to Scale.

Figure 9: Geology Map – Te Kopuru

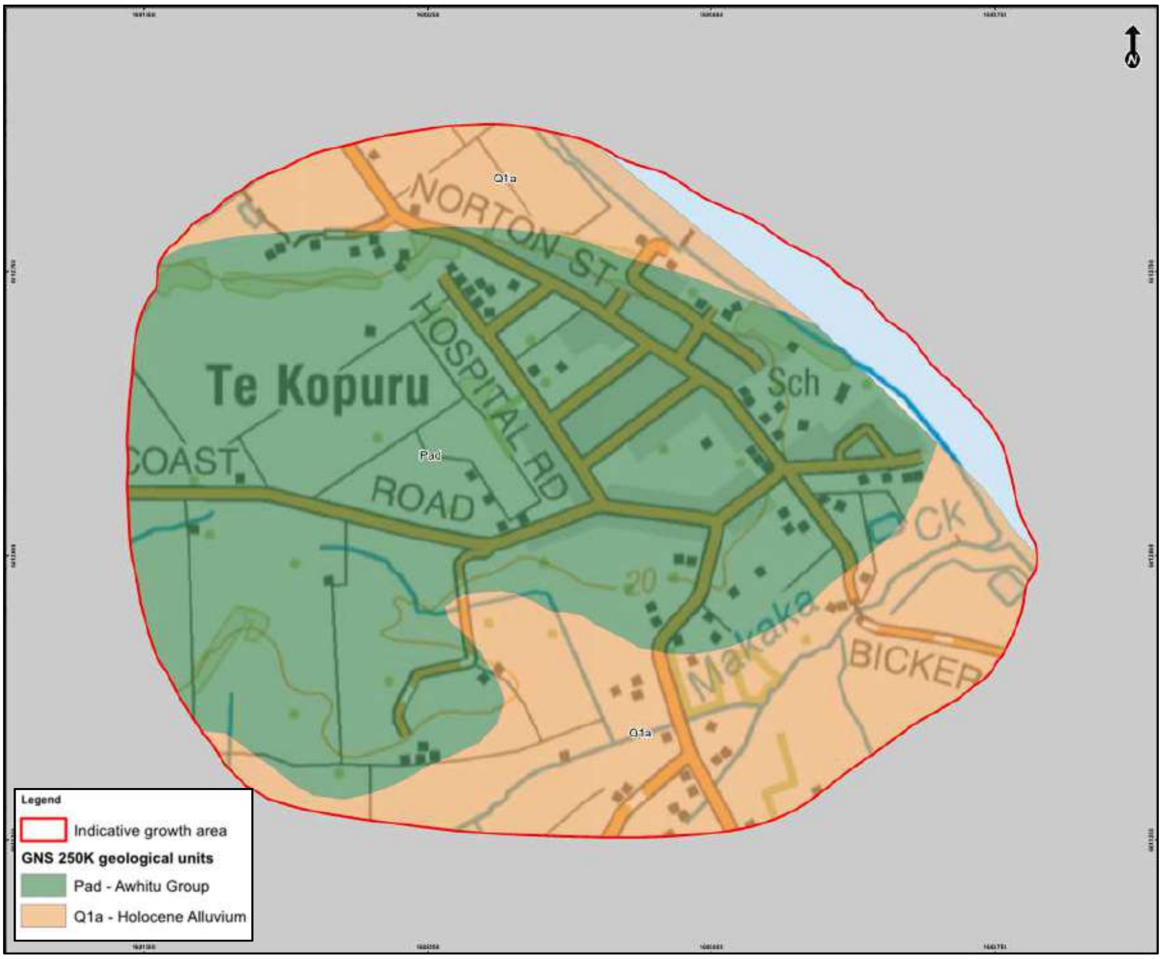


Image adapted from GNS QMAP. Not to Scale.

7.2 Kariotahi Group

The Kariotahi Group encompasses Early Pleistocene to Holocene-aged coastal sand deposits including shallow marine, beach and dune sands. In the WCS study area, fixed and mobile (or active) dune deposits are mapped along and just inland from the coast at Baylys Beach, Glinks Gully and Omamari. The Kariotahi Group is further subdivided into Pleistocene and Holocene-age dune units, as described in the following sections.

7.2.1 Pleistocene Fixed Dunes (eQd)

Early to Middle Pleistocene fixed parabolic dune deposits are mapped along the west coast extending inland. They typically comprise weakly cemented and uncemented sands with intercalated paleosols and lenses of muddy sandstone, carbonaceous mudstone and peat are sometimes present locally in interdune areas. They are often capped by well-developed soil and lignite beds.

7.2.2 Holocene Fixed Dunes (Q1dp)

The younger Holocene-aged fixed parabolic and transverse dune deposits are also mapped along the west coast extending inland. They typically comprise loose and poorly consolidated sands with interdune lake and swamp deposits of minor sand, mud and peat.

7.3 Awhitu Group Fixed Dunes (Pad)

Pliocene to Early Pleistocene aged fixed dune and interdune deposits of the Awhitu Group are present within Te Kopuru. These older dune deposits generally consist of moderately to weakly consolidated, dune-bedded sandstone with undulating bounding surfaces generally with intercalated paleosols, lignite and carbonaceous mudstone and sandstone.

7.4 Tauranga Group

Holocene-aged alluvium of the Tauranga Group is mapped in the low lying areas within the Omamari and Te Kopuru study areas, associated with the Wairoa River in Te Kopuru and smaller incised streams in both areas.

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.

7.4.1 Holocene Alluvium (Q1a)

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.

7.5 Unmapped Units

7.5.1 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 offal pits.

No such deposits have been mapped within the study areas, as only the largest and most significant fill areas have been recorded at the 1:250,000 map scale. However, pre-existing fill is likely to be present within the study areas 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.

7.5.2 Colluvium

Colluvium and landslide deposits have not been separately mapped within the study areas. 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 slope instability deposits (generally shallow-seated) were mapped as part of our photo interpretation and geomorphic field mapping and have been incorporated into the Geomorphological Map presented in Figures 14 through 17.

8 Groundwater

Publicly available groundwater data for the study areas is limited, with only eight available groundwater bores referenced for groundwater level data. Six bores are located within Te Kopuru and two within Baylys Beach.

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 in the low lying flood plain areas, underlain by Holocene Alluvium, is likely to be at levels comparable to the stream and river levels. Within the Kariotahi Group and Awhitu Group fixed dunes, groundwater levels are likely deeper, particularly in elevated dunes where the sandy soils may be more free draining. However, perched groundwater surfaces may be expected at the interface with less permeable soil units, including clay and peat beds.

Based on reported groundwater bore records, groundwater was encountered at or near the ground surface in the low-lying areas mapped as the Holocene Alluvium within Te Kopuru, whereas groundwater was measured at between 27 m and 28.6 m depth within the elevated area mapped as being underlain by Awhitu Group sediments.

Groundwater was measured at 48.8 m depth near the coast and 66.6 m depth inland at Baylys Beach within the Pleistocene dunes of the Kariotahi Group.

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 areas. The nearest active fault is the Waikopua Fault located approximately 140 km southeast of Glinks Gully, to the southeast of Auckland City.

10 Ground Slope Angles

Slope steepness within the WCS study areas varies from relatively flat in the valleys and flood plains along the Wairoa River, to quite steep in the elevated dunes along the west coast. Some areas of Awhitu Group dunes within Te Kopuru and areas mapped as Holocene Fixed Dunes along the west coast appear to support the steepest slopes within the study area, while the Tauranga Group alluvium support more subdued topographic relief.

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

Figure 10: Topographic Slope Angles – Omamari

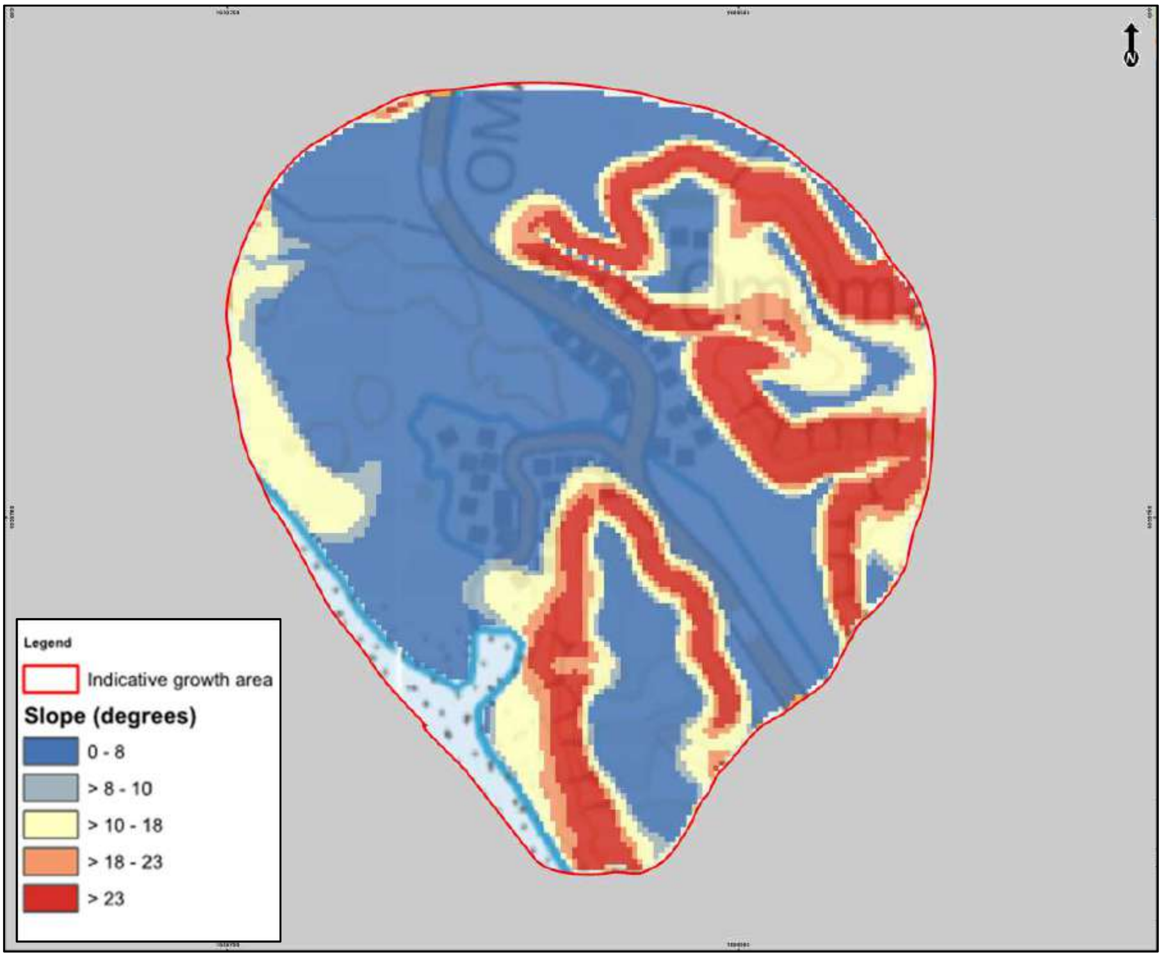


Image sourced from Land Information New Zealand, CC-BY-3.0. Not to Scale.

Figure 11: Topographic Slope Angles – Baylys Beach

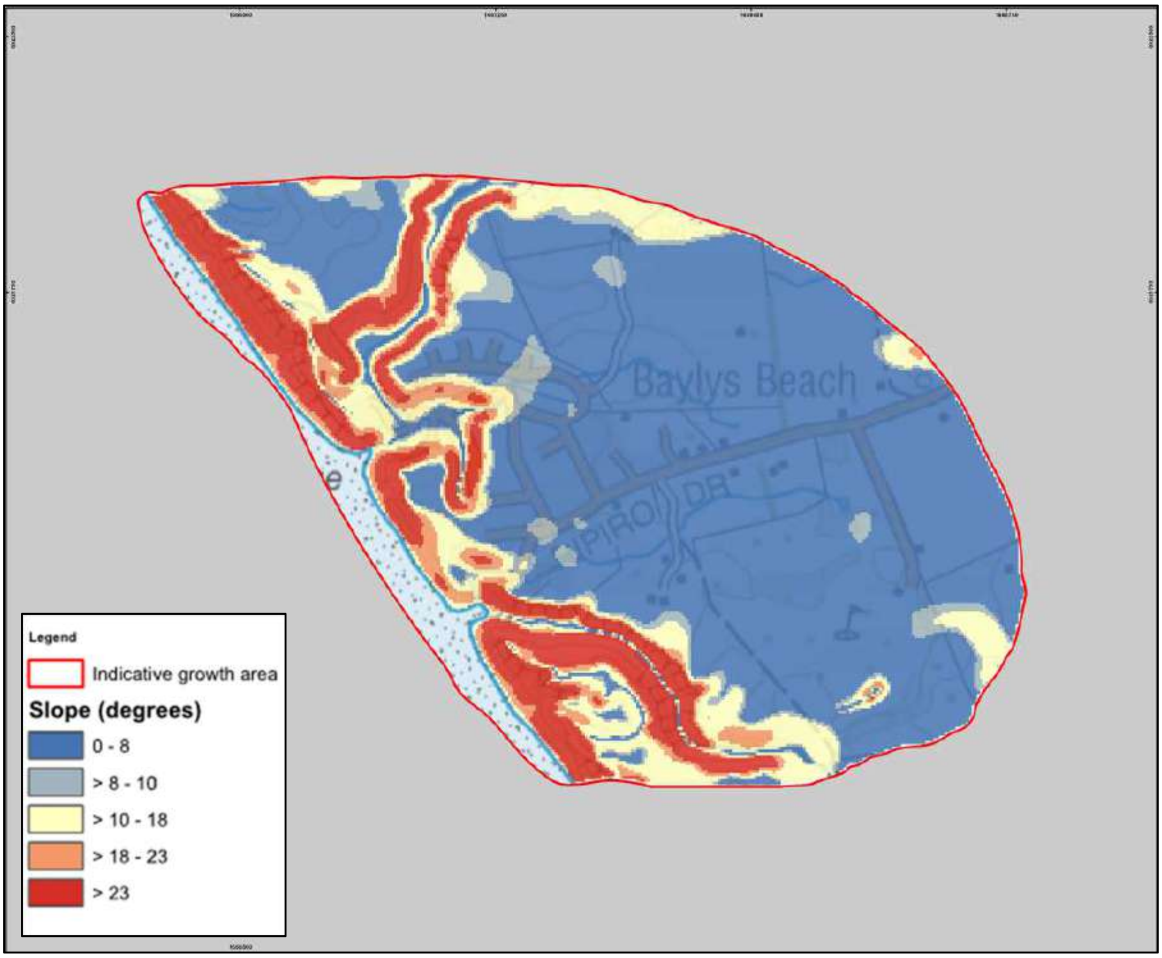


Image sourced from Land Information New Zealand, CC-BY-3.0. Not to Scale.

Figure 12: Topographic Slope Angles – Glinks Gully

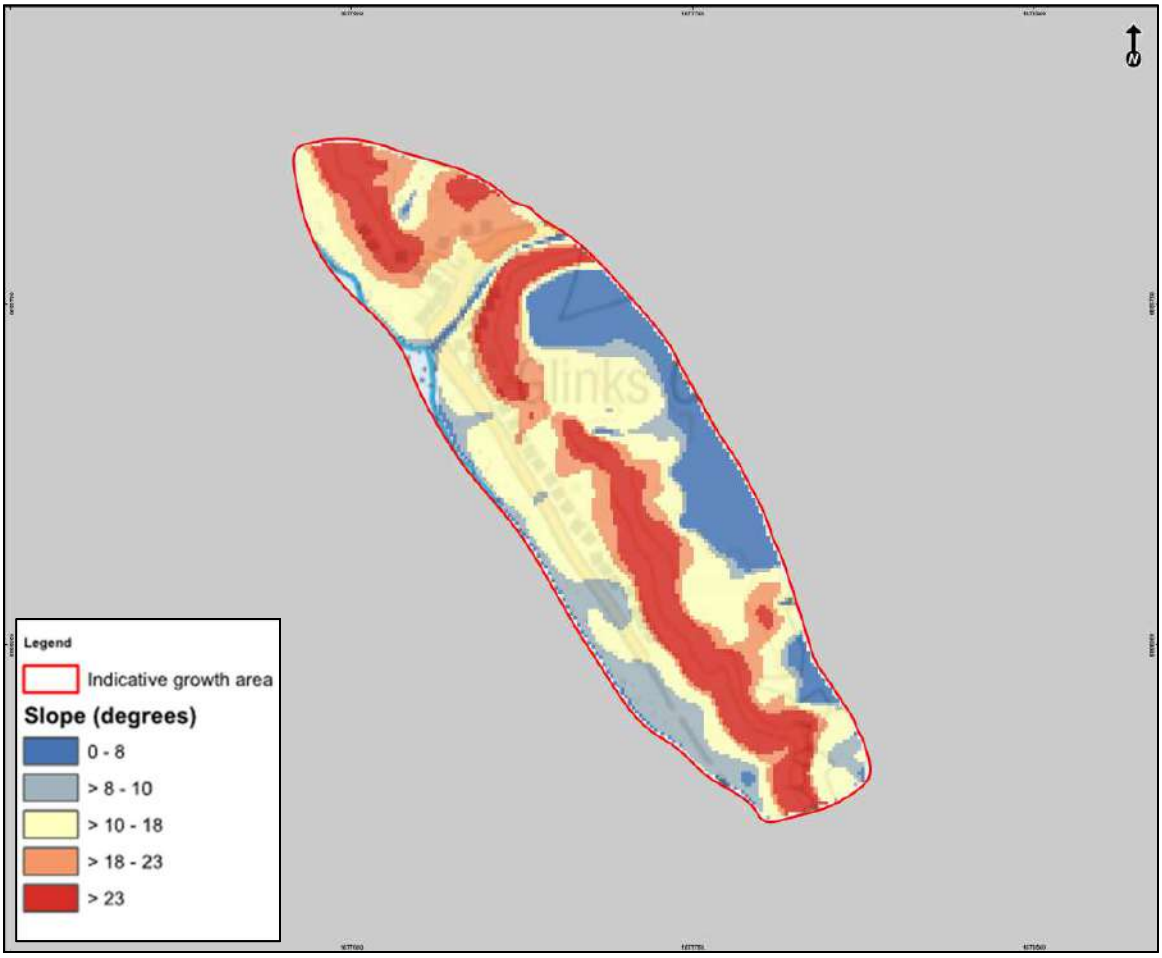


Image sourced from Land Information New Zealand, CC-BY-3.0. Not to Scale.

Figure 13: Topographic Slope Angles – Te Kopuru

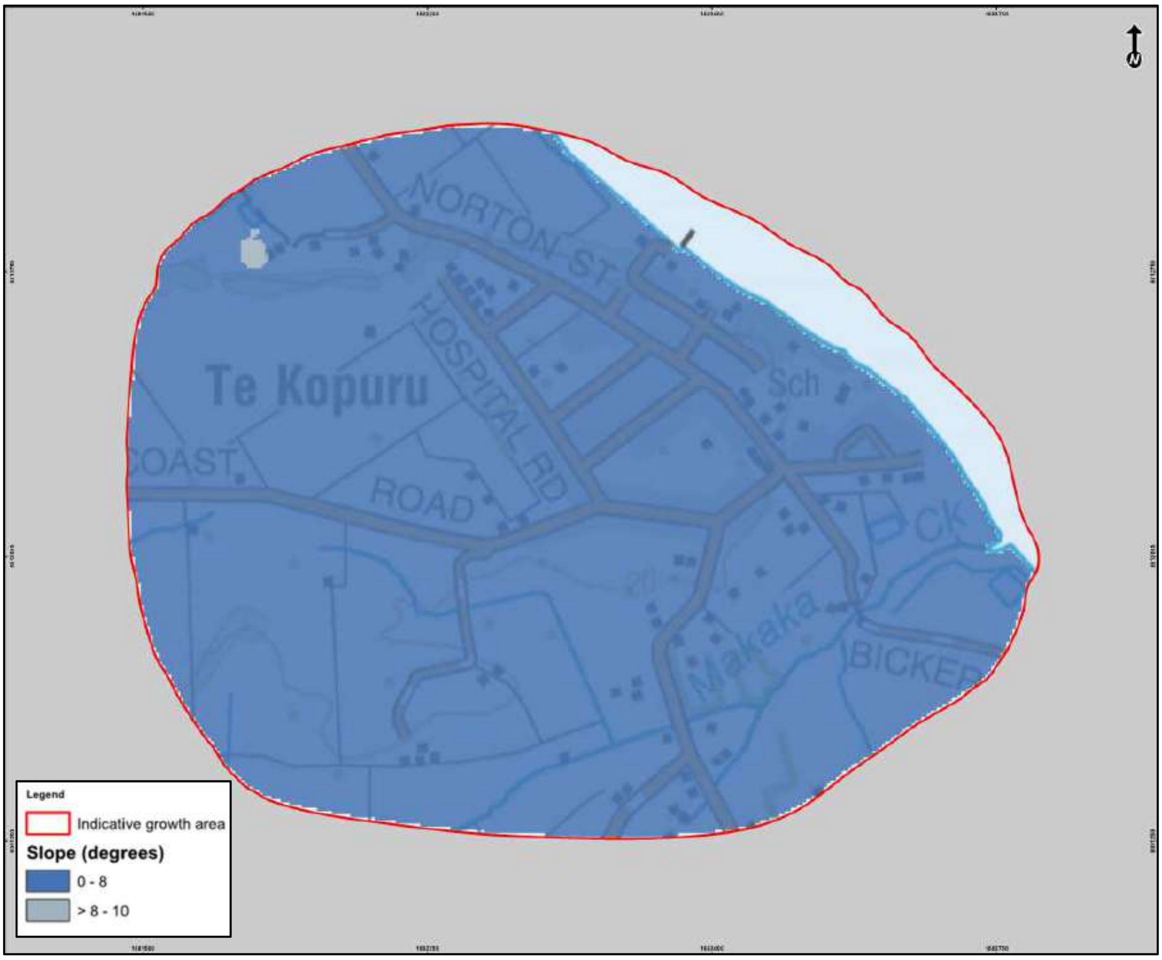


Image sourced from Land Information New Zealand, CC-BY-3.0. Not to Scale.

11 Geotechnical Hazard Discussion

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

11.1 Seismic Hazards

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

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

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

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

11.2 Slope Instability

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

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

Shallow slumping and soil creep are generally caused by loose, unconsolidated sediments that have failed along over-steepened slopes or have slowly moved downslope through the action of gravity. These features are often difficult to observe at 1:25,000 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.

Volcanic activity presents some level of 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 Northland volcanic field is generally considered to be dormant and 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 of sedimentary 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

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 - 1957 Retrolens Aerial Photo Series	Omamari – No available photograph. Baylys Beach – The majority of roads within the town were present at this time as dirt roads (excluding Sunset Drive and Pipi Place). Some residential development predominantly along Seaview Road, Coates Avenue and Cynthia Place. The area surrounding the town was generally utilised for farm paddocks. There is an oval shaped area of bare land north of the township where Sunset Drive is currently located; this appears to be associated with agricultural purposes. No large instability features are evident, however the elevated dunes to the west of the township appear to be less vegetated and eroded than currently. Glinks Gully – Glinks Road, Tasman Heights and Marine Drive were present during this time as dirt roads. Residential development was present predominantly around Glinks Road and sparsely along Marine Drive. Much of the elevated areas of the dunes northeast of Marine Drive were exposed and sparsely vegetated. No signs of significant instability observed. Te Kopuru – Majority of current roads were present as dirt roads (Norton Street, West Coast Road, Hospital Road, Graham Street, Agnes Street, Wordsworth Avenue, Pouto Road, etc.). Much of the township was developed with residential dwellings. The surrounding area was rurally developed.
1961 - 63 Retrolens Aerial Photo Series	Omamari – Omamari Road and Omamari Beach Road were present at this time as dirt roads, however the surrounding area was predominantly rural with less than ten isolated residential structures. Exposed, non-vegetated dune areas north of Omamari appear to extend further inland than currently. The gully to the east of Omamari Road, Omamari Beach Road and Babylon Coast Road appeared to be sparsely vegetated and scarps were exposed at the gully head. Baylys Beach – No available photograph. Glinks Gully – No available photograph. Te Kopuru – No available photograph.
1977 - 1979 Retrolens Aerial Photo Series	Omamari – Residential densification of the main township. The stream extending around the northern and western parts of the township appeared to be in the current alignment. Baylys Beach – Residential densification of the main township, particularly in the central area off Seaview Road and Kelly Street. No evidence of bare oval feature noted in 1952. The golf course appeared to be present. No evidence of significant instability observed. Exposed dunes west of township appeared to be more vegetated than 1952. Glinks Gully – Rope Crescent and the campground were present. Residential densification south of Glinks Road and along Marine Drive. No signs of significant instability observed. Elevated dune areas northeast of Marine Drive had increased vegetation. Te Kopuru – Slight residential densification, particularly along West Coast Road. No significant change observed.

Date	Description
1982 - 86 Retrolens Aerial Photo Series	Omamari – No significant change observed. Several more residential structures in the main township. Baylys Beach – Residential densification particularly near Ocean View Terrace. No evidence of significant instability observed. Glinks Gully – No significant change observed. Te Kopuru – Farm pond present southeast of town. No significant change observed.
1991 - 96 Retrolens Aerial Photo Series	Omamari – No available photograph. Baylys Beach – No significant change observed. The edge of the farmland east of Glinks Gully appeared to be more defined. Glinks Gully – Dwelling constructed at the end of Tasman Heights Road at the crest of the slope. No signs of significant instability observed. Te Kopuru – A second farm pond present southeast of town. No significant change observed.
2003 - 2018 Google Earth	Omamari – No significant change observed. Baylys Beach – Residential intensification, particularly east of the township. Development of Sunset Drive and associated cul-de-sacs and several dwellings in 2010 – 2011. Glinks Gully – No significant change observed. Te Kopuru – No significant change observed.

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

13 Geomorphological Assessment

13.1 Stereo-Paired Aerial Photo Interpretation

We supplemented geologic mapping within the study area with interpretation of stereoscopic aerial photographs obtained from WSP Opus. The photo interpretive mapping was performed using stereo-paired aerial photos from the following:

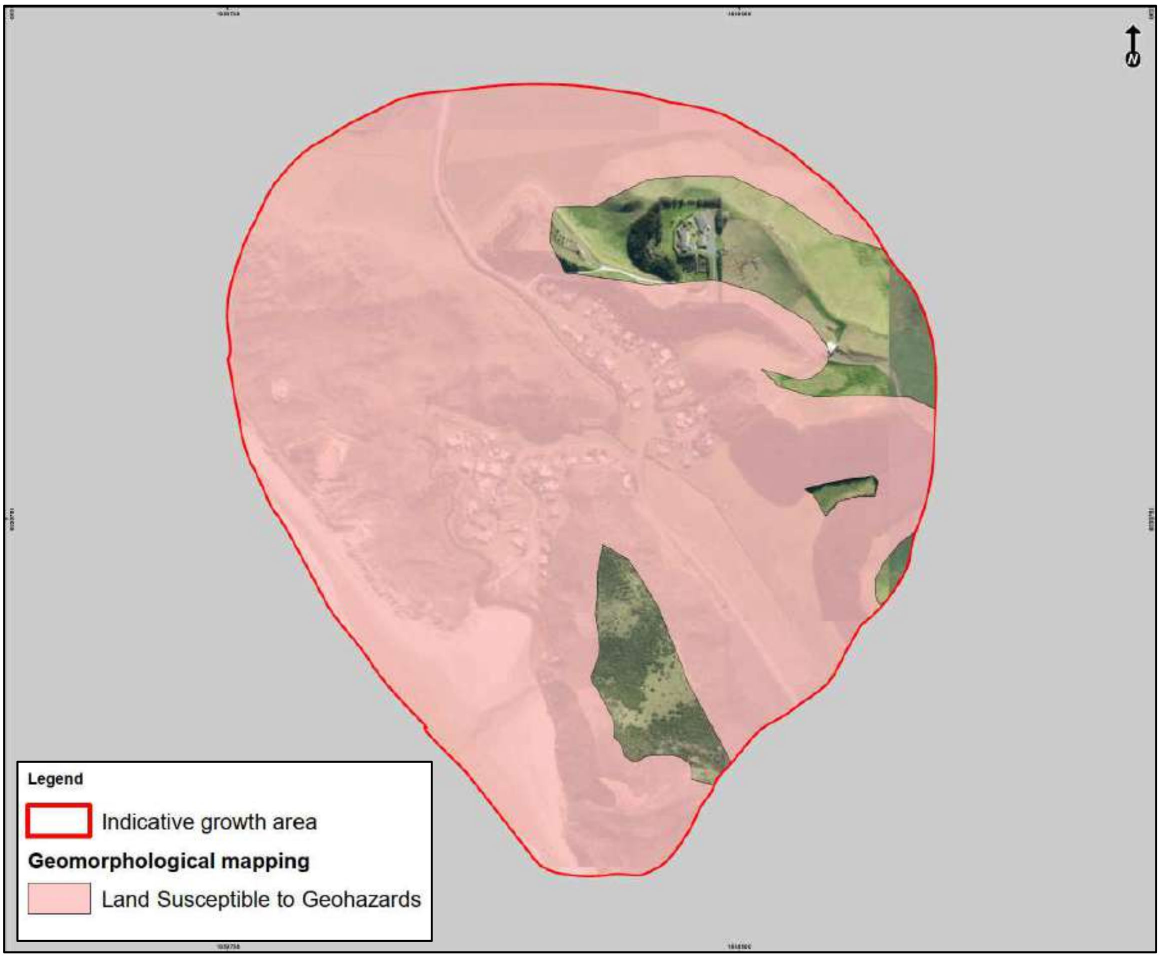
- Omamari - Flight SN 5091 K/3 and K/4, flown on 10 January 1979.
- Baylys Beach - Flight SN 5091 N/2 and N/3, flown on 10 January 1979.
- Glinks Gully – Flight SN 8104 C/2 and C3, flown on 10 January 1983.
- Te Kopuru – Flight SN 8104 B/6 and B/7, flown on 10 January 1983.

A middle-range scale of 1:25,000 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 Figures 14 through 17. 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.

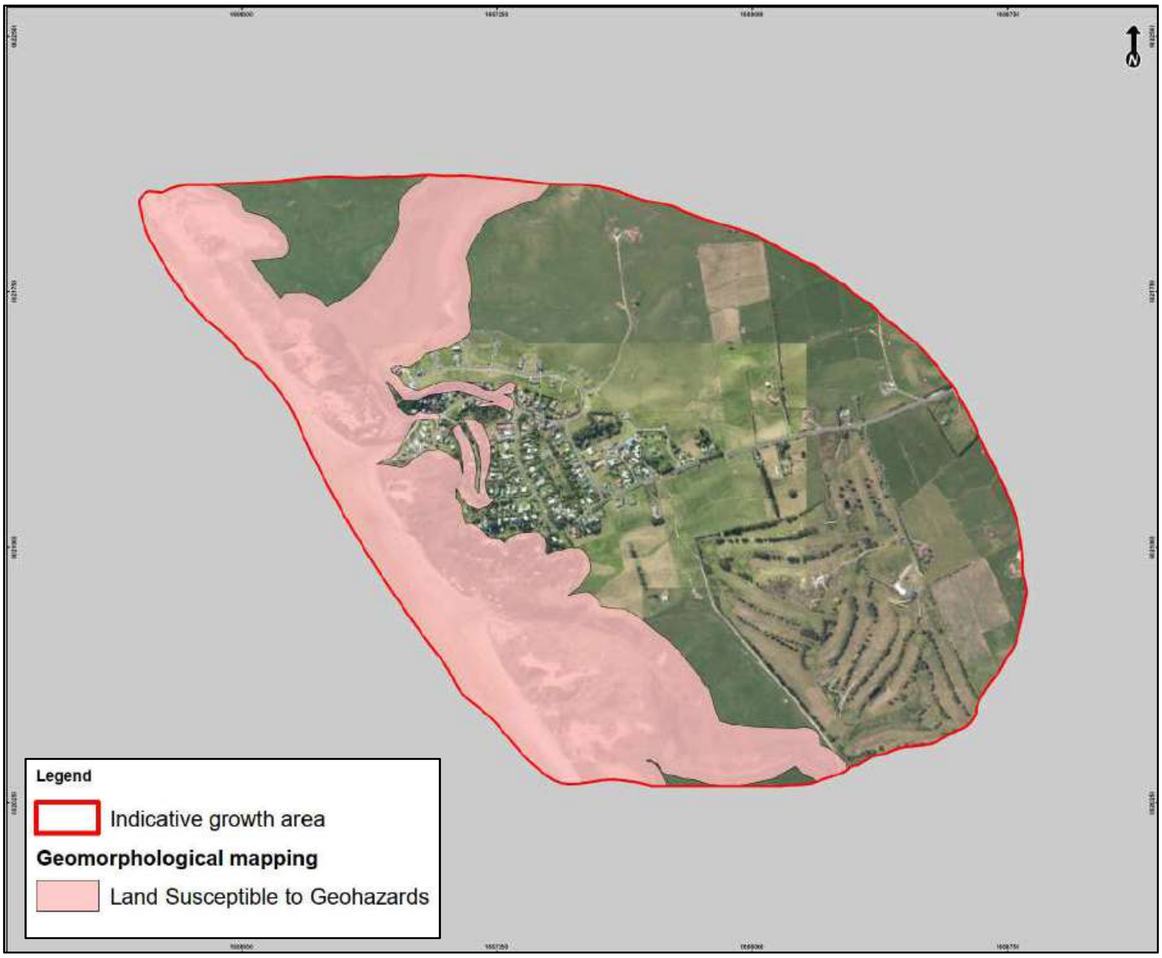
The geomorphic mapping performed for this study should be considered a reconnaissance level effort, and is intended to provide a generalised delineation of geotechnical hazards for planning-level site evaluations. The accuracy was limited by the scale of the aerial images and other factors such as vegetative cover, farming, and urban development. The mapping depicted on Figures 14 through 17 should be supplemented by detailed site-specific geomorphic mapping for design level studies.

Figure 14: Geomorphological Mapping – Omamari



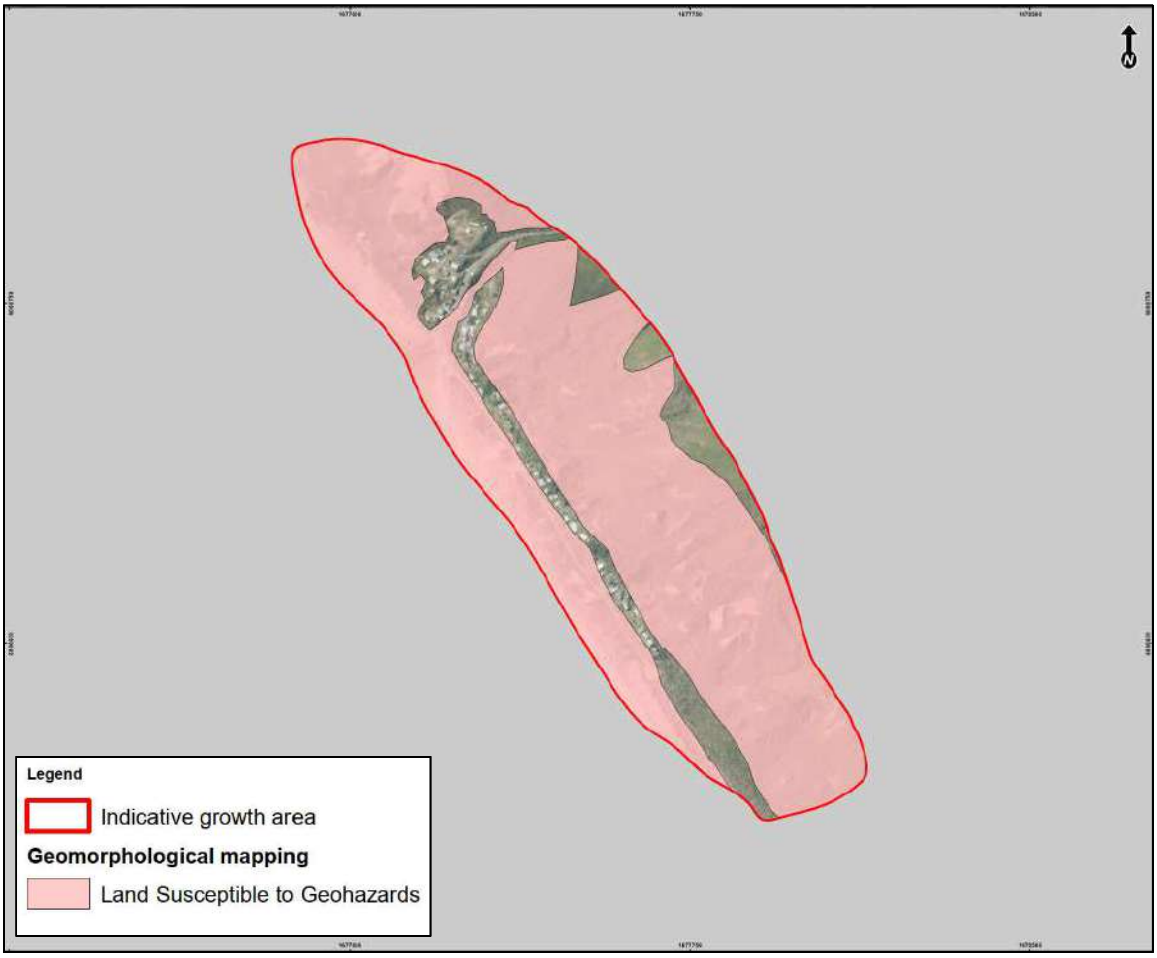
Base image sourced from Land Information New Zealand, CC-BY-3.0. Not to Scale.

Figure 15: Geomorphological Mapping – Baylys Beach



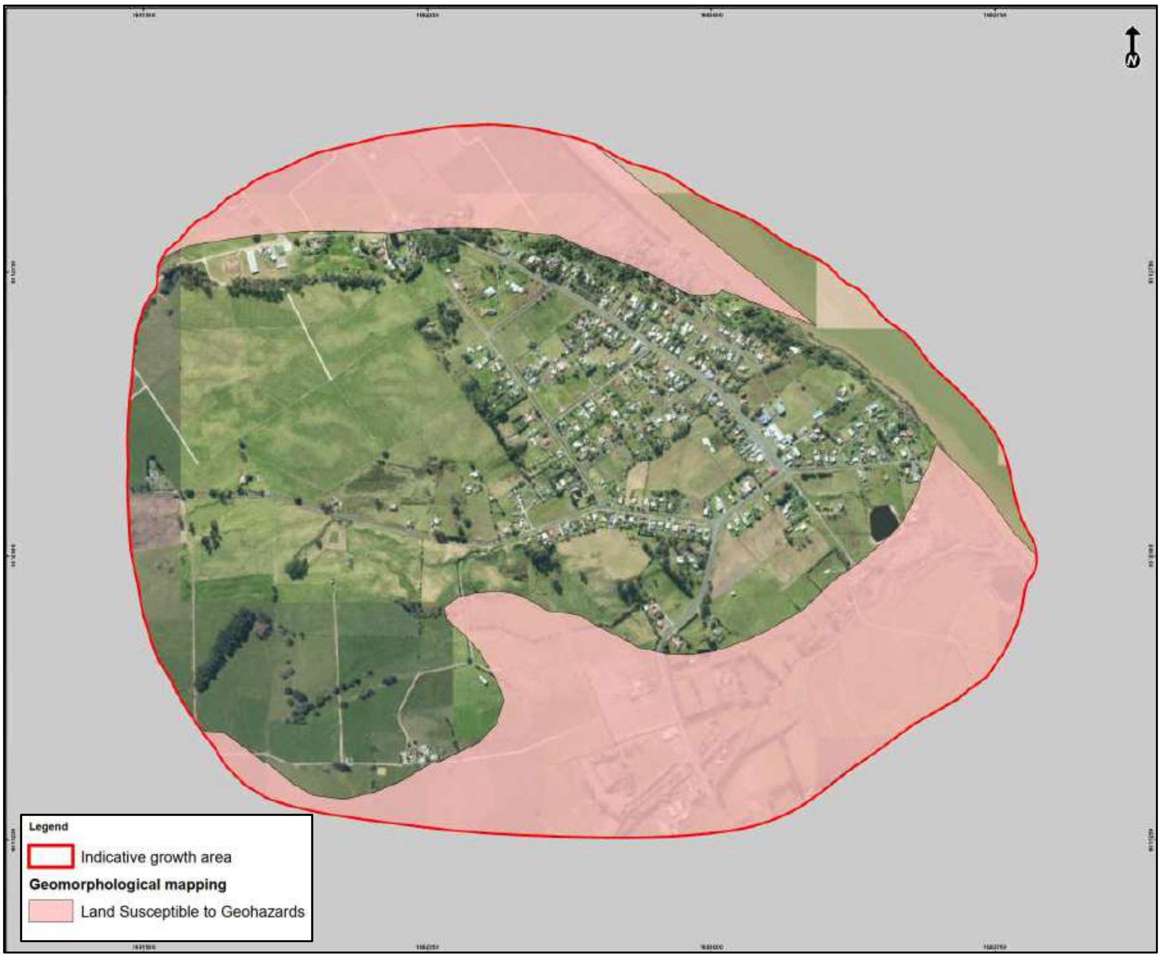
Base image sourced from Land Information New Zealand, CC-BY-3.0. Not to Scale.

Figure 16: Geomorphological Mapping – Glinks Gully



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

Figure 17: Geomorphological Mapping - Te Kopuru



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 areas to observe typical ground conditions and geomorphological features. Our mapping was not intended to provide a detailed geomorphic assessment of the areas. 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 coastal WCS study areas (Omamari, Baylys Beach and Glinks Gully) generally consist of steeps coastal dunes, rolling dune derived hills which extend inland from the coast and broad valleys.

The variably vegetated dunes along the coast extend from the beach up to over approximately 60 m in elevation (Photos 1 and 2). The landform remains generally stable up to approximately 70 degrees (Photo 3), however shallow instability features are present on some of the vegetated slopes, and erosion and pervasive slope instability is evident in sparsely vegetated areas and areas influenced by water (i.e. overland flow paths), particularly at the coast (Photos 4 and 5).

The coastal dune exposures commonly have unconsolidated to moderately consolidated sand and extremely weak sandstone outcrops, as well as paleosols and lignite horizons, particularly in the upper dune areas (Photos 5 and 6).

Inland, the hill systems are bisected by broad valleys and steeply incised streams (Photo 7), which generally flow through the central part of the focus areas and drain through to the coast. In Omamari, a low-lying inland valley (Photo 8) underlain by alluvium extends approximately parallel to the coast and drains through the central portion of the study area to the beach.

Evidence of shallow soil creep in the form of hummocky ground and soil ridges is located on the flanks of inland hills (Photo 9). Several small headscarps (<1 m high) were observed at the crest of hill slopes (Photo 10).

In the Te Kopuru study area, the landform is dominated by an elevated terrace in the central area (Photo 11), underlain by Awhitu Group fixed dunes, and a low-lying, relatively level Holocene-aged alluvial plane in the southeast and southwest of the study area (Photo 12). Rolling hills and moderate slopes were observed in pasture land at the geological boundary in the southern part of the study area. Whereas a steep, weak to extremely weak sandstone outcrop was observed at the boundary near the boat ramp in the north-eastern part of the study area (Photo 13). The majority of the township is located on the elevated area, while the low-lying areas are predominantly utilised for agricultural purposes.

Several streams with associated wetland vegetation were observed in the low-lying alluvial area in the south, draining to the Wairoa River in the east of the study area (Photo 14).

13.2.2 Rock Outcrops

Only limited areas were observed to have rock outcrops. Where exposed, we observed weak to extremely weak, weakly consolidated to unconsolidated, dune bedded, sandstone (Photo 13).

13.2.3 Borrow Areas

Several areas were observed during our site visit to the Baylys Beach that appeared to be open borrow areas (Photos 15 and 16). These were likely local quarry sources for farm improvements or roading. Local areas of instability were observed near the crest of one of the excavations due to the over-steepened nature of the slopes. A discussion on geotechnical hazards associated with open pit quarries is in Section 15.2.

13.2.4 Surficial Deposits

Holocene alluvial deposits are mapped in the low-lying areas in the southern and north-eastern parts of the Te Kopuru study areas, as well as in the inland valley area within the central part of the Omamari study area. These areas appear to be relatively level and no signs of slope instability were observed.

Figure 18: Site Photographs

Photo 1: Drone photo looking northwest from the south of the Glinks Gully study area.

Photo 2: Drone photo looking southeast from the south of the Glinks Gully study area.

Photo 3: Steep dune on the coast at Baylys Beach.

Photo 4: Erosion of the dunes at Baylys Beach.

Photo 5: Up to approximately 1 m thick lignite outcrop exposed at the coast in the south of the Baylys Beach study area.

Photo 6: Drone photo of exposed paleosols in the upper part of the dunes at Glinks Gully.

Photo 7: Steeply incised stream in the north-western part of the Omamari study area.

Photo 8: Broad valley and gully with dune terraces in the northern part of the Omamari study area.

Photo 9: Hummocky land and terracettes on a slope in the north of the Omamari study area.

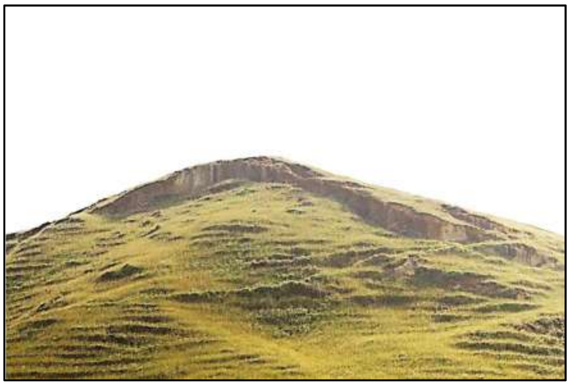


Photo 10: The headscarp of a large landslide and evidence of shallow soil creep in the southern Omamari study area.

Photo 11: Drone photo looking south from the boat ramp in the northeast of the Te Kopuru study area.

Photo 12: Drone photo looking east along Bickers Road in the southeast of the Te Kopuru study area.

Photo 13: Exposed Awhitu Group (Pad) sandstone in the northeast of the Te Kopuru study area.

Photo 14: Low lying stream in the southern part of the Te Kopuru study area.

Photo 15: Inferred open borrow pit located in the southeast of the Baylys Beach study area.

Photo 16: Inferred open borrow pit located to the northeast of the Baylys Beach study area.

14 Geotechnical Hazards Identified in the WCS Areas

14.1 General

Based on the findings of this geotechnical assessment, we consider the primary geotechnical constraints of the WCS Indicative Growth Areas to be slope instability, liquefaction and lateral spread potential, 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.

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

Hazards within areas mapped as 'Low' potential would only be expected to affect a structure in events unlikely to occur in the design life of the structure and therefore would require a lower level of geotechnical investigation. The hazard potential of areas mapped as 'Low' may become higher risk 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 moderate 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 high level of geotechnical investigation.

14.2.4 Combined Geohazard Map

As part of this geotechnical assessment, ENGEO has compiled a Combined 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, liquefaction and lateral spread potential, and settlement due to soft compressible soils).

This map 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 WCS focus areas 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 Wairoa River (i.e. within the active channel of the river and within some of the Holocene deposits adjacent the river).

14.3.2 Ground Shaking

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

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

14.3.3 Liquefaction and Lateral Spread

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

Areas outside of the GNS dataset are unshaded in Figures 19 through 22.

Low Liquefaction and Lateral Spread Potential

None of the WCS study areas are considered to have a low liquefaction and lateral spreading potential. This is due to the mapped geology within the study areas generally consisting of loose granular material and alluvial sediments, which are generally considered to be liquefiable under seismic conditions.

Medium Liquefaction and Lateral Spread Potential

Holocene (Q1dp), Pleistocene and Pliocene-aged dunes (eQd and Pad) comprising unconsolidated to weakly consolidated dune sands sometimes form terraces up to 60 m high above present day flood plain levels.

Although the upper areas of the dunes are not likely to be saturated by shallow groundwater, we consider these areas to have a potential to liquefy under ULS conditions due to the loose granular nature of the soils. Given that the dunes form steep slopes near the coasts, lateral spread is also possible during a ULS event.

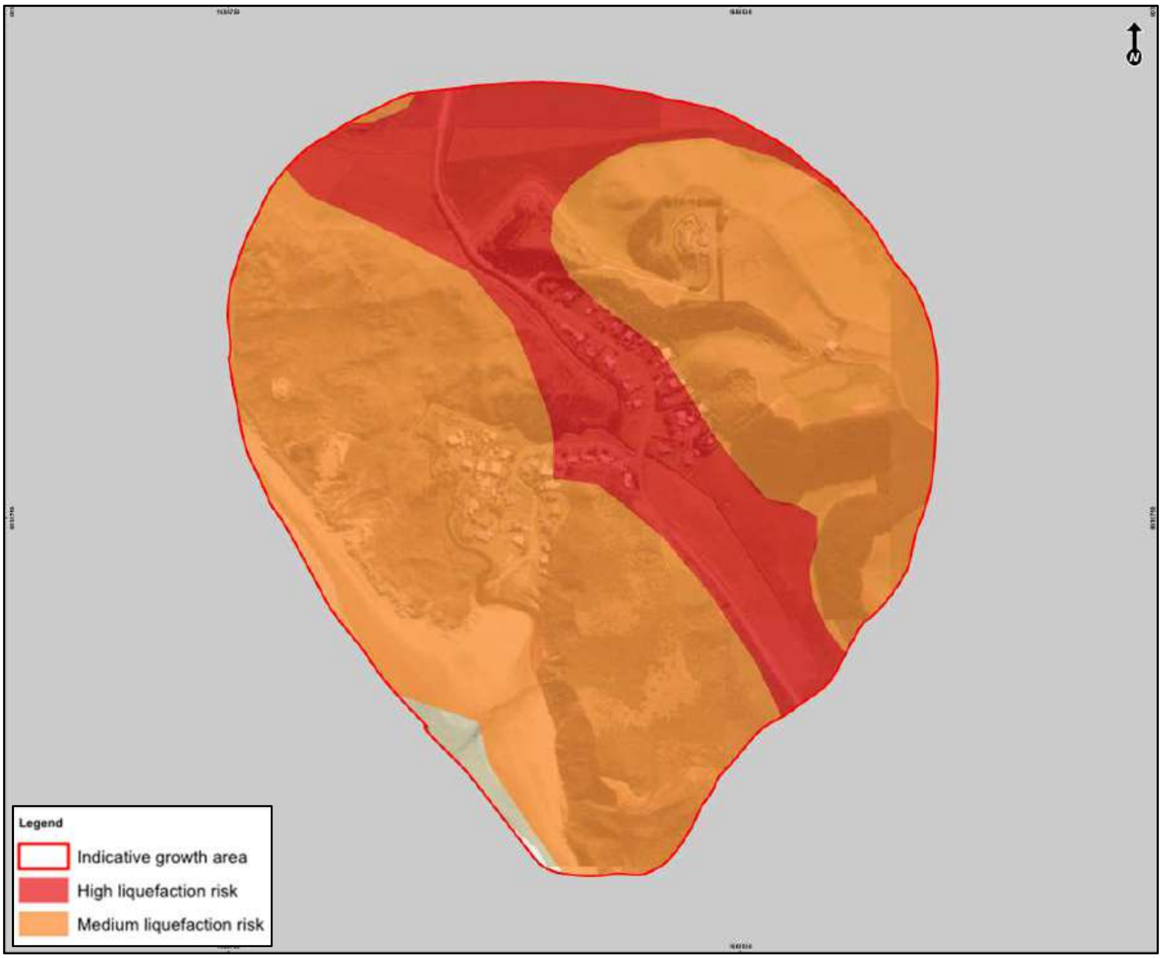
Given the potential for poorly consolidated, coarse-grained soils to be present below groundwater within the lower dune areas, we consider liquefaction and lateral spread potential within this unit to be medium.

High Liquefaction and Lateral Spread Potential

Young Holocene alluvial deposits (Q1a) are mapped along the stream valley alignment in the central and northern areas of Omamari (Figure 19) and in the low-lying areas in the southern and northern parts of Te Kopuru (Figure 22). These deposits generally consist of soft and poorly consolidated mud, sand and gravel and occupy low elevation areas associated with shallow groundwater.

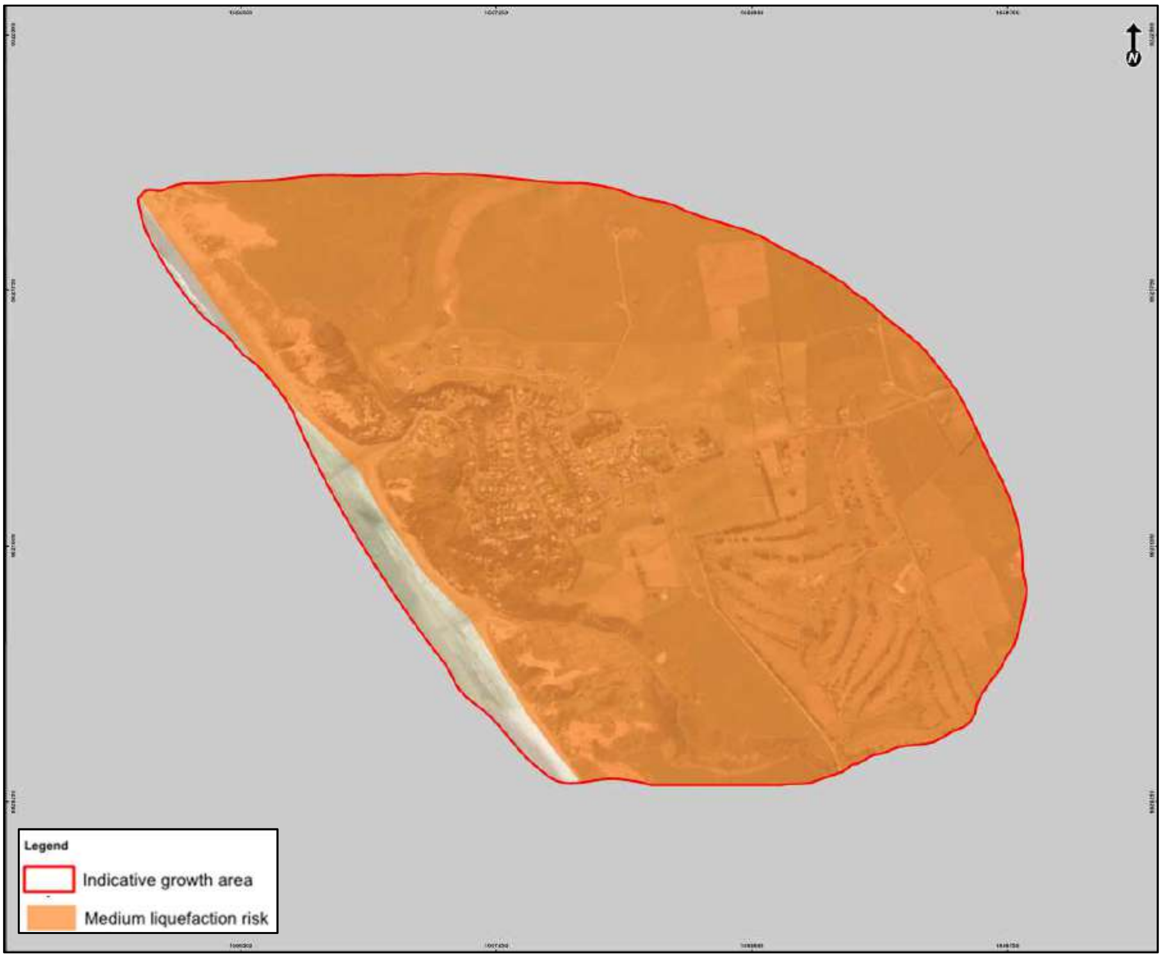
We consider these areas to have a potential to experience liquefaction under SLS conditions. Due to the potential granular nature of these soils and expected high groundwater, we consider the liquefaction and lateral spread potential of the Holocene Alluvium to be high.

Figure 19: Liquefaction and Lateral Spread Susceptibility Map - Omamari



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

Figure 20: Liquefaction and Lateral Spread Susceptibility Map – Baylys Beach

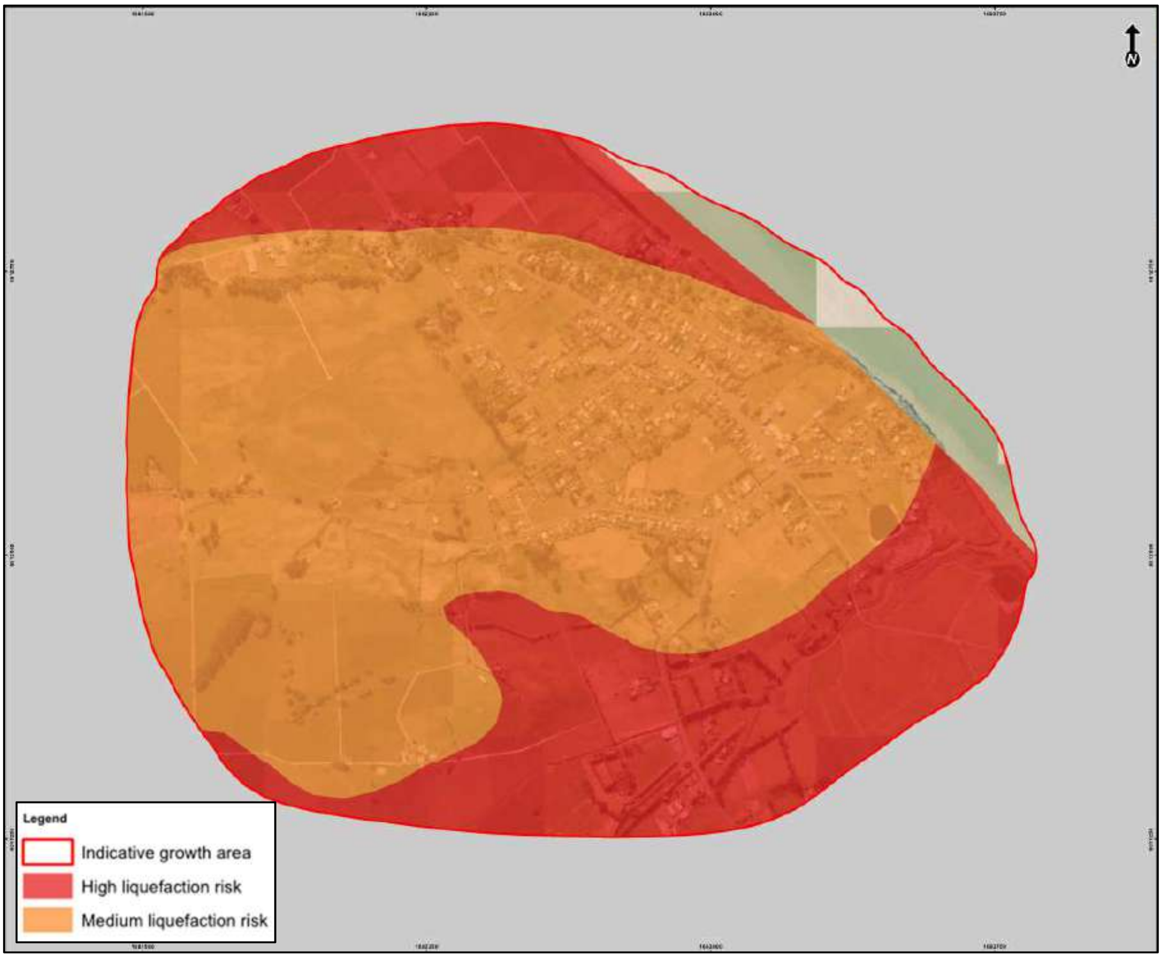


Base image sourced from Land Information New Zealand, CC-BY-3.0. Not to Scale.

Figure 21: Liquefaction and Lateral Spread Susceptibility Map – Glinks Gully

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

Figure 22: Liquefaction and Lateral Spread Susceptibility Map – Te Kopuru



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.

Holocene, Pleistocene and Pliocene-aged fixed sand dune deposits were observed at slopes up to approximately 70 degrees. 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 be stable at slopes less than 14 to 16 degrees.

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.

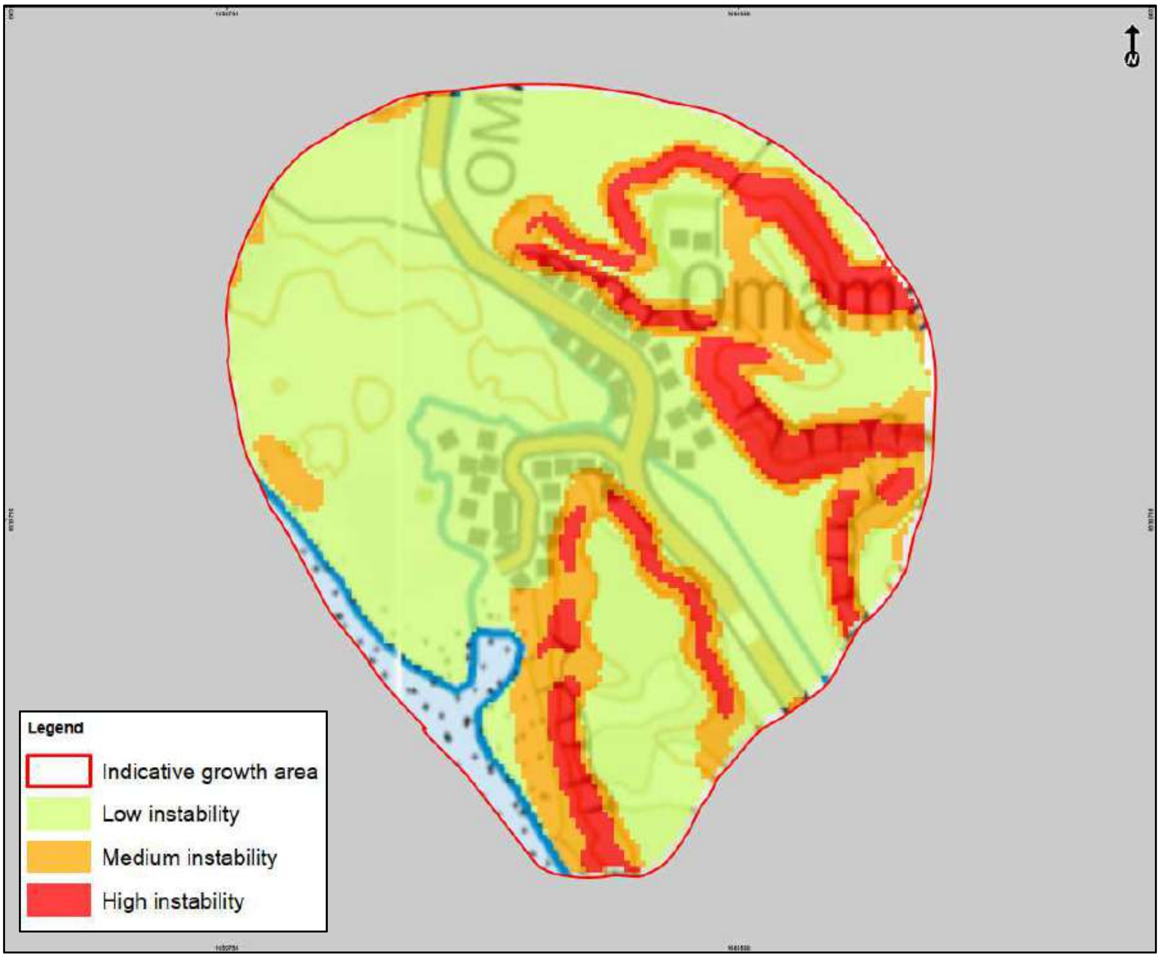
Based on GNS, previous geotechnical assessments, and our experience working in similar sediments, we have developed slope profile ranges which are presented in Table 2. Slope profile ranges categorise the potential for instability in each geological unit as low, medium, and high, with corresponding slope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

Table 2: Slope Instability Profile

Geologic Unit	Slope Instability Potential based on Slope Profile Ranges		
	Low	Medium	High
Pleistocene Fixed Dunes (eQd)	<14°	14-26°	>26°
Holocene Fixed Dunes (Q1dp)	<14°	14-26°	>26°
Awhitu Group Fixed Dunes (Pad)	<16°	16-33°	>33°
Holocene Alluvium (Q1a)	<10°	10-23°	>23°

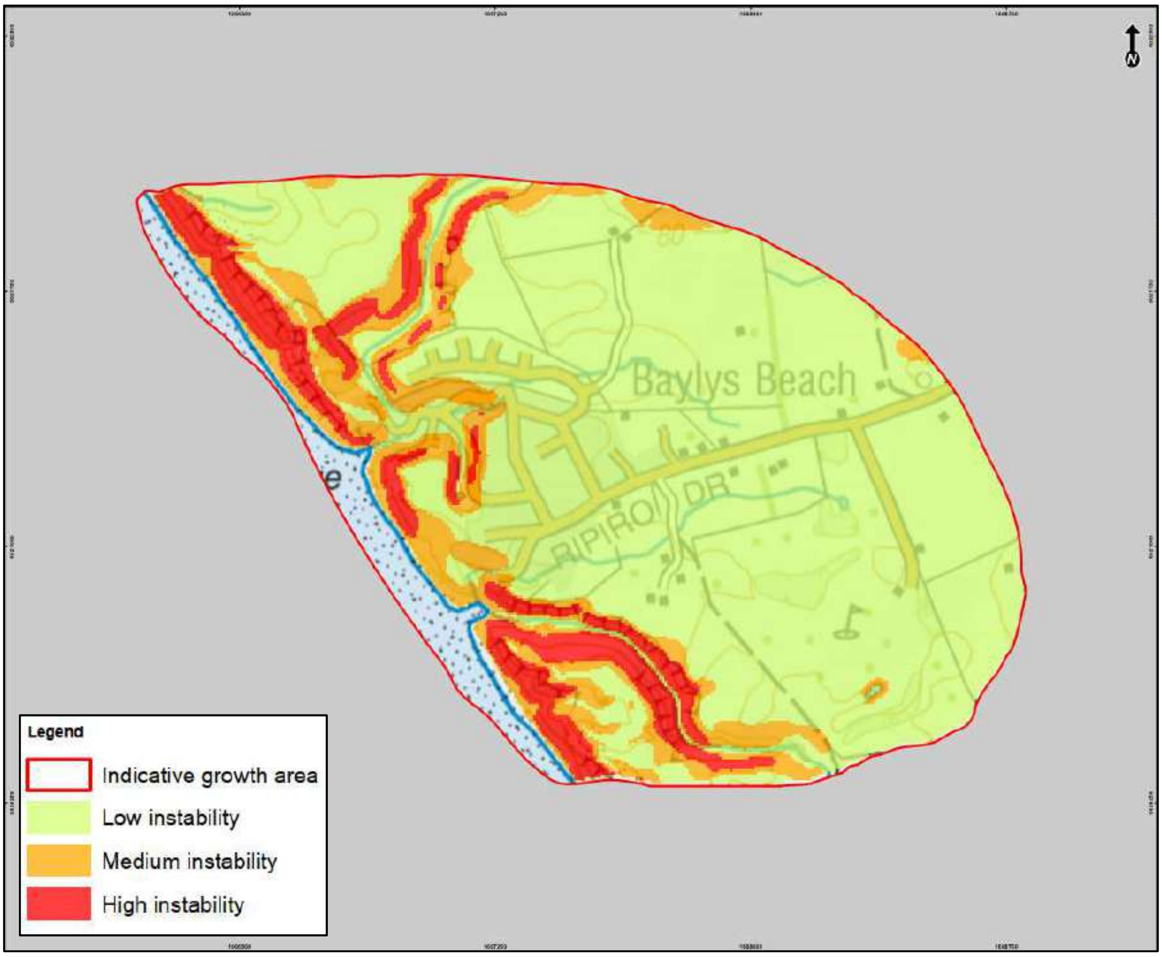
The slope profile ranges have been applied to the LiDAR contour and elevation data to generate the Slope Instability Potential map presented in Figures 23 through 26. It is important to note that the “Low Instability Potential” category does not imply that instability will not occur on these slopes. 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 23: Slope Instability Potential - Omamari



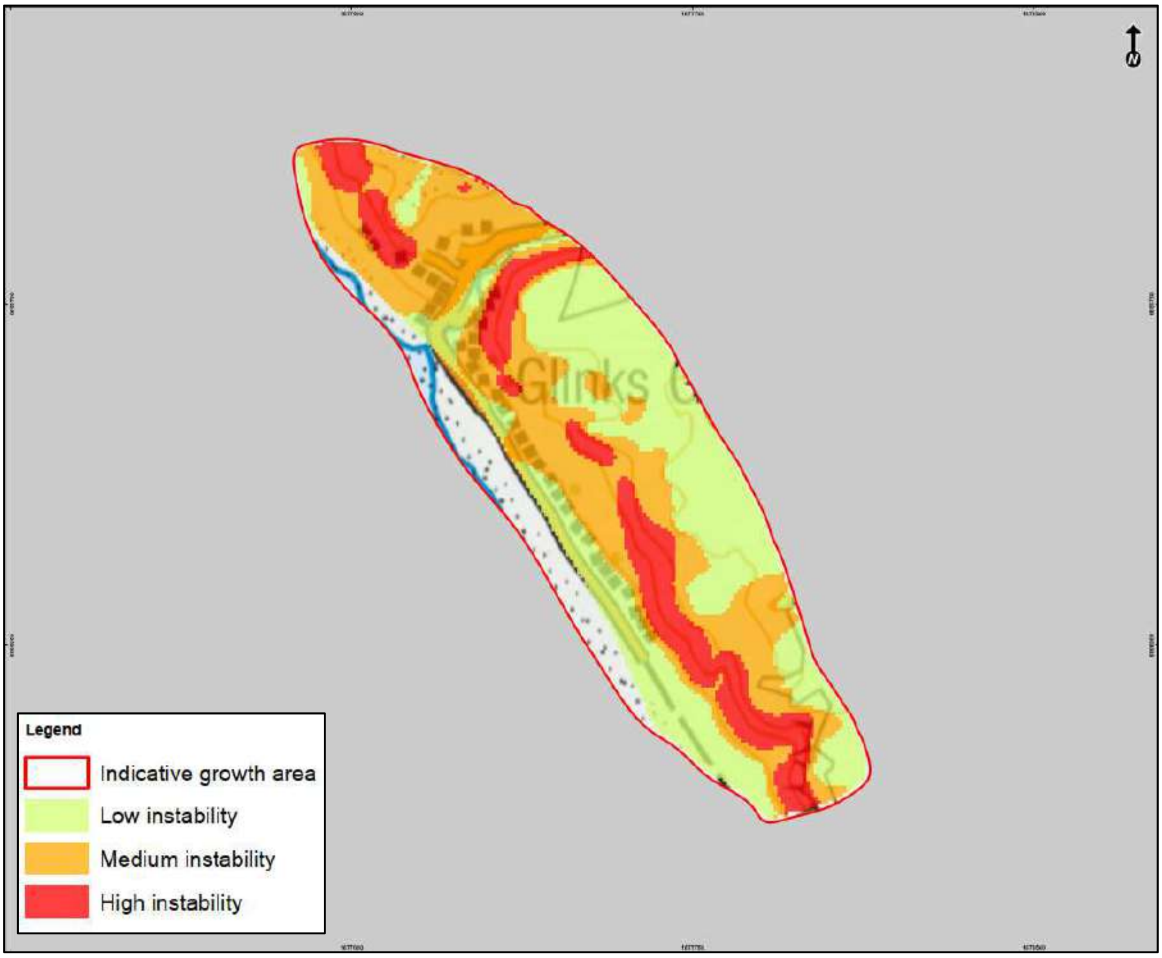
Base image sourced from Land Information New Zealand, CC-BY-3.0. Not to Scale.

Figure 24: Slope Instability Potential – Baylys Beach



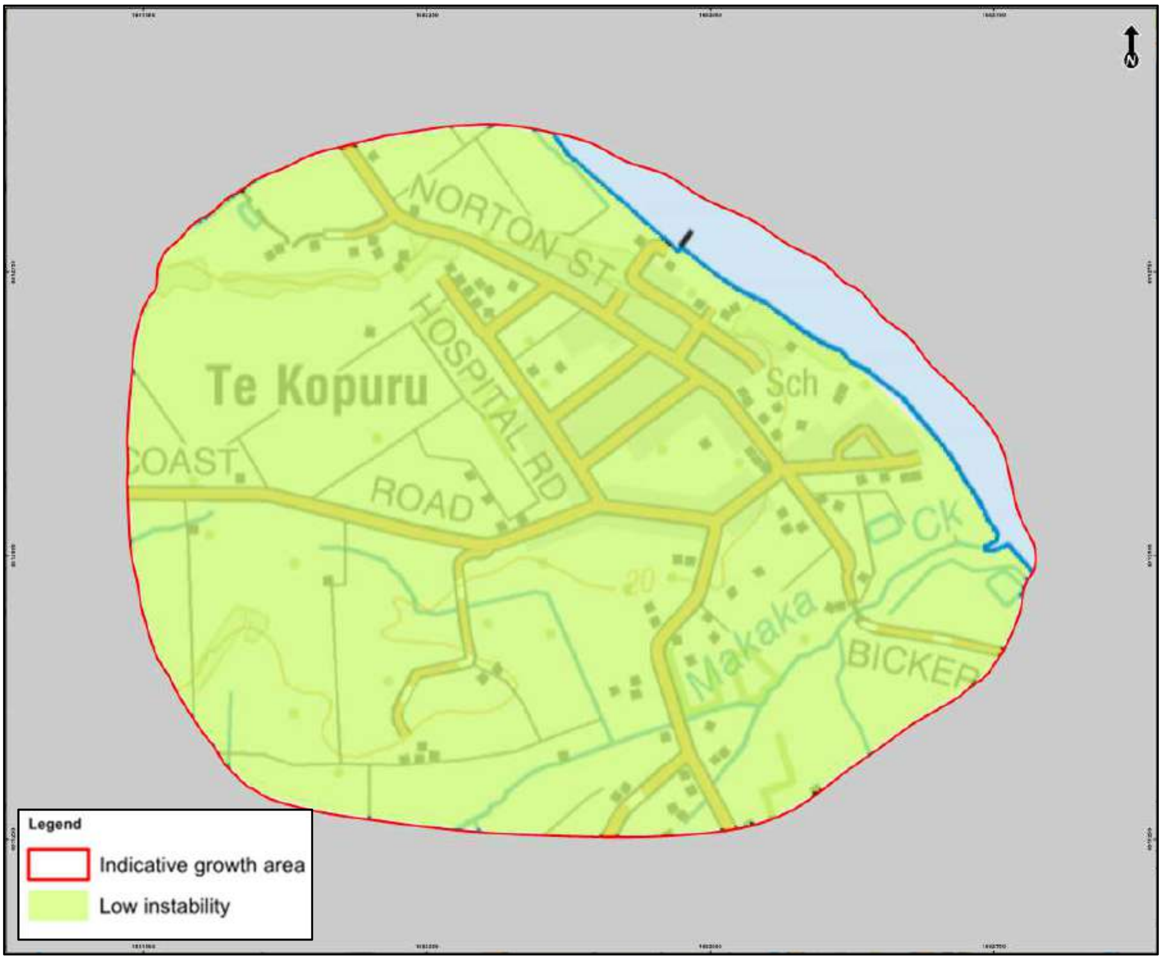
Base image sourced from Land Information New Zealand, CC-BY-3.0. Not to Scale.

Figure 25: Slope Instability Potential – Glinks Gully



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

Figure 26: Slope Instability Potential – Te Kopuru



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 16 degrees in Awhitu Group Fixed Dunes, 14 degrees in Kirotahi Group Fixed Dunes, or 10 degrees 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.
- 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 deposits within the study area (refer to Figures 6 through 9) 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 (Q1a) 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

Sand sediments, sandstone and mudstone of the Kariotahi and Awhitu Group dune deposits are not considered to be susceptible to settlement under loading. However, the Pleistocene fixed dune deposits (eQd) sometimes contain intercalated peat lenses, which may be susceptible to consolidation. If lenses of peat or associated organic soil is encountered during site investigations, then potential consolidation settlement should be considered.

Areas having low consolidation settlement potential are unshaded in Figure 27 through 30.

Medium Consolidation Settlement Potential

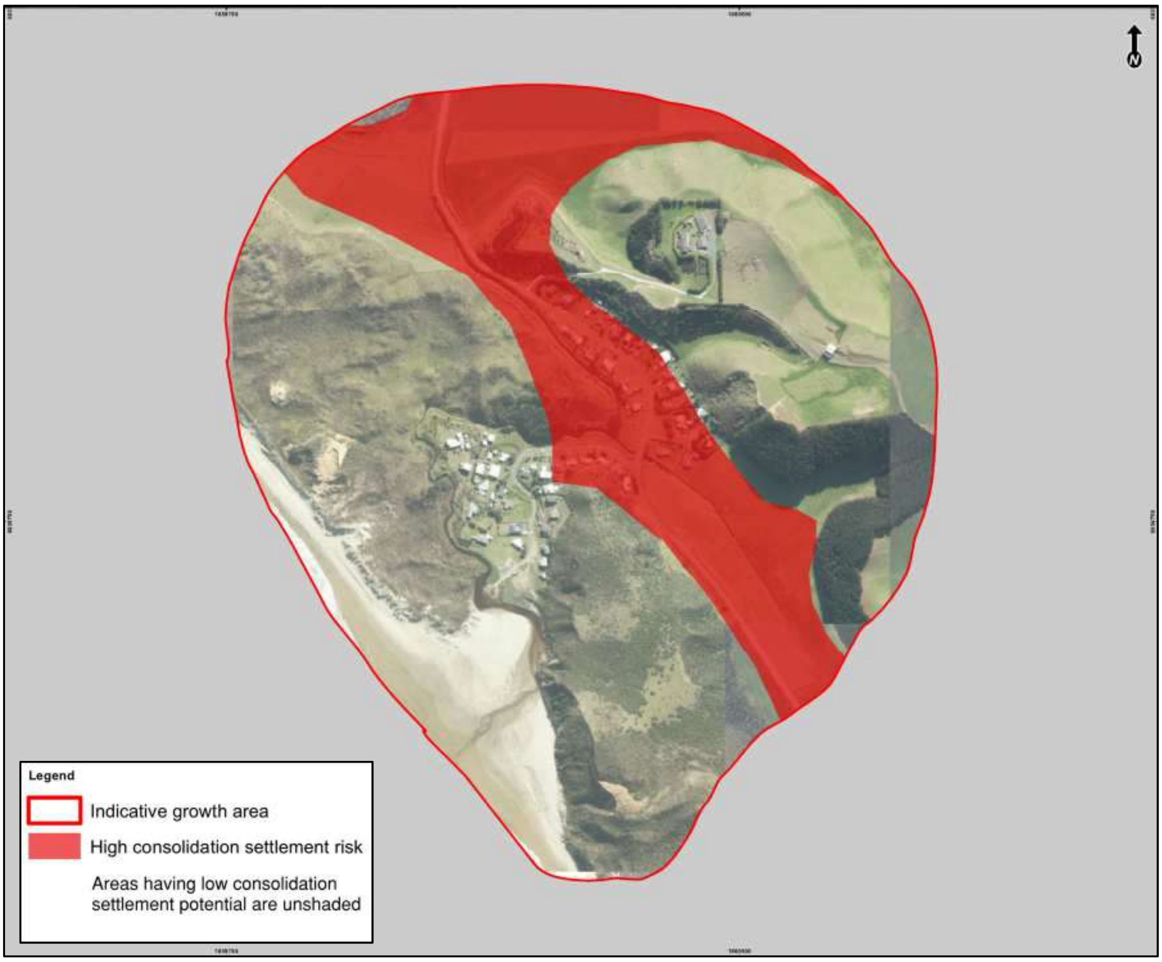
None of the WCS study areas are considered to have a medium consolidation settlement potential. This is due to the mapped geology within the study areas generally consisting of either alluvial sediments or uncemented to weakly cemented dune sands.

High Consolidation Settlement Potential

Young Holocene alluvial deposits (Q1a) are mapped along the stream valley alignment in the central and northern areas of Omamari (Figure 27) and in the low lying areas in the southern and northern areas of Te Kopuru (Figure 30). These deposits comprise mud, sand and gravel, with peat and organic beds. These soils, however, are considered to be soft and poorly consolidated.

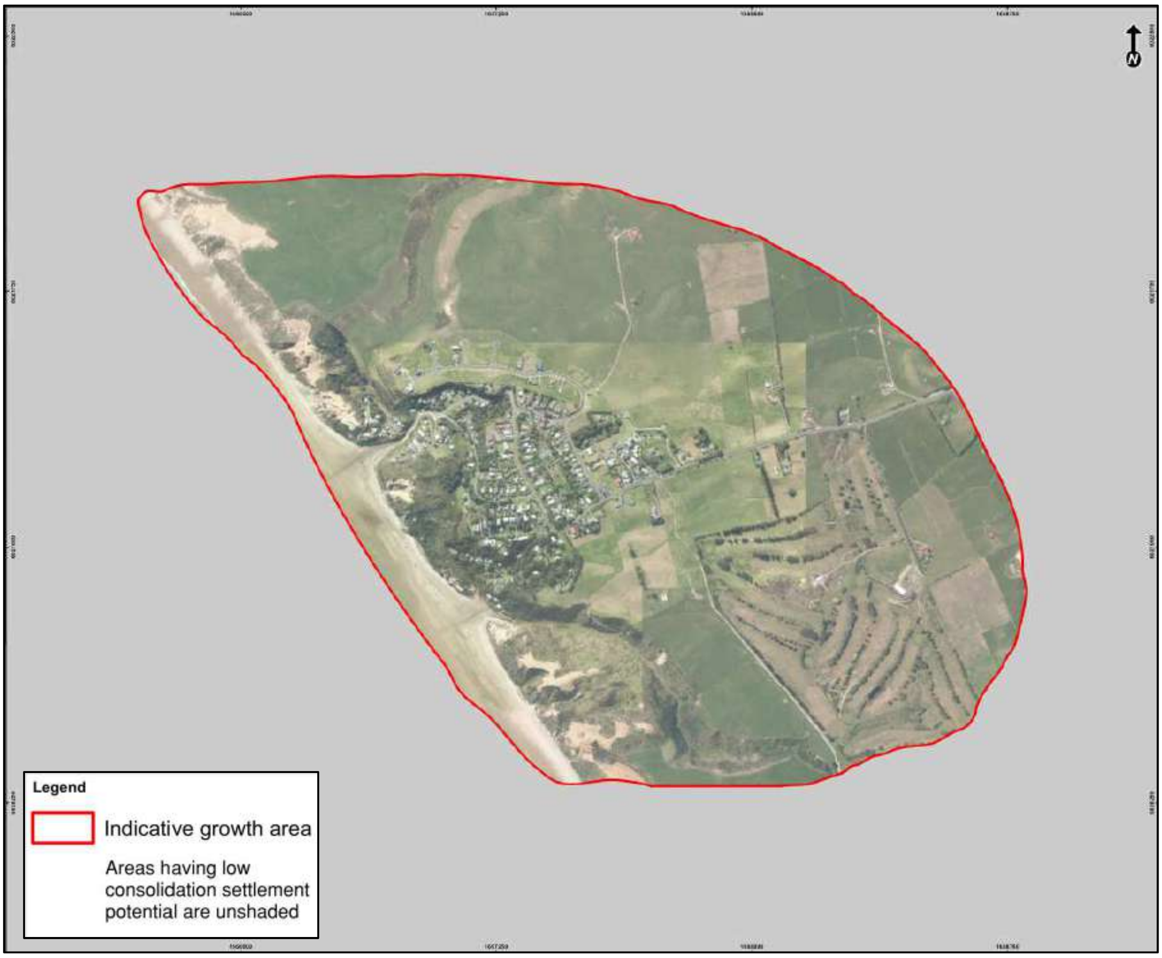
Given the likely presence of organic material and soft clay layers, we consider these areas to have a high potential to experience consolidation settlement under loading.

Figure 27: Settlement Susceptibility Map - Omamari



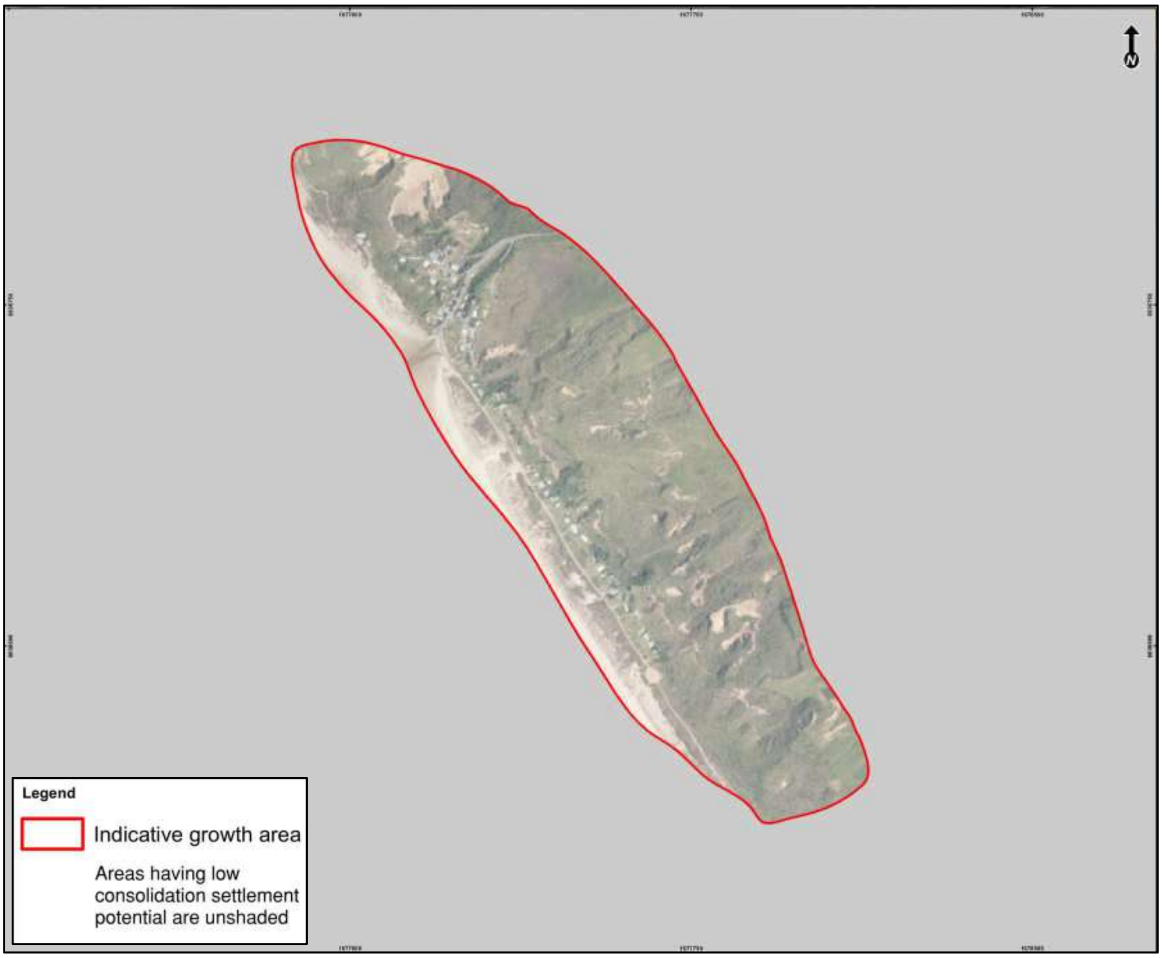
Base image sourced from Land Information New Zealand, CC-BY-3.0. Not to Scale.

Figure 28: Settlement Susceptibility Map – Baylys Beach



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

Figure 29: Settlement Susceptibility Map – Glinks Gully



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

Figure 30: Settlement Susceptibility Map – Te Kopuru

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 dune 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.
- 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 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, liquefaction and lateral spread potential, and settlement due to soft compressible soils). Areas where multiple geotechnical hazards 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 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 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 Geotechnical Hazard Summary Table

Level	Colour	Assessed Geotechnical hazard 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 over-steepened 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 geotechnical hazards affect the land, and the suitability of the land for the intended development. 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.
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 are 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. 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.
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 is subject to comprehensive geotechnical investigation and design to determine the magnitude to which the assessed geotechnical hazards affect the site, and the implications of the development proposals on the existing landform. 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.

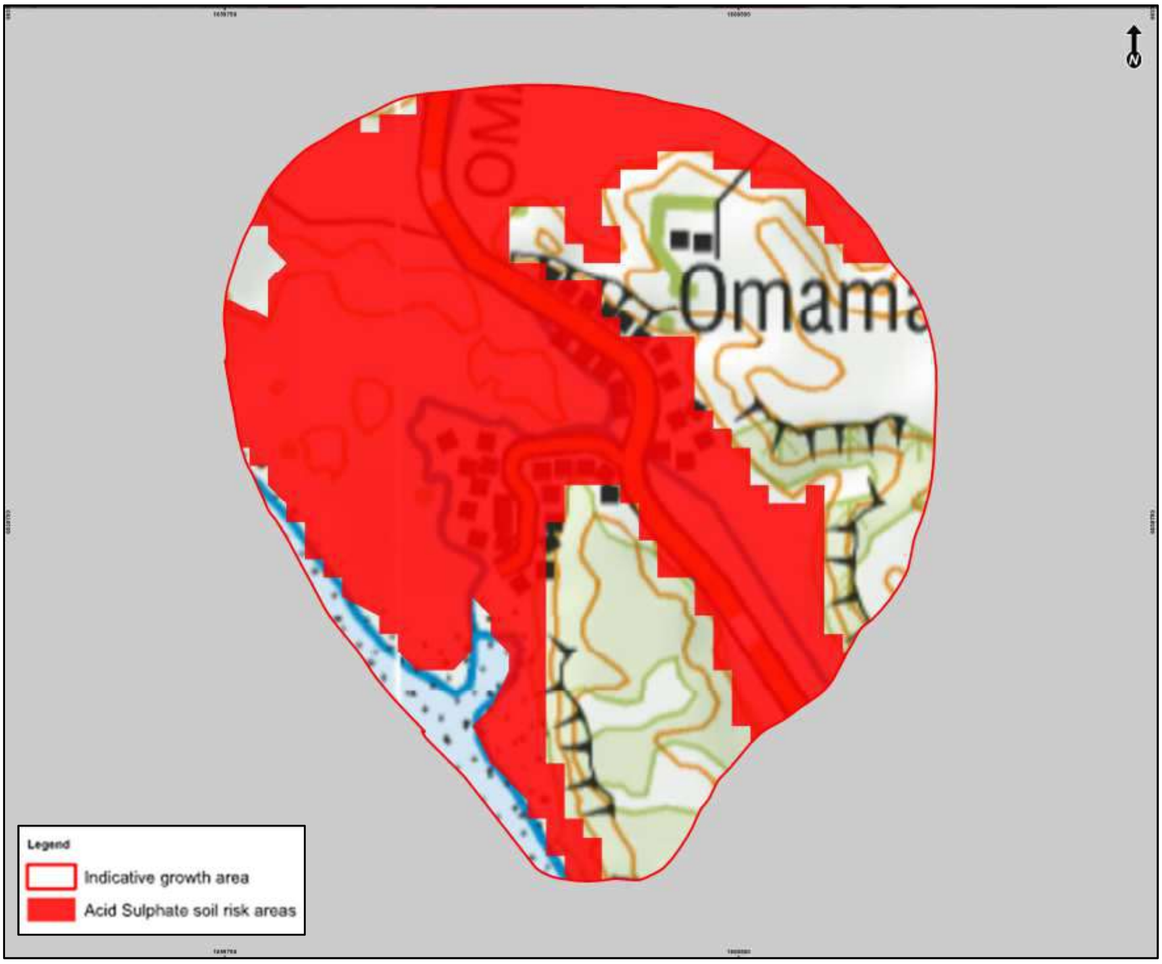
15.1 Sulphate Attack on Concrete

Some Holocene and Pleistocene soil deposits within the study area (refer to Figures 6 through 9) 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 WCS study areas (Figures 31 through 34).

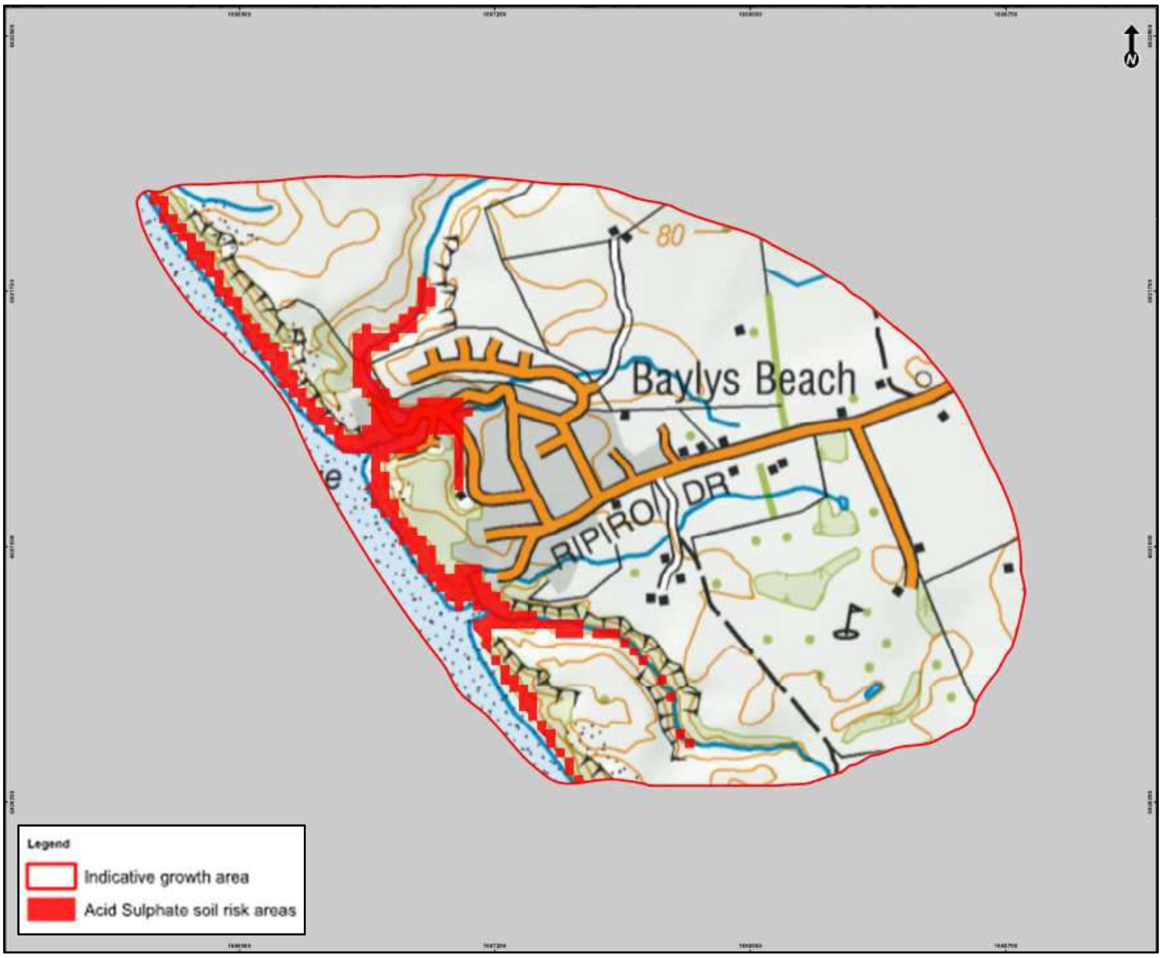
Discussion on risk levels and investigation methodology is provided in Kaipara District Council's Acid Sulphate Soils Policy Basic Planning Guide.

Figure 31: Acid Sulphate Soil Risk Map – Omamari



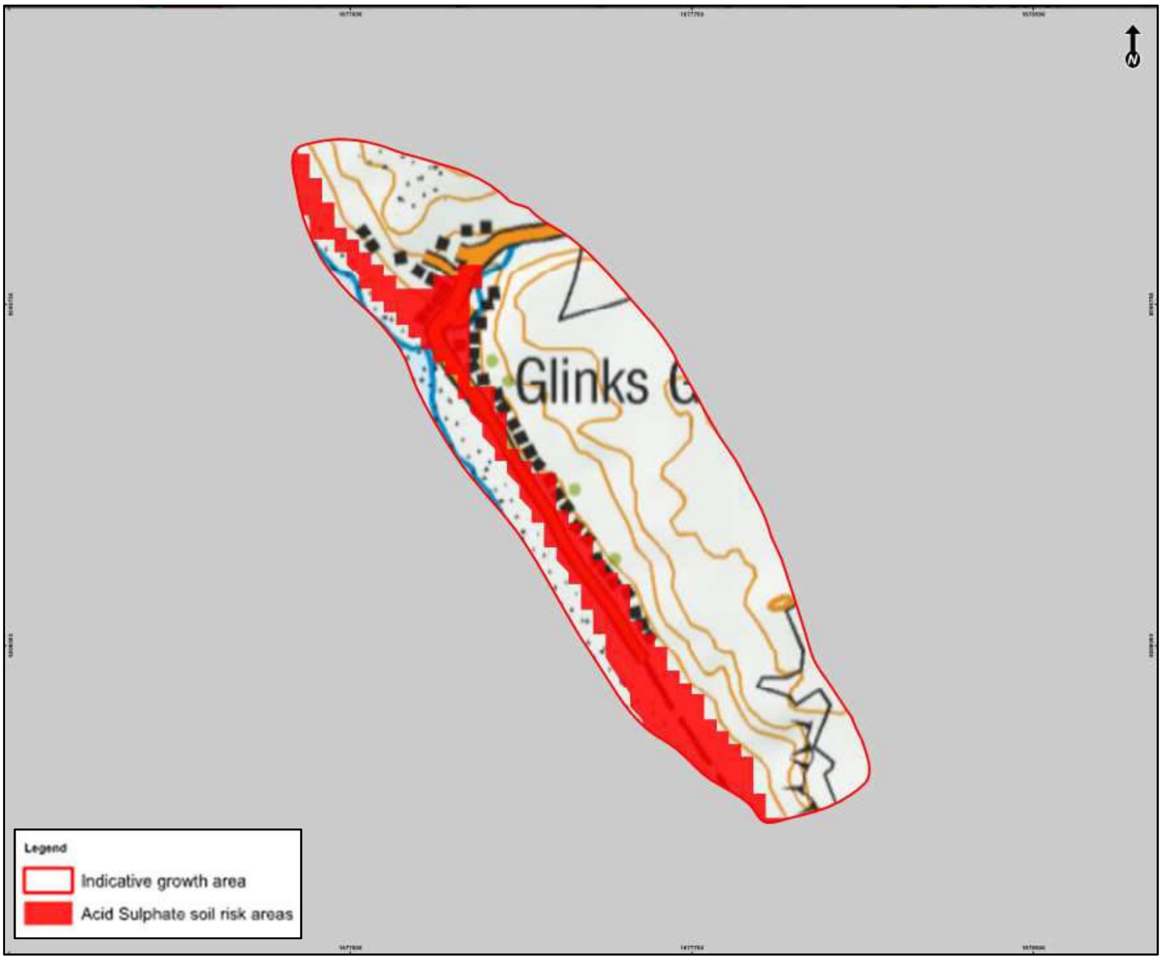
Base image sourced from Land Information New Zealand, CC-BY-3.0 and WSP-Opus Whangarei Office. Not to Scale.

Figure 32: Acid Sulphate Soil Risk Map – Baylys Beach



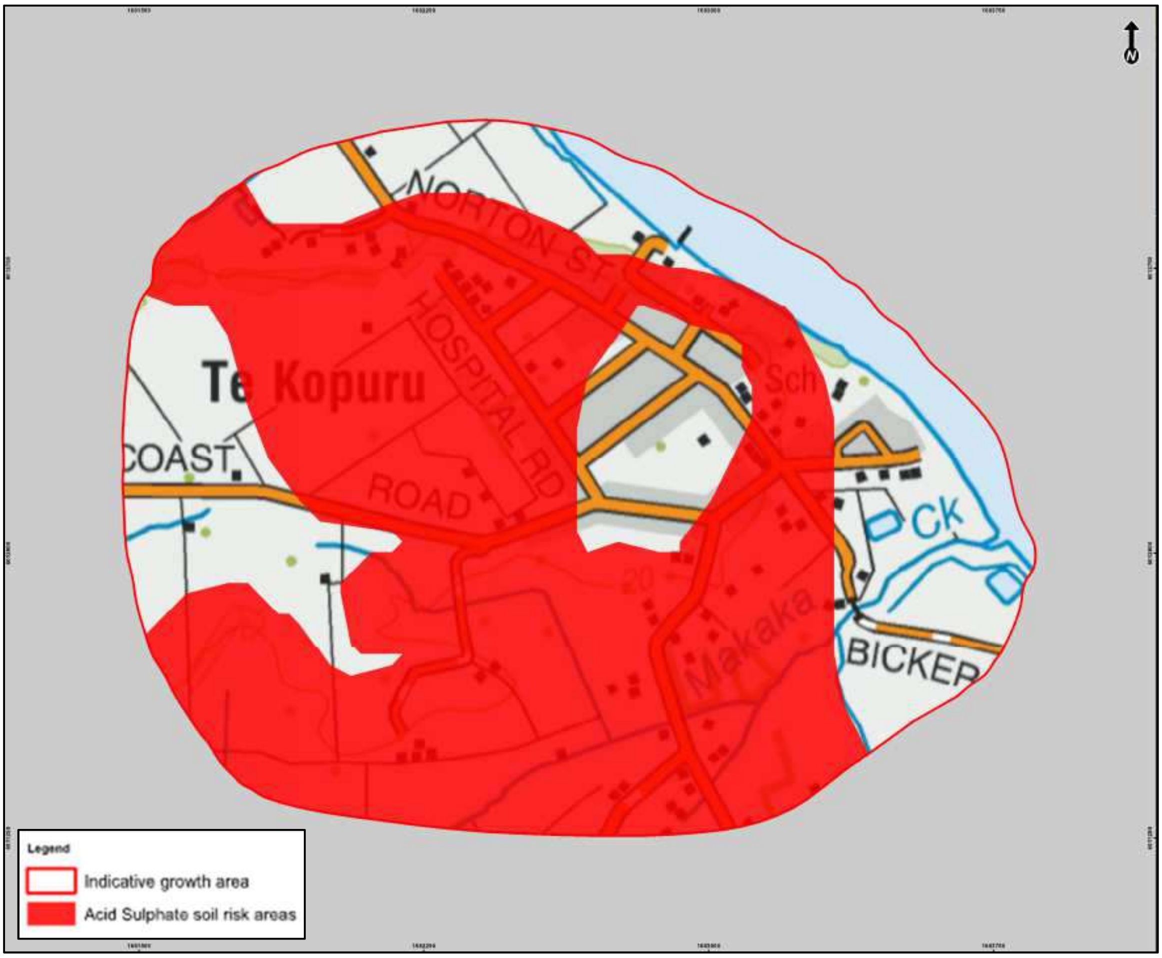
Base image sourced from Land Information New Zealand, CC-BY-3.0 and WSP-Opus Whangarei Office. Not to Scale.

Figure 33: Acid Sulphate Soil Risk Map – Glinks Gully



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

Figure 34: Acid Sulphate Soil Risk Map – Te Kopuru



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

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 east of the study area and there are no known commercial mine or quarry sites within the WCS study areas.

As previously discussed, multiple shallow, open pit 'borrow areas' were observed on private properties within the Baylys Beach study area. Mining and quarrying can lead to multiple environmental, erosional and instability hazards. Any further 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, interdune deposits, 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 the WCS areas. 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 WCS study areas.

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 unfavorable. The soil needs to be permeable enough to pass the water and yet capable of retaining 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 can be an important factor for some systems, particularly those which 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 conditions are not favorable 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 the WCS Areas

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 maps depicting the potential for on-site effluent disposal in the WCS study areas (Figures 35 through 38) 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.

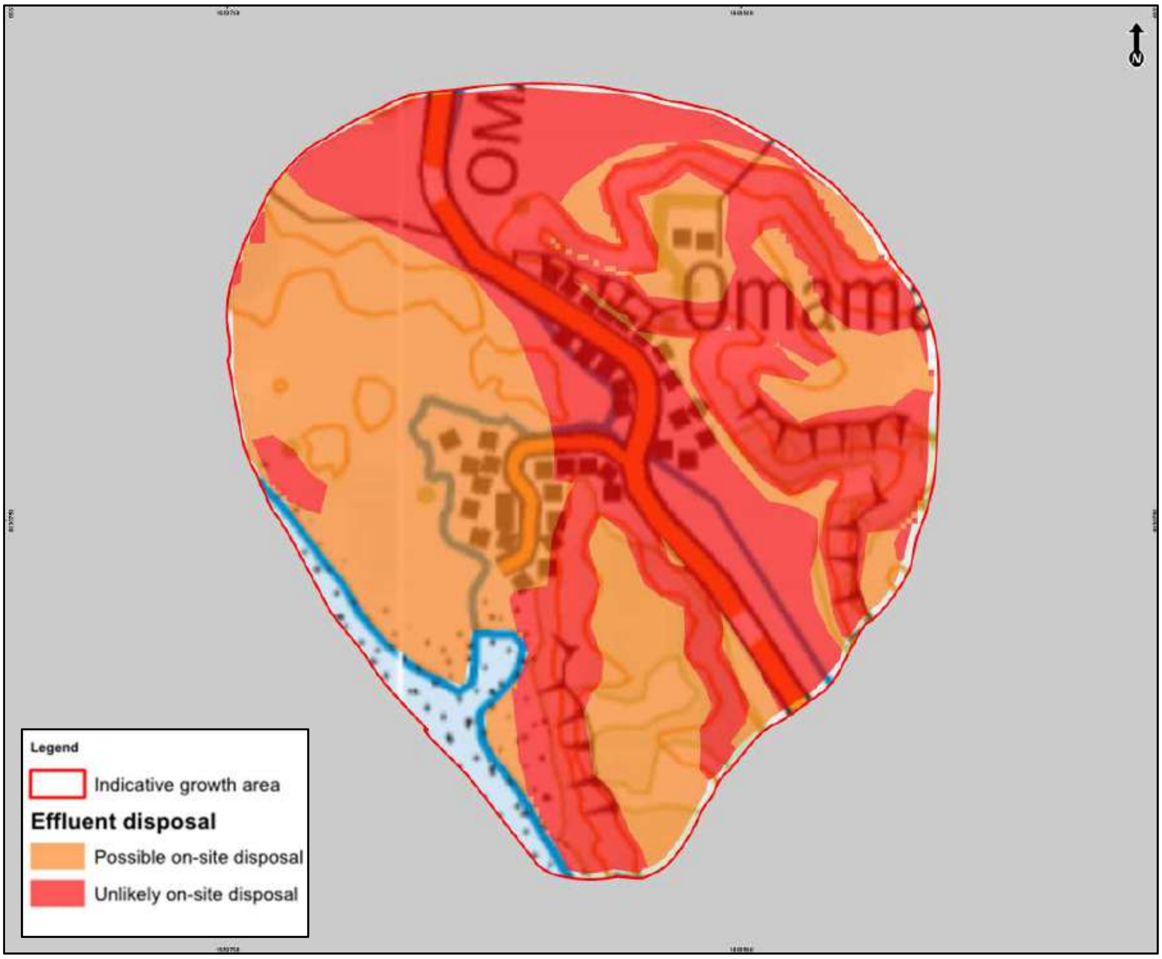
16.2.1 Kariotahi and Awhitu Groups

Holocene alluvium and Holocene to Pleistocene-aged 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 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 dune sands 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.

16.2.2 Tauranga Group

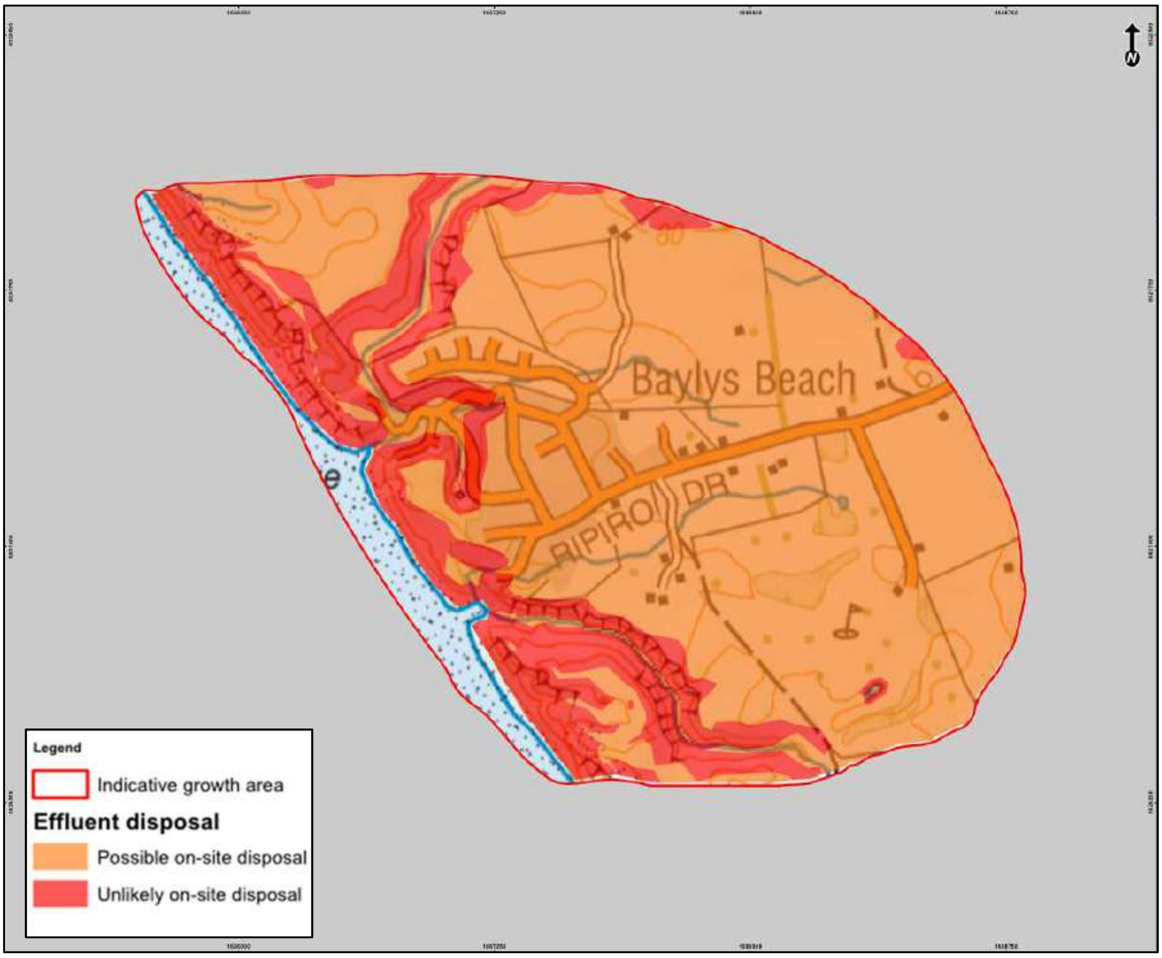
Due to its low-lying topography, typical near-surface groundwater table, and mandatory setback requirements from clean water sources, Holocene Alluvium units are considered to have low effluent disposal potential and have been mapped as unlikely.

Figure 35: On-Site Effluent Disposal Potential Map - Omamari



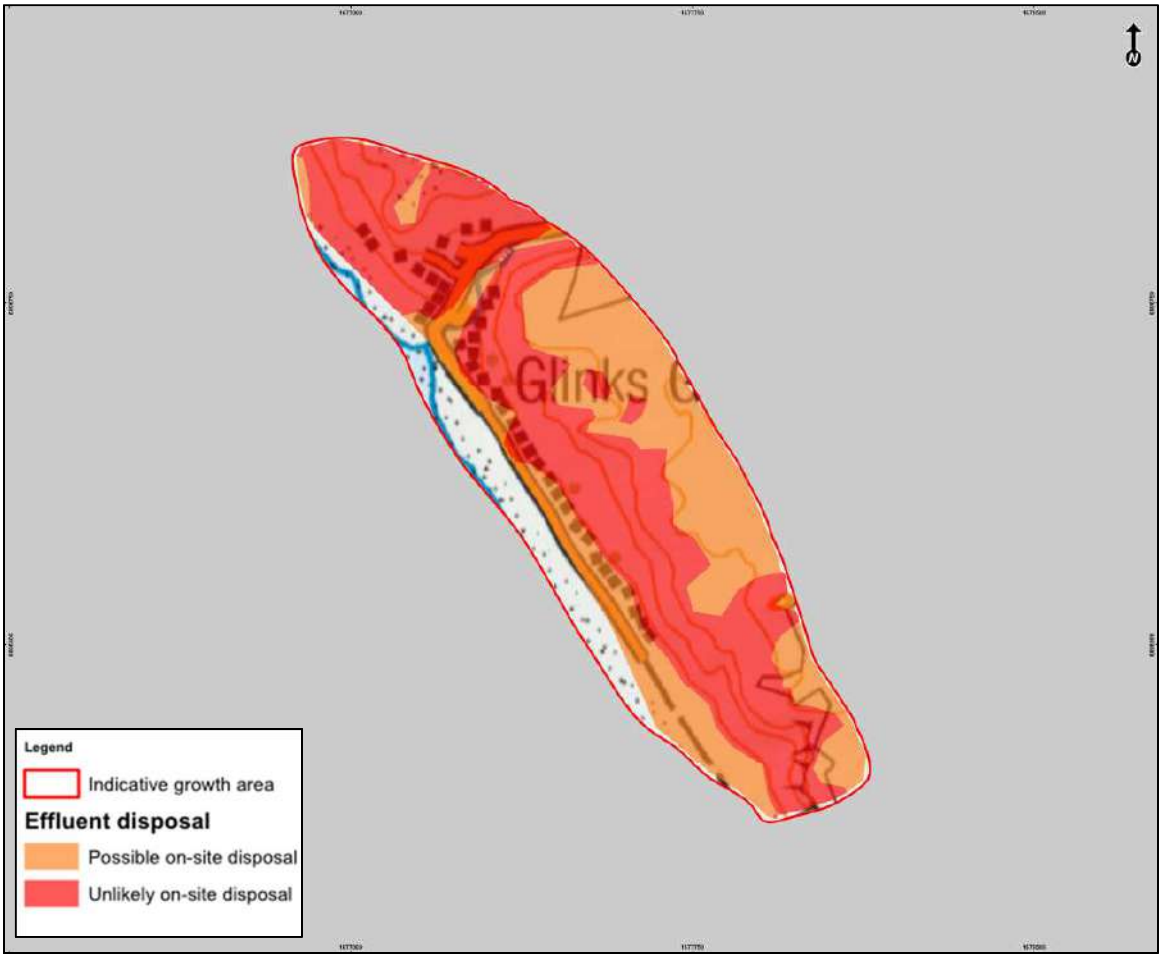
Base image sourced from Land Information New Zealand, CC-BY-3.0. Not to Scale

Figure 36: On-Site Effluent Disposal Potential Map – Baylys Beach



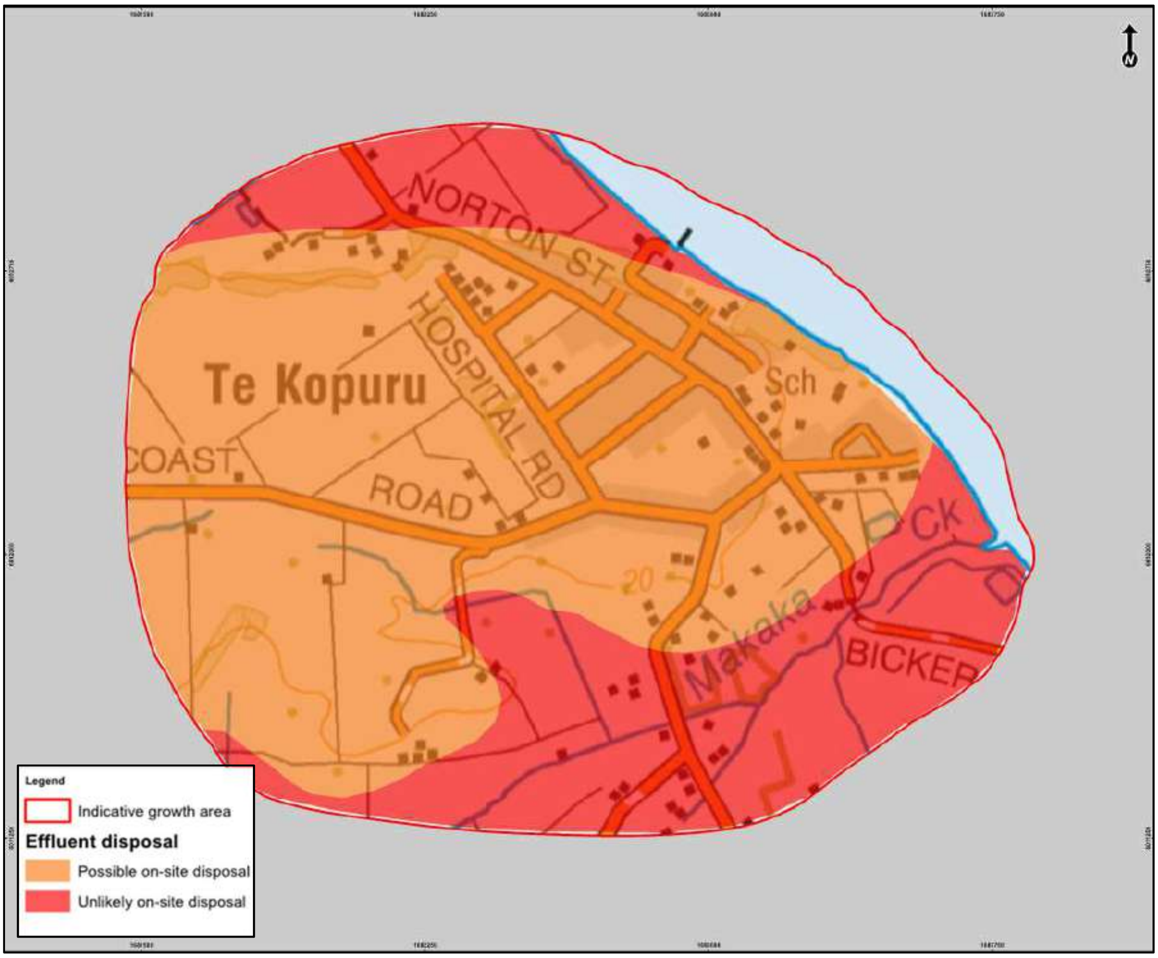
Base image sourced from Land Information New Zealand, CC-BY-3.0. Not to Scale

Figure 37: On-Site Effluent Disposal Potential Map – Glinks Gully



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

Figure 38: On-Site Effluent Disposal Potential Map – Te Kopuru



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 the WCS areas 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 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 systems serving the wider community, and a requirement for specifically designed on-site stormwater disposal systems in areas not serviced by the reticulated network.

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

Under no circumstances should soakage pits or uncontrolled flows be permitted to discharge onto or into 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 geotechnical hazards.

iii. It should be appreciated that the geotechnical hazards 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. 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 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

Craig Wright, CMEngNZ (PEngGeol)
Associate Engineering Geologist

Report reviewed by

Heather Lyons
Associate Engineering Geologist

Richard Justice, CMEngNZ (PEngGeol)
Principal Engineering Geologist

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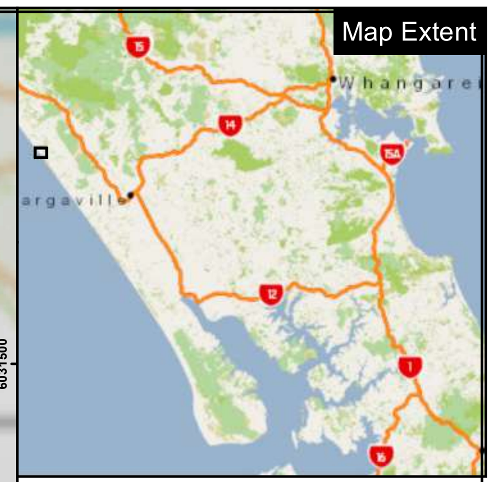
APPENDIX A:

Geotechnical Hazard Maps



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

0 240 Metres

PROJECTION: NZGD 2000 New Zealand Transverse Mercator

Auckland Office
8 Greydene Place, Takapuna, Auckland 0622
Tel: 09 972 2205, www.engeo.co.nz

Title:

Combined Geohazard Plan
Omamari

Client: Kaipara District Council		Appendix: A
Project: Geotechnical survey and hazard mapping	Designed: CW Drawn: RW Checked: RJ Date: Apr 19	Size: A2
Proj No: 15601.000.000	Scale: 1:4,567	Revision: A

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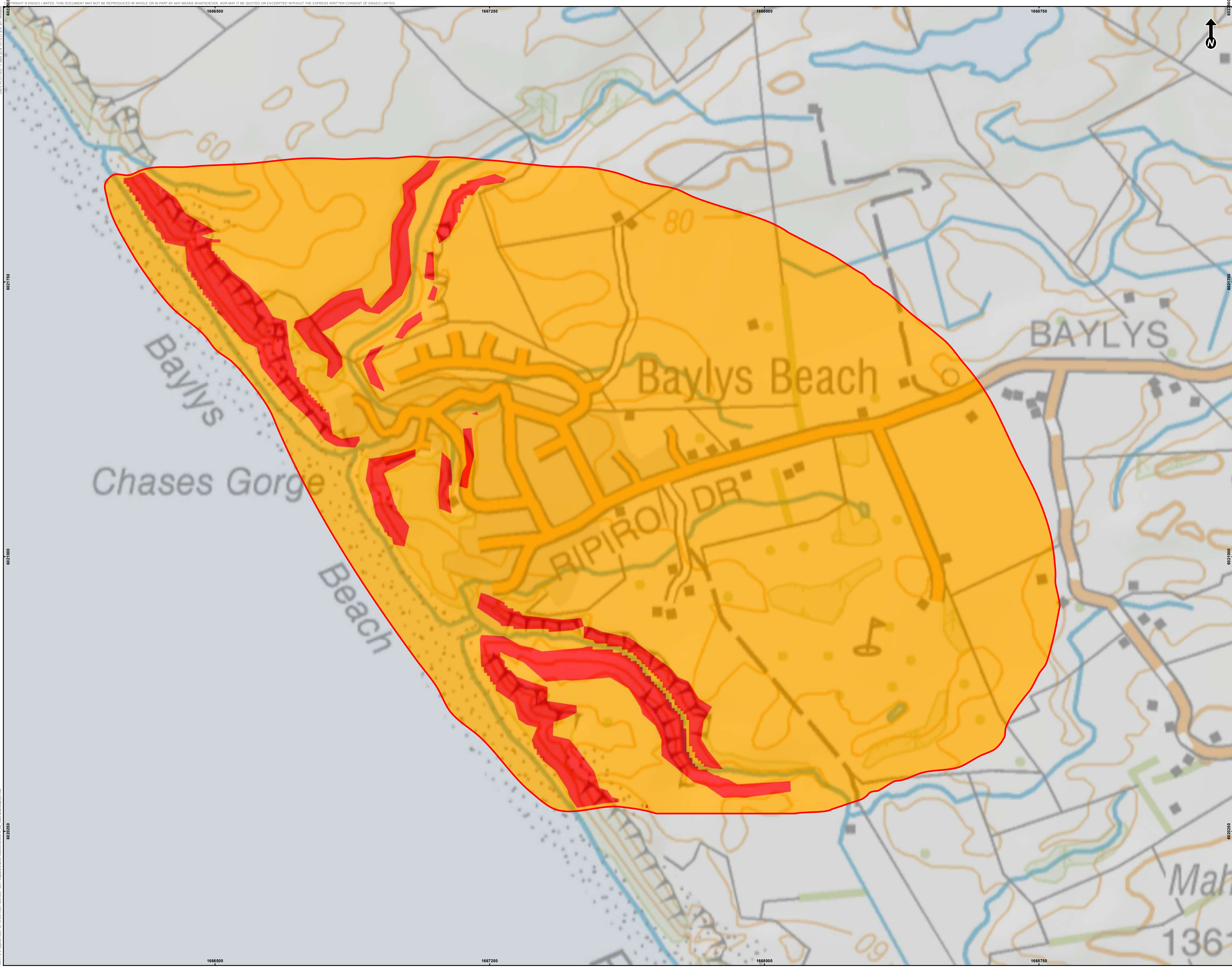

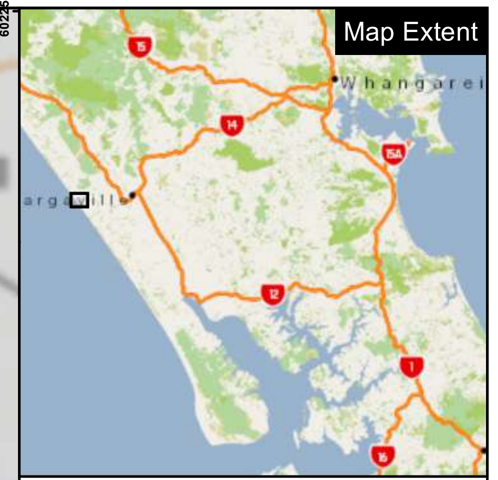

Legend

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

0 340 Metres

PROJECTION: NZGD 2000 New Zealand Transverse Mercator

ENGEO

Auckland Office
8 Greydene Place, Takapuna, Auckland 0622
Tel: 09 972 2205, www.engeo.co.nz

Title:
Combined Geohazard Plan
Baylys Beach

Client: Kaipara District Council

Appendix: A

Project: Geotechnical survey and hazard mapping

Designed: CW
Drawn: RW
Checked: RJ
Date: Apr 19

Size: A2

Proj No: 15601.000.000

Scale: 1:6,500

Revision: A

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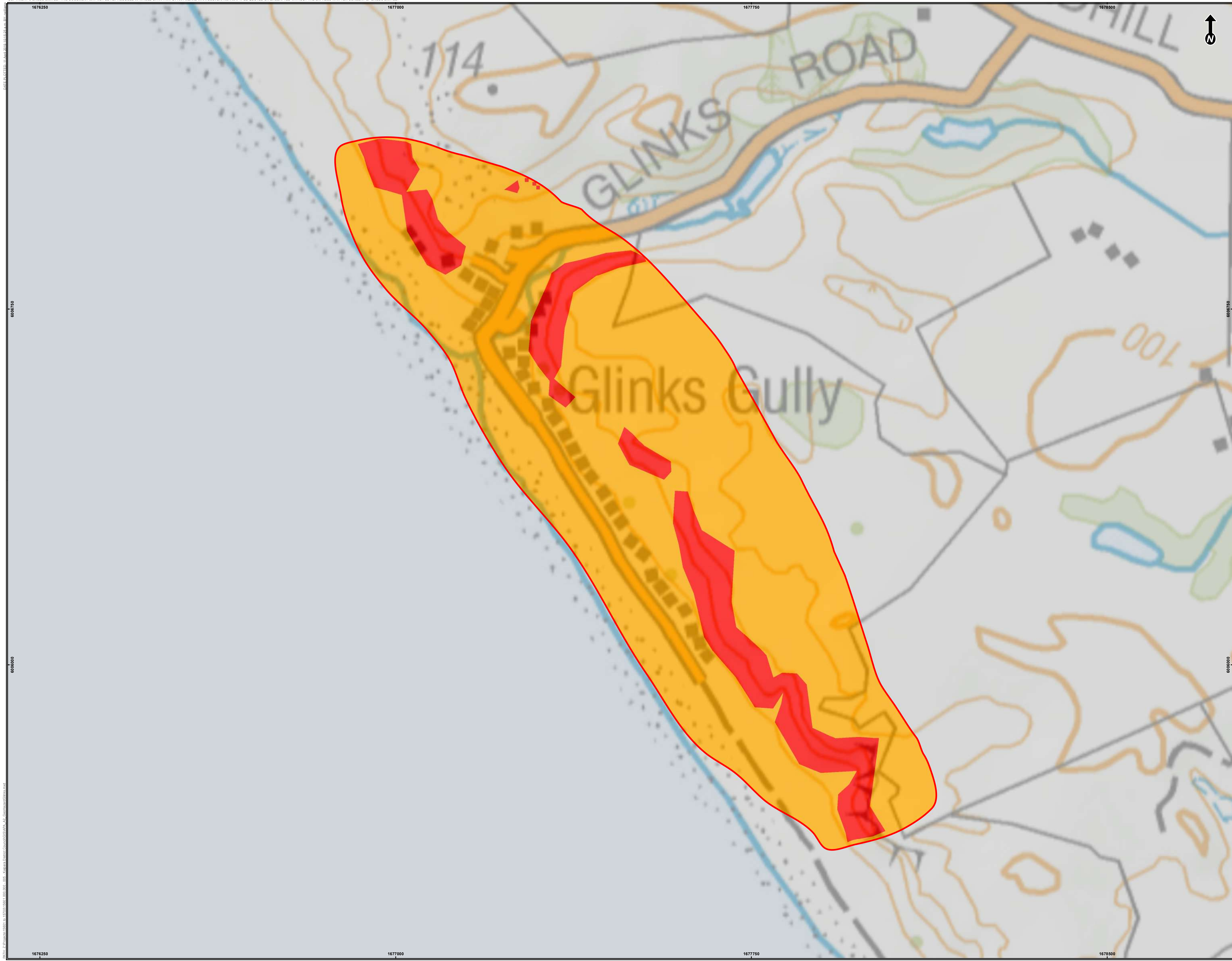
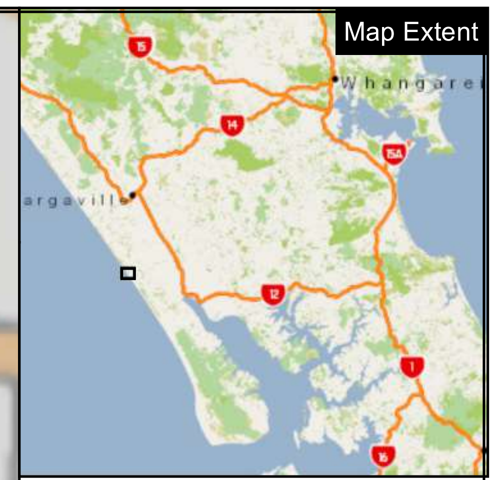


Map Extent



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

0 250 Metres

PROJECTION: NZGD 2000 New Zealand Transverse Mercator

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8 Greydene Place, Takapuna, Auckland 0622
Tel: 09 972 2205, www.engeo.co.nz

Title:
Combined Geohazard Plan
Glinks Gully

Client: Kaipara District Council		Appendix: A
Project: Geotechnical survey and hazard mapping	Designed: CW Drawn: RW Checked: RJ Date: Apr 19	Size: A2
Proj No: 15601.000.000	Scale: 1:5,000	Revision: A

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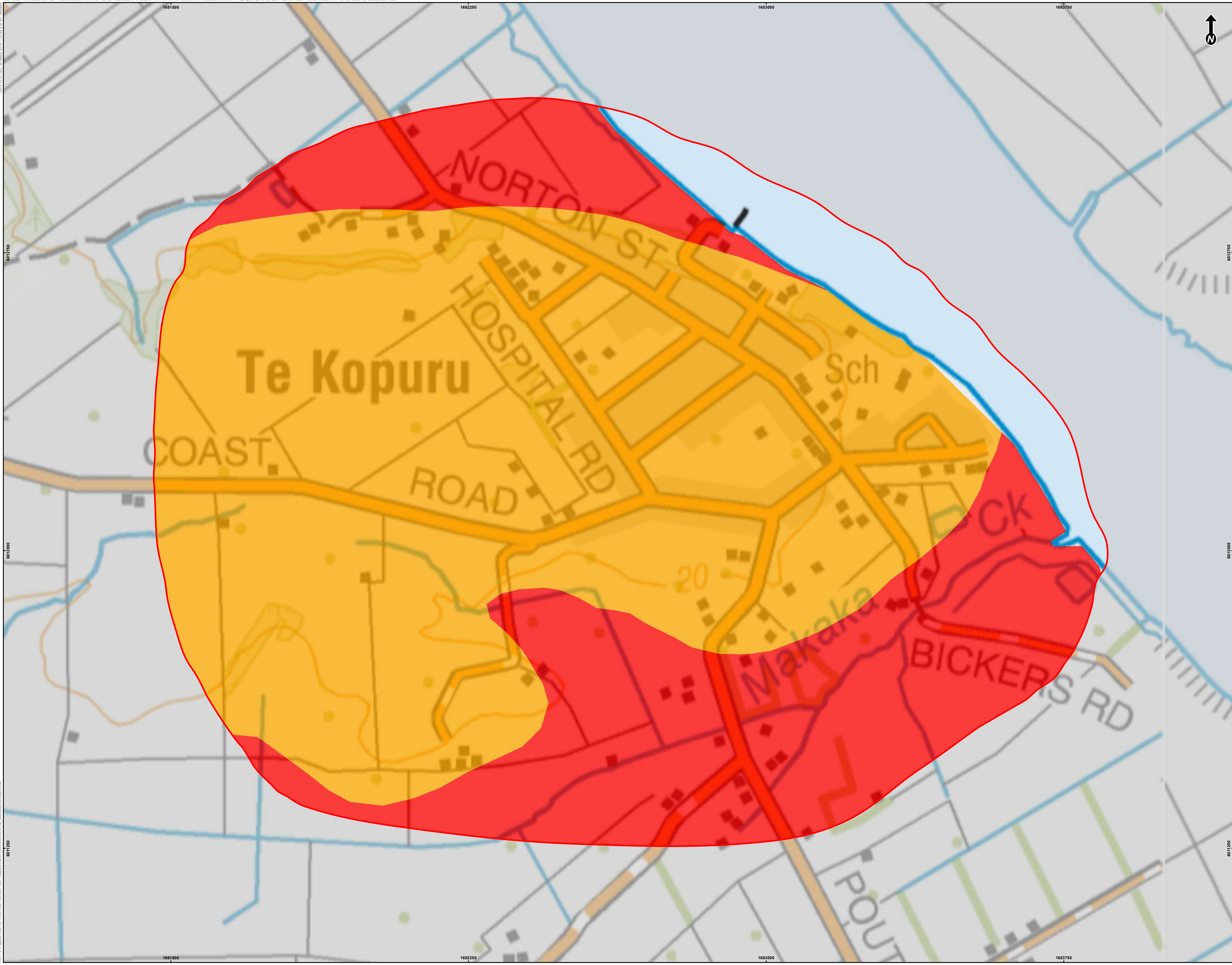

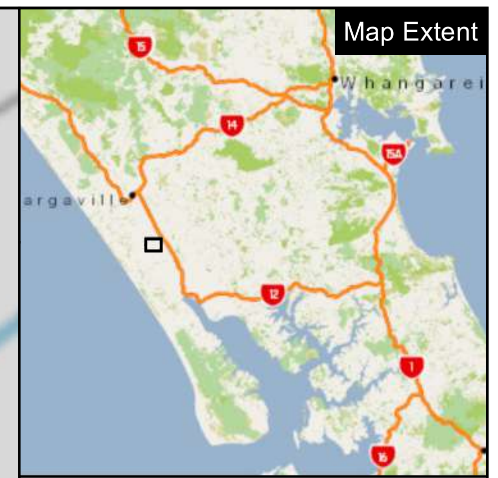

Legend

- 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 — 320 Metres

PROJECTION: NZGD 2000 New Zealand Transverse Mercator

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Tel: 09 972 2205, www.engeo.co.nz

Title:

Combined Geohazard Plan
Te Kopuru

Client: Kaipara District Council		Appendix: A Size: A2
Project: Geotechnical survey and hazard mapping	Designed: CW	
	Drawn: RW	
	Checked: RJ	
	Date: Mar 19	
Proj No: 15601.000.000	Scale: 1:6,000	Revision: A

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