# New Zealand Aluminium Smelters Limited

# NZAS Closure Preliminary Study

## Geology Report

12533899-4100-CI-RPT-00001
CAL.11-4100-B-REP-00001

Revision 0

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# 1. Introduction

## 1.1 Context

Rio Tinto (RT) engaged GHD to undertake a Preliminary Study (PS) for the closure of New Zealand Aluminium Smelter (NZAS). The PS is being completed in accordance with RT Closure Study Definition Guidance Note (CSDGN) RTPR-PMT-GND-0015.

Section 13 of the CSDGN requires the completion of a preliminary geological assessment related to final landforms at the site.

## 1.2 Purpose of Document

This report provides a preliminary geological assessment of the NZAS site for the purposes of providing baseline knowledge which may be used to inform closure planning, in particular final landforms. The unconsolidated sediments across the site have the potential to be used in landform design as a fill material.

This report concentrates on the in-situ surface and sub-surface geology at the Tiwai Point and Peninsula. Mineral waste (i.e., waste rock or tailings) is not present at the NZAS site and therefore the focus of this report relates to the characterisation and use of in-situ 'clean' material potentially used for encapsulation/fill.

## 1.3 Limitations and Disclaimer

### 1.3.1 Limitations

The accuracy of GHD's geology assessment is limited by:

- The intended purpose of the collected data
- Time constraint
- Inspection methodologies and tools that were able to be utilised given the limited time and physical access available
- Unknown impact of closure activities, unknown final landform design and the ultimate end use of the assets

GHD's geology assessments were applicable at the time of inspection, and do not represent the projected condition of the assets at the commencement of the hold period.

### 1.3.2 Disclaimer

This report has been prepared by GHD's subconsultant Okane for New Zealand Aluminium Smelter Ltd (NZAS Ltd) and may only be used and relied on by NZAS Ltd for the purpose agreed between GHD and NZAS Ltd as set out in this report.

GHD and its subconsultants otherwise disclaims responsibility to any person other than NZAS Ltd arising in connection with this report. GHD and its subconsultants also exclude implied warranties and conditions, to the extent legally permissible.

The services undertaken by GHD and its subconsultants in connection with preparing this report were limited to those specifically detailed in the report and are subject to the scope limitations set out in the report.

The opinions, conclusions and any recommendations in this report are based on conditions encountered and information reviewed at the date of preparation of the report. GHD and its subconsultants have no responsibility or obligation to update this report to account for events or changes occurring subsequent to the date that the report was prepared.

The opinions, conclusions and any recommendations in this report are based on assumptions made by GHD and its subconsultants described in this report. GHD and its subconsultants disclaims liability arising from any of the assumptions being incorrect.

GHD and its subconsultants have prepared this report on the basis of limited field inspection, as well as input information provided by NZAS Ltd that GHD and its subconsultants have not independently verified or checked beyond the agreed scope of work. GHD and its subconsultants do not accept liability in connection with such unverified information, including errors and omissions in the report which were caused by errors or omissions in that information.

# 2. Background

## 2.1 Closure Domains

New Zealand Aluminium Smelters Limited (NZAS) have operated an aluminium smelter at Tiwai Point, approximately 20 km to the south of the city of Invercargill, since 1971. Tiwai Peninsula, adjacent to Tiwai Point, is located between the estuarine Awarua Bay to the north, and Foveaux Strait and the open ocean to the south. Tiwai Point and Peninsula are predominantly composed of Quaternary unconsolidated beach sediments overlying volcanic and metamorphic basement rocks.

The Tiwai Point and Peninsula has been subdivided into domains according to the 2020 basis of design as follows (GHD, 2020; Figure 2-1):

- Landfill – located at Tiwai Point consisting of NZAS built landfill south of the Smelter Domain, including the Haysom Dross site;
- Smelter – located at Tiwai Point and includes all buildings and infrastructure of the Smelter;
- Wharf – located at the west end of the peninsula. In this report the Wharf is included in the Smelter Domain;
- Spent Cell Liner (SCL) Storages – located on the south coast of the Freehold Domain, where the SCL is stored on pads;
- RT Freehold Land – located on Tiwai Peninsula, east of the Smelter Domain; and
- RT Leasehold Land – comprises most of the Tiwai Peninsula and contains the bores that comprise the water bore field supplying water to the Smelter.

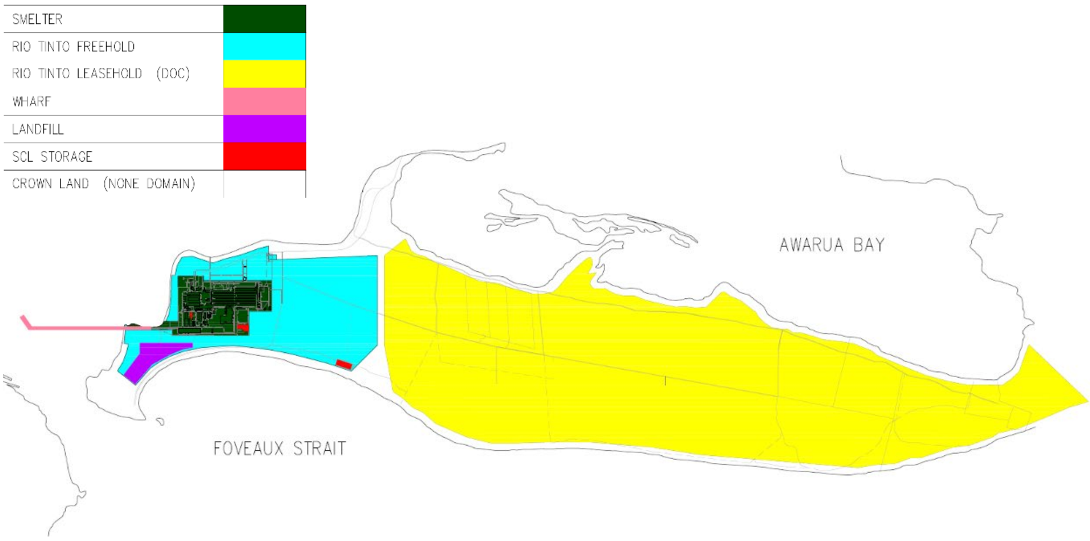



**Figure 2-1 Tiwai Point and Peninsula domain map**

## 2.2 Site Visit

Kirstine Malloch, Senior Geochemist for Okane, a subconsultant to GHD, visited Tiwai Point and Peninsula over 3 days from the 23 to 25 November 2021. Observations of surficial geology during the site visit are incorporated into this report.

## 2.3 Documents Reviewed

Hydrogeology and groundwater reports were reviewed to provide an understanding of the subsurface geology and the thicknesses of the sedimentary units, as well as expected depth to basement rocks.

The following documents were reviewed for this report:


- Bonisch Consultants. 2010. Drawing of landfill test bore locations - NZAS Tiwai Point. Dated 1 June 2010 (3831 - Bore Locations.pdf).
- GCNZ Consultants. 1990. Tiwai Point Groundwater Review. New Zealand Aluminium Smelters Ltd. Dated April 1990. (GCNZ, 1990, Tiwai Point Groundwater Review.pdf).
- GHD. 2020. New Zealand Aluminium Smelters Ltd. NZAS Closure Preliminary Study: Basis of Design. Report no. 12533899-8100-MD-BOD-00001, CAL.11-8100-G-BOD-00001, Revision A dated October 2020.
- King A. 2007. Earthquake damage assessment profile NZ Aluminium Smelter- Tiwai Point. Institute of Geological & Nuclear Sciences Limited (GNS) Science Consultancy Report 2006/42. Dated November 2006.
- Kirk RM, Lauder GA. 2000. Significant coastal lagoon systems in the South Island, New Zealand. Coastal processes and lagoon mouth closure. Science for Conservation 146. Department of Conservation, Wellington.
- MetOcean Solutions. 2017. Coastal erosion assessment along Tiwai Peninsula. Report prepared for New Zealand's Aluminium Smelter. Rev0, dated 15 May 2017.
- Mossman DJ. 1970. The geology of the Greenhills ultramafic complex, Bluff Peninsula, Southland, New Zealand. PhD thesis, University of Otago.
- NZAS. 2005a. Drawing: NZAS groundwater bores 53-C-01216.pdf. Drawing no. 53-C-01216. Dated December 2005. Updated 2020 (Updated Active Bores List 2020.pdf).
- NZAS. 2005b. SCL Groundwater Report. New Zealand Aluminium Smelters Limited. Dated 16 September 2005. (SCL groundwater report 2005.pdf).
- NZAS. 2006. Comprehensive groundwater monitoring of bores in areas of potential contamination (RT HSE Action of Nov 2005 Audit). Dated 22 April 2009.
- NZAS. 2017. HSE Management Plan E06.3. Management of coastal erosion on Tiwai Peninsula. Version 1. Dated August 2017.
- NZAS. 2019. NZAS HSE Management Plan - Water quality and protection management plan. Version 4. Dated June 2019.
- Rio Tinto. 2018. Closure Study Definition Guidance, Guidance Note. Revision 0. Dated 15 December 2018.
- Royds Consulting. August 1994. Geotechnical Investigation Report – Tiwai Smelter 1994 Upgrade Facility 42 Potline.3C.
- Royds Consulting. August 1994. Geotechnical Investigation Report – Tiwai Smelter 1994 Upgrade Facility 33 Anode Baking Furnance.
- SKM. 2003. Landfill Metal Recovery Study. Dross volume investigation. Rev 1. Dated 15 July 2003.
- Turnbull IM, Allibone AH. (compilers) 2003. Geology of the Murihiku area. Institute of Geological and Nuclear Sciences 1:250,000 geological map 20. 1 sheet and 74 p. Lower Hutt, New Zealand. Institute of Geological and Nuclear Sciences Limited.

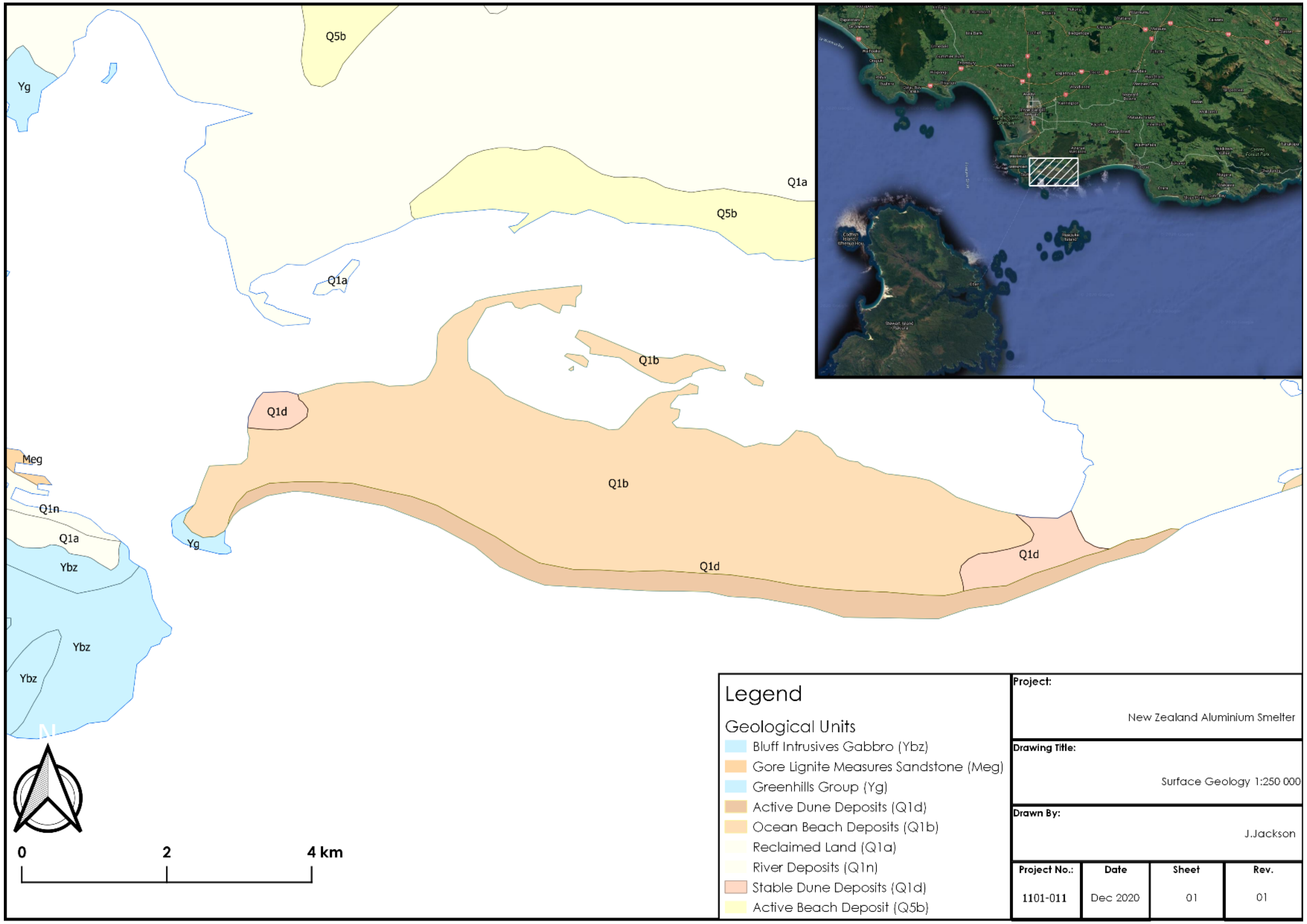
- URS New Zealand Limited. 2003. Final Report. Tiwai landfill and Haysom's dross cell. Assessment of environmental effects - groundwater. Prepared for New Zealand Aluminium Smelters Ltd. Dated 16 September 2003. (R001-h Haysom dross environmental effects on groundwater.pdf).
- Woodward-Clyde (NZ) Ltd. 1994a. Groundwaters of Tiwai Peninsula, volumes 1 and 2. Environmental study for NZAS.
- Woodward-Clyde (NZ) Ltd. 1994b. Landfill Study. Report to NZAS. Dated May 1994.
- Woodward-Clyde (NZ) Ltd. 1996. Spent cathode lining Stage 2 landfill siting investigation. Final draft report prepared for New Zealand Aluminium Smelters. Dated November 1996.

# 3. Site Geological Information

## 3.1 General Geology

The Tiwai Point Peninsula is predominantly comprised of Quaternary unconsolidated beach deposits comprised of beach (pea) gravels and sands (Figure 3-1). An extensive area of pea gravel occurs as well-developed ridges orientated east-west along the peninsula (Q1b; Turnbull and Allibone, 2003). Pea gravels are comprised of well-rounded, flattened mostly quartz and some darker clasts likely of eroded local basement rocks (Greenhills Group; Figure 3-2). The ridges represent a complex mass of prograde beach fronts marking former positions of the oceanic shoreline (Figure 3-3). Sand and gravels have been reworked from the floor of Foveaux Strait, which was land connection to Stewart Island during the last glacial period (Kirk and Lauder, 2000). During the last post-glacial sea level rise, considerable volumes of coarse sediments were swept up to form Tiwai Peninsula.

Active sand dune and back-beach ridge fields comprised of sand and gravel are mapped along the southern beach and beneath the Smelter Domain (Q1d), as well as on the far eastern extent of the peninsula where it connects with the mainland. Beneath the sand and gravels are older sediments comprising clays, sandy mudstones, muddy sandstones, sandstones and lignites (GCNZ, 1990). In places, test bores have intersected > 60 m thickness of unconsolidated sediments overlying basement rock, although the exact location of these bores is not known as it is not provided on the drill logs (GCNZ, 1990). Generally, these deeper test bores comprise pea gravel and sands to 16 to 25 m below ground level (bgl), then progressively with depth more clays, and the dominance of mudstones and sandy mudstones over sands and gravels, and the presence of lignite.




## Figure 3-1 Geological map of the Tiwai Peninsula

Modified from: Turnbull and Allibone (2003)

**Figure 3-2 Surficial unconsolidated sediments comprised of pea gravels**

Length of tape measure = 0.5 m

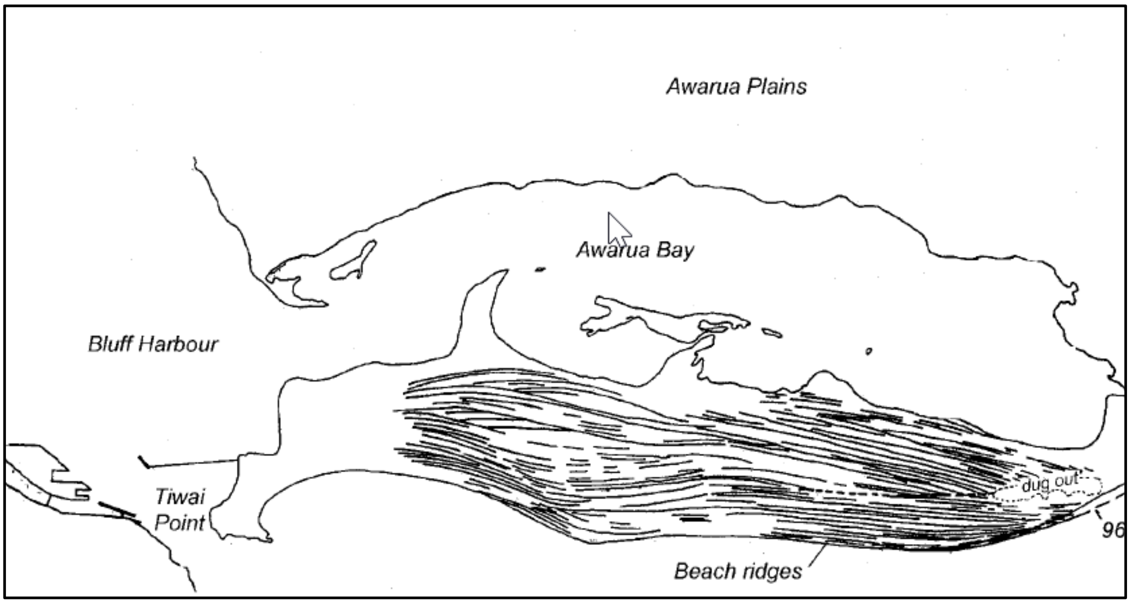



**Figure 3-3 Geomorphology of beach ridges at Tiwai Peninsula**

Source: Kirk and Lauder (2000).

Hard rock outcrops of basement rocks at Tiwai Point comprise basalt, keratophyre, altered diorite, albite-actionolite schist and granite of the Greenhills Group (Figure 3-4; Mossman, 1970; Turnbull and Allibone, 2003), which also outcrop along the Bluff Peninsula. Basement rock forms reefs on both the ocean and harbour sides of Tiwai Point, with hard rock exposed in the upper intertidal area.

**Figure 3-4 Outcrop of Greenhills Group near Tiwai Wharf (looking east)**

Tiwai Peninsula encloses Awarua Bay from the sea and Foveaux Strait. To the north of Awarua Bay, the Awarua Plains consist of an extensive area of well-developed and actively growing peat mires at least 15 m thick (Turnbull and Allibone, 2003).

## 3.2 Geomorphology

Steep coarse sand and gravel beach ridges of Tiwai Peninsula separate the internal water body of Awarua Bay from Foveaux Straight and open ocean (Figure 3.3). Awarua Bay is a long estuarine arm at the eastern end of the Bluff Harbour. The wave energy generated by frequent storm events in the South Ocean contributes to alternating areas of accretion and erosion driven by the longshore sediment transport patterns, although some of this is dispersed by Stewart Island and other smaller islands to the south (MetOcean, 2017).

## 3.3 Hydrogeology

The Tiwai Peninsula is underlain by a large freshwater aquifer, recharged solely by rainfall. The aquifer is situated in 20-30 m of beach (pea) gravels, covering an area of 2,315 ha and extending to an average depth of 20 m below sea level (bsl; NZAS, 2019). This aquifer is sourced by NZAS via wells 1, 1A, 2, 3, 4 and 6 to provide water to site. Permeability in the aquifer decreases from west to east along the peninsula. Because the beach ridge geomorphology is orientated in an east-west direction, ground water moves more easily along the peninsula than across, with permeability across the aquifer about quarter of that along the aquifer. The lower permeability across the aquifer allows the water table to rise higher than it otherwise would (GCNZ, 1990). Older and finer sediments underlie the aquifer. The mean hydraulic conductivity of the unconsolidated sediments is 1.1x10-5 m/s (URS, 2003).

Seawater was noted to have moved into the aquifer, above the older and less permeable sediments, with movement more noticeable on the harbour/estuary side of peninsula (GCNZ, 1990).

Shallow groundwater was found to be present at 2.7 to 3.5 m depth below ground level (Royds 1994).

There are no surface water resources on Tiwai Peninsula apart from a small duck pond(s) located to the far east of the peninsula.

## 3.4 Geochemistry

Minimal information on the geochemistry or mineralogy of the unconsolidated sediments at NZAS is available. The groundwater aquifer in the Leased Land Domain is mainly a sodium chloride type water with a component of calcium bicarbonate (Figure 3-5; Woodward-Clyde 1994b). For the production wells (well 1, 1A, 2, 3, 4 and 6), groundwater is slightly acid to slightly alkaline (pH 6.8 to 7.7) with moderately low dissolved solids (up to 250 mg/L) and low salinities (up to 69 mg/L Cl; GCNZ, 1990). A trend was identified in water types, with sodium chloride dominated water in well 1A at the west end of the bore field to calcium bicarbonate dominated water at the east end, with corresponding increase in total dissolved solids from west to east. GCNZ suggested that the groundwater through flow is greater in the west where higher permeabilities exist. The water in the west is similar in its major components to rainwater. In the east, slower groundwater movement due to less permeable materials, has provided sufficient time for greater dissolution of material which includes shell fragments, increasing total dissolved solids and dominance of calcium bicarbonate type water.

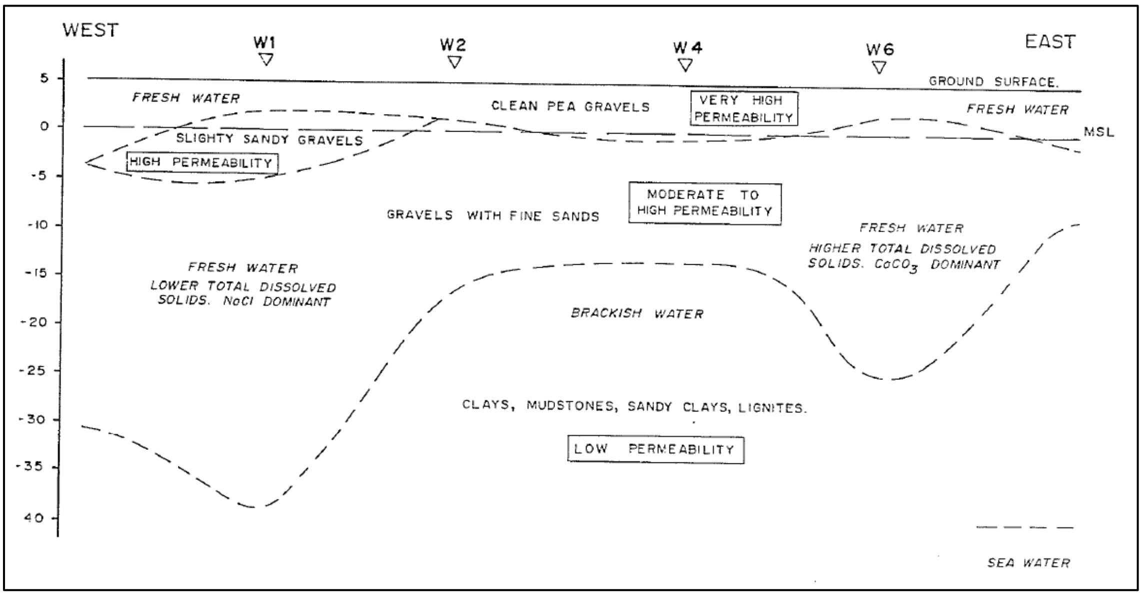



**Figure 3-5 Cross section through the Tiwai Peninsula illustrating water quality types**

Source: GCNZ (1990).

## 3.5 Earthquake and Seismic Hazards

The seismic hazard of the NZAS site was assessed by the Institute of Geological and Nuclear Sciences Limited (GNS; King, 2007). The site was deemed to be one of the lower seismicity regions of New Zealand, with earthquake motions dominated by relatively low levels of background seismicity. In terms of historical seismicity, there are no known earthquakes of magnitude 6 or greater that have occurred within 50 km of the site. The closest modelled fault in the GNS's National Seismic Hazard Model is a hypothesised fault located at the base of the

Longwood Range which is 42 km from NZAS.  This fault is modelled by GNS as producing magnitude 7.1 earthquakes with an average recurrence interval of about 3000 years.

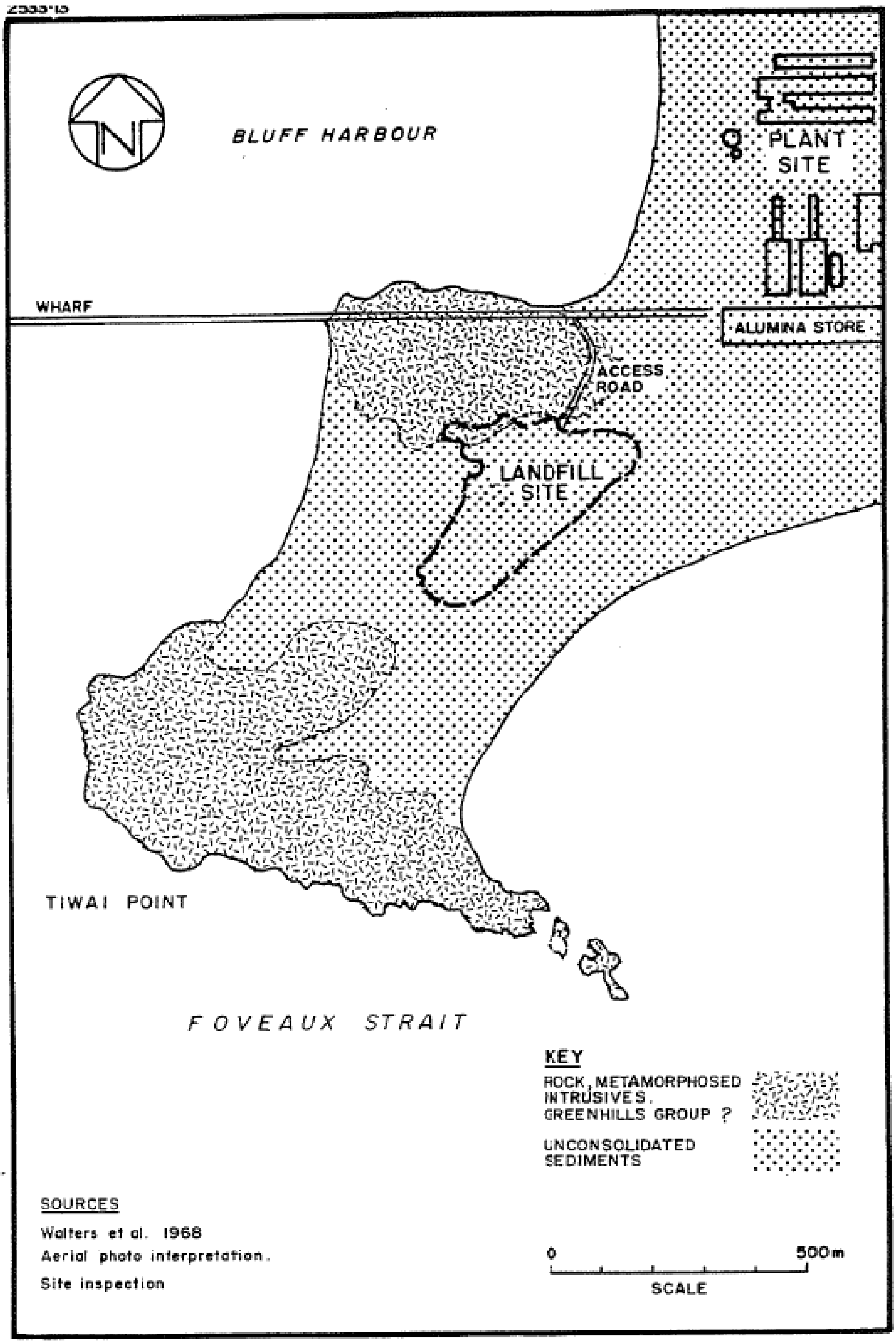
More distant, large magnitude earthquake sources, such as the Alpine Fault system or the Fiordland subduction zone, are expected to produce very large magnitude earthquakes (magnitude 8 or greater) at relatively short recurrence intervals (~ 300 years).  However, this high seismic zone is, at its closest point, around 100 km from NZAS and its contribution to the ground shaking hazard is similar to that from smaller events closer to the site.

# 4. Domain Geology

Detail on surface and subsurface geology, where known, is discussed by domains in the following sections.

## 4.1 Landfill Domain

Unconsolidated sediments in the Landfill Domain are underlain by hard, dense fine-grained intermediate intrusive basement rocks belonging to the Greenhills Group (Figure 4-1). Sediments are thin to the northwest and southwest where the basement outcrops at Tiwai Point and Tiwai Rocks (southwest of the Smelter Domain, near the Tiwai Wharf). Sediments are thickest beneath the south-western part of the actual landfill, which corresponds to a depression in the basement Greenhills Group (Figure 4-2; URS, 2003). Minimal gravel, and some peat and silt were encountered in boreholes, with sands directly overlying indurated basement rock. Sediments are poorly to moderately sorted and poorly stratified (Woodward-Clyde, 1994a). Woodward-Clyde (1996) noted extensive iron oxide staining in gravels in some bores. Piezometer data shows that groundwater from beneath the landfill flows down gradient to both the eastern and western coastlines, discharging to both the ocean and harbour beaches (URS, 2003).




## Figure 4-1 Landfill surficial geology

Source: Woodward-Clyde (1994a).

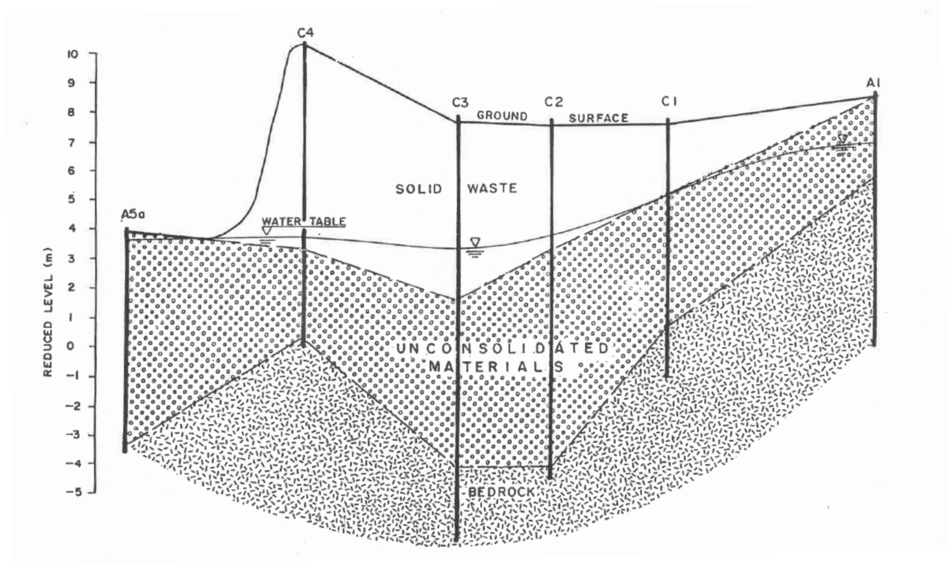



**Figure 4-2 North (Bore A1) to south (Bore A5a) cross section through the Landfill Domain**

Source: Woodward-Clyde (1994b).

Between the south drain discharge point and the smelter wharf, the shoreline was noted to be eroding (Woodward-Clyde, 1994b). Around this area were small gravel beaches above high neap tide level with extensive intertidal flats with coarse sand and gravel surficial sediments.

### 4.1.1 Haysom's Dross

The eastern most part of the landfill contains the Haysom's dross area, where sediments are up to 13 m thick, consisting of sands and gravels overlying mudstone deposits. This area is south of the Smelter Domain near the southern coastline of Tiwai Peninsula (Figure 4-3). There is a transition with the appearance of sand at a depth of approximately 6 m bgl that has an associated decrease in conductivity from 1.0 x $10^{-4}$ m/s to 1.0 x $10^{-5}$ m/s (URS, 2003). Hydraulic gradients are variable, averaging 0.001 m/m (1V to 1000H).

Gravels in the eastern portion of this area (south of the Smelter Domain), tended to be sandy gravels grading into interbedded sands and gravels in the western portion of the area with extensive iron staining at some locations (Woodward-Clyde, 1996). At all test pit and bore locations, gravels were noted to extend > 6 m.

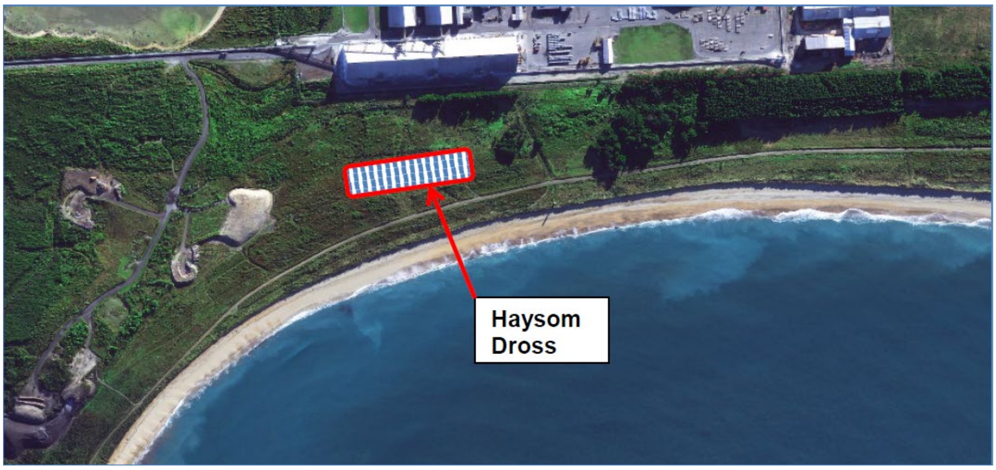



**Figure 4-3 Location of Haysom Dross between the Landfill Domain to the west and Smelter Domain to the north**

Source: NZAS (2017).

## 4.2 Smelter Domain

Woodward-Clyde (1994a) noted that the geology at the Smelter Domain is similar to that encountered at the SCL Storages Domain and the Leasehold Land Domains (unconsolidated sediments; Figure 4-4 and Figure 4-5). Woodward-Clyde suggested that the Smelter Domain geology is a transition zone from the gravel rich units in the Leasehold Land Domain to the sands of the Landfill Domain. Drill log data indicates a greater amount of sand is present in the shallow gravels at the Smelter Domain than those in Leased Land Domain (Woodward-Clyde 1994a). Exposed gravels along the coast, north of the Tiwai wharf, show layers that are gravel-rich and clast-supported, between layers that matrix-supported with the presence of fine sand (Figure 4-4).

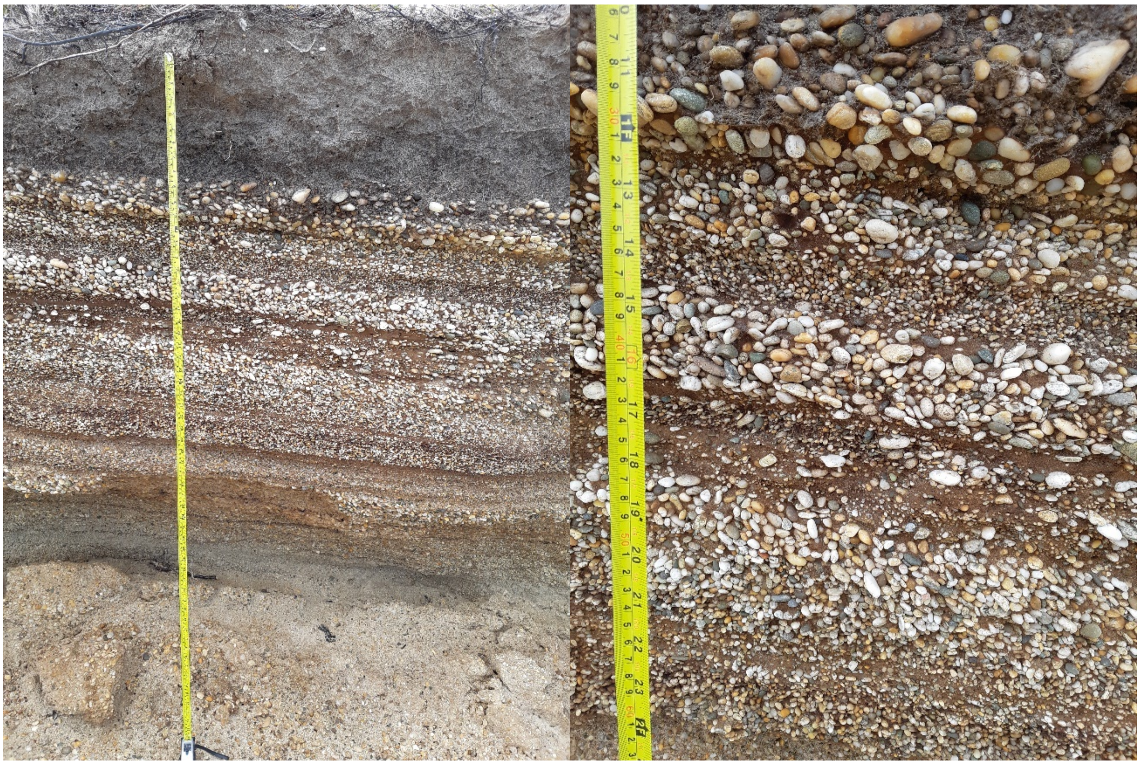


**Figure 4-4 Excavation of near surface pea gravels at the coast north of the Tiwai Wharf, adjacent to the Smelter**

Tape measure 1.5 m in the left photo


### Figure 4-5 Location of pea gravel exposure at coast (Figure 4-4)

Geology in the Smelter Domain (Woodward-Clyde, 1994a and Royds 1994) can be summarised as follows:

- 0.1 to 0.9 m fill found to be gravel fill in the Adobe Baking Furnace and Potline areas.
- 0 – 6.5 m: Sandy gravels comprising rounded moderately well sorted pea gravels with a matrix of fine to coarse sand, this deposit was found to 12 m to 13.8 m in four locations location in the western area of the Adove Baking Furnace;
- 6 - 17 m: Gravelly sands with shell fragments, slight consolidation of the unit;
- 14 – 18.8 m: Greenish gravelly sand changing to a sandy gravel (present in places); and
- > 16 m: Poorly sorted sands, being more cohesive and consolidated with some clay, silt and pea gravels. Silt was encountered from 18 m in most locations to the depth of the boreholes. Silt was present in all Potline investigation areas but only in the western area of the Adobe Baking Furnace Area.

Particle size distribution test were undertaken on five sample retrieved from test pits undertaken by Royds in 1994, at depths of 1.5, 1.7 m, 2,1 m, 3.3 m and 3.5 m. These found sandy gravels in most locations with a gravel and also a sandy, poorly graded gravel. This highlights the variability of the deposits in this area.

Disturbed ground beneath the Smelter Domain (Figure 4-6) represents a natural pre-construction depression that was infilled with surface materials, likely pea gravels and sand, to level the site. This infilled depression has an influence on groundwater flow (Woodward-Clyde, 1994a). Reviewing old aerial photos of the site (ca 1963) suggests that this depression was likely a partially naturally infilled lagoonal wetlands area with some surface water present (Figure 4-7).

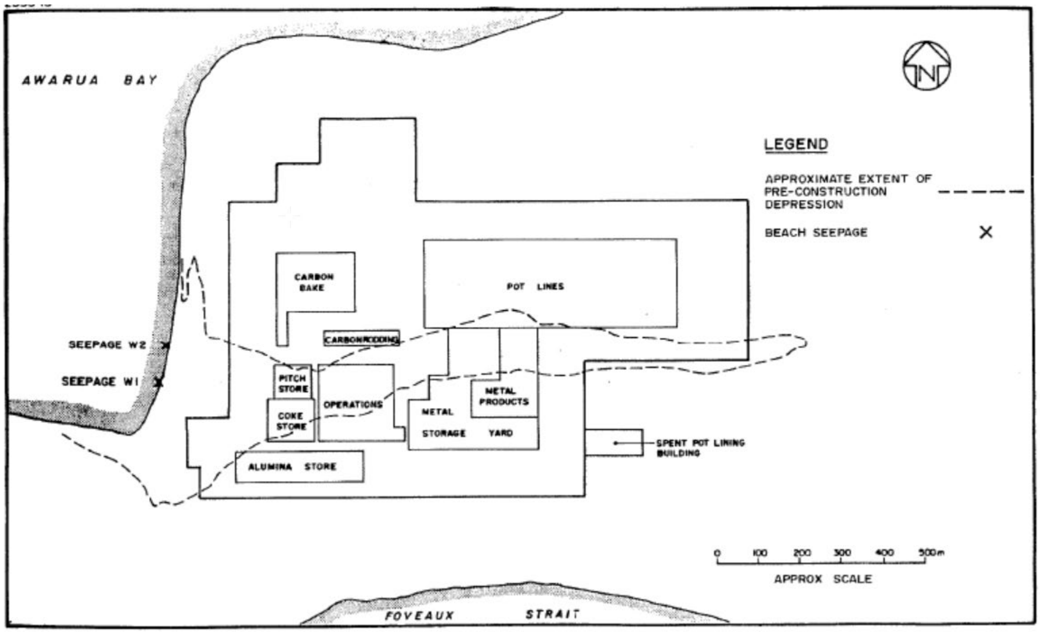



**Figure 4-6 Location of pre-construction depression at the Smelter Domain**

Source: Woodward-Clyde (1994a).



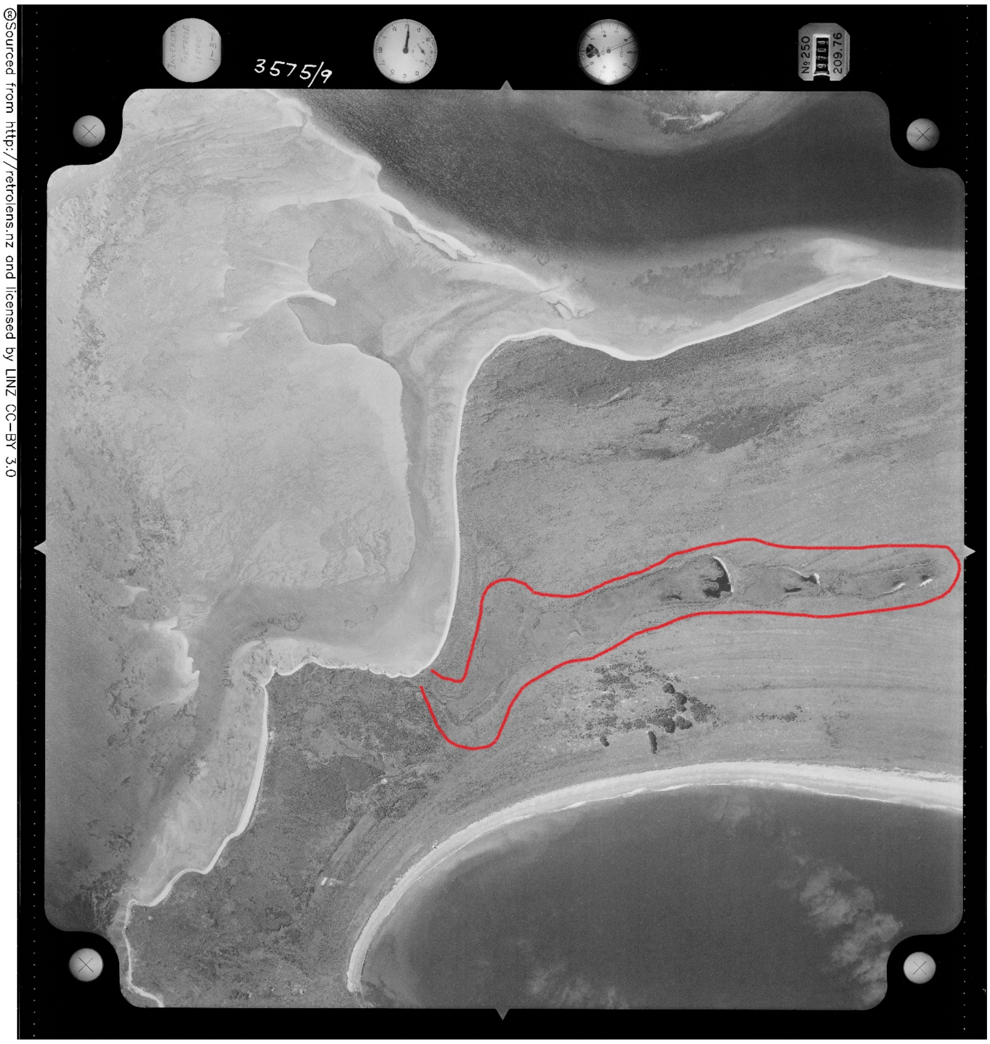



**Figure 4-7 1962 aerial photo of the Smelter Domain illustrating the (wetlands) depression**

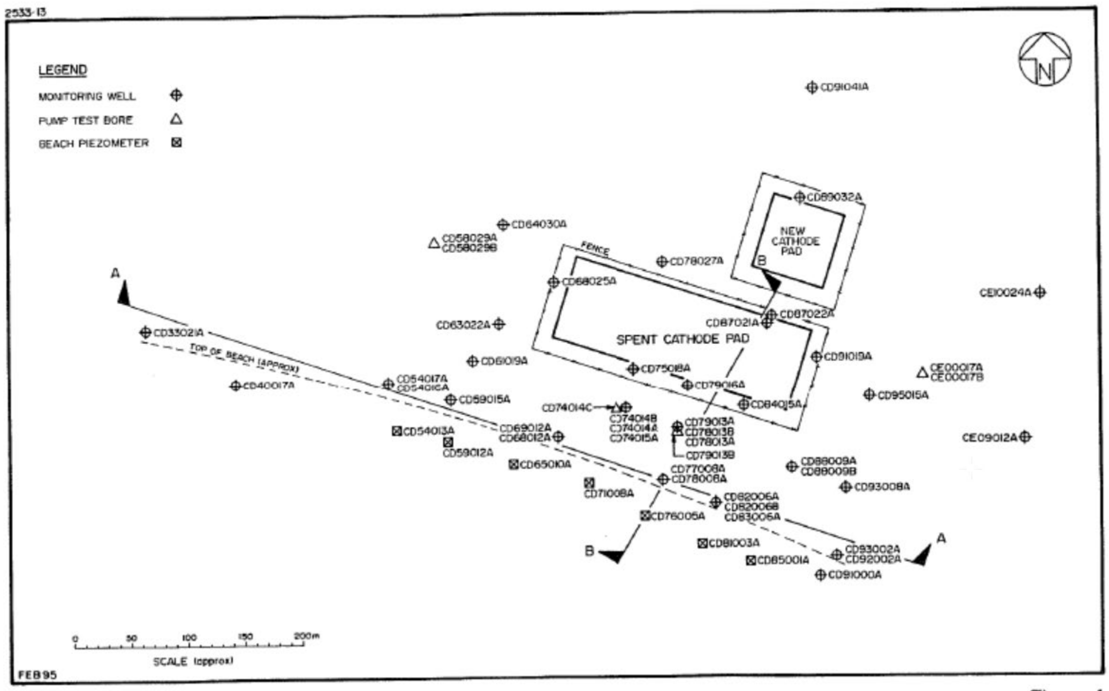
Source: http:retrolens.nz (1962)

There is considerable variation in the hydrogeological characteristics with depth and direction both due to the depositional nature of the in-situ materials as well as the infill in the depression. Because of strong lineation of permeability along the peninsula, groundwater moves more readily along the peninsula (east-west direction) than across the peninsula (Woodward-Clyde, 1994a). Pumping tests indicate a hydraulic transmissivity of about 730 $m^2/d$ for the disturbed sandy gravels (in the infill depression) beneath the Smelter Domain. This value is similar to transmissivities in the Leasehold Land Domain and higher than those in the SCL and Landfill Domains. Deeper formations with greater sand content are expected to have lower transmissivity than sandy gravels.

## 4.3 SCL (Spent Cell Lining) Storages Domain

Sedimentary units underlying and surround the SCL pad (Figure 4-8 and Figure 2-1) have been defined (Woodward-Clyde, 1994a; NZAS, 2005b) as follows:

- Pea gravel to a depth of 12-14 m (Figure 4-9 and Figure 4-10);
- Underlain by a fine sands and shell unit to a depth of 18-20 m; and
- Silt, clay and peat (lower permeability) which form an aquifer boundary at the base of the fine sands unit.




## Figure 4-8 Location map of SCL Pad and Section A-A and B-B

Source: Woodward-Clyde (1994a).

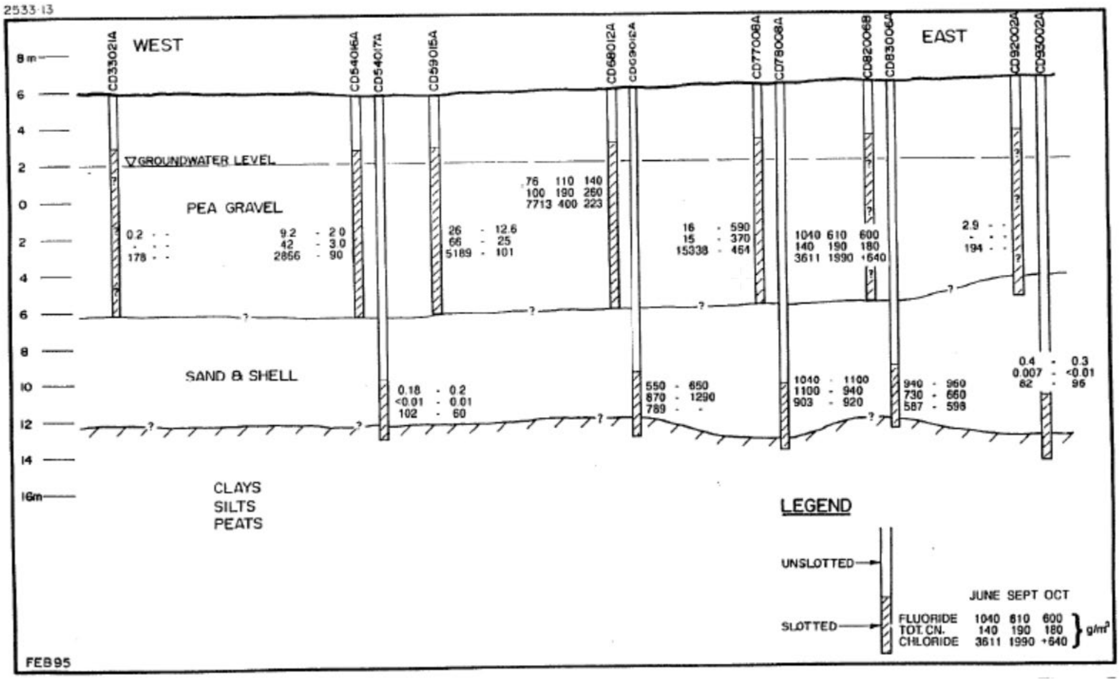



**Figure 4-9 East-west cross section of the geology and groundwater level below the SCL Pad**

Source: Woodward-Clyde (1994a).

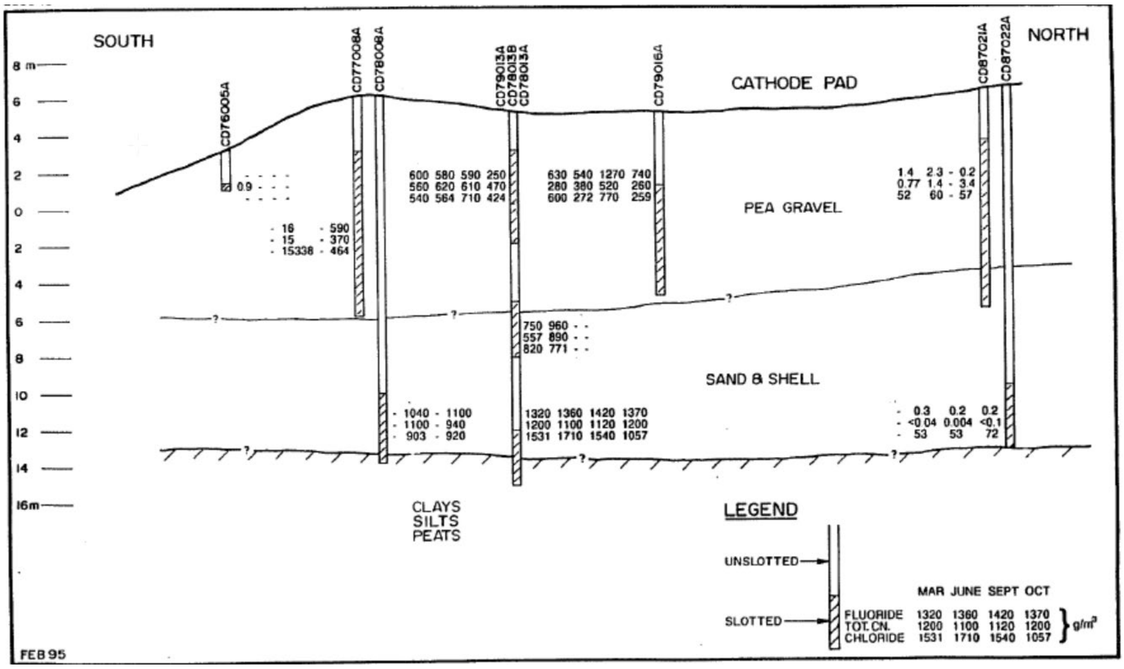



**Figure 4-10 North-south cross section of the geology below the SCL Pad (Section B-B)**

Source: Woodward-Clyde (1994a).

Groundwater flow is noted to be greater in the pea gravel unit than the fine sands because of the higher permeability of the gravels (NZAS, 2005b). In the area south of the SCL (Figure 4-8) groundwater is 2 m bgl (Figure 4-9).

## 4.4 Leasehold land Domain (Peninsula)

The Leasehold Land Domain contains the borefield that supplies water to the Smelter Domain (Figure 4-11). Drill logs and resistivity logs for this borefield supply information on the sub-surface geology of the Tiwai Peninsula. The Leasehold Land Domain is comprised of an extensive beach (pea) gravel and sand deposits developed into well-defined ridges that are orientated in an east-west direction (Figure 3-3). On the surface, the area is dominated by pea gravels with one area of surficial sand deposit noted during the site visit along the northernmost track that transverses the peninsula and adjacent elevated dune (Figure 4-12 and Figure 4-13). Older sediments comprising clays, sandy mudstones, muddy sandstones, sandstones and lignites occur 20 to 30 m bgl beneath the sands and gravels forming a less permeable layer (Figure 4-14 and Figure 4-15; GCNZ, 1990). Hard basement rock was intersected by deep test bores at 60- 65 m bgl, underlying less permeable multiple muddy sandstones and lignite units (GCNZ, 1990). The exact location of these deeper test bore collars is not known.

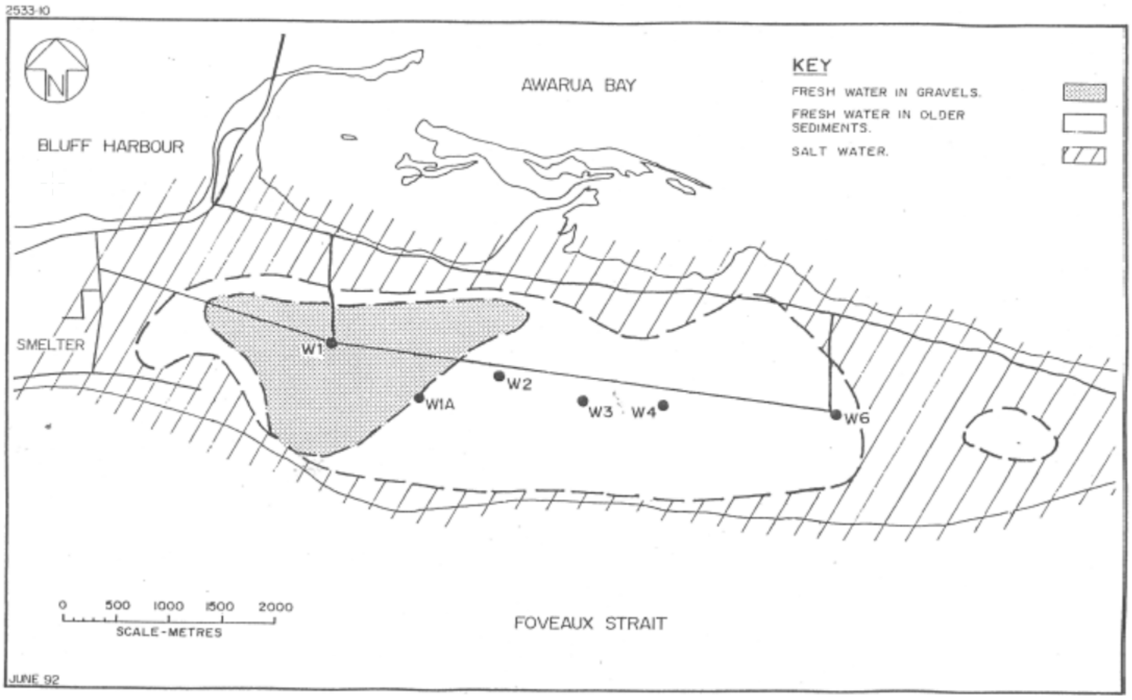



**Figure 4-11 Location of bore field in the RT Leasehold Land Domain**

Source: Map of Aquifer Location.pdf.

**Figure 4-12 Cross bedding in fine sand (top) and cementing of fine sand along the road track (bottom)**


**Figure 4-13 Location of sand deposit (Figure 4-12)**

Source: Google maps (2020).

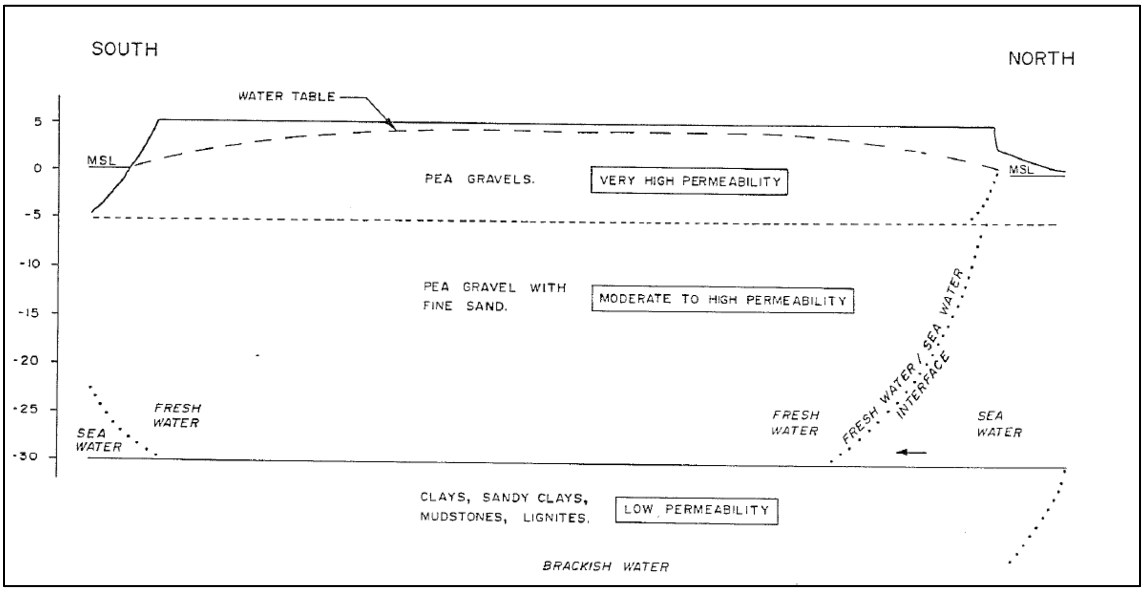



**Figure 4-14 Generalised N-S cross section of the RT Leasehold Land Domain**

Source: GCNZ (1990)

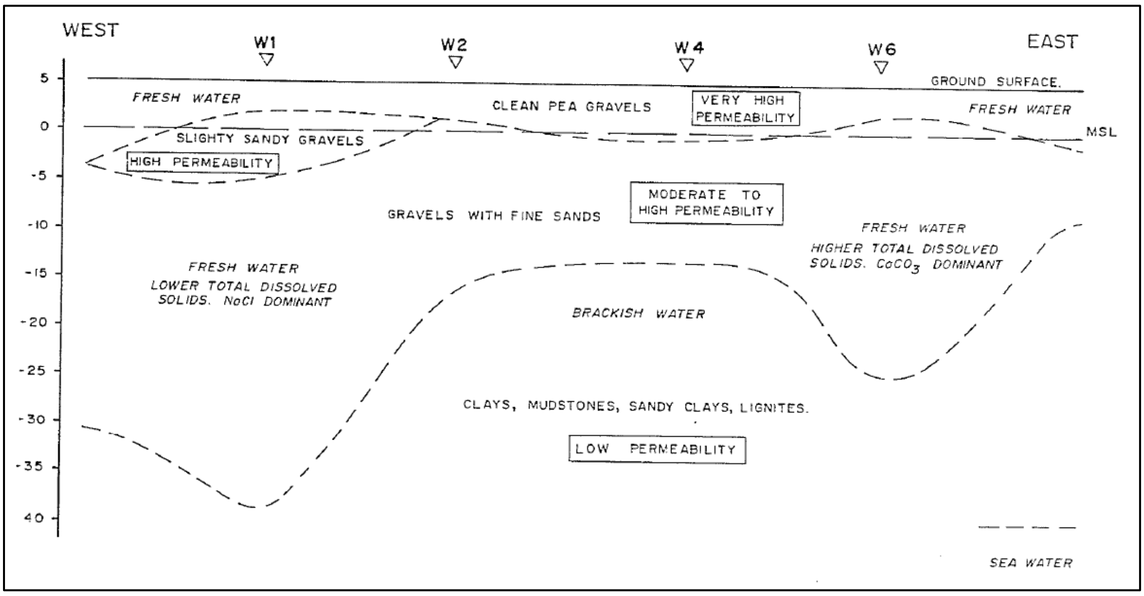



**Figure 4-15 Generalised W-E cross section of the RT Leasehold Land Domain with water bores**

Source: GCNZ (1990).

The depth to the older, less permeable sediments (clays, silts) varies, deepest at W1 in the west, highest under W2 and W4 and dropping again at W6 in the east (Figure 4-15). Changes in depth of the older sediments were interpreted by GCNZ (1990) as paleochannels cut into older sediments prior to the formation of the peninsula sands and pea gravels.

## 4.5 Freehold Land Domain

Nearby wells in the Leasehold Land Domain (Well 1/1A; Figure 4-11) and in the SCL Storages Domain indicate that pea gravels in this area may be at least 10 m thick before grading into more sand dominated units. However, the only known well on the freehold land domain is Well 15(w), excluding the SCL Domain. Well 15 is a decommissioned water well to the east of the Smelter Domain (Figure 4-16). Well 15 was used to supply the site with water during the initial construction phase, so was likely drilled in the early 1970s (NZAS, 2006). The bore logs for this well could not be located so the subsurface geology in the Freehold Land Domain is poorly understood (excluding the SCL Domain).

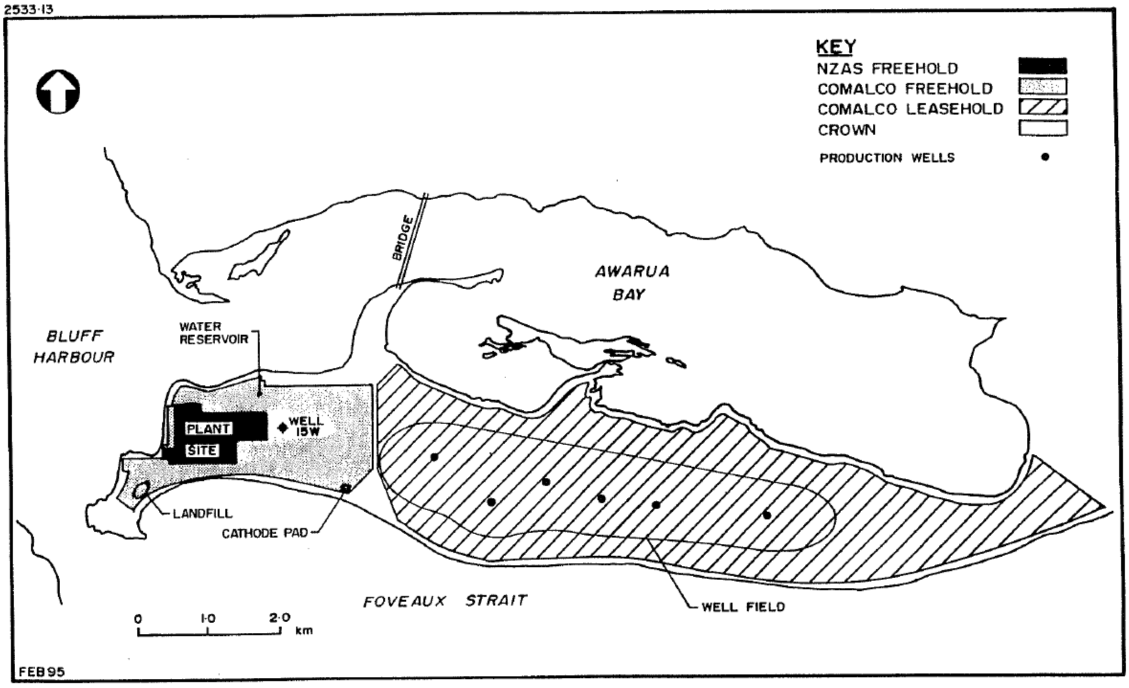



**Figure 4-16 Tiwai Peninsula Map with Well 15 (W15) on the RT Freehold Land Domain**

Source: Woodward-Clyde (1994a).

# 5. Knowledge and Data Gaps Identified

Knowledge gaps were considered with reference to Rio Tinto's Closure Study Definition Guidance Note (Rio Tinto, 2018). Consideration was also given to the fact that the unconsolidated sediments have the potential to be used in landform design as a cover material, and the information required to make decisions on suitably for this purpose. In this context, the following knowledge and data gaps were identified:

- There was limited data available around the geochemical, mineralogical or physical attributes of the in-situ unconsolidated sediments, other than qualitative data from the historical bore hole logs. However, in terms of understanding this in-situ materials for use in the development of final landform designs, this gap is not considered a risk.
- Limited chemical analysis of the unconsolidated sediments is restricted to contaminants and contaminant assessment. There is no information or quantitative data around growth medium suitably and soils fertility. Given the abundance of the pea gravel material on the surface and the vegetative cover that exists on this material, the lack of chemical analysis is not considered to be an appreciable risk for the Preliminary Study.

  **Recommendation**: It is recommended that a detailed assessment of the available onsite growth medium that could be borrowed for post-rehabilitation be completed as part of the Final Study. This would include assessment of medium suitability, fertility, organic content and other analysis, focusing on growth medium located in the areas proposed for borrow material as part of the Preliminary Study.
- There is presently limited physical analysis on the unconsolidated sediments (refer Royds 1994) such as bulk density, particle size distribution, specific gravity, moisture holding capacity, compaction testing etc, to assess growth medium suitably for revegetation initiatives. Given the abundance of the pea gravel material on the surface and the vegetative cover that exists on this material, the lack of physical analysis is not considered to be an appreciable risk for the Preliminary Study.

  **Recommendation**: It is recommended that a detailed assessment of the physical properties of any backfill material to be sourced (borrowed) from site is completed to inform the detailed design of void backfill specifications (voids created from removal of subsurface infrastructure).
- There is limited information on the sub-surface geology in the Freehold Land Domain, due to the scarcity of boreholes in the area to provide this information, and the loss of records for Well 15 (W15). Taking into account the homogenous nature of the geology at the Tiwai Point and Peninsula it can be assumed that there would be no unexpected changes in the geology in the freehold domain, and therefore the lack of borehole data is not considered to be a risk to the geological understanding of the Freehold Land Domain.

# 6. Acronyms

The acronyms that apply to this document are outlined in Table 6-1.

**Table 6-1 Acronyms**

| Acronym | Definition |
|---|---|
| bgl | Below ground level |
| bsl | Below sea level |
| CSDGN | Closure Study Definition Guidance Note |
| ha | Hectare |
| km | Kilometre |
| m | Metre |
| $m^2$/d | Squared metres per day |
| mg/L | Milligrams per litre |
| m/m | Metre per metre |
| m/s | Metres per second |
| NZAS | New Zealand Aluminium Smelters |
| PS | Preliminary Study |
| RT | Rio Tinto |
| SCL | Spent Cell Lining |
| WBS | Work Breakdown Structure |

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