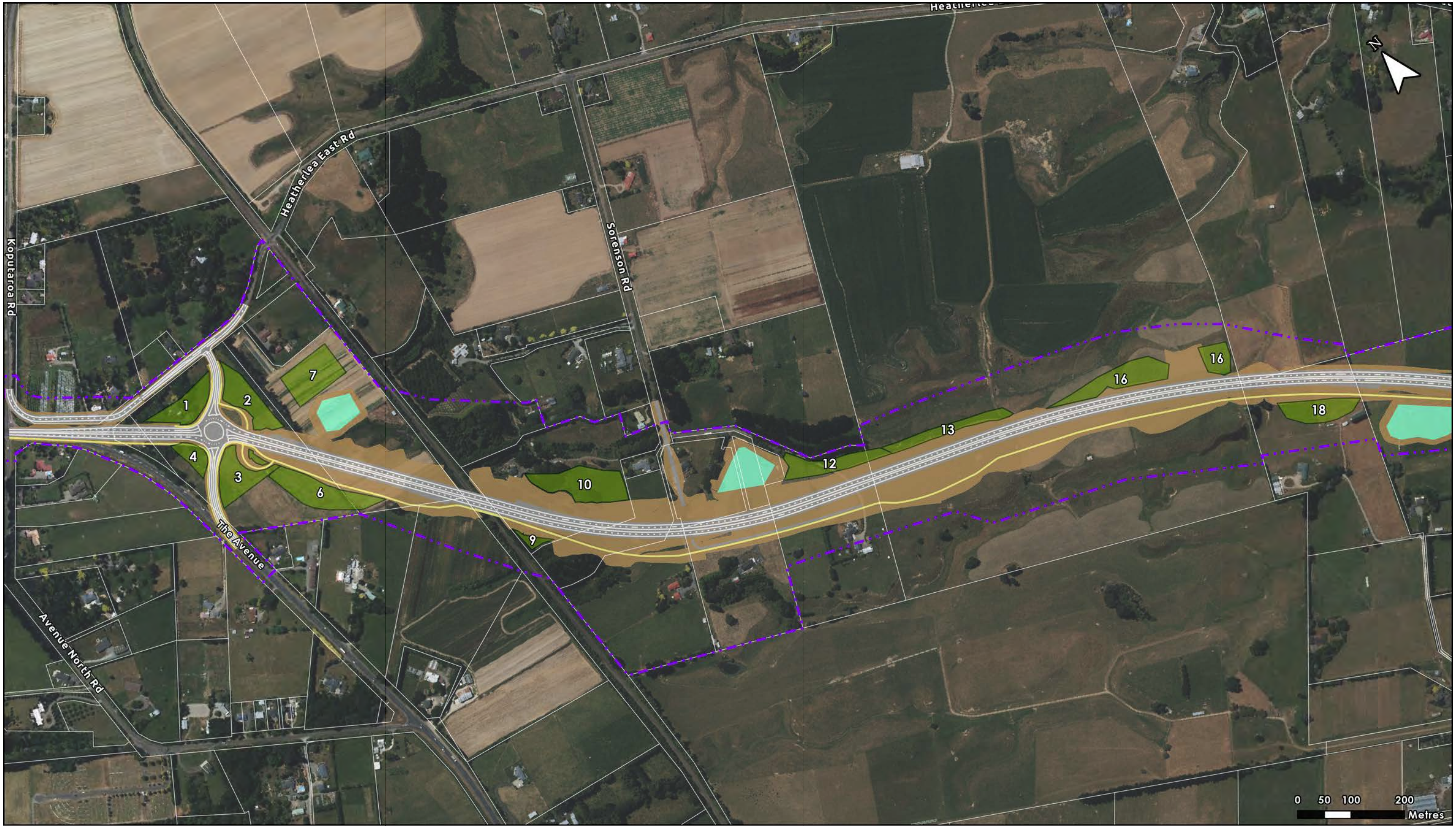
B2: Long List of Spoil Sites Assessed in MCA Process



Stantec

Final Spoil Sites Recommended for Consenting

Chainage 10000 - 12400

WAKA KOTAHI NZ TRANSPORT AGENCY

Data Sources: Stantec, Land Information New Zealand
Basemap sourced from Land Information New Zealand.
Map projected in NZGD 2000 New Zealand Transverse Mercator coordinate system.

Author: rmcpherson, Stantec (2022)
Reviewed by: egkeli, jgesche, Stantec (2022)
Project Code: 310203848
Export Date: 05/8/2022

O2NL Spoil Sites Recommended for Consideration (July 2022)
O2NL Proposed Designation
Property Parcels

O2NL Draft Design (DF5 20220714)
Road User Markings
Road Surface
Shared Use Path
Bridges
Earthworks
Ponds

Final Spoil Sites Recommended for Consenting

Chainage 12400 - 14000

Stantec

WAKA KOTAHI NZ TRANSPORT AGENCY

Data Sources: Stantec, Land Information New Zealand
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Author: rmcpherson, Stantec (2022)
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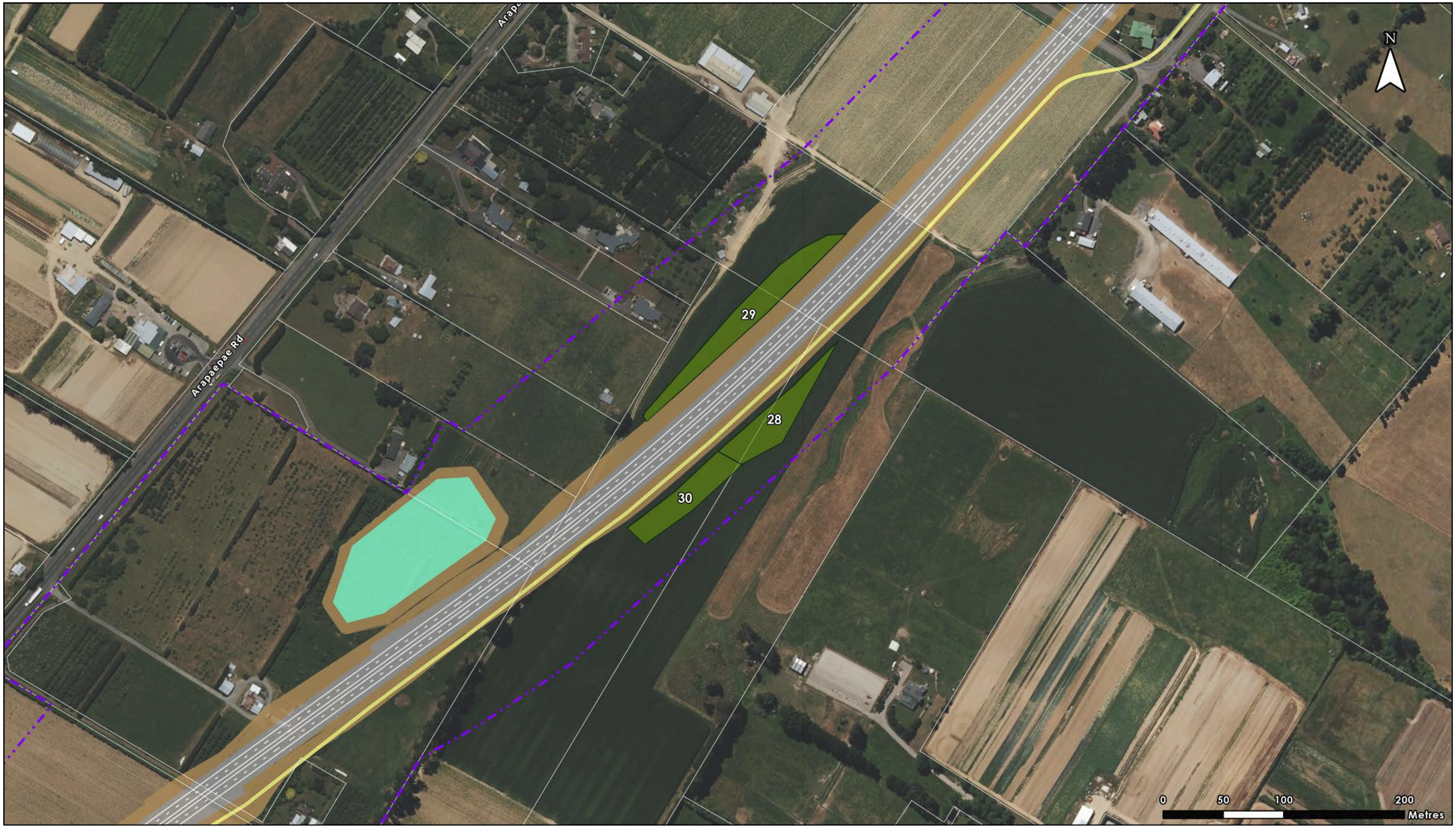


Stantec

Final Spoil Sites Recommended for Consenting

Chainage 14800 - 15600

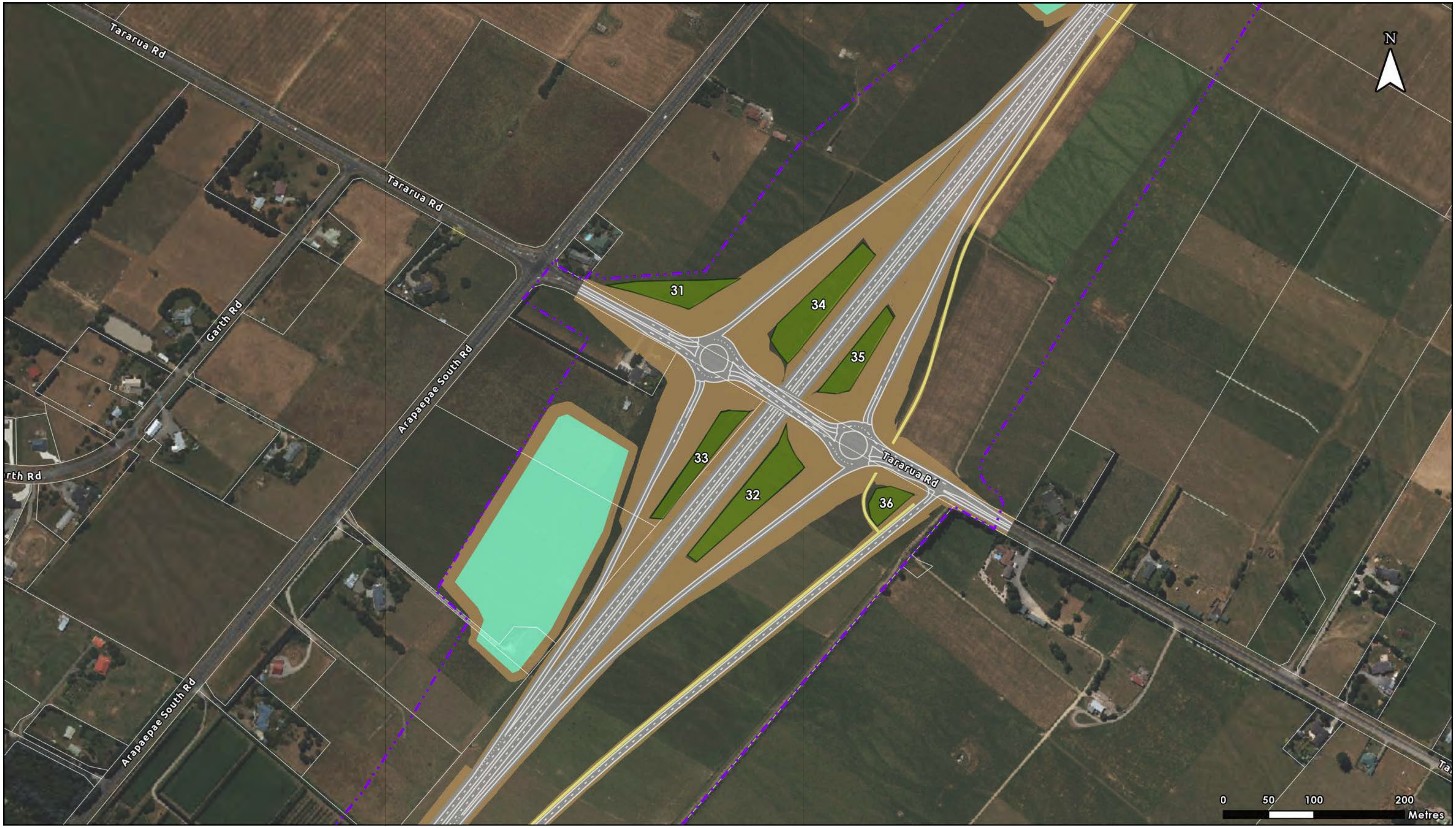
WAKA KOTAHI NZ TRANSPORT AGENCY

Data Sources: Stantec, Land Information New Zealand
Basemap sourced from Land Information New Zealand.
Map projected in NZGD 2000 New Zealand Transverse Mercator coordinate system.

Author: rmcpherson, Stantec (2022)
Reviewed by: egkeli, jgesche, Stantec (2022)
Project Code: 310203848
Export Date: 05/8/2022

O2NL Spoil Sites Recommended for Consideration (July 2022)
O2NL Proposed Designation
Property Parcels

O2NL Draft Design (DF5 20220714)
- Road User Markings
- Road Surface
- Shared Use Path
- Bridges
- Earthworks
- Ponds



Stantec

Final Spoil Sites Recommended for Consenting

Chainage 17800 - 18800

WAKA KOTAHI NZ TRANSPORT AGENCY

Data Sources: Stantec, Land Information New Zealand
Basemap sourced from Land Information New Zealand.
Map projected in NZGD 2000 New Zealand Transverse Mercator coordinate system.

Author: rmcpherson, Stantec (2022)
Reviewed by: egkeli, jgesche, Stantec (2022)
Project Code: 310203848
Export Date: 05/8/2022

O2NL Spoil Sites Recommended for Consideration (July 2022)
O2NL Proposed Designation
Property Parcels

O2NL Draft Design (DF5 20220714)
Road User Markings
Road Surface
Shared Use Path
Bridges
Earthworks
Ponds

Stantec

Final Spoil Sites Recommended for Consenting

Chainage 20200 - 22600

WAKA KOTAHI NZ TRANSPORT AGENCY

- O2NL Spoil Sites Recommended for Consideration (July 2022)
- O2NL Proposed Designation
- Property Parcels

O2NL Draft Design (DF5 20220714)

- Road User Markings
- Road Surface
- Shared Use Path
- Bridges
- Earthworks
- Ponds

Data Sources: Stantec, Land Information New Zealand
Basemap sourced from Land Information New Zealand.
Map projected in NZGD 2000 New Zealand Transverse Mercator coordinate system.

Author: rmcpherson, Stantec (2022)
Reviewed by: egkeli, jgesche, Stantec (2022)
Project Code: 310203848
Export Date: 05/8/2022

Stantec

Final Spoil Sites Recommended for Consenting

Chainage 22800 - 25100

WAKA KOTAHI NZ TRANSPORT AGENCY

Data Sources: Stantec, Land Information New Zealand
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Author: rmcpherson, Stantec (2022)
Reviewed by: egkeli, jgesche, Stantec (2022)
Project Code: 310203848
Export Date: 05/8/2022

O2NL Spoil Sites Recommended for Consideration (July 2022)
O2NL Proposed Designation
Property Parcels

O2NL Draft Design (DF5 20220714)
Road User Markings
Road Surface
Shared Use Path
Bridges
Earthworks
Ponds

Stantec

Final Spoil Sites Recommended for Consenting

Chainage 24600 - 26200

WAKA KOTAHI NZ TRANSPORT AGENCY

O2NL Spoil Sites Recommended for Consideration (July 2022)

O2NL Proposed Designation

Property Parcels

O2NL Draft Design (DF5 20220714)

Road User Markings

Road Surface

Shared Use Path

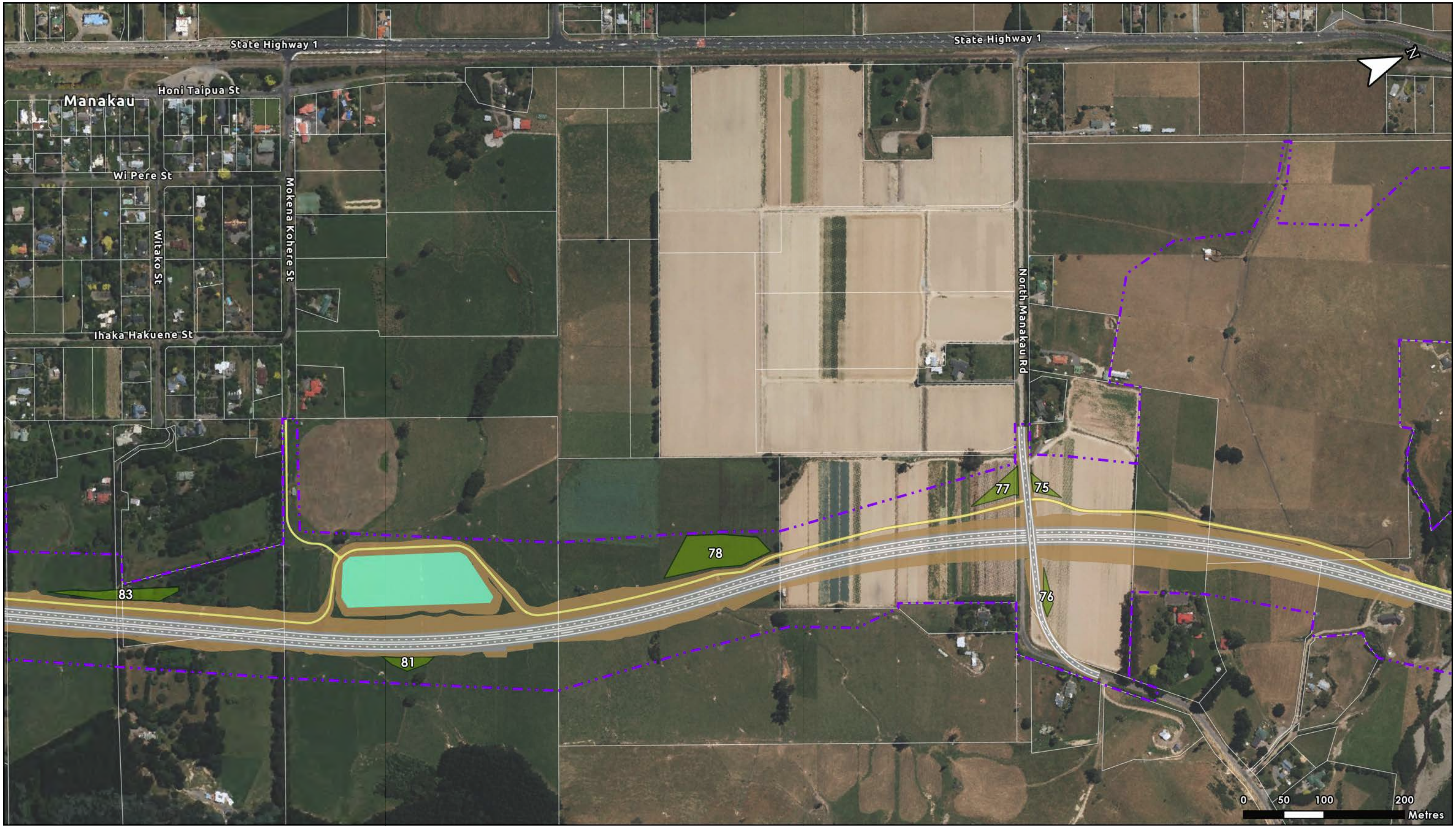
Bridges

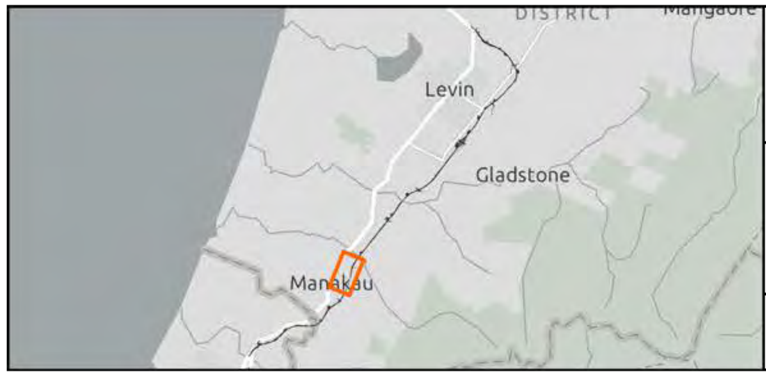
Earthworks

Ponds

Data Sources: Stantec, Land Information New Zealand
Basemap sourced from Land Information New Zealand.
Map projected in NZGD 2000 New Zealand Transverse Mercator coordinate system.

Author: rmcpherson, Stantec (2022)
Reviewed by: egkell, jgesche, Stantec (2022)
Project Code: 310203848
Export Date: 05/8/2022





Stantec

Final Spoil Sites Recommended for Consenting

Chainage 26600 - 28500

WAKA KOTAHI NZ TRANSPORT AGENCY

O2NL Spoil Sites Recommended for Consideration (July 2022)

O2NL Proposed Designation

Property Parcels

O2NL Draft Design (DF5 20220714)

Road User Markings

Road Surface

Shared Use Path

Bridges

Earthworks

Ponds

Data Sources: Stantec, Land Information New Zealand
Basemap sourced from Land Information New Zealand.
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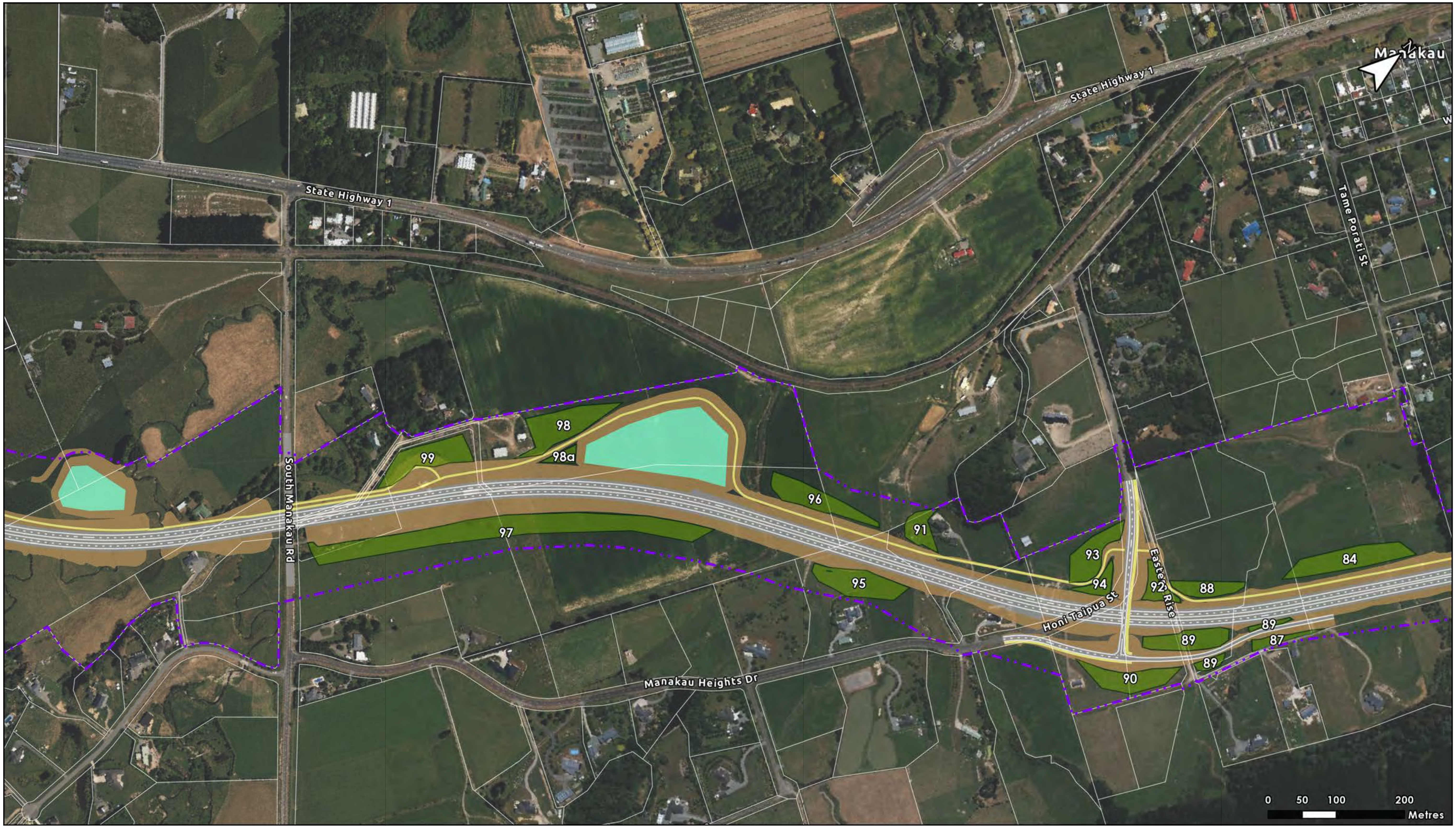

Stantec

Final Spoil Sites Recommended for Consenting

Chainage 28500 - 30500

WAKA KOTAHI NZ TRANSPORT AGENCY

	O2NL Spoil Sites Recommended for Consideration (July 2022)
	O2NL Proposed Designation
	Property Parcels

O2NL Draft Design (DF5 20220714)

- Road User Markings
- Road Surface
- Shared Use Path
- Bridges
- Earthworks
- Ponds

Data Sources: Stantec, Land Information New Zealand
Basemap sourced from Land Information New Zealand.
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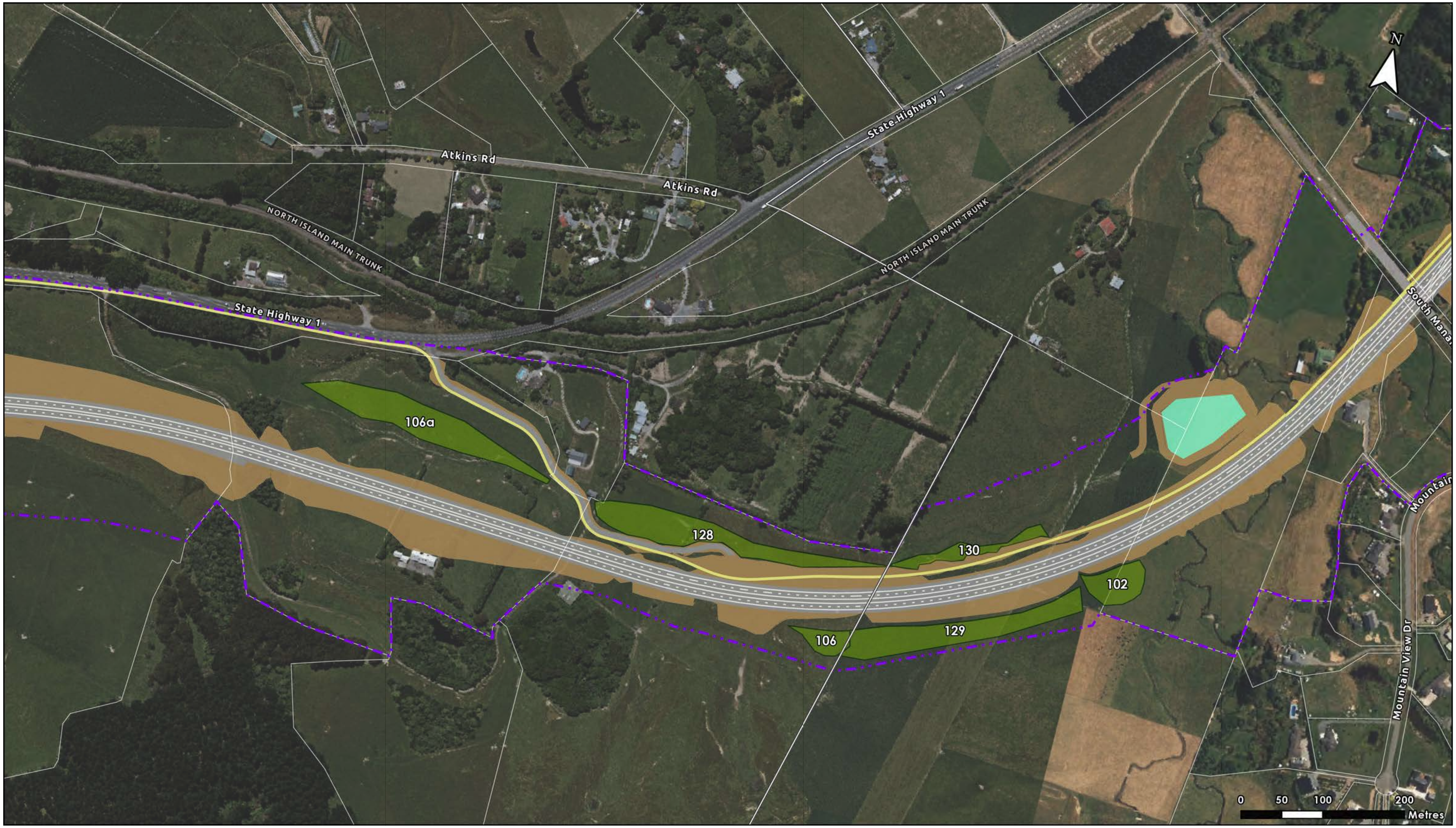
Project Code: 310203848
Export Date: 05/8/2022



Stantec

Final Spoil Sites Recommended for Consenting

Chainage 30200 - 31800

WAKA KOTAHI NZ TRANSPORT AGENCY

Data Sources: Stantec, Land Information New Zealand
Basemap sourced from Land Information New Zealand.
Map projected in NZGD 2000 New Zealand Transverse Mercator coordinate system.

Author: rmcpherson, Stantec (2022)
Reviewed by: egkeli, jgesche, Stantec (2022)
Project Code: 310203848
Export Date: 05/8/2022

O2NL Spoil Sites Recommended for Consideration (July 2022)
O2NL Proposed Designation
Property Parcels

O2NL Draft Design (DF5 20220714)
Road User Markings
Road Surface
Shared Use Path
Bridges
Earthworks
Ponds

Final Spoil Sites Recommended for Consenting

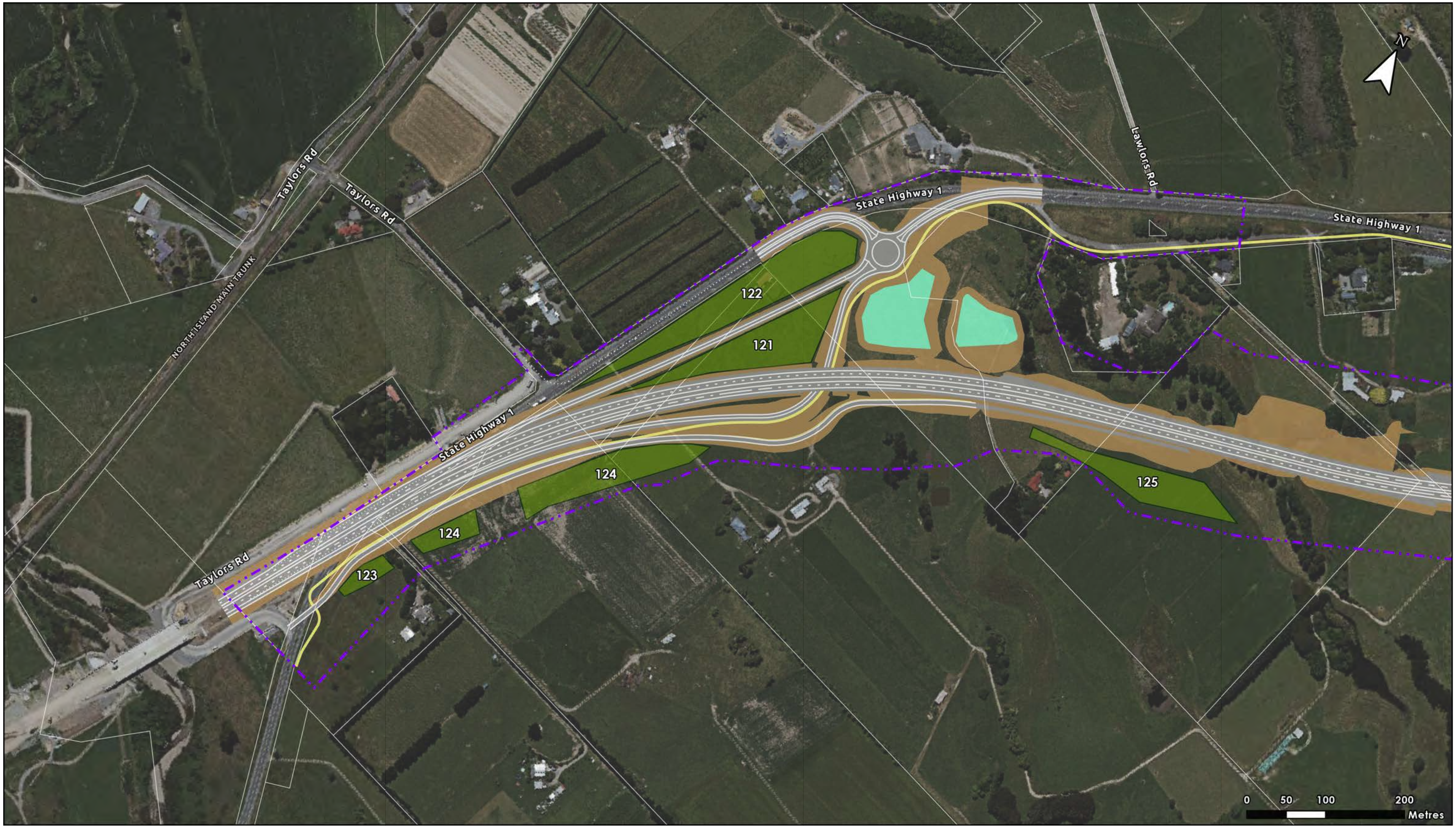
Chainage 32100 - 33600

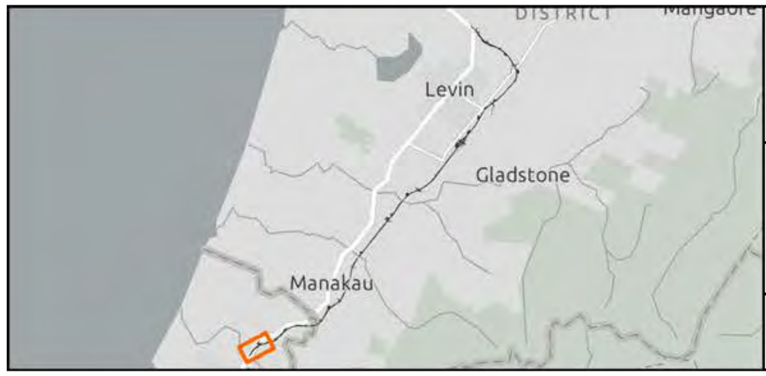
Data Sources: Stantec, Land Information New Zealand
Basemap sourced from Land Information New Zealand.
Map projected in NZGD 2000 New Zealand Transverse Mercator coordinate system.

Author: rmcpherson, Stantec (2022)
Reviewed by: egkeli, jgesche, Stantec (2022)
Project Code: 310203848
Export Date: 05/8/2022

O2NL Spoil Sites Recommended for Consideration (July 2022)
O2NL Proposed Designation
Property Parcels

O2NL Draft Design (DF5 20220714)
- Road User Markings
- Road Surface
- Shared Use Path
- Bridges
- Earthworks
- Ponds





Stantec

Final Spoil Sites Recommended for Consenting

Chainage 33600 - 35000

WAKA KOTAHI NZ TRANSPORT AGENCY

O2NL Spoil Sites Recommended for Consideration (July 2022)

O2NL Proposed Designation

Property Parcels

O2NL Draft Design (DF5 20220714)

- Road User Markings
- Road Surface
- Shared Use Path
- Bridges
- Earthworks
- Ponds

Data Sources: Stantec, Land Information New Zealand
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Author: rmcpherson, Stantec (2022)
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Project Code: 310203848
Export Date: 05/8/2022

DESIGN WITH COMMUNITY IN MIND

Communities are fundamental. Whether around the corner or across the globe, they provide a foundation, a sense of place and of belonging. That's why at Stantec, we always design with community in mind.

We care about the communities we serve—because they're our communities too. This allows us to assess what's needed and connect our expertise, to appreciate nuances and envision what's never been considered, to bring together diverse perspectives so we can collaborate toward a shared success.

We're designers, engineers, scientists, and project managers, innovating together at the intersection of community, creativity, and client relationships. Balancing these priorities results in projects that advance the quality of life in communities across the globe.

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Appendix 4.5 Material Supply Sites Summary Report

Ōtaki to north of Levin Highway Project

Appendix 4.5: Material Supply Study Report

PREPARED FOR WAKA KOTAHI NZ TRANSPORT AGENCY| JULY 2022

We design with community in mind

Stantec

Revision schedule

Rev No	Date	Description	Signature of Typed Name (documentation on file)			
			Prepared by	**Checked by**	**Reviewed by**	**Approved by**
1	15.03.2022	First Draft	Ken Clapcott			
2	22.06.2022	Draft for Comment	Ken Clapcott / Chris Hansen		Jamie Povall	
3	31.07.2022	Final	Ken Clapcott / Chris Hansen	Phil Peet	Jamie Povall	Jon England

The conclusions in the Report are Stantec's professional opinion, as of the time of the Report, and concerning the scope described in the Report. The opinions in the document are based on conditions and information existing at the time the document was published and do not take into account any subsequent changes. The Report relates solely to the specific project for which Stantec was retained and the stated purpose for which the Report was prepared. The Report is not to be used or relied on for any variation or extension of the project, or for any other project or purpose, and any unauthorized use or reliance is at the recipient's own risk.

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Quality statement

Project manager	Project technical lead
Jon England	Jamie Povall

PREPARED BY Ken Clapcott / Chris Hansen	31 / 07 / 2022
CHECKED BY Phil Peet	31 / 07 / 2022
REVIEWED BY Jamie Povall	31 / 07 / 2022
APPROVED FOR ISSUE BY Jon England	31 / 07 / 2022

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PO Box 13-052, Armagh, Christchurch 8141
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Abbreviations

Enter Abbreviation	Enter Full Name
DBC	Detailed Business Case
DCR	Design & Construction Report
Ō2NL Project	Ōtaki to north of Levin Highway Project
CEDF	Cultural & Environmental Design Framework
RMA	Resource Management Act 1991

1 Introduction

1.1 Overview of Ō2NL Project

Waka Kotahi NZ Transport Agency (Waka Kotahi) is preparing Resource Management Act 1991 (RMA) approvals (designation and resource consents) to construct, operate and maintain the Ōtaki to north of Levin Highway Project (Ō2NL Project).

The Ō2NL Project will deliver a significantly improved state highway connection between State Highway 1 (SH1) at Taylors Road north of Ōtaki, and SH1 just north of Levin. At the southern end, the Ō2NL Project will tie-in with the Peka to Ōtaki (PP2Ō) highway, currently under construction. The Ō2NL Project is included in the NZ Upgrade Programme to 'improve safety and access, support economic growth, provide greater route resilience, and better access to walking and cycling facilities'.

1.2 The Purpose of the Material Supply Study

Through the preparation of the Detailed Business Case (DBC) it was identified that the current earthworks design of the Ō2NL Project relies on a significant amount of fill, exceeding the amount of material that is anticipated to be won through earthwork cut activities. The current design (Revision DF5.0 – dated May 2022) is based on a shortfall of 800,000 to 1,500,000+ m^3 of earth material being found (or imported) for structural embankment fill. Design constraints, notably grade separating local roads from the highway, topography and geological conditions, cause this unfavourable cut/fill material balance.

In order to resolve this issue, a process has been developed to investigate locations that can be used to supply bulk fill earth material to the Ō2NL Project and the resource consents required.

The Material Supply Sites Study objectives are to:

- Identify material supply source options.
- Confirm sites are technically viable.
- Secure access to resources.
- If required, obtain approvals for the Material Supply Sites needed.

A key focus of the study has been to identify sites that can leave a legacy and create a positive environment for future generations, as informed by the Cultural and Environmental Design Framework (CEDF). This can be achieved by removing the material in a way that extends the landscape and leaves it in a form that the excavations are not obvious. Stantec's acknowledges the project's iwi partners who provided the inspiration for this positive legacy approach to the study.

Stantec also acknowledges Chris Hansen (from Chris Hansen Consultants Ltd) for his involvement into the study and contribution into this report.

1.3 Options to Address Shortfall in Bulk Material

A number of options have been identified to address this shortfall in bulk material for the Ō2NL Project. These include:

1. Commercial Suppliers
2. Materials within the proposed Ō2NL Designation
3. Materials outside the proposed Ō2NL Designation

Option 1 involves obtaining further knowledge and information from existing supplies and the industry. The known commercial sources within the region are shown in Figure 4.5 1.

Figure 4.5 1: Known commercial sources within the region

The Ō2NL Project team will continue to investigate this option, with tasks including:

- A survey of existing quarry suppliers within the region to determine the availability of materials for the project.
- Close liaison with councils and the quarry industry to determine if any new quarry operations within the region are planned.

Sourcing material solely from commercial suppliers would likely result in significant additional costs which may impact the Ō2NL Project's economic feasibility. Transporting material from commercial sources would also generate significant additional truck movements on the existing roading network resulting in considerable environmental and traffic impacts.

Options 2 and 3 include undertaking a Material Supply Study that goes through a process of identifying numerous options, and then undertaking an assessment to ascertain a shortlist and ultimately the selection of the preferred Material Supply Sites. This process is documented within this report.

2 Key Principles and Values

Through Waka Kotahi's partnership with Mana Whenua, core principles and values for the Ō2NL Project have been established. These are summarised below.

Core principles

- Tread Lightly, with the whenua
- Me tangata te whenua (treat the land as a person)
- Kia māori te whenua (let it be its natural self)
- Create an Enduring Community Legacy
- Kia māori te whakaaro (normalise māori values)
- Me noho tangata whenua ngā mātāpono (embed the principles in all things)
- Tū ai te tangata, Tū ai te whenua, Tū ai te Wai (elevate the status of the people, land and water

Core values

- Te Tiriti (spirit of partnership)
- Rangātiratanga (leadership – professionalism – excellence)
- Ūkaipotanga (care – constructive behaviour towards each other)
- Pukengatanga (mutual respect)
- Manaakitanga (generosity – acknowledgement – hospitality)
- Kaitiakitanga (environmental stewardship)
- Whanaungatanga (belonging- teamwork)
- Whakapapa (connections)

Together, the core principles and values bring a focus on the Ō2NL Project development and design response for positive, measurable outcomes. These core principles and values have shaped the Material Supply Sites approach and findings, with the process described further in section 5.

3 Estimation of Bulk Fill Materials Required

The alignment has been broken into zones based on the project design, geology, topography and a potential construction zoning system. This system allows earthwork volumes to be quantified per zone and establish where there are material supply deficits. The zones are summarised in Table 4.5.1.

Table 4.5.1: Alignment Zone Breakdown

No.	Zone Start	Zone Finish	Ch Start (Approx.)	Ch Finish (Approx.)	Length (m) (approx.)
1	Northern end (SH1)	Arapaepae / Macdonald (SH57)	10000	13300	3300
2	Arapaepae / McDonald (SH57)	Queen Street	13300	16100	2800
3	Queen Street	Property Boundary	16100	19100	3000
4	Property Boundary	Ohau River	19100	22600	3500
5	Ohau River	North Manakau Road	22600	27100	4500
6	North Manakau Road	Regional Boundary	27100	30900	3800
7	Regional Boundary	Southern End	30900	34900	4000

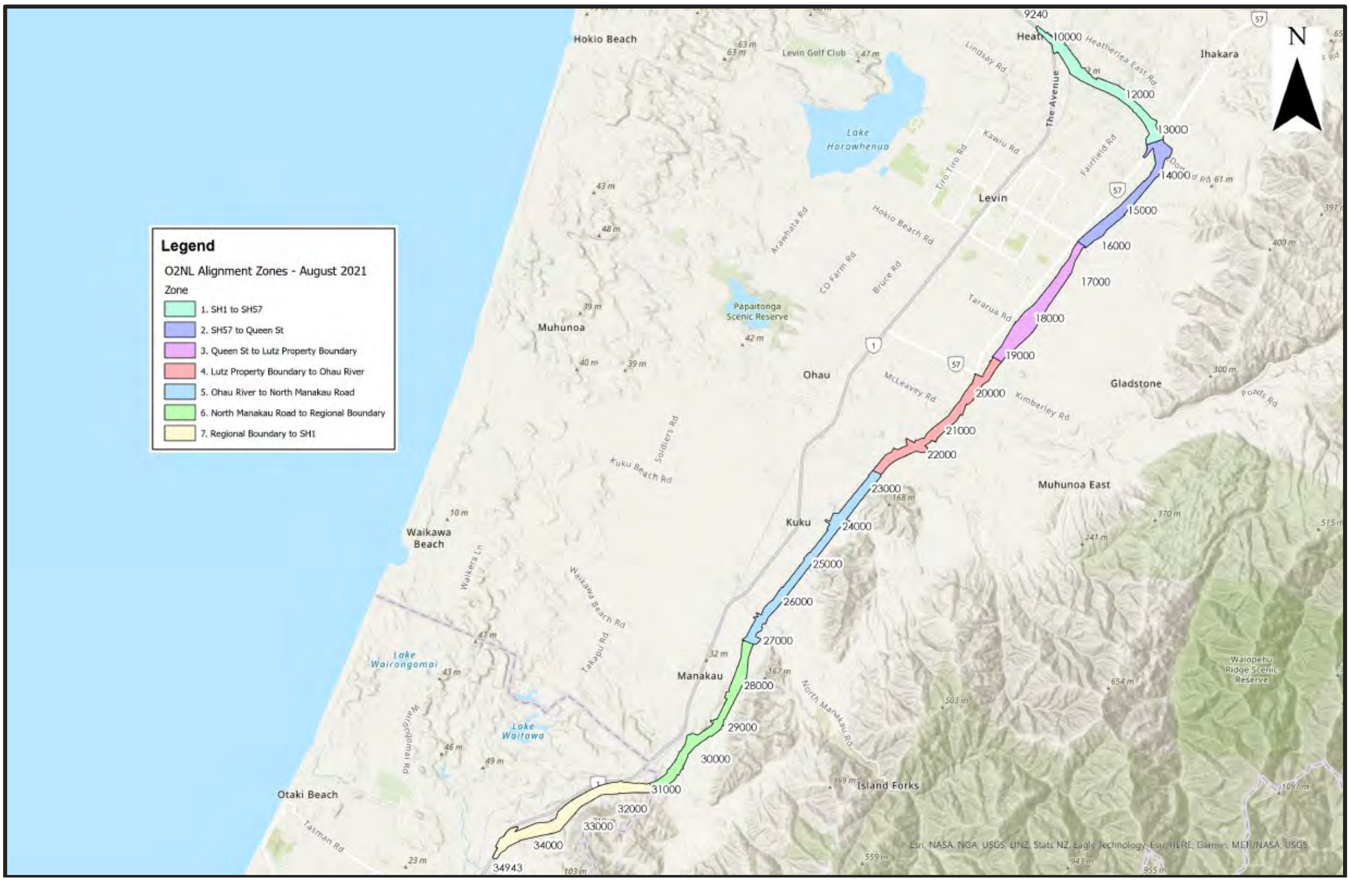


Figure 4,5.2: Alignment by Zone

Based on the concept design, anticipated fill requirements are presented in Table 4.5.2. Anticipated fill requirements are calculated volumes over and beyond what's available/reusable from the project cuttings. A percentage of the total cut material will need to be "spoiled or disposed" as it is deemed unsuited for earthwork construction of state highways.

Table 4.5.2: Ō2NL Project Fill Demand

Zone	Modelled Fill Volume Demand	Anticipated Extra Fill Demand* (Approx.)
1	378,000	68,000
2	148,000	77,000
3	285,000	130,000
4	231,000	45,000
5	447,000	230,000
6	512,000	423,000
7	411,000	0

**Additional fill material that cannot be sourced within zone based on expected material re-use*

4 Site Selection Considerations

4.1 Embankment Design Constraints / Opportunities

To achieve project goals (economic, carbon, core principle/values etc), a key objective of the Material Supply Site study was to identify supply sites within close proximity to where the fill is required.

Design constraints conditions currently cause an unfavourable cut/fill material balance due to:

- Flood levels which dictate the minimum road level of the highway (i.e., the required cover (fills) over culverts, bridge levels)
- Fills required for grade-separation (going over/under existing roads)
- Achieving horizontal/vertical geometric alignment
- Avoiding groundwater level interception at East of Levin

4.2 Geology and Geomorphology

A summary of the geological setting, published geology and the project's geological model (including a 18 page drawing set of the Projects' geological model) is provided within Stantec's Geotechnical Consenting Design Report[1]. Figure 4.5.3 summarises the published geology along the alignment.

Material source options considered for material supply of bulk road embankment fill include:

- Rock (Tt Rakaia Terrane Greywacke)
- Alluvial Deposits (Q1a/Q2a/Q3a Gravels)
- Shoreline Deposits (Q5b Sands)

This study categorised the Material Supply Sites into these three source options.

[1] SH1 Ōtaki To North Levin Highway Project, Appendix 4.1 - Geotechnical Consenting Design Report, July 2022

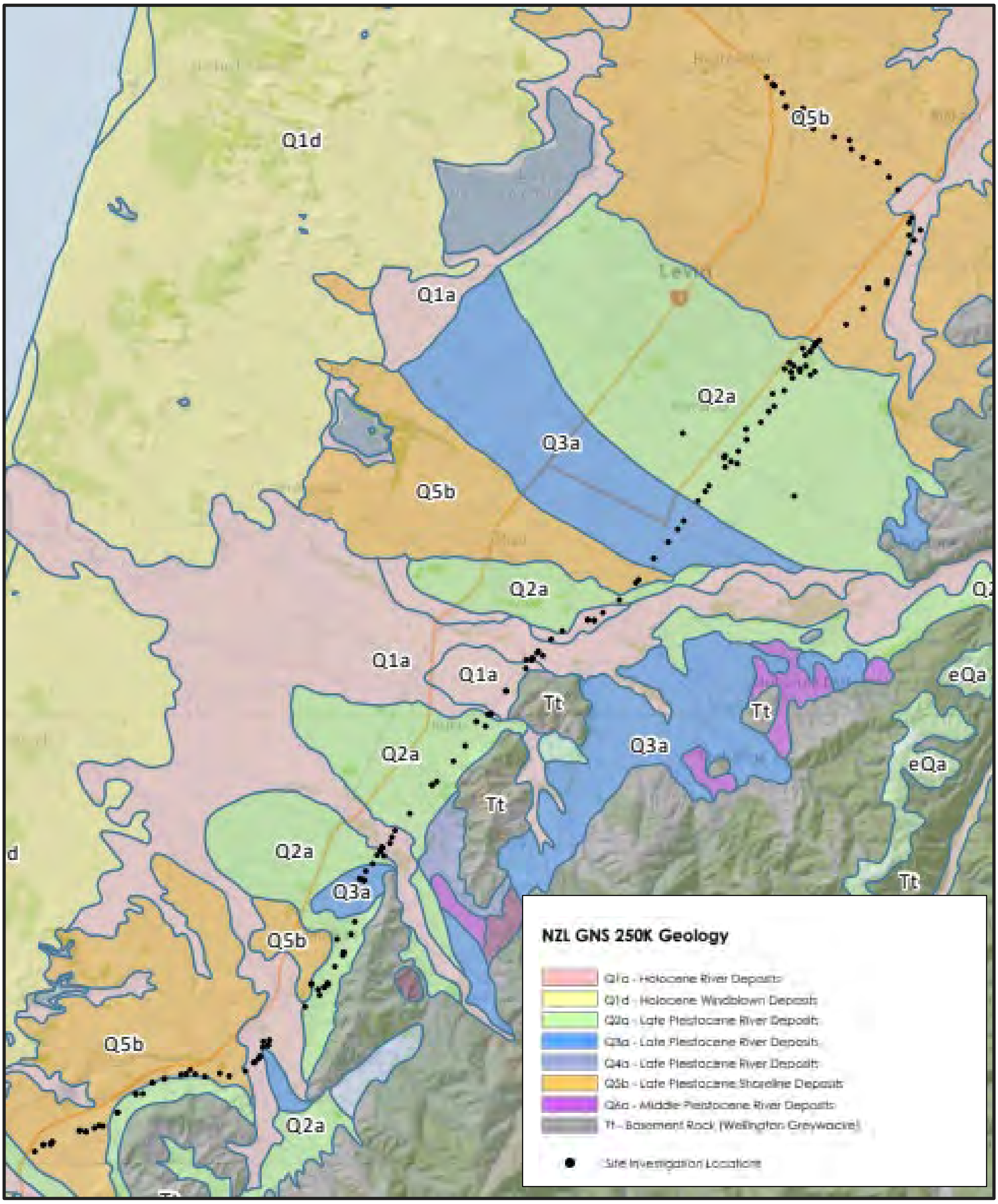


Figure 4.5.3: Published Geology along the alignment

In addition to the Stantec Geotechnical Interpretative Report, two technical memorandums have been compiled focusing on collating factual information and interpretation specifically relevant to the Material Supply Study. These include memorandums on Alluvial Deposits (Q1a/Q2a/Q3a Gravels) and Shoreline Deposits (Q5b Sands) and are attached within **Appendix 4.5.4**.

For completeness, an additional technical memorandum is also attached within **Appendix 4.5.4**. This was focused on exploring the quarry viability of the Q2a Gravels located East of Levin. This site was subsequently discarded in the long to short site selection process.

The Loess (surficial material) has been assessed (within the Geotechnical Interpretative report) to be challenging for reuse and therefore has not been targeted for material supply.

5 Material Supply Sites Selection Methodology

5.1 Long to Short List of Material Supply Sites

Through the DBC, it has been identified that there is a shortfall of material for structural road embankment fill, as outlined above. In order to address this matter, a process to identify locations and to develop a 'legacy and outcome' approach to selecting and then designing Material Supply Sites has been closely worked through with iwi partners using an assessment matrix aligned with the core principles and values, as outlined in Section 2 above. The agreed focus was on selecting sites that can ultimately result in a positive legacy outcome.

The first step in the Material Supply Site selection process was to identify a long list of potential site locations for evaluation. A long list of potential Material Supply Site locations was initially identified by the Stantec Geotechnical Team using the geotechnical information available, supported by a whanau consultation process, including a series of public events, undertaken by our iwi partners. This exercise resulted in 38 potential Material Supply Site locations being identified. Refer **Appendix 4.5.1** for figures illustrating site locations.

To ensure the Ō2NL Project's core principles and values are brought into the selection process, the following assessment matrix was developed with iwi partners:

Table 4.5.3: Assessment Matrix - Tread lightly, with Whenua

	Evaluation Criteria (higher score the better, no-go if fatally flawed)			
	1	2	3	Fatal Flaw?
Minimise earthworks	Final form of the site will fit the existing landscape	Offers a good yield, allowing other sites to be avoided	Avoids important sites (including nearby) and has a low 'discovery' profile	
Select sites close to where the material is required as fill	Less than 1km from where the material will be needed	Within the designation/or more straightforward property arrangements	The only site in this area so will contribute to a good 'spread'	
Minimise impact on waterways	Offset from active waterways	Avoids floodplain	No excavation below groundwater is needed to get a good yield	
Minimise impact on whakapapa	Avoids named natural features	Avoids areas of known settlement, events, stories, trade, travel, mahinga kai	Avoids other identified sites including wahi tapu	
Minimise impact on ecology	Avoids indigenous vegetation	Existing hydrological patterns can be retained	Avoids disruption of existing habitats including ecological pathways	
Minimise impact on community (note close sites will reduce disruption and improve safety)	There is a logical and short transport route that will avoid public roads	The site is located away from public areas or is to be screened using bunds/planting	There are very few houses with a view of the site (existing or proposed)	

Table 4.5.4: Assessment Matrix - Create an Enduring Legacy

	1	2	3	Fatal flaw?
Rehabilitation and restoration	The site can be easily revegetated (take no more than 10-15 years to achieve good cover?); rock sites take longer	The site is able to be linked with other rehabilitation and restoration planting for the project	Rehabilitation of the site will make a positive contribution to ecological pathways and/or threatened habitat types	
Hazard management	The site could improve flood management			
Community benefits	The site has potential as a quarry post project	The site provided business/property opportunities for mana whenua	Final form & rehabilitation provides opportunity for SUP designation and/or highway stopping place, including appropriate access to streams/other features	

The matrix assessment approach led to the identification of the following criteria used to identify the long list of sites:

- Proximity to the future highway designation
- Good spread of sites along the highway alignment and especially at the areas where Material Supply Sites are expected to be mostly needed.
- Opportunities for landscaping interventions without impact on the natural environment
- Opportunities provided by geomorphological features (e.g. natural terraces) to level off or provide more usable land to farms or adjacent properties, and
- No effect on environmental, archaeological, cultural or other constraints based on the Project Design Team's existing knowledge (at the time).

A table summarising the iwi partners matrix assessment of the long list is provided in **Appendix 4.5.1**.

In parallel with iwi partners assessment, the long list was also evaluated at an 'initial level' by technical specialist assessors using a "traffic light signal assessment" process. A table summarising the full traffic light signal assessment of the long list is provided in **Appendix 4.5.1**.

The technical specialist assessors (i.e. organisations) who contributed to the long list evaluation process are set out in Table 4.5.5 below.

Table 4.5.5: Technical Specialist Assessors

Evaluation Topic	Technical Specialist Assessor (Organisation)	Technical Specialist Assessor
Landscape / Visual	Isthmus	Gavin Lister/Lisa Rimmer
Terrestrial Ecology	Wildland Consultants Ltd	Nick Goldwater
Aquatic Ecology	EOS Ecology	Alex James
Archaeology and Heritage	Insite Archaeology	Daniel Parker
Built Heritage	Ian Bowman	Ian Bowman
Flooding and Stormwater	Stantec	Andrew Craig
Groundwater	SLR	Jack McConchie
Water Quality	Stantec	Keith Hamill/Kristy Harrison
Transport	Stantec	Phil Peet
Noise & Vibration	Altissimo	Michael Smith
Social	Beca	Jo Healy
Air Quality	Pattle Delamore Partners	Andrew Curtis
Highly Productive Land Values	Land Vision	Lachie Grant
Contaminated Land	Stantec	Kathryn Halder

Following selection of the technical specialist assessors, each were given access to Google Earth KMZ files that include polygons for each site and indicative access, and an Excel spreadsheet to record their traffic light signal evaluations for each long listed Material Supply Site location. This evaluation system enabled each technical specialist assessor to record whether they had low, medium or high-level concerns with any of the sites as follows:

- Green (or 1) if an option is likely to have only minor impacts or issues
- Orange (or 2) if an option is likely to have moderate impacts or issues, and
- Red (or 3) if an option is likely to have serious or significant negative impacts or issues.

The purpose of this initial assessment was to identify any 'fatal flaws' with the long list of sites from an environmental perspective that would mean the site is not taken to the next level of investigation. This assessment also provided environmental opportunities to be identified which resulted in the identification of important indigenous vegetation being located on site #25 that needed to be retained, and the identification of an alternative new site #36 just north of site #25 for further assessment. The outcomes of the traffic light signal assessment were provided to iwi partners.

At the same time, a collection of sites were visited by iwi partners, CEDF and archaeology experts and based on that site visit, further sites were excluded on the basis that proposed use of the site would cause significant disturbance and would not be able to developed in a manner that delivered positive legacy outcomes.

5.2 Final Short List of Material Supply Sites

The next step in the process was to determine a short list of Material Supply Sites based on the outcomes of the long list process. The final short list of Material Supply Sites and the reason they were selected is set out in Table 4.5.6. A total of fourteen sites were discarded as they were fatally flawed as part of the "Tread lightly, with Whenua" assessment criteria. The majority of the potential rock source sites were included in these discarded sites.

Table 4.5.6: Final Short List of Material Supply Sites Progressed Further

Material Supply Site ID	Location (Approx. Chainage)	Traffic Light Signal Evaluation	Key Reasons for Progressing Material Supply Site
#15 (South of Waikawa Stream)	26500 - 27100	Green – Orange	There are no 'red' traffic light signals for this site. There are a six 'orange' signals relating to: air quality; archaeology; transport; contaminated land; social and high class soils. Archaeology would turn 'green' if testing determines no site present/destroyed or bounds of site identified and avoided.
#19 North of Waikawa Stream)	25700 - 26100	Green – Orange	There are no 'red' traffic light signals for this site. There are six 'orange' signals relating to: freshwater ecology; terrestrial ecology; transport; contaminated land; social and high class soils. Freshwater ecology would turn 'green' if a 20m setback from stream and transport if an alternative access considered. The remainder of the signals are 'green'.
#36 North of Ohau River	22000	Green	There are no 'red' traffic light signals for this site. All signals are 'green' apart from two 'orange'' signals (air quality & social) primarily due to possible air quality effects on nearby crops and impacts on a large area of farmland and one house.
#34a	12000	Green	There are no 'red' traffic light signals for this site. All signals are 'green' apart from three 'orange' signals relating to: landscape, social & water quality.

The next step of the process involved undertaking geotechnical investigations of the short-listed sites (where land access was available) to confirm geotechnical assumptions to provide a higher level of confidence regarding material available. The outcomes of these geotechnical investigations are summarised in Section 6 below, with further technical information contained within the memorandums within **Appendix 4.5.4**.

At the same time iwi partners undertook a review of the process so far and, in discussions with ecologists, hydrogeologists, hydrologists and water quality experts, confirmed that short listed sites were appropriate.

During this review, iwi identified an opportunity for a wetland or lake to be created at site #36 that would meet the legacy outcome focus of the Project. This opportunity was investigated further to determine whether creating a wetland or open water area is feasible from a hydrology and flood management perspective, and whether there would be any adverse environmental effects on groundwater conditions, and in particular Lake Papaitonga and Punahau/Lake Horowhenua. Creating an open water area also provides an off-setting opportunity for the loss of open water from the Project. A workshop was held with relevant experts to consider at a high-level whether it was feasible for the site to be developed as a wetland or open water area, with no adverse environmental effects on Lake Papaitonga or Punahau/Lake Horowhenua. The hui concluded a wetland on the site was feasible from a hydrological perspective.

Conceptual designs on the short-listed sites were prepared showing a possible extent of excavations, contours, access etc, along with initial, high level, indicative concepts, to illustrate rehabilitation options and to test the opportunities to preserve, restore, enhance and create positive outcomes at each of the sites. These draft designs are shown in the initial concept drawings included in **Appendix 4.5.2**.

The initial concept drawings of the short listed sites were then provided to the technical specialist assessors to undertake a more detail assessment to determine if there were any environmental effects relevant to their area of discipline. **Appendix 4.5.3** collates the responses from the experts in a table format, with a summary of the assessments provided in Section 6 below.

In response to a number of matters raised in the detail assessment of concept drawings provided by experts, the perimeter extent of each of the short-listed Material Supply Sites were reviewed and refined.

6 Preferred Material Supply Sites

6.1 General description

The resultant short list of Material Supply Sites (identified in Table 4.5.3 above) have been chosen as they provide opportunity to develop an end form landscape that has similar characteristics to the current environment.

For the 3 alluvial sites (site #15, #19 and #36), the work can be designed so that the position of existing terraces are moved horizontally in manner that retains /mimics existing riverine sinuosity. These sites are all carefully located to avoid direct effects on water courses and no adverse effects on groundwater are anticipated (to be confirmed by proposed geotechnical investigations and future assessment during detailed design).

For the Qb5 sand site (site #34a), the existing wetland can be enhanced and restored. There will be no additional effects on groundwater, water, native bush / trees (the area impacted is in grass) and wetlands.

Sites were also selected on the basis that they could provide a positive legacy outcome. For example, as discussed above, there is an opportunity to develop a wetland on site #36 as a legacy outcome for the Ō2NL Project with no adverse effects on groundwater conditions.

The final short-listed sites are all located within the Horizons RC and Horowhenua DC areas of jurisdiction.

The following sections provide a description of the final short-listed sites, a summary of the geotechnical investigation that were undertaken, and the required actions that were identified from Technical Specialist assessment.

6.2 Site #15 – South of Waikawa Steam

6.2.1 Geotechnical Assessments

6.2.1.1 Topography / Slope Landform / Surface Conditions

This site lies on the floodplain, slightly elevated from the contemporary bed of the Waikawa Stream. Topography at the site is flat to very gently sloping towards the terraced slopes above the Waikawa river.

Two drainage channels cut through the site, in a north-south and a south-west to north-east orientation. The channels are typically 1m across and up to 1m deep. The site is currently used as grazing farmland.

Figure 4.5.4 shows the borrow site area (enclosed within the dashed blue line) in the context of the published geological map (Begg & Johnston, 2000) and the nearby site investigations

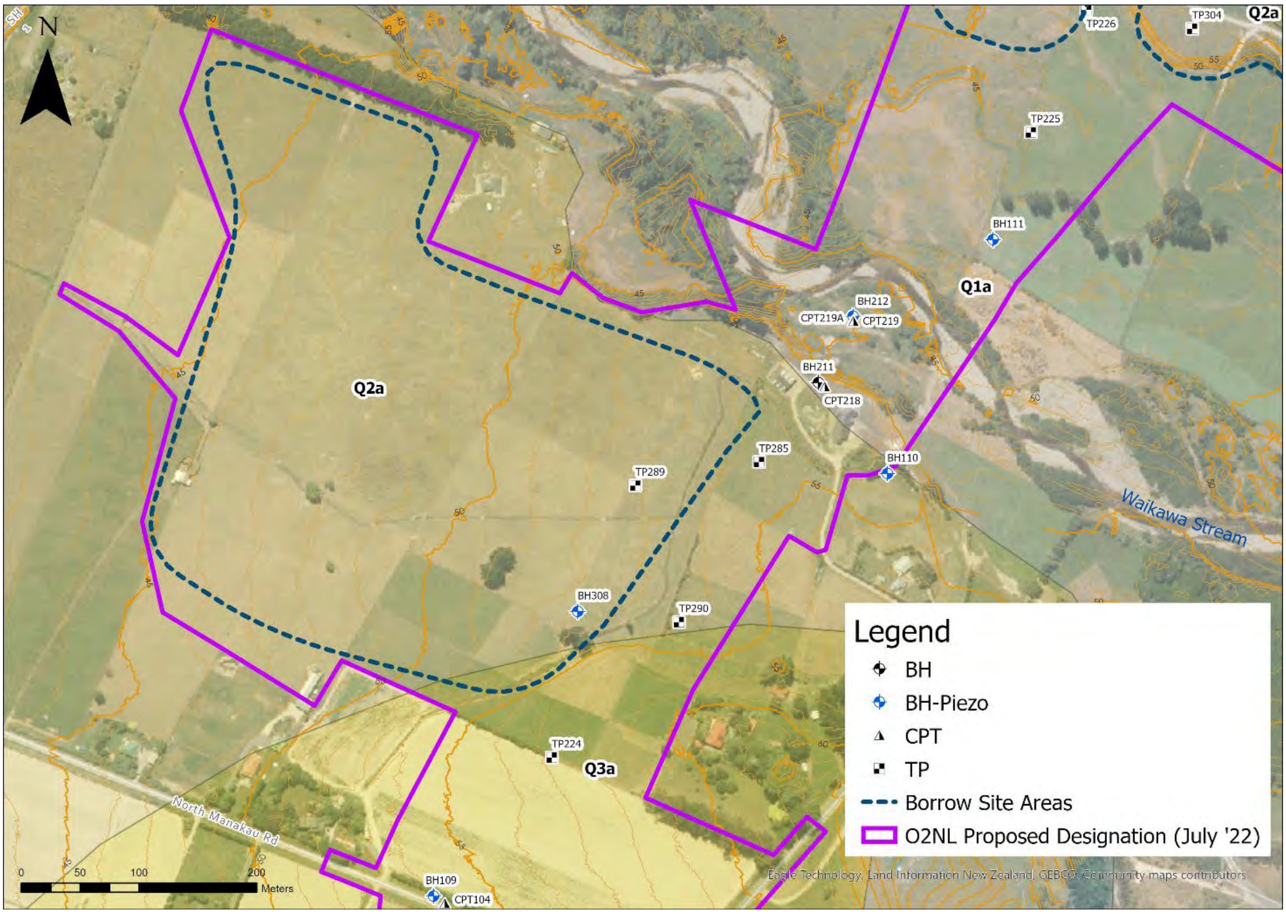


Figure 4.5.4: Site plan - South of Waikawa Stream

6.2.1.2 Subsurface Conditions and Geologic Interpretations

The Waikawa Stream South Site is shown on the GNS 1:250,000 Geology map of New Zealand to be situated in the Q2a Pleistocene alluvium geological unit. Table 4.5.7 presents the available investigation data for the site.

Table 4.5.7: Summary of Site Investigations – South of Waikawa Stream

Investigation ID	Investigation Type	Coordinates (NZTM 2000)		Elevation (m RL, WGN 1953)	Approx. Chainage	Termination Depth (m BGL)	Depth where Gravels of Interest Encountered (m BGL)
		Easting	Northing				
BH109	Borehole	1788177	5491389	54.2	27094	30.45	3.45 – 30.45
BH210	Borehole	1788248	5491362	55.1	27095	30.45	2.90 – 30.45
BH211	Borehole	1788504	5491825	52.6	26559	34.95	1.50 – 34.95
BH308	Borehole	1788300	5491630	52.5	26822	15.35	1.50 – 15.35
TP224	Test pit	1788278	5491507	57.3	26950	3.80	2.40 – 3.80
TP223*	Test pit	1788190	5491191	51.0	27277	3.60	2.10 – 3.60
TP285	Test pit	1788454	5491758	54.2	26644	3.80	0.30 – 3.80
TP289	Test pit	1788349	5491738	52.9	26709	3.40	0.10 – 3.40
TP290	Test pit	1788386	5491622	53.8	26796	3.50	0.05 – 3.50
CPT104	CPT	1788187	5491383	54.3	27096	3.24	Refusal on gravels?
CPT217	CPT	1788251	5491359	55.4	27097	11.34	Refusal on gravels?
CPT218	CPT	1788509	5491822	52.8	26559	1.53	Refusal on gravels?

The expected ground conditions at the area of interest based on the forementioned investigations is summarised in Table 4.5.8 below.

Table 4.5.8: Waikawa Stream South Site Expected Ground Conditions

Unit Name	Description	Typical Depth to the Top of Layer (m bgl)	Typical Thickness Range (m)	SPT 'N' Range (average)
Q2a/Qa3 Pleistocene Alluvium – Undifferentiated	Medium dense to very dense, silty GRAVEL with minor clay and sand layers	0 - 6	13 - 15	0 – 50 (16)

BH308 has the only piezometer within the proposed area. Groundwater levels have varied from 4.9 to 6.9m BGL, with measurements undertaken towards the end of summer when the water table is likely to be depressed. The ground water level may be higher during winter months.

Ponded water was observed within surface depressions during site visits in October 2021, but these were perceived as perched.

6.2.2 Actions resulting from Technical Specialist assessment

The detail assessment of Site #15 confirmed there were no significant environmental effects on flooding and hydrology; freshwater ecology; terrestrial ecology; archaeology; noise and vibration; landscape & visual; heritage; water quality; groundwater; and erosion and sediment control.

Actions resulting from Technical Specialist assessment include:

- Air Quality – perimeter extent of Site #15 has been changed to exclude the residential property from within the site; any dust effects would be managed through a Construction Management Plan; alternative water supplies can be made available if required.
- Transport - traffic effects will be managed through a Construction Traffic Management Plan, site controls and timeframes for material extraction.

- Contaminated Land – the perimeter extent of Site #15 has been modified to avoid a potential dump, but this will need be confirmed through further investigations.
- Social - perimeter extent of Site #15 has been changed to exclude the residential property from within the site; the changed perimeter extent goes further west; the rehabilitation of the site would see approximately 1/3 of the site (to the west) be restored to pasture; the remainder of the site will include landscape and visual planting, restoration wetlands and future access to Waikawa Stream and a recreation reserve via the Shared Use Path has positive community benefits.
- High Class Soils – while there will be a loss of high class soils, it is proposed to reinstate approximately 1/3 of the site (to the west) into pasture.

These actions have been taken or are included as planned management regimes within the Assessment of Environmental Effects.

6.3 Site #19 – North of Waikawa Stream

6.3.1 Geotechnical Assessments

6.3.1.1 Topography / Slope Landform / Surface Conditions

The topography of the site is flat to very gently sloping towards the Waikawa Stream to the south. The southern-most extent of the site is bounded by an alluvial terrace approximately 7m higher in elevation. A small drainage channel spanning 1m across and 1m deep passes from north-west to south-east through the site and connects to a tributary of the Waikawa Stream approximately 300m south of the site. The site is currently used as grazing farmland and crop paddocks.

Figure 4.5.5 shows the borrow site areas (enclosed within the blue dashed lines) in the context of the published geological map (Begg & Johnston, 2000).

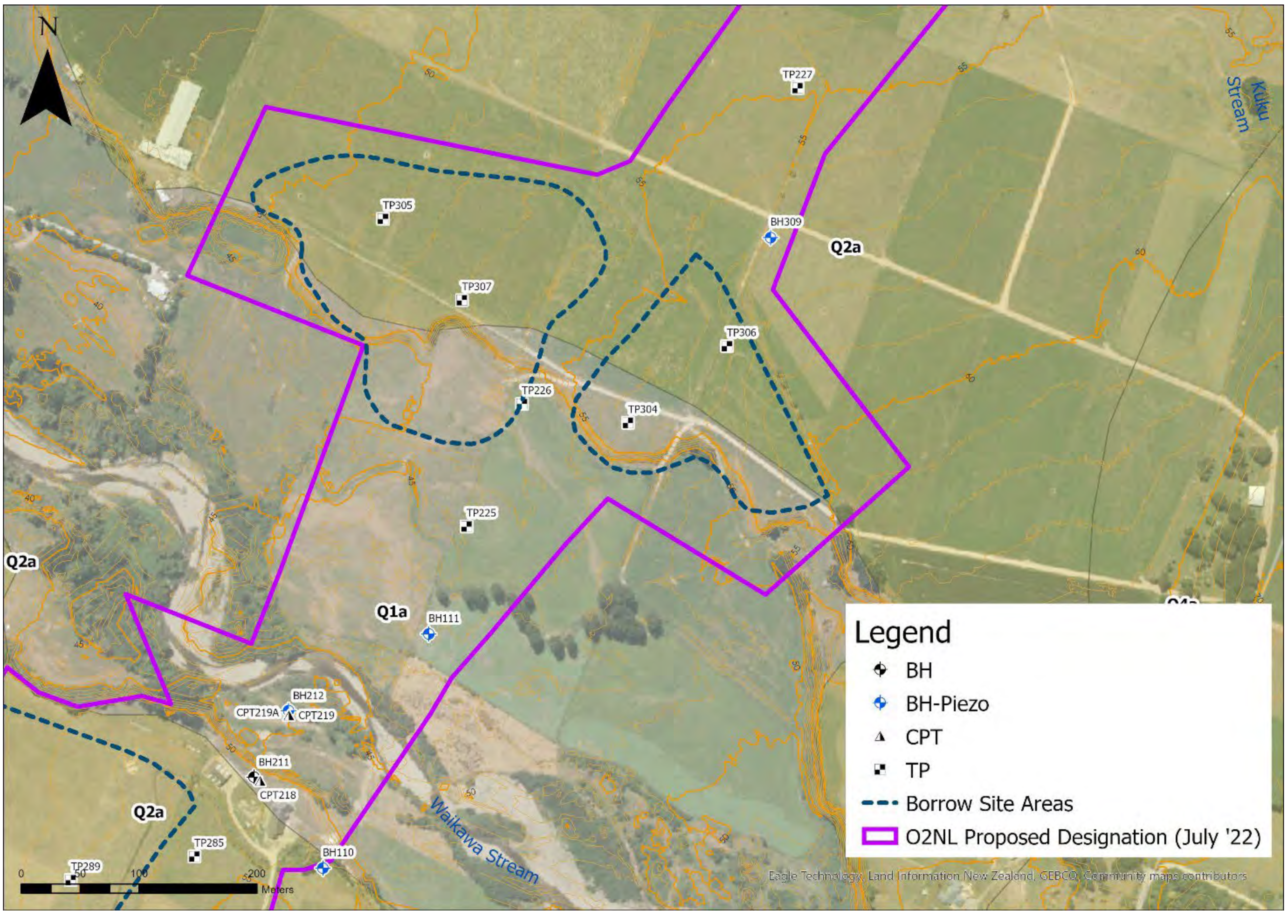


Figure 4.5.5: Site plan - North of Waikawa Stream

6.3.1.2 Subsurface Conditions and Geologic Interpretations

The Waikawa Stream North Site is shown on the GNS 1:250,000 Geology map of New Zealand to be situated in the Q2a Pleistocene alluvium geological unit. Table 4.5.9 presents the available investigation data for the site.

Table 4.5.9: Summary of Site Investigations - North of Waikawa Stream

Investigation ID	Investigation Type	Coordinates (NZTM 2000)		Elevation (m RL, WGN 1953)	Approx. Chainage	Termination depth (m BHL)	Depth where Gravels of Interest Encountered (m BGL)
		Easting	Northing				
BH309	Borehole	1788943	5492283	56.9	25918	15.45	1.65 – 15.45
TP304	Test Pit	1788822	5492126	56.4	26116	3.5	1.6 – 3.5
TP305	Test Pit	1788614	5492299	51.9	26110	3.4	0.6 – 3.4
TP306	Test Pit	1788906	5492191	56.5	26013	3.2	1.2 – 3.2
TP307	Test Pit	1788681	5492230	53.0	26122	3.5	0.8 – 3.5
TP226	Test Pit	1788732	5492142	46.2	26159	3.9	0.6 – 2.7
TP227	Test Pit	1788966	5492410	54.8	25804	4.1	2.1 – 4.1

The expected ground conditions at the area of interest based on the forementioned investigations is summarised in Table 4.5.10 below.

Table 4.5.10: Waikawa Stream North Site Expected Ground Conditions

Unit Name	Description	Typical Depth to the Top of Layer (m bgl)	Typical Thickness Range (m)	SPT 'N' Range (average)
Loess	Stiff, clayey SILT, moderate to high plasticity.	0	0.5 – 1.5	-
Q2a/Q3a Pleistocene Alluvium	Medium dense to very dense, silty GRAVEL with minor clay and sand layers.	0 - 6	13 - 15	0 – 50

Groundwater levels have been measured in the piezometer within BH309.

Groundwater levels varied from 10.3 to 13.0m BGL, with groundwater measurement undertaken towards the end of summer when the water table is likely to be depressed. The ground water level may be higher during winter months. The nearby BH111 has also recorded groundwater level depth >10m BGL.

6.3.2 Actions resulting from Technical Specialist assessment

The detail assessment of Site #19 confirmed there were no significant environmental effects on flooding and hydrology; air quality; archaeology; noise & vibration; landscape & visual; heritage; water quality; groundwater; high class soils; and erosion and sediment control.

Actions resulting from Technical Specialist assessment include:

- Freshwater Ecology – southern boundaries have been adjusted to provide a buffer to Stream 27.1; ESC Plan manages sediment on eastern boundary close to Stream 28
- Terrestrial Ecology – western boundary amended to avoid small area of vegetation, trees on eastern side to be identified.
- Transport - traffic effects will be managed through Construction Traffic Management Plan; an alternative new accessway onto SH1 from Kuku East Rd should be investigated as part of this plan.

- Contaminated Land – further investigation of the low point of the site to be undertaken.
- Social – planting included to manage potential visual effects on two houses.

These actions have been taken or are included as planned management regimes within the Assessment of Environmental Effects.

6.4 Site #36 – North East of Ohau River

6.4.1 Geotechnical Assessments

6.4.1.1 Topography / Slope Landform / Surface Conditions

The site is relatively flat with small hummocks representing historical river or stream banks. The southernmost extent of the site is bounded by a series of small alluvial terraces that extend to the active river channel. The site is currently used as grazing farmland and crop paddocks.

Figure 4.5.6 shows the borrow site area (enclosed within the blue dashed line) in the context of the published geological map (Begg & Johnston, 2000).

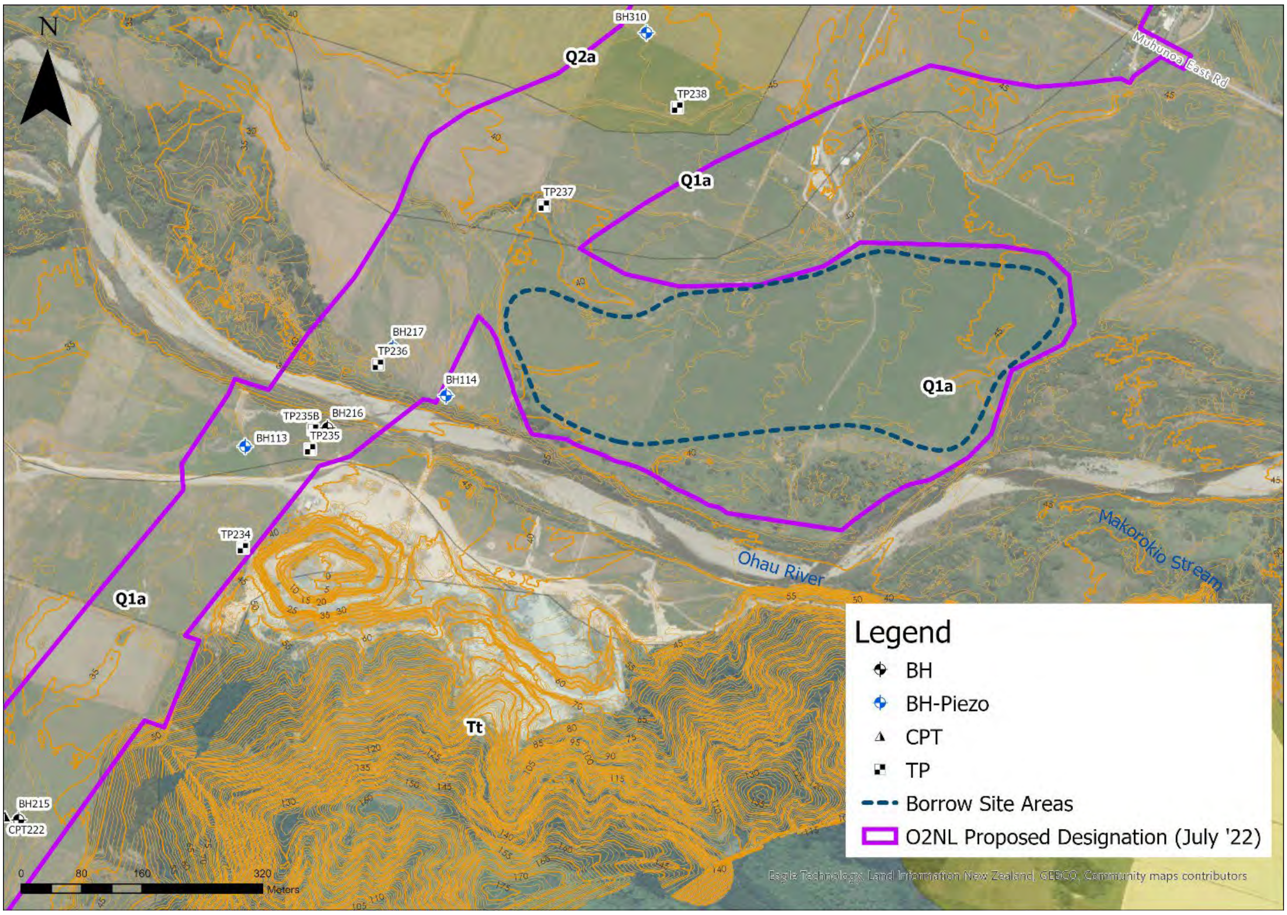


Figure 4.5.6: Site plan - Northeast of Ōhau River

6.4.1.2 Subsurface Conditions and Geologic Interpretations

The Ohau River North east Site is shown on the GNS 1:250,000 Geology map of New Zealand to be situated within the Q1a Holocene alluvium geological unit.

This area was not targeted during the 2022 Stage 3 investigations due to late identification of this Material Supply Site. We have interpreted the nearby investigations which are generally within the designation corridor, north of the Ohau River. The actual ground conditions at the site may be different than described and this site has increased risk of unknown geological and groundwater conditions.

Table 4.5.11 presents a summary of the relevant intrusive investigations completed near the area of interest.

Table 4.5.11: Summary of nearby site investigations - Northeast of Ohau River

Investigation ID	Investigation Type	Coordinates (NZTM 2000)		Elevation (m RL, WGN 1953)	Approx. Chainage	Termination Depth (m BGL)	Depth where Gravels of Interest Encountered (m BGL)
		Easting	Northing				
BH114	Borehole	1791048	5494886	38.5	22560	27.0	0.2 – 25.5
BH217	Borehole	1790977	5494949	37.9	22560	35.0	1.5 – 27.0
TP236	Test Pit	1790958	5494927	38.2	22590	4.0	0.2– 4.0
TP237	Test Pit	1791178	5495138	39.1	22281	3.6	1.3 – 3.6
TP238	Test Pit	1791355	5495268	44.2	22058	3.8	0.3 – 3.8
TP310	Test Pit	1791543	5495415	47.1	21827	3.0	0.1 – 3.0

The expected ground conditions at the area of interest based on the forementioned investigations is summarised in Table 4.5.12 below.

Table 4.5.12: Ohau River North East Site Expected Ground Conditions

Unit Name	Description	Typical Depth to the Top of Layer (m bgl)	Typical Thickness Range (m)	SPT 'N' Range (average)	Qc Range
Q1a Holocene Alluvium	Silty sandy GRAVEL, with cobbles, loose to very dense.	0	5 - 12	10 - 50+	Q1a Holocene Alluvium

6.4.2 Actions resulting from Technical Specialist assessment

The detail assessment of Site #36 confirmed there were no significant environmental effects on flooding and hydrology; freshwater ecology; terrestrial ecology; air quality; archaeology; transport; noise & vibration; contaminated land; landscape & visual; heritage; water quality; groundwater; and erosion and sediment control.

Actions resulting from Technical Specialist assessment include:

- Social – any dust and noise effects on house will be managed through a Construction Management Plan; rehabilitation planting included with ecology and natural character mitigation.

6.5 Site #34a – Koputaroa

6.5.1 Geotechnical Assessments

6.5.1.1 Topography / Slope Landform / Surface Conditions

The site is positioned on the northern edge of a gully, which has incised from the adjacent terrace. The terrace is undulating with moderately sloping hills. A farm dam is located at the western extent of the gully as forms a small pond.

Figure 4.5.7 shows the borrow site area (enclosed within the blue dashed line) in the context of the published geological map (Begg & Johnston, 2000).

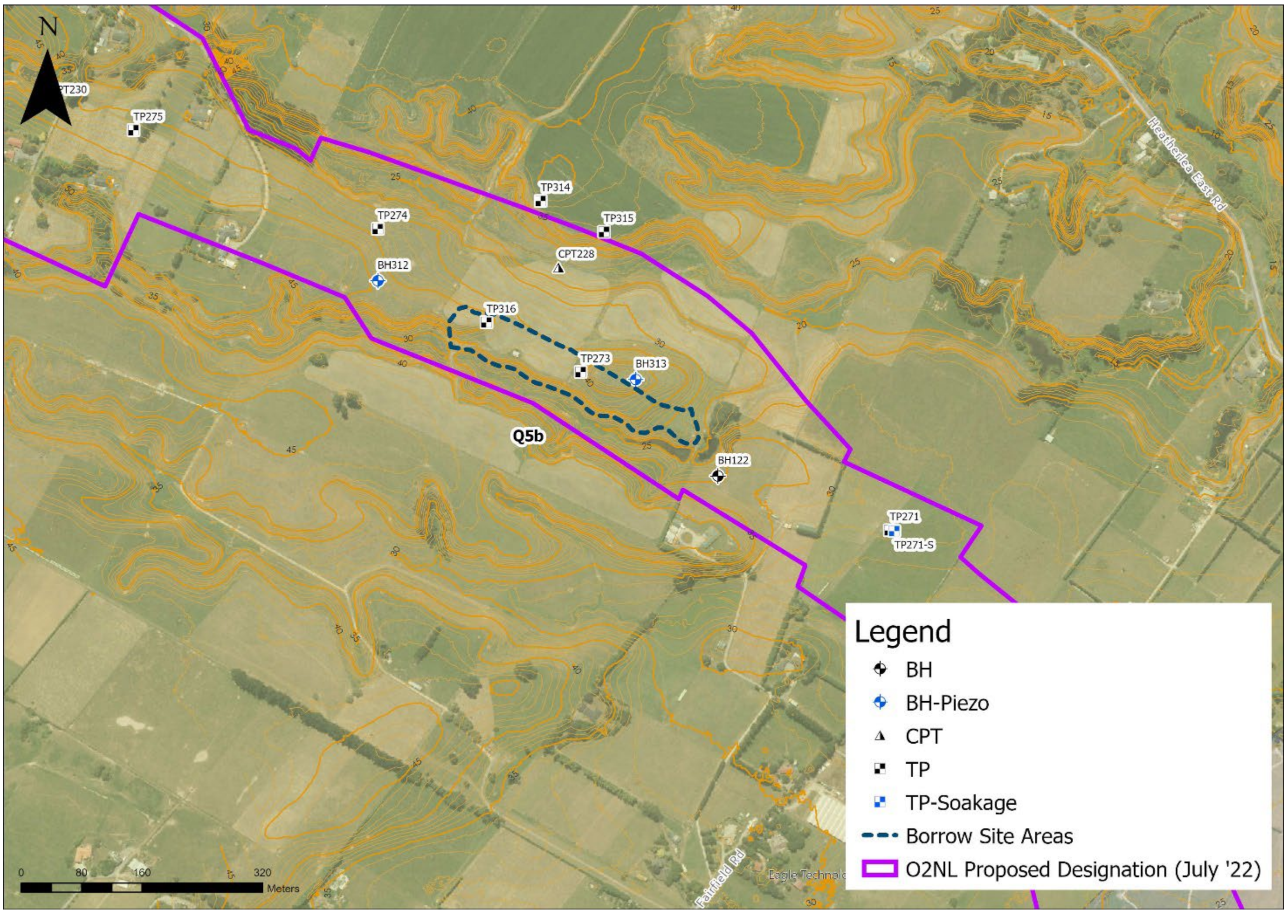


Figure 4.5.7: Site plan - Koputaroa

6.5.1.2 Subsurface Conditions and Geologic Interpretations

The Koputaroa Site is shown on the GNS 1:250,000 Geology map of New Zealand to be situated within the Q5b Shoreline Deposits geological unit.

Table 4.5.13 presents a summary of the relevant intrusive investigations completed near the area of interest.

Table 4.5.13: Summary of Nearby Site Investigations – Koputaroa Site

Investigation ID	Investigation Type	Coordinates (NZTM 2000)		Elevation (m RL, WGN 1953)	Approx. Chainage	Termination Depth (m bgl)
		Easting	Northing			
BH122	Borehole	1796056	5502678	29.5	12150	19.78
BH312	Borehole	1795605.0	5502937.0	45.5	11559	15.45
BH313	Borehole	1795947.0	5502806.0	44.1	11933	15.38
TP273	Test Pit	1795874	5502816	38.0	11850	3.50
TP274	Test Pit	1795605	5503006	38.5	11550	3.90
TP275	Test Pit	1795281	5503137	41.7	11200	3.20
TP276	Test Pit	1795027	5503350	49.2	10850	3.90
TP314	Test Pit	1795821	5503043	38.2	11717	3.50
TP315	Test Pit	1795905	5503002	36.7	11805	3.50
TP316	Test Pit	1795749	5502882	41.2	11716	3.40

The expected ground conditions at the area of interest based on the forementioned investigations is summarised in Table 4.5.14 below.

Table 4.5.14: Koputora Site Expected Ground Conditions

Unit Name	Description	Typical Depth to the Top of Layer (m bgl)	Typical Thickness Range (m)	SPT 'N' Range (average)
Loess	Silty CLAY, firm to very stiff, moist, low to moderate plasticity.	0	1 - 3	-
Q5b Pleistocene Shoreline Deposits	*Fine to medium SAND, some silt, medium dense to very dense. Density typically increases with depth.*	*1 - 3*	*20+*	*10 – 50+*

Groundwater levels have been measured in the piezometer within BH312 and BH313. Groundwater levels have varied from 7.3 to 11.3m BGL. It is perceived that this represents a perched groundwater within the terrace.

6.5.2 Actions resulting from Technical Specialist assessment

The detail assessment of Site #34a confirmed there were no significant environmental effects on flooding and hydrology; freshwater ecology; terrestrial ecology; air quality; archaeology; transport; noise & vibration; contaminated land; heritage; groundwater; high class soils; and erosion and sediment control. It was noted that while there were no significant archaeology, potentially this site has a likely archaeological site in the vicinity.

Actions resulting from Technical Specialist assessment include:

- Landscape - mitigated through planting batter below highway and the restoration planting suggested;
- Social – overall landscape mitigation proposed for corridor manage effects on nearby house(s);
- Water Quality - potential sediment discharges will be managed through standard erosion and sediment control included in the ESC Plan; potential impacts on water temperature will be addressed by stream and wetland revegetation already proposed as part of the Project.

These actions have been taken or are included as planned management regimes within the Assessment of Environmental Effects.

7 Recommendations for Future Works

7.1 Geotechnical Investigations

Additional geotechnical investigations are recommended at each of the preferred sites to; confirm groundwater levels, ascertain spatial variability of the subsurface material, and ensure the excavated material will be fit for purpose. The information obtained will also be used to confirm the temporary and permanent design of the sites.

7.2 Design

7.2.1 Temporary works

Temporary design will need to incorporate:

- Erosion and Sediment Control measures
- Final Construction Methodology, including
    - Any staged excavations
    - Areas in which spoiled material is used for recontouring

7.2.2 Permanent

Permanent design will need to incorporate:

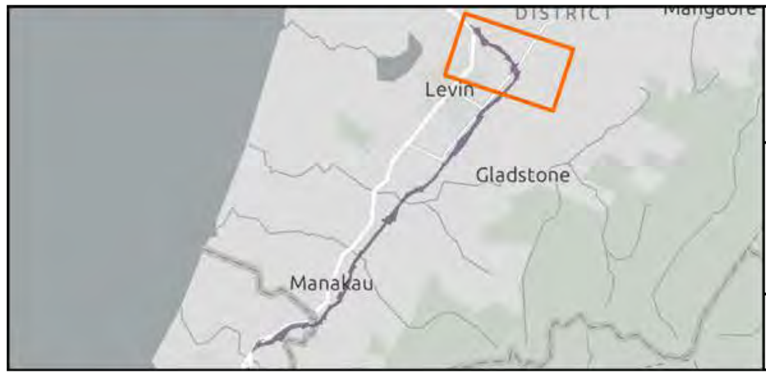
- Final volume demands required from the Project
- The principles developed during this study and included in the CEDF
- Drainage considerations

Appendices

We design with community in mind

Appendix 4.5.1 Summary of the Long List Assessment

Figures Illustrating "Long List" Locations



Stantec

O2NL Material Supply - Long List

Zone 1: SH1 to SH57

WAKA KOTAHI NZ TRANSPORT AGENCY

- O2NL Proposed Designation 20210729
- O2NL Potential Material Supply Sites
- O2NL Potential Material Supply Sites Access Routes
- 10m Contours
- River / Stream
- Property Parcels
- Roads

Data Sources: Stantec, Land Information New Zealand
Basemap Service Credits: Eagle Technology, LINZ, StatsNZ, NIWA, Natural Earth, © OpenStreetMap contributors., LINZ, Stats NZ, Eagle Technology, Esri, HERE, Garmin, FAO, METI/NASA, USGS
Coordinate System: NZGD 2000 New Zealand Transverse Mercator

Author: rmcpherson, Stantec (2022)
Project Code: 310203848
Export Date: 2022-01-19 1:35 PM

Stantec

O2NL Material Supply - Long List

Zone 2: SH57 to Queen St

WAKA KOTAHI NZ TRANSPORT AGENCY

- O2NL Proposed Designation 20210729
- O2NL Potential Material Supply Sites
- O2NL Potential Material Supply Sites Access Routes
- 10m Contours
- River / Stream
- Property Parcels
- Roads

Data Sources: Stantec, Land Information New Zealand
Basemap Service Credits: Eagle Technology, LINZ, StatsNZ, NIWA, Natural Earth, © OpenStreetMap contributors., LINZ, Stats NZ, Eagle Technology, Esri, HERE, Garmin, FAO, METI/NASA, USGS
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Project Code: 310203848
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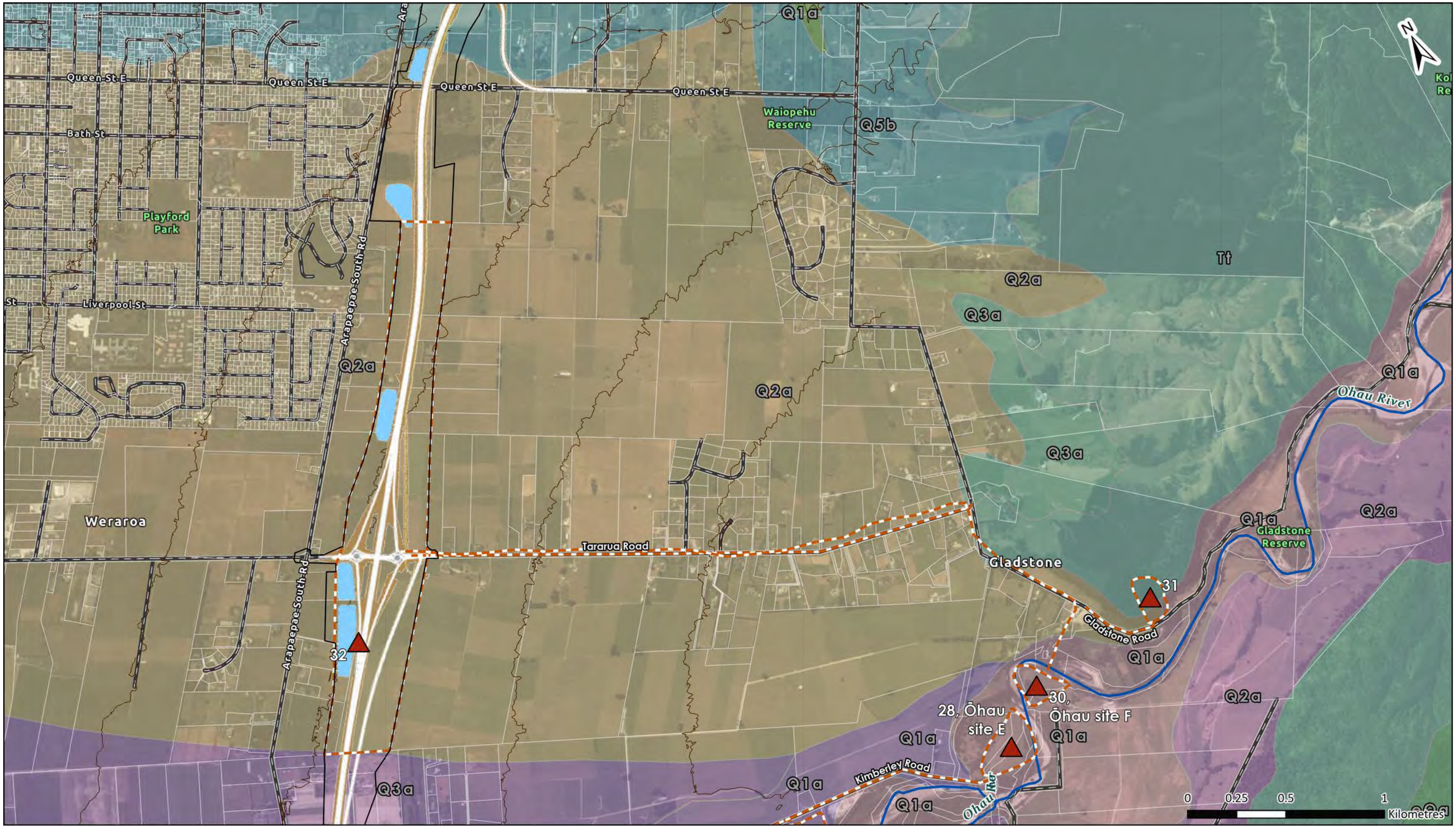

O2NL Material Supply - Long List

Zone 3: Queen St to Lutz Property Boundary

Stantec

WAKA KOTAHI NZ TRANSPORT AGENCY

- O2NL Proposed Designation 20210729
- O2NL Potential Material Supply Sites
- O2NL Potential Material Supply Sites Access Routes
- 10m Contours
- River / Stream
- Property Parcels
- Roads

Data Sources: Stantec, Land Information New Zealand
Basemap Service Credits: Eagle Technology, LINZ, StatsNZ, NIWA, Natural Earth, © OpenStreetMap contributors., LINZ, Stats NZ, Eagle Technology, Esri, HERE, Garmin, FAO, METI/NASA, USGS
Coordinate System: NZGD 2000 New Zealand Transverse Mercator

Author: rmcpherson, Stantec (2022)
Project Code: 310203848
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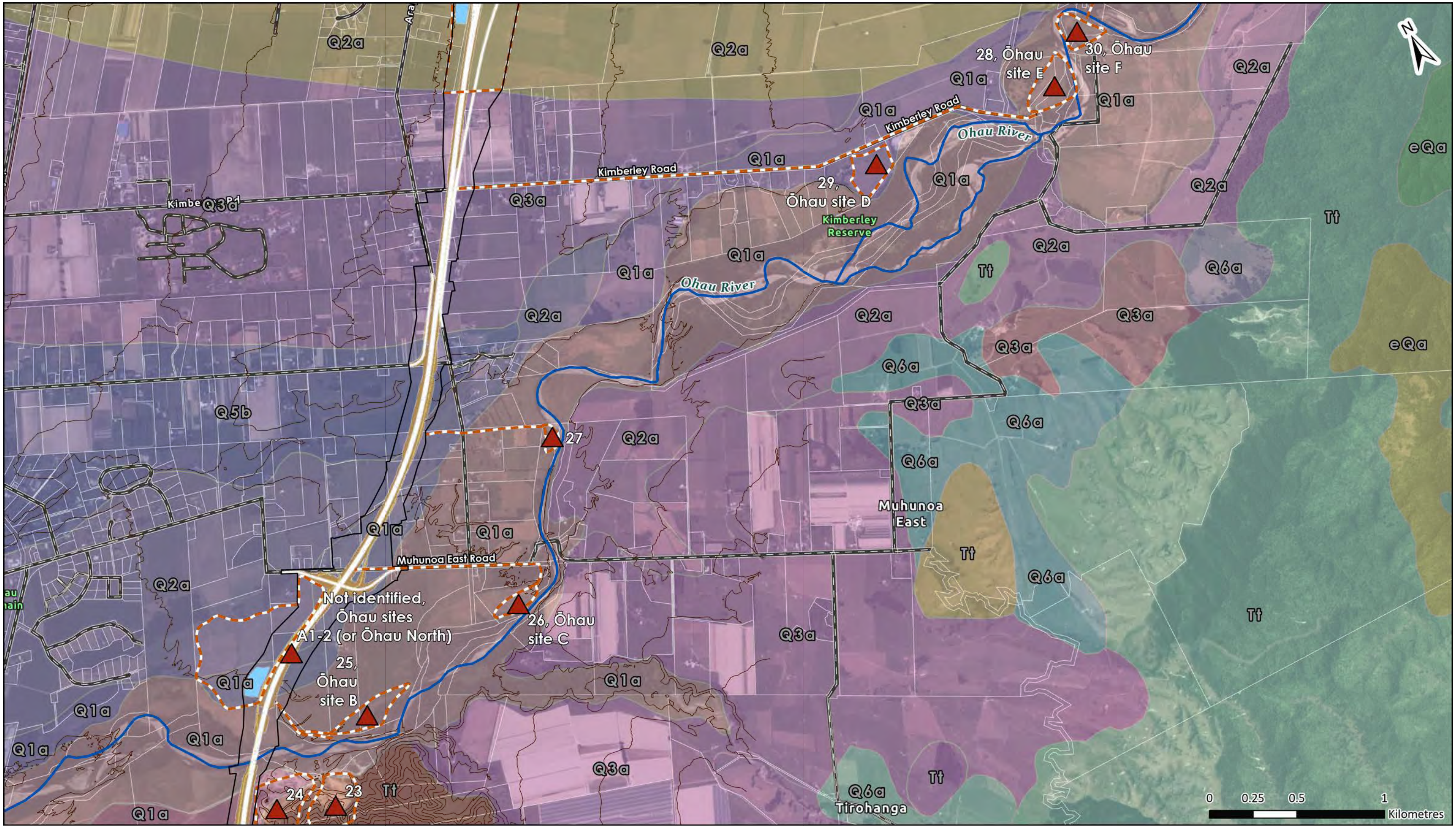

O2NL Material Supply - Long List

Zone 4: Lutz Property Boundary to Ohau River

Stantec

WAKA KOTAHI NZ TRANSPORT AGENCY

- O2NL Proposed Designation 20210729
- O2NL Potential Material Supply Sites
- O2NL Potential Material Supply Sites Access Routes
- 10m Contours
- River / Stream
- Property Parcels
- Roads

Data Sources: Stantec, Land Information New Zealand
Basemap Service Credits: Eagle Technology, LINZ, StatsNZ, NIWA, Natural Earth, © OpenStreetMap contributors., LINZ, Stats NZ, Eagle Technology, Esri, HERE, Garmin, FAO, METI/NASA, USGS
Coordinate System: NZGD 2000 New Zealand Transverse Mercator

Author: rmcpherson, Stantec (2022)
Project Code: 310203848
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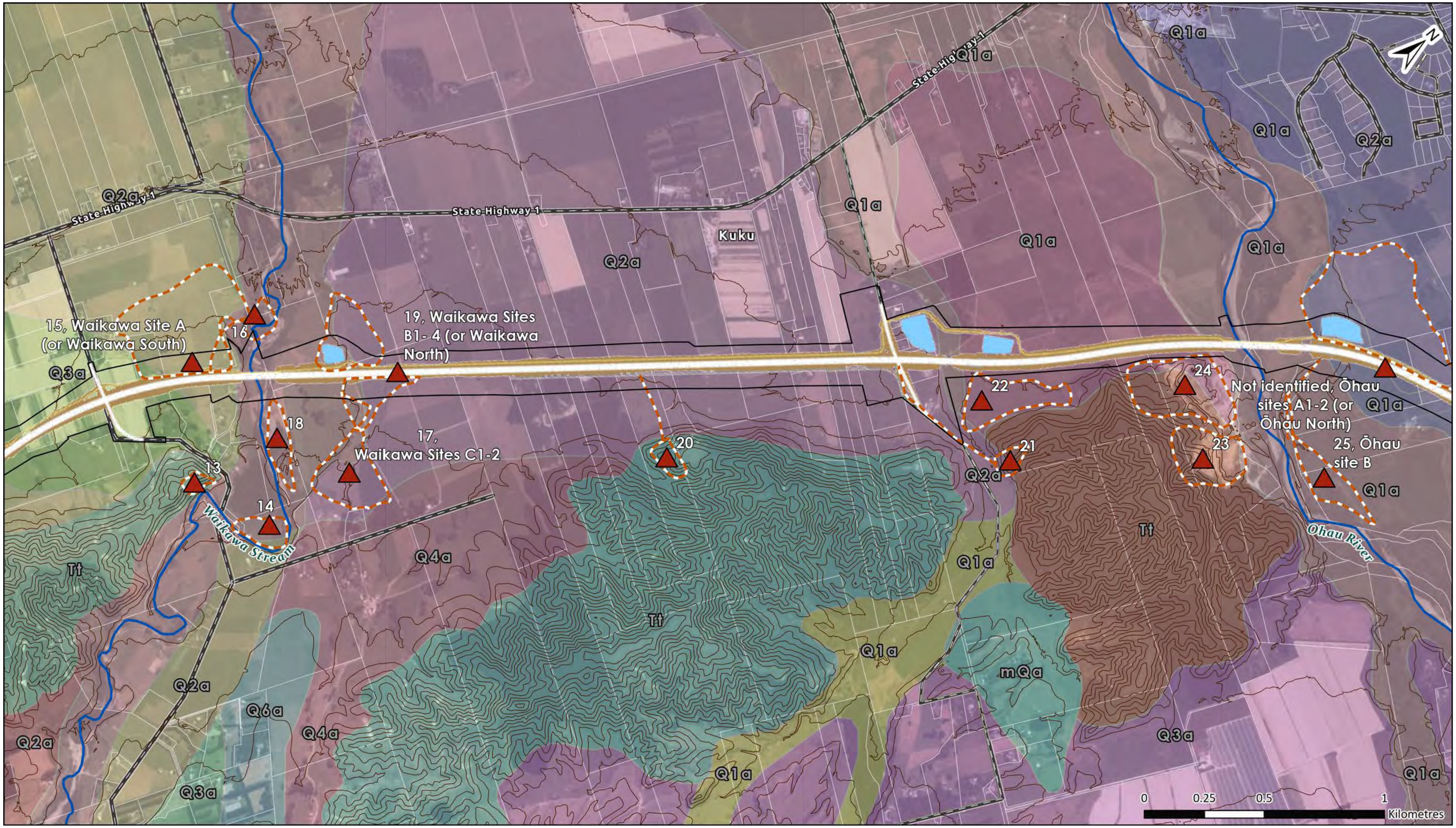


O2NL Material Supply - Long List

Zone 5: Ohau River to North Manukau Road

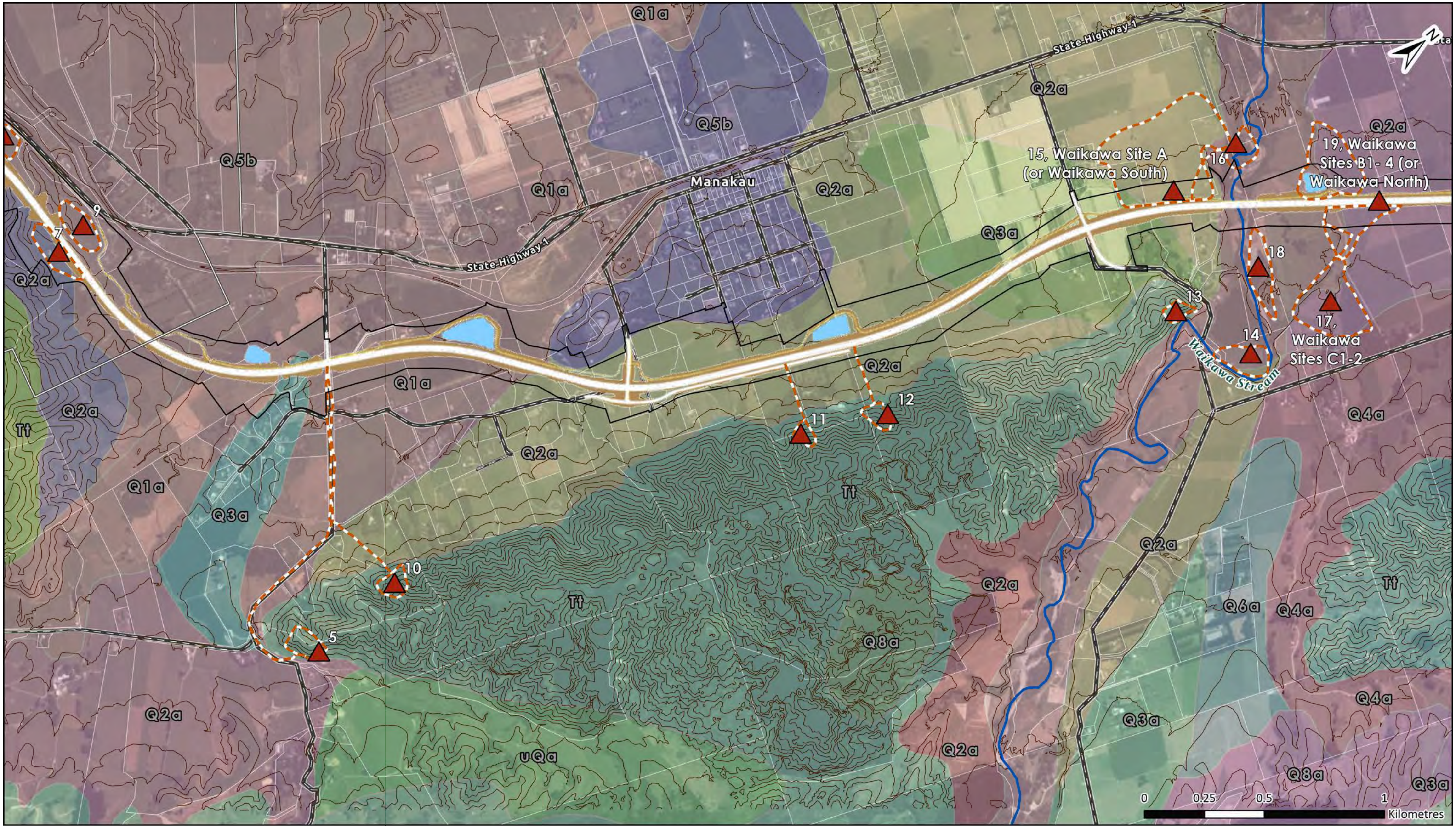
Stantec

WAKA KOTAHI NZ TRANSPORT AGENCY

- O2NL Proposed Designation 20210729
- O2NL Potential Material Supply Sites
- O2NL Potential Material Supply Sites Access Routes
- 10m Contours
- River / Stream
- Property Parcels
- Roads

Data Sources: Stantec, Land Information New Zealand
Basemap Service Credits: Eagle Technology, LINZ, StatsNZ, NIWA, Natural Earth, © OpenStreetMap contributors., LINZ, Stats NZ, Eagle Technology, Esri, HERE, Garmin, FAO, METI/NASA, USGS
Coordinate System: NZGD 2000 New Zealand Transverse Mercator

Author: rmcpherson, Stantec (2022)
Project Code: 310203848
Export Date: 2022-01-19 1:35 PM



O2NL Material Supply - Long List

Zone 6: North Manukau Road to Regional Boundary

- O2NL Proposed Designation 20210729
- O2NL Potential Material Supply Sites
- O2NL Potential Material Supply Sites Access Routes
- 10m Contours
- River / Stream
- Property Parcels
- Roads

Data Sources: Stantec, Land Information New Zealand
Basemap Service Credits: Eagle Technology, LINZ, StatsNZ, NIWA, Natural Earth, © OpenStreetMap contributors., LINZ, Stats NZ, Eagle Technology, Esri, HERE, Garmin, FAO, METI/NASA, USGS
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Author: rmcpherson, Stantec (2022)
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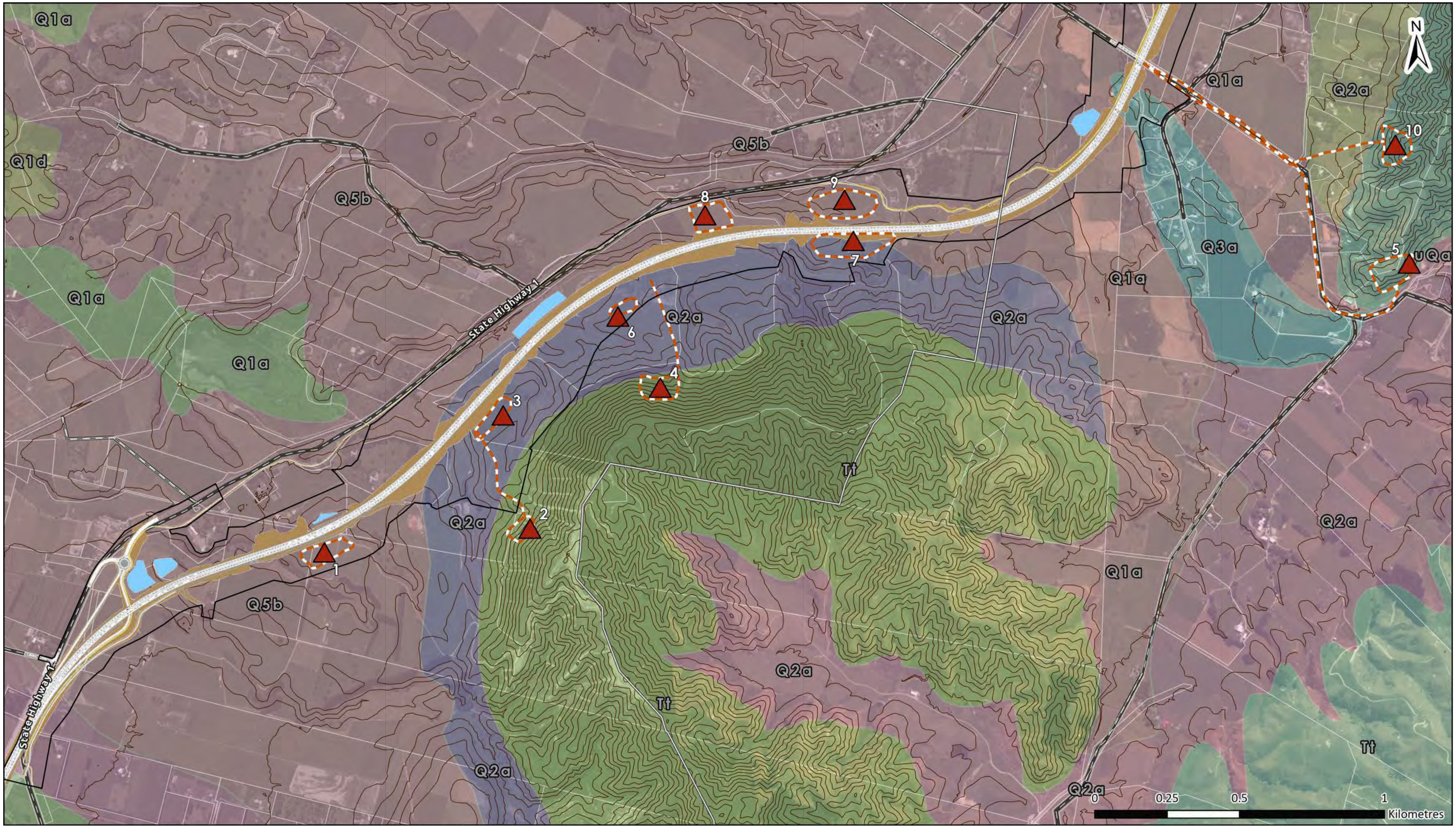


Stantec

O2NL Material Supply - Long List

Zone 7: Regional Boundary to SH1

WAKA KOTAHI NZ TRANSPORT AGENCY

O2NL Proposed Designation 20210729
O2NL Potential Material Supply Sites
O2NL Potential Material Supply Sites Access Routes
10m Contours
River / Stream
Property Parcels
Roads

Data Sources: Stantec, Land Information New Zealand
Basemap Service Credits: Eagle Technology, LINZ, StatsNZ, NIWA, Natural Earth, © OpenStreetMap contributors., LINZ, Stats NZ, Eagle Technology, Esri, HERE, Garmin, FAO, METI/NASA, USGS
Coordinate System: NZGD 2000 New Zealand Transverse Mercator

Author: rmcpherson, Stantec (2022)
Project Code: 310203848
Export Date: 2022-01-19 1:35 PM

IWI Partners Matrix Assessment

Site ID (Long List Aug'21)	New Site ID (Nov'21)	Geology	Location	Tread Lightly, with the whenua (18)						Enduring Legacy (7)			Total (25)	Notes
				Earthworks (3)	Proximity (3)	Waterways (3)	Historical (3)	Ecology (3)	Disruption (3)	Revegetation (3)	Hazard management (1)	Community benefits (3)		Refer to Material Supply Whānau pack Draft D 22nd Feb 2022 for explanation of criteria noting summary titles e.g.
Sand sites - refer to Material Supply- Q5b Shoreline deposits, powerpoint update 9th March 2022														Minimise impact on the Community = 'Disrptuion in this table
~~1~~	~~Pukehou~~	~~Sand sources~~		~~2~~	~~3~~	~~1~~	~~tbc~~	~~2~~	~~2~~	~~2~~	~~NA~~	~~0~~	~~12~~	NO LONGER REQUIRED. No hīkoi, concern re impact on wetlands below, no SUP proximity.
~~3~~	~~Pukehou~~	~~Sand sources~~		~~2~~	~~3~~	~~1~~	~~tbc~~	~~2~~	~~2~~	~~2~~	~~NA~~	~~0~~	~~12~~	NO LONGER REQUIRED. No hīkoi, concern re impact on wetlands below, no SUP proximity
~~6~~	~~Pukehou~~	~~Sand sources~~		~~2~~	~~3~~	~~1~~	~~tbc~~	~~2~~	~~2~~	~~2~~	~~NA~~	~~0~~	~~12~~	NO LONGER REQUIRED. no hīkoi, concern re impact on wetlands below, no SUP proximity
~~7~~	~~Pukehou~~	~~Sand sources~~		~~2~~	~~3~~	~~1~~	~~tbc~~	~~1~~	~~1~~	~~2~~	~~NA~~	~~0~~	~~10~~	NO LONGER REQUIRED concerns re impacts on bush remnants, house removed, no SUP proximity
~~8~~	~~Pukehou-below~~	~~Sand sources~~		~~2~~	~~3~~	~~1~~	~~tbc~~	~~1~~	~~2~~	~~2~~	~~NA~~	~~1~~	~~12~~	NO LONGER REQUIRED no hīkoi, concerns re impacts on bush remnants
~~9~~	~~Pukehou- below~~	~~Sand sources~~		~~2~~	~~3~~	~~1~~	~~tbc~~	~~1~~	~~2~~	~~2~~	~~NA~~	~~1~~	~~12~~	NO LONGER REQUIRED no hīkoi, concerns re impacts on bush remnants, building removal?
34	Koputoroa	Sand sources		2	3	1	tbc	1	2	1	NA	1	11	no hīkoi, limited legacy outcomes
34a	Koputoroa	Sand sources		2	3	1	tbc	2	2	3	NA	2	15	no hīkoi, this would extend an existing wetland, ecologists comment is that this would be positive-restore/create habitat and potential access to wider mahinga kai area, whakapapa assessment required to complete the evaluation
35	Koputoroa	Sand sources		2	3	1	tbc	2	2	2	NA	0	12	no SUP proximity
Alluvial and Rock sources- refer to Material Supply Whānau pack Draft D 22nd Feb 2022														
2		Rock Sources	Pukehou				fatal flaw						0	fatal flaw notes tbc with partners
4		Rock Sources	Pukehou				fatal flaw						0	fatal flaw notes tbc with partners
5		Rock Sources	Hanawera Ridge				fatal flaw						0	fatal flaw notes tbc with partners
10		Rock Sources	Hanawera Ridge				fatal flaw						0	fatal flaw notes tbc with partners
11		Rock Sources	Hanawera Ridge				fatal flaw						0	fatal flaw notes tbc with partners
12		Rock Sources	Hanawera Ridge				fatal flaw						0	fatal flaw notes tbc with partners
13		Rock Sources	Hanawera Ridge				fatal flaw						0	fatal flaw notes tbc with partners
14		Alluvial Sources	Waikawa	2	0	1	*tbc*	2	1	3	0	0	9	no hīkoi, information on important sites, whakapapa required to complete assessment
18		Alluvial Sources	Waikawa	2	1	1	*tbc*	1	3	3	0	0	11	no hīkoi, information on important sites, whakapapa required to complete assessment
15	Waikawa Site A (or Waikawa South)	Alluvial Sources	Waikawa	2	2	2	*tbc*	3	3	3	0	1	16	information on important sites, whakapapa required to complete assessment
17	Waikawa Sites C1-2	Alluvial Sources	Kuku tributary	2	0	1	*tbc*	2	1	3	0	0	9	no hīkoi, information on important sites, whakapapa required to complete assessment
19	Waikawa Sites B1- 4 (or Waikawa North)	Alluvial Sources	Waikawa	2	2	2	*tbc*	3	3	3	0	1	16	information on important sites, whakapapa required to complete assessment
20		Rock Sources	Poroporo				fatal flaw							fatal flaw notes tbc with partners
21		Rock Sources	Ōtararere				fatal flaw							fatal flaw notes tbc with partners
22		Alluvial Sources					fatal flaw							fatal flaw notes tbc with partners
24		Rock Sources	Ōtararere				fatal flaw							fatal flaw notes tbc with partners
23		Rock Sources	Ōtararere				fatal flaw							fatal flaw notes tbc with partners
n/a	Ōhau sites A1-2 (or Ōhau North)	Alluvial Sources	Ōhau River				*fatal flaw*							fatal flaw notes tbc with partners
25	Ōhau site B	Alluvial Sources	Ōhau River	2	2	1	*tbc*	0	3	2	0	0	10	no hīkoi, information on important sites, whakapapa required to complete assessment
26	Ōhau site C	Alluvial Sources	Ōhau River	2	2	1	*tbc*	3	1	3	0	0	12	information on important sites, whakapapa required to complete assessment
27		Alluvial Sources	Ōhau River	2	2	1	*tbc*	0	3	2	0	0	10	no hīkoi, information on important sites, whakapapa required to complete assessment
~~29~~	~~Ōhau site D~~	~~Alluvial Sources~~	~~Ōhau River~~	~~2~~	~~1~~	~~3~~	~~*tbc*~~	~~3~~	~~3~~	~~2~~	~~0~~	~~0~~	~~14~~	UNAVAILABLE information on important sites, whakapapa required to complete assessment
~~28~~	~~Ōhau site E~~	~~Alluvial Sources~~	~~Ōhau River~~	~~2~~	~~1~~	~~1~~	~~*tbc*~~	~~0~~	~~3~~	~~3~~	~~0~~	~~0~~	~~10~~	UNAVAILABLE no hīkoi, information on important sites, whakapapa required to complete assessment
~~30~~	~~Ōhau site F~~	~~Alluvial Sources~~	~~Ōhau River~~	~~2~~	~~0~~	~~1~~	~~*tbc*~~	~~0~~	~~3~~	~~3~~	~~0~~	~~0~~	~~9~~	UNAVAILABLE no hīkoi, information on important sites, whakapapa required to complete assessment
31		Rock Sources	Gladstone Rd	1	0	3	*tbc*	1	0	0	0	0	5	information on important sites, whakapapa required to complete assessment
32		Alluvial Sources	East of Levin				fatal flaw							fatal flaw notes tbc with partners
33		Rock Sources	MacDonald Rd	1	1	3	*tbc*	3	2	1	0	1	12	benefits relate to future quarry, information on important sites, whakapapa required to complete assessment
36	NEW SITE	Alluvial sources	Ōhau River	3	2	1	*tbc*	3	2	3	0	2	16	no hīkoi. Repo/Roto options to be investigated during detailed design. Ecologists comment is that this would be positive-restore/create habitat including large scale open water. Legacy outcomes including access from the SUP progressed through hydrology and geotech screen. Community benefits include possible rongoa, mahinga kai source. Whakapapa assessment required to complete the evaluation

Technical Expert Traffic Light Assessment

O2NL MATERIAL SUPPLY SITES STUDY

Technical Expert Traffic Light Assessment (Long List)

Site ID (long List Aug '21)	Flooding	Freshwater Ecology	Terrestrial Ecology	Air Quality	Archaeology	Transport	Noise & Vibration	Contaminated Land	Landscape	Social	Heritage	Water Quality	Groundwater	HC Soils	Key Comments on Red ranking	Key comments on amber ranking - priority sites only
1	Green	Green	Green	Green	Green	Green	Green	Green	Green	Green	Green	Green	Red	Green	**Groundwater** - No hydrological effects or interaction with surface water bodies. Any groundwater is likely to be at depth. However, this site is on a marine terrace and the interfluve between two of the better formed and preserved 'box valleys' that have been eroded into the Otaki Sandstone (Q5b). This makes the site distinctive and geomorphically significant.	
2	Green	Amber	Green	Green	Green	Green	Green	Green	Red	Green	Green	Green	Green	Green	**Landscape** - Excavation into side of Pukehou, a significant landmark.	
3	Green	Green	Green	Green	Green	Green	Green	Green	Green	Green	Green	Green	Amber	Green		
4	Green	Amber	Green	Green	Green	Green	Green	Green	Red	Green	Green	Green	Green	Green	**Landscape** - Excavation into side of Pukehou, a significant landmark.	
6	Green	Green	Green	Green	Green	Green	Green	Green	Green	Green	Green	Green	Amber	Green		
7	Green	Green	Amber	Red	Green	Green	Green	Green	Green	Green	Green	Green	Amber	Green	**Air Quality** - close proximity to a number of receptors.	
8	Green	Green	Green	Green	Green	Green	Green	Green	Green	Green	Green	Green	Amber	Green		
9	Green	Amber	Amber	Amber	Green	Green	Green	Green	Green	Green	Green	Green	Amber	Green		
5	Green	Red	Red	Red	Green	Green	Amber	Green	Amber	Amber	Green	Amber	Green	Green	**Freshwater Ecology** - Close proximity to Manakau Stream and current extent encroaches on tributary stream. Looks to require removal of riparian vegetation. Access would require temporary crossings to be installed in Manakau Stream. Could be reduced to an orange light if area tweaked to avoid stream channel; **Terrestrial Ecology** - Would require removal of indigenous vegetation on steep hillslope. Potential for indigenous fauna to be harmed or killed during vegetation removal; **Air Quality** - Christmas tree farm next door	
10	Green	Amber	Red	Red	Green	Green	Amber	Green	Red	Amber	Green	Green	Green	Green	**Terrestrial Ecology** - Would require removal of what appears to be intact indigenous vegetation on steep hillslope. Potential for indigenous fauna to be harmed or killed during vegetation removal.; **Air Quality** - Farmstay less than 200 m away; **Landscape** - Would quarry into side spur of Hanawera hill behind Manakau Heights. Visual effects on Manakau Heights valley, would extend and exacerbate adverse visual effects in an area already significantly adversely affected.	
11	Green	Amber	Amber	Amber	Green	Amber	Green	Green	Red	Amber	Green	Green	Green	Green	**Landscape** - Would quarry into spur of Hanawera hill behind Manakau. Elevated location on side of hill. Visual effects on eastern end of Manakau village and valley.	
12	Green	Amber	Amber	Green	Green	Amber	Green	Green	Red	Amber	Green	Green	Green	Green	**Landscape** - Would quarry into spur of Hanawera hill behind Manakau. Elevated location on side of hill. Visual effects on eastern end of Manakau village, valley, and neighbour.	
13	Green	Amber	Red	Red	Amber	Amber	Amber	Green	Red	Amber	Green	Amber	Green	Green	**Terrestrial Ecology** - Likely to involve removal of native riparian vegetation on steep slopes. Very little riparian vegetation remains in this part of the catchment; **Air Quality** - Road passes a number of sensitive receptors; **Landscape** - Would quarry into (and disfigure) the knoll at northern end of Hanawera hill. Elevated in a reasonably visible location. Visual effects from North Manakau Road and properties in vicinity. Natural character effects on Waikawa Stream.	
14	Red	Red	Green	Red	Amber	Amber	Amber	Green	Amber	Amber	Green	Amber	Green	Green	**Flooding** - active meandering floodplain, could recover some material and allow to re-fill naturally, but risky long term requiring active management for small recovery; **Freshwater Ecology** - Close proximity to Waikawa Stream and parts may look to be in channel. Looks to require removal of riparian vegetation. Could be green if area tweaked to avoid Waikawa Stream channel and riparian vegetation. Could site remediation include creation of floodplain wetland habitat and perhaps even open water habitats? With the neighbouring river and forest remnant, it could be great opportunity to create mosaic of linked habitats; **Air Quality** - Road passes a number of sensitive receptors.	

O2NL MATERIAL SUPPLY SITES STUDY

Technical Expert Traffic Light Assessment (Long List)

Site ID (long List Aug '21)	Flooding	Freshwater Ecology	Terrestrial Ecology	Air Quality	Archaeology	Transport	Noise & Vibration	Contaminated Land	Landscape	Social	Heritage	Water Quality	Groundwater	HC Soils	Key Comments on Red ranking	Key comments on amber ranking - priority sites only
15*																**Air Quality** - Large Area, encompasses a residential property; **Archaeology** - Section of this site includes the site of the Parikawau Shag hunting location (also crossed by Climies track, but physical traces not expected). Would be green if testing determines no site present/destroyed or bounds of site identified and avoided. Can be avoided by removing Lot1 DP 362812 portions; **Transport** - Access SH1 via North Manakau Road. Issues with short stacking. Also a lot of material sites in this proximity could result in very high volumes of turning trucks; **Contaminated Land** - Further investigation of historical photos (Retrolens.nz) suggests that the potential landfill site 700692 is closer to the borrow site than indicated at the northern boundary of this borrow site. The extent of this borrow site could be reduced to avoid this area. Further investigation would be required. Site 700060 is located across the river from this borrow site; **Social -** Though partially within the designation this is a large area that will extend disturbance further west and take up a much larger (nearly half) area of farmland that is anticipated to impact functionality. One house directly backs onto the site however it is assumed that this will already be acquired by the project. (The polygon indicating the area cuts through an existing farm shed but it is assumed this is an approximate representation only and that this can be adjusted to avoid this if property not acquired). Assumption made that post use site will be part of overall landscaping mitigation for corridor and or used as part of road, SUP or stormwater. The area outside the designation will need to be restored to be in fitting with the landscape and use; **HC Soils** - Significant area of highly productive 3s2 land.
16															**Flooding** - active meandering floodplain, could recover some material and allow to re-fill naturally, but risky long term requiring active management for small recovery; **Freshwater Ecology** - Close proximity to Waikawa Stream and parts may be within floodplain. As recently as June 2016 main river channel was within the proposed extraction area. Concerns that river may change course and be flowing within the area between now and extraction period. Looks to require removal of riparian vegetation; **Terrestrial Ecology** - Would require removal of riparian vegetation. Very little riparian vegetation remains in this part of the catchment; **Contaminated Land** - Further investigation of historical photos (Retrolens.nz) suggests that the potential landfill site 700692 is closer to the borrow site than indicated. Historical disturbed land and trucks observed within the footprint of this borrow site it is unclear if this was to extract gravel or to dispose of material further investigation would be required. Site 700060 is located across the river from this borrow site.	
18															**Flooding** - active meandering floodplain, could recover some material and allow to re-fill naturally, but risky long term requiring active management for small recovery; **Freshwater Ecology** - Close proximity to Waikawa Stream and parts may be within floodplain. As recently as Feb 2015 main river channel was within the proposed extraction area. Concerns that river may change course and be flowing within the area between now and extraction period. Looks to require removal of riparian vegetation; **Terrestrial Ecology** - Would require removal of locally important remnant of riparian vegetation which has been proposed as a potential terrestrial offset site. Very little riparian vegetation remains in this part of the catchment;	
17															**Freshwater Ecology** - Looks to directly impact Stream 27.1, a moderate ecological value tributary of Waikawa Stream. Alluvium extraction here would likely require stream diversion and potential offsetting. Is there potential to split area in two and avoid disturbing stream?	

O2NL MATERIAL SUPPLY SITES STUDY

Technical Expert Traffic Light Assessment (Long List)

Site ID (long List Aug '21)	Flooding	Freshwater Ecology	Terrestrial Ecology	Air Quality	Archaeology	Transport	Noise & Vibration	Contaminated Land	Landscape	Social	Heritage	Water Quality	Groundwater	HC Soils	Key Comments on Red ranking	Key comments on amber ranking - priority sites only
19*																**Freshwater Ecology** - Comes close to Stream 27.1 at two locations. Would be green if area tweaked to be minimum 20 m away from this stream; **Terrestrial Ecology** - Small area of mahoe-mamaku-blackberry-barberry scrub will be affected in western site. Potential for indigenous fauna to be harmed or killed during vegetation removal; **Transport** - As with 15, but sites north of the river use one lane bridge on N Manakau Road. A better alternative may be a new accessway onto SH1 near Tatum Park; **Contaminated Land -** Further investigation of historical photos (Retrolens.nz) suggests that the potential landfill (Site 700060) is located closer to the borrow site than indicated at the western boundary of this borrow site. Historical disturbed land observed close to the farm buildings and shows an area filled in over time. It is unclear what this fill consisted of and further investigation would be required. The extent of this borrow site could be reduced to avoid this area; **Social** - Partially within the designation although will extend construction works further towards 2 houses which are located less than 100m from the proposed borrow site. There would be a reduction in farmland although a fairly large area of a functional shape remains. Assumption made that post use site will be part of overall landscaping mitigation for corridor and or used as part of road, SUP or stormwater. The area outside the designation would need to be restored to be in keeping with the surrounding landscape and use; **HC Soils** - Significant area of highly versatile land which is outside the corridor.
20															**Terrestrial Ecology** - Would require removal of what appears to be intact indigenous vegetation on steep hillslope. Potential for indigenous fauna to be harmed or killed during vegetation removal.	
22																
21																
24															**Landscape** - It would use an existing quarry. It consent already exists then those effects would be assumed as part of the existing environment. If not (assumed situation for red traffic light), it would compound the existing adverse effects of the quarry in a cumulative manner. It is a sensitive and prominent location at the north end of Ōterere overlooking the Ōhau River. It would be very visible from the highway and plains. Although set back from the Ōhau River, there would be some adverse natural character effects. (There may be options to extend the existing quarry to a more modest extent as part of a strategy to close and rehabilitate it).	
23																
n/a*																**Social** - Partially within designation but also covers a large area of farmland outside of this that was not previously impacted. Remaining farmland in this block may no longer be viable due to large reduction in size and awkward shape (which was not the case before). Two houses within 50 and 75m away. Assumption made that post use site will be part of overall landscaping mitigation for corridor and or used as part of road, SUP or stormwater. The area outside the designation will need to be restored in keeping with the surround landscape and use requirements; **HC Soils** - Very large area of highly productive land (3s2).
25															**Terrestrial Ecology** - Would require removal of indigenous riparian vegetation which has been proposed as a potential terrestrial offset site. Potential for indigenous fauna to be harmed or killed during vegetation removal.	
36*																**Air Quality -** Looks like crops are nearby and could get effected / Source assumed to be the same as 25**; Social** - Outside of designation, close to house and impacts a large area of farmland.
26																
27															**Air Quality** - Close to residential properties and no access road so will need to be built	

O2NL MATERIAL SUPPLY SITES STUDY

Technical Expert Traffic Light Assessment (Long List)

Site ID (long List Aug '21)	Flooding	Freshwater Ecology	Terrestrial Ecology	Air Quality	Archaeology	Transport	Noise & Vibration	Contaminated Land	Landscape	Social	Heritage	Water Quality	Groundwater	HC Soils	Key Comments on Red ranking	Key comments on amber ranking - priority sites only
29															**Air Quality** - Close to residential property; **Noise & Vibration** - Longer haul road that passes close to many properties; **Landscape** - Would cut into high terrace at edge of plain. However, the configuration limits ability to mimic natural landform (it would resemble a quarry pit) and is sensitive location at entrance to Kimberley Reserve.	
28															**Freshwater Ecology** - Close proximity to Ōhau River and parts may be within floodplain. As recently as June 2020 part of flowing river channel was within the proposed extraction area. Looks to require removal of riparian vegetation. Could be green if area tweaked to avoid Ōhau River channel and riparian vegetation. Is there potential for remediation of site to create floodplain wetland habitat?; **Terrestrial Ecology** - Currently impacts exotic and indigenous riparian vegetation and potential wetland habitat to the west. Could be green if boundary amended to avoid riparian vegetation and wetland. Some potential for remediation of site to create floodplain wetland habitat that links with existing riparian habitats;**Noise & Vibration** - Longer haul road that passes close to many properties.	
30															**Freshwater ecology** - Close proximity to Ōhau River and parts may be within floodplain. Looks to require removal of riparian vegetation. Could be orange if area tweaked to avoid Ōhau River channel and riparian vegetation. Also need to consider access as may require temporary fording of Ōhau River to link to Gladstone Road. Is there potential for remediation of site to create floodplain wetland habitat?; **Terrestrial Ecology** - Currently impacts exotic and indigenous riparian vegetation and potential wetland habitat to the west. Could be green if boundary amended to avoid riparian vegetation and wetland. Some potential for remediation of site to create floodplain wetland habitat that links with existing riparian habitats;**Air Quality** - Access road goes over water and through a house… then travels long distance; **Noise & Vibration** - Longer haul road that passes close to many properties; **Landscape** - Would cut into low terrace within Ohau River flood plain. Moderate adverse effects on natural character of Ōhau River. Cut could be contoured to resemble a natural scarp, and the peninsula rehabilitated to mitigate adverse natural character effects. Would need to be designed to maintain the existing river meander. Appears to be closer to neighbouring properties than site 28. Additional adverse effects on natural character from access across river required.	
31															**Noise & Vibration** - Longer haul road that passes close to many properties; **Landscape** - Would cut into low terrace within Ohau River flood plain. Moderate adverse effects on natural character of Ōhau River. Cut could be contoured to resemble a natural scarp, and the peninsula rehabilitated to mitigate adverse natural character effects. Would need to be designed to maintain the existing river meander. Appears to be closer to neighbouring properties than site 28. Additional adverse effects on natural character from access across river required.	
32																
33															**Noise & Vibration** - Longer haul road that passes close to many properties. Lesser effects closer to SH57**.**	
34																

O2NL MATERIAL SUPPLY SITES STUDY

Technical Expert Traffic Light Assessment (Long List)

Site ID (long List Aug '21)	Flooding	Freshwater Ecology	Terrestrial Ecology	Air Quality	Archaeology	Transport	Noise & Vibration	Contaminated Land	Landscape	Social	Heritage	Water Quality	Groundwater	HC Soils	Key Comments on Red ranking	Key comments on amber ranking - priority sites only
34a																**Landscape** - While 34 entailed widening a cut into the terrace on uphill side of highway, 34a would entail removing a section of terrace altogether between the highway and a gully that is earmarked for restoration for ecology and natural reasons. The removal of the terrace will have some adverse effects on natural character and also provide opportunities for naturalisation. On the one hand it will alter the gully's natural landform and increase the highway's visible presence from the gully. On the other hand it will provide opportunity to construct a larger naturalised wetland which would be visible from the highway and have a naturalised appearance. The orange score indicates that there are some adverse effects compared to 34, and that opportunities for enhancement depend on how the work is carried out: **Social** - House within 200m (need to confirm if this will be acquired as part of project), site on land already indicated for disturbance (within designation). May result in increased disturbance. Assumption made that post use site will be part of overall landscaping mitigation for corridor and or used as part of road, SUP or stormwater where it is within the corridor; **Archaeology** - while a 'green' rating given, potentially this site could be 'orange' as likely archaeological site in the vicinity; **Water Quality** - Koputaroa Stream catchment - located directly adjacent to an unnamed first order tributary of the Koputaroa Stream (stream ID 41) which includes an online farm dam. Potential for runoff to enter the watercourse. Easy access immediately adjacent to O2NL corridor.
35																

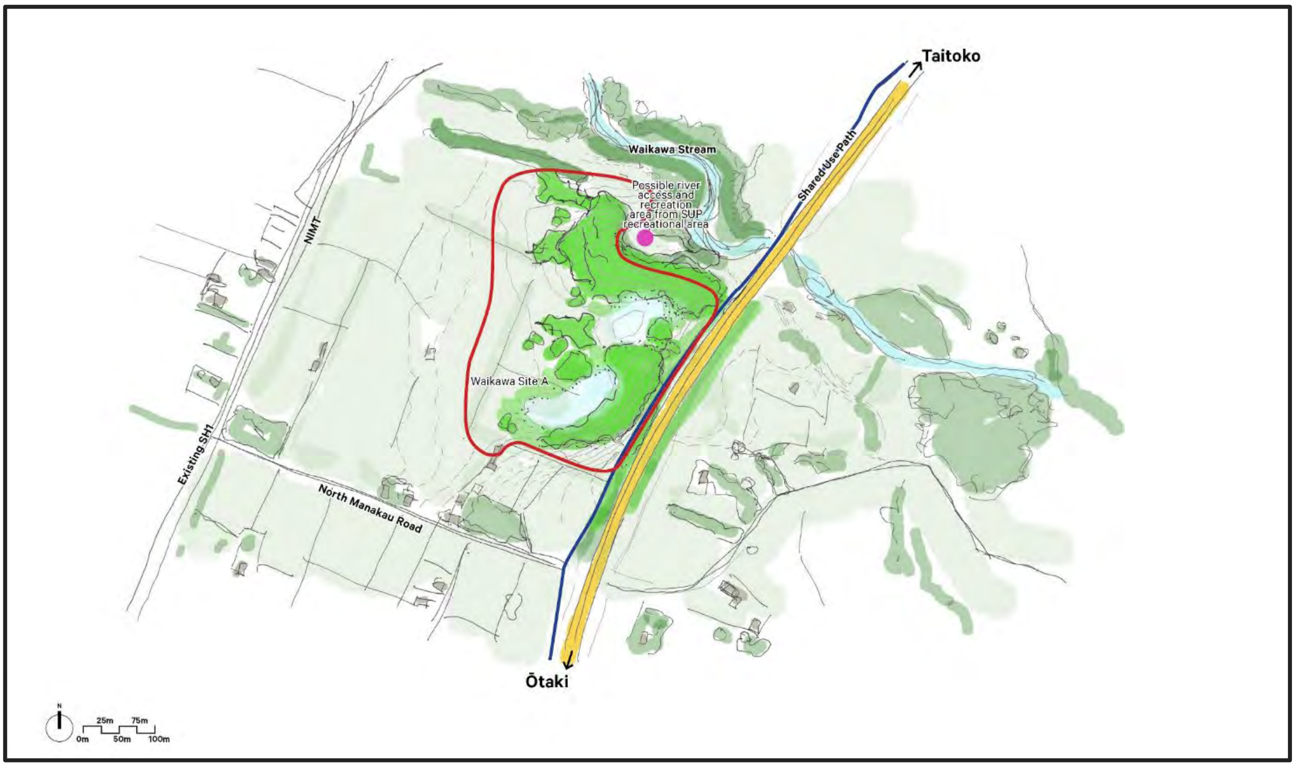
* Preferred sites

Appendix 4.5.2 Material Supply Sites Drawings

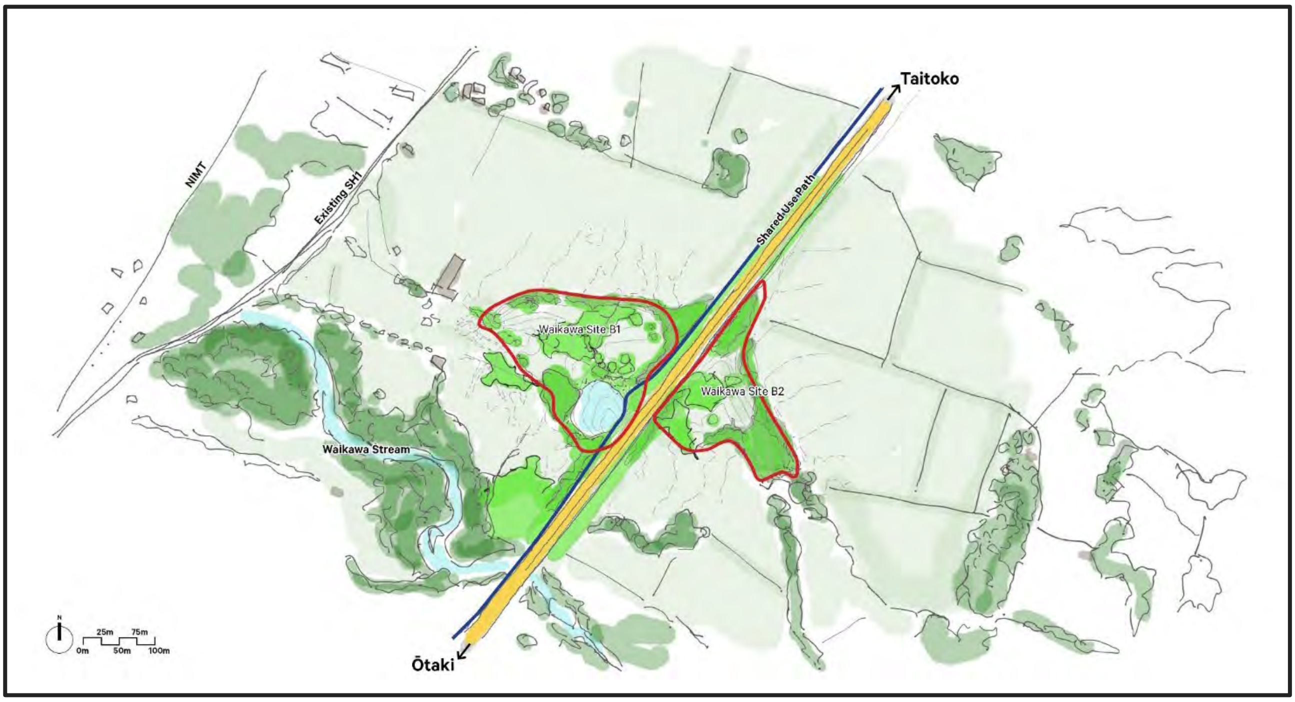
Concept Drawings of Preferred Sites

The following are the concept drawings proposed to experts to undertake an initial detail assessment of the preferred 4 Material Supply Sites:

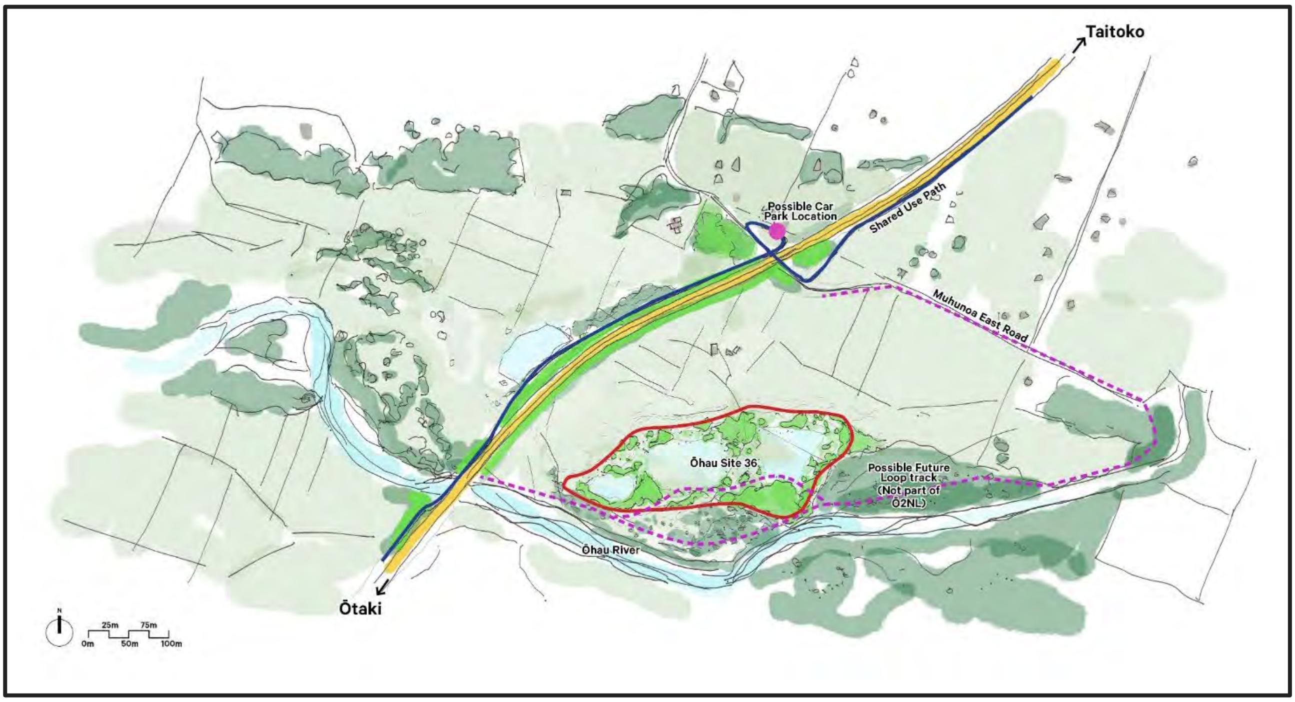
Site #15 – South of Waikawa Stream



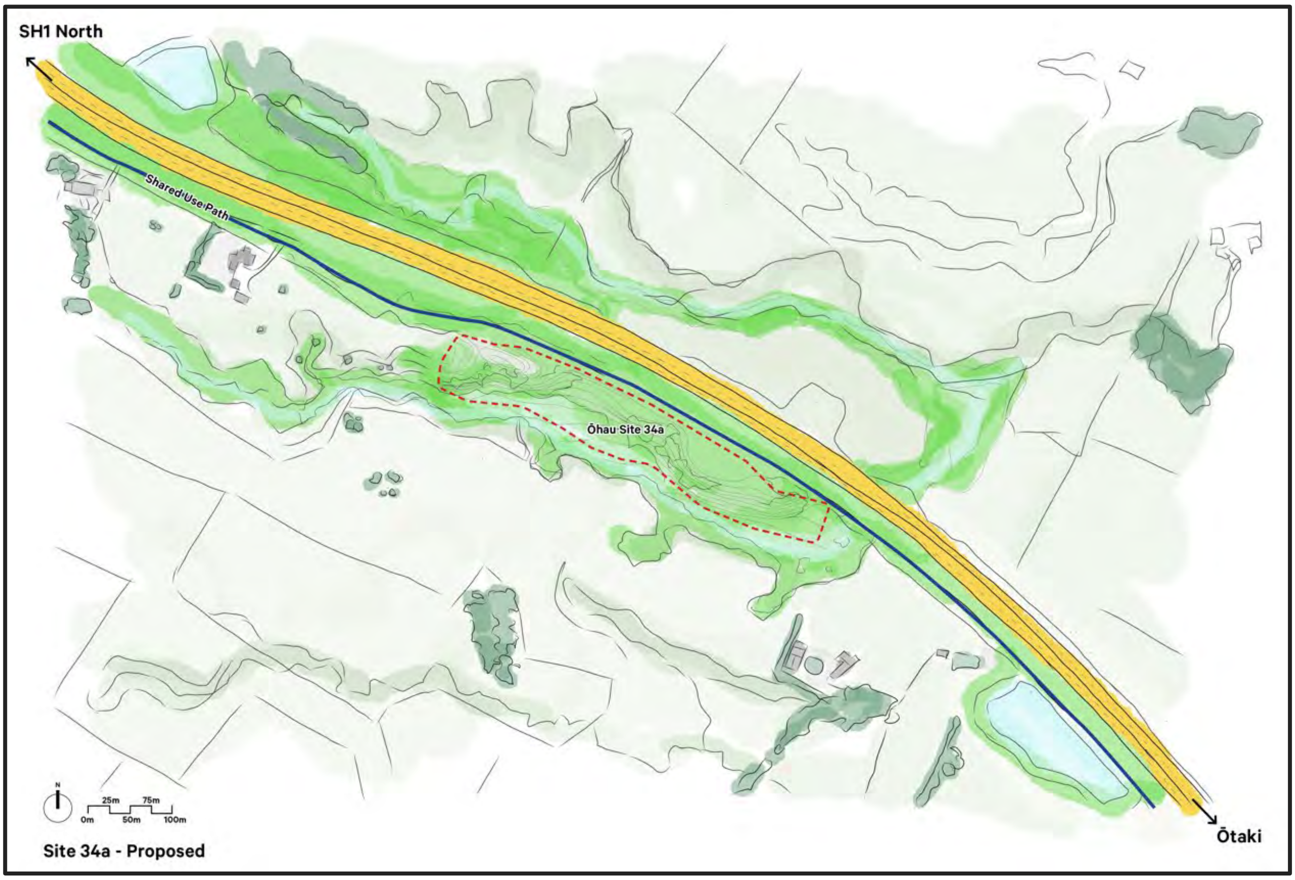
Site #19 – North of Waikawa Stream



Site #36 – North-east of Ohau River



Site #34a – Koputaroa



General Arrangement Drawings

REV	REVISIONS	DRN	CHK	APP	DATE
G	ISSUED FOR RMA CONSENT	SS			
F	ISSUED FOR CONSENT - DRAFT	SS	KW	JP	08.04.22
E	ISSUED FOR INFORMATION	SS	KC	JP	04.03.22
D	ISSUED FOR CONSENTING - DRAFT	SS	KW	JP	09.12.21
C	ISSUED FOR CONSENTING - RE-ISSUE DRAFT REVIEW	SS	KW	JP	09.09.21
B	ISSUED FOR CONSENTING - DRAFT REVIEW	SS	KW	JP	30.08.21
A	ISSUED FOR DBC	SS	KW	JP	18.06.21

SURVEYED		
DESIGNED	Steve Muller	18.06.21
DRAWN	Steve Sutton	18.06.21
CAD REVIEW	Steve Sutton	18.06.21
DESIGN CHECK	Jamie Povall	08.04.22
DESIGN REVIEW	Keith Weale	08.04.22
APPROVED		
PROF REGISTRATION:		

NOT APPROVED

Stantec

Client: WAKA KOTAHI NZ TRANSPORT AGENCY

WAKA KOTAHI
ŌTAKI TO NORTH OF LEVIN HIGHWAY PROJECT

GENERAL ARRANGEMENT PLAN - INDICATIVE
SHEET 2

Status Stamp: FOR CONSENT

Date Stamp

Scales: 1 : 4000 (A3)

Drawing No. 310203848-01-100-C1001

Rev. G

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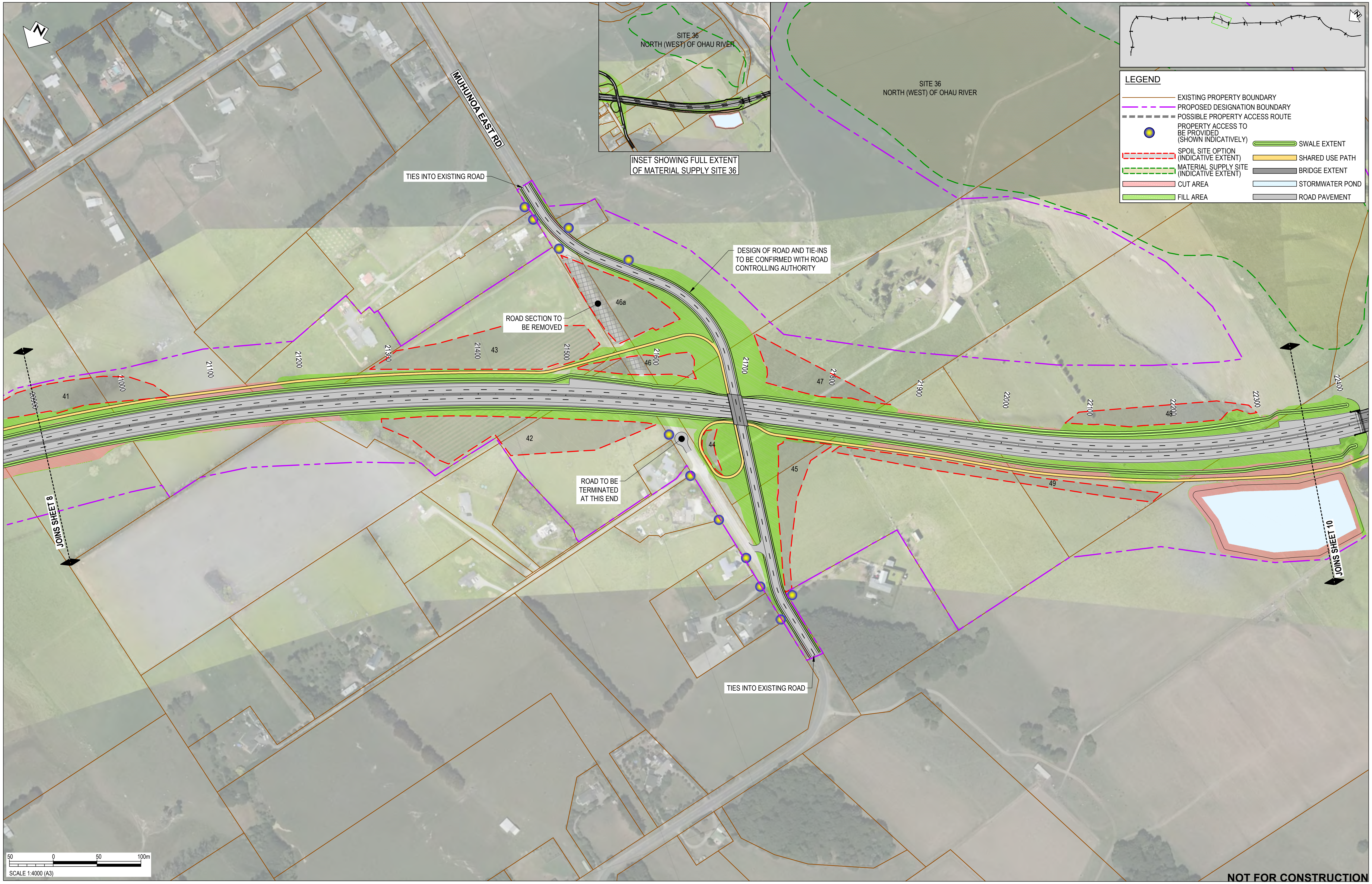

NOT FOR CONSTRUCTION

REV	REVISIONS	DRN	CHK	APP	DATE
G	ISSUED FOR RMA CONSENT	SS			
F	ISSUED FOR CONSENT - DRAFT	SS	KW	JP	08.04.22
E	ISSUED FOR INFORMATION	SS	KC	JP	04.03.22
D	ISSUED FOR CONSENT - DRAFT	SS	KW	JP	09.12.21
C	ISSUED FOR CONSENTING - RE-ISSUE DRAFT REVIEW	SS	KW	JP	09.09.21
B	ISSUED FOR CONSENTING - DRAFT REVIEW	SS	KW	JP	30.08.21
A	ISSUED FOR DBC	SS	KW	JP	18.06.21

SURVEYED		
DESIGNED	Steve Muller	18.06.21
DRAWN	Steve Sutton	18.06.21
CAD REVIEW	Steve Sutton	18.06.21
DESIGN CHECK	Jamie Povall	08.04.22
DESIGN REVIEW	Keith Weale	08.04.22
APPROVED		
PROF REGISTRATION:		

NOT APPROVED

Stantec

Client:

WAKA KOTAHI NZ TRANSPORT AGENCY

WAKA KOTAHI

ŌTAKI TO NORTH OF LEVIN HIGHWAY PROJECT

GENERAL ARRANGEMENT PLAN - INDICATIVE

SHEET 9

Status Stamp: FOR CONSENT

Date Stamp

Scales: 1 : 4000 (A3)

Drawing No.: 310203848-01-100-C1008

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REV	REVISIONS	DRN	CHK	APP	DATE
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E	ISSUED FOR INFORMATION	SS	KC	JP	04.03.22
D	ISSUED FOR CONSENT - DRAFT	SS	KW	JP	09.12.21
C	ISSUED FOR CONSENTING - RE-ISSUE DRAFT REVIEW	SS	KW	JP	09.09.21
B	ISSUED FOR CONSENTING - DRAFT REVIEW	SS	KW	JP	30.08.21
A	ISSUED FOR DBC	SS	KW	JP	18.06.21

SURVEYED		
DESIGNED	Steve Muller	18.06.21
DRAWN	Steve Sutton	18.06.21
CAD REVIEW	Steve Sutton	18.06.21
DESIGN CHECK	Jamie Povall	08.04.22
DESIGN REVIEW	Keith Weale	08.04.22
APPROVED	NOT APPROVED	
PROF REGISTRATION:		

Stantec

Client: WAKA KOTAHI NZ TRANSPORT AGENCY

WAKA KOTAHI
ŌTAKI TO NORTH OF LEVIN HIGHWAY PROJECT

GENERAL ARRANGEMENT PLAN - INDICATIVE
SHEET 10

Status Stamp: FOR CONSENT

Date Stamp

Scales: 1 : 4000 (A3)

Drawing No.: 310203848-01-100-C1009

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REV	REVISIONS	DRN	CHK	APP	DATE
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E	ISSUED FOR INFORMATION	SS	KC	JP	04.03.22
D	ISSUED FOR CONSENT - DRAFT	SS	KW	JP	09.12.21
C	ISSUED FOR CONSENTING - RE-ISSUE DRAFT REVIEW	SS	KW	JP	09.09.21
B	ISSUED FOR CONSENTING - DRAFT REVIEW	SS	KW	JP	30.08.21
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DESIGNED	Steve Muller	18.06.21
DRAWN	Steve Sutton	18.06.21
CAD REVIEW	Steve Sutton	18.06.21
DESIGN CHECK	Jamie Povall	08.04.22
DESIGN REVIEW	Keith Weale	08.04.22
APPROVED	NOT APPROVED	
PROF REGISTRATION:		

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GENERAL ARRANGEMENT PLAN - INDICATIVE
SHEET 12

Status Stamp: FOR CONSENT

Date Stamp

Scales: 1 : 4000 (A3)

Drawing No. 310203848-01-100-C1011 | Rev. G

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REV	REVISIONS	DRN	CHK	APP	DATE
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E	ISSUED FOR INFORMATION	SS	KC	JP	04.03.22
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A	ISSUED FOR DBC	SS	KW	JP	18.06.21

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CAD REVIEW	Steve Sutton	18.06.21
DESIGN CHECK	Jamie Povall	08.04.22
DESIGN REVIEW	Keith Weale	08.04.22
APPROVED		
PROF REGISTRATION:		

NOT APPROVED

Client:

WAKA KOTAHI
ŌTAKI TO NORTH OF LEVIN HIGHWAY PROJECT

GENERAL ARRANGEMENT PLAN - INDICATIVE
SHEET 13

Status Stamp: FOR CONSENT

Date Stamp:

Scales: 1 : 4000 (A3)

Drawing No.: 310203848-01-100-C1012

Rev.: G

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Appendix 4.5.3 Summary of Detailed Assessments of Preferred Sites

O2NL MATERIAL SUPPLY SITE STUDY
SUMMARY OF DETAILS EFFECTS ASSESSMENT – ALLUVIAL MATERIAL SUPPLY SITES #15, 19, 36 & Q5b SAND MATERIAL SITE #34a

31 May 2022

Site #15 – South of Waikawa Stream

Technical Expert	Assessment
Transport	This site would be accessed via North Manakau Road. This intersection has some safety concerns due to the short stacking length between the state highway and the railway line which would need to be managed. If material is moving south, there is potential for internal haul routes to be used to move material to reduce the number of trucks exiting on North Manakau Road. Access onto North Manakau Road from SH1 is good from both directions. This can be mitigated by prohibiting right turns from North Manakau Road. Further comment on final Site #15 perimeter extent: This site was originally given amber due to the short stacking and likely number of trucks required for haulage. It has increased in size approximately 20%. This would remain an amber and would likely still be able to be mitigated to green depending on the improvements, site controls and timeframes for material extraction.
Freshwater Ecology	This site does not include any permanently flowing stream channels. However, it does include former water race channels (Stream 26 in technical report). These are now defunct, however may still have some drainage function during heavy rain events (i.e., are ephemeral channels), which is something to be aware of during the extraction period in terms of ESC. Once constructed, any such inputs could be advantageous at maintaining any constructed wetland habitats. The boundary of this site comes within ~70 m of the active Waikawa Stream channel. This stream has a very mobile channel and it is possible that at some stage in the future it may move to be within the Site 15 area. This is a natural process, and not any issue from a freshwater ecology perspective, but something to be aware of when rehabilitating the site.
Terrestrial Ecology	No indigenous vegetation or wetlands have been identified/mapped within footprint of borrow site. Four small patches of what appears to be exotic treeland are present in the footprint, although these will need to be confirmed with a site visit. The footprint also encroached on a small area of exotic riparian vegetation. Entire area appears to be grazed, therefore no potential habitat for indigenous lizards and snails. Will impact some degraded farm streams (will need offsetting).
Noise & Vibration	This site abuts the main Ō2NL alignment between North Manakau Road and Waikawa Stream. There are 5 dwellings within 200m of the supply site, however each of these dwellings is also affected by noise from earthworks from the highway itself. Therefore the effects of the material supply site will mainly be due to increased duration / frequency of activities. Any truck movements on North Manakau Road will be consistent with other construction traffic and subject to the Construction Traffic Management Plan (CTMP). There are no dwellings within 50m of the supply site. Mitigation in the form of screening may be appropriate to the dwellings south of the site. **Figure 1** below shows buffers from the material supply site, as well as the main construction footprint and buffers (in thinner lines).

Technical Expert	Assessment
Flooding & Hydrology	There would be no detrimental effects on flooding upstream or downstream as a result of material extraction. The site could provide a slight benefit in terms of flood risk, by capture and attenuation of overland flow that heads toward existing SH1 west of the site. There is a small discontinued water race across the site. The material supply site will serve to capture and route a similar catchment size to the outlet. The route of the historical water race will still be used as an overland flow path to pass excess runoff in exceedance events, with attenuation included by design so that the future peak discharge would be less than existing. I have recently provided a proposed westward extension to the designation as shown below (refer to **Figure 2**), to allow the drainage / water race invert to be lowered slightly allowing greater material extraction (same footprint, but slightly deeper along the western boundary). The site outline currently shows a small extension onto the Waikawa floodplain near the proposed O2NL bridge – details is not provided but it is understood that this may be intended as a potential construction corridor rather than forming part of material supply or legacy outcomes. Care should be taken in detailed design to protect the river bank in this location, to avoid increasing potential risk of lateral scour from the Waikawa Stream which is highly mobile. The site also extends beyond the (current) draft proposed designation – so either the designation should be extended or the material supply area constrained to within the designation. (Updated 240522)
Groundwater	No effect on surface water features or water balance. The nearest bore to the site (BH308 located outside of material supply site #15) indicates that the groundwater may get within 5m of the ground surface and therefore material could likely be excavated at this site to 5m before the ground surface before interacting with the water table or groundwater. Likely above the contemporary floodplain and therefore no effect on any existing hazard. It is recommended that, should this site be considered further, at least one piezometer and water level recorder be installed in immediate vicinity of the proposed borrow pit. Additional comment 230522: Further investigation using piezometers is required to confirm the surface water/groundwater interactions so that these can subsequently be enhanced and promoted. This information is essential to the final design and therefore function of the proposed environment.
Water Quality	Site 15 contains alluvial materials. It is located south of Waikawa Stream and immediately west of the proposed highway. It is approximately 160,000 m2 in area and 150,000-320,000m3 in volume. As the site is located immediately adjacent to the proposed highway, it is easily accessible and no new roads are required. The site is mainly agricultural land, but also includes the floodplain of the Waikawa Stream, and a farmhouse. The site extends up to the edge of the Waikawa Stream[1] (stream ID 25) and crosses 620 metres of an unnamed first order tributary (ID 26) and is immediately adjacent to another watercourse. Of the four short-listed sites, this is the only one that extends up to a major stream and that will excavate one, possibly two watercourses. From aerial photography it cannot be determined if the smaller watercourses are permanent or intermittent, but both have defined channels. If excavation extends up to the Waikawa Stream, this will result in bank instability and potential direct discharges of sediment to the stream. It is recommended that this is avoided by enforcing a setback (ideally 50 metres) from Waikawa Stream. Excavations of one or both small watercourses should be avoided, where possible. Where this is not possible, erosion and sediment measures should be employed to minimise water quality impacts, with mitigation applied for any loss of stream length. north-eastern extent of this site to avoid direct impacts on the Waikawa Stream. Any loss in stream length should be mitigated by the restoration or recreation of stream(s) in other parts of the Project.

[1] The current extent of material supply site #15 is mapped up to the edge of Waikawa Stream. According to Chris Hansen (27/05/22 pers. comm.), no excavation is occurring in this area, and it has only been included in the footprint of the site to enable legacy outcomes to be fulfilled (i.e. providing public access to the Waikawa Stream).

Technical Expert	Assessment
	Standard erosion and sediment control should also be implemented. (Updated 270522)
Landscape & Visual	There will be some adverse landscape effects during excavation, and from modifying the natural landform. Such effects will be remedied through construction of what would be a reasonably naturalistic landform, and rehabilitation of the site with indigenous habitat and vegetation. This would compare with the current farmland. The net outcome is potentially positive. There will be some adverse effects on perceptions of natural character during construction, although the site will be buffered from the Waikawa Stream - the excavation will occur behind an island of terrace, and because the excavation will occur in the context of construction works along the highway corridor. The rehabilitated site will have a naturalistic appearance and will merge with the natural character enhancement proposed along the Waikawa Stream. It will increase the amount of natural vegetation and habitat along the corridor. It will contribute to some extent to both biophysical and perceptual aspects of natural character. The net outcome is potentially positive.
Heritage	There are no heritage sites identified near this site so therefore there are no adverse effects.
Archaeology	The main factor of consideration is the close proximity to the Waikawa Stream. There are no specific archaeological sites recorded in the area, but there is a possibility that archaeological sites could be found in this area (without detailed survey it is difficult to assess due to the complex history of the area, movements of the stream, have flood deposits destroyed or protected sites etc).
Air Quality	Medium risk of effects - Site 15 is an alluvial source and is located close to sensitive receptors and the close proximity of works means that nuisance dust issues could arise. In order to decrease the overall ranking to green, PDP consider that the residences (13 and 12A North Manakau Rd) bordering the soil site would not be occupied during the works and appropriate mitigation measures adopted to minimise impacts on homeowners. This could include for example offering alternate water supplies if they current use roof collected water or property cleaning. This assessment outcome remains unchanged. (Updated 250522)
Social/Community	Though partially within the existing Project designation this is a large area that will extend disturbance and land requirements further west and take up a much larger area of existing farmland. It is noted that this impact is on a property level rather than a community level. It the house is not part of the required area but will be close to the supply site.. It will be located adjacent to the Shared Use Path (SUP) and in proximity to Ngati Wehi Wehi Marae. It is indicated that this will form a natural area in the future in keeping with the surrounding area. Opportunities indicated in the supporting documentation include possible river access and recreation area (reserve adjacent to river) from the SUP indicating it could become an area for recreation, mahinga kai and rongoā. On this basis any existing use of the river would be enhanced and it would provide additional community assets and align with the values the communities identify with regards to their local rivers as important natural and recreational assets. The improved planting may provide improvement the quality of the local living environment. Without the development of a community asset the site may have negligible impact once rehabilitated, provided it could be used as previously (such as farmland)) and there are not residual visual impacts. If the option to establish a community asset is realised this could have low to moderate positive community impacts on community character, community services, way of life and health and wellbeing. (Updated 240522)
Contaminated Land	It is acknowledged that the material supply site located to south of the Waikawa Stream will be defined to avoid a potential dump site however the current extents provided in the drawings still covers ground that is likely to have been part of the dump site as indicated by historical photos.

Technical Expert	Assessment
HC Soils	Loss of highly productive land with no mitigation options available. Site 15 was “orange” in initial TLA so this reclassification would no doubt make no difference to the overall classification particularly when there are no core values or principles related to productive land so the TLA with respect to productive land appears meaningless.
ESC	From an Erosion and Sediment Control perspective, there is nothing remarkable about Site #15, other than the proximity to the Waikawa Stream. It is noted that the final contours tie into the upper terrace, above the 100 year flood plain, and therefore it appears the site has the protection of the 100 year flood during extraction. It is considered that erosion and sediment control devices that comply with the GWRC ESC Guideline could be installed to provide control for this site.
Iwi/CEDF	Iwi partners aware of preferred site and seem fine with it; the change to the boundary to avoid house and old rubbish pit has also been discussed with iwi partners. Iwi partners are preparing Cultural Impact Assessments (CIA) and the CEDF audit process and these two mechanisms allow detailed issues to be identified as relevant. (Updated 310522)

Site #19 – North of Waikawa Stream

Technical Expert	Assessment
Transport	As with Site 15, this site would be accessed via North Manakau Road but with additional local road haulage including a 1-way bridge. The same concerns relating to North Manakau Road exist here. As this site is north of Waikawa Stream, the opportunity exists to use local haul roads to access Kuku East Road in a limited fashion to manage truck volumes at North Manakau Road. Other mitigation would also be to prohibiting right turns from North Manakau Road. Further comment on final Site #15 perimeter extent: This site has remained approximately the same size with one portion becoming marginally larger and one marginally smaller. No change to the assessment.
Freshwater Ecology	1. West of Ō2NL - This site does not include any permanently flowing stream channels. The southern tip of the site does however, come too close to Stream 27.1 (a permanently flowing stream of “moderate” ecological value). The boundary of the site needs to be adjusted to be at least 20 m away from the stream channel. It would be great if any rehabilitation of this site via planting could be integrated with proposed revegetation of this stream within the designation. 2. East of Ō2NL - This site does not include any permanently flowing stream channels. The southern tip of the site does however, come too close to Stream 27.1 (a permanently flowing stream of “moderate” ecological value). The boundary of the site needs to be adjusted to be at least 20 m away from the stream channel. Eastern boundary does come close to Stream 28 which is a constructed ephemeral channel, which is something to consider from ESC perspective.

Technical Expert	Assessment
Terrestrial Ecology	Western site intersects with a small area of māhoe-mamaku-blackberry-barberry scrub, although this vegetation has already been accounted for in the terrestrial offsets model given that is occurs within the alignment footprint and is therefore assumed to be impacted. Western extent overlaps a small area of vegetation that could support indigenous species and also wetland habitat. The boundary should be amended to avoid these areas (see **Figure 3** below). Eastern site likely to have negligible impacts, although the identity of the two trees should be confirmed. No wetlands or indigenous vegetation has been identified in the footprint. Most of the sites are grazed or used for cropping so are unlikely to support indigenous lizards and snails.
Noise & Vibration	This site also accesses the alignment directly. There is only 1 dwelling within 200m of the supply site. This dwelling will observe increased noise from the supply site compared to general construction works. While compliance with construction noise criteria could be achieved with no specific mitigation, bunding should be considered as part of the supply site design. **Figure 4** below shows the buffers around the site.
Flooding & Hydrology	[Site #19 East & West) There would be no detrimental effects on flooding upstream or downstream as a result of material extraction. The site has the potential to offer a very slight flood benefit if allowed to flood in major events (for example >1:10 AEP) by offering additional floodplain storage potential. Integration of the stormwater pond into the western side will be an important design consideration to maximise material recovery and legacy outcomes. Resilient integration with the main river floodplain will be important in terms of levels, ecological legacy and scour resistance. (Updated 240522)
Groundwater	No effect on surface water features or water balance. The water table may be relatively deep given the distance from and elevation above the stream. Likely above the contemporary floodplain and therefore no effect on any existing hazard. It is recommended that, should this site be considered further, at least one piezometer be installed in immediate vicinity of the proposed borrow pit. Additional comment 230522: Further investigation using piezometers is required to confirm the surface water/groundwater interactions so that these can subsequently be enhanced and promoted. This information is essential to the final design and therefore function of the proposed environment.
Water Quality	Site 19 contains alluvial materials. It is located north of Waikawa Stream and is divided by the Ō2NL corridor, meaning that it is partly located east, and partly west, of the proposed highway. It is approximately 75,000 m2 in area and 200,000-320,000m3 in volume. As the site is located either side of the proposed highway, it is easily accessible and no new roads are required. The site is agricultural land, located approximately 170 m north of the Waikawa Stream on the upper and lower river terrace and escarpment. It is immediately north of an unnamed third order tributary of the Waikawa Stream (stream ID 27.1) and immediately west of a first order tributary of Kuku Stream (ID 28). These watercourses are immediately adjacent to, but outside, of the zone of work. Aerial photographs indicate that some small areas of ponding (wetlands?) may to be present at the base of the escarpment within the site. The main impacts on water quality will be potential erosion and sediment discharges to the two streams. This will be insignificant compared to the activities already being undertaken along the proposed highway. No additional mitigation required. Potential sediment discharges can be managed through standard erosion and sediment control. (Updated 270522)

Technical Expert	Assessment
Landscape & Visual	There will be some adverse landscape effects during excavation, and from modifying the natural landform. Such effects will be remedied through construction of a naturalistic landform, and rehabilitation of the site with indigenous habitat and vegetation – replacing the existing farmland. The net outcome is potentially positive. There will be minimal adverse effects on perceptions of natural character during construction, because of the distance of the works from the Waikawa Stream (typically 150m – 250m), and because the excavation will occur in the context of construction works along the highway corridor. The rehabilitated site will merge with the natural character enhancement proposed along the Waikawa Stream, and with planting around the stormwater wetland. It will increase the amount of natural vegetation and habitat along the corridor. It will contribute to both biophysical and perceptual aspects of natural character. The net outcome is potentially positive.
Heritage	There are no heritage sites identified near this site so therefore there are no adverse effects.
Archaeology	In addition to the general potential for sites in the vicinity of the Waikawa, there is a shag (kawau) hunting site called Parikawau (see **Figure 5** below). It unclear if the site is within the bounds of option 15 (possibly 16), if it has survived etc, but it is something to take into account. Further field investigation may be helpful here and I expect there is ample opportunity for minor changes to avoid/minimise adverse effects if direct evidence of archaeological material is discovered. However, the presence of a possible site at this stage would not rise to the level of a fatal flaw or suggest the need for radical changes at this stage (speaking as an archaeologist, but iwi may approach that differently). I think the presence of the site also creates opportunities for integrating cultural elements into the restoration/revegetation process at the conclusion of the material extraction.
Air Quality	Low risk of effects - However as the area is away from sensitive receptors and is within or in close proximity to the designation boundary it is unlikely to cause any adverse effects in terms of air quality.
Social/Community	Though partially within the existing Project designation this is a large area of farmland that will extend disturbance and land requirements further west and take up a much larger area of existing farmland. It is noted that this impact is on a property level rather than a community level. Two homes are within 100m from the proposed borrow site. Once operation it has the opportunity to provide a visual buffer to the new Corridor. However it is noted that the ground level is lowered either side of the new corridor making the new corridor potentially more prominent in the landscape. It will also be dependent on how surrounding land use is integrated into current functions. It will be located adjacent to the Shared Use Path and it is noted the planting scheme will provide an enhanced experience for the shared use path users. On this basis (the mitigation is carried out) it is considered that it would have once established have a negligible impact for the sub-local community (new planting may provide improvement to the quality of the sub-local local living environment). For SUP users it may have a low positive impact. (Updated 240522)
Contaminated Land	There is a low point at the North eastern side of this site that may encounter unnatural fill material and should be avoided.
HC Soils	Western side approximately .5 ha - .25ha Class 1 and .25ha Class IVs1 land; Eastern side majority Class 1. Loss of highly productive land with no mitigation options available. Site 19 was “orange” in initial TLA so this reclassification would no doubt make no difference to the overall classification particularly when there are no core values or principles related to productive land so the TLA with respect to productive land appears meaningless. (Updated 300522)

Technical Expert	Assessment
ESC	From an Erosion and Sediment Control perspective, there is nothing remarkable about Site #19, other than the proximity to the Waikawa Stream. It is considered that erosion and sediment control devices that comply with the GWRC ESC Guideline could be installed to provide control for this site.
Iwi/CEDF	Iwi partners aware of preferred site and seem fine with it. Iwi partners are preparing Cultural Impact Assessments (CIA) and the CEDF audit process and these two mechanisms allow detailed issues to be identified as relevant. (Updated 310522)

Site #36 – North of Ōhau River

Technical Expert	Assessment
Transport	Different routes will be used from this site depending on the destination of the carted material. Access to southern zones is likely via Bishops Road and northern sites through Arapaepae Road. There are no issues in terms of access to the north, but access to and from the south is problematic as Muhunoa East Road has a size constraint with the rail overbridge and McLeavey and Bishops Roads have short stacking and other rail safety issues. Further comment on final Site #15 perimeter extent: This site has become slightly larger, equivalent to an additional 10%. This would remain an amber and would likely still be able to be mitigated to green depending on the improvements, site controls and timeframes for material extraction.
Freshwater Ecology	This site does not include any permanently flowing stream channels. The boundary does come within ~30 m of the active Ohau River channel, which may be advantageous if it is possible to provide some kind of connection to the river. There is potential to create permanent open water habitat at this site that can provide habitat for numerous indigenous species. A periodic surface water connection to the Ohau River would allow fish species to colonise, such as shortfin tuna/eels.
Terrestrial Ecology	The site would require the removal of some indigenous vegetation along the northern river terrace. This vegetation would to be identified and quantified so that appropriate offsetting can be carried out. Fauna mitigation is likely to be required. No wetlands or streams are present in the footprint. Excellent restoration potential in terms of creating wetland habitat that links to riparian forest. It is intended to use the areas of open water created at this site to offset the cumulative loss of open water (i.e., ponds) within the alignment footprint.
Noise & Vibration	This site is located between Ohau River and Muhunoa Road East. Again, access to the alignment will minimise haulage via the local road network. There are no dwellings within 200m of the proposed supply sites. **Figure 6** below shows the buffers around the site.

Technical Expert	Assessment
Flooding & Hydrology	There would be no detrimental effects on flooding upstream or downstream as a result of material extraction. The site represents a very slight advantage in terms of flood risk, due to additional storage of flood water on a wider floodplain in some events. The proposed outline currently shows a small clash with an overland flow path on the north-western side of the site (O2NL chainage 22250), which could be easily addressed by either modifying the proposed outline or by re-alignment of the overland flow path within the proposed designation extent. The terrace does have some overland flow in major events (larger than approximately 1:10 AEP current climate), so the scour resistance and long term morphological stability of the river and embankments around the site will need to be considered during detail design. Similarly, sustainability and minimising maintenance requirements will be important for the outlet at the western / downstream end. Resilient integration with the main river floodplain will be important in terms of levels, ecological legacy and scour resistance. Whilst the river is relatively stable currently, there remains the possibility that future injections of gravel from earthquakes or severe storms can increase the risk of aggradation, lateral erosion and avulsion. (Updated 240522)
Groundwater	No effect on surface water features or water balance. The water table may be relatively deep given the distance from and elevation above the stream. Likely well above the contemporary floodplain and a significant distance from the Ohau River. Therefore, no effect on any existing hazard. Will need to avoid any interaction with potential paleochannels and overland flow paths. Should an extreme event occur could provide some additional flood storage. It is recommended that, should this site be considered further, at least one piezometer be installed in immediate vicinity of the proposed borrow pit. Additional comment 230522: Further investigation using piezometers is required to confirm the surface water/groundwater interactions so that these can subsequently be enhanced and promoted. This information is essential to the final design and therefore function of the proposed environment. Need to explore the option of providing a 'formal' surface hydraulic connection to the river during higher flows to provide some flushing and improved dynamics of any open water. This would be facilitated by the upstream of the 'pit' being on the outside of a meander and the downstream end being on a straight reach.
Water Quality	Site 36 contains alluvial materials. It is located between the Ō2NL corridor and the Ohau River (stream ID number 33). It is approximately 136,000 m^2 in area and between 180,000-400,000m^3 in volume. As the site is located in close proximity to the proposed highway, it is easily accessible for construction machinery and no new roads are required. The site is located on the Ohau River terrace and is separated from the river by a width of between 40-180 metres. This area is grazed with sparse trees and shrubs. A narrow band of fenced vegetation occurs adjacent to the river. Two small watercourses are mapped immediately to the north and east of the proposed site (stream ID 34 and N/A). These appear to be historic or ephemeral watercourses that would only flow during heavy rainfall. During extreme flood events, the proposed aggregate supply site would become inundated with water from the Ohau River. Up to a 1 in 10-year Annual Exceedance Probability (AEP) event the area receives rainfall and minimal surface water flows from surrounding farmland. In a 1:100 AEP, the area would become inundated by the Ohau River. The main impacts on water quality will be potential erosion and sediment discharges, particularly caused by scour during extreme flood events. Due to the low frequency of such events (>1:10 AEP) mitigation is not considered appropriate. This is because actions such as bunding against extreme events would be prohibitive, and could potentially increase flooding downstream. No additional mitigation required. Potential sediment discharges can be managed through standard erosion and sediment control. (Updated 270522)

Technical Expert	Assessment
Landscape & Visual	There will be some adverse landscape effects during excavation, and from modifying the natural landform. Such effects will be remedied through construction of a naturalistic landform, and rehabilitation of the site with indigenous habitat and vegetation – replacing the existing farmland. The net outcome is potentially positive. There will be some adverse effects on perceptions of natural character during construction, although the site is buffered by the Ohau River by the ecological and natural character works proposed as part of Ō2NL, and the excavation will occur in the context of construction works along the highway corridor. The rehabilitated site will merge with the natural character enhancement proposed along the river margins. It will increase the amount of natural vegetation and habitat along the corridor. The net outcome is potentially positive.
Heritage	There are no heritage sites identified near this site so therefore there are no adverse effects
Archaeology	The main factor for consideration is the close proximity to the Ohau River. There are no specific archaeological sites recorded in the area, but there is a possibility that archaeological sites could be found in this area (without detailed survey it is difficult to assess due to the complex history of the area, movements of the river, have flood deposits destroyed or protected sites etc). In addition, the team should be aware that there was a homestead complex belonging to an early settler's family just outside the boundary of the proposed extent (see **Figure 7** below, John Davies house and buildings). There is currently a milkshed and other farm buildings in the area and it won't be affected by the current plans, but it is something to be aware of if there is a possibility this location needs to be crossed to enable vehicle access or the farming facilities are dismantled (if the current farm setup is determined to be impractical).
Air Quality	Low risk of effects - The alluvial resources at this location have the potential to be high in silt and therefore have a high dust potential. The length of the haul road has decreased and therefore the potential for dust generation has also reduced. Based on this, and the site being away from sensitive receptors, the assessment rating has decreased from medium to low as it is unlikely to cause any adverse effects in terms of air quality. (Updated 250522)
Social/Community	This site is outside the current proposed designation footprint impacting a large area of farmland and is in close proximity to an existing dwelling. It provides opportunities in the future to consider a possible future loop trail on northern bank of Ohau -Muhunoa East Road (to be developed by others). It provides an improved river environment that is a valued and used recreational asset for the local community. Assuming this is in keeping with the surrounding environment. On that basis once established, it is considered to have a negligible impact for the sub-local community (improved planting may provide improvement the quality of the sub-local local living environment).
Contaminated Land	There has been no HAIL activity identified on this site. The site has been farmland since prior to 1961. As with any farmland there is a possibility historical farm dumps could be encountered and historic buildings if they exist within the footprint of the borrow site may have other contaminants (Lead, asbestos etc) associated with them. The likelihood of this at site #36 is unknown. It is understood that someone has looked at historic farm and early settlers dump sites but this information has not been seen to date.

Technical Expert	Assessment
HC Soils	Loss of highly productive land with no mitigation options available. Site 36 is above Site 26 and was classified as “green” under the initial assessment under the assumption it was mostly LUC unit 4s1 where in fact it is LUC unit 2s1. The traffic light assessment should have been “orange” for site 36.
ESC	From an Erosion and Sediment Control perspective, there is nothing remarkable about Site #36, other than the proximity to the Ohau River. It is noted that the final contours tie into the upper terrace, above the 100 year flood plain, and therefore it appears the site has the protection of the 100 year flood during extraction. I am of the opinion that erosion and sediment control devices that comply with the GWRC ESC Guideline could be installed to provide control for this site.
Iwi/CEDF	Iwi partners support open water option – at hui 2303 have agreed to design further open water option. Iwi partners are preparing Cultural Impact Assessments (CIA) and the CEDF audit process and these two mechanisms allow detailed issues to be identified as relevant. (Updated 310522)

Site #34a – Q5b Sand Site at Koputaroa

Technical Expert	Assessment
Transport	This was originally given a green site due to the reduction in required transport from the zone 4 sites. While it appears to have gotten smaller, the same points remain valid. Remains green.
Freshwater Ecology	As per the TLA, this site does not include any permanently flowing stream channels. While the original proposal included a proposed enlargement of the pond which was supported as it would address some of the loss of open water in upper Koputaroa catchment, it is understood the pond extension idea was not really viable. However this site still has ecological benefits resulting in permanent removal of cattle from an area of the catchment and creation of a wetland environment. Therefore, the original “green” assessment of the site stands, with the proviso that works are carefully managed to minimise adverse effects (e.g., sedimentation) on the adjacent ponds and wetland.
Terrestrial Ecology	Entirely within pasture and does not intersect with any seepage wetlands. Unlikely to have any adverse ecological effects as long as wetland hydrology/groundwater is not impacted and robust sediment controls are implemented.
Noise & Vibration	There is only one PPF (Protected Premises and Facilities) within 200m of the site – site is ‘green’ from a noise and vibration perspective.
Flooding & Hydrology	There would be no detrimental effects on flooding either upstream or downstream as a result of material extraction. The boundary provided is set back from the (ephemeral) stream floodplain, although it is understood that the proposed site will be integrated into an online wetland (i.e. not separated from the stream). The site represents a very slight advantage in terms of flood risk (due to additional storage of flood water on a wider floodplain).

Technical Expert	Assessment
Groundwater	There are no ‘red flags’ and the proposal is generally supported. Notwithstanding this, the final design must extend and connect to the existing box valley i.e., extend the extent of the flat valley floor. Careful design and construction will be required to ensure the enhancement and extension of existing hydrological/wetland processes and not the replacement of the existing wetland environment. Further investigation using piezometers is required to confirm the surface water/groundwater interactions so that these can subsequently be enhanced and promoted.
Water Quality	Site 34a contains Qb5 sands. It is located between the Ō2NL corridor and an unnamed first order tributary of the Koputaroa Stream (stream ID number 41). It is approximately 17,900 m^2 in area and between 40,000 – 80,000m^3 in volume. As the site is located adjacent to the proposed highway, it is easily accessible for construction machinery and no new roads are required. The site is located on agricultural land that slopes towards the unnamed tributary to the south. A small farm dam is located to the south-east of the proposed aggregate supply site. From topography, the tributary appears to be an intermittent steam, with permanent water behind the dam. The watercourse itself is outside of but immediately adjacent the zone of work. The main impacts on water quality will be potential erosion and sediment discharges, and possible increases in water temperature through removal of shading from the northern bank. This will be insignificant compared to the activities already being undertaken along the proposed highway. No additional mitigation required. Potential sediment discharges can be managed through standard erosion and sediment control. Potential impacts on water temperature will be addressed by stream and wetland revegetation already proposed as part of the Project.
Landscape & Visual	It appears the terrace will be removed to a level a little higher than the gully so as not to disrupt hydrology of the wetland. The lowered ground could be planted with wet forest. While it would not increase the extent of the wetland, it would provide a deeper margin around the gully. This is consistent with the intent to restore the gully for natural character purposes. The only adverse effects would be increased visibility of the highway from the nearest houses to the SE and S (161 and 157 Fairfield Road). This would be mitigated through planting batter below highway and the restoration planting mentioned above. Overall, the revisions would not change previous ratings for this site.
Heritage	There are no heritage sites identified near this site so therefore there are no adverse effects
Archaeology	An assessment of the revised site #34a confirms it is of lesser extent than the previous design freeze, so the probability of encountering an archaeological site also reduced – as per the TLA, this site could possibly be Orange as there is the potential for archaeological sites to be found in the area (archaeological site located further up gully, beyond extraction site).
Air Quality	Site 34a is located within the designation footprint and therefore unlikely to cause any adverse effects in terms of air quality.
Social/Community	House within 200m (need to confirm if this will be acquired as part of Project) of site on land already indicated for disturbance (within designation). May result in increased disturbance. Assumption made that post use site will be part of overall landscaping mitigation for corridor and or used as part of road, SUP or stormwater where it is within the corridor. Site remains orange as per TLA.
Contaminated Land	There has been no HAIL activity identified on this site from Council records. Farmland observed since prior to 1939. No historical development of farm buildings seen on this site although there is a possibility for unexpected discovery of an old farm dump in areas next to the river.

Technical Expert	Assessment
HC Soils	Approximately half of the site is Class 6, with the rest Class 2. The location of the proposed corridor compromises the remaining piece of highly productive land – this could have been avoided if the proposed road was against the edge of the site (designation) to minimise the effect/loss of highly productive land. Overall the site is 'green'.
ESC	Essentially from an Erosion and Sediment Control perspective there is nothing remarkable about the site, other than the proximity to the watercourse. The site is characterised by gentle contours and should be quite simple and straight forward from an ESC perspective. I am of the opinion that erosion and sediment control devices that comply with the GWRC ESC Guideline could be installed to provide control for these sites.
Iwi/CEDF	Iwi partners aware of preferred site and seem fine with it. Iwi partners are preparing Cultural Impact Assessments (CIA) and the CEDF audit process and these two mechanisms allow detailed issues to be identified as relevant.

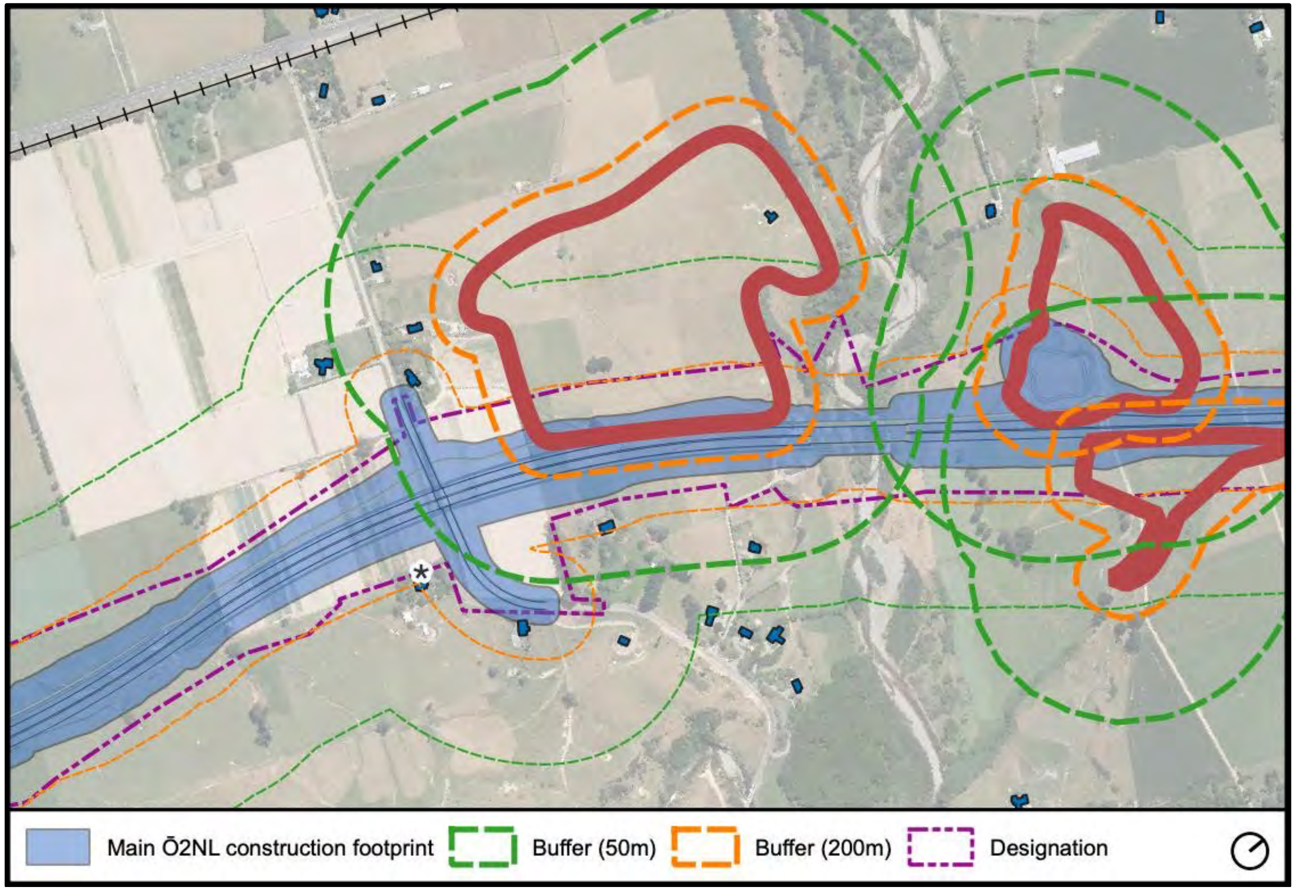

Figure 1 – Noise & Vibration buffers around site #15

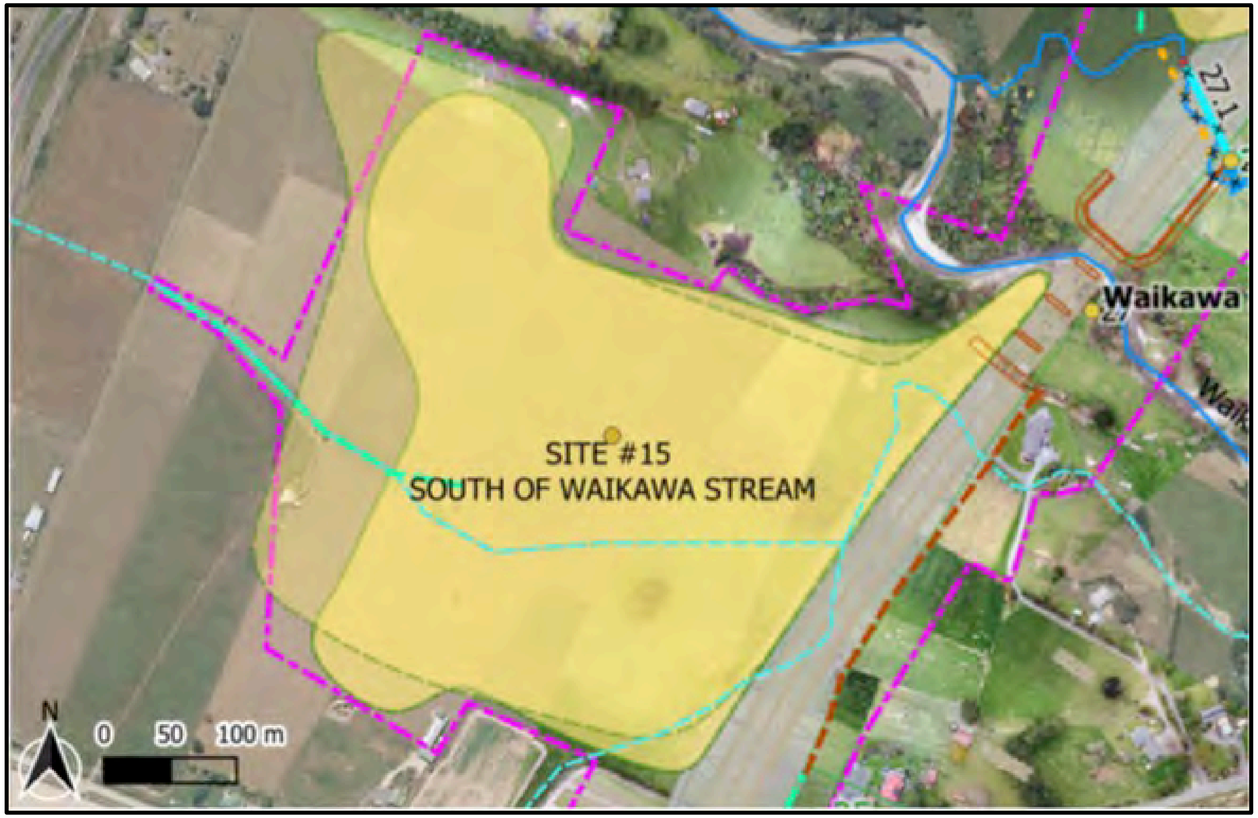

Figure 2 – Proposed westward extension to the designation recommended by Andrew Craig

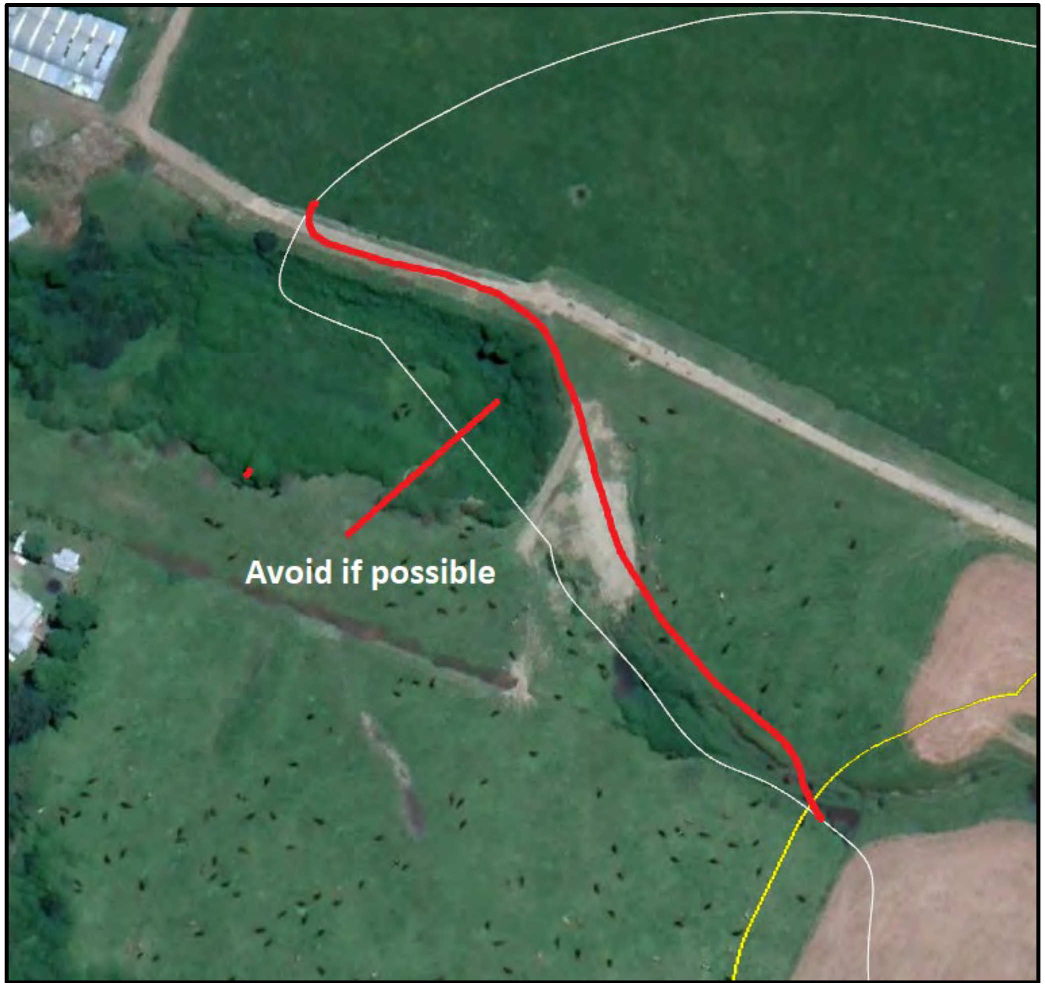

Figure 3 - Western extent of Site 19 showing potential overlap with indigenous vegetation and potential wetland

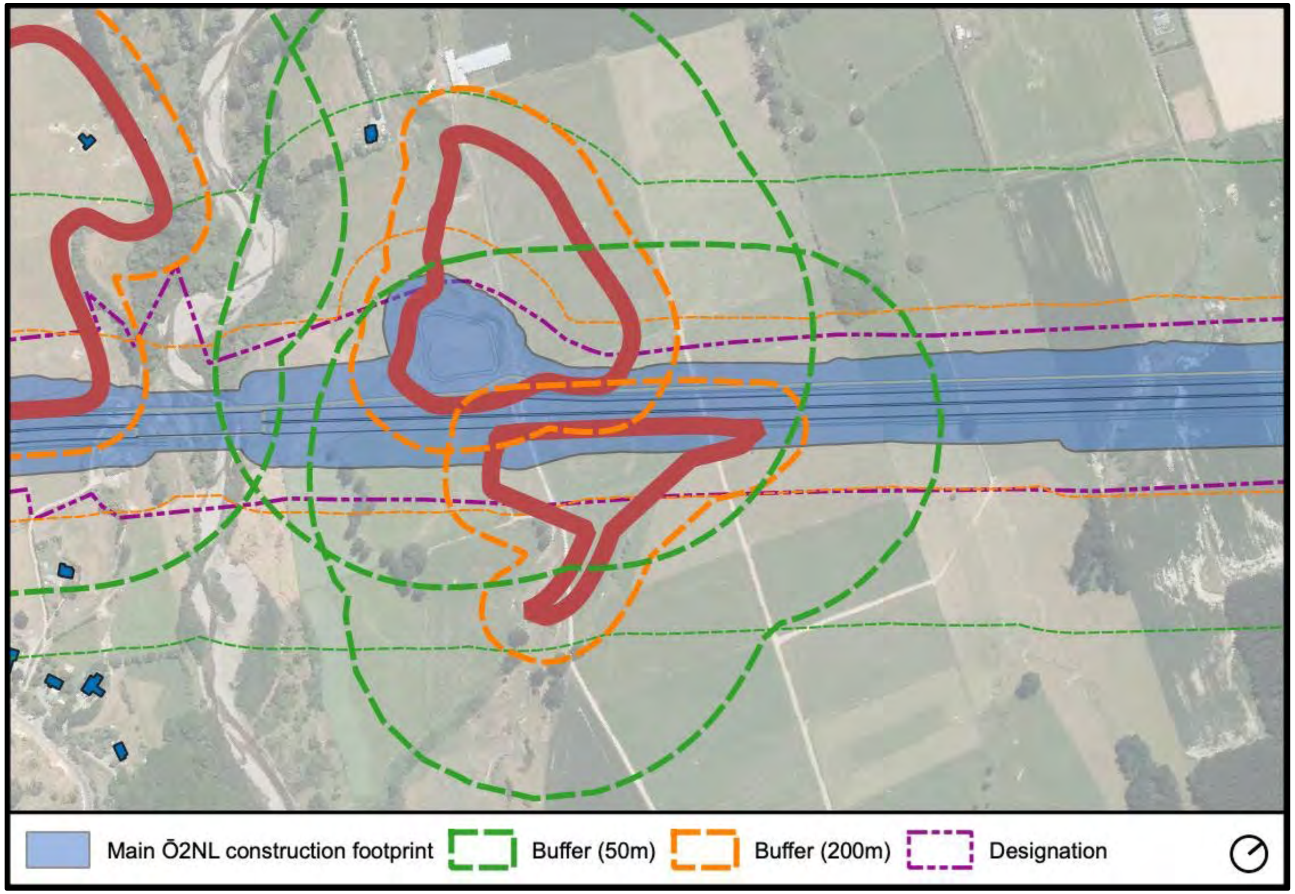

Figure 4 - Noise & Vibration buffers around site #19

Figure 5 - Hunting site called Parikawau

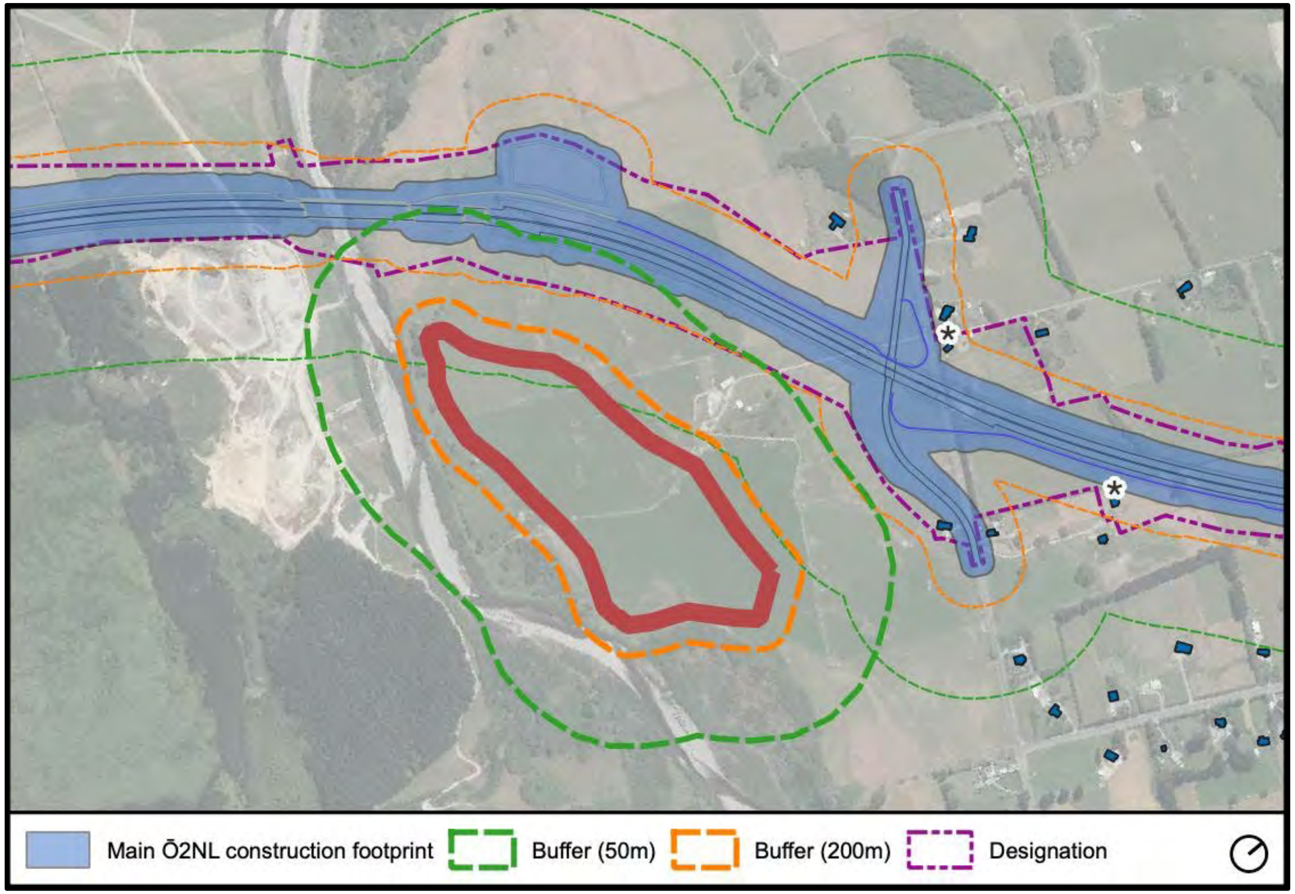

Figure 6 - Noise & Vibration buffers around site #36

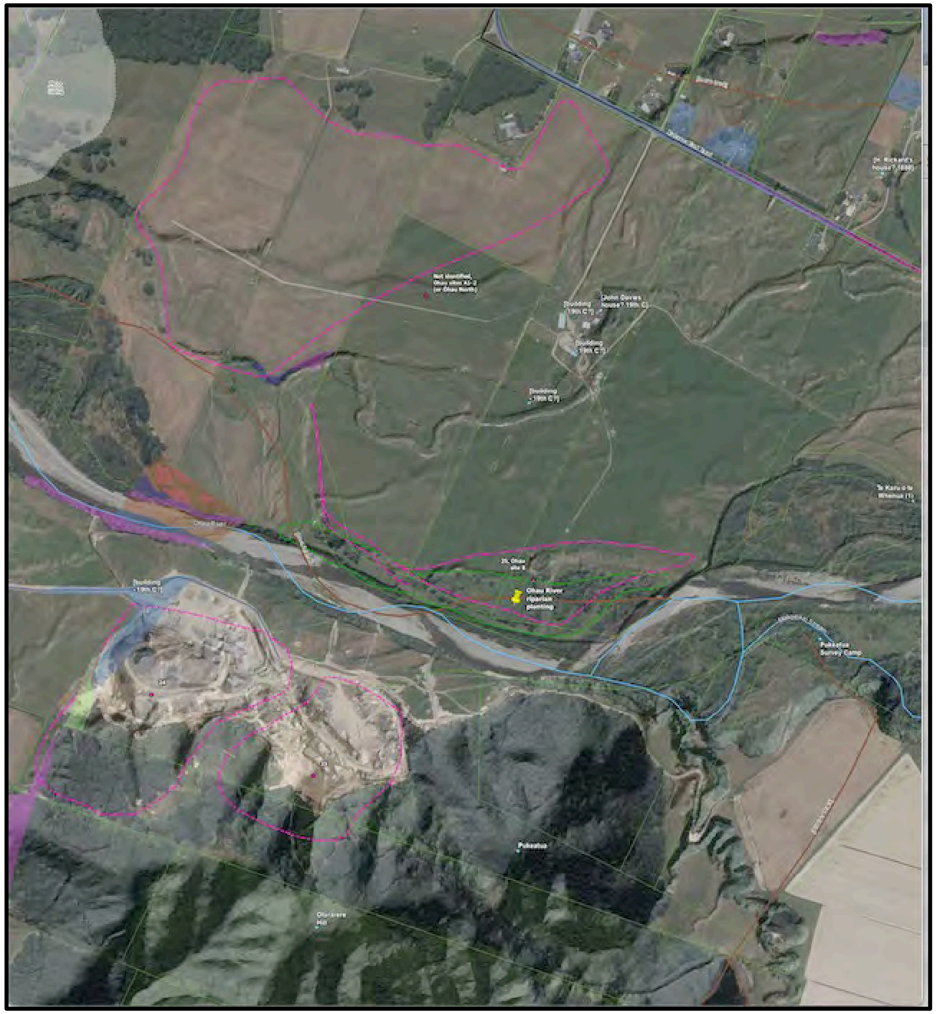

Figure 7 – John Davies house and buildings

Appendix 4.5.4 Geotechnical Memorandums

Geotechnical Assessment Memorandum for Q5b Shoreline Deposits, May 2022

Otaki to North Levin (O2NL) Geotechnical Assessment Memorandum for Q5b Shoreline Deposits (Sands)

The conclusions in the Report are Stantec's professional opinion, as of the time of the Report, and concerning the scope described in the Report. The opinions in the document are based on conditions and information existing at the time the document was published and do not take into account any subsequent changes. The Report relates solely to the specific project for which Stantec was retained and the stated purpose for which the Report was prepared. The Report is not to be used or relied on for any variation or extension of the project, or for any other project or purpose, and any unauthorized use or reliance is at the recipient's own risk.

Stantec has assumed all information received from the Client and third parties in the preparation of the Report to be correct. While Stantec has exercised a customary level of judgment or due diligence in the use of such information, Stantec assumes no responsibility for the consequences of any error or omission contained therein.

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Rev. no	Date	Description	Prepared by	Checked by	Reviewed by	Approved by
1	03-08-2021	Expediated factual information compilation and re-use interpretation of Q5b sand material	KC/RC	EG	IA	JP
2	30-05-2022	Q5b Sand material interpretation	KC/RC	JG	EG	JP

1 Introduction

Stantec has been engaged by Waka Kotahi to undertake geotechnical investigations and reporting for the Otaki to North Levin (O2NL) project. The first stage of the geotechnical investigation was completed in 2020, the second stage in 2021 and the third stage in 2022. The investigation results are presented within Stantec's Geotechnical Factual Report[1].

The purpose of this memorandum is to summarise factual results and provide geotechnical interpretation of the re-useability of the Q5b shoreline material (referred to Q5b Sands).

The Q5b sand material represents a geological formation as shown on published geological maps[2]. The proposed O2NL alignment crosses significant lengths of Q5b material between SH1 (Ch. 10,000) to SH57 (Ch. 13,000) north of Levin and between Ch. 30,700 to Ch 34,000 north of the Otaki River. Refer to Figures 2.1 and 2.2 respectively.

This Q5b sands are currently targeted for use as a bulk/general embankment fill, either as an efficient cut-to-fill process, or an efficient borrow-to-fill process. This assumption has been flagged as considerable project risk, with significant consequential effects.

An initial version of this memorandum recommended to avoid the re-use of this material if possible. However, on completion of a subsequent Material Supply (Borrow) Study[3], alternatives were not readily and efficiently available, and this has resulted in the need to rely on Q5b sand material for embankment construction. Assuming the material was going to be re-used, initial recommendations included:

- *Desktop review of historical documentation relating to the construction of SH57 between Shannon and Linton.*
- *Additional geotechnical investigation / testing targeting Q5b sand material source sites.*
- *Discussion with local Contractors regarding workability.*
- *Feasibility desktop assessment on using potential mixing (i.e., gravels) or additives (i.e., lime or fly ash).*
- *Constructability / compaction trial (material in natural state).*
- *Constructability / compaction trial (potential mixing (i.e., gravels) or additives (i.e., lime or fly ash).*

Excluding the field trials, these tasks have been completed and documented within this revised document.

The overall objective of this memorandum is to provide a compilation of the relevant geotechnical information, present a discussion on re-use interpretation of the Q5b sands, and provide recommendations going forward. The intent is that it will be appended to Stantec Geotechnical Interpretative Report[4].

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[1] Geotechnical Factual Report for SH1 Ōtaki to North Levin, Rev C, Stantec, May 2022
[2] 1:250,000 Institute of Geological and Nuclear Sciences (IGNS) Geology of the Wellington Area, Map 10
[3] Ōtaki to North Levin (Ō2NL) Material Supply Study Report, Stantec, May 2022 (pending)
[4] Preliminary Geotechnical Interpretative Report for SH1 Ōtaki to North Levin, Rev D Stantec, May 2022

2 Location Plans

2.1 Northern Extent - Ch. 10,000 to Ch. 13,000

Figure 2.1, below, shows the investigation locations within the Q5b sands, at the northern extent of the alignment.

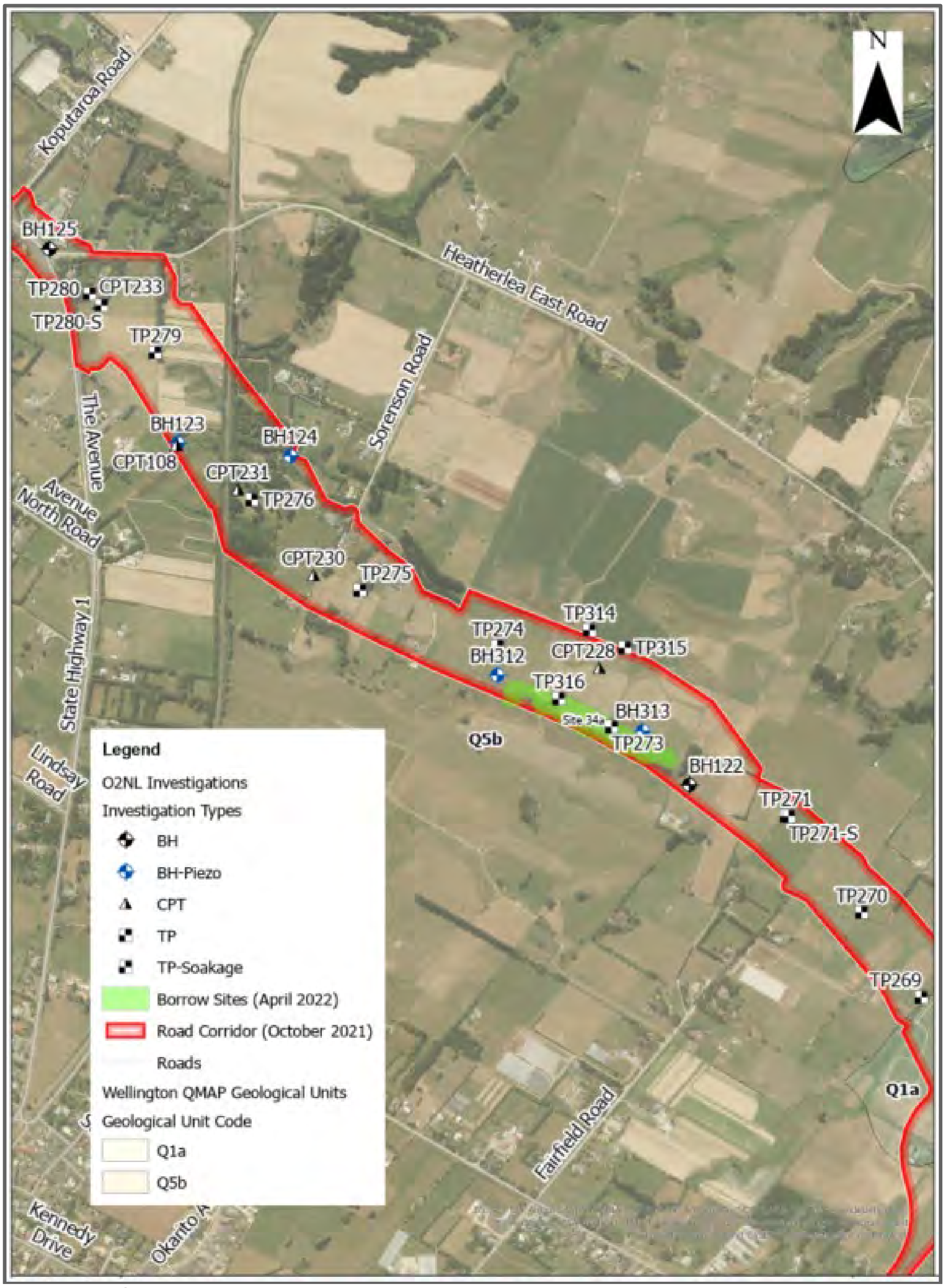

Figure 2.1: O2NL Northern Extent

2.2 Southern Extent - Ch. 30,700 to Ch. 34,000

Figure 2.2, below, shows the investigation locations within the Q5b sands, at the southern extent of the alignment.

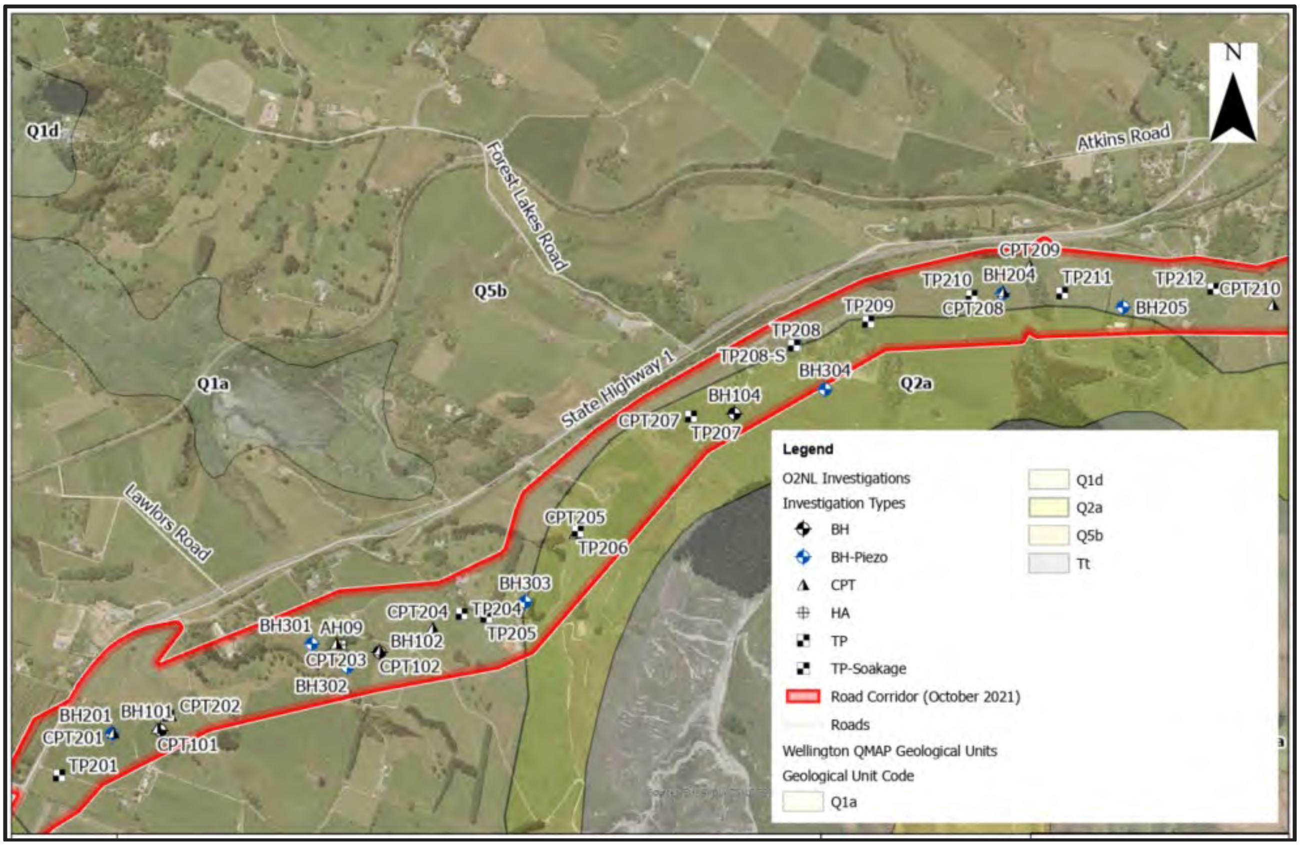

Figure 2.2: O2NL Southern Extent

Note that Q5b sand material was encountered elsewhere along the route, but this study focused on the northern and southern extents where of the alignment is primarily expected to be underlain by this material.

3 Knowledge of Q5b Sand Material

3.1 Published Geological Knowledge

The Q5b formation, as mapped and defined on 1:250,000 geological map of the Institute of Geological and Nuclear Sciences (IGNS) [5], is described as late Pleistocene age shoreline (ocean and beach) deposits, consisting of sand and marine gravel with sand commonly being overlaid by loess and fan deposits.

The Q5b formation of the IGNS geological map is inferred to include the following stratigraphy, described in the literature pertinent to the project area:

- The Otaki formation, consisting of two units, the Otaki Beach sand and Otaki Dune sand.
- Cover-beds of loess that generally overlie the Otaki and other geological formations in the wider area of the project. Loess consists of a sequence of up to four units of a total thickness of 4 m (Palmer et al. 1988[6]). The upper loess contains the Aokautere Ash. Loess sheets are typically discontinuous in the area and a complete sequence is rare. Generally, one or two loess units are missing, sometimes replaced by sands.
- The Koputaroa sands, which overlie the Otaki formation at the areas west and north of Levin, and possibly in the Otaki - Te Horo areas (Hawke and McConchie, 2005[7]).

The Otaki formation is underlain by the Pukehou formation. This is believed to correspond to the formation denoted as Q6 in the IGNS geological map, described as middle Pleistocene poorly graded to moderately sorted river gravel underlying loess-covered, commonly eroded aggradational surfaces. The formation wedges out against gravels about 2km west of State Highway 1. In the boreholes carried out for the Otaki to North Levin alignment, the Pukehou formation was inferred to have been encountered at depths greater than 20 – 25 m from the ground level in boreholes at the south part of the alignment. The formation is described as blue clay, blue fine sand, blue peaty sand, grey clayey silt, or fine grey sand (Sewell, 1991[8]). Occasional thin gravel lenses (0.2- 0.3 m) are also present. Almost without exception, peat, wood or carbonaceous matter are noted within it.

The Otaki formation and the Koputaroa sands are discussed in more detail in the following sections, as they are encountered near the ground surface and will influence aspects of the design and construction of the Otaki to North Levin motorway, as described in Section 1 of this memo.

3.1.1 Otaki formation

The Otaki formation is a predominantly shallow-water marine deposit, as described by Oliver (1948)[9]. In comparing the texture and composition of the Otaki Formation with the present-day coastal deposits to the west, Oliver made the following observations:

1. Sand in the Otaki Formation is generally more rounded than present-day beach and dune sand; and
2. Otaki Formation has a higher ferromagnesian content than present-day beach and dune sand.

Oliver considered the formation to be a predominantly shallow-water marine deposit with dune sands laid above coalescing alluvial fans.

The two units consisting of the Otaki formation are described in more detail below, from the older to the youngest stratigraphical member of the sequence (based on Sewell, 1991).

Otaki Beach Sand:
The lower stratigraphically unit of the Otaki formation is a light olive-grey, fine- to medium-grained gravelly sand with occasional sharply defined interbeds and lenses of yellow-grey to very pale orange, silty sand. The sand is generally moderately hard and maintains a stable vertical face at existing cuttings. However, outcrops of moderately soft sand are not uncommon and seem to have resulted from slight weathering. The unit is described as sandstone in the geological references, as the sandy soils have been cemented, to variable degrees.

The unit is referenced in the literature to have a thickness ranging from 13 m to 20 m. In the boreholes carried out along the Otaki to North Levin alignment, it was found with typical thicknesses ranging between 10 m and 14 m.

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[5] Begg, J.G.; Johnston, M.R. (compilers) 2000: Geology of the Wellington area: scale 1:250,000. Lower Hutt: Institute of Geological & Nuclear Sciences. Institute of Geological & Nuclear Sciences 1:250,000 geological map 10. 64 p. + 1 folded map.

[6] Palmer A, Barnett R, Pillans B, Wilde R 1988. Loess, river aggradation terraces and marine benches at Otaki, southern North Island, New Zealand. In: Eden D, Furkert R ed. Loess: its distribution, geology and soils. Proceedings of an International Symposium on Loess, New Zealand, 14-21 February 1987. Balkema. Pp 163-174.

7 Hawke R. M & McConchie J. A. (2005) The source, age, and stabilisation of the Koputaroa dunes, Otaki-Te Horo, New Zealand.

[8] Sewell, A. H., (1991) Paleoenvironmental Analysis of Quaternary starta in the Levin area, Thesis, Massey University.

[9] Oliver, R. L., 1948, The Otaki Sandstone and its geological history: N.Z. D.S.I.R. Geological Memoirs, v. 7, p. 49 p.

Silty beds and organic layers, well stratified or with crossbedding are described within the formation. The silty beds are interpreted in the literature to reflect periodic heavy influxes of fine sediment into an otherwise sand-dominated environment. The interbedding and nature of the Otaki Beach sand layers indicate a foreshore sub-environment of a wave-dominated shoreline (Elliot 1986)[10]. The silty beds are possibly the result of infrequent flood episodes of adjacent rivers into an open beach environment.

Otaki beach sand grades up into Otaki dune sand, which is described below.

Otaki Dune Sand:
The Otaki Dune sand consists of orange brownish grey, fine to coarse graded sands and silty sands. The unit is characterised by intense crossbedding, consisting of alternating thin (2 – 3 mm) silty laminae containing carbonaceous matter.

3.1.2 Koputaroa Sands

Cowie (1963)[11] distinguished the much younger Koputaroa phase dune-sands (18,000 to 35,000 years old) from what Oliver had previously included as part of the Otaki Formation in the Levin area. He noted a strongly weathered clay separated the two units which indicated a period of intense and prolonged weathering.

Cowie considered the Koputaroa dune-sands to be of fluvial origin primarily because they accumulated during the Last Glaciation when sea level was considerably lower. Based on Hawke and McConchie (2005)[12], the Koputaroa dune sand is almost identical to the Holocene dune sand, but it is distinctly different to that derived from local rivers.

3.2 Stantec's Investigation Field Descriptions

The Q5b stratigraphy described in Section 3.1, have been encountered in the boreholes carried out along the Otaki to North Levin alignment. The different units are generally described as follows in the boreholes along the alignment:

- **Loess:** described as silty CLAY, to clayey SILT, often interlayered with sand and gravel, brown, to light yellowish-brown with orange mottles. The layer is often encountered directly on the ground surface, below the topsoil, and has a thickness from 0.5 m and up to 4 m, but it was also absent from some boreholes and test pits.
- **Koputaroa Sand:** encountered as SAND with some silt to silty SAND, brown, medium dense to dense. The layer has been interpreted to be up to 7 – 10 m thick, it overlies the Otaki formation and is found either directly on the ground surface or below a layer of loess.
- **Otaki Dune Sand:** This unit of the Otaki formation is described as fine to medium silty SAND to SAND with silt and clay, brown. The unit is generally medium dense but could also be dense to very dense. Interlayers of reddish-brown silty clay layers and organics have been observed. Often these layers denote the transition from the dune sands to the underlying Otaki beach sands unit. The thickness of the dune sand unit is of the order of 10 to 15 m.
- **Otaki Beach Sand:** This unit of the Otaki formation is described as fine to medium SAND with some silt, silty SAND, brown to grey-brown. The layer is generally very dense and often retrieved partially cemented. The thickness of the layer in the boreholes was found to be up to 10 – 15 m.

It is generally difficult to distinguish the Otaki dune sands from the Otaki beach sands in the boreholes, especially when the latter are not cemented. Distinguishing between the two layers in the ground model developed for the project was primarily based on the N_{SPT} values and the degree of cementation, with the higher values, believed to correspond to the Otaki beach sands.

3.3 Geotechnical or Construction Knowledge

Stantec are not aware of any previous geotechnical testing results or assessment of the Q5b sand material.

Stantec understands (via discussion with WSP) that the Q5b sand material was not encountered in the nearby Pekapeka to Otaki project.

It is acknowledged that SH57 passes through mapped Q5b areas between Shannon and Linton. Waka Kotahi (Sarah Heappy) undertook a drive-by and confirmed fill slopes are present but couldn't confirm if they were constructed using Q5b sand material. Stantec understands (via discussion with WSP) silty sand material was utilised for construction (job overseen by Opus) of these fills, but contractors had to condition (dry) the material and it was only suitable for summer construction.

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[10] Elliot, T., 1986, Siliclastic Shorelines, in ch. 7 of Reading, H. G., ed., Sedimentary Environments and Facies [2nd ed.]: London, Blackwell Scientific Publications, p. 155-188.

[11] Cowie, J. D., 1963, Dune-building phases in the Manawatu District, New Zealand: New Zealand Journal of Geology and Geophysics, v. 6, p. 268-280.

[12] Hawke R.M. & McConchie J.A. (2005) The source, age, and stabilisation of the Koputaroa dunes, Otaki-Te Horo, New Zealand, New Zealand Journal of Geology and Geophysics, 48:3, 517-522

Waka Kotahi (Sarah Heappy) discussed the potentially workability of the Q5b sands with local Contractor Stan Goodman. Mr Goodman believed the Q5b sand material was workable, noting that a high level of earthworks management would be required. The conversation derived the following suggestions for earthworks planning:

- 70% of the cut Q5b sand material should be efficient to use as “cut to fill”.
- Drying of 4-5% moisture content can be typically achieved via discing (over 2 days if conditions allow) prior to compaction. Drying >5% becomes more challenging to achieve.
- Lime conditioning may be advantageous to extend the earthwork season.
- Pneumatic tyre roller compaction is likely the most suitable type for construction.

4 Investigations Completed

Investigations within the mapped Q5b area (southern and northern extents) and the O2NL road corridor have been completed by Stantec between June 2020 to March 2022. Stantec has completed ten boreholes within these areas during the O2NL Stage 1 and 2 investigations. All boreholes were completed by Griffiths Drilling with a PQ sized core barrel using a sonic drilling methodology per NZS 4411:2001 Environmental Standard for drilling of Soil and Rock.

Stantec has completed fifteen test pits within the Q5b area (southern and northern extents) as part of the Stage 2 and Stage 3 investigations. Test pits were excavated by Goodmans Contracting and Rocka Excavation between April 2021 – March 2022 using a 14t wheeled excavator.

Stantec has completed fourteen cone penetration tests (CPT) within the Q5b area over the Stage 1 and Stage 2 investigations. Stage 1 investigations were completed by Griffiths Drilling in 2020 and Stage 2 investigations by Ground Investigations Ltd in 2021.

Logging and sampling of the boreholes and test pits were completed by Stantec geologists. Samples have been stored at secure Waka Kotahi containers before testing.

4.1 Northern Extent - Ch. 10,000 to Ch. 13,000

Table 4.1 presents a summary of the relevant intrusive investigations completed with the Q5b material located within the northern extent of the project.

Table 4.1: Summary of Investigations Completed with the Q5b Material (northern extent)

Investigation ID	Investigation Type	Coordinates (NZTM 2000)		Elevation (m RL, WGN 1953)	Approx. Chainage	Termination Depth (m bgl)	Depth where Q5b Encountered (m bgl)	Q5b Sands Subunits
		Easting	Northing					
BH119	Borehole	1795114	5499693	49.4	16150	30.44	3.85 - >30.44	3.85 – 9.00 Koputaroa Sand 9.00 – 12.00 Otaki Dune Sand 12.00 – 30.44 Otaki Beach Sand
BH122	Borehole	1796056	5502678	29.5	12150	19.78	3.00 >19.78	3.00 – 8.00 Koputaroa Sand 8.00 – 19.78 Otaki Dune Sand
BH123	Borehole	1794852.3	5503483.3	48.5	10650	30.88	2.00 >30.88	2.00 – 8.00 Koputaroa Sand 8.00 – 17.30 Otaki Dune Sand 17.30 – 30.88 Otaki Beach Sand
BH124	Borehole	1795116.8	5503452.7	40.95	10800	30.12	3.00 >30.12	3.00 – 7.30 Otaki Dune Sand 7.30 – 30.12 Otaki Beach Sand
BH125	Borehole	1794550	5503940	48.6	10100	19.92	1.75 - >19.92	1.75 – 5.35 Koputaroa Sand 5.35 – 7.50 Otaki Dune Sand 7.50 – 19.92 Otaki Beach Sand
BH127	Borehole	1796143.6	5500632.1	42.7	14780	19.86	1.70 – 19.86	1.70 – 9.00 Otaki Dune Sand 9.00 – 19.86 Otaki Beach Sand
BH227	Borehole	1796429.7	5500713.2	40.3	14527	25.25	0.80 – 25.25	0.80 – 5.90 Koputaroa Sand 5.90 – 14.00 Otaki Dune Sand 16.5 – 25.25 Otaki Beach Sand
BH223	Borehole	1795791.6	5500072.3	50	15425	19.8	2.00 – 19.80	2.00 – 5.20 Koputaroa Sand 5.20 – 8.90 Otaki Dune Sand 8.90 – 19.80 Otaki Beach Sand
BH229	Borehole	1795312.8	5499775.2	52	15986	19.65	3.30 – 19.65	3.30 – 12.60 Koputaroa Sand 12.60 – 15.40 Otaki Dune Sand 15.40 – 19.65 Otaki Beach Sand
BH222	Borehole	1795230.9	5499645.3	51.1	16137	30.14	3.00 – 30.14	3.00 – 22.00 Otaki Dune Sand 22.00 -30.14 Otaki Beach Sand
BH221	Borehole	1795069.2	5499377.2	53	16456	19.88	8.80 – 19.88	8.80 – 19.88 Otaki Dune Sand
BH312	Borehole	1795605.0	5502937.0	45.5	11559	15.45	0.40 – 15.45	0.40 – 3.40 Koputaroa Sand 3.40 – 15.45 Otaki Dune Sand
BH313	Borehole	1795947.0	5502806.0	44.1	11933	15.38	0.20 – 15.38	0.20 – 9.00 Koputaroa Sand

Investigation ID	Investigation Type	Coordinates (NZTM 2000)		Elevation (m RL, WGN 1953)	Approx. Chainage	Termination Depth (m bgl)	Depth where Q5b Encountered (m bgl)	Q5b Sands Subunits
		Easting	Northing					
								9.00 – 13.15 Otaki Dune Sand 13.15 – 15.38 Otaki Beach Sand
TP259	Test Pit	1796058	5500314	45.5	15071	3.60	1.00 – 3.60	1.00 – 3.60 Koputaroa Sand
TP261	Test Pit	1796432	5500762	39.4	14489	3.30	1.50 – 3.30	1.50 – 3.30 Koputaroa Sand
TP269	Test Pit	1796603	5502179	24.6	12861	3.70	0.80 – 3.70	0.80 – 3.70 Otaki Dune Sand
TP270	Test Pit	1796462	5502379	24.2	12600	3.80	0.80 - >3.80	0.80 – 2.10 Otaki Dune Sand 2.10 – 3.80 Otaki Dune Sand OR Otaki Beach Sand
TP271	Test Pit	1796284	5502606	28.5	12300	3.50	0.80 - >3.50	0.80 – 3.5 Otaki Dune Sand
TP273	Test Pit	1795874	5502816	38.0	11850	3.50	1.90 - >3.50	1.90 – 3.50 Otaki Dune Sand
TP274	Test Pit	1795605	5503006	38.5	11550	3.90	1.50 - >3.90	1.50 – 3.90 Otaki Dune Sand
TP275	Test Pit	1795281	5503137	41.7	11200	3.20	1.10 - >3.20	1.10 – 3.20 Otaki Dune Sand
TP276	Test Pit	1795027	5503350	49.2	10850	3.90	0.10 - >3.90	0.10 – 0.55 Koputaroa Sand 0.55 – 3.90 Otaki Dune Sand
TP279	Test Pit	1794799	5503697	49.0	10450	3.50	0.90 - >3.50	0.90 – 3.50 Otaki Dune Sand
TP280	Test Pit	1794645	5503835	49.2	10200	3.80	1.90 - >3.80	1.90 – 3.80 Koputaroa Sand
TP314	Test Pit	1795821	5503043	38.2	11717	3.50	1.20 - >3.50	1.20 – 3.50 Otaki Dune Sand
TP315	Test Pit	1795905	5503002	36.7	11805	3.50	0.80 - > 3.40	0.80 – 3.40 Otaki Dune Sand
TP316	Test Pit	1795749	5502882	41.2	11716	3.40	0.80 - >3.40	0.80 – 3.40 Otaki Dune Sand
CPT108	CPT	1794849	5503479	48.7	10650	8.22	1.60 - >8.22	1.60 – 8.22 Koputaroa Sand
CPT228	CPT	1795844.6	5502954.6	23.1	11800	6.78	2.50 - >6.78	2.50 – 6.78 Otaki Dune Sand
CPT230	CPT	1795171.6	5503172.8	42.3	11050	17.45	1.5 - >17.45	1.50 – 7.50 Otaki Dune Sand 7.50 – 17.45 Otaki Beach Sand
CPT231	CPT	1794993.9	5503374.4	49.3	10800	9.23	2.70 - >9.23	2.70 – 6.90 Otaki Dune Sand 6.90 – 9.00 Otaki Beach Sand
CPT233	CPT	1794668.3	5503811.4	49.5	10250	10.66	0.90 - >10.66	0.90 – 4.70 Koputaroa Sand 4.70 – 7.40 Otaki Dune Sand 7.40 – 10.66 Otaki Beach Sand

4.2 Southern Extent - Ch. 30,700 to Ch. 34,000

Table 4.2 presents a summary of the relevant intrusive investigations completed with the Q5b material located within the southern extent of the project.

It is noted that the depths where Q5b material have been encountered shown in the last column of both Tables 4.1 and 4.2 are based on the ground model we have interpreted based on the geotechnical data available at this stage of design. Some of the depths shown in the Tables may be slightly modified in the next stages of design of the alignment, as more information becomes available.

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Table 4.2: Summary of investigations completed with the Q5b material (southern extent)

Investigation ID	Investigation Type	Coordinates (NZTM 2000)		Elevation (m RL, Wel 1953)	Approx Chainage	Termination Depth (m bgl)	Depth where Q5b Unencountered (m bgl)	Q5b Subunits
		Easting	Northing					
BH101	Borehole	1783347	5487230	23.1	34100	19.63	1.20 - >19.63	1.20 – 13.5 Otaki Dune Sand 13.5 – 19.63 Otaki Beach Sand
BH102	Borehole	1783897	5487426	31.7	33500	19.88	2.50 - >19.88	2.5 – 16.5 Otaki Dune Sand 16.5 – 19.88 Otaki Beach Sand
BH104	Borehole	1784788	5488023	36.8	32400	19.86	3.00 - >19.86	3.00 – 8.00 Otaki Dune Sand 8.00 – 19.86 Otaki Beach Sand
BH201	Borehole	1783225.8	5487220.5	27.2	34200	30.38	6.36 - >30.38	6.36 – 19.50 Otaki Dune Sand (6.36 to 9.0 potentially Loess) 19.50 – 30.38 Otaki Beach Sand
BH204	Borehole	1785461.5	5488325.4	55.8	31650	19.95	4.50 - >19.95	4.50 – 19.95 Otaki Dune Sand
BH205	Borehole	1785762.7	5488289.9	64.7	31354	15.45	0.25 – 15.45	0.25 – 10.90 Otaki Dune Sand 10.90 – 15.45 Otaki Beach Sand
BH301	Borehole	1783727	5487446	30.4	33665	15.45	1.10 – 15.45	1.10 – 15.45 Otaki Dune Sand
BH302	Borehole	1783817	5487389	31.1	33592	15.45	1.35 – 15.45	1.35 – 15.45 Otaki Dune Sand
BH303	Borehole	1784263	5487552	52.1		15.45	1.20 – 15.45	1.20 – 15.45 Otaki Dune Sand
BH304	Borehole	1785015	5488085	45.6	32180	15.15	3.00 – 15.15	3.00 – 8.70 Otaki Dune Sand 8.70 – 15.15 Otaki Beach Sand
TP202	Test Pit	1783368	5487267	19.3	34050	3.6	2.00 - >3.60	2.00 – 3.60 Otaki Dune Sand
TP204	Test Pit	1784104	5487522	35.4	33300	3.8	2.30 - >3.80	2.30 – 3.80 Otaki Dune Sand
TP205	Test Pit	1784166	5487514	41.9	33218	4.25	2.10 - >4.25	2.10 – 4.25 Otaki Dune Sand
TP206	Test Pit	1784395	5487729	24.3	32904	3.7	2.80 - >3.70	2.80 – 3.70 Otaki Dune Sand
TP207	Test Pit	1784679	5488017	25.7	32500	4.0	3.70 – >4.00	3.70 – 4.00 Otaki Dune Sand
TP208	Test Pit	1784941	5488193	25.7	32200	3.5	1.40 - >3.50	1.40 – 3.50 Otaki Dune Sand
TP209	Test Pit	1785124	5488254	28.7	32000	4.0	2.30 - >4.00	2.30 – 4.00 Otaki Dune Sand
TP210	Test Pit	1785383	5488319	59.3	31750	4.0	0.45 - >4.00	0.45 – 4.00 Otaki Dune Sand
TP211	Test Pit	1785610	5488326	55.4	31510	4.0	1.10 – >4.00	1.10 – 4.00 Otaki Dune Sand
TP212	Test Pit	1785990	5488337	57.0	31100	3.9	3.10 - >3.90	3.10 – 3.90 Otaki Dune Sand

Investigation ID	Investigation Type	Coordinates (NZTM 2000)		Elevation (m RL, Wel 1953)	Approx Chainage	Termination Depth (m bgl)	Depth where Q5b Unencountered (m bgl)	Q5b Subunits
		Easting	Northing					
TP213	Test Pit	1786393	5488375	55.3	30723	3.70	1.30 - >3.70	1.30 – 3.70 Otaki Dune Sand
CPT101	CPT	1783340	5487235	23.1	34100	11.5	1.60 - >11.50	1.60 – 11.50 Otaki Dune Sand
CPT102	CPT	1783898	5487431	31.6	34050	2.13	1.70 - >2.13	1.70- 2.13 Otaki Dune Sand
CPT201	CPT	1783229.5	5487223.7	27.4	34200	2.88	Not encountered	--
CPT202	CPT	1783373.5	5487266.3	19.5	34050	13.41	2.10 - >13.41	2.10 – 13.41 Otaki Dune Sand
CPT204	CPT	1784031.0	5487486.5	26.9	33350	12.38	3.30 - >12.38	3.30 – 12.38 Otaki Dune Sand
CPT205	CPT	1784388.1	5487723.4	23.6	32900	12.73	3.20 - >12.73	3.20 – 12.73 Otaki Dune Sand
CPT207	CPT	1784674.6	5488018.8	25.3	32500	8.12	3.90 - >8.12	3.90 – 8.12 Otaki Dune Sand
CPT208	CPT	1785462.8	5488329.4	55.8	31650	23.22	4.90 - >23.22	4.90 – 20.00 Otaki Dune Sand 20.00 – 23.22 Otaki Beach Sand
CPT210	CPT	1786138.5	5488296.7	51.1	31000	10.15	1.70 - >10.15	1.70 – 10.15 Otaki Dune Sand (1.7 – 3.8 potentially interbedded Loess)

5 Laboratory Testing

5.1 Testing Standards

Testing was undertaken by Geocivil laboratory, in accordance with the following standards:

- Particle Size Distribution (wet sieve) tested in accordance with ASTM D6913-17
- Particle Size Distribution (hydrometer) tested in accordance with NZS 4402:1986 Test 2.8.1, 2.8.4
- Natural Water Content tested in accordance with Test 2.1, NZS4402:1986
- Density of Soil tested in accordance with Test 5.1.4 & 5.1.5, NZS4402:1986
- Atterberg Limits tested in accordance with ASTM D4318 - 00
- NZ Compaction Test via the Standard Compaction Test in accordance with NZS 4402:1986 Test 4.1.1
- California Bearing Ratio tested in accordance with NZS 4407: 2015, Test 3.15.

It should be noted that ASTM D6913-17 defines fine sands as the material between 0.075mm – 0.475mm whilst NZ geological guidelines (used for field descriptions) defines fine sands as the material between 0.075mm – 0.2mm. The ASTM D6913-17 standard has been used to facilitate the derivation of material properties from industry-accepted empirical relationships, including the liquefaction triggering assessments.

5.2 Testing Summary

5.2.1 Northern Extent - Ch. 10,000 to Ch. 13,000

Table 5.2a presents a summary of the relevant laboratory testing that was undertaken (within Q5b material, northern extent).

Table 5.2a: Laboratory Testing Summary (within Q5b material, northern extent)

Sample ID	Particle Size Distribution (Wet Sieve)	Particle Size Distribution (Hydrometer)	Natural Water Content	Atterberg Limits	NZ Compaction Test	California Bearing Ratio
BH119	4	-	4	-	-	-
BH122	1	-	1	-	-	-
BH123	3	-	3	-	-	-
BH124	1	-	1	-	-	-
BH125	1	-	1	-	-	-
BH221	2	-	3	1	-	-
BH222	3	-	3	-	-	-
BH223	2	-	2	-	-	-
BH227	2	-	4	-	-	-
BH229	3	-	-	1	-	-
BH312	10	-	10	-	-	-
BH313	9	-	9	-	-	-
TP259	1	-	1	-	-	1
TP261	1	-	1	1	-	-
TP269	1	-	1	-	-	-
TP270	1	-	1	-	-	-
TP271	1	-	1	-	-	-
TP273	1	-	1	-	1	1
TP274	1	-	1	1	1	1
TP276	1	-	1	-	-	-
TP279	1	-	1	-	-	-
TP280	1	-	1	-	-	-
TP314	1	-	1	-	1	-
TP315	1	-	1	-	1	-
TP316	1	1	2	1	1	-

5.2.2 Southern Extent - Ch. 30,700 to Ch. 34,000

Table 5.2b presents a summary of the relevant laboratory testing that was undertaken (within Q5b material, southern extent).

Table 5.2b: Laboratory Testing Summary (within Q5b material, southern extent)

Sample ID	Particle Size Distribution (Wet Sieve)	Particle Size Distribution (Hydrometer)	Natural Water Content	Atterberg Limits	NZ Compaction Test	California Bearing Ratio
BH101	2	-	2	-	-	-
BH102	3	1	3	-	1	2
BH104	2	-	2	-	-	-
BH201	1	-	1	1	-	-
BH204	7	-	7	1	-	-
BH205	-	-	4	2	-	-
BH301	10	-	10	-	-	-
BH302	10	-	10	-	-	-
BH303	10	-	10	-	-	-
BH304	9	-	10	3	-	-
TP202	-	-	-	-	1	1
TP204	1	-	1	-	1	1
TP208	2	-	2	-	2	-
TP209	1	-	1	1	1	1
TP210	1	1	1	-	1	1
TP212	2	-	2	1	1	-

6 Laboratory Testing Summarisation

6.1 Laboratory Results Summary

6.1.1 Northern Extent - Ch. 10,000 to Ch. 13,000

Table 6.1a presents a summary of relevant laboratory testing results (within Q5b material, northern extent).

Table 6.1a: Laboratory Testing Results (within Q5b material, northern extent).

Sample ID	Depth (m bgl)	Particle Size Distribution (Wet Sieve)					Provisional Classification According to USCS	Natural Water Content (%)	GWL (m bgl) Observations (at Time of Sampling)	Terrain (at Sampling Location)	Q5b Subunits
		% Gravel	% Coarse Sand	% Medium Sand	% Fine Sand	% Silt /Clay					
		>4.75 mm	4.75 – 2mm	2 – 0.475mm	0.475 – 0.075mm	<0.075mm					
BH119	4.5 - 4.9	0.2	0.3	3.1	73.5	22.9	SM/SC	35.9	Undetermined	Flat	Koputaroa Sand
BH119	6.0 - 6.4	0	0.2	1.4	89.2	9.2	SP-SM/SC	20.9	Undetermined	Flat	Koputaroa Sand
BH119	10.5 - 10.95	0.2	0.1	1.8	81.1	16.8	SM/SC	27.4	Undetermined	Flat	Otaki Dune Sand
BH119	15.0 - 15.5	0	0.2	4.8	80.5	14.5	SM/SC	26.2	Undetermined	Flat	Otaki Beach Sand
BH122	4.0 – 4.5	0	0.6	1.7	84.5	13.2	SM/SC	16.6	Undetermined	Flat	Koputaroa Sand
BH122	9.0 – 9.45	0	0	0.9	84.9	14.2	SM/SC	23.4	Undetermined	Flat	Otaki Dune Sand
BH123	4.0 - 4.2	0	0	1	86.5	12.5	SM/SC	24.2	10.45	Top of terrace	Koputaroa Sand
BH123	5.75 - 6.0	0	0.1	0.8	85.4	13.7	SM/SC	23.3	10.45	Top of terrace	Koputaroa Sand
BH123	9.0 - 9.45	0	0	0.7	75.7	23.6	SM/SC	21.7	10.45	Top of terrace	Otaki Dune Sand
BH124	5.0 - 5.25	0	0.7	2.1	82.3	14.9	SM/SC	19.3	5.9	Top of terrace	Otaki Dune Sand
BH125	3.8 – 4.0	0	0	0.3	25.6	74.1	MH/ML/CL/CH	71.8	Undetermined	Top of terrace	Koputaroa Sand
BH125	6.0 – 6.6	0	0	1.5	87.1	11.4	SP SM/SC	24.8	Undetermined	Flat	Otaki Dune Sand
BH221	9.0 – 9.45	0	0	0.9	88.6	10.5	SP	29.7	2.85	Flat	Otaki Dune Sand
BH221	15.0 – 15.45	0	0	2.1	84.4	13.4	SM/SC	24.8	2.85	Flat	Otaki Dune Sand
BH222	4.50 – 4.84	0	0	1.0	89.5	9.6	SP	26.5	7.1	Flat	Otaki Dune Sand
BH222	9.0 - 9.45	0	0	0.8	87.8	11.4	SP	22.1	7.1	Flat	Otaki Dune Sand
BH222	15.0 - 15.45	0	0	1.2	87.8	11.0	SP	30.9	7.1	Flat	Otaki Dune Sand
BH223	5.5 – 6.45	1.6	0.2	1.1	21	76.1	MH/ML/CL/CH	40	Undetermined	Flat	Otaki Dune Sand
BH223	13 – 13.95	0	0	1.2	22.5	76.3	MH/ML/CL/CH	25.8	Undetermined	Flat	Otaki Beach Sand
BH227	16.0 – 18.0	23	6.5	9.4	16.5	44.6	MH/ML/CL/CH	7.4	Undetermined	Flat	Otaki Beach Sand
BH227	20.0 - 21.0	20.8	5.8	11.4	17.2	44.8	MH/ML/CL/CH	9.8	Undetermined	Flat	Otaki Beach Sand
BH229	5.5 – 6.0	0	0	0.3	11.4	88.3	MH/ML/CL/CH	26.5	3.43	Flat	Koputaroa Sand
BH229	6.0 – 7.0	0	0	0.3	84.9	14.7	SM/SC	22.9	3.43	Flat	Koputaroa Sand
BH229	15.0 – 16.0	0	0	0.1	11.8	88	MH/ML/CL/CH	22.1	3.43	Flat	Otaki Dune Sand/ Otaki Beach Sand
BH312	1.5 – 1.95	0	0	2	79	19	SM/SC	20.6	7.34	Top of terrace	Koputaroa Sand
BH312	3.0 – 3.45	0	0	2	44	54	MH/ML/CL/CH	49.1	7.34	Top of terrace	Koputaroa Sand
BH312	4.5 – 4.95	0	0	1	93	6	SP	17.8	7.34	Top of terrace	Otaki Dune Sand
BH312	6.0 – 6.45	0	0	1	89	10	SP	19.8	7.34	Top of terrace	Otaki Dune Sand
BH312	7.5 – 7.95	0	0	1	88	11	SP	19.1	7.34	Top of terrace	Otaki Dune Sand
BH312	9.0 – 9.45	0	0	0	91	9	SP	15.1	7.34	Top of terrace	Otaki Dune Sand
BH312	10.5 – 10.95	0	0	1	85	14	SM/SC	21.3	7.34	Top of terrace	Otaki Dune Sand
BH312	12.0 – 12.45	0	0	0	89	11	SP	20.4	7.34	Top of terrace	Otaki Dune Sand
BH312	13.5 – 13.95	0	0	1	85	14	SM/SC	22.9	7.34	Top of terrace	Otaki Dune Sand
BH312	15.0 -15.45	0	0	0	90	10	SP	22.7	7.34	Top of terrace	Otaki Dune Sand

Sample ID	Depth (m bgl)	Particle Size Distribution (Wet Sieve) % Gravel >4.75 mm	% Coarse Sand 4.75 – 2mm	% Medium Sand 2 – 0.475mm	% Fine Sand 0.475 – 0.075mm	% Silt /Clay <0.075m m	Provisional Classification According to USCS	Natural Water Content (%)	GWL (m bgl) Observations (at Time of Sampling)	Terrain (at Sampling Location)	Q5b Subunits
BH313	1.5 – 1.95	0	0	1	89	10	SP	19.2	11.15	Top of terrace	Koputaroa Sand
BH313	3.0 – 3.45	0	0	0	75	25	SM/SC	20.1	11.15	Top of terrace	Koputaroa Sand
BH313	4.5 – 4.95	0	0	0	84	16	SM/SC	16.2	11.15	Top of terrace	Koputaroa Sand
BH313	6.0 – 6.45	0	0	1	87	12	SM/SC	15.7	11.15	Top of terrace	Koputaroa Sand
BH313	7.5 – 7.95	0	0	1	26	73	MH/ML/CL/CH	51.5	11.15	Top of terrace	Koputaroa Sand
BH313	9.0 – 9.45	0	0	1	87	12	SP SM/SC	19.0	11.15	Top of terrace	Otaki Dune Sand
BH313	10.5 – 10.95	0	0	0	89	11	SP	22.9	11.15	Top of terrace	Otaki Dune Sand
BH313	13.5 – 13.80	0	0	0	81	19	SM/SC	17.3	11.15	Top of terrace	Otaki Beach Sand
BH313	15.0 -15.38	0	0	1	82	17	SM/SC	12.2	11.15	Top of terrace	Otaki Beach Sand
TP259	2.3 – 2.5	21.3	1.5	5.4	67.9	3.9	SP	22.9	2.9 (seepage), 3.2 (strong flow)	Flat	Koputaroa Sand
TP261	2.0 – 2.5	0	0.3	4.4	88.7	6.5	SP	25.0	2.6 (strong flow)	Flat	Koputaroa Sand
TP269	2.3 – 2.5	0	0.5	10.7	76.7	12	SP SM/SC	37.4	2.3 (seepage), 2.8 (strong flow)	Flat	Otaki Dune Sand
TP270	2.2 – 2.5	0	0	1	92	7	SP	25.2	2.1 (seepage), 2.5 (strong flow)	Flat	Otaki Dune Sand
TP271	2.5 – 3.0	0	0	4	72	24	SM/SC	21.4	Not encountered	Top of terrace	Otaki Dune Sand
TP273	2.0 – 2.3	0	0	2	95	3	SP	9.5	Not encountered	Top of terrace	Otaki Dune Sand
TP274*	2.2 – 3.5	0	0	0	48	52	ML	9.9	Not encountered	Top of terrace	Otaki Dune Sand (potentially captured bottom of Loess)
TP279	1.6 – 1.9	0	0	4	59	38	SM/SC	15.5	Not encountered	Flat	Otaki Dune Sand
TP280	2.0 – 2.3	0	0	2	66	32	SM/SC	23.6	2.9 (seepage)	Flat	Koputaroa Sand
TP314	3.3 – 3.5	0	0	0	91	9	SP	16.4	Not encountered	Top of terrace	Otaki Dune Sand
TP315	2.4 – 2.6	0	0	1	91	9	SP	10.1	Not encountered	Top of terrace	Otaki Dune Sand
TP316	3.2 – 3.4	0	0	0	37	63	MH/ML/CL/CH	29.8	Not encountered	Top of terrace	Otaki Dune Sand

** Non-plastic*

6.1.2 Southern Extent - Ch. 30,700 to Ch. 34,000

Table 6.1b presents a summary of relevant laboratory testing results (within Q5b material, southern extent).

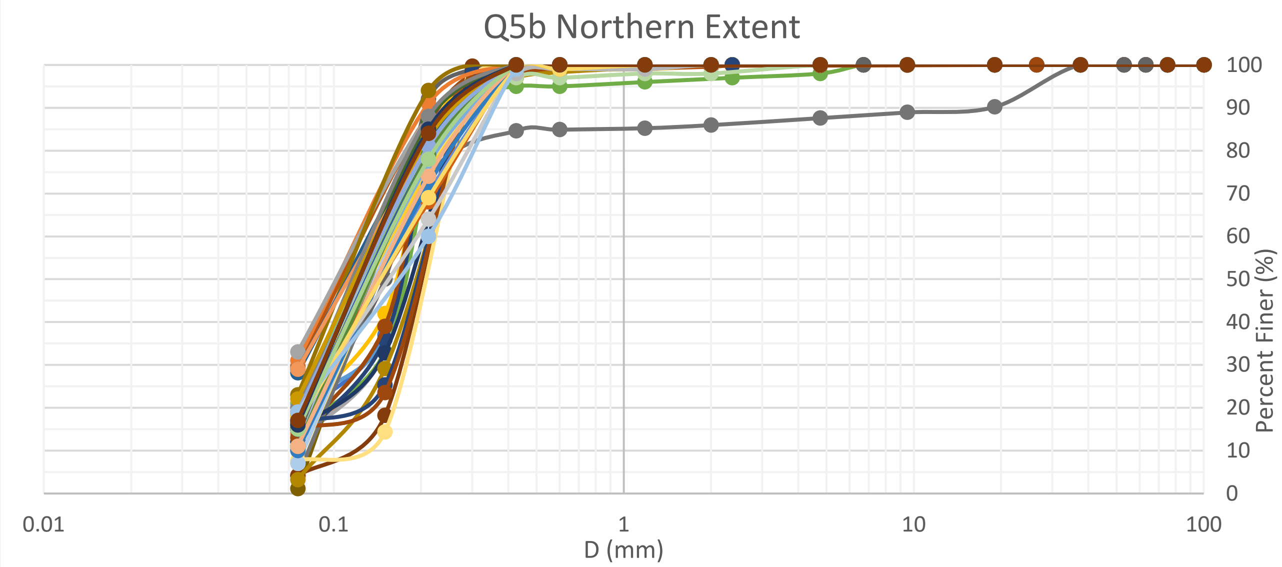
Table 6.1b: Laboratory Testing Results (within Q5b material, southern extent).

Sample ID	Depth (m bgl)	Particle Size Distribution (Wet Sieve)					Provisional Classification According to USCS	Natural Water Content (%)	GW Observations (at Time of Sampling)	Terrain (at Sampling Location)	Q5b Subunits
		% Gravel	% Coarse Sand	% Medium Sand	% Fine Sand	% Silt /Clay					
		>4.75 mm	4.75 – 2mm	2 – 0.475mm	0.475 – 0.075mm	<0.075mm					
BH101	3.0 – 3.45	0	0	0.5	85.5	14	SM/SC	25.2	Undetermined	Flat	Otaki Dune Sand
BH101	6.5 – 6.95	0	0	0.6	87.6	11.8	SP SM/SC	27.4	Undetermined	Flat	Otaki Dune Sand
BH102	4.5 – 4.95	0	0	0.6	78.7	20.7	SM/SC	28.1	Undetermined	Flat	Otaki Dune Sand
BH102	7.5 – 7.95	2.2	1	2.3	79.6	14.9	SM/SC	27.0	Undetermined	Top of terrace	Otaki Dune Sand
BH102	10.5–10.95	0	0.2	1.2	81	17.6	SM/SC	25.8	Undetermined	Top of terrace	Otaki Dune Sand
BH104	7.5 – 7.95	0	0	0.3	87.1	12.6	SM/SC	18.5	Undetermined	Top of terrace	Otaki Dune Sand
BH104	9.0 – 9.4	0	0	0.1	84.7	15.2	SM/SC	23.5	Undetermined	Top of terrace	Otaki Beach Sand
BH201	10.5 – 11.8	0	0	0.2	92.1	7.7	SP	25.7	Undetermined	Flat	Otaki Dune Sand
BH204*	4.5 – 4.95	0	0	0	85	15	SM/SC	13.6	19.09/16.33 Max	Top of terrace	Otaki Dune Sand
BH204	9.0 – 9.45	0	0	0	96	4	SP	10.7	19.09/16.33 Max	Top of terrace	Otaki Dune Sand
BH204	7.5 – 7.95	0	0	0	77	23	SM/SC	18.1	19.09/16.33 Max	Top of terrace	Otaki Dune Sand
BH204	10.5 – 10.95	0	0	1	70	29	SM/SC	38.4	19.09/16.33 Max	Top of terrace	Otaki Dune Sand
BH204	13.5 – 13.95	0	0	0	85	15	SM/SC	24.1	19.09/16.33 Max	Top of terrace	Otaki Dune Sand
BH204	15.0 -15.45	0	0	1	83	16	SM/SC	25.3	19.09/16.33 Max	Top of terrace	Otaki Dune Sand
BH301	1.5 – 1.95	0	0	1	70	29	SM/SC	30.5	10.50	Top of terrace	Otaki Dune Sand
BH301	3.0 – 3.45	0	0	2	88	10	SM/SC	18.1	10.50	Top of terrace	Otaki Dune Sand
BH301	4.5 – 4.95	0	0	1	81	18	SM/SC	25.0	10.50	Top of terrace	Otaki Dune Sand
BH301	6.0 – 6.45	0	0	1	83	16	SM/SC	19.0	10.50	Top of terrace	Otaki Dune Sand
BH301	7.5 – 7.95	0	0	0	79	21	SM/SC	18.1	10.50	Top of terrace	Otaki Dune Sand
BH301	9.0 – 9.45	0	0	0	85	15	SM/SC	63.7	10.50	Top of terrace	Otaki Dune Sand
BH301	10.5 – 10.95	0	0	0	81	19	SM/SC	24.1	10.50	Top of terrace	Otaki Dune Sand
BH301	12.0 – 12.45	0	0	0	80	20	SM/SC	22.6	10.50	Top of terrace	Otaki Dune Sand
BH301	13.5 – 13.95	0	0	0	78	22	SM/SC	19.5	10.50	Top of terrace	Otaki Dune Sand
BH301	15.0 -15.45	0	0	0	76	24	SM/SC	20.8	10.50	Top of terrace	Otaki Dune Sand
BH302	1.5 – 1.95	0	0	1	89	10	SP	24.0	10.42	Top of terrace	Otaki Dune Sand
BH302	3.0 – 3.45	0	0	0	89	11	SP	19.7	10.42	Top of terrace	Otaki Dune Sand
BH302	4.5 – 4.95	0	0	0	81	19	SM/SC	20.5	10.42	Top of terrace	Otaki Dune Sand
BH302	6.0 – 6.45	0	0	0	89	11	SP	19.7	10.42	Top of terrace	Otaki Dune Sand
BH302	7.5 – 7.95	0	0	1	80	19	SM/SC	18.5	10.42	Top of terrace	Otaki Dune Sand
BH302	9.0 – 9.45	0	0	1	83	16	SM/SC	17.3	10.42	Top of terrace	Otaki Dune Sand
BH302	10.5 – 10.95	0	0	1	80	19	SM/SC	20.7	10.42	Top of terrace	Otaki Dune Sand
BH302	12.0 – 12.45	0	0	0	85	15	SM/SC	27.0	10.42	Top of terrace	Otaki Dune Sand
BH302	13.5 – 13.95	0	0	0	84	16	SM/SC	21.3	10.42	Top of terrace	Otaki Dune Sand

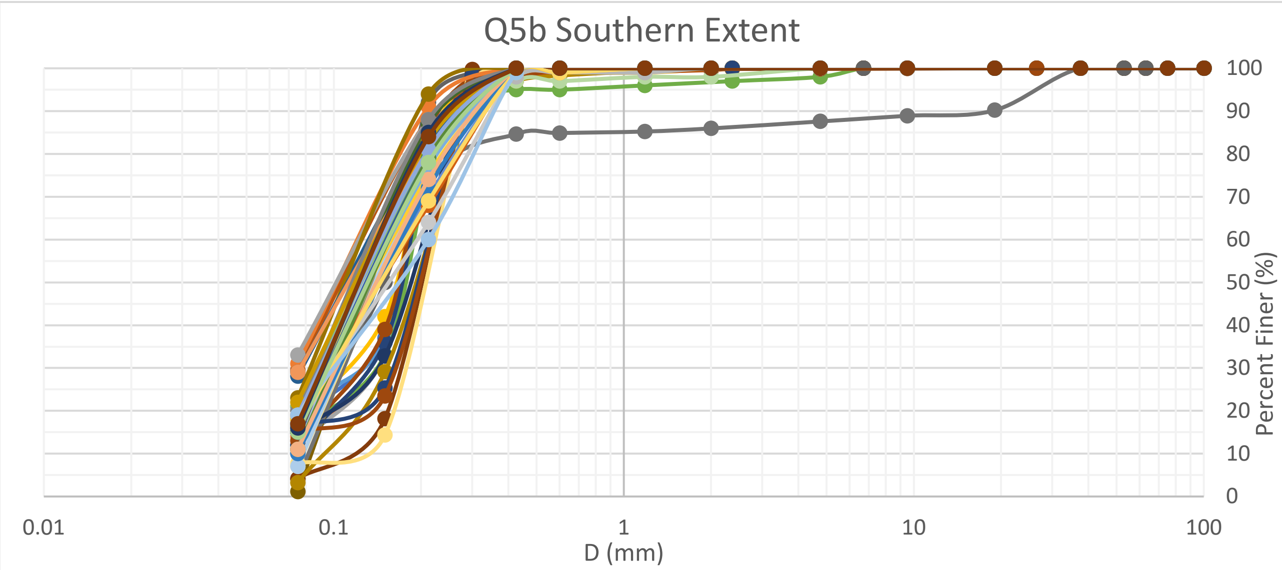
Sample ID	Depth (m bgl)	Particle Size Distribution (Wet Sieve) % Gravel >4.75 mm	% Coarse Sand 4.75 – 2mm	% Medium Sand 2 – 0.475mm	% Fine Sand 0.475 – 0.075mm	% Silt /Clay <0.075mm	Provisional Classification According to USCS	Natural Water Content (%)	GW Observations (at Time of Sampling)	Terrain (at Sampling Location)	Q5b Subunits
BH302	15.0 -15.45	0	0	0	83	17	SM/SC	19.8	10.42	Top of terrace	Otaki Dune Sand
BH303	1.5 – 1.95	0	0	1	88	11	SP	16.7	Not encountered	Top of terrace	Otaki Dune Sand
BH303	3.0 – 3.45	0	0	1	88	11	SP	14.8	Not encountered	Top of terrace	Otaki Dune Sand
BH303	4.5 – 4.95	0	0	0	81	19	SM/SC	19.8	Not encountered	Top of terrace	Otaki Dune Sand
BH303	6.0 – 6.45	0	0	1	88	11	SP	16.5	Not encountered	Top of terrace	Otaki Dune Sand
BH303	7.5 – 7.95	0	0	0	93	7	SP	17.8	Not encountered	Top of terrace	Otaki Dune Sand
BH303	9.0 – 9.45	0	0	0	93	7	SP	15.7	Not encountered	Top of terrace	Otaki Dune Sand
BH303	10.5 – 10.95	0	2	1	80	17	SM/SC	18.9	Not encountered	Top of terrace	Otaki Dune Sand
BH303	12.0 – 12.45	0	0	1	82	17	SM/SC	17.5	Not encountered	Top of terrace	Otaki Dune Sand
BH303	13.5 – 13.95	0	0	0	69	31	SM/SC	17.4	Not encountered	Top of terrace	Otaki Dune Sand
BH303	15.0 -15.45	0	0	0	67	33	SM/SC	16.0	Not encountered	Top of terrace	Otaki Dune Sand
BH304	3.0 – 3.45	0	0	0	19	81	MH/ML/CL/CH	19.0	5.74 Manual	Top of terrace	Otaki Dune Sand
BH304	4.5 – 4.95	0	0	0	39	61	MH/ML/CL/CH	30.8	5.74	Top of terrace	Otaki Dune Sand
BH304	6.0 – 6.45	0	0	1	72	27	SM/SC	21.1	5.74	Top of terrace	Otaki Dune Sand
BH304	7.5 – 7.95	1	1	7	20	71	MH/ML/CL/CH	62.0	5.74	Top of terrace	Otaki Dune Sand
BH304	9.0 – 9.45	0	0	5	87	8	SP	21.5	5.74	Top of terrace	Otaki Beach Sand
BH304	10.5 – 10.95	0	0	1	76	23	SM/SC	14.1	5.74	Top of terrace	Otaki Beach Sand
BH304	12.0 – 12.45	0	0	0	86	14	SM/SC	16.5	5.74	Top of terrace	Otaki Beach Sand
BH304	13.5 – 13.95	0	0	1	83	16	SM/SC	17.8	5.74	Top of terrace	Otaki Beach Sand
BH304	15.0 -15.45	0	0	1	72	27	SM/SC	8.1	5.74	Top of terrace	Otaki Beach Sand
TP204	3.0 - 3.5	0	0	3	94	3	SP	9.8	Not encountered	Top of terrace	Otaki Dune Sand
TP208	2.2 – 2.4	0	0	3	68	30	SM/SC	32.7	2.4 (strong flow)	Valley	Otaki Dune Sand
TP208	2.8 – 3.4	12	2	1	80	4	SP	25.2	2.4 (strong flow)	Valley	Otaki Dune Sand
TP209*	2.5 – 3.4	0	0	1	71	28	SM/SC	21.8	1.2 (Very localised seepage)	Valley	Otaki Dune Sand
TP210	3.6 – 4.0	0	0	1	98	1	SP	9.7	Not encountered	Top of terrace	Otaki Dune Sand
TP212	3.2 – 3.6	0	0	0	83	17	SM/SC	17.4	Not encountered	Valley	Otaki Dune Sand
TP212*	3.6 – 3.9	0	0	2	83	15	SM/SC	17.1	Not encountered	Valley	Otaki Dune Sand
** Non-plastic*											

6.2 Particle Size Distribution Plots

Figures 6.2a to 6.2b presents Particle Size Distribution plots for the Q5b Material. The curves limit is 0.075mm as per ASTM D6913-17.



6.2a: Particle Size Distribution for Q5b Materials – Northern Extent



6.2b: Particle Size Distribution for Q5b Materials – Southern Extent

6.3 NZ Compaction Test

Table 6.3 presents the results from the NZ standard compaction test with plots presented in Figure 6.2a to 6.2m.

Table 6.3: Results from the NZ standard Compaction Test

Sample ID	Depth (m bgl)	Natural Moisture Content, w_n (%)	Optimum Moisture (Water) Content, w_o (%)	Max Dry Density, $\rho_{d,max}$ (t/m³)	Terrain (at Sampling Location)	Q5b Subunits
BH102	5.0 – 15.0	27.0	14.00	1.76	Top of terrace	Otaki Dune Sand
TP202	2.5 – 3.6	24.6	19.03	1.61	Valley	Otaki Dune Sand
TP204	3.0 – 3.5	9.8	17.66	1.63	Top of terrace	Otaki Dune Sand
TP208	2.2 – 2.4	32.7	17.41	1.74	Valley	Otaki Dune Sand
TP208	2.8 – 3.2	25.2	15.39	1.69	Valley	Otaki Dune Sand
TP209	2.5 – 3.4	21.8	15.14	1.80	Valley	Otaki Dune Sand
TP210	3.6 – 4.0	9.7	16.16	1.68	Top of terrace	Otaki Dune Sand
TP212	3.2 – 3.6	17.4	20.20	1.63	Valley	Otaki Dune Sand
TP273	2.0 – 2.3	9.5	15.36	1.64	Top of terrace	Otaki Dune Sand
TP274	2.2 – 3.5	9.9	14.59	1.72	Top of terrace	Otaki Dune Sand
TP314	3.3 – 3.5	17.0	17.10	1.73	Top of terrace	Otaki Dune Sand
TP315	2.4 – 2.6	9.0	12.20	1.69	Top of terrace	Otaki Dune Sand
TP316	3.2 – 3.4	30.0	22.30	1.57	Top of terrace	Otaki Dune Sand

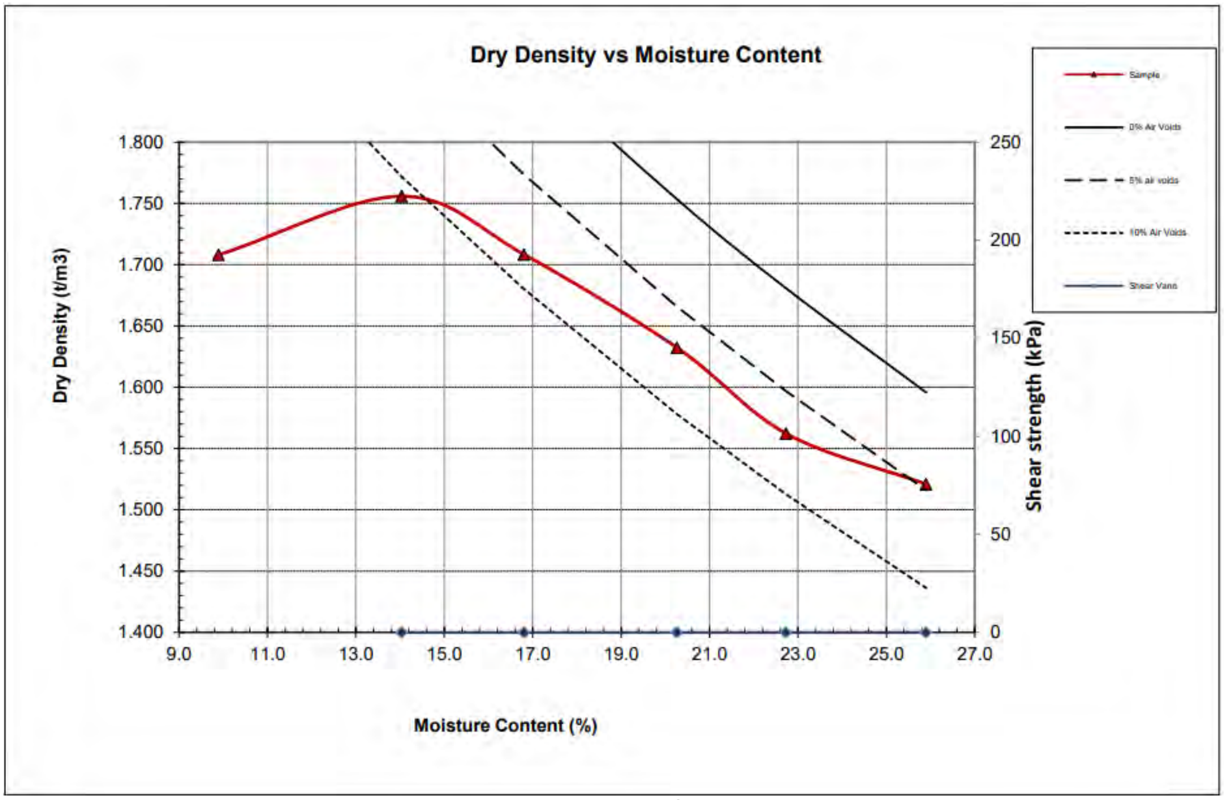


Figure 6.3a: BH102 5.0 – 15.0 m - Dry Density vs. Moisture Content Plot

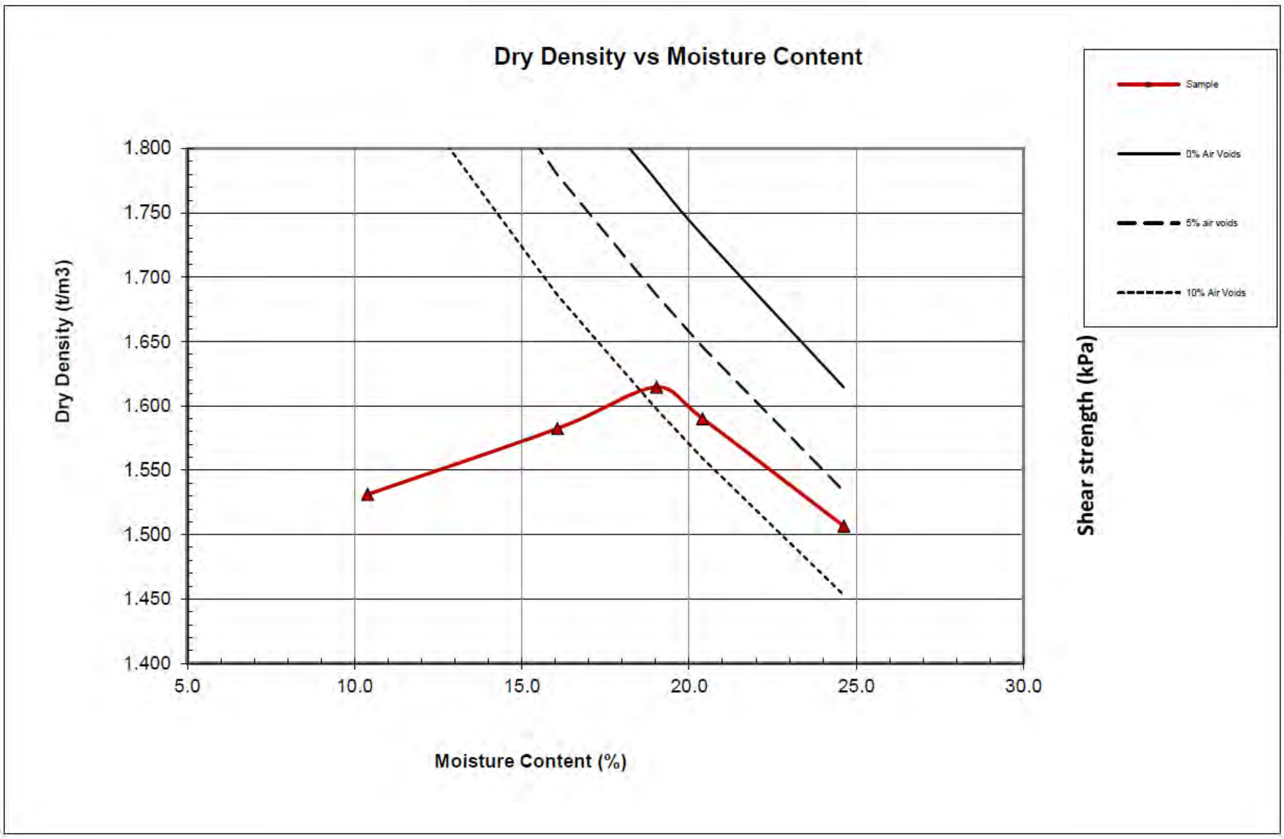


Figure 6.3b: TP202 2.5 – 3.6 m - Dry Density vs. Moisture Content Plot

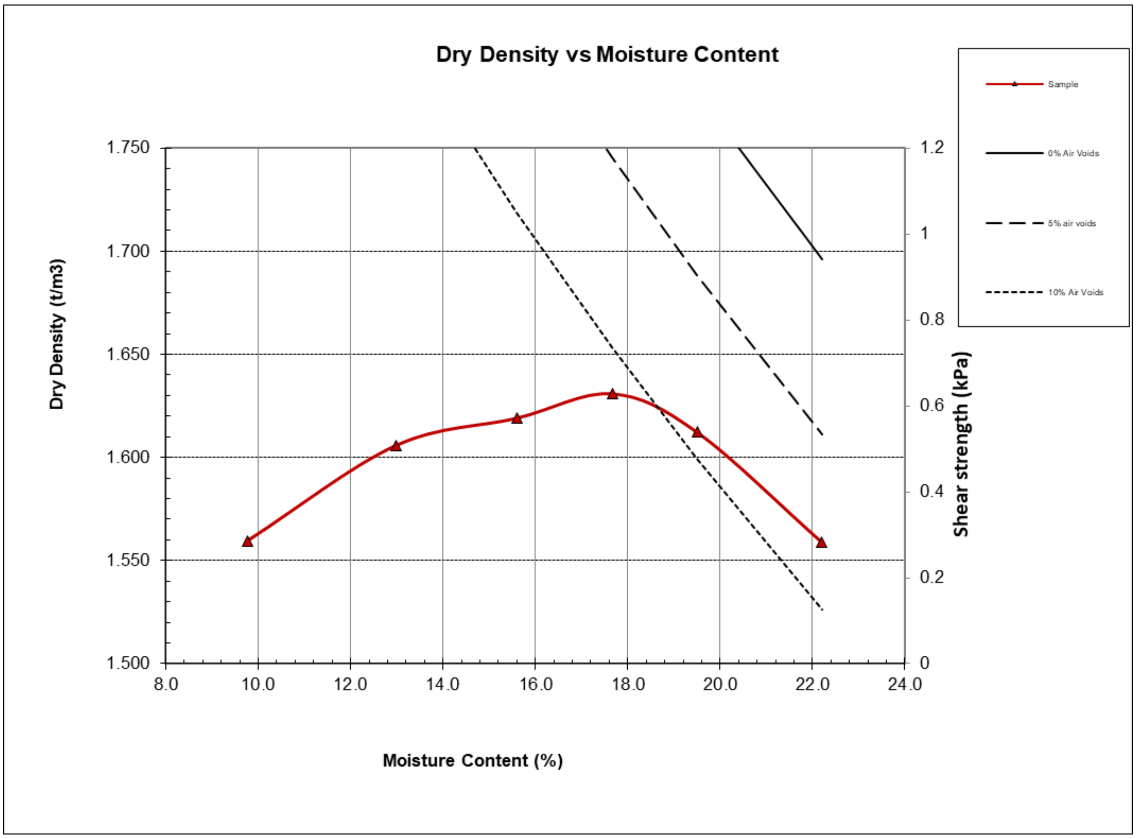


Figure 6.3c: TP204 3.0 – 3.5 m - Dry Density vs. Moisture Content Plot

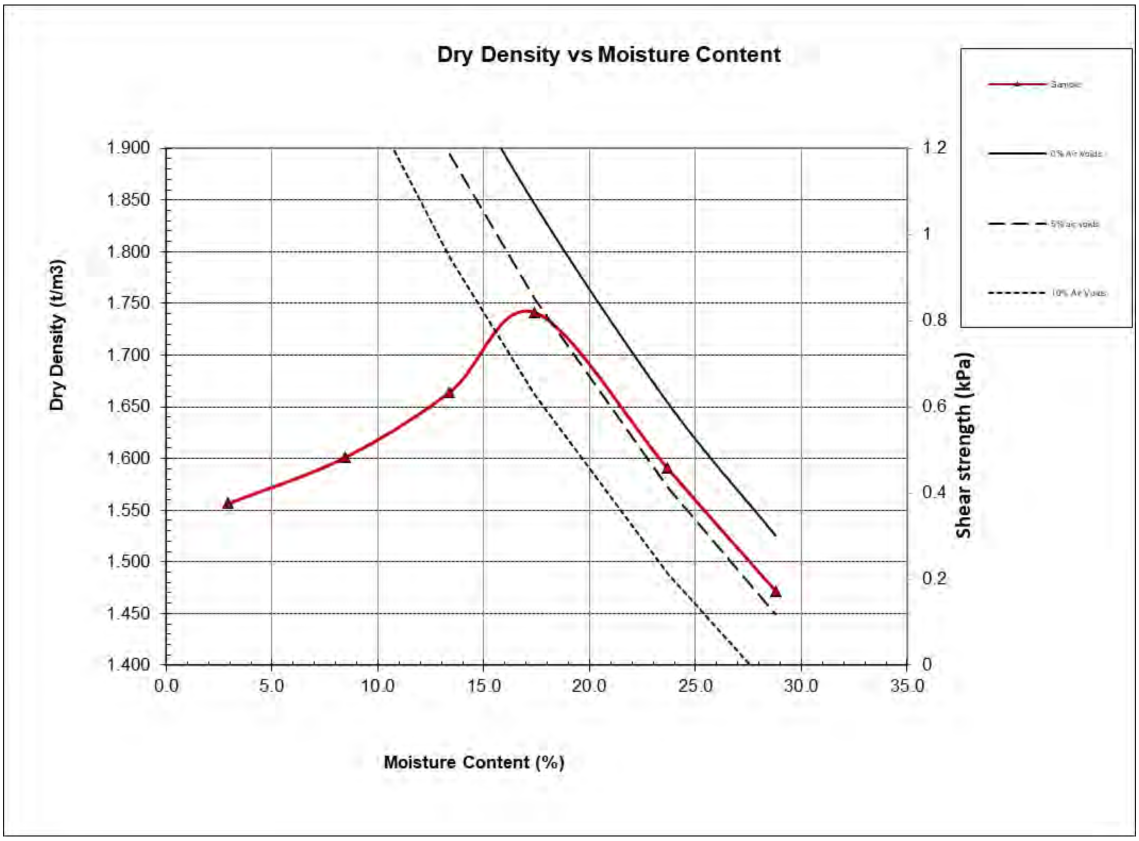


Figure 6.3d: TP208 2.2 – 2.4 m - Dry Density vs. Moisture Content Plot

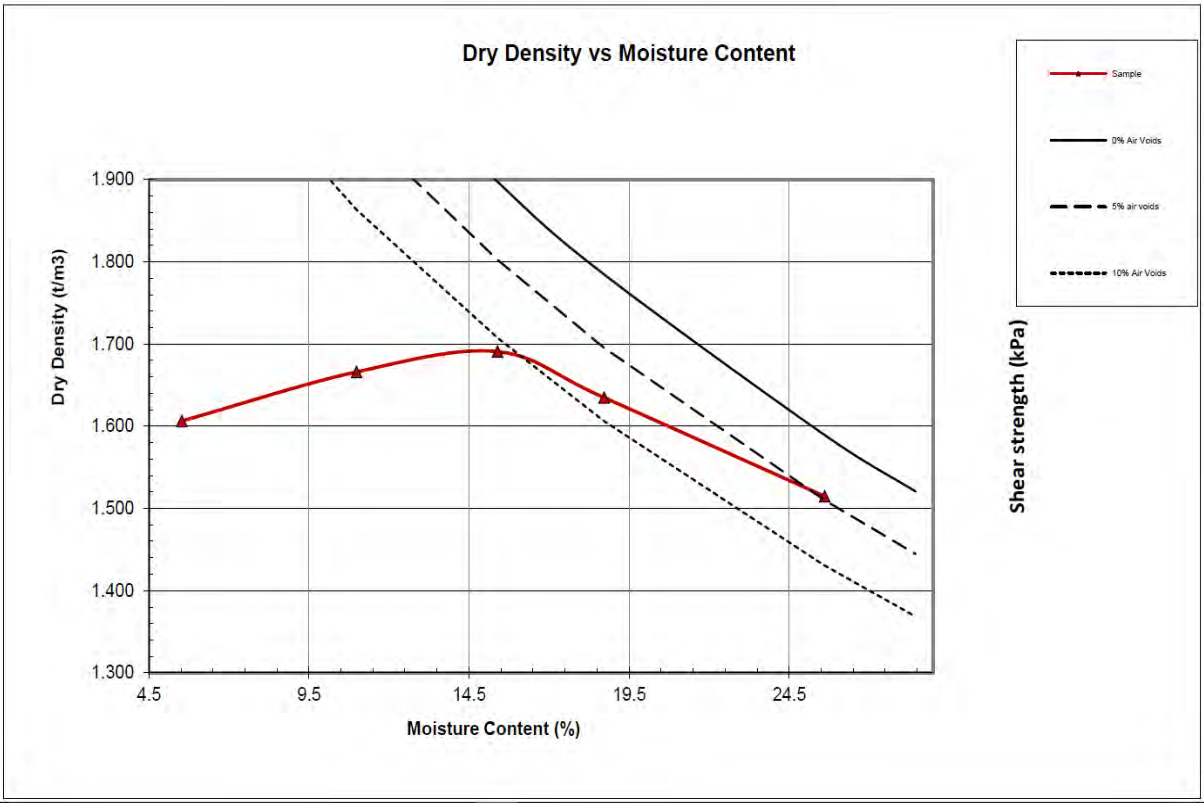


Figure 6.3e: TP208 2.8 – 3.2 m - Dry Density vs. Moisture Content Plot

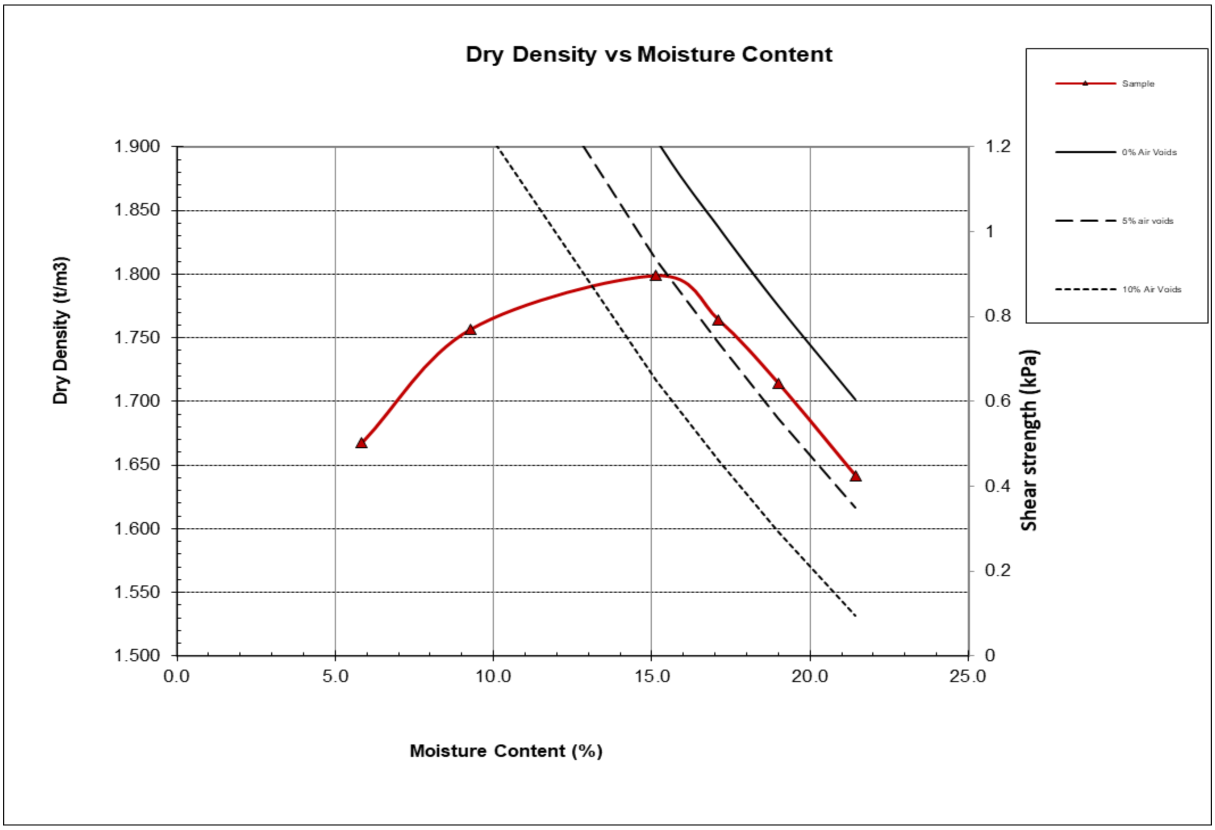


Figure 6.3f: TP209 2.5 – 3.4 m - Dry Density vs. Moisture Content Plot

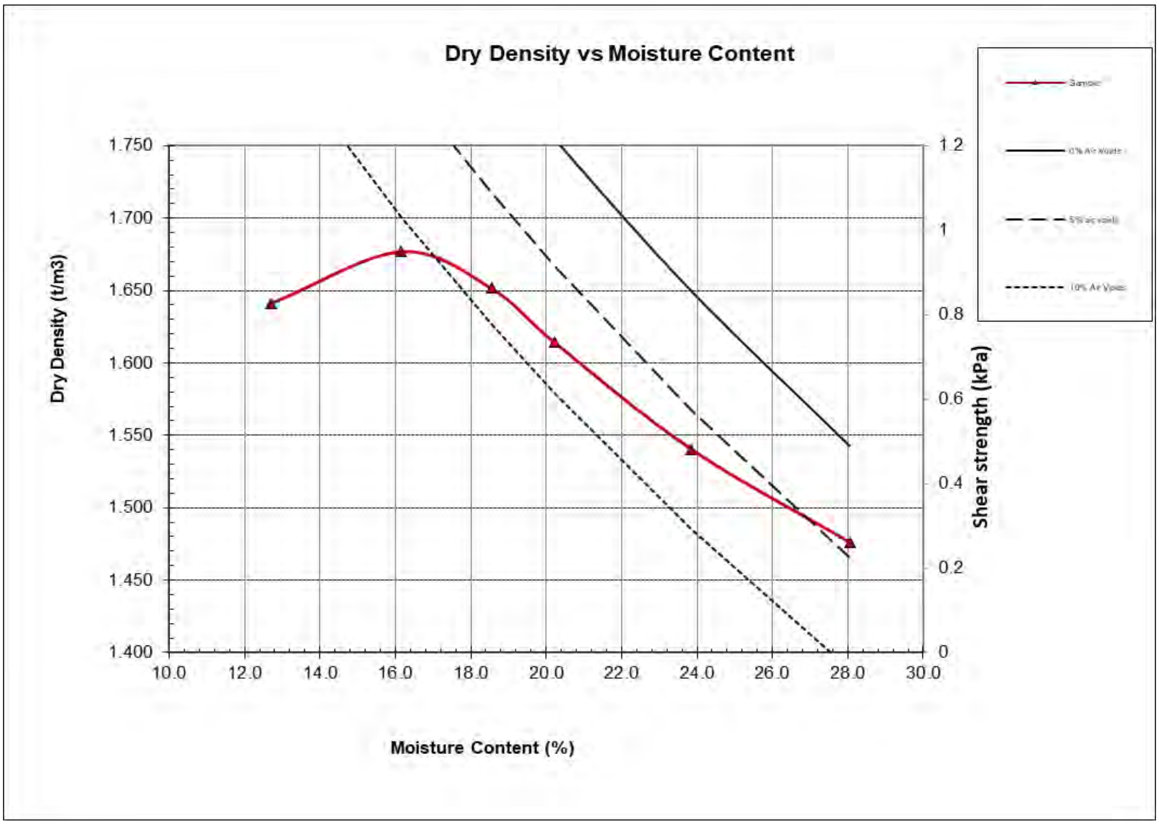


Figure 6.3g: TP210 3.6 – 4.0 m - Dry Density vs. Moisture Content Plot

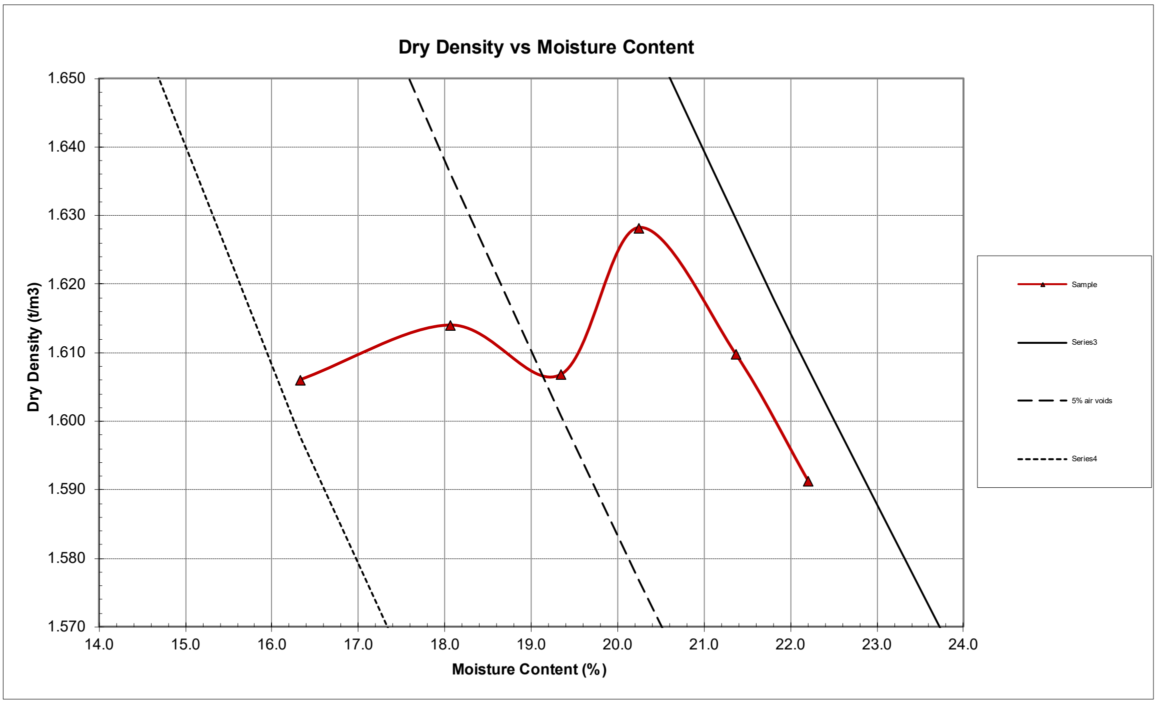


Figure 6.3h: TP212 3.3 – 3.6 m - Dry Density vs. Moisture Content Plot

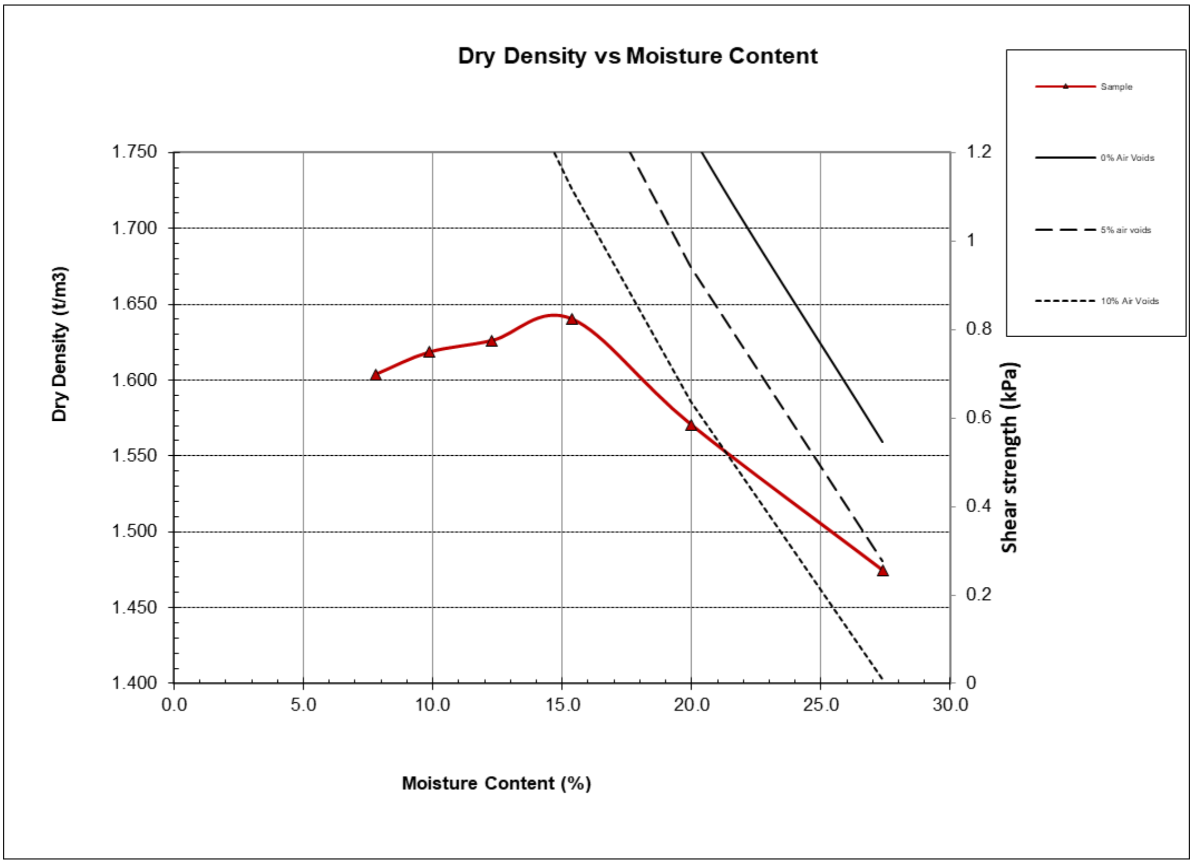


Figure 6.3i: TP273 2.0 – 2.3 m - Dry Density vs. Moisture Content Plot

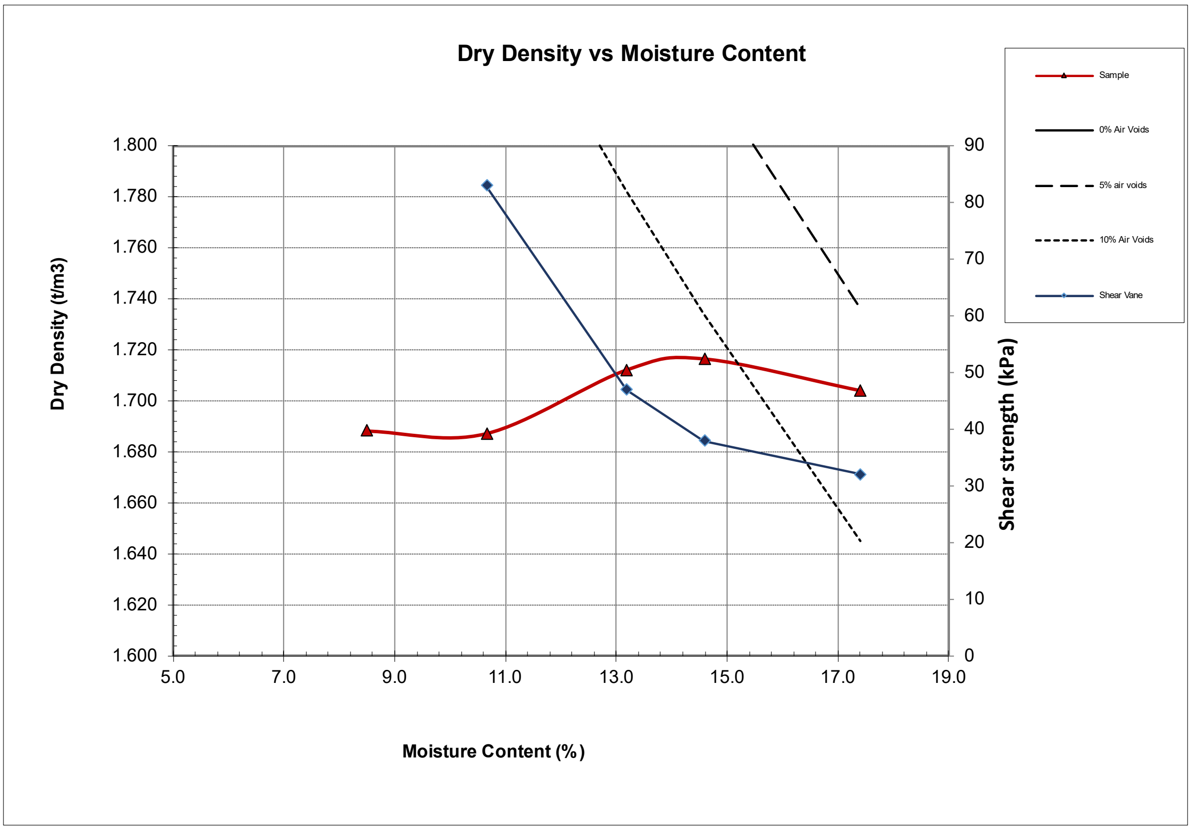


Figure 6.3j: TP274 2.2 – 3.5 m - Dry Density vs. Moisture Content Plot

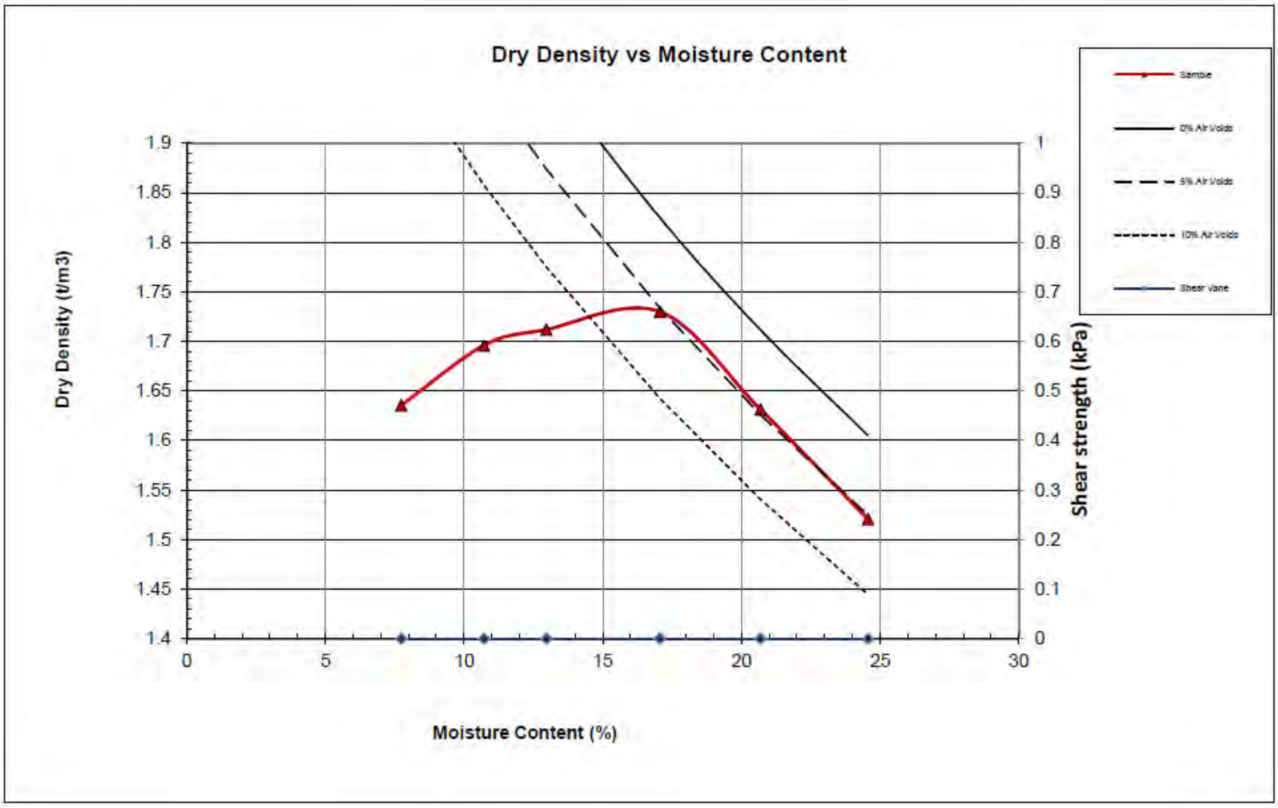


Figure 6.3k: TP314 3.3 – 3.5 m - Dry Density vs. Moisture Content Plot

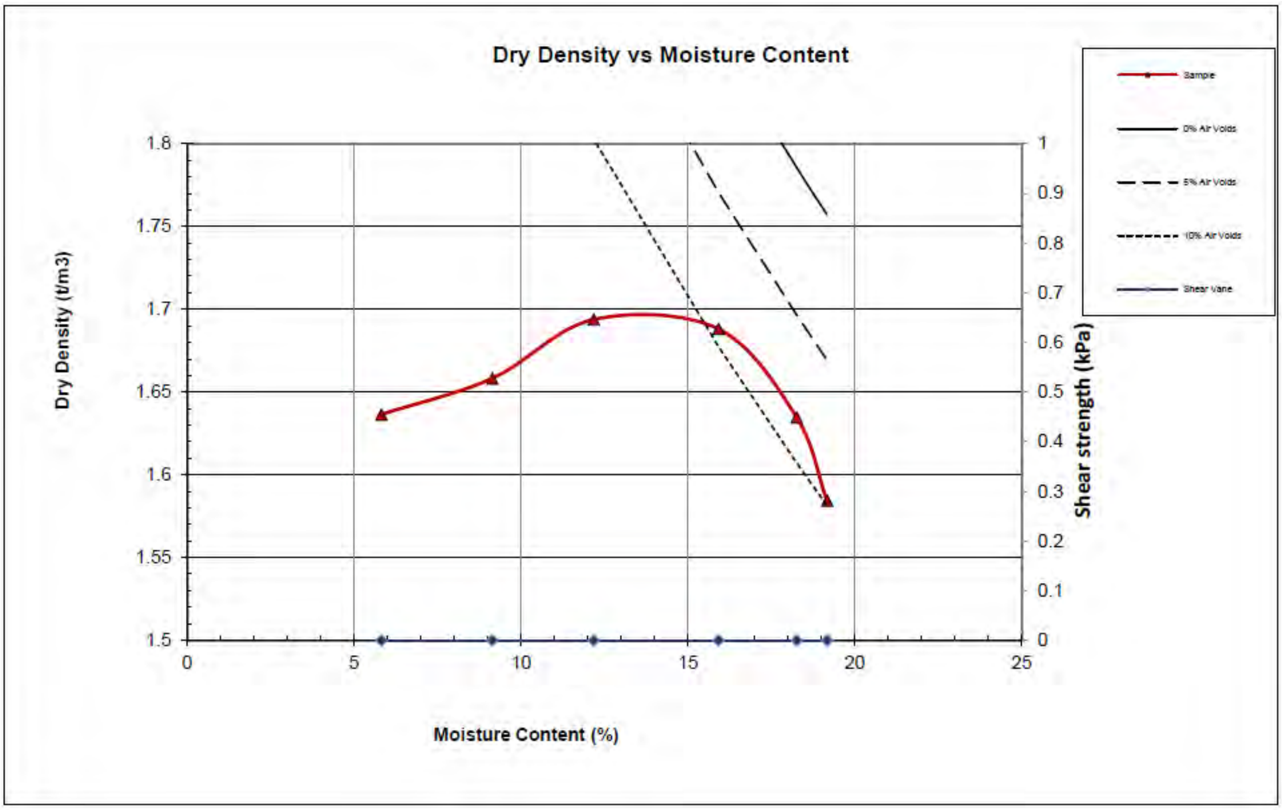


Figure 6.3l: TP315 2.4 – 2.6 m - Dry Density vs. Moisture Content Plot

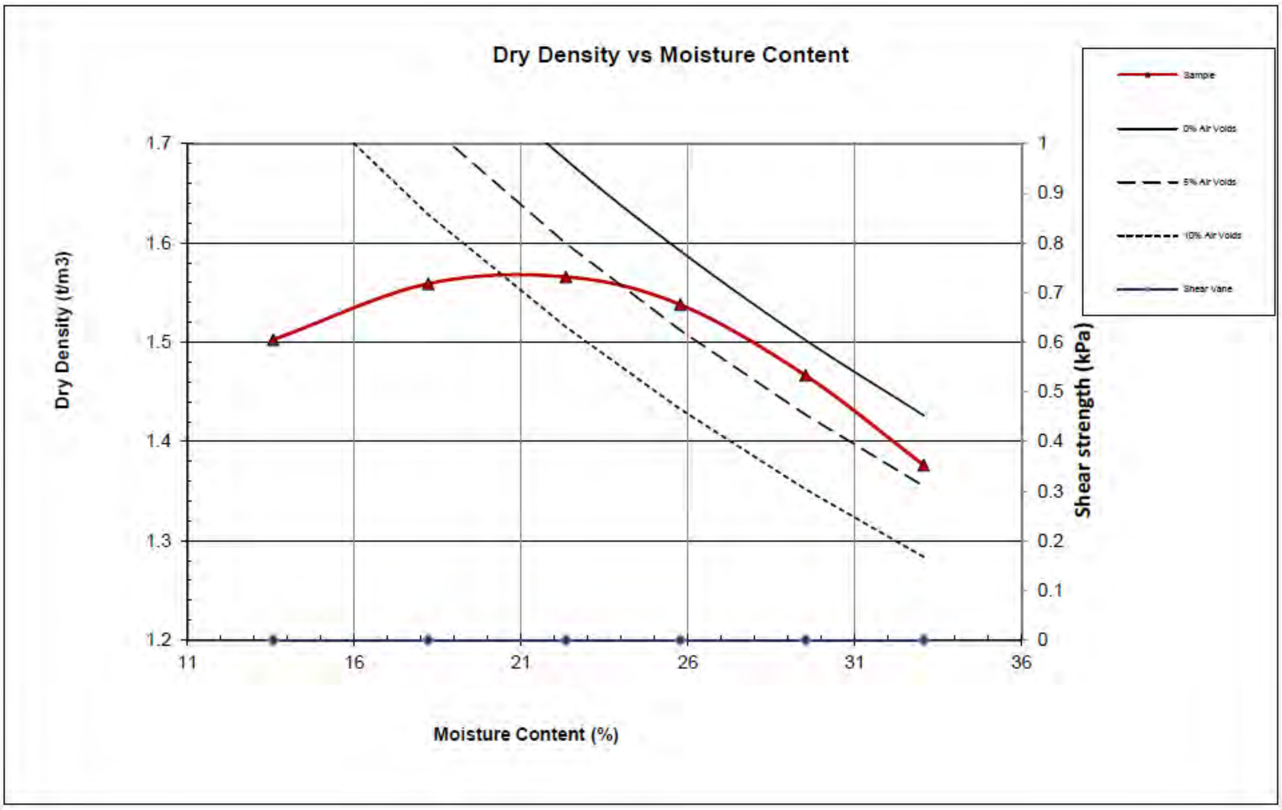


Figure 6.3m: TP316 3.2 – 3.4 m - Dry Density vs. Moisture Content Plot

6.4 California Bearing Ratio

Table 6.4 presents Q5b Material California Bearing Ratio (CBR) results. Testing comments are also provided.

Table 6.4: Q5b Material California Bearing Ratio Results

Sample ID	Depth (m bgl)	Bulk Density (t/m3)	Dry Density (t/m3)	CBR (%)	Comments
BH102	5.0 - 15.0	1.96	1.62	1.5	Soaked CBR @ natural water content
BH102	5.0 - 15.0	1.95	1.62	1.5	Unsoaked @ natural water content
TP204	3.0 - 3.5	1.92	1.63	30.0	Soaked CBR @ Optimum water content
TP209	2.5 - 3.4	2.06	1.75	9.0	Tested at Optimum Water Content - 6% water, by mass removed from the sample.
TP210	3.6 - 4.0	1.96	1.69	25.0	Soaked CBR @ Optimum water content
TP210	3.6 - 4.0	1.95	1.68	30.0	Unsoaked @ Optimum water Content
TP259	2.3 -2.5	2.03	1.64	110	Soaked CBR
TP273	2.0 - 2.3	1.79	1.58	14.0	3% water added, by mass, Standard compactive effort.
TP274	2.2 – 3.5	1.86	1.69	17.0	Tested at Optimum Water Content. No water content adjustment is required.

6.5 Natural Moisture Content

Figures 6.5a and 6.5b presents Q5b Sand Material Natural Moisture Content (NMC) versus depth. Samples obtained from terraces have been separately shown as "Top of terrace" whilst the remaining samples were retrieved from "flat terrain". Outliers >50% have not been presented.

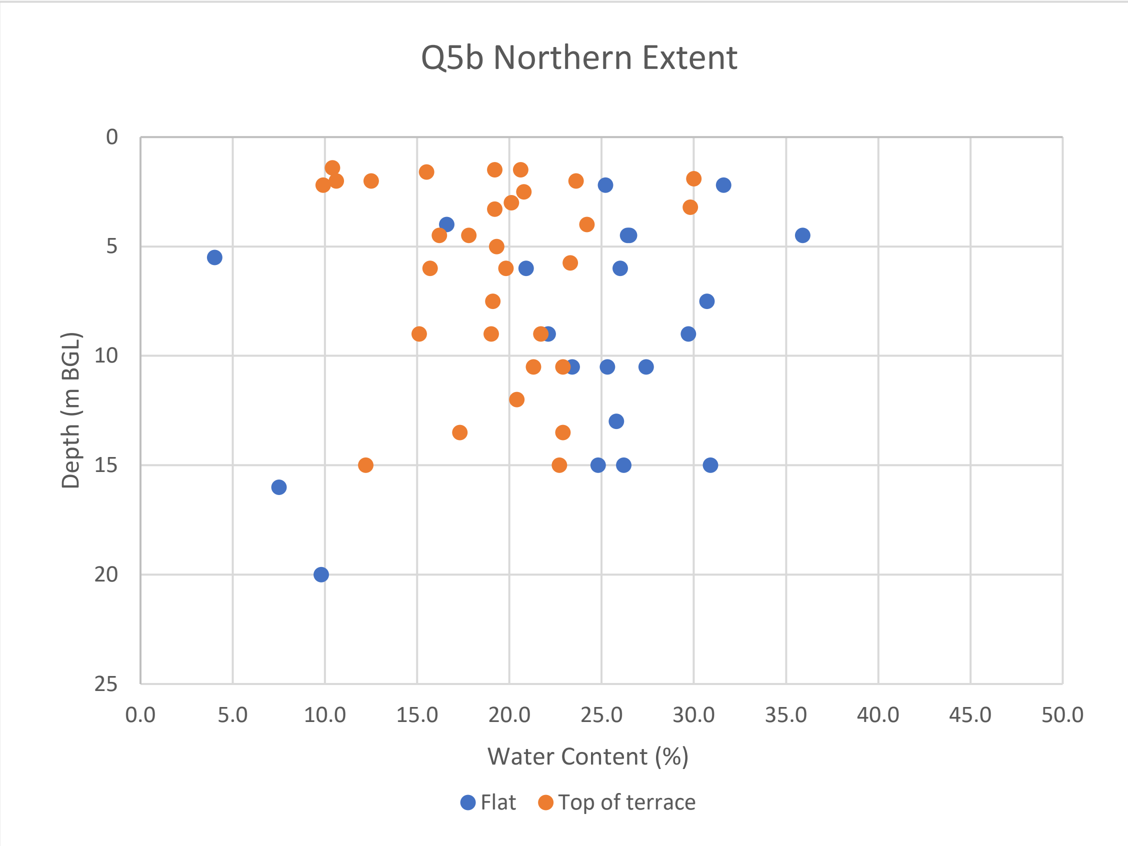


Figure 6.5a: Q5b Material NWC versus Depth Northern Extent – All samples

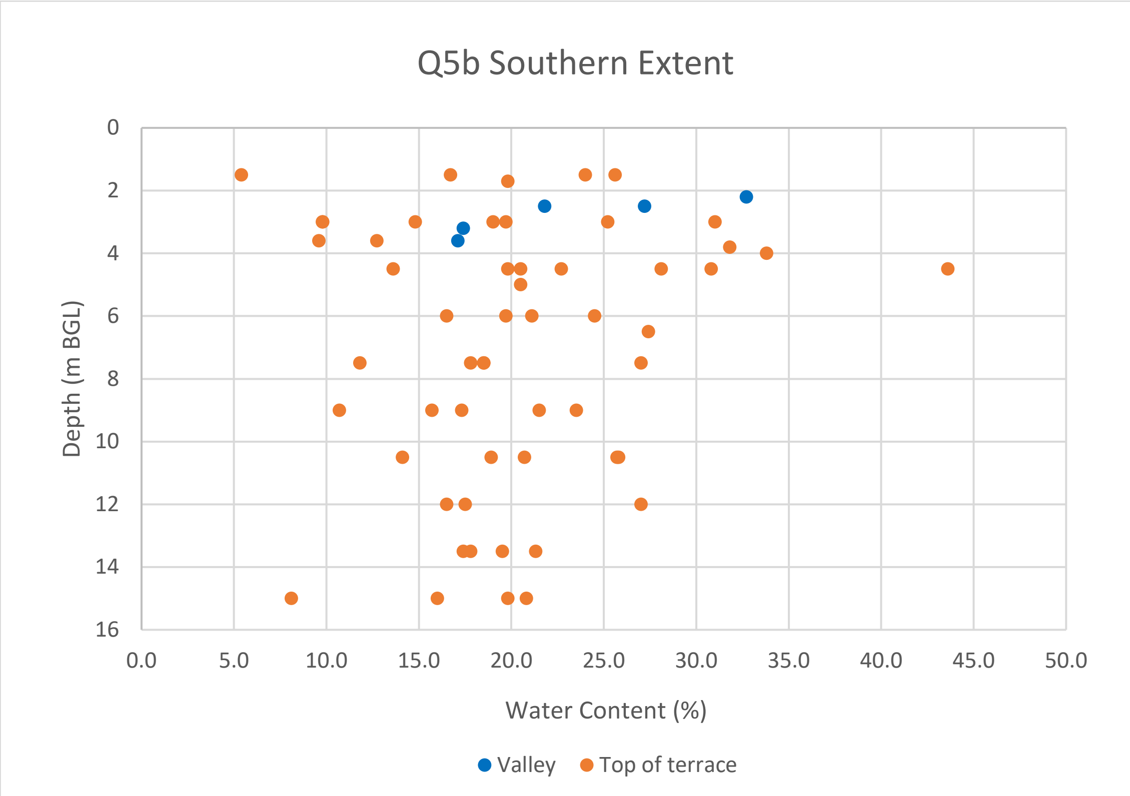


Figure 6.5b: Q5b Material NWC versus Depth Southern Extent – All samples

6.6 Hydrometer Plots

Figures 6.6 presents Q5b Material Hydrometer Plots.

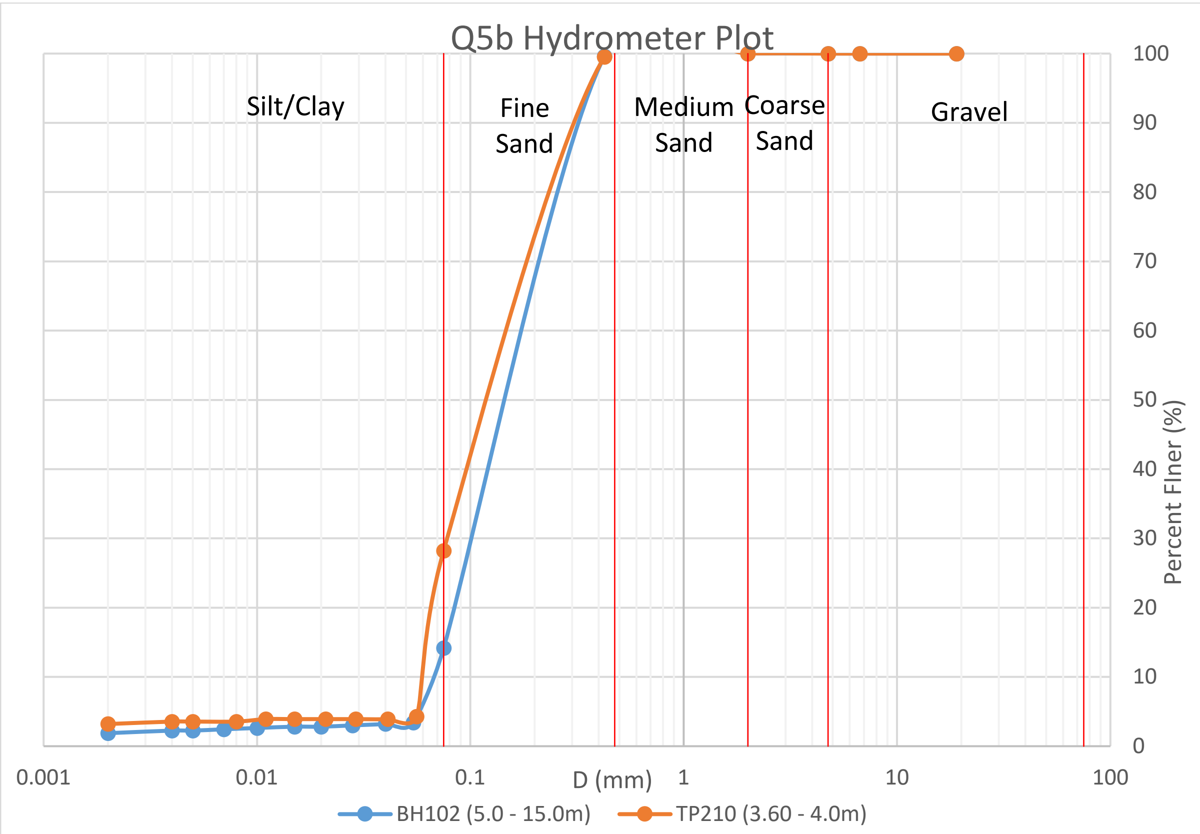


Figure 6.6: Q5b Material - Particle Size Distribution (Hydrometer) Plot

7 Q5b Material Re-usability

7.1 Observations / Conclusions

The following observations have been made:

- General observations:
  - The material classified in the Q5b formation is generally described as fine silty sand to sand, with minor clay in places. The presence of fines, predominantly silts, was notable.
  - The material was generally described as moist, but in many cases as wet or saturated.
  - The material liquefied when wetted and shaken.

- Results from classification testing:
  - Q5b sand material fines content was typically between 15% - 20% but ranged from 1% to 38% There was a number of outliers, but these were discounted (as deemed the sample captured lens/pockets consisting of a finer material).
  - Moisture content testing of “all” in-situ samples generally showed high values. Ignoring outliers (>50%), this averaged at 21.1% (with a median of 20.6%), with a range between 4.0% – 49.1%.
  - Moisture content testing of “Top of Terrace” samples showed slightly lower values. Ignoring outliers (>50%), this averaged at 20.6% (with a median of 19.8%), with a range between 5.4% – 49.0%. This suggests the Q5b sand material located within the terraces is dryer than the material from the valley floors.
  - The fine-grained material is non-plastic to low plasticity (limited testing performed).
  - Laboratory results did not conclude notable trends to differentiate between northern and southern Q5b sand material.
  - Laboratory results did not conclude notable trends to differentiate between Q5b sand material encountered at different depths. Albeit there is a wider range of natural moisture contents near the surface, than at depth. This potentially suggests that materials near the surface are more prone to fluctuating moisture contents (with infiltration from rainfall events likely being the primary source of moisture).

- Results from the compaction testing:
  - Optimum Water Content ranged from 14.0% to 22.3%, averaging 16.6%. It appears the range is associated with varying levels of fines content in the tested samples.
  - Material with the higher fines content (28% – 52%) achieved an average MDD of 1.75 t/m^3, whilst material with a lower fines content (1% – 9%) achieved an average MDD of 1.68 t/m^3.
  - The material with the higher fines content tended to have curves trending between the 0.0% - 5.0% air void lines.
  - Curve peaks were relatively steep, with curves dropping relatively steeply after optimal conditions were achieved.

Based on the above observations, Stantec concludes:

- Q5b sand material in its native state will likely prove challenging to compact. Vibratory compaction has the potential to liquefy the material. Pneumatic tyre roller compacting is expected to be the most suitable methodology; however, the high fines and water contents are expected to create challenges that will need to be managed.

- Natural Moisture Contents are generally above Optimum Moisture Content. This is demonstrated with Figure 7.1 where a distribution of tests results are plotted against Natural Moisture Content (for two data sets). The graph shows the percentage of tests results greater than the NMC listed on the horizontal axis. The average OMC is shown as a red vertical line for comparative purposes. The samples obtained from sites located on the top of the terraces (orange line) are considered the best representation of the material that will be utilised for fill. This illustrates approximately 77% of samples tested had a NMC greater than the average OMC. Assuming that the Q5b sand material can be dried up to 5%, and the average OMC is 16.6%, a good indicator for reuse is to observe the percentage of results at a NMC = 21.6% (ie 16.6 + 5 = 21.6%). This is shown as a green vertical line.

  Observations show:

    - ~40% (77% – 37%) of the material should be able to be dried efficiently via discing.
    - ~37% of the material is likely to be too wet to efficiently dry.

Acknowledging that some of this wetter material could be mixed with the dryer proportion (NMC <16.5%), the resulting assumption of 70% reuse proposed by Stan Goodman appears reasonable.

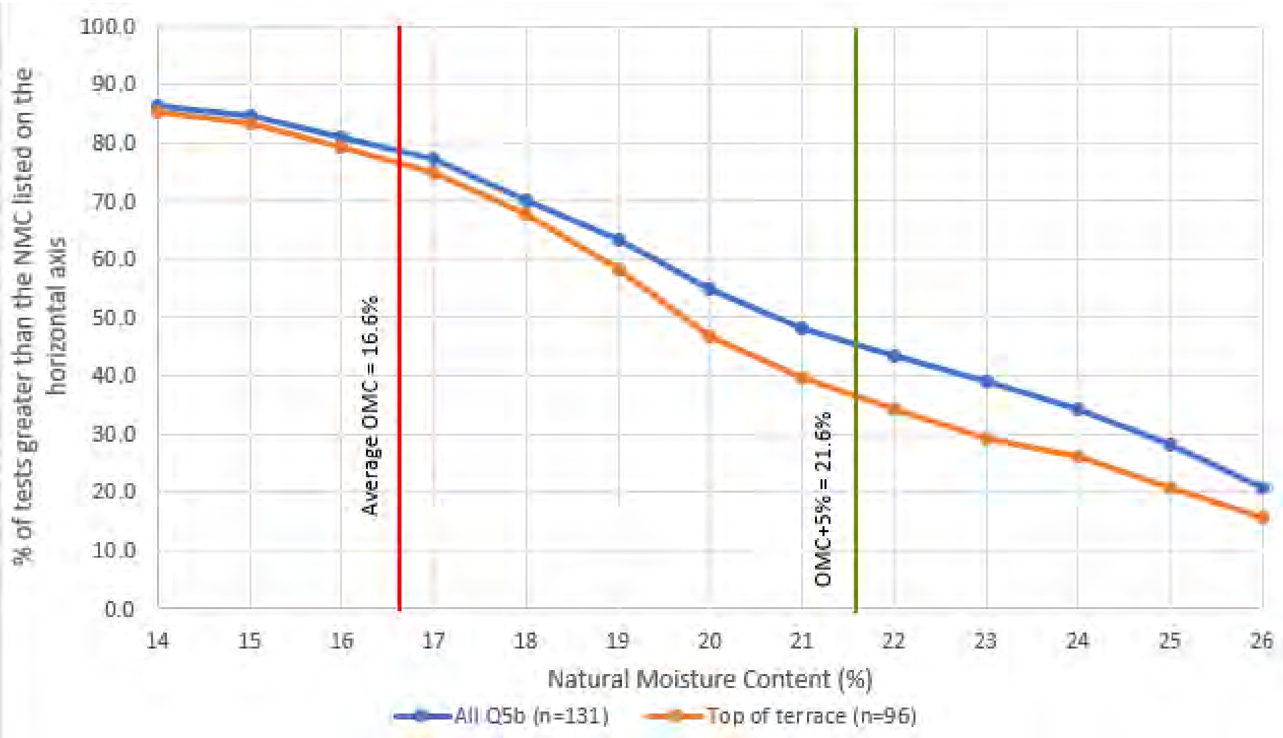


Figure 7.1: Q5b Sand Material Natural Moisture Content (NMC) Distribution of Test results

- A large proportion (~40%) of freshly cut Q5b sand material is likely going to need to be dried out before reuse. Re-using the material at greater than optimum conditions (without drying) will result in poor compaction that will lead to a reduction of densities/strengths being achieved. This will need careful consideration when developing the earthworks quality control specification and evaluating the seismic performance of fill embankments.

- Any drying of the Q5b sand material will create project construction risk, as the process is weather and time dependent. Due to the large cut to fill volumes required, the drying process creates programming and logistical challenges. These need to be considered during project planning and earthworks management.

- Figure 7.3 presents Table1.4 from the Earth Manual[13] which suggests a material of Q5b's composition is "fair" in terms of workability. It is commonly accepted within the geotechnical profession that as fines content increase over 10 to 15%, the workability of the material becomes more challenging. A higher fines content can also change how the compacted material performs under loading. Design and seismic assessment of embankment constructed of Q5b fill material is yet to be completed.

[13] Earth Manual, Part 1, 3rd Edition, US Department of the Interior, Bureau of Reclamation

Table 1-4.—Engineering use chart for compacted soils

Engineering Properties of Compacted Soil[1]						Relative Desirability for Various Uses (No. 1 is considered the best)							
						Rolled earth dams			Canal sections		Foundations and fills		
Soil group name	Group symbol	Perme-ability[2]	Shear strength (saturated)	Compressibility (saturated)	Workability as a construction material	Homo-geneous embank-ment	Core	Shell	Erosion-resistant blanket or belt	Compacted earth lining	Imper-vious	Per-vious	Resistance to frost heave
Well-graded gravel	GW	Pervious	Excellent	Negligible	Excellent	—	—	1	1	—	—	1	1
Poorly graded gravel	GP	Pervious	Good	Negligible	Good	—	—	2	2	—	—	3	2
Silty gravel	GM	Semipervious to impervious	Good	Negligible	Good	2	4	—	4	4	1	4	6
Clayey gravel	GC	Impervious	Good to fair	Very low	Good	1	1	—	3	1	2	6	5
Well-graded sands	SW	Pervious	Excellent	Negligible	Excellent	—	—	3 if gravelly	6	—	—	2	3
Poorly graded sands	SP	Pervious	Good	Very low	Fair	—	—	4 if gravelly	7 if gravelly	—	—	5	4
Silty sands	SM	Semipervious to impervious	Good	Low	Fair	4	5	—	8 if gravelly	5 erosion critical	3	7	12
Clayey sands	SC	Impervious	Good to fair	Low to medium	Good	3	2	—	5	2	4	8	7
Silt	ML	Semipervious to impervious	Fair	Medium	Fair	6	6	—	—	6 erosion critical	6	9	11
Lean clay	CL	Impervious	Fair	Medium	Good to fair	5	3	—	9	3	5	10	9
Organic silt and organic clay	OL	Semipervious to impervious	Poor	Medium to high	Fair	8	8	—	—	—	7	11	—
Elastic silt	MH	Semipervious to impervious	Fair to poor	High	Poor	9	9	—	—	—	8	12	10
Fat clay	CH	Impervious	Poor	High	Poor	7	7	—	10	—	9	13	8
Organic silt and organic clay	OH	Impervious	Poor	High	Poor	10	10	—	—	—	10	14	—
Peat and other highly organic soils	PT	—	—	—	—	—	—	—	—	—	—	—	—

[1] Compacted to at least 95 percent of laboratory maximum dry density or to at least 70 percent relative density.
[2] Impervious: < 1 ft/yr (1×10^{-6} cm/s)
Semipervious: 1 to 100 ft/yr (1×10^{-6} cm/s to 1×10^{-4} cm/s).
Pervious: > 100 ft/yr (1×10^{-4} cm/s).

Figure 7.3: Table1.4 from the Earth Manual

7.2 Recommendations

- Proceed with planning/consenting O2NL with the assumption that Q5b sand material will be challenging to re-use. This includes advancing with the following assumptions:
    - During earthwork planning and cost estimating, assume:
        - 70% of the cut Q5b sand material will be efficient to use as “cut to fill”.
        - 30% will need to be spoiled with a bulking factor of 1.2
        - that a large majority (40 to 80%) of the material will need to be dried via discing (or alternative process) prior to compaction
        - that 2% lime conditioning may be advantageous to extend the earthwork season, and lime use should therefore be allowed for.
        - allow program contingency for adverse weather.

- Undertake a constructability / compaction trial (material in natural state) to validate the assumptions above. Consider constructability / compaction trials that involve additives (i.e., lime).

- Undertake a detailed seismic stability assessment to ascertain how the Q5b sand material performs (and deforms) when utilised as an embankment fill.

- During the planning phase, allow for the inclusion of a gravel base layer and the use of geogrid (ground improvements) for the higher embankments. Requirement of the use of a gravel layer and geogrid to be determined during the detailed design.

- Consider undertaking additional investigations at proposed Q5b sand material supply (borrow) sites.

Geotechnical Assessment Memorandum for Q2a/Q3a Gravels in Proximity to Ohau River and Waiakawa Stream, May 2022

Otaki to North Levin (O2NL)
Geotechnical Assessment Memorandum for Material Supply (Borrow) Sites located at the South/North of Waikawa Stream and the Northeast of Ōhau River.

The information contained in this memorandum is accurate to the best of our knowledge at the time of issue. The interpretations as to the likely subsurface conditions contained in this report are based on the site observations and field investigations made at discrete locations as described in this report. The type, spacing and frequency of the investigations, sampling, and testing of materials were selected to meet the technical, financial and time requirements agreed by the client. Stantec NZ accepts no liability for any unknown or adverse ground conditions that would have been identified had further investigations, sampling, and testing been undertaken. This report does not purport to describe all the site characteristics and properties.

Quality statement

Rev. no	Date	Description	Prepared by	Checked by	Reviewed by	Approved by
1	30-05-2022		KC/RC	JG	EG	JP

1 Introduction

1.1 Brief

Stantec has been engaged by Waka Kotahi to undertake geotechnical investigations and reporting for the Otaki to North Levin (O2NL) project. The first stage of the geotechnical investigation was completed in 2020, the second stage in 2021 and the third stage in 2022. The investigation results are presented within Stantec's Geotechnical Factual Report[1].

The purpose of this memorandum is to summarise factual results and provide a geotechnical interpretation for the re-useability of the proposed alluvial gravel material supply (borrow) sites. These proposed sites are:

- South of Waikawa Stream (Site 15)
- North of the Waikawa Stream (Site 19)
- Northeast of Ōhau River (Site 36).

This alluvial material is currently targeted for use as a bulk/general embankment fill.

The objectives of this memorandum are to provide a compilation of the relevant geotechnical information for each site, present a discussion on re-use interpretation, and provide recommendations.

The memorandum is intended to supplement the Material Supply (Borrow) Study[2] and Geotechnical Interpretative Report[3]

1.2 Background

The ongoing geotechnical assessments have identified the Q2a and Q3a Late Pleistocene River deposit geological units (as mapped by (Begg & Johnston, 2000)4) as being potentially suitable material for re-use. Certain materials in the Q1a Holocene River deposits have also been identified as such.

The target material is generally described as sandy gravels, acknowledging that some portion of finer grain materials may be present.

Based on the geological interpretation along the proposed highway designation, locations of potential borrow sites, where significant areas of this material may be encountered, have been identified. These have been refined to the three sites discussed in this memorandum.

For the purpose of our assessments these geological units have been denoted as "Q1a Holocene Alluvium (Q1a)" and "Q2a/Q3a Pleistocene Alluvium (Q2a/Q3a)". Further classification is detailed in the Interpretive Report.

[1] Geotechnical Factual Report for SH1 Ōtaki to North Levin, Rev C, Stantec, 2022
[2] Material Supply (Borrow) Study for SH1 Ōtaki to North Levin, Rev A, Stantec, 2022
[3] Geotechnical Interpretive Report for SH1 Ōtaki to North Levin, Rev D, Stantec, 2022
[4] Geology of the Wellington area: scale 1:250,000. Map 10. Institute of Geological & Nuclear Sciences. Begg & Johnston, 2000

2 South of Waikawa Stream (Borrow Site #15)

2.1 Site Description

Figure 2-1 shows the borrow site area (enclosed within the dashed green line) in the context of the published geological map (Begg & Johnston, 2000) and the nearby site investigations. The proposed O2NL alignment crosses Q2a/Q3a material from Waikawa Stream (Ch. 26,500) to North Manukau Road (Ch. 27,100).

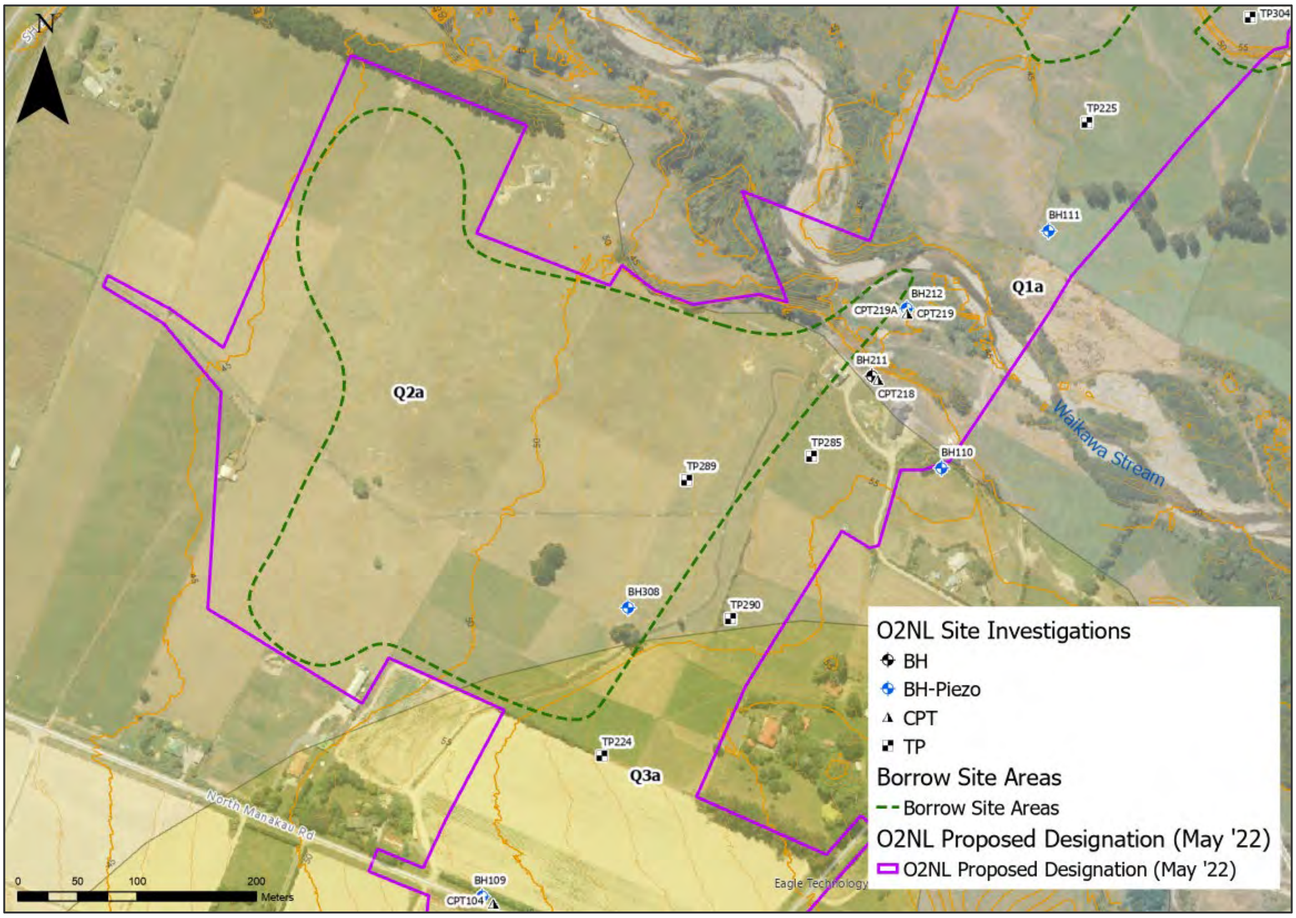


Figure 2-1: Site plan - South of Waikawa Stream

2.2 Topography / Slope Landform / Surface Conditions

This site lies on the floodplain, slightly elevated from the contemporary bed of the Waikawa Stream. Topography at the site is flat to very gently sloping towards the terraced slopes above the Waikawa river (Figure 2-2).

Two drainage channels cut through the site, in a north-south and a south-west to north-east orientation. The channels are typically 1m across and up to 1m deep. The site is currently used as grazing farmland.

Figure 2-2: Terrace found at 121A North Manakau Road. The terrace is located between BH211 and BH212, on the southern bank of the Waikawa River.

2.3 Investigations Completed

The following site investigations were completed within or near the area of interest by Stantec between June 2020 and March 2022:

- Four (4) sonic boreholes.
- Four (4) test pits.
- Three (3) cone penetration tests (CPT).
- One (1) groundwater monitoring piezometer.
- One (1) geophysical survey.

The location information is summarised in Table 2-1 below and the investigation logs, results and interpretation are presented in the Factual and Interpretive Reports.

Table 2-1: Summary of Site Investigations – South of Waikawa Stream

Investigation ID	Investigation Type	Coordinates (NZTM 2000)		Elevation (m RL, WGN 1953)	Approx. Chainage	Termination depth (m BGL#)	Depth where gravels of interest encountered (m BGL)
		Easting	Northing				
BH109	Borehole	1788177	5491389	54.2	27094	30.45	3.45 – 30.45
BH210	Borehole	1788248	5491362	55.1	27095	30.45	2.90 – 30.45
BH211	Borehole	1788504	5491825	52.6	26559	34.95	1.50 – 34.95
BH308	Borehole	1788300	5491630	52.5	26822	15.35	1.50 – 15.35
TP224	Test pit	1788278	5491507	57.3	26950	3.80	2.40 – 3.80
TP223*	Test pit	1788190	5491191	51.0	27277	3.60	2.10 – 3.60

Investigation ID	Investigation Type	Coordinates (NZTM 2000)		Elevation (m RL, WGN 1953)	Approx. Chainage	Termination depth (m BGL#)	Depth where gravels of interest encountered (m BGL)
		Easting	Northing				
TP285	Test pit	1788454	5491758	54.2	26644	3.80	0.30 – 3.80
TP289	Test pit	1788349	5491738	52.9	26709	3.40	0.10 – 3.40
TP290	Test pit	1788386	5491622	53.8	26796	3.50	0.05 – 3.50
CPT104	CPT	1788187	5491383	54.3	27096	3.24	Refusal on gravels?
CPT217	CPT	1788251	5491359	55.4	27097	11.34	Refusal on gravels?
CPT218	CPT	1788509	5491822	52.8	26559	1.53	Refusal on gravels?

BGL = Below Ground Level
*Out of site area, but included as considered relevant

2.4 Subsurface Conditions and Geological Interpretation

A geological interpretation of the entire highway alignment has been undertaken as part of the Interpretative Reporting.

The expected ground conditions at the area of interest based on the forementioned investigations are summarised in Table 2-2 below.

Table 2-2: Expected Ground Conditions – South of Waikawa Stream

Unit Name	Generalised Material Description	Typical Depth to the Top of Layer (m BGL)	Typical Thickness Range (m)	SPT 'N' Range (average)
Q2a/Q3a Pleistocene Alluvium	Medium dense to very dense, silty GRAVEL and COBBLES, with minor clay and sand layers.	0 - 6	13 - 15	0 – 50 (16)

2.5 Groundwater

BH308 has the only piezometer within the proposed area. Groundwater levels have varied from 4.9 to 6.9m BGL, with measurements undertaken towards the end of summer when the water table is likely to be depressed. The ground water level may be higher during winter months.

Ponded water was observed within surface depressions during site visits in October 2021, but these were perceived as perched.

2.6 Laboratory Testing

2.6.1 Testing Standards

Testing was undertaken by Geocivil laboratory, in accordance with the following standards:

- Particle Size Distribution (wet sieve) tested in accordance with ASTM D6913-17.
- Natural Water Content tested in accordance with Test 2.1, NZS4402:1986.
- Density of Soil tested in accordance with Test 5.1.4 & 5.1.5, NZS4402:1986.
- Atterberg Limits tested in accordance with ASTM D4318 – 00.
- NZ Standard Compaction Test in accordance with NZS 4402:1986 Test 4.1.1.
- California Bearing Ratio tested in accordance with NZS 4407: 2015, Test 3.15.

It should be noted that ASTM D6913-17 defines fine sands as the material between 0.075mm – 0.475mm whilst NZ geological guidelines (used for field descriptions) defines fine sands as the material between 0.075mm – 0.2mm. The ASTM D6913-17 standard has been used to facilitate the derivation of material properties from industry-accepted empirical relationships, including the liquefaction triggering assessments.

2.6.2 Testing Summary

Geotechnical laboratory testing was targeted at representative material targeted for re-use (ie gravely material). The quantities of tests undertaken are summarised below.

Table 2-3: Lab Testing Quantity Summary - South of Waikawa Stream

Sample ID	Particle Size Distribution	Natural Water Content	Atterberg Limits	NZ Compaction Test	California Bearing Ratio
TP224	1	-	-	-	1
TP285	1	1	-	-	-
TP289	2	2	-	1	-
TP290	2	2	1	1	-
TP223	1	2	-	1	2

2.7 Laboratory Test Results

2.7.1 Summary

The laboratory test results are summarised below.

Table 2-4: Laboratory Testing Results Summary - South of Waikawa Stream

Sample ID	Depth (m BGL)	Particle Size Distribution (Wet Sieve)					USCS Classification	Water Content (%)
		% Gravel	% Coarse Sand	% Medium Sand	% Fine Sand	% Silt/Clay		
		>4.75 mm	4.75 – 2mm	2 – 0.475mm	0.475 – 0.075mm	<0.075mm		
TP224	2.50 – 3.80	73.1	7.5	0.9	1.4	17.1	GM	7.6
TP285	1.40 – 2.40	72.0	10.4	7.3	3.2	7.1	GP	6.4
TP289	1.00 - 1.20	52.0	6.0	6.0	3.0	33.0	GM	5.2
TP289	2.60 – 2.80	77.0	8.0	9.0	3.0	3.0	GP	4.4
TP290	0.50	61.2	12.7	13.1	6.8	6.2	GM	17.1
TP290	1.65 – 1.85	66.8	14.2	11.5	2.2	5.3	GW	9.0
TP223	3.30 – 3.60	69.1	13.0	11.8	4.6	1.5	GW	6.9

2.7.2 Particle Size Distribution Plots

Figure 2-3 presents Particle Size Distribution plots for the alluvial gravels south of Waikawa Stream.

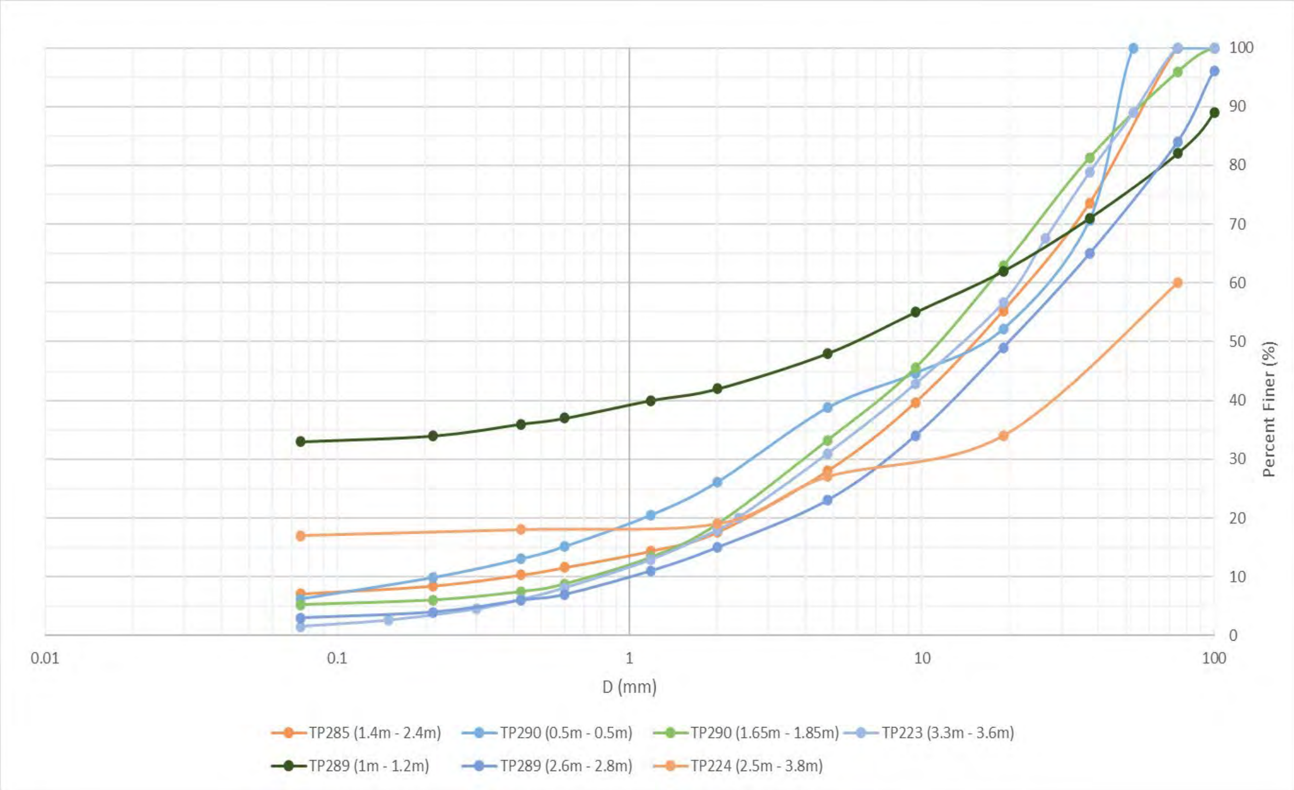


Figure 2-3: Particle Size Distribution (Wet sieve) Plot - South of Waikawa Stream Alluvial Gravel Material

2.7.3 Coefficients of Uniformity and Curvature

Coefficients of Uniformity, C_u, and Curvature, C_c, were calculated for locations where a "D_{10}" was available from the grading results. Table 2-5 present the results.

Table 2-5: Coefficients of Uniformity and Curvature – South of Waikawa Stream

Sample ID	Depth (m BGL)	D_{60}	D_{30}	D_{10}	C_u	C_c
TP285	1.40 – 2.40	23.80	5.60	0.40	60.60	3.30
TP224	2.50 – 3.80	19.00	5.60	0.04	448.90	38.5
TP223	3.30 – 3.60	21.30	4.50	0.80	25.60	1.20
TP290	0.50	26.80	2.80	0.20	120.80	1.40
TP290	1.65 – 1.85	17.40	4.10	0.80	23.10	1.30
TP289	2.60 – 2.80	31.72	7.77	1.04	30.65	1.84

2.7.4 Atterberg Limits

The materials encountered at the site were generally granular and non-cohesive, therefore extensive Atterberg Limit (plasticity) testing was not undertaken. A single test was completed on a sample from a pocket of fine-grained material and is included to illustrate the variability of the material. Results are shown in Table 2-6 below. This material was not targeted for testing as it is assumed that selective "borrowing" would occur with pockets of cohesive material being discarded. Additional intrusive testing is recommended to better understand the variability of the material.

Table 2-6: Atterberg Limits Test Results - South of Waikawa Stream

Sample ID	Depth (m BGL)	Moisture Content, w_n (%)	Liquid Limit (LL, %)	Plastic Limit (%)	Plasticity Index (%)
TP290	0.50	17.1	87	58	29

2.7.5 NZ Compaction Test

Table 2-7 presents the results from the NZ Standard Compaction test with plots presented in Figure 2-4 to Figure 2-6.

Table 2-7: NZ Standard Compaction Test Results – South of Waikawa Stream

Sample ID	Depth (m BGL)	Natural Moisture Content, w_n (%)	Optimum Moisture (Water) Content, w_o (%)	Max Dry Density, $\rho_{d, max}$ (t/m³)
TP290	1.65 – 1.85	9.0	9.0	2.08
TP223	3.30 – 3.60	11.5	12.2	2.01
TP289	2.60 – 2.80	6.1	9.0	2.14

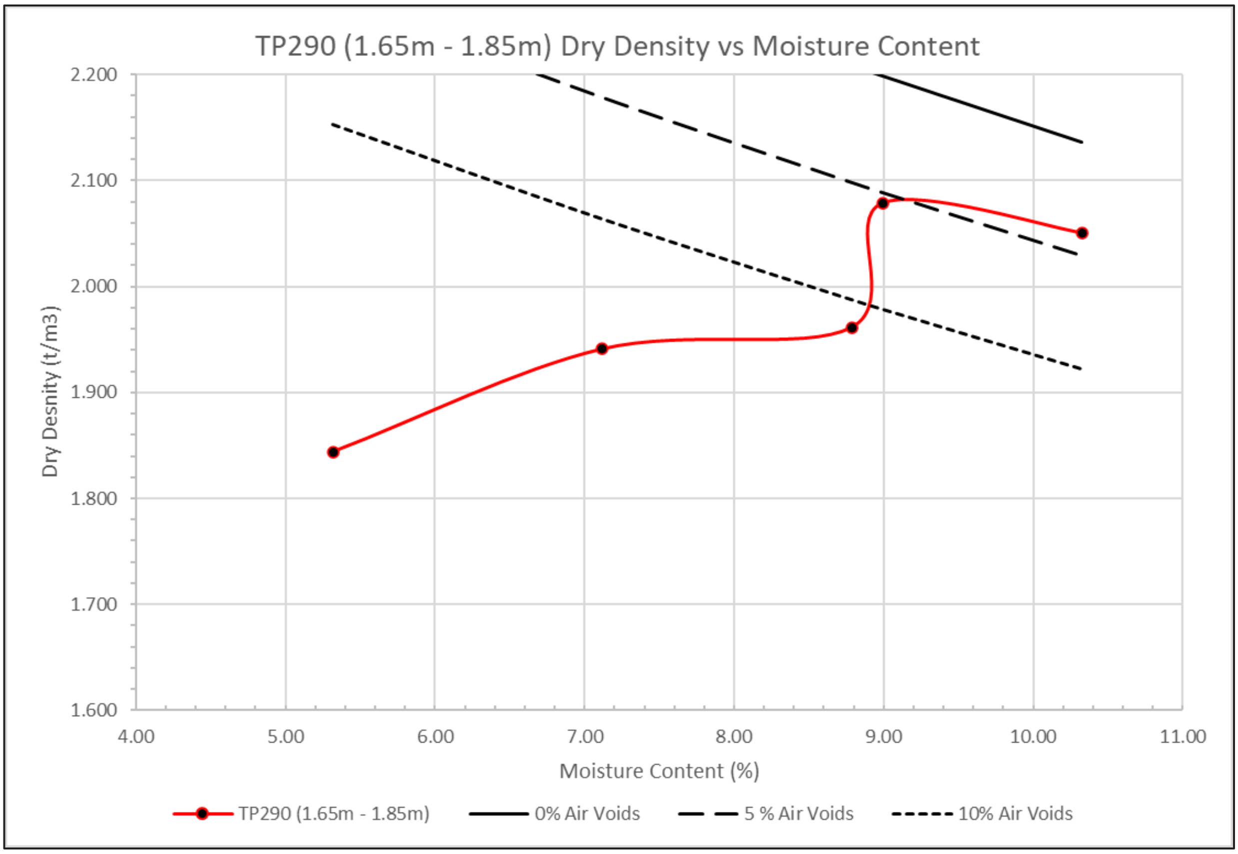


Figure 2-4: TP290 (1.65 – 1.85m) Dry Density vs. Moisture Content Plot

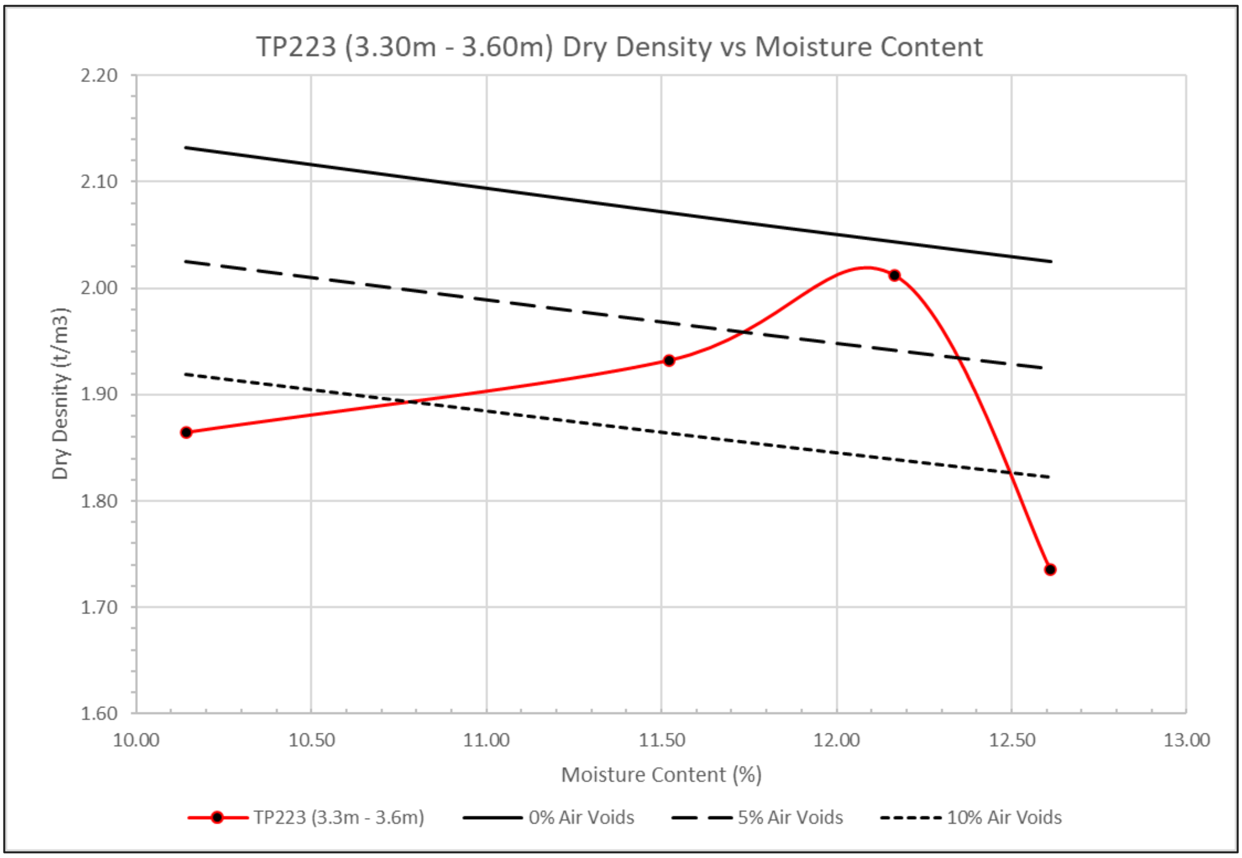


Figure 2-5: TP223 (3.30 - 3.60m) Dry Density vs. Moisture Content Plot

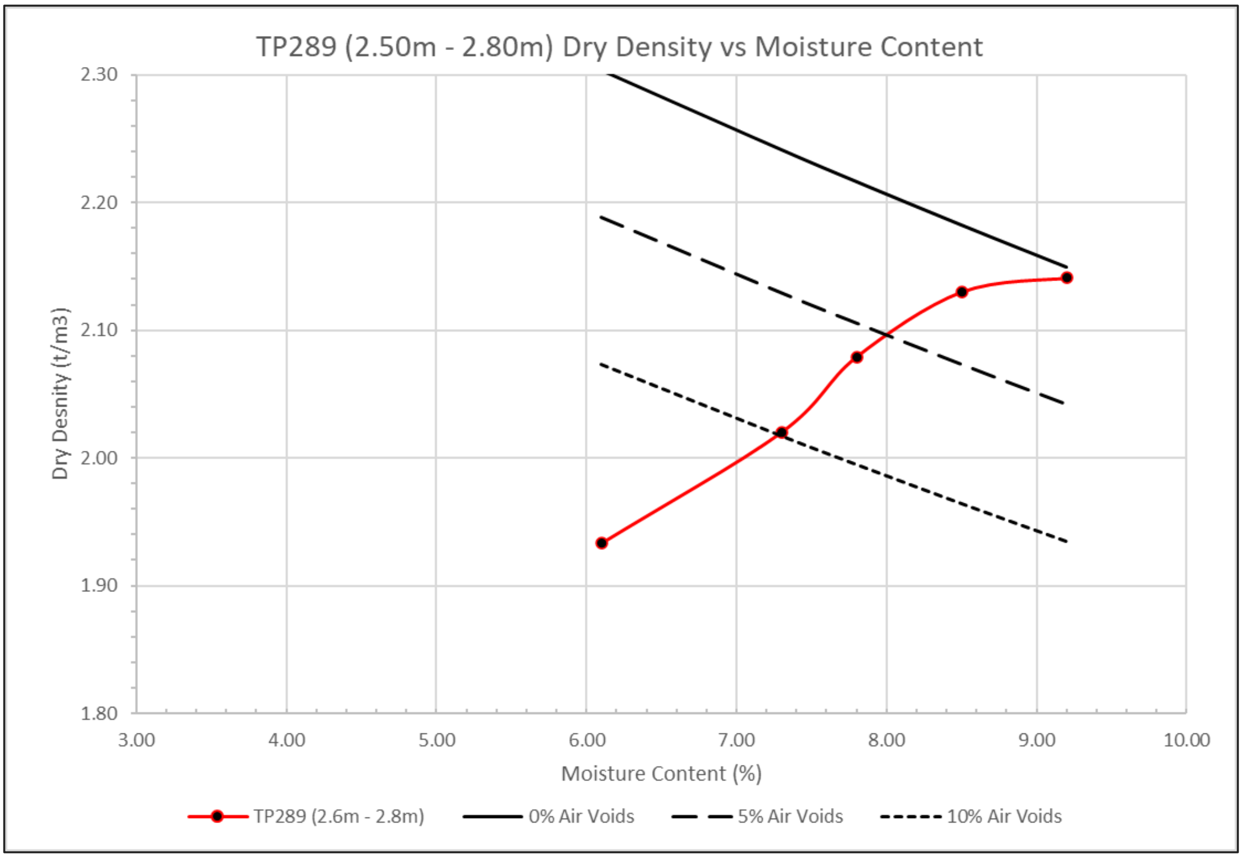


Figure 2-6: TP289 (2.50 – 2.80) Dry Density vs. Moisture Content Plot

2.7.6 California Bearing Ratio (CBR)

California Bearing Ratio (CBR) test results are presented in Table 2-8 below.

Table 2-8: CBR Results - South of Waikawa Stream

Sample ID	Depth (m BGL)	Bulk Density (t/m3)	Dry Density (t/m3)	CBR (%)	Comments
TP224	2.5 – 3.8	1.98	1.77	16	Soaked @ optimum water content
TP223	3.3 – 3.6	2.14	1.93	40	Soaked @ natural water content
TP223	3.3 – 3.6	2.15	1.93	50	Unsoaked @ natural water content

3 North of Waikawa Stream

3.1 Site Description

Figure 3-1 shows the borrow site areas (enclosed within the dashed green lines) in the context of the published geological map (Begg & Johnston, 2000) and the nearby site investigations. Q2a/Q3a material is expected north of the Waikawa Stream alluvial terrace.

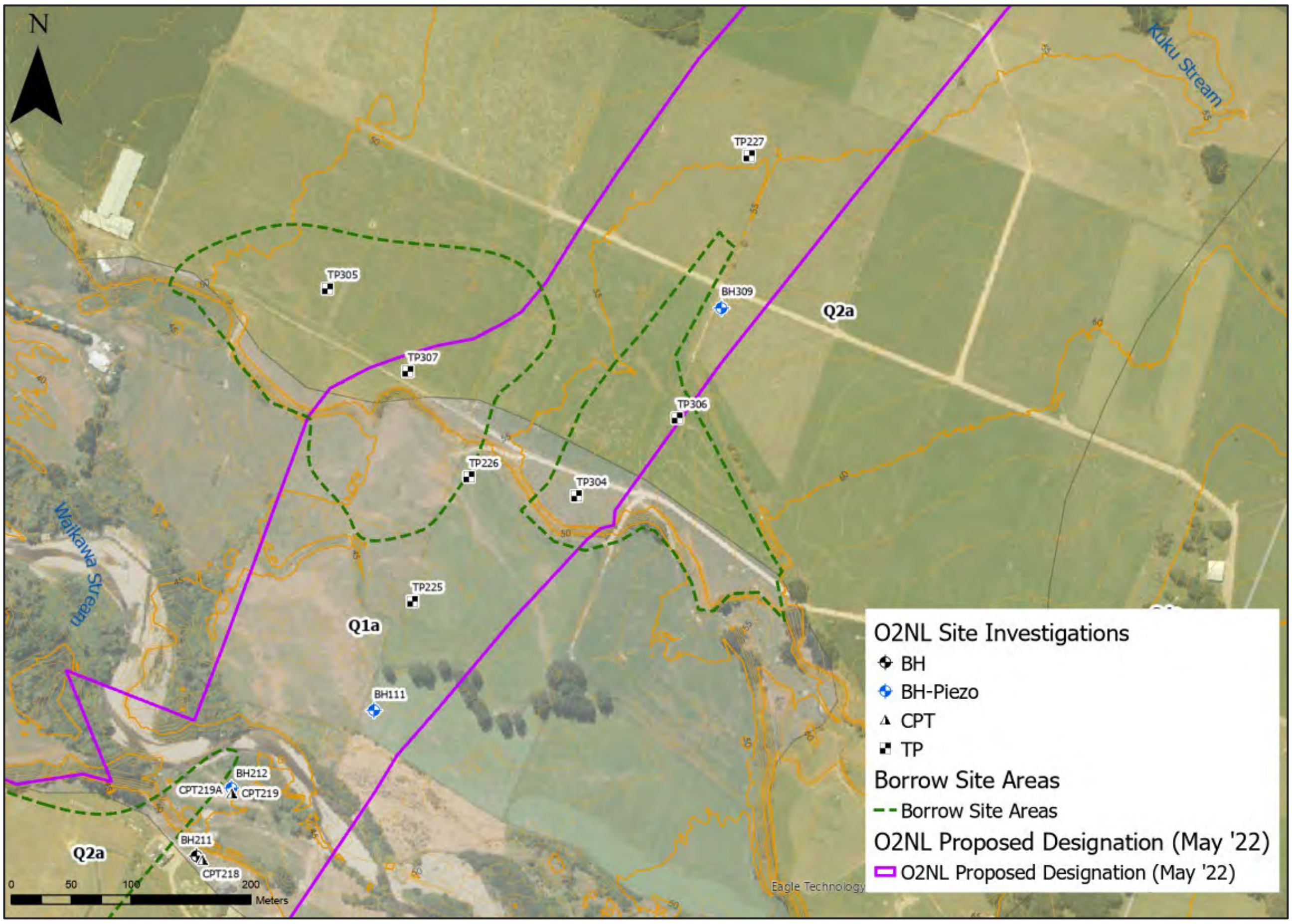


Figure 3-1: Site plan - North of Waikawa Stream

3.2 Topography / Slope Landform / Surface Conditions

The topography of the site is flat to very gently sloping towards the Waikawa Stream to the south. The southern-most extent of the site is bounded by an alluvial terrace approximately 7m higher in elevation. A small drainage channel spanning 1m across and 1m deep passes from north-west to south-east through the site and connects to a tributary of the Waikawa Stream approximately 300m south of the site. The site is currently used as grazing farmland and crop paddocks.

3.3 Investigations Completed

The following site investigations were completed within or near the area of interest by Stantec between June 2020 and March 2022:

- Six (6) test pits.
- One (1) borehole.
- One (1) groundwater monitoring piezometer.

The location information is summarised in Table 3-1 below and the investigation logs, results and interpretation are presented in the Factual and Interpretive Reports.

Table 3-1: Summary of Site Investigations - North of Waikawa Stream

Investigation ID	Investigation Type	Coordinates (NZTM 2000)		Elevation (m RL, WGN 1953)	Approx. Chainage	Termination Depth (m BHL)	Depth where Gravels of Interest Encountered (m BGL)
		Easting	Northing				
BH309	Borehole	1788943	5492283	56.9	25918	15.45	1.65 – 15.45
TP304	Test Pit	1788822	5492126	56.4	26116	3.5	1.6 – 3.5
TP305	Test Pit	1788614	5492299	51.9	26110	3.4	0.6 – 3.4
TP306	Test Pit	1788906	5492191	56.5	26013	3.2	1.2 – 3.2
TP307	Test Pit	1788681	5492230	53.0	26122	3.5	0.8 – 3.5
TP226	Test Pit	1788732	5492142	46.2	26159	3.9	0.6 – 2.7
TP227	Test Pit	1788966	5492410	54.8	25804	4.1	2.1 – 4.1

3.4 Subsurface Conditions and Geological Interpretation

A geological interpretation of the entire highway alignment has been undertaken as part of the Interpretative Reporting.

The expected ground conditions at the area of interest based on the forementioned investigations are summarised in Table 3-2 below.

Table 3-2: Expected Ground Conditions - North of Waikawa Stream

Unit Name	Description	Typical Depth to the Top of Layer (m BGL)	Typical Thickness Range (m)	SPT 'N' Range (average)
Loess	Stiff, clayey SILT, moderate to high plasticity.	0	0.5 – 1.5	-
Q2a/Q3a Pleistocene Alluvium	Medium dense to very dense, silty GRAVEL with minor clay and sand layers.	0 - 6	13 - 15	0 – 50 (16)

3.5 Groundwater

Groundwater levels have been measured in the piezometer within BH309.

Groundwater levels varied from 10.3 to 13.0m BGL, with groundwater measurement undertaken towards the end of summer when the water table is likely to be depressed. The ground water level may be higher during winter months. The nearby BH111 has also recorded groundwater level depth >10m BGL.

3.6 Laboratory Testing

3.6.1 Testing Summary

Geotechnical laboratory testing was targeted at representative material targeted for re-use (ie gravely material). The quantities of tests undertaken are summarised below.

Table 3-3: Lab Testing Quantity Summary - North of Waikawa Stream

Sample ID	Particle Size Distribution (Wet Sieve)	Natural Water Content	Atterberg Limits	NZ Compaction Test	California Bearing Ratio
BH309	-	-	1	-	-
TP226	1	1	1	-	-
TP227	1	1	1	-	-
TP304	1	1	-	-	-
TP305	1	1	-	1	1
TP306	1	1	-	-	1
TP307	1	1	-	1	1

3.7 Laboratory Test Results Presentation

3.7.1 Summary

The laboratory test results are summarised below.

Table 3-4: Laboratory Testing Results Summary - North of Waikawa Stream

Sample ID	Depth (m BGL)	Particle Size Distribution (Wet Sieve)					Classification according to USCS	Natural Water Content (%)
		% Gravel	% Coarse Sand	% Medium Sand	% Fine Sand	% Silt /Clay		
		>4.75mm	4.75 – 2mm	2 – 0.475mm	0.475 – 0.075mm	<0.075mm		
TP226	2.00 – 2.40	79	6	9	4	1	GP	-
TP227	3.80 – 4.10	69	10	10	5	5	GW	-
TP304	1.90 – 2.10	75	8	9	3	5	GW	6.4
TP305	2.60 – 2.80	76	9	9	3	3	GW	7
TP306	3.00 – 3.20	68	10	9	7	6	GP	9.0
TP307	1.60 – 1.80	72	9	11	4	4	GW	8.1

3.7.2 Particle Size Distribution Plots

Figure 3-2 presents Particle Size Distribution plots for the alluvial gravels north of the Waikawa Stream.

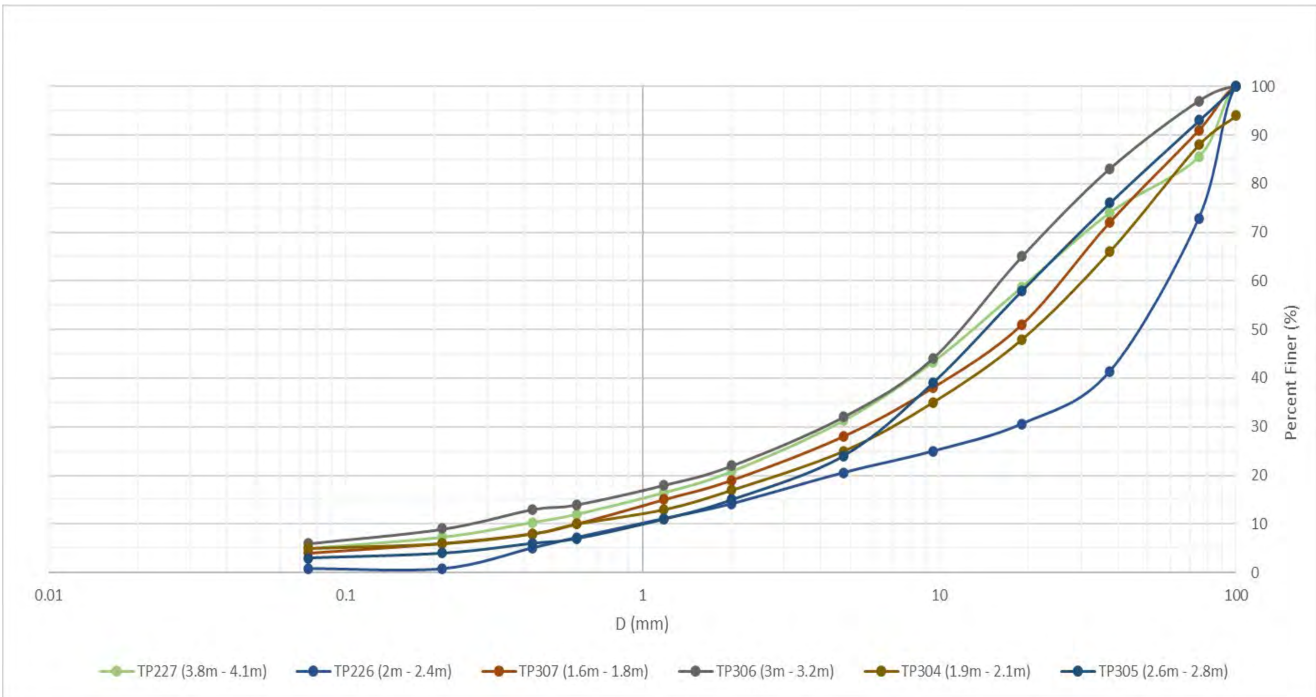


Figure 3-2: Particle Size Distribution (Wet Sieve) Plot - North of Waikawa Stream

3.7.3 Coefficients of Uniformity and Curvature

Coefficients of Uniformity, C_u, and Curvature, C_c, were calculated for locations where a "D_{10}" was available from the grading results. Table 3-5 present the results.

Table 3-5: Coefficients of Uniformity and Curvature - North of Waikawa

Sample ID	Depth (m BGL)	D_{60}	D_{30}	D_{10}	C_u	C_c
TP226	2.00 – 2.40	59.76	17.42	1.04	57.7	4.9
TP227	3.80 – 4.10	20.23	4.48	0.425	47.6	2.3
TP304	1.90 – 2.10	31.33	7.13	0.60	52.22	2.7
TP305	2.60 – 2.80	21.06	6.65	1.04	20.34	2.03
TP306	3.00 – 3.20	16.74	4.20	0.27	63.1	4.0
TP307	1.60 – 1.80	26.93	5.70	0.60	44.9	2.0

3.7.4 Atterberg Limits

Table 3-6 presents the results from the Atterberg Limits test completed in the south of Waikawa gravels.

Table 3-6: Atterberg Limit Test results – North of Waikawa Stream

Sample ID	Depth (m BGL)	Natural Moisture Content, w_n (%)	Liquid Limit (LL, %)	Plastic Limit (%)	Plasticity Index (%)
TP226	2.7 – 3.0	24.9	31	19	12

3.7.5 NZ Compaction Test

Table 3-7 presents the results from the NZ standard compaction test with plots presented in Figure 3-3 to Figure 3-4.

Table 3-7: NZ Standard Compaction Test Results – North of Waikawa Stream

Sample ID	Depth (m BGL)	Natural Moisture Content, w_n (%)	Optimum Moisture (Water) Content, w_o (%)	Max Dry Density, $\rho_{d,\,max}$ (t/m³)
TP305	2.60 – 2.80	7.0	12.0	2.00
TP307	1.60 – 1.80	9.0	11.2	2.05

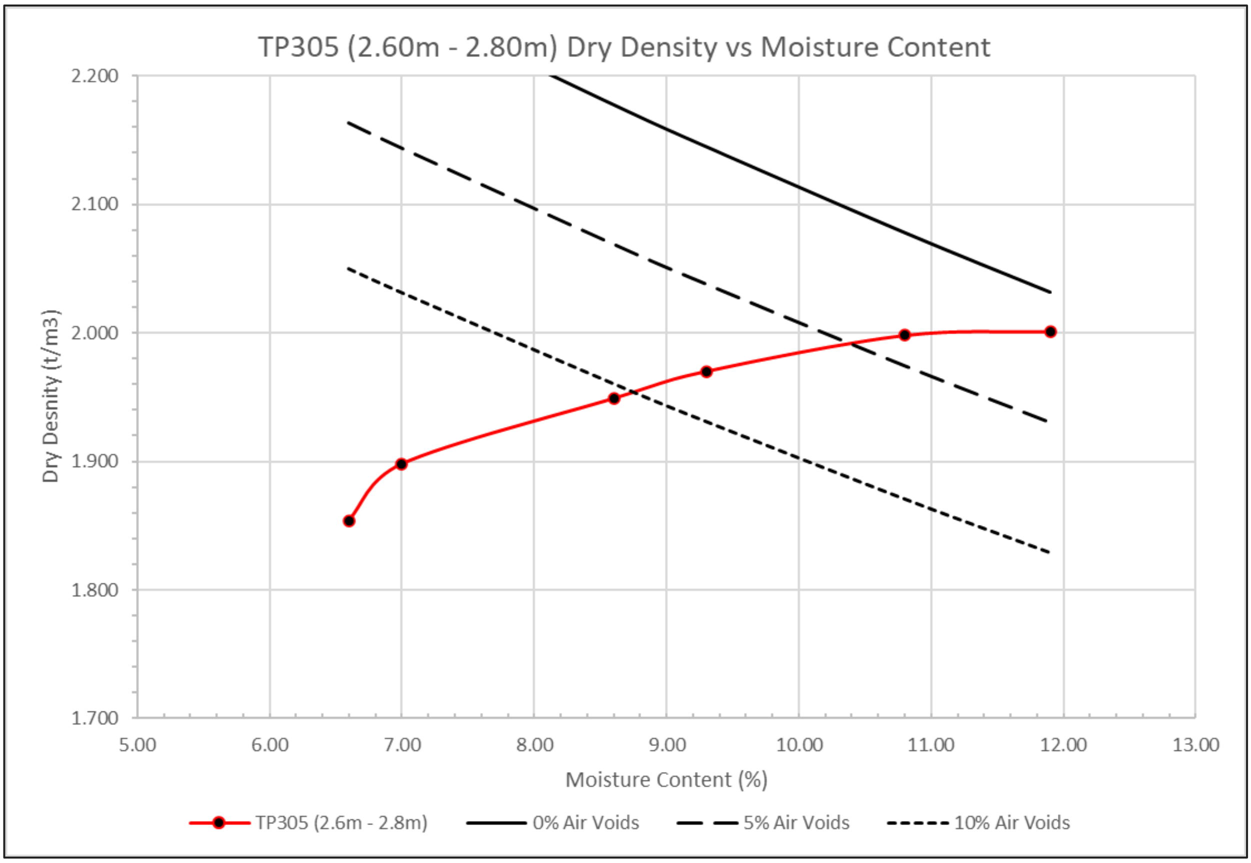


Figure 3-3: TP305 (2.60 - 2.80m) Dry Density vs. Moisture Content Plot

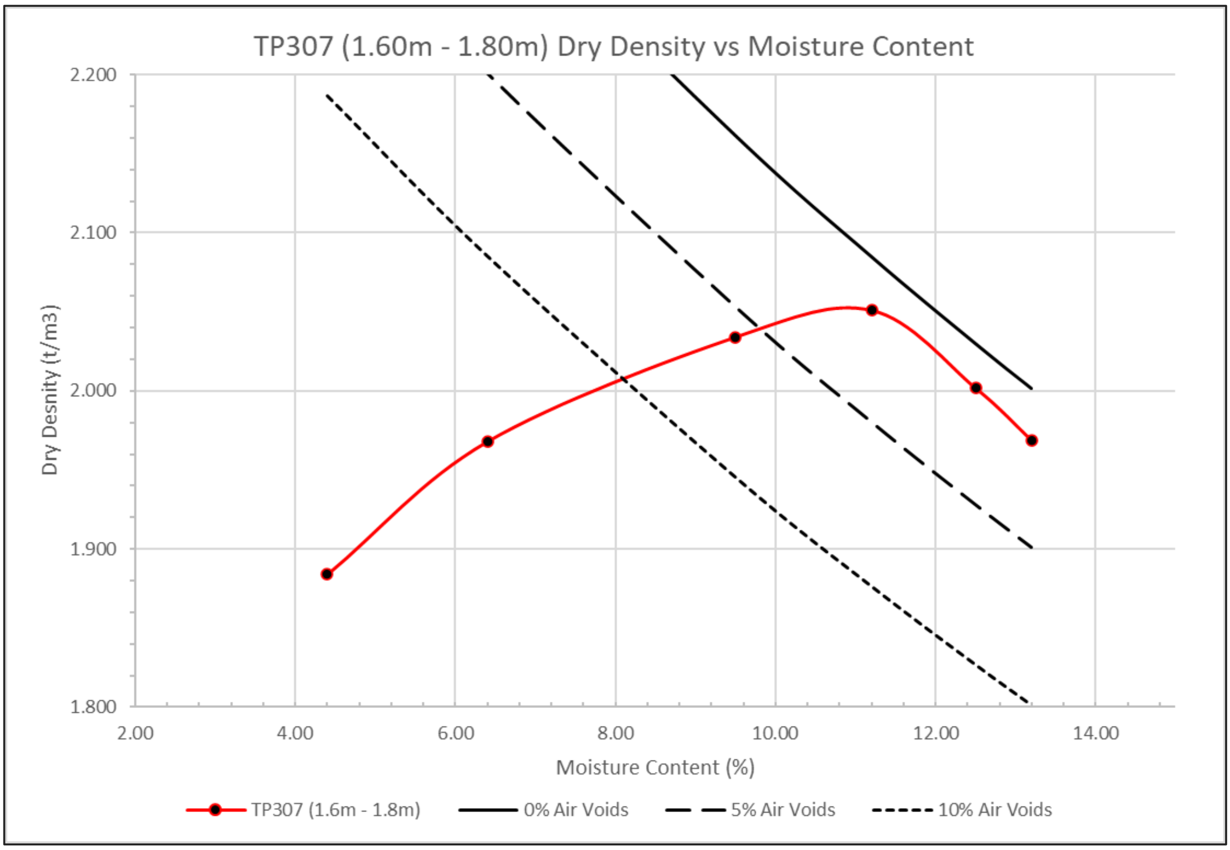


Figure 3-4: TP307 (1.60 – 1.80m) Dry Density vs. Moisture Content Plot

3.7.6 California Bearing Ratio (CBR)

California Bearing Ratio (CBR) lab test results are presented in Table 3-8 below.

Table 3-8: CBR Results - North of Waikawa Stream

Sample ID	Depth (m BGL)	Bulk Density (t/m3)	Dry Density (t/m3)	CBR (%)	Comments
TP305	2.60 - 2.80	2.23	2.02	40	Tested at natural water content
TP306	1.40 – 1.60	2.13	1.87	25	Tested at natural water content
TP307	1.60 – 1.80	2.16	1.99	55	Tested at natural water content

4 Northeast of Ōhau River

4.1 Site Description

Figure 4-1 shows the borrow site area (enclosed within the green dashed line) in the context of the published geological map (Begg & Johnston, 2000) and the nearby site investigations. The proposed O2NL alignment is within the Q1a Holocene Alluvium in this area.

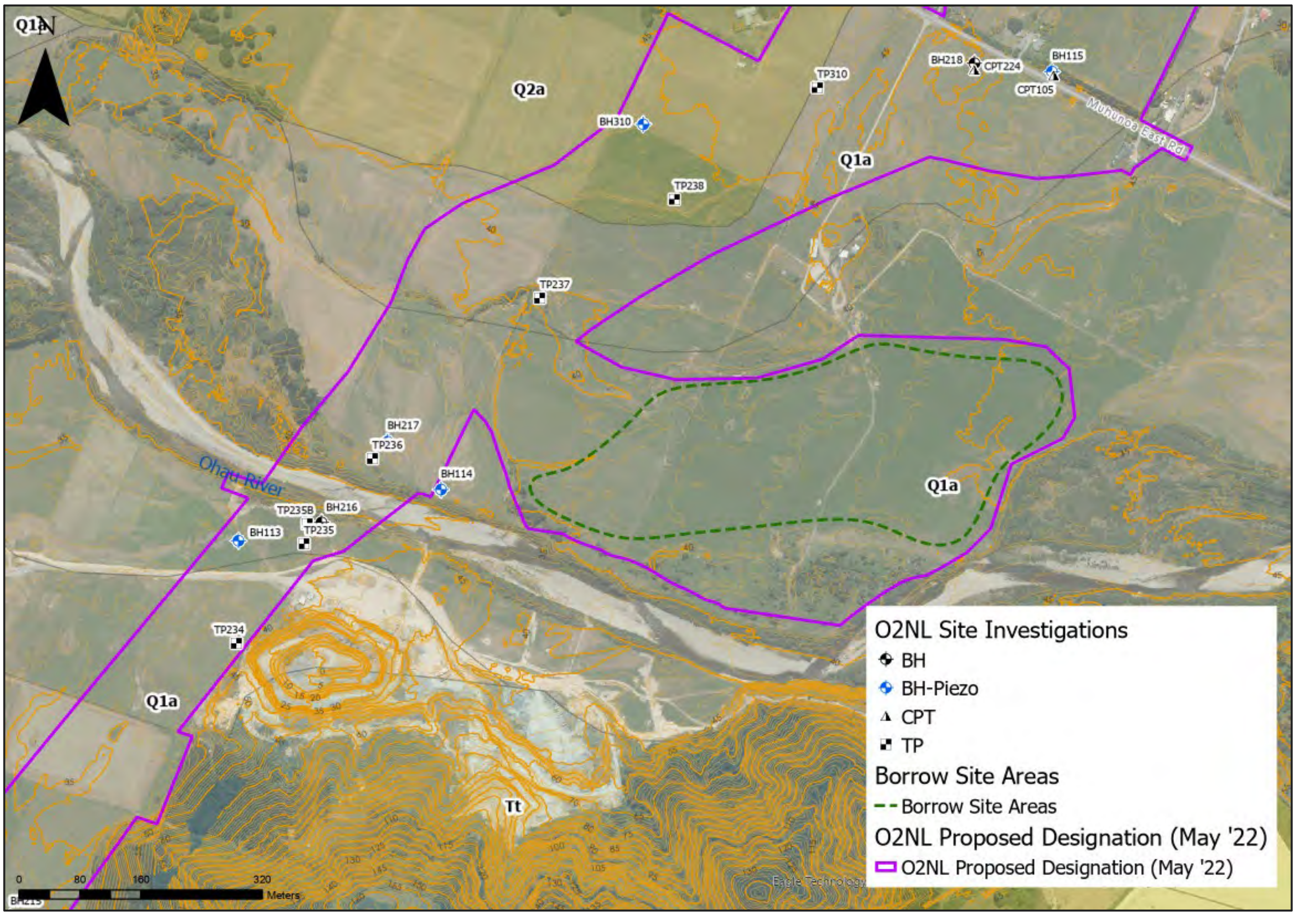


Figure 4-1: Site plan - Northeast of Ōhau River

4.2 Topography / Slope Landform / Surface Conditions

The site is relatively flat with small hummocks representing historical river or stream banks. The southernmost extent of the site is bounded by a series of small alluvial terraces that extend to the active river channel. The site is currently used as grazing farmland and crop paddocks.

4.3 Investigations Completed

This area was not targeted during the 2022 Stage 3 investigations due to late identification of this material supply site. We have interpreted the nearby investigations which are generally within the designation corridor, north of the Ōhau River. The actual ground conditions at the site may be different than described.

Table 4-1 presents a summary of the relevant intrusive investigations completed near the area of interest.

Table 4-1: Summary of Nearby Site Investigations - Northeast of Ōhau River

Investigation ID	Investigation Type	Coordinates (NZTM 2000)		Elevation (m RL, WGN 1953)	Approx. Chainage	Termination Depth (m BGL)	Depth where Gravels of Interest Encountered (m BGL)
		Easting	Northing				
BH114	Borehole	1791048	5494886	38.5	22560	27.0	0.2 – 25.5
BH217	Borehole	1790977	5494949	37.9	22560	35.0	1.5 – 27.0
TP236	Test Pit	1790958	5494927	38.2	22590	4.0	0.2– 4.0
TP237	Test Pit	1791178	5495138	39.1	22281	3.6	1.3 – 3.6
TP238	Test Pit	1791355	5495268	44.2	22058	3.8	0.3 – 3.8
TP310	Test Pit	1791543	5495415	47.1	21827	3.0	0.1 – 3.0

4.4 Subsurface Conditions and Geological Interpretation

A geological interpretation of the entire highway alignment has been undertaken as part of the Interpretative Reporting.

The expected ground conditions at the area of interest as inferred from the investigations carried out near the area are summarised in Table 4-2 below.

Table 4-2: Inferred Ground Conditions - Northeast of Ōhau River

Unit Name	Description	Typical Depth to the Top of Layer (m BGL)	Typical Thickness Range (m)	SPT 'N' Range (average)
Q1a Holocene Alluvium	Silty sandy GRAVEL, with cobbles, loose to very dense.	0	5 - 12	10 - 50+

4.5 Groundwater

The closest piezometer to the borrow area (BH114) has recorded (based on >12months of monitoring) groundwater level fluctuations between 2.2 and 3.9m BGL.

4.6 Laboratory Testing

4.6.1 Testing Summary

Geotechnical laboratory testing was targeted at representative material targeted for re-use (ie gravely material). The quantities of tests undertaken are summarised below.

Table 4-3: Laboratory Testing Summary - Northeast of Ōhau River

Sample ID	Particle Size Distribution (Wet Sieve)	Natural Water Content	Atterberg Limits	NZ Compaction Test	California Bearing Ratio
BH114	2	2	2	-	-
BH217	2	2	2	-	-
TP236	1	1	-	-	-
TP237	1	1	1	-	-
TP238	1	1	-	-	-
TP310	1	1	-	1	1

4.7 Laboratory Test Results

4.7.1 Summary

The laboratory test results are summarised below.

Table 4-4: Laboratory Testing Results Summary - Northeast of Ōhau River

Sample ID	Depth (m BGL)	Particle Size Distribution (Wet Sieve)						Classification according to USCS	Natural Water Content (%)
		% Gravel	% Coarse Sand	% Medium Sand	% Fine Sand	% Silt /Clay			
		>4.75mm	4.75 – 2mm	2 – 0.475mm	0.475 – 0.075mm	<0.075mm			
BH114	1.95 – 2.50	65	6	10	8	11		GM/GC/GP/GW	3.6
BH114	7.50 – 7.95	0	0	0	40	51	9	GM/GC/GP/GW	21.0
BH217	7.00 – 7.80	33	7	16	17	25		SM/SC	14.4
BH217	12.0 – 13.0	45	9	14	14	18		GM/GC	8.4
TP236	2.00 – 2.50	69	7	15	7	2		GW	3.6
TP237	1.50 – 1.80	58	12	20	5	4		GP	5.0
TP238	2.40 – 2.70	79	8	9	2	3		GW	5.2
TP310	2.60 - 2.80	75	11	10	3	1		GW	-

4.7.2 Particle Size Distribution Plots

Figure 4-2 presents Particle Size Distribution plots for the alluvial gravel material northeast of the Ōhau River.

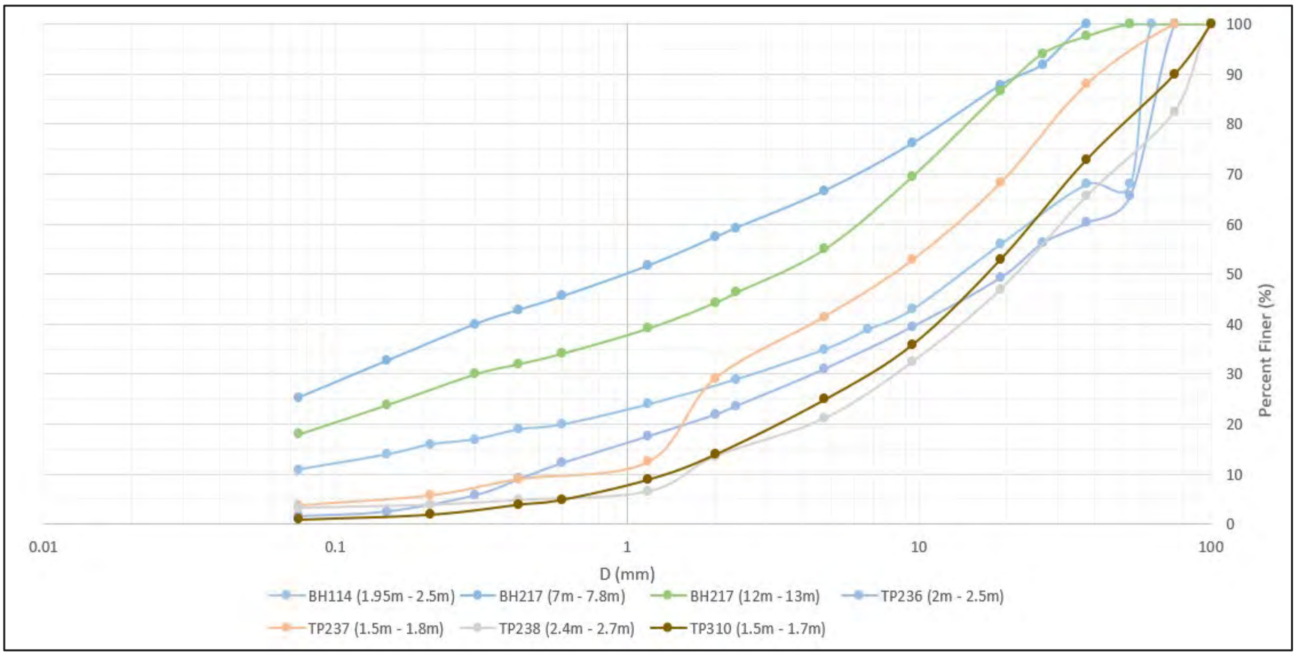


Figure 4-2: Particle Size Distribution (Wet sieve) Plot – Northeast of Ōhau River

4.7.3 Coefficients of Uniformity and Curvature

Coefficients of Uniformity, C_u, and Curvature, C_c, were calculated for locations where a "D_{10}" was available from the grading results. Table 4-5 present the results.

Table 4-5: Coefficients of Uniformity and Curvature – Northeast of Ōhau River

Sample ID	Depth (m BGL)	D_{60}	D_{30}	D_{10}	C_u	C_c
BH114	7.50 – 7.95	0.075	0.040	0.003	28.1	7.8
TP236	2.00 – 2.50	37.5	4.41	0.48	77.6	1.1
TP237	1.50 – 1.80	13.93	2.21	0.68	20.6	0.5
TP238	2.40 – 2.70	31.66	8.63	1.53	20.7	1.5
TP310	1.50 – 1.70	25.48	6.91	1.34	18.95	1.39

4.7.4 Atterberg Limits

Table 4-6 presents the results from the Atterberg Limits test completed on samples from around the Northeast of Ōhau River site. It should be noted the majority of these are at depths greater than the proposed excavations but are included to provide at indication of the properties of the pockets/layers of fine material present.

Table 4-6: Atterberg Limit Test Results - Northeast of Ōhau River

Sample ID	Depth (m BGL)	Natural Moisture Content, w_n (%)	Liquid Limit (LL, %)	Plastic Limit (%)	Plasticity Index (%)	Classification according to USCS
BH114	7.50 – 7.95	21.0	23	17	6	ML-CL
BH114	9.00 – 9.45	38.8	50	23	27	CH
BH217	7.00 – 7.80	14.4	-	-	Non-Plastic	-
BH217	9.45 – 9.90	29.5	-	-	Non-Plastic	-
TP237	0.60 – 0.80	26.0	40	27	13	ML

4.7.5 NZ Compaction Test

Table 4-7 presents the results from the NZ standard compaction test with plots presented in Figure 4-3.

Table 4-7: NZ Standard Compaction Test Results - Northeast of Ōhau River

Sample ID	Depth (m BGL)	Natural Moisture Content, w_n (%)	Optimum Moisture (Water) Content, w_o (%)	Max Dry Density, $\rho_{d,\,max}$ (t/m³)
TP310	1.50 – 1.70	5.8 - 7.1	8.7	2.07

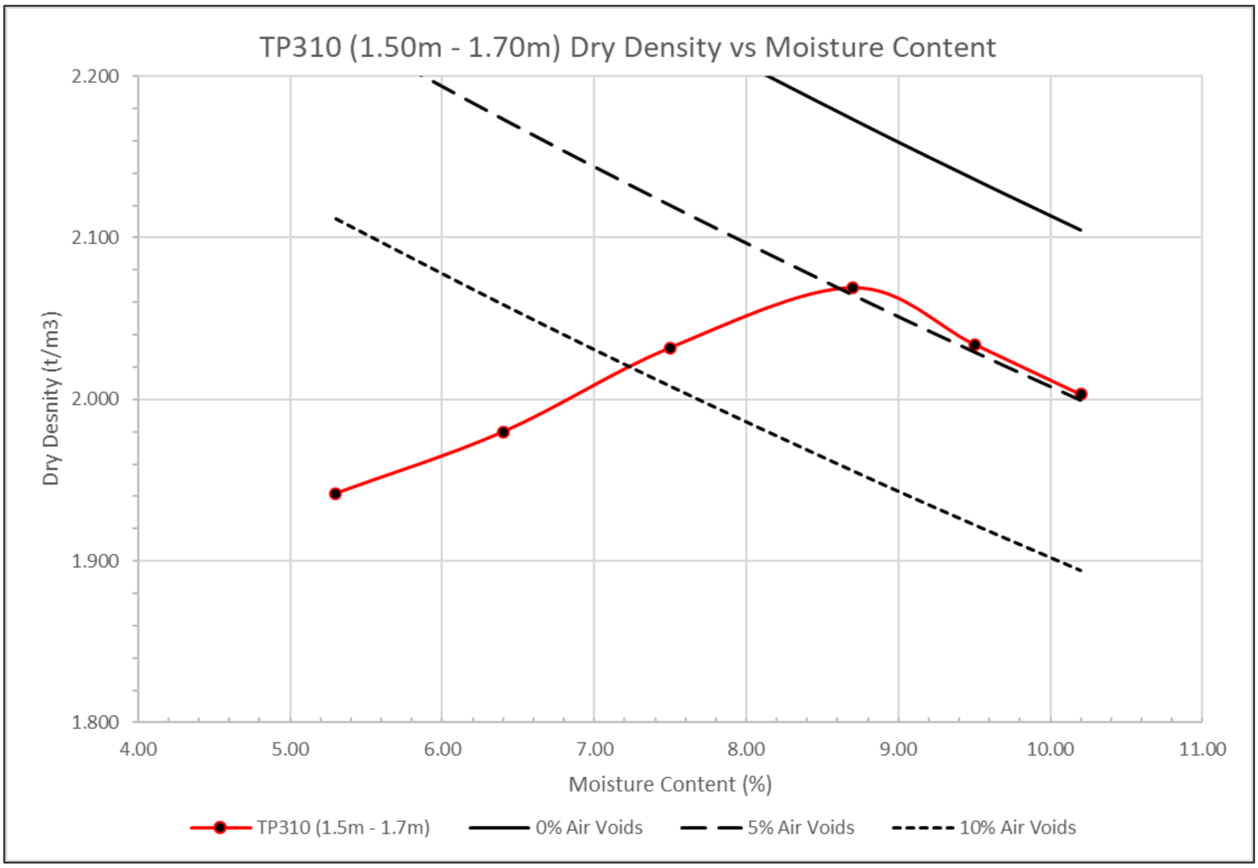


Figure 4-3: TP310 (1.50 – 1.70m) Dry Density vs. Moisture Content Plot

4.7.6 California Bearing Ratio (CBR)

California Bearing Ratio (CBR) lab test results are presented in Table 4-8.

Table 4-8: California Bearing Ratio (CBR) Test Results - Northeast of Ōhau River

Sample ID	Depth (m BGL)	Bulk Density (t/m3)	Dry Density (t/m3)	CBR (%)	Comments
TP310	1.50 – 1.70	2.11	1.97	60.0	Tested at natural water content

5 Material Re-usability

5.1 Observations / Conclusions

The following observations were made:

- Material appears to be relatively consistently graded with a typically high proportion of gravel.
- Fines content typically ranged from 1% – 18%, with an average of 7-8% (excluding outliers >18%). Three samples tested with greater than 18% fines, likely related to pockets of silts and clays which relates to the expected variable depositional history of the area. Select discarding or mixing of this finer grained material will be required during construction.
- The Q2a/Q3a gravelly material at Waikawa Stream appears to be less variable (and contain less fines) then the inferred Q1a gravelly material Northeast of Ōhau River.
- Compaction results appear typical for a material of this nature and suggest it should be suitable for general/bulk fill for embankment construction. It is noted that some graphs show irregular "curve fits" and therefore these have been interpreted using engineering judgement.
- CBR testing results ranged 16% – 60% and suggest material would be suitable for general/bulk fill for embankment construction.
- No investigations have been completed within the Northeast of Ōhau River (#36) Site, with interpretation based on nearby investigations. Therefore, this site has the lowest confidence of interpretation and therefore the presents the highest risk of unknown ground conditions going forward.

Figure 5-1 presents Table 1.4 from the Earth Manual[5] which suggests the Q1 and Q2a/Q3a material (soil type: GW, GP, GM, GC) located between Waikawa Stream to North Manukau Road is considered "good" to "excellent" for workability as a construction material. The lower "number ratings" are considered the best.

Table 1-4.—Engineering use chart for compacted soils

Engineering Properties of Compacted Soil[1]						Relative Desirability for Various Uses (No. 1 is considered the best)							
						Rolled earth dams			Canal sections		Foundations and fills		
Soil group name	Group symbol	Perme-ability[2]	Shear strength (saturated)	Compressibility (saturated)	Workability as a construction material	Homo-geneous embank-ment	Core	Shell	Erosion-resistant blanket or belt	Compacted earth lining	Imper-vious	Per-vious	Resistance to frost heave
Well-graded gravel	GW	Pervious	Excellent	Negligible	Excellent	—	—	1	1	—	—	1	1
Poorly graded gravel	GP	Pervious	Good	Negligible	Good	—	—	2	2	—	—	3	2
Silty gravel	GM	Semipervious to impervious	Good	Negligible	Good	2	4	—	4	4	1	4	6
Clayey gravel	GC	Impervious	Good to fair	Very low	Good	1	1	—	3	1	2	6	5
Well-graded sands	SW	Pervious	Excellent	Negligible	Excellent	—	—	3 if gravelly	6	—	—	2	3
Poorly graded sands	SP	Pervious	Good	Very low	Fair	—	—	4 if gravelly	7 if gravelly	—	—	5	4
Silty sands	SM	Semipervious to impervious	Good	Low	Fair	4	5	—	8 if gravelly	5 erosion critical	3	7	12
Clayey sands	SC	Impervious	Good to fair	Low to medium	Good	3	2	—	5	2	4	8	7
Silt	ML	Semipervious to impervious	Fair	Medium	Fair	6	6	—	—	6 erosion critical	6	9	11
Lean clay	CL	Impervious	Fair	Medium	Good to fair	5	3	—	9	3	5	10	9
Organic silt and organic clay	OL	Semipervious to impervious	Poor	Medium to high	Fair	8	8	—	—	—	7	11	—
Elastic silt	MH	Semipervious to impervious	Fair to poor	High	Poor	9	9	—	—	—	8	12	10
Fat clay	CH	Impervious	Poor	High	Poor	7	7	—	10	—	9	13	8
Organic silt and organic clay	OH	Impervious	Poor	High	Poor	10	10	—	—	—	10	14	—
Peat and other highly organic soils	PT	—	—	—	—	—	—	—	—	—	—	—	—

[1] Compacted to at least 95 percent of laboratory maximum dry density or to at least 70 percent relative density.
[2] Impervious: < 1 ft/yr (1 x 10^{-6} cm/s)
Semipervious: 1 to 100 ft/yr (1 x 10^{-6} cm/s to 1 x 10^{-4} cm/s).
Pervious: > 100 ft/yr (1 x 10^{-4} cm/s).

Figure 5-1: Table 1.4 from Earth Manual

[5] Earth Manual, Part 1, 3rd Edition. US Department of The Interior. Bureau of Reclamation, 1998.

5.2 Geotechnical Recommendations

Based on investigations completed to date, Stantec believe the three alluvial gravel sites identified are suitable for bulk/general fill for the construction of the road embankments.

Given the depositional history of the material, variation is to be expected and encountering pockets of unsuitable material should be allowed for. This unfavourable material could be spoiled or potentially mixed to enable reuse (or both). Additional geotechnical testing will aid in establishing the degree of variability, and therefore allow more informed project and site-specific planning. If pockets/layers of finer materials are regularly encountered, additional testing should also target these, with the assumption that the that mixing will be undertaken.

The piezometers located within South of Waikawa Stream (Site 15) and North of the Waikawa Stream (Site 19) should be monitored for a minimum of 12 months to establish groundwater level fluctuations. Ideally, there should be two to three piezometers at each site. This is particularly relevant if the restoration/rehabilitation of the site involved the establishments of wetlands or open water (i.e., ponds/lakes).

Based on the above discussion, the following geotechnical additional investigations are recommended in Table 5-1. It is recommended that the investigations are completed as soon as possible.

Table 5-1: Recommended Additional Geotechnical Investigations

Site	Borehole/Piezometer	Test Pit	Lab Testing
South of Waikawa Stream (Site 15)	1	5	Yes
North of the Waikawa Stream (Site 19)	1	3	Yes
Northeast of Ōhau River (Site 36)	3	8	Yes

6 References

Begg, J., & Johnston, M. (2000). *Geology of the Wellington area: scale 1:250,000. Map 10.* Lower Hutt: Institute of Geological & Nuclear Sciences.

Reclamation, B. (1998). *Earth Manual, Part 1, 3rd Edition. Earth Manual, Part 1, 3rd Edition, US Department of The Interior.*

Stantec. (2022). *Geotechnical Factual Report for SH1 Ōtaki to North Levin, Rev C.* Auckland.

Stantec. (2022). *Geotechnical Interpretive Report for SH1 Ōtaki to North Levin, Rev D.*

Stantec. (2022). *Material Supply (Borrow) Study for SH1 Ōtaki to North Levin, Rev A.*

Stantec's Geotechnical Factual Memorandum for Q2a Gravels, Rev 1, 2 August 2021 (East of Levin)

Stantec

Otaki to North Levin (O2NL)
Geotechnical Factual Memorandum for Q2a Gravels

Rev. no	Date	Description	Prepared by	Checked by	Reviewed by	Approved by
1	2 August	Interim factual Q2a gravel memo to inform quarry viability assessment	RC	KC	EG	JP

1 Introduction

Stantec has been engaged by Waka Kotahi to undertake geotechnical investigations and reporting for the Otaki to North Levin (O2NL) project. The first stage of geotechnical investigations was completed in 2020 and the second stage is currently progressing. The 2020 investigation results are presented within Stantec's Geotechnical Factual Report (Rev A – October 2020), and the intent is that the Geotechnical Factual Report (GFR) will be updated to include the 2021 results. This update will be completed after investigations are complete with an expected GFR issue in September 2021

The purpose of this memorandum is to summarise and provide interim factual results in an advance of the GFR issue. Although there are some lab results outstanding, the majority of the investigations and lab testing within the gravelly material east of Levin, which are mapped within the Q2a formation, as shown on 1:250,000 Institute of Geological and Nuclear Sciences (IGNS) Geology of the Wellington Area, Map 10, have been completed. The proposed O2NL alignment crosses the gravels of the Q2a formation between Kimberley Road and Queen St (East of Levin). Refer Figure 2.1.

The current O2NL vertical alignment between Kimberley Street and Queen Street East is within a large cut through the Q2a gravel material. The intent is that the Q2a material becomes available for re-use. An opportunity has been identified that this material could be potentially quarried/processed into a higher-grade aggregate.

The overall objective of this memorandum is that the geotechnical factual information is compiled and presented so a quarrying technical specialist can undertake an assessment of the viability of quarrying/processing the Q2a gravel into higher-grade aggregates.

2 Location Plan

Figure 2.1, below, shows the investigation locations within the Q2a gravel east of Levin. The site investigation plan is also appended in Appendix A.1.

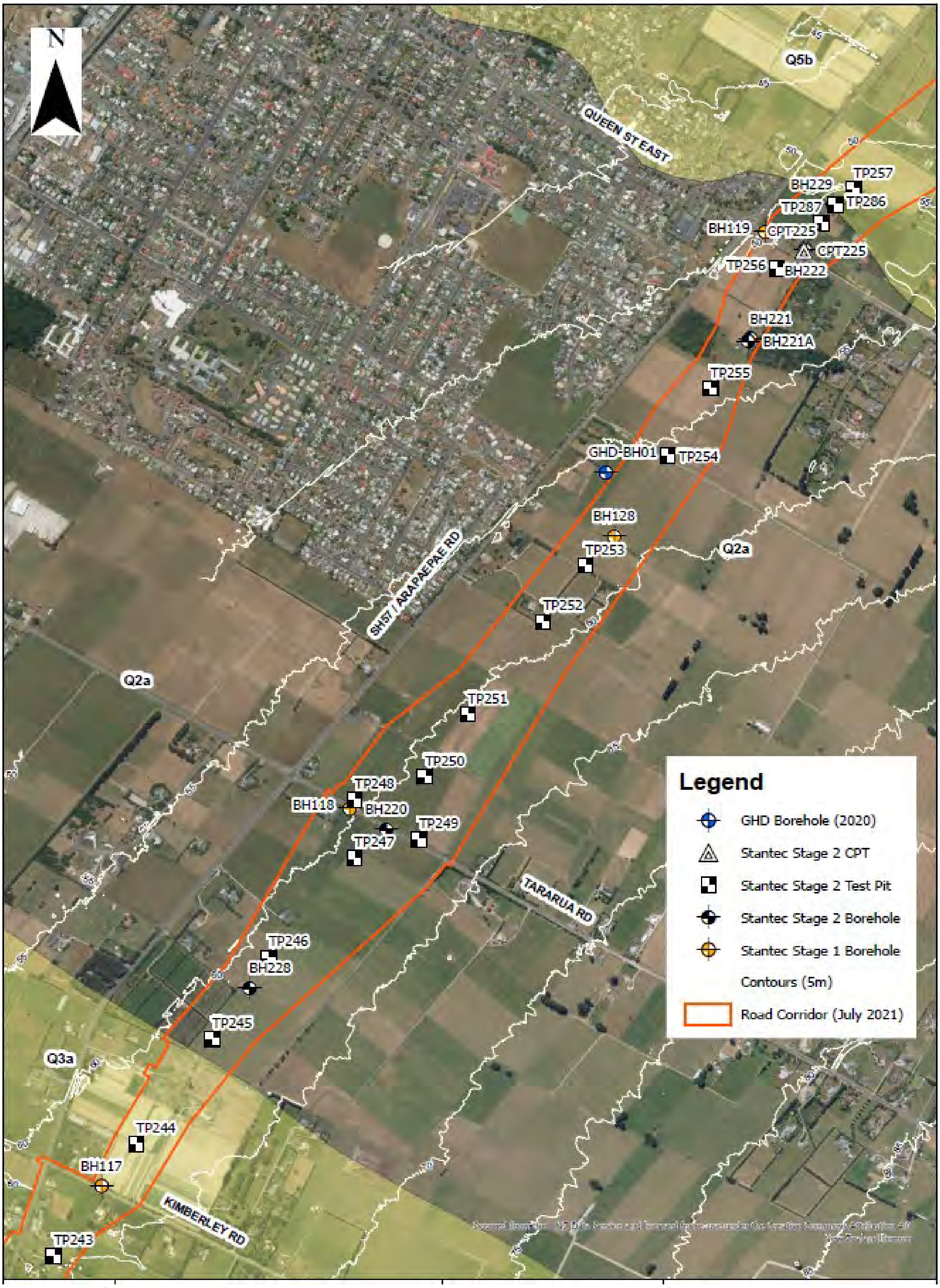


Figure 2.1: **Site Investigation Plan with investigation locations within the Q2a gravel**

3 Material Field Description

The Q2a formation is described on the IGNS map as late Pleistocene river and aggradational terrace deposits, consisting of poorly to moderately sorted gravel with minor sand or silt, underlying terraces. The unit also includes minor fan gravel.

Due to the different deposition processes of the soil materials classified under the Q2a formation, their nature and composition was found to vary along the length of the alignment. The different soils encountered in the investigations along the alignment consist of:

- Silty SAND to SAND with some silt
- CLAY to silty CLAY
- Sandy SILT to SILT
- Silty / clayey GRAVEL
- Sandy GRAVEL
- Sandy / cobbly GRAVEL

The fine-grained materials are predominantly encountered at the wider area of Manakau and south of the Manakau stream.

The coarse-grained materials of the Q2a formation are encountered at the area east of Levin. They are expected to be fairly consistently present in this area, at depths from 0.5 to 4 m below ground level and with thicknesses exceeding 10 m.

Even in this area it should be expected that the composition of the Q2a gravel may vary within close distances, for example in the percentage of fines contents or the percentage and size of cobbles present. A characteristic example is BH128 and TP253 (carried out at a distance of 100m apart) which had a noticeable difference in fines and cobble content between 2.0 and 3.0m bgl.

A layer of finer loess soils has been observed to overlay the Q2a gravel east of Levin. The thickness of the loess soils was typically ~0.5m thick but is expected to vary from 0.2 m to up to 3.0 – 4.0 m locally.

4 Investigations Completed

Investigations within the mapped Q2a area (east of Levin) and O2NL road corridor have been completed by Stantec and GHD between June 2020 to June 2021. Stantec has completed six boreholes during the O2NL Stage 1 and 2 investigations and GHD has completed one borehole within the road corridor in December 2020, as part of the Taraika project.

All boreholes were completed by Griffiths Drilling using a PQ sized core barrel with a sonic drilling methodology in accordance with NZS 4411:2001 Environmental Standard for drilling of Soil and Rock.

Stantec has completed 12 test pits within the Q2a area (east of Levin) as part of the Stage 2 investigations. Test pits were completed by Goodman's Contracting between 8 April - 12 May using a 14tn wheeled excavator.

Logging and sampling of the boreholes and test pits was completed by a Stantec geologist. Samples have been stored at a secure Waka Kotahi container prior to testing.

Table 4.1 presents a summary of the relevant intrusive investigations completed within the Q2a gravel material (East of Levin).

Table 4.1: Summary of Investigations

Investigation ID	Investigation Type	Coordinates (NZTM 2000)		Elevation (m RL, WGN 1953)	Approximate Chainage	Termination depth (m bgl)	Depth Q2a Gravel Encountered
		Easting	Northing				
TP245	Test Pit	1793478	5497304	61.8	19050	3.80	0.2 - >3.8
TP246	Test Pit	1793645	5497545	61.1	18750	3.90	0.2 - >3.9
TP247	Test Pit	1793899	5497840	61.2	18350	3.90	0.2 - >3.9
TP248	Test Pit	1793900	5498013	59.9	18200	3.50	0.6 ->3.5
TP249	Test Pit	1794090	5497895	62.3	18200	3.50	0.5 - >3.5
TP250	Test Pit	1794108	5498082	60.8	18050	3.50	0.7 - >3.5
TP251	Test Pit	1794235	5498266	60.7	17800	3.50	0.7 - >3.5
TP252	Test Pit	1794458	5498540	58.5	17500	3.90	0.3 - >3.9
TP253	Test Pit	1794583	5498707	58.5	17250	3.50	0.8 - >3.5
TP254	Test Pit	1794827	5499033	55.8	16850	3.60	0.45 - >3.6
TP255	Test Pit	1794954	5499232	54.5	16600	3.70	0.7 - >3.7
TP256	Test Pit	1795151	5499587	51.2	16200	3.70	0.6 - >3.7
BH118	Borehole	1793884.6	5497986.1	59.8	18200	22.50	1.5 - >22.5
BH128	Borehole	1794668.0	5498785.0	58.6	17150	28.50	1.3 - 15.2
BH220	Borehole	1793993.0	5497925.0	61.4	18200	30.12	1.5 - >30.1
BH221	Borehole	1795069.2	5499377.2	52.7	16450	19.88	0.15 - 6.7
BH221a	Borehole	1795065.2	5499370.6	52.7	16450	7.50	0.15 - 7.5
BH228	Borehole	1793587.6	5497454.1	65.0	18850	25.0	0.5 - 11
GHD-BH01	Borehole	1794644.0	5498982.0	56.1	17000	15.0	1.5 - >15

The borehole and test pit logs are currently preliminary in status.

5 Laboratory testing

5.1 Testing Standards

Testing was undertaken by Geocivil laboratory, in accordance with the following standards:

- Particle Size Distribution tested in accordance with ASTM D6913-17.
- NZ Compaction Test via the Vibrating Hammer Compaction Test in accordance with NZS 4402: 1986, Test 3.1.3.
- Crushing Resistance tested in accordance with NZS 4407: 2015, Test 3.10.
- Weathering Quality Index tested in accordance with NZS 4407: 2015, Test 3.11.
- California Bearing Ratio tested in accordance with NZS 4407: 2015, Test 3.15.
- (Sample prepped via Vibrating Hammer Compaction at Optimum Water Content).

Performance requirements to TNZ M/4: 2006 SP/SM4:060418 Specification for Basecourse Aggregate (TNZ M/4).

5.2 Testing summary

Table 5.2 presents a summary of the relevant laboratory testing that was undertaken.

Table 5.2: Laboratory Testing Summary

Sample ID	Depth (m bgl)	Particle Size Distribution	NZ Compaction Test	Crushing Resistance	Weathering Quality Index	California Bearing Ratio
TP245	2.5 - 3.5	1	1	1	1	1
TP246	3.2 – 3.5	1	-	1	-	-
TP247	2.7 - 3.9	1	1	1	1	-
TP248	3.0 - 3.4	1	-	-	-	-
TP250	3.0 - 3.5	1	-	-	-	1
TP251	2.6 – 2.6	1	-	-	-	-
TP252	2.9 – 3.2	1	-	-	-	-
TP253	2.9 – 3.2	1	-	-	-	-
TP254	3.4 – 3.6	1	-	-	-	1
TP255	2.8 – 3.1	1	-	-	-	-
BH118	2.0 – 2.8* 6.5 – 7.2*	2	-	-	-	-
BH128	1.7 – 2.3* 5.0 – 5.4	2	-	-	-	-
BH220	6.2 – 6.6	1	-	-	-	-
BH228	6.5 – 8.0	1	-	-	-	-
* *Potentially interpretated as not a Q2a gravel material, or mixed with an upper layer*						

Ethylene Glycol Accelerated Weathering Testing on samples from TP246 and TP252 are in progress.

The testing results are currently in draft status.

6 Laboratory Testing Summarisation

6.1 Particle Size Distribution

6.1.1 Test Pits

Table 6.1a presents Q2a Gravel Material (East of Levin) Particle Size Distribution Results (from test pit samples), with plots presented Figure 6.1a.

Table 6.1a: Q2a Material Particle Size Distribution Results (Test pit samples)

Sample ID	Depth (m bgl)	% Gravels	% Coarse Sand	% Medium Sand	% Fine Sand	% Silt/Clay
		>4.75mm	4.75 – 2.00	2.00 – 0.475	0.475 – 0.075	<0.075
TP245	2.5 - 3.5	70	9	10	5	6
TP246	3.2 – 3.5	72	11	10	3	3
TP247	2.7 - 3.9	70	12	13	3	3
TP248	3.0 - 3.4	74	9	11	4	2
TP250	3.0 - 3.5	66	12	12	5	5
TP251	2.6 – 2.6	79	9	9	3	1
TP252	2.9 – 3.2	*TBC*	*TBC*	*TBC*	*TBC*	*TBC*
TP253	2.9 – 3.2	65	12	12	5	6
TP254	3.4 – 3.6	74	10	9	3	4
TP255	2.8 – 3.1	77	10	10	2	1

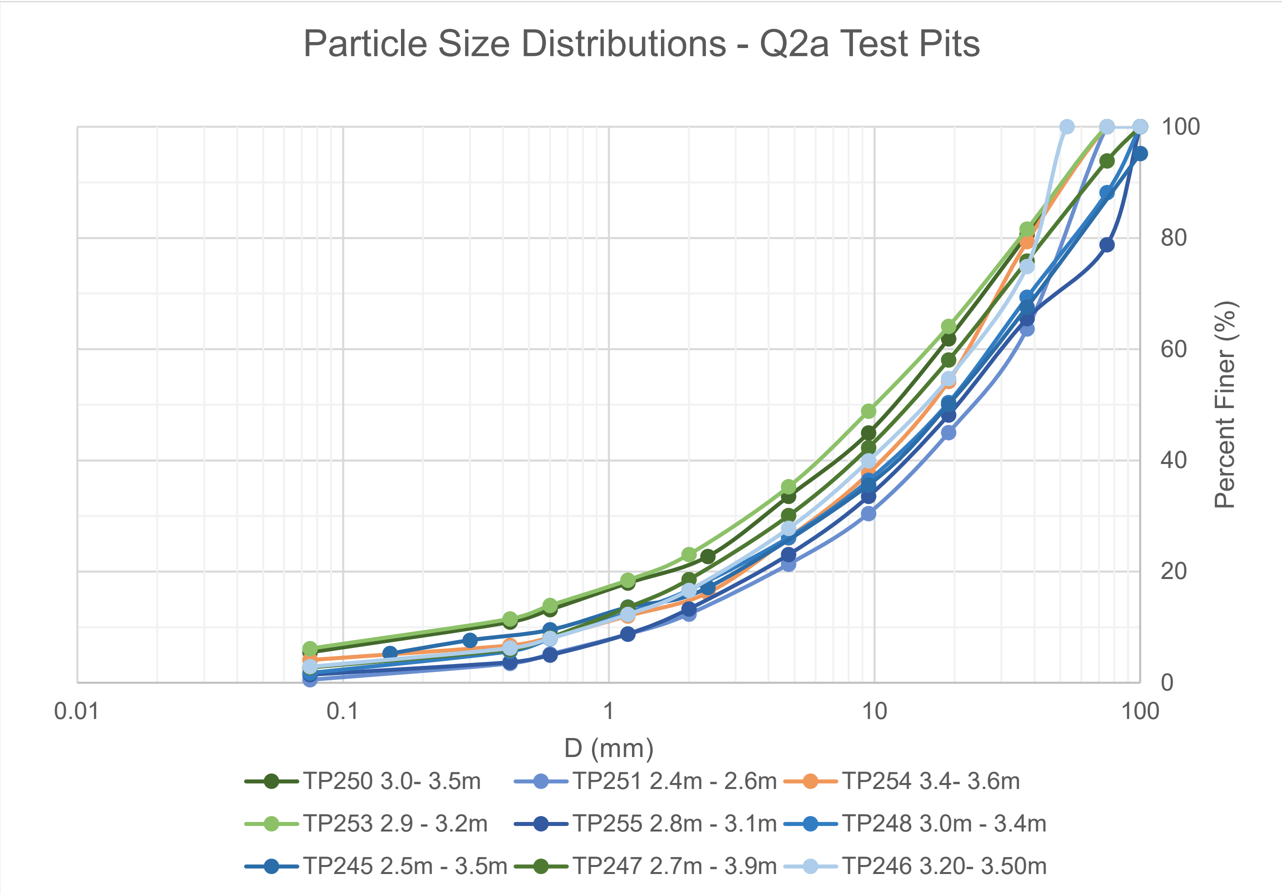


Figure 6.1a: Q2a Material - Particle Size Distribution Plot (Test pit samples)

Gravel clasts >100mm diameter and cobbles were rarely sampled, so typically in-situ material is coarser in nature then depicted by testing results.

6.1.2 Bore Holes

Table 6.1b presents Q2a Gavel Material (East of Levin) Particle Size Distribution Results (from Borehole samples), with plots presented Figure 6.1b

Table 6.1b: Q2a Material Particle Size Distribution Results (Borehole samples)

Sample ID	Depth (m bgl)	% Gravels	% Coarse Sand	% Medium Sand	% Fine Sand	% Silt/Clay
		>4.75mm	4.75 – 2.00	2.00 – 0.475	0.475 – 0.075	<0.075
BH118	2.0 – 2.8	54.5	12.7	16.7	6.9	9.2
BH118	6.5 – 7.2	59.8	8	12	6.9	13.3
BH128	1.7 – 2.3	36.5	11	20.1	12.4	20.0
BH128	5.0 – 5.4	51.8	11.3	15.8	8.5	12.6
BH220	6.2 – 6.6	48	11	10	12	19
BH228	6.5 – 8.0	*TBC*	*TBC*	*TBC*	*TBC*	*TBC*

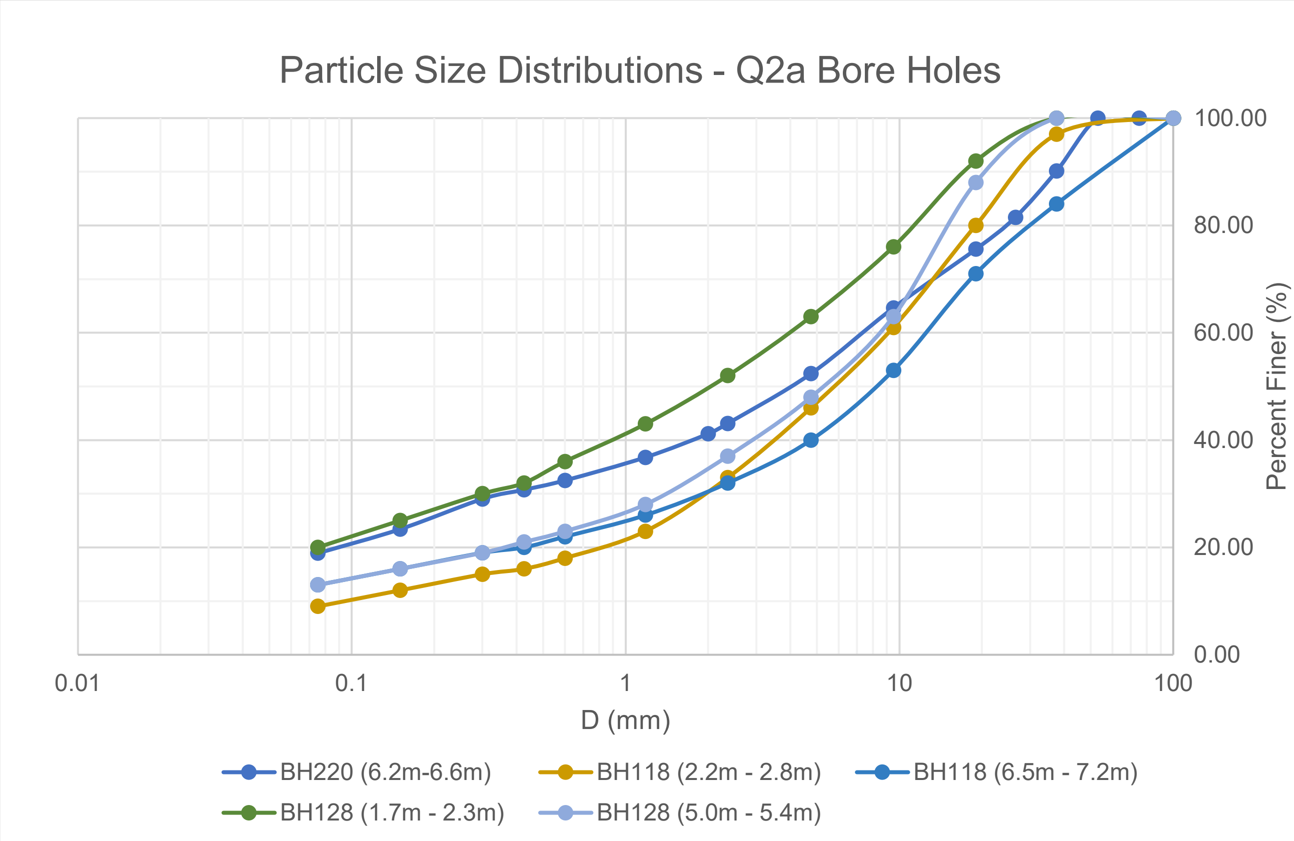


Figure 6.1b: Q2a Material - Particle Size Distribution Plot (Borehole samples)

Clast size limited to core barrel diameter (85mm), which increases the fractions of fines. It is also inferred that sonic drilling through dense gravels creates additional fine material within the sample, so typically in-situ material is coarser in nature then depicted by testing results.

6.2 NZ Compaction Test

Table 6.2 presents the results from the NZ compaction test, with plots presented with Figure 6.2a to 6.2b

Table 6.2: Results from NZ Compaction Test

Sample ID	Depth (m bgl)	Natural Water Content, wn (%)	Optimum Water Content, wo (%)	Max Dry Density, ρd,max (t/m³)2
TP245	2.5 – 3.5	5.63	6.50	2.26
TP247	2.7 – 3.9	5.36	6.50	2.22

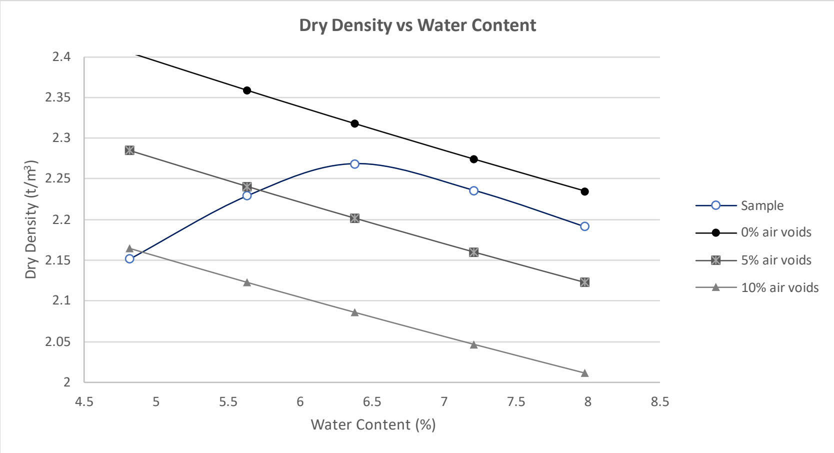


Figure 6.2a: TP245 2.5m to 3.5m - Dry Density Vs Water Content Plot

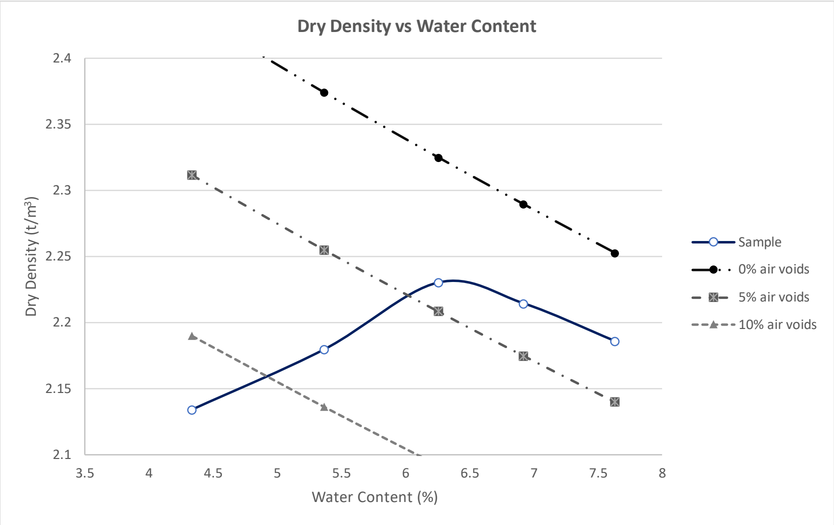


Figure 6.2b: TP247 2.7m to 3.9m - Dry Density Vs Water Content Plot

6.3 Crushing Resistance

Table 6.3 presents the Q2a Material Crushing Resistance results.

Table 6.3: Q2a Material Crushing Resistance Results

Sample ID	Depth (m bgl)	Specified Load (kN)	Greater Than / Lest Than	% Passing 2.36 mm sieve
TP245	2.5 – 3.5	130	Greater Than	2.6
TP246	3.2 – 3.5	130	Greater Than	3.1
TP247	2.7 – 3.9	130	Greater Than	2.4

TNZ M/4: 2006 requires that the Crushing Resistance Test, under a load of 130 kN, must produce less than 10% fines passing 2.36 mm sieve size.

6.4 Weathering Quality Index

Table 6.4 presents the Q2a Material Weathering Quality Index results.

Table 6.4: Q2a Material Weathering Quality Index Results

Sample ID	Depth (m bgl)	% of dry sample retained on 4.75 mm)	Cleanness value of wash water	Weathering quality index
TP245	2.5 – 3.5	97.4	98.0	AA
TP247	2.7 – 3.9	98.4	98.0	AA

TNZ M/4: 2006 requires the aggregate shall have a quality index of AA, AB, AC, BA, BB or CA

6.5 California Bearing Ratio

Table 6.5 presents Q2a Material California Bearing Ratio results.

Table 6.5: Q2a Material California Bearing Ratio Results

Sample ID	Depth (m bgl)	Bulk Density (t/m3)	Dry Density (t/m3)	% Oversize material	CBR (%)	Comments
TP245	2.50 - 3.50	2.36	2.18	53.99	**135.00**	1% water added, by mass
TP250	3.00 - 3.45	2.32	2.14	33.24	**90.00**	Soaked
TP254	3.40 - 3.60	2.29	2.14	45.26	**140.00**	Soaked

TNZ M/4: 2006 requires the soaked CBR of the basecourse aggregate shall not be less than 80%.

7 Flow chart for Basecourse Aggregate Testing

Figure 7.1 presents an extract from TNZ M/4: 2006, which illustrates the testing sequence for basecourse aggregates.

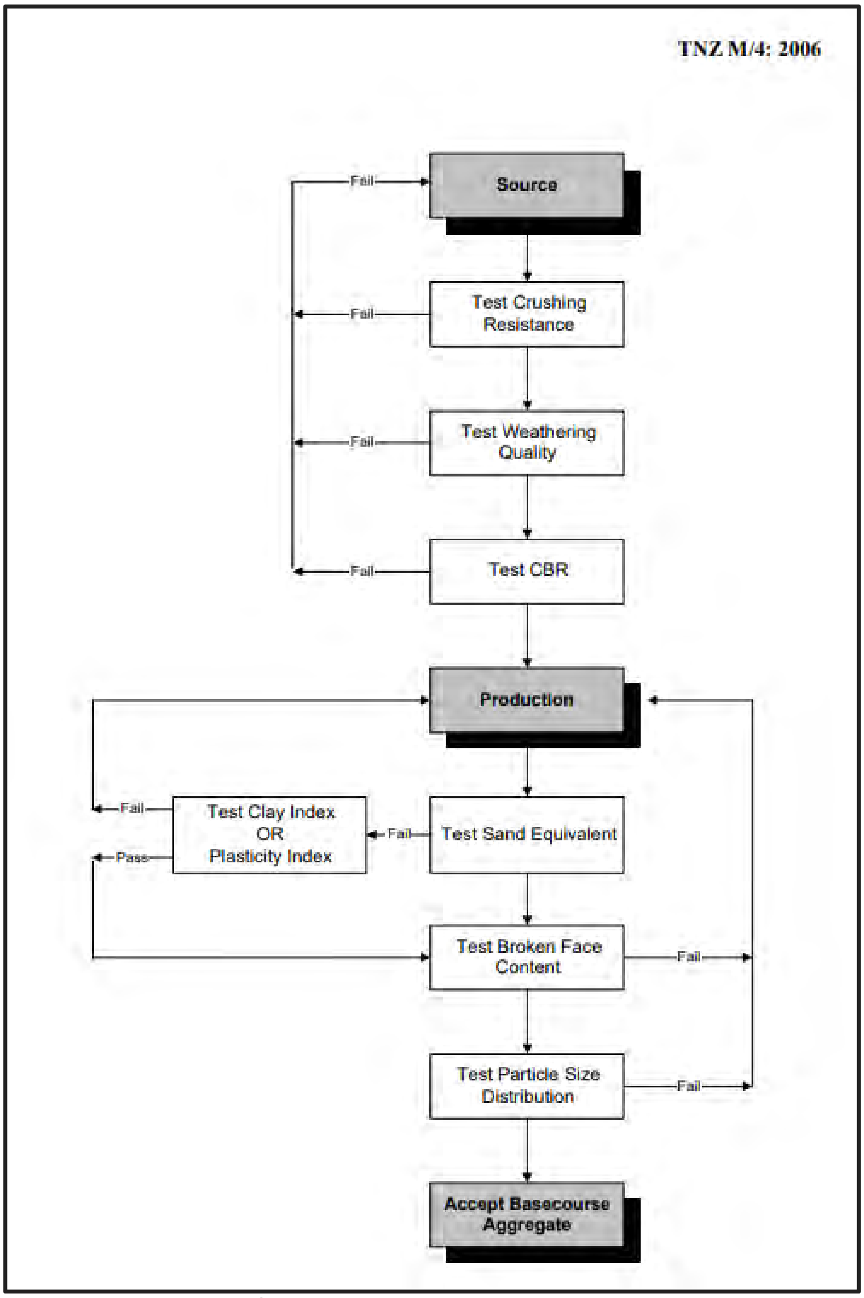


Figure 7.1: Flow chat for Basecourse Aggregate Testing

Appendices

A1 Site Investigation Plan

A2 Borehole Core and Photo Logs

BH118
BH128
BH220
BH221
BH221a
BH228
GHD-BH01

A3 Test Pit Logs

TP245
TP246
TP247
TP248
TP249
TP250
TP251
TP252
TP253
TP254
TP255
TP256

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Appendix 4.6 Schedule of Design Refinements

Freeze & Date	Geometrics	Structures	Stormwater	Earthworks / geotech
DF2 **30 August 2021**	• Initial Draft DBC Design • New highway in cutting east of Levin	• Baseline design	• Longitudinal swale and grey infrastructure. • Culvert locations and sizing	• Baseline design • Inclusion of cut/fill slope grades based on geo stability assessment
DF2.5 **08 Sept 2021**	• Drawing scale reduced • SUP connection added to Manakau village / school • Individual property access points added • Median and edge barrier extents removed from plans • Added adjacent Speed & Infrastructure Programme (online safety works) schematic layouts into plan sets • Dual SUPs removed from NIMT bridge, new underpass added further north	• Reduced deck width at NIMT crossing as northern SUP no longer required	• Design pond locations and sizes	
DF3 **9 Dec 2021**	• East of Levin, new highway level removed from trench cutting, changed to at-grade (with changes to Queen and Tararua) • Queen Street realigned to north of existing QSE with new roundabout connection to SH57/Arapaepae • SUP taken off Arapaepae Road and onto east side of new highway east of Levin, New location of underpass at new SH1/SH57 roundabout • Changes to horizontal alignment South Manakau (CH30000) to Forest Lakes area (CH32000)	• Extents of ground improvements added • Reinforced earth blocks added • Rock rip-rap scour protection added to watercourse bridges • Queens Street East road bridge relocated and deck cross-section reconfigured • Queens Street East footbridge drawings added • Waikawa Stream flood relief culvert size increased and reconfigured to a triple box	• Refine sizing of swales • Refine sizing and soakage design • First phase rock armour / revetment inclusion at bridge locations • Additional ponds added east of Levin due to change in longitudinal grade / low points • Pond footprint / number reduced at new SH57 roundabout • Pond removed South of S. Manakau Rd and north of Ohau River • Changes to culvert location and sizing in response to geometric changes • Widen bridge spans at Waiauti and Ohau flood relief based on updated hydraulic model results.	• Inclusion of Spoil Sites
DF4 **20 April 2022**	• Change in vertical profile / finished RL (to K=71 value) at rail crossing in north and in area to south of South Manakau Road • Sorenson ROW reviewed due to vertical changes above. • Change in edge treatment cross sectional profile, steeper front slope and reduced offset to edge barrier • SUP at Kuku changed to be at edge of Highway (avoid Treeland) • SUP taken under bridge at Kuku and at grade crossing on Kuku removed • Vertical alignment of SH57 Underpass amended	• Value engineering elements added namely: • Reduce median to 3m across all bridges, bar NIMT and Waiauti bridges • Incorporate 20 degree skew into NIMT and Taylors bridges • Queens St East road bridge span reduced and deck reconfigured • SUP added to Kuku Stream Bridge • Queens St East Footbridge main span increased from 30m to 34m • Increase in Waiauti Stream bridge span	• Refine positions and sizes of culverts, ponds, soakage and swales/pipes with geometrics. • Rock armouring refinement at bridge sites • 450m reduction in stream reclamation from DF3 • 150m reduction in culvert length from DF3 • SW pond at Kuku amended to be clear of bush • Removal of redundant pond at CH33500	• Cut and fills reduced following vertical profile change • Inclusion of Material Supply (Borrow) Sites. • Some refinement of Spoil Site locations / perimeter extents (Changes documented within Spoil Site Report). • Geological model plan/section dwgs created. • Reduced fill requirements in north and south based on revised vertical profile
DF5 **19 August 2022**	• Change to Queen Street reconnection • Inclusion of East West Arterial (Liverpool Street) • Update to accessway / track designs • Refinement of access and SUP at CH31300	• As per geometrics • Amendment of underpass locations and sizing at CH31000 and CH33000	• Refinement on treatment pond at Queen Street • Inclusion of abstraction and storage ponds • Revision of pond layout to reduce impact on existing watercourse at CH32400	• Minor refinement to extents for both Material Supply (Borrow) and Spoil Sites • Geological model plan/section dwgs updated

Appendix 4.7 Potential surface sources of construction water

O2NL CONSTRUCTION WATER

Appendix 4.7: Potential surface sources of construction water

Prepared for: Waka Kotahi (NZ) Transport Agency

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Version No: -v0.1
June 2022

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BASIS OF REPORT

This report has been prepared by SLR Consulting Australia Pty Ltd (SLR) with all reasonable skill, care and diligence, and taking account of the timescale and resources allocated to it by agreement with Waka Kotahi (NZ) Transport Agency (the Client). Information reported herein is based on the interpretation of data collected, which has been accepted in good faith as being accurate and valid.

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DOCUMENT CONTROL

Reference	Date	Prepared	Checked	Authorised
720.30017.00000-R01-v0.1	12 October 2022	Oliver Anderson	Deborah Maxwell	Jack McConchie
720.30017.00000-R01-v0.1	30 June 2022	Oliver Anderson	Deborah Maxwell	Jack McConchie

CONTENTS

1 Introduction

As part of the investigations relating to the potential construction of Ōtaki to North Levin Highway Project (Ō2NL Project), options to abstract 'construction water' from the Ohau River and the Waikawa, Manakau, Koputaroa and Waitohu Streams are being explored. Water will likely be pumped to storage ponds, to buffer any mismatch between water supply and demand, and then conveyed to construction zones along the length of the proposed highway. Additional water storage along the route would provide further security of supply.

It is estimated that an average daily abstraction of 2,350m^3 of water, with a maximum daily abstraction of 3,900m^3, will be required to support construction of the Ō2NL Project. These volumes equate to continuous average abstraction rates of 27L/s and 45L/s, respectively. The total abstraction will be taken from a combination of the water available from each of the five rivers and streams. The abstraction from any specific stream is proposed to be consistent with the requirements of the relevant planning policies and rules.

To support consideration of options to provide the water necessary for construction, including the risk of periods of restricted abstraction, low flow analyses for the Ohau River and Waikawa, Manakau, Koputaroa and Waitohu Streams were undertaken. The potential effects of the abstraction on the flow regimes and instream values of these waterways were also considered.

This report therefore assesses the low flow behaviour of these rivers and streams and discusses the impacts of abstraction of 'construction water', at a combined rate of up to 3,900m^3/day, on their flow regimes.

2 Demand Analysis

During construction of the Ō2NL Project, water will be required to support several activities relating to the earthworks and pavements. The demand for water is expected to be considerably smaller at the start of construction and increase as the Project progresses. It is anticipated that water will be required:

- For dust suppression to meet compliance requirements, and for the health and safety of workers;
- To achieve maximum compaction density of pavements and fills;
- To condition any fill to meet geotechnical requirements;
- To hydrate and activate cement for stabilisation processes; and
- For lubrication of machine rollers so that the material does not stick.

Given that that the precise construction methodology has not been specified, there is some uncertainty as to the exact volume of water that might be required, and considerable daily variability is expected. It is noted that only the minimum volume of water required to meet very specific purposes will be abstracted and that water will only be abstracted during the construction seasons over the duration of the Project.

The overall strategy for managing water demand is to firstly minimise requirements and then to utilise water that becomes available to the Project through existing consented takes (from boreholes or takes that are authorised to occur on land that is acquired to allow construction of the Ō2NL Project). Additional opportunities to recycle water collected on site through dewatering and erosion and sediment control devices will also be explored. It is unknown how much water will become available through these sources.

Given the inherent uncertainty of the requirement for construction water, the risk associated with balancing the supply and demand for water, potential periods of restricted abstraction caused by low flows, and the nature of resource consents which specify maximum rates of abstraction, a water permit for the maximum potential volume that may be required is being sought. This will ensure that the Project can be practicably constructed.

3 Existing Constraints

3.1 Hydrological constraints

Given the volume of construction water required, it is likely that the total abstraction will come from a combination of sources. Waitohu Stream is likely the only water source with the potential to meet the total demand, although even on this river abstraction would be restricted during periods of low flow. The Ohau River and Waikawa, Manakau and Koputaroa Streams are associated with several different management units, divided into sub-zones identified within Horizon's One Plan. Waitohu Stream is associated with the Kāpiti Coast Surface Water Management Zone, managed by Greater Wellington Regional Council (GWRC). The relevant sub-zones, including their currently available Core Allocations, are:

- Ohau_1b (Lower Ohau River) – 409m^3/day;
- West_9a (Waikawa) – 4,498m^3/day;
- West_9b (Manakau) – 156m^3/day;
- Mana_13e (Koputaroa) – 351m^3/day; and
- Waitohu Stream – 3,240m^3/day.

It should be noted that these volumes are those currently availability from each sub-zone independent of the others. Consequently, if water is allocated in one sub-zone it may change the volume available in another sub-zone.

Abstraction of water from any of these sources is subject to minimum flow restrictions. For the Ohau River (Ohau at Rongomatane), the minimum flow is 0.820m^3/s. The minimum flow for the Waikawa Stream (at North Manakau Road) is 0.220m^3/s, while the minimum flow for the Manakau Stream (at SH1 Bridge) is 0.040m^3/s. Restrictions in the Koputaroa catchment are based on the minimum flow measured in the Manawatū River at Teachers College i.e., 12.240m^3/s. For the Waitohu Stream (Waitohu at Water Supply Intake) the minimum flow is 0.140m^3/s. The abstraction of construction water from any of these waterways is likely to be extremely difficult to consent below the minimum flows. The nature of the minimum flows and their implications for the Ō2NL Project are discussed in detail later.

Since abstraction will be restricted during periods of low river flow, it is necessary that the frequency, magnitude, and duration of these periods are determined so that the risk to the Ō2NL Project can be quantified. The potential impact of these periods of restricted abstraction on construction activities can be mitigated by a range of measures, including the provision of water storage along the route. This storage will improve the security of water supply and mitigate the effect of restricted abstraction during periods of low flow in the river.

3.2 Planning constraints

Under Horizon's One Plan, the abstraction of water is managed by the Core Allocation from each catchment and the Minimum Flow below which all abstractions must cease. The abstraction of construction water must be consistent with these metrics for it to be a Controlled Activity. Meeting these requirements, however, means that any potential adverse environmental effects of the proposed abstraction have already been considered and are regarded as 'acceptable' under the One Plan. This report therefore focuses on the potential availability of water to support the construction of the Project obtained from the various rivers and streams under this planning framework.

The One Plan and the Proposed Natural Resources Plan, however, also provide for the Supplementary Allocation of water that is outside of the core allocation discussed above. One Plan Policy 5-17 allows for a supplementary allocation from rivers and streams in circumstances where the water is only abstracted when the river flow is greater than the median flow. The total amount of water taken by way of a supplementary allocation must not exceed 10% of the actual flow in the river at the time of abstraction. Similarly, Policy P124 (of the Proposed Natural Resources Plan) allows for a supplementary water take of up to 10% of actual flow in the river when flow in the Waitohu exceeds the median.

Essentially, a Supplementary Allocation allows for 'water harvesting' during higher flows in the river when there are no adverse effects on either the environment, or existing users under the Core Allocation. It is possible therefore that the Ō2NL Project could also make use of a Supplementary Allocation from each river or stream. This would allow water storage along the Project corridor to be filled prior to having to rely solely on the Core Allocation and abstraction above the minimum flow. Use of a Supplementary Allocation, when combined with water storage, therefore has the potential to mitigate the potential risk to the Project of extended periods when the rivers and streams are below their respective minimum flows.

Since the hydrological risks associated with accessing a Supplementary Allocation are small, and any potential adverse hydrological effects negligible, the implications of Supplementary Allocations are not discussed further in this report.

4 Hydrological Setting

The Horowhenua District contains many hydrological features, including Punahau / Lake Horowhenua to the west of Levin, and a network of rivers and streams which drain an area of approximately 395km^2. These waterways generally flow north-west, from headwaters in the Tararua Range to the coast, or the Manawatū River in the case of Koputaroa Stream.

Because of the steep topography of the Tararua Range, the rivers and streams respond rapidly to rainfall; however, they are also prone to extended periods of low flow during times of low rainfall. Consequently, the flows of these rivers and streams exhibit a high degree of variability. This will act as a constraint on any potential abstraction of construction water. The relevant sub-zones and catchments of the various rivers and streams considered from the perspective of construction water are shown in **Figure 1.**

The Ohau River flows from the confluence of the North and the South Ohau Rivers in the Tararua Range. It drains the Ohau_1 sub-zone, initially flowing north before continuing westward, southeast of Levin, and discharging to the Tasman Sea.

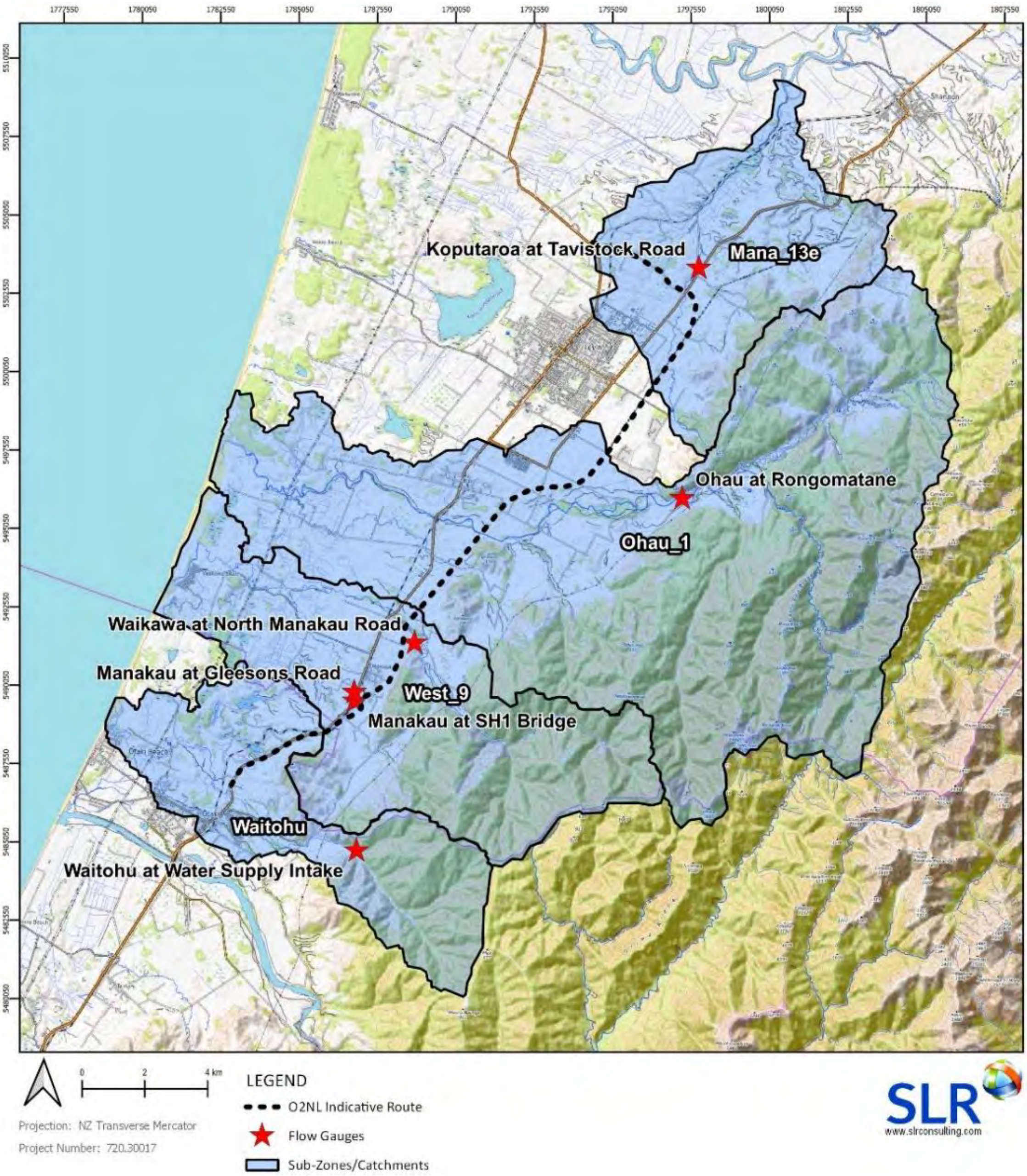

Figure 1: Locations of flow recorders used when assessing the potential effect of abstracting 'construction water' from the Ohau River, and Waikawa, Manakau, Koputaroa and Waitohu Streams.

Draining the West_9 sub-zone, Waikawa Stream flows north/north-west from its headwaters in the Tararua Range. South of Ohau township, Waikawa Stream heads west and flows to the Tasman Sea at Waikawa Beach.

Manakau Stream also drains the West_9 sub-zone, beginning just south of Manakau township and flowing north-west. Approximately 3km east of Waikawa Beach, Manakau Stream joins Waikawa Stream.

The headwaters of Koputaroa Stream are in Kohitere Forest at the foothills of the Tararua Range, east of Levin and north of the Ohau River. The stream flows in a northerly direction before joining the Manawatū River, west of Shannon. Koputaroa Stream drains part of the extensive Mana_13 sub-zone.

Waitohu Stream is part of the Kāpiti Coast Surface Water Zone, which lies in the north-west of the Wellington region on the boundary with Horowhenua District and Horizon's region. Waitohu Stream drains a catchment area of $54km^2$, with headwaters in the Tararua foothills to the southeast of Ōtaki. The stream flows northwest, turning westward north of Ōtaki, before discharging into the Tasman Sea at Ōtaki Beach.

The Ohau_1 and West_9 sub-zones can be grouped together as they are both within the Horowhenua Groundwater Management Zone, which covers an area of $395km^2$. To the north, the Mana_13 sub-zone lies at the southern end of the Manawatū Groundwater Zone. The major land use in the Horowhenua zone is agriculture, with 16% used for sheep and beef farming. Dairy farming accounts for a further 19%. Native bush covers 35% of the zone, mostly within the conservation area of the Tararua Range. The remaining land is used for forestry (7%), various forms of agriculture, and urban development. Levin is the largest urban area within the catchment, with some smaller communities serving agricultural areas. The land use over the length of Koputaroa Stream through the Manawatū zone is similar. Approximately 40% of the Waitohu catchment is covered in native and exotic forests. The remainder of the catchment includes a variety of land uses, such as pastoral farmed floodplains, small lakes, wetlands, sand dunes, and urban areas.

5 Hydrometric Data

5.1 Flow series

Six flow sites are present in the vicinity of the proposed Ō2NL Highway (**Figure 1**). Two on Manakau Stream, and one on each of the Ohau River and Waikawa, Koputaroa and Waitohu Streams.

The Ohau at Rongomatane flow record is suitable for assessing the potential effects of abstraction from the Ohau River. The gauge is located where the river exits the Tararua Ranges, approximately 3km east (upstream) of the indicative Ō2NL Project corridor. This location is at the transitional point where the river changes from a narrow, confined channel to a wider meandering channel across the piedmont/coastal plain. The gauging station and recorder are maintained by Horizons. Since the flow recorder is a significant distance upstream of the proposed Ō2NL Project, any analysis of the potential effect of the abstraction of construction water will be conservative i.e., the effects will be less than assessed as the actual flows in the Ohau River will be slightly greater at the point of abstraction than assumed.

The Waikawa at North Manakau Road recorder is located approximately 5km south of Ohau township, and 500m east of the indicative Ō2NL Project corridor. At this site, Waikawa Stream is approximately 10m wide, with relatively flat agricultural land on the north bank, and hilly forestry blocks to the south. Downstream, Waikawa Stream meanders across a flat, agricultural floodplain. Because of the proximity of the flow recorder to the Ō2NL Project, the potential reliability and effect of abstraction from Waikawa Stream are likely to be well defined. There may be slight changes in flow caused by the interaction of the river with the adjacent riparian unconfined aquifer. This could lead to variation between flow at the recorder and actual flow at a proposed location of abstraction, however, any effects will be small and likely impossible to quantify. The gauging station and recorder are maintained by Horizons.

Flow has been recorded at two sites on the Manakau Stream. The Manakau at Gleesons Road recorder is located about 500m south of the Manakau township; the Manakau at State Highway 1 (SH1) Bridge recorder is approximately 200m further downstream. The stream channel between these recorders is narrow and meandering, with flat agricultural land on either side. Between the two recorders, there is no diversion of water or any tributaries entering the stream. Consequently, basing the hydrological assessment of Manakau Stream on a combined flow series from both the Gleesons Road and SH1 at Bridge recorders, provides a more accurate and robust analysis of the potential effect of abstraction from the stream because of the longer flow record. The combined flow series and subsequent assessment will be referred to as 'Manakau Combined'. These gauging stations and recorders were or are maintained by Horizons. Again, because of the proximity of these flow recorders to the Ō2NL Project, the potential reliability and effect of abstraction from Manakau Stream are likely to be well defined using these data.

The effects of abstraction from the Koputaroa Stream can be assessed by analysing the flow series from the Koputaroa at Tavistock Road recorder. This recorder is located approximately 5km north-east of Levin, and 6.5km upstream of Koputaroa Stream's confluence with the Manawatū River. This site and flow record were maintained by Horizons from 1974-1996, after which the site was decommissioned. The gauging site and flow recorder have been subsequently reinstated to support the development of the Ō2NL Project, although the recent record is relatively short. The site is now maintained by NIWA on behalf of the Ō2NL Project.

The contributing catchment upstream of Tavistock Road is approximately 16.08km^2. Immediately upstream and downstream of the recorder, the stream has a narrow, confined channel. From approximately 5km upstream of the Tavistock Road recorder, downstream to its confluence with the Manawatū River, Koputaroa Stream meanders through flat agricultural land. All significant tributaries to Koputaroa Stream are a considerable distance either upstream or downstream from the Tavistock Road recorder.

The Project corridor, and therefore any potential abstraction of construction water, is likely to be a significant distance upstream of the flow recorder. For example, the catchment area upstream of McDonald Road, a possible source of abstraction, is only about 40% of that upstream of Tavistock Road. Since flows, particularly low flows, in a river or stream are largely a function of catchment area, flows in Koputaroa Stream near McDonald Road are likely to be only about 40% of those recorded downstream at Tavistock Road. The implications of this for the potential abstraction of construction water is described in more detail later in this report.

The Waitohu at Water Supply Intake recorder is suitable for assessing the impact of any potential abstraction of construction water from this catchment. The gauge is located approximately 4.5km east of Ōtaki, where the Waitohu Stream exits the foothills of the Tararua Ranges. Steep forested land borders the stream to the north of the gauge, with flatter pastoral land to the south. The channel is narrow with little variation immediately upstream and downstream of the flow recorder. The gauging station and recorder are maintained by GWRC.

Since the flow recorder on Waitohu Stream is a significant distance upstream of the proposed Ō2NL Project, any analysis of the potential effect of the abstraction of construction water will be conservative i.e., the effects will be less than assessed as the actual flows in Waitohu Stream will be slightly greater at the point of abstraction than assumed.

No independent quality assurance of the flow records described above has been undertaken. However, the hydrometric sites and flow records have been maintained by either Horizons (all sites except that on Waitohu Stream and until recently the Koputaroa Stream) or GWRC. It is therefore assumed that measurements, gaugings, and ratings have been undertaken in a manner consistent with industry best practice.

The data from Koputaroa Stream, while obtained from Horizons hydrometric archive, are not fully quality assured. Flow record notes state that many of the annual maximum flows, including the largest in the record, occurred during times the recorder was not operating. These peak flows have therefore been derived by taking measurements of debris levels or correlating with local flow records. The conclusion of the rating team was that peak flows should be reasonably accurate. No comments are provided regarding the reliability of the low flow record. As these are the only available data, they have been assumed accurate for the purposes of this analysis.

5.2 Flow Analyses

Given the requirements of Horizon's One Plan and any potential abstraction regime, it is likely that the abstraction of construction water will be managed on the basis of the mean daily flow. Consequently, the quasi-instantaneous flow series (i.e., 15-min flow data) from each river or stream were converted the mean daily flows and the following analyses are based on those data.

The Ohau, Waikawa, Manakau, Koputaroa and Waitohu exhibit a high degree of variability, both within their own flow series and when compared to each other. The Ohau River is the largest of the four waterways (**Table 1)** and recorded flows have ranged from a minimum of 0.585m^3/s (March 1989), to a maximum of over 183m^3/s (January 2008) (**Figure 2**). In comparison, flows recorded in Waikawa Stream have ranged from 0.19m^3/s to 44.5m^3/s (**Table 1**). The minimum flow was recorded in April 2014, while the maximum flow was recorded in January 2008 (**Figure 3**). Waikawa Stream is the second largest of the five waterways, with a mean flow approximately five times higher than those of the Manakau and Koputaroa Streams, although four times smaller than the mean flow of the Ohau River (**Table 1**). The Manakau Stream and Koputaroa Streams have recorded minimum flows of 0.009 m^3/s and 0.012m^3/s, respectively (**Table 1**). The maximum recorded flow in Manakau Stream was 20.7m^3/s in January 2008 (**Figure 4**), while in the Koputaroa the maximum flow of 7.982m^3/s was recorded in December 1976 (**Figure 5**). Flow in the Waitohu Stream has ranged from a minimum of 0.065m^3/s, to a maximum of 34.7m³/s (**Table 1**). The Waitohu Stream experienced this minimum flow in April 2003, while the maximum flow occurred in January 2008 (**Figure 6**).

The flow regimes of the Ohau River and Waikawa and Waitohu Streams are typical of waterways draining pastoral hill-country at the foothills of the Tararua Range. Flows are generally higher than those of the Manakau and Koputaroa Streams, which are typical of waterways draining low-lying, flat agricultural land.

Table 1: Summary statistics of the mean daily flows at the five sites (m^3/s).

Site	Min	Max	Mean	Std Dev	L.Q.*	Median	U.Q.**
Ohau at Rongomatane	0.585	183.9	6.47	7.83	2.46	4.15	7.45
Waikawa at North Manakau Road	0.191	44.5	1.47	1.72	0.57	0.95	1.72
Manakau Combined	0.009	20.7	0.25	0.43	0.11	0.14	0.23
Koputaroa at Tavistock Road	0.012	8.0	0.24	0.33	0.07	0.15	0.28
Waitohu at Water Supply Intake	0.065	34.7	0.98	1.39	0.30	0.54	1.12

* *L.Q. is the Lower Quartile flow i.e., the flow that is exceeded 75% of the time*
** *U.Q. is the Upper Quartile flow i.e., the flow that is exceeded 25% of the time*

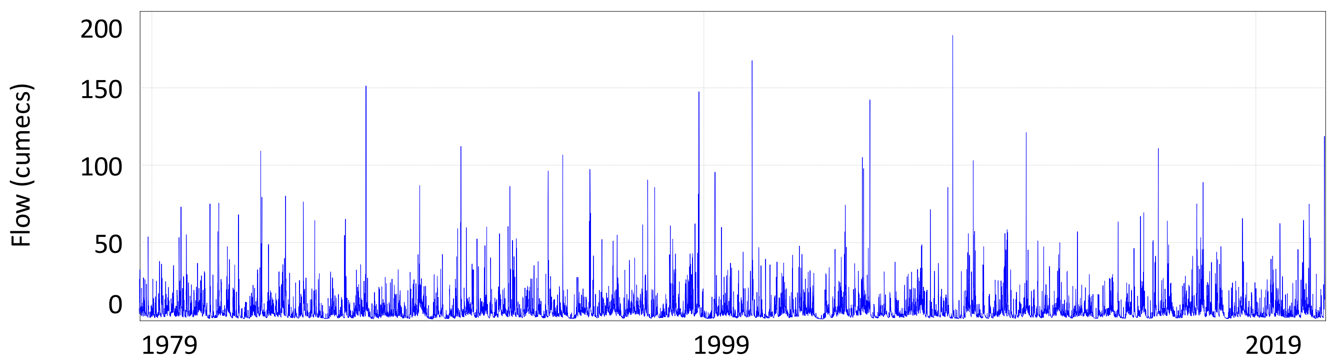

Figure 2: Ohau at Rongomatane mean daily flow series (1978-2021).

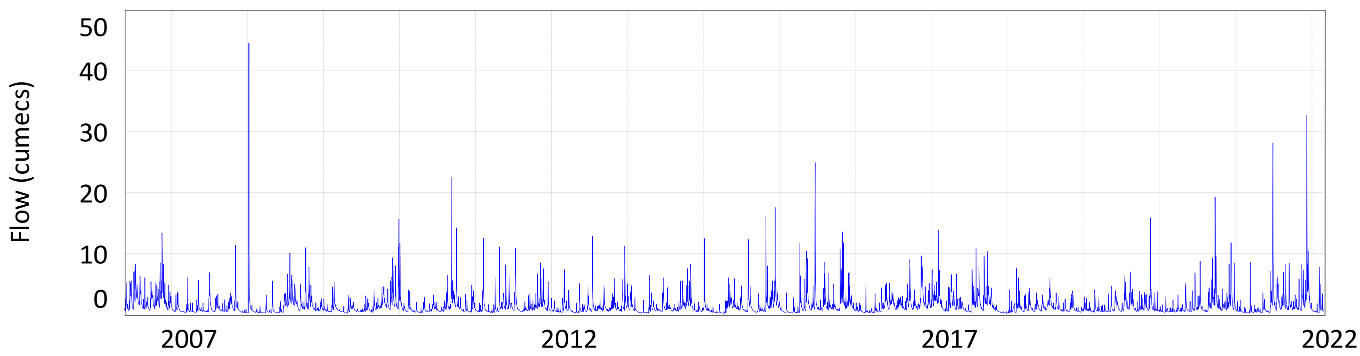

Figure 3: Waikawa at North Manakau Road mean daily flow series (2006-2022).

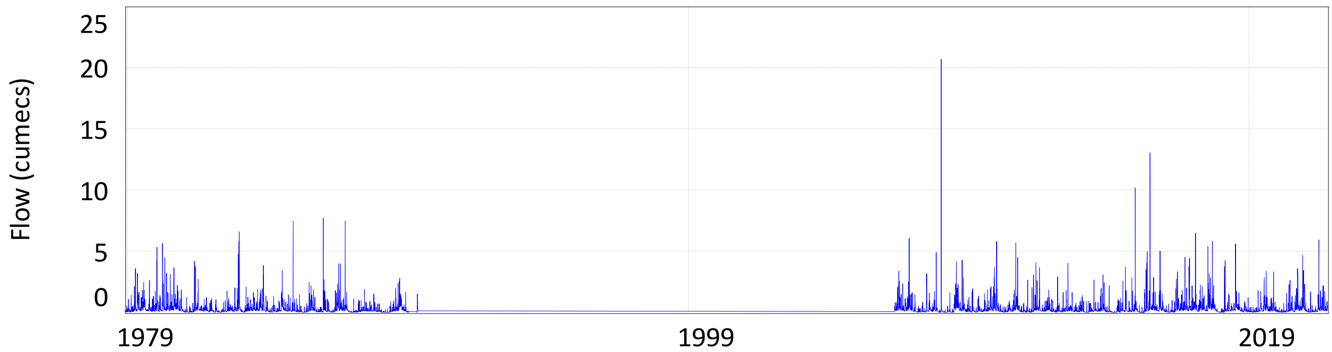

Figure 4: Manakau Combined mean daily flow series (1978-2021). The flat line is when no data exists.

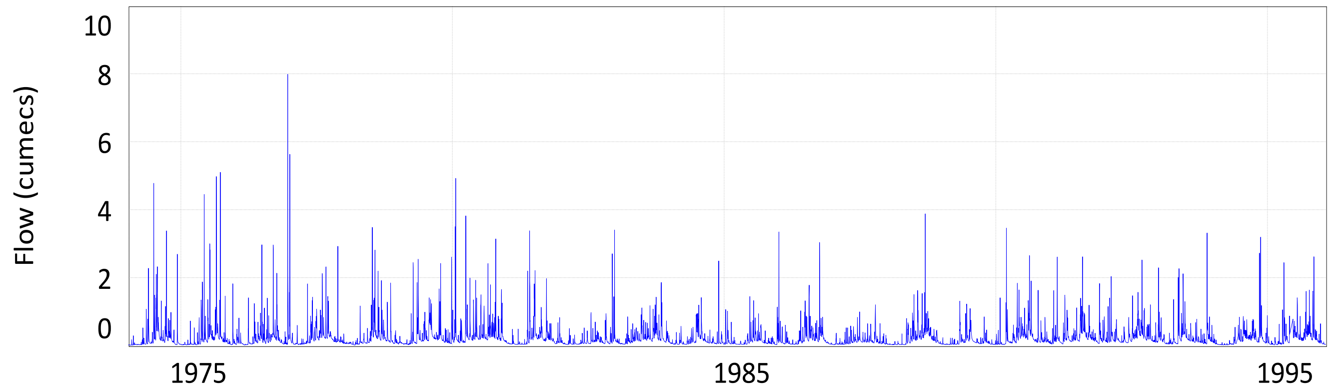

Figure 5: Koputaroa at Tavistock Road mean daily flow series (1974-1996).

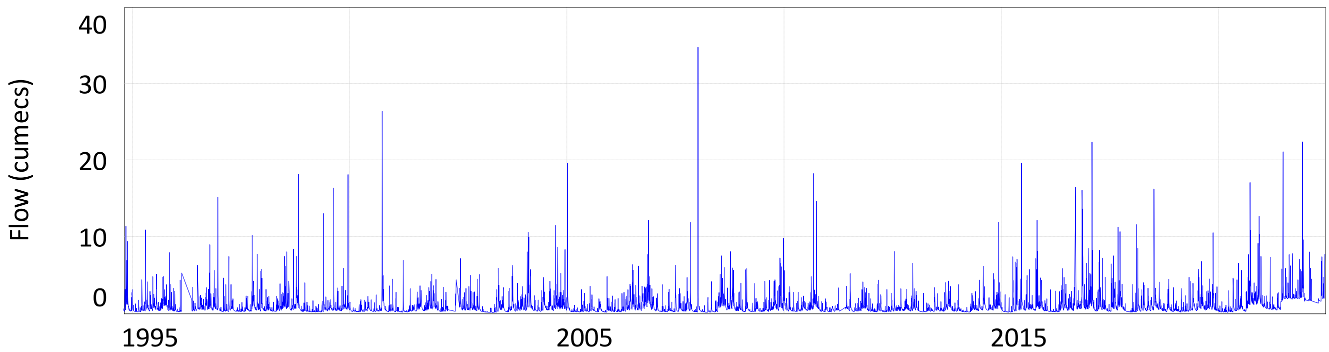

Figure 6: Waitohu at Water Supply Intake mean daily flow series (1994-2022).

Each of these waterways experience sustained periods of moderate to low flow over most of their records. These periods are interspersed with occasional flood and fresh events of varying magnitude (**Figure 2** through **Figure 6**). Typically, flood/fresh events in each of the waterways follow a cyclic pattern. In the Ohau River and Waikawa and Waitohu Streams, larger flows tend to occur every 3-5 years. Larger flows in the Manakau and Koputaroa Streams generally happen every 1-2 years. Higher and moderate-high flows occur most frequently during winter and spring, and lower flows at the end of summer and into autumn. The extreme maximum flows in each waterway appear to occur in either January or December (i.e., summer months) and are typically of short duration. Any sustained periods of moderate-high flow generally occur in winter and spring.

6 Core Allocation

Each sub-zone has a Core Allocation. The estimated maximum combined abstraction of construction water of 3,900m^3/day is greater than the core allocation currently remaining from the Ohau River (409m^3/day), Manakau (156m^3/day), Koputaroa (351m^3/day) and Waitohu (3,240m^3/day). Although the estimated maximum abstraction of construction water is less than the currently available allocation from Waikawa Stream (4,498m^3/day), it represents 86% of the total available allocation. However, when the available allocations from each river or stream are combined, there is a potential allocation of 8,654m^3/day available. The maximum abstraction of 3,900m^3/day represents only 45% of this total available allocation.

Abstraction of construction water will not likely occur during winter and abstraction would be required only during the construction of the Ō2NL Highway i.e., a relatively short duration. It will, however, be necessary to 'share' the maximum required abstraction between the five waterways to avoid exceeding the Core Allocation of any particular sub-zone. The majority of 'construction water' abstracted under the Core Allocation framework will likely need to come from the Waikawa and Waitohu Streams.

7 Minimum Flows

Minimum flows are used to manage the abstraction of water from rivers to maintain in-stream values during periods of low flow. A minimum flow, however, does not prevent the flow in a river or stream decreasing below that threshold, which it does naturally when low rainfall and runoff conditions persist. The minimum flow simply restricts abstraction, and therefore the effects of abstraction.

The setting of a minimum flow is informed by the best available information at the time. In the early 1990's, this often involved the detailed Instream Flow Incremental Methodology (IFIM). Using the IFIM, the minimum flow is set to retain 90% of the instream habitat; with the focus generally on trout rather than native fishes.

Minimum flows will vary at different locations along a river depending on catchment area and the physical characteristics of the channel. Therefore, professional judgement informs the final minimum flow which is adopted.

Because of the limited number of IFIM determinations in the Manawatū when preparing the One Plan, Horizons undertook a study to compare the IFIM data available to the 1-day Mean Annual Low Flow (MALF). It was found that for rivers with a MALF greater than 3.7m^3/s, the IFIM could be correlated to a flow of 80% of the MALF. At the time of the One Plan, using data from 1-July-1923 through 1-July 2008, the MALF of the Manawatū River was 15.3m^3/s (**Figure 7**). Since 80% of the MALF (15.3m^3/s) was 12.24m^3/s, this was adopted as the minimum flow at the Teachers' College hydrometric site.

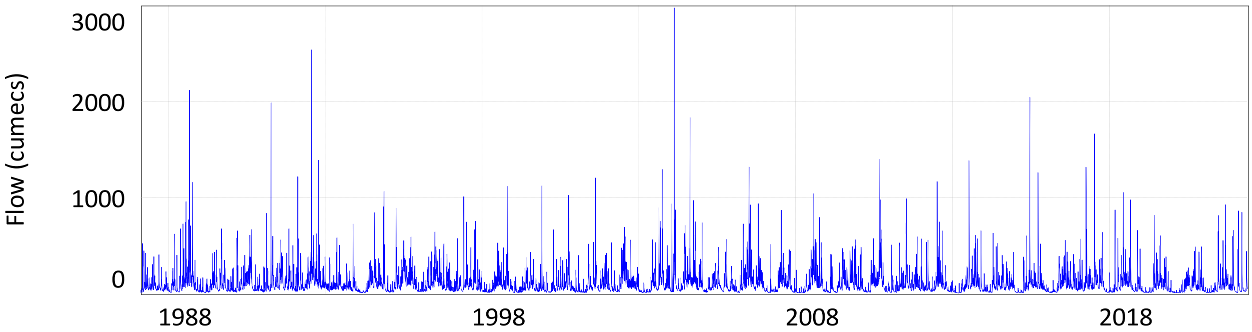

Figure 7: Manawatū at Teachers College mean daily flow series (1974-2021).

The same approach has been used to derive the minimum flows for the following sites:

- Ohau at Rongomatane – 0.820m^3/s;
- Waikawa at North Manakau Road – 0.220m^3/s;
- Manakau at SH1 Bridge – 0.040m^3/s; and
- Waitohu at Water Supply Intake – 0.140m^3/s.

Extending the analysis to include data up until 2022 (**Figure 7**), the MALF at the Manawatū at Teachers College site would be 14.7m^3/s (not 15.3m^3/s) and the minimum flow would be 11.76m^3/s and not 12.24m^3/s. This analysis can also be completed for the other sites to see if there have been any changes in their flow regimes over more recent years that might affect the minimum flows.

Recalculating the MALF for Ohau at Rongomatane gives a value of 1.089m^3/s and a minimum flow of 0.871m^3/s. For Waikawa at North Manakau Road, the MALF increases to 0.286m^3/s which gives a new minimum flow value of 0.228m^3/s. The updated MALF for Manakau Combined gives a value of 0.068m^3/s, which provides a minimum flow of 0.055m^3/s. The minimum flow for the Waitohu Stream is 0.146m^3/s, based on an updated MALF of 0.182m^3/s.

It should be noted that, because of the limited flow data available for Koputaroa Stream, abstraction is managed by the minimum flow in the Manawatū at Teachers College i.e., a flow of 12.24m^3/s at that site. While developing an abstraction regime for construction water from this stream will involve consideration of the actual flows, the trigger for when any abstraction must cease will still be referenced to flow in the Manawatū at Teachers College.

All of the recalculated minimum flows are the same as or slightly higher than those provided by Horizons and GWRC. However, irrespective of the above analysis, it is likely that those minimum flows provided in Horizon's One Plan, and by GWRC, are those that would be adopted in any resource consent process. The magnitude of any potential effects of abstraction, however, will be reduced because of the higher low flow regimes that appear to currently exist within these rivers and streams.

8 Periods of Restricted Abstraction

8.1 Minimum flows

Horizons' One Plan and the GWRC PRNP set minimum flows for the abstraction of water forming part of the Core Allocation in the sub-zones containing the various waterways. **Table 2** displays the minimum flows for each sub-zone, the hydrometric site to which they are related, and waterway they affect.

Table 2: Minimum flow restrictions for relevant sub-zones, set by Horizons' One Plan (Ohau_1b, West_9a, West_9b and Mana_13e) and GWRC's PRNP (Waitohu).

Sub-Zone	Minimum Flow (m^3/s)	Site measured from	Affected waterway
Ohau_1b	0.820	Ohau at Rongomatane	Ohau River
West_9a	0.220	Waikawa at North Manakau Road	Waikawa Stream
West_9b	0.040	Manakau at SH1 Bridge	Manakau Stream
Mana_13e	12.240	Manawatū at Teachers College	Koputaroa Stream
Waitohu	0.140	Waitohu at Water Supply Intake	Waitohu Stream

Flow has fallen below the minimum flow in the Ohau at Rongomatane (**Table 3** & **Figure 8**) and Waikawa at North Manakau Road (**Table 4** & **Figure 9**) for less than 1% of their respective records. At Manakau Combined, flow has fallen below the minimum flow for approximately 2% of the time (**Table 5** & **Figure 10**) and at Manawatū at Teachers College flow has fallen below the minimum flow for just over 1% of the time (**Table 6** & **Figure 11**). Flow in the Manawatū at Teachers College acts as the trigger site for controlling abstraction from Koputaroa Stream. On that basis, Koputaroa Stream has only been subjected to restrictions for approximately 1% of the time. In the Waitohu at Water Supply Intake, flow has fallen below the minimum flow for approximately 3% of the time (**Table 7** & **Figure 12**).

Table 3: Frequency distribution of mean daily flows recorded at Ohau at Rongomatane (1978-2021).

	0	1	2	3	4	5	6	7	8	9
0	183.90	38.40	28.78	23.94	21.09	18.99	17.45	16.12	14.97	14.07
10	13.30	12.63	12.05	11.50	11.00	10.53	10.10	9.71	9.35	9.02
20	8.73	8.45	8.19	7.93	7.69	7.45	7.23	7.03	6.83	6.65
30	6.48	6.32	6.17	6.03	5.89	5.76	5.62	5.49	5.36	5.24
40	5.13	5.02	4.91	4.80	4.70	4.60	4.51	4.41	4.33	4.24
50	4.15	4.07	3.98	3.90	3.83	3.75	3.67	3.60	3.52	3.45
60	3.38	3.31	3.25	3.18	3.12	3.06	3.00	2.94	2.88	2.82
70	2.76	2.70	2.64	2.58	2.52	2.46	2.40	2.34	2.29	2.23
80	2.17	2.11	2.06	2.00	1.94	1.89	1.83	1.78	1.71	1.65
90	1.59	1.53	1.47	1.41	1.33	1.26	1.18	1.10	1.01	0.88
100	0.59									

Frequency distribution tables like that above present the percentage of time the flow exceeds a particular value. In this example, 100% of the time flows exceed 0.59m^3/s (the minimum flow ever recorded). For 0% of the time flows have exceeded 183.9m^3/s (the maximum flow ever recorded). All other percentages can also be interpolated from the table where the various rows contain the 10 percentiles and the columns to 1 percentiles e.g., for 64% of the time flow exceeds 3.12m^3/s and for 22% of the time it exceeds 8.19m^3/s.

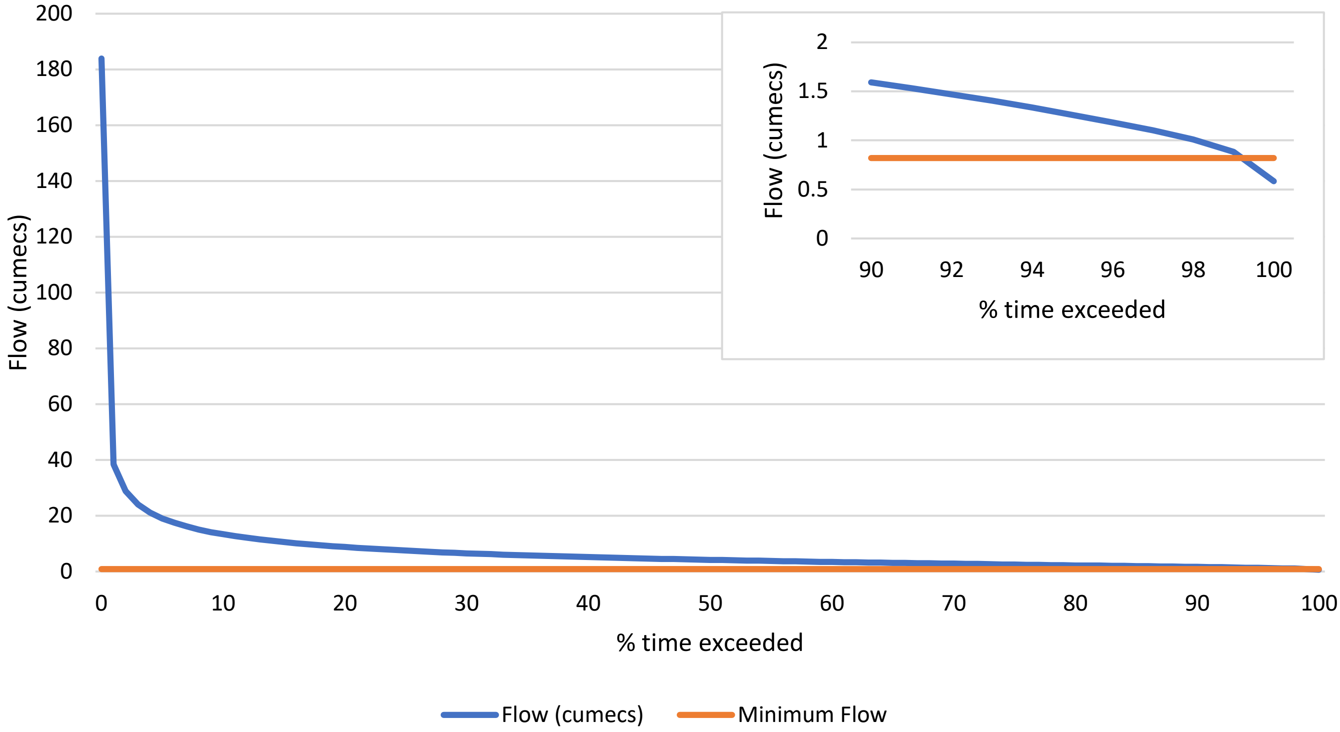

Figure 8: Distribution of mean daily flows at Ohau at Rongomatane (1978-2021) – and the minimum flow.

Table 4: Distribution of mean daily flows recorded at Waikawa at North Manakau Road (2006-2022).

	0	1	2	3	4	5	6	7	8	9
0	44.47	8.21	6.30	5.37	4.76	4.30	3.93	3.64	3.40	3.20
10	3.02	2.87	2.74	2.61	2.50	2.40	2.30	2.21	2.14	2.06
20	2.00	1.94	1.87	1.82	1.77	1.72	1.67	1.62	1.58	1.54
30	1.50	1.46	1.43	1.39	1.36	1.32	1.29	1.26	1.23	1.20
40	1.18	1.15	1.13	1.10	1.08	1.06	1.04	1.01	0.99	0.97
50	0.95	0.93	0.91	0.90	0.88	0.86	0.84	0.83	0.81	0.79
60	0.78	0.76	0.75	0.73	0.72	0.70	0.69	0.67	0.66	0.64
70	0.63	0.62	0.61	0.59	0.58	0.57	0.56	0.55	0.53	0.52
80	0.51	0.50	0.49	0.48	0.47	0.45	0.44	0.43	0.42	0.41
90	0.40	0.39	0.37	0.36	0.34	0.33	0.31	0.29	0.27	0.25
100	0.19									

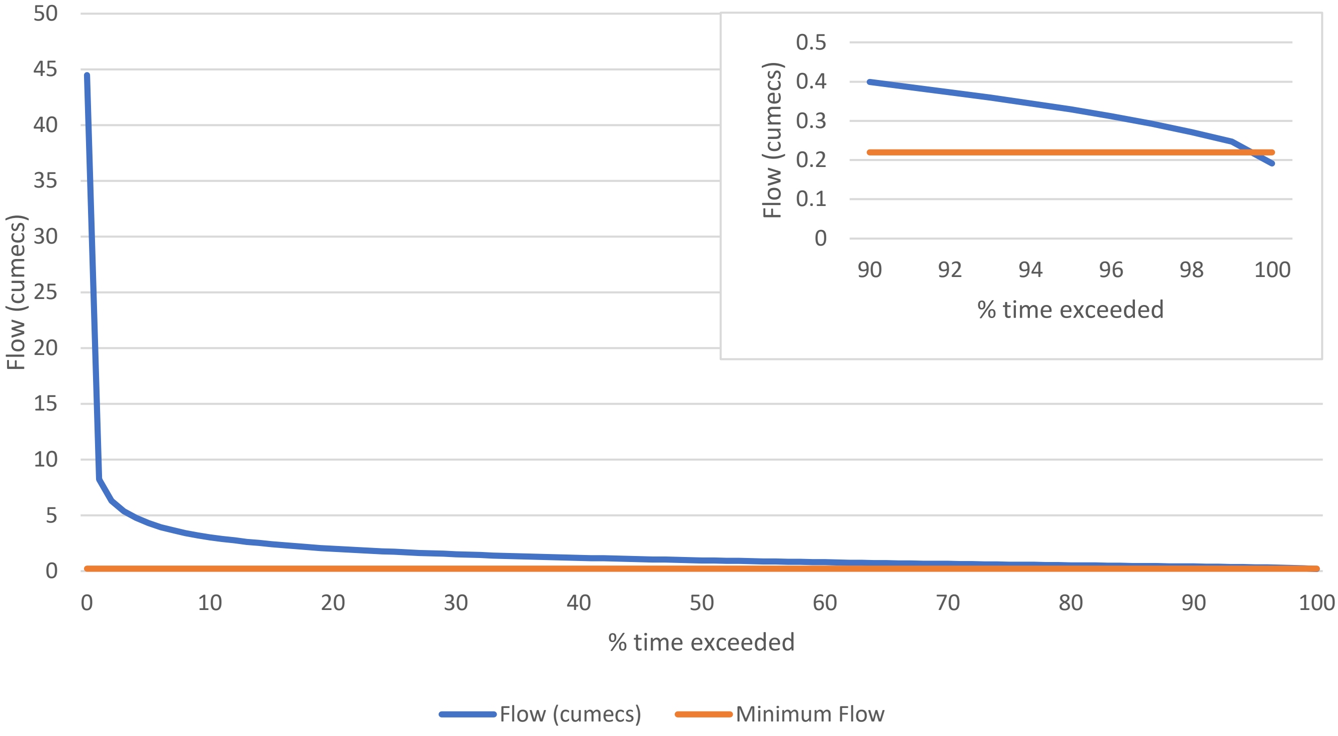

Figure 9: Distribution of mean daily flows at Waikawa at North Manakau Road (2006-2022) – and the minimum flow.

Table 5: Distribution of mean daily flows recorded at Manakau Combined (1978-2021).

	0	1	2	3	4	5	6	7	8	9
0	20.67	1.94	1.41	1.12	0.94	0.82	0.73	0.66	0.60	0.55
10	0.51	0.47	0.44	0.41	0.39	0.37	0.35	0.33	0.31	0.30
20	0.28	0.27	0.26	0.25	0.24	0.23	0.22	0.21	0.20	0.20
30	0.19	0.18	0.18	0.17	0.16	0.16	0.15	0.15	0.15	0.15
40	0.15	0.15	0.15	0.14	0.14	0.14	0.14	0.14	0.14	0.14
50	0.14	0.13	0.13	0.13	0.13	0.13	0.13	0.13	0.13	0.13
60	0.12	0.12	0.12	0.12	0.12	0.12	0.12	0.12	0.11	0.11
70	0.11	0.11	0.11	0.11	0.11	0.11	0.10	0.10	0.10	0.10
80	0.10	0.10	0.10	0.10	0.09	0.09	0.09	0.09	0.09	0.08
90	0.08	0.07	0.07	0.06	0.06	0.06	0.05	0.05	0.04	0.03
100	0.01									

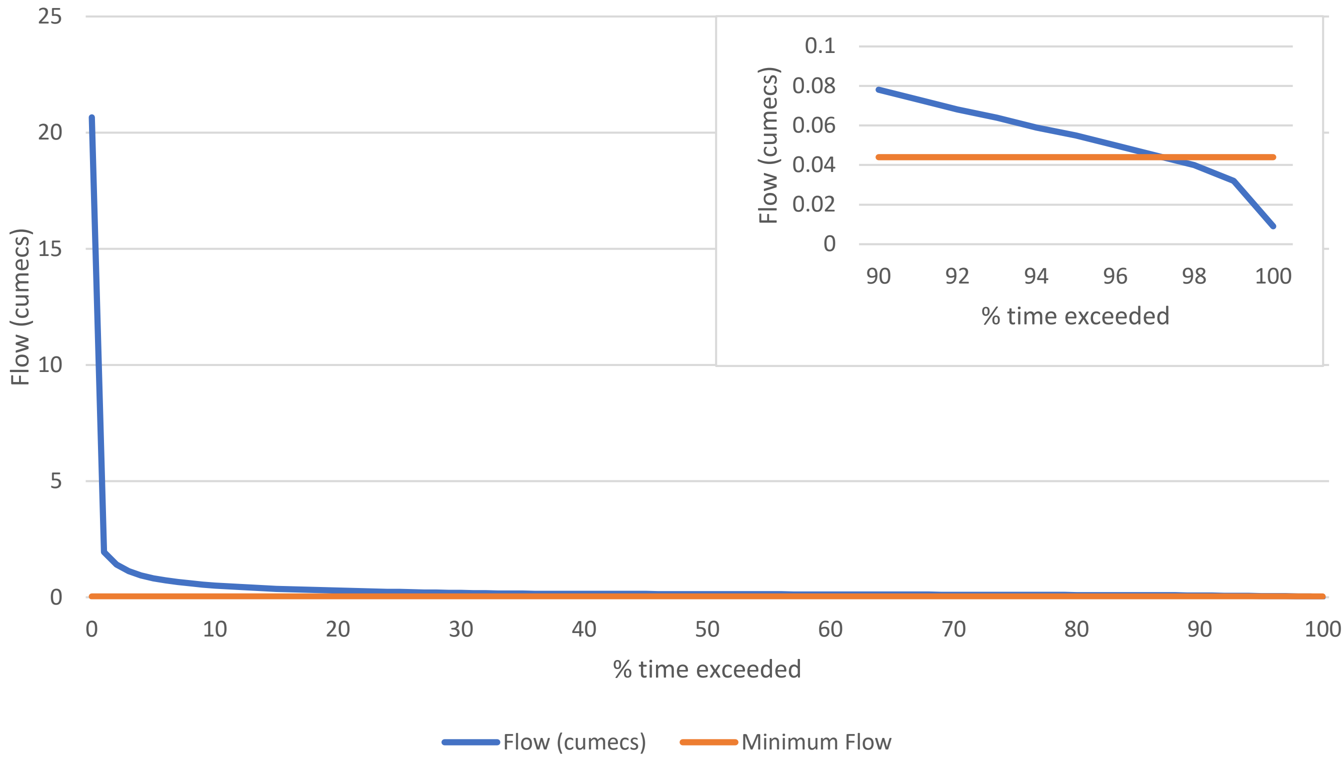

Figure 10: Distribution of mean daily flows at Manakau Combined (1978-2021) – and the minimum flow.

Table 6: Distribution of daily mean flows at Manawatū at Teachers College (1987-2022).

	0	1	2	3	4	5	6	7	8	9
0	2972.11	578.14	451.94	386.38	345.91	313.32	287.76	268.15	251.10	235.82
10	223.16	211.51	201.28	192.23	184.05	176.81	170.20	164.27	158.68	153.33
20	148.42	143.71	139.28	134.86	130.83	127.23	123.87	120.61	117.47	114.54
30	111.67	108.91	106.22	103.59	101.01	98.52	96.09	93.66	91.39	89.13
40	87.03	84.97	82.95	80.99	79.07	77.20	75.38	73.70	72.06	70.45
50	68.82	67.19	65.63	64.07	62.57	61.12	59.67	58.23	56.84	55.49
60	54.17	52.87	51.61	50.38	49.10	47.84	46.57	45.32	44.11	42.90
70	41.75	40.59	39.44	38.29	37.13	36.03	34.97	33.91	32.76	31.64
80	30.54	29.47	28.45	27.48	26.53	25.62	24.60	23.56	22.57	21.70
90	20.85	19.92	18.99	18.05	17.10	16.19	15.37	14.47	13.50	12.15
100	9.02									

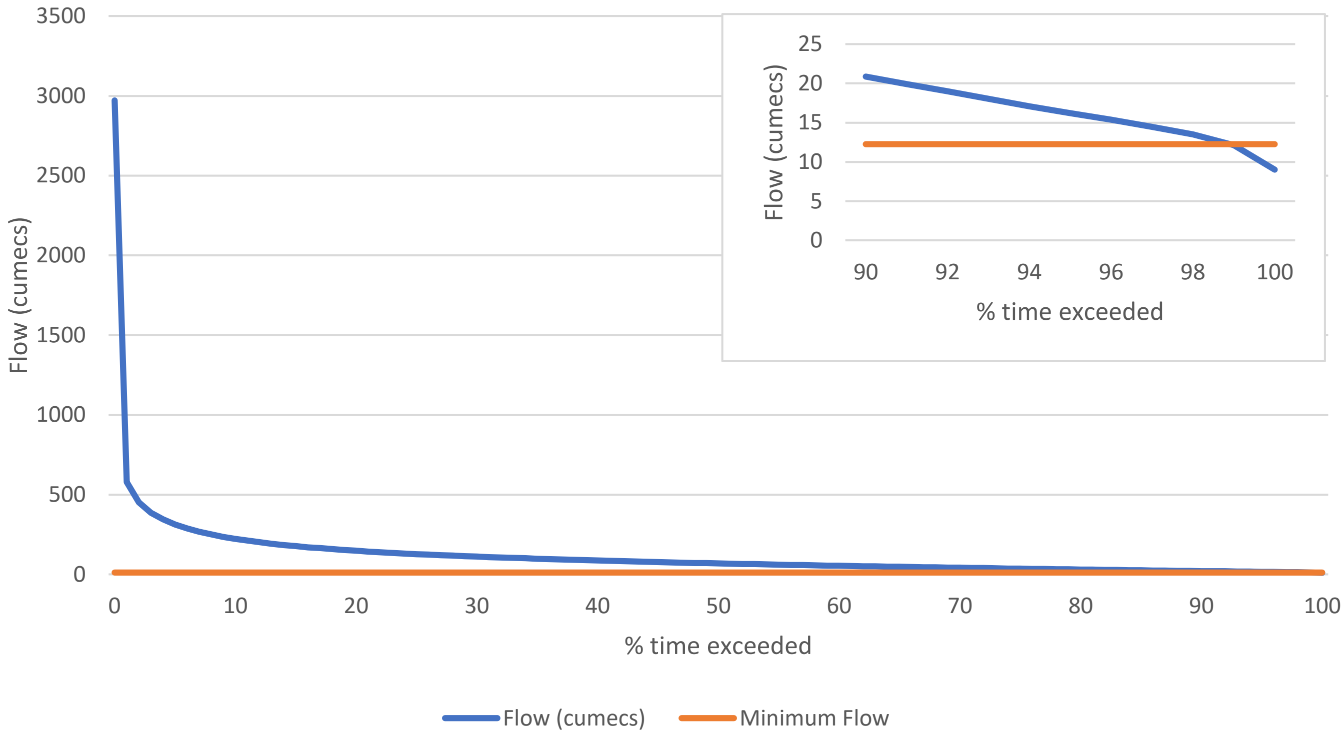

Figure 11: Distribution of mean daily flows at Manawatū at Teachers College (1987-2022) – and the minimum flow. This site is used to apply restrictions to the Koputaroa Stream.

Table 7: Distribution of mean daily flows at Waitohu at Water Supply Intake (1994-2022).

	0	1	2	3	4	5	6	7	8	9
0	34.72	6.51	4.81	4.02	3.48	3.12	2.82	2.59	2.40	2.23
10	2.01	1.99	1.92	1.85	1.75	1.68	1.61	1.55	1.49	1.43
20	1.37	1.32	1.26	1.21	1.16	1.12	1.08	1.04	0.10	0.96
30	0.93	0.90	0.87	0.85	0.82	0.80	0.77	0.75	0.73	0.71
40	0.70	0.68	0.66	0.65	0.63	0.61	0.60	0.58	0.57	0.56
50	0.54	0.53	0.52	0.50	0.49	0.48	0.47	0.46	0.45	0.44
60	0.43	0.42	0.41	0.40	0.39	0.38	0.37	0.36	0.36	0.35
70	0.34	0.33	0.32	0.31	0.30	0.30	0.29	0.28	0.27	0.27
80	0.26	0.25	0.24	0.24	0.23	0.22	0.22	0.21	0.20	0.20
90	0.19	0.18	0.17	0.17	0.16	0.15	0.15	0.14	0.13	0.12
100	0.07									

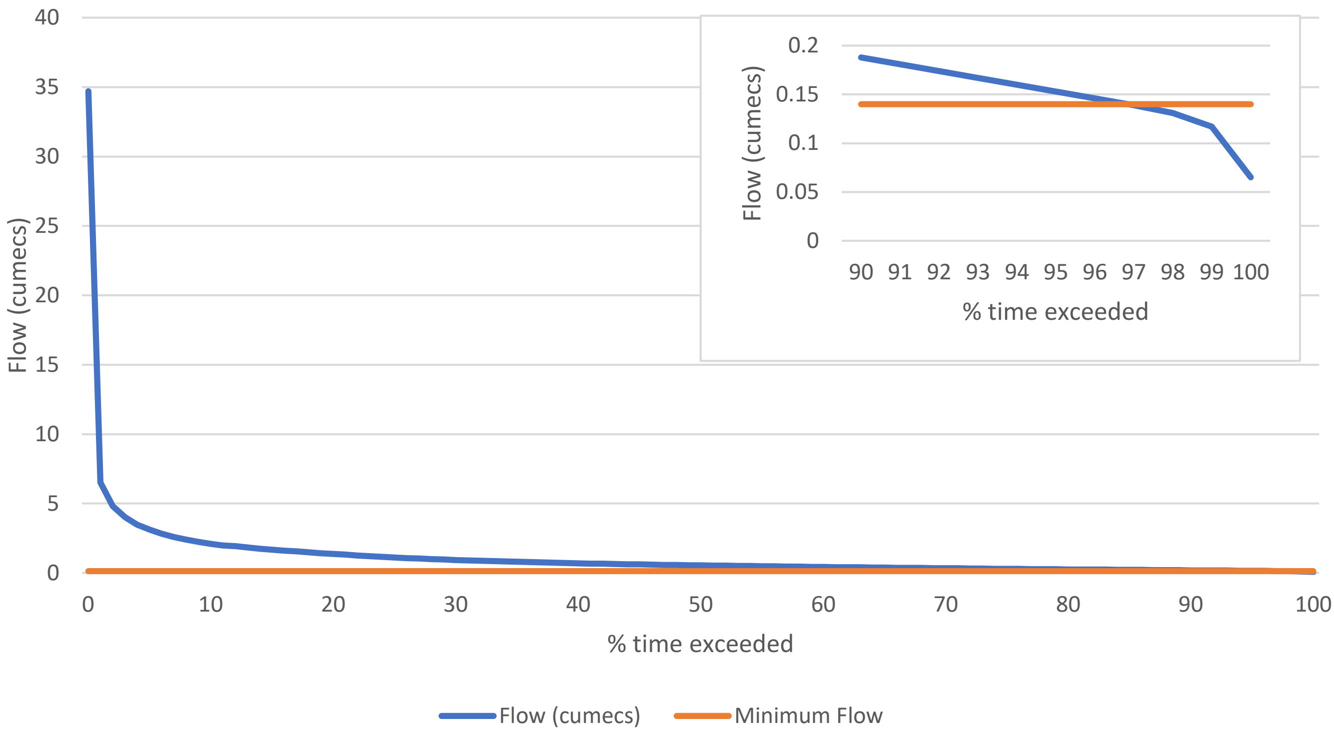

Figure 12: Distribution of mean daily flows at Waitohu at Water Supply Intake (1994-2022) – and the minimum flow.

The above analysis assumes that any abstraction of construction water is downstream of the flow monitoring site used to manage the abstraction. If abstraction was to be from upstream of the monitoring site, this could have a significant effect on the flow measured downstream and therefore the periods of abstraction. As discussed previously, this is only likely to be a potential problem with respect to abstraction from Koputaroa Stream, where any abstraction is likely to be a significant distance upstream of the flow recorder at Tavistock Road.

Since it is likely that the total abstraction of construction water will be from a combination of all five waterways, any abstraction is likely to have minimal impact on the duration of time that flows are below the minimum flow.

The above analysis considers only the percentage of time when abstraction may be restricted over the entire year. However, it is likely that periods of restricted abstraction occur during summer and autumn i.e., during the peak of the construction season when water demand is likely to be highest and river flows lowest. More detailed analysis of the distribution and duration of periods of restricted abstraction is therefore necessary.

8.2 Days below minimum flow

Abstraction of water from the Core Allocation is restricted when the mean daily flow drops below the minimum flow. Consequently, the daily mean flow series from each potential water source were analysed to identify the number of days each year when flow falls below the minimum threshold, and when these low flows occurred.

Figure 13 through **Figure 17** show the total number of days, and the maximum number of consecutive days, when flows fell below each site's respective minimum flow. Note that the time series show the data in 'water years', i.e., 1 July to 30 June. This is to avoid splitting low flow periods over summer across two calendar years and consequently under-estimating the potential effect of prolonged periods when abstraction would be restricted.

At each of the sites, the number of days when flows fall below the minimum flow varies considerably from year to year. Flows dropped below the threshold of 0.820m^3/s in only six years of the 43-year long record from the Ohau at Rongomatane; however, in 2002/03 flow was below this threshold for 50-days. Similarly, in only 2-years of the 16-year record for the Waikawa at North Manakau Road, did flows drop below the threshold of 0.220m^3/s. There were 10-days in 2013/14 where the flow was below the threshold, and six days in 2017/18.

In 29 of the 44-years of the Manakau Combined record, flows remained above the 0.040m^3/s threshold, while 1987/88 had 62-days below this threshold. At Manawatū at Teachers College, flow dropped below the threshold (12.240m^3/s) in 25 of the 35-years for which data are available. The largest number of days (33) occurred in 2012/13. During the 28-year Waitohu at Water Supply Intake flow record, there were 16-years when at least one day had flow below the minimum threshold. In 2002/03, there was 79-days where flow fell below the minimum threshold, the most of any year in the record.

Therefore, prolonged periods of flows below the minimum flow have occurred at each site. The maximum number of consecutive days flows fell below the minimum flow at each site are presented in **Figure 13** through **Figure 17**. At Ohau at Rongomatane, there was a maximum of 25 consecutive days where flows fell below 0.820m^3/s; in 2002/03. In 2013/14, the Waikawa at North Manakau Road recorded a maximum of nine consecutive days when flows fell below 0.220m^3/s. Flow was below the minimum flow for 21 consecutive days in 1987/88 at Manakau Combined and 28 consecutive days in 2012/13 for the Manawatū at Teachers College. Flows in the Waitohu at Water Supply Intake fell below the minimum threshold (0.140m^3/s) for a maximum of 26 consecutive days in 2002/03.

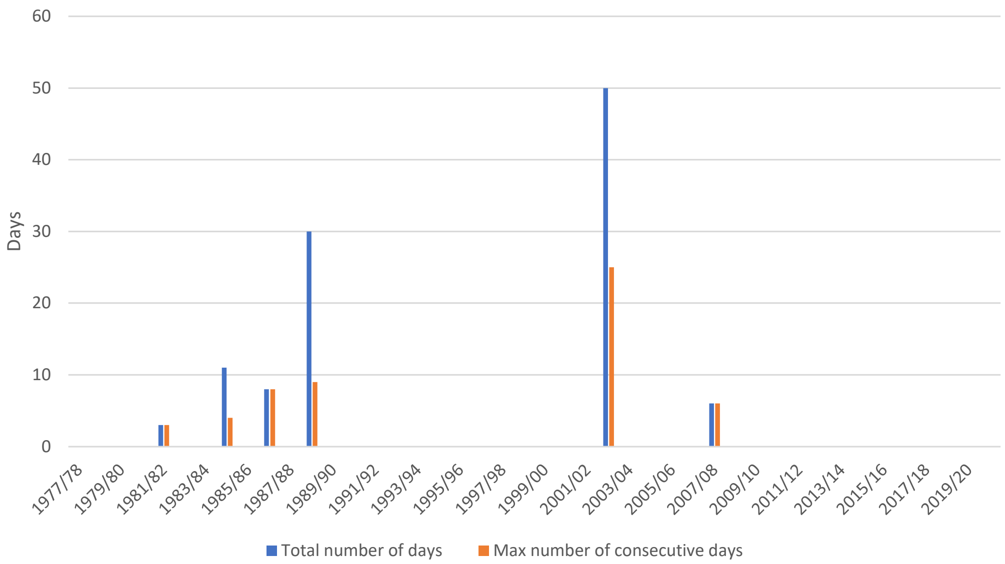

Figure 13: Total number of days, and longest consecutive period, when mean daily flows at Ohau at Rongomatane have fallen below 0.820m^3/s.

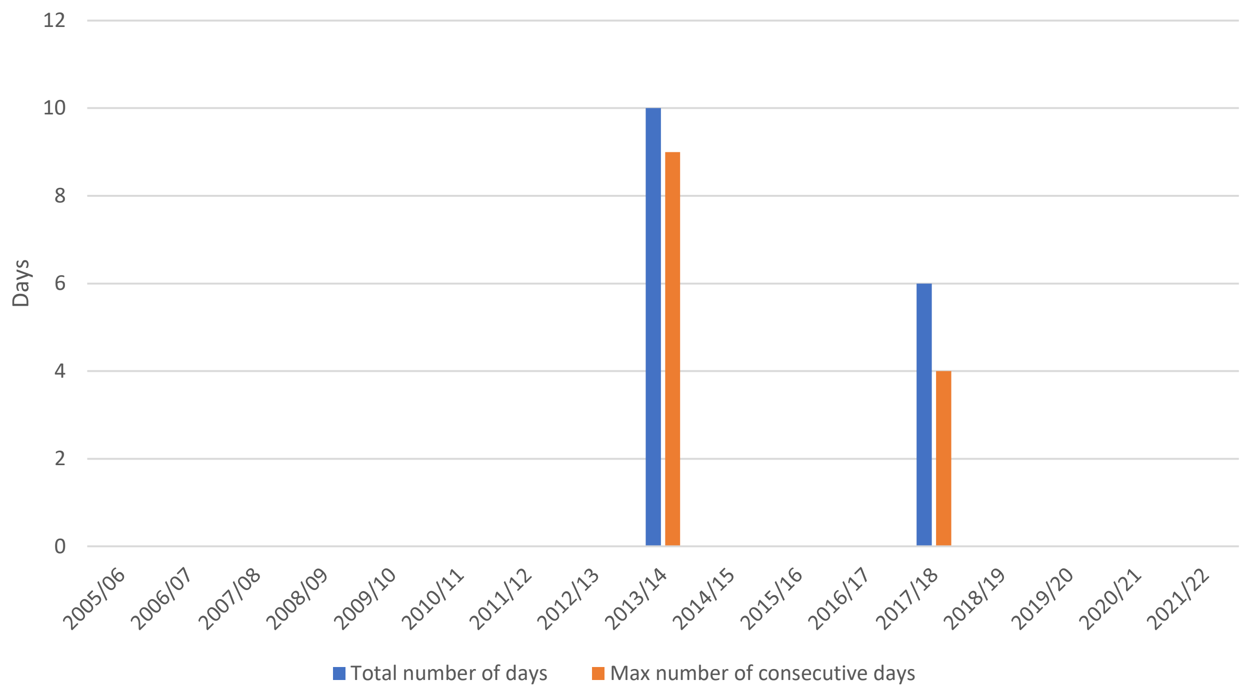

Figure 14: Total number of days, and longest consecutive period, when mean daily flows at Waikawa at North Manakau Road have fallen below 0.220m³/s.

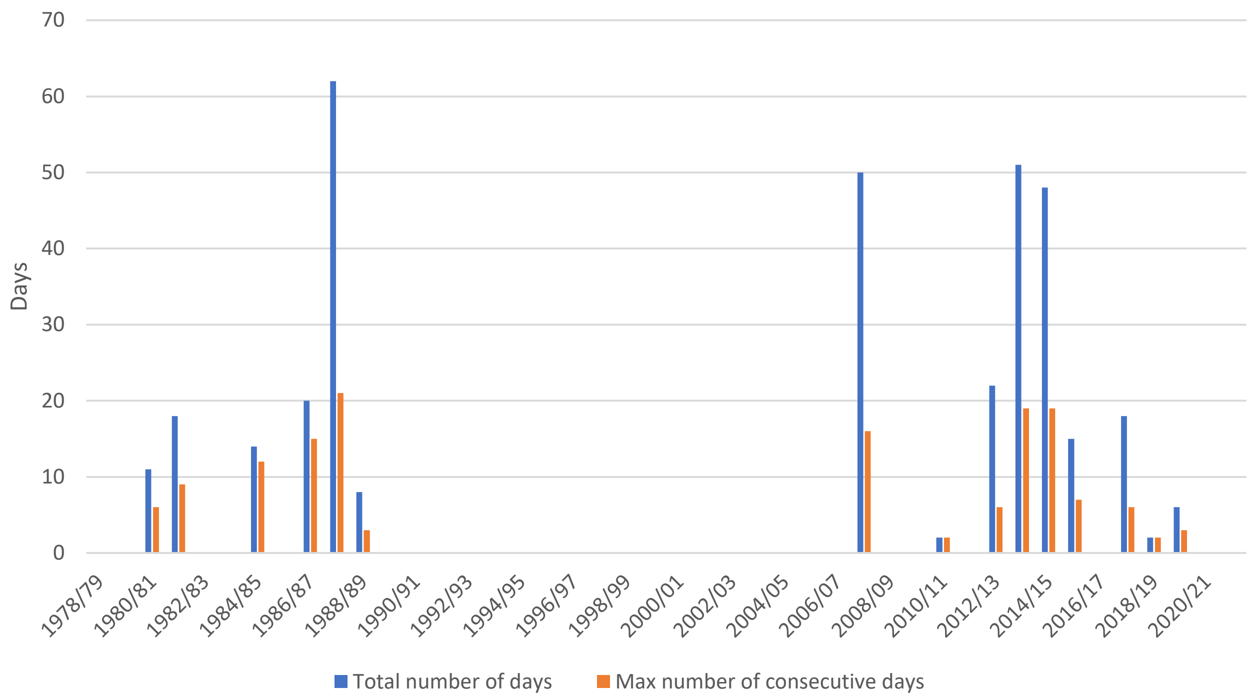

Figure 15: Total number of days, and longest consecutive period, where mean daily flows at Manakau Combined have fallen below 0.040m³/s.

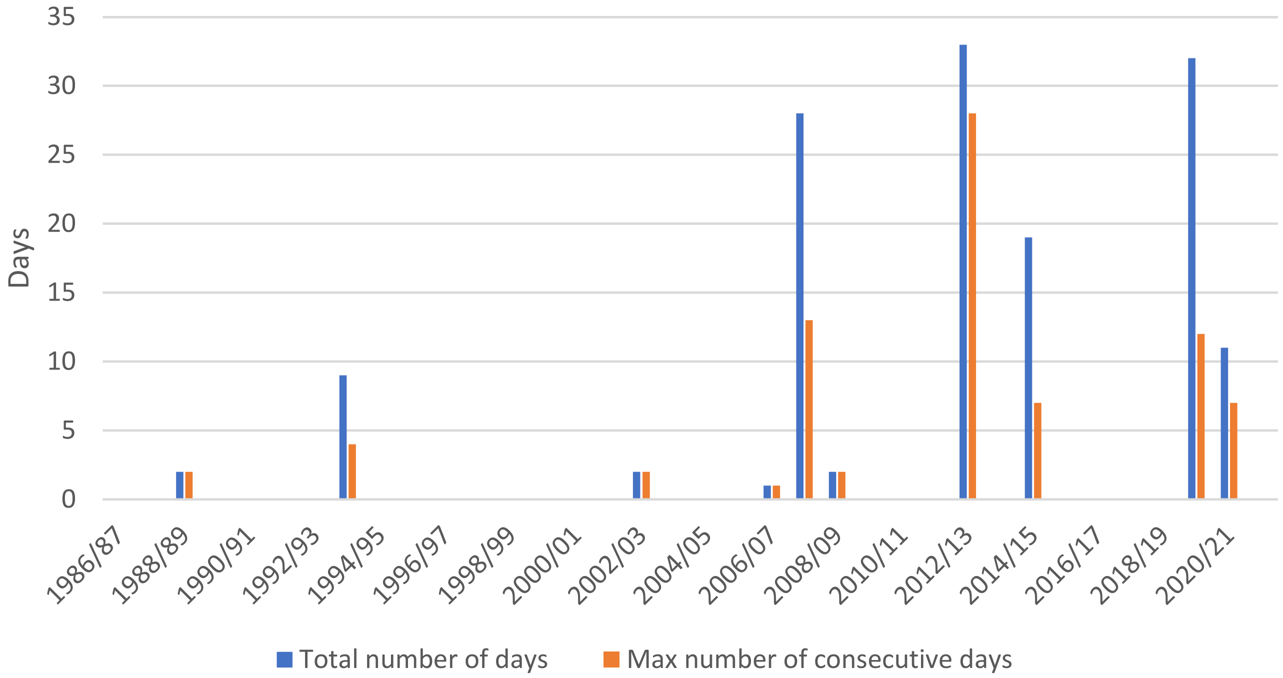

Figure 16: Total number of days, and longest consecutive period, where mean daily flows at Manawatū at Teachers College have fallen below 12.240m^3/s.

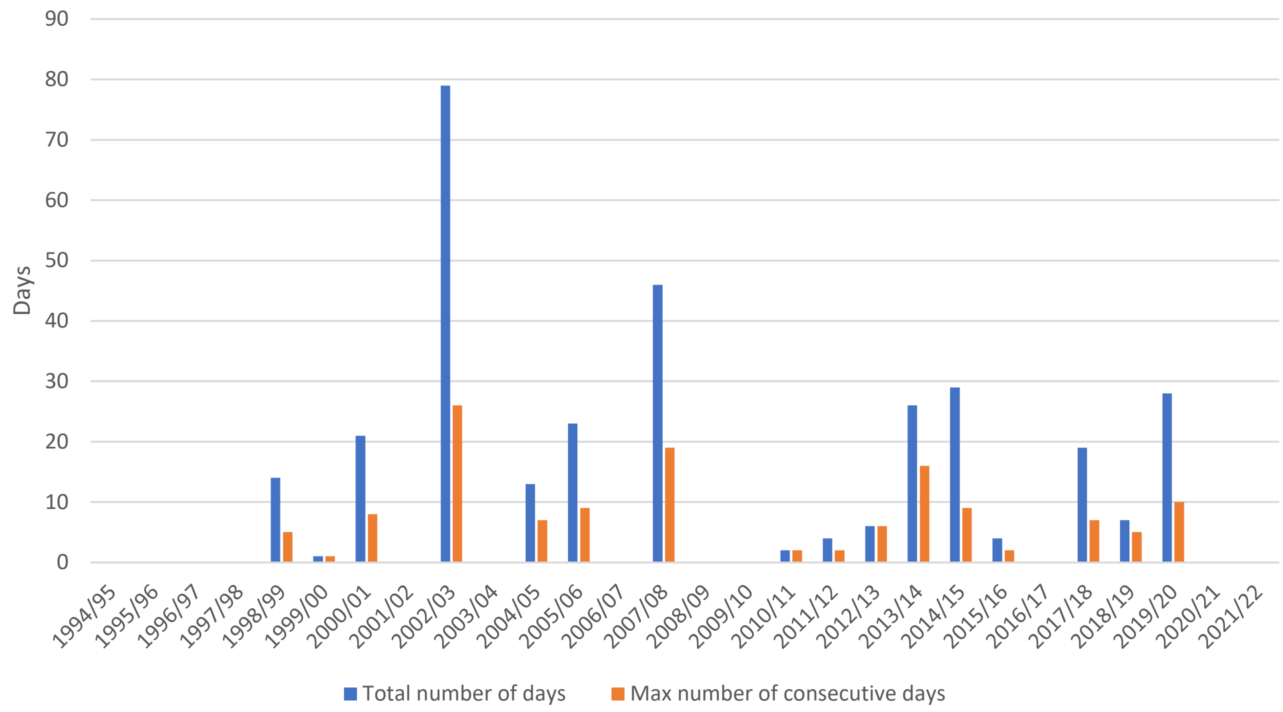

Figure 17: Total number of days, and longest consecutive period, where mean daily flows at Waitohu at Water Supply Intake have fallen below 0.140m^3/s.

Table 8 provides a summary of the days when flows fell below minimum flows at each potential water source, and when these occurred. Periods of low flow predominantly occur between January and May i.e., summer/autumn, which is likely to be during the peak of the construction season.

Table 8: Summary of the number of days when flows fell below the minimum flow, and when they occurred, for each of the flow series.

	Total number of days when flows fell below the minimum flow				
	Ohau at Rongomatane	**Waikawa at North Manakau Road**	**Manakau Combined**	**Manawatū at Teachers College**	**Waitohu at Water Supply Intake**
Jan	13	1	35	7	21
Feb	18	0	77	55	50
Mar	38	1	120	73	115
Apr	29	9	71	4	71
May	10	0	26	0	24
Jun	0	0	0	0	0
Jul	0	0	0	0	2
Aug	0	0	0	0	3
Sep	0	0	0	0	3
Oct	0	0	0	0	0
Nov	0	0	0	0	18
Dec	0	5	18	0	15

Managing the supply of construction water during these periods of restricted abstraction could be achieved by reducing water demand and using water storage ponds along the route. The ponds would provide some security of supply and a buffer between the supply and demand for water. The ability to refill these ponds after a period of restricted abstraction necessitates rates and daily volumes of abstraction that are higher than the average demand for water to support the Project. It may also require the use of a Supplementary Allocation, and consequently the ability to abstract up to 10% of any flow above the median flow for a particular river or stream.

To identify the frequency of prolonged periods below the minimum flow, frequency analyses were conducted on the number of consecutive days below the minimum flow at each site (**Table 9**). It is considered that the consecutive number of days is the critical metric in this analysis since it would be possible to manage individual days below the minimum flow relatively easily using water storage.

Table 9 shows that the long periods of consecutive days below minimum flow are relatively infrequent. At Ohau at Rongomatane, the Average Recurrence Interval (ARI) of a low-flow event that persists for 25 days, such as that which occurred in 2003, is approximately 100-years. At Manawatū at Teachers College, the 28-day event in 2012/13 has an estimated 67-year ARI. The 9-day low-flow event in the Waikawa at North Manakau Road in 2013/1014 had an ARI of approximately 35-years. At Manakau Combined the low-flow event of 1988/89, which persisted for 21 consecutive days, had an ARI of approximately 22-years. At Waitohu at Water Supply Intake the low flow event that occurred in 2002/03, and persisted for 26 days, had an ARI of approximately 50-years.

Table 9: Magnitudes and frequencies of periods of consecutive days when flows fall below the minimum flow at each site. **Note: a Pearson Type 3 statistical distribution is assumed when deriving the design events.**

		Number of consecutive days when flows fall below the minimum flow, rounded to the nearest whole day				
ARI (Years)	**AEP (%)**	**Ohau at Rongomatane**	**Waikawa at North Manakau Road**	**Manakau Combined**	**Manawatū at Teachers College**	**Waitohu at Water Supply Intake**
5	20	0	0	9	1	7
10	10	2	2	14	5	13
20	5	6	5	20	12	18
50	5	16	11	27	23	26
100	1	26	17	33	33	32
200	0.5	37	23	39	44	38
500	0.2	53	32	46	59	47
1000	0.1	66	39	52	72	53

9 Possible Abstraction Regime

It should be noted that the flow at any abstraction point may differ from that at the relevant gauge location. However, with respect to the Ō2NL Project, this is not likely to be a significant issue. The flow recorders on the Ohau River and Waitohu Stream are located a significant distance upstream of the Ō2NL corridor. Consequently, the flows in these rivers and streams used in the above analyses are likely to be slightly conservative i.e., low. Any potential effect of the abstraction of water has therefore been potentially over-estimated.

The flow recorders on both the Manakau and Waikawa Streams are located close to the Project corridor. The flows used in the analysis are therefore likely to be appropriate and realistic.

Flows in Koputaroa Stream have been, and are currently, measured at Tavistock Road. The flow record and flow regime at this location were discussed earlier. However, the Project corridor, and therefore any potential abstraction of construction water, is likely to be a significant distance upstream of this flow recorder. For example, the catchment area upstream of McDonald Road, a possible source of abstraction, is only about 40% of that upstream of Tavistock Road.

Obviously, flow is proportional to catchment area. While flood flows have been shown to vary as a function of catchment area to the power of 0.8, low flows tend to vary in direct proportion to catchment area. This is because while flood flows are affected largely by the characteristics of the storm rainfall, low flows are controlled by those characteristics that affect drainage of the catchment e.g., slope, soil, and geology. Based on data in the River Environment Classification (REC), the areas of the Koputaroa catchment upstream of Tavistock Road and McDonald Road are 19.6km² and 7.6km² respectively (Figure 18). Consequently, flows in the Koputaroa Stream at McDonald Road are likely to be only about 39% of those measured downstream at Tavistock Road.

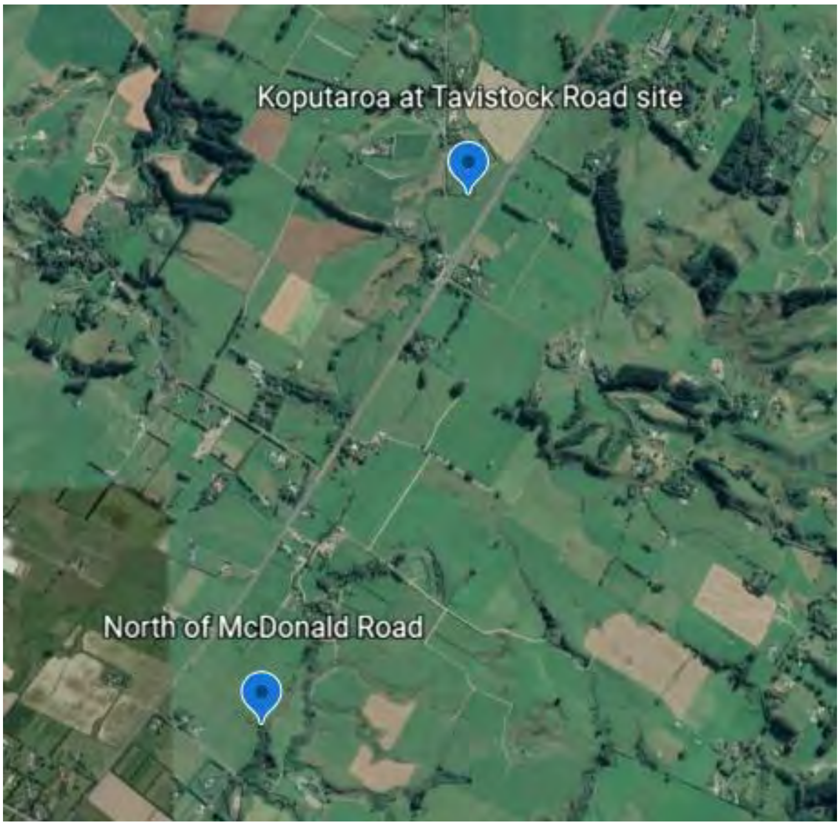

Figure 18: Location of the two sites for which flows have been estimated.

Scaling the flows and various hydrological metrics from the Koputaroa Stream at Tavistock Road, upstream to the vicinity of McDonald Road, gives the estimates shown in Table 10.

Table 10: Summary statistics of the estimated mean daily flows in Koputaroa Stream at McDonald Road (L/s).

Site	Min	Max	Mean	Std Dev	L.Q.	Median	U.Q.
Koputaroa at McDonald Road	5	3120	94	129	27	59	109

Note: *Flows estimated in the Koputaroa Stream at McDonald Road are significantly lower than recorded at Tavistock Road. The minimum flow at McDonald Road would likely be only about 11L/s.*

As discussed previously, this report proposes abstracting water to support the construction of the Ō2NL Project from several rivers and stream traversed by the proposed highway. This will minimise any potential environmental effects of abstraction, while also minimising a range of effects from having to transport water and use it out of the catchment from which it is sourced.

Possible criteria for any abstraction regime for construction water might include:

- Abstraction from the Core Allocation remaining currently within each of the water management zones;

- Abstraction of only up to two-thirds of the remaining core allocation. This will leave at least one-third of the remaining core allocation available for other potential users during the construction of the Project. Because of the small volume of the core allocation remaining within the Ohau catchment, the proposal is to seek the full volume remaining of this allocation;
- A maximum combined volume of 3,900m^3/day from the remaining Core Allocation for the various rivers and streams traversed by the Project;
- An average combined volume of 2,350m^3/day from the remaining Core Allocation for the various rivers and streams traversed by the Project;
- Abstraction only when flow is above the minimum flow for each river or stream;
- Extensive use of water storage along the proposed alignment to provide a buffer between the supply and demand for water to support construction activities. This will allow any potential environmental effects to be minimised;
- Abstraction only for the duration of the Project; and
- A Supplementary Allocation of 10% of the flow in the rivers and streams once they exceed the median flow.

One possible strategy for obtaining the water necessary for the construction of the Project is provided in Table 11. It should be noted that this scenario involves abstracting water at an extremely low rate (i.e., only 10% of the minimum flow) but continuously throughout the day. Abstraction at 10% of the minimum flow is only slightly higher than the margin of error for open channel flow measurements, generally regarded as ±8%; although many regional councils assume that any flow within ±10% is compliant.

This scenario just fails to provide the maximum required volume of construction water i.e., 3,708m^3/day compared to 3,900m^3/day. The required volume of water to meet construction needs could, however, be obtained by raising the rate of abstraction slightly. A higher rate of abstraction, but still within the core allocation, would likely have no measurable effect on the flow regimes and hydrology of the various rivers and streams. The simplest approach to meet the demand for construction water might be to abstract water at a rate of up to 10% of the mean daily flow, whenever flows are above the minimum flow. Additional water to support the construction could also be obtained from a Supplementary Allocation, abstracting up to 10% of any flow above the median in each of the rivers and streams.

The Project Aquatic Ecologist should provide advice as to the maximum rates of abstraction that can be sustained at any specific site without affecting instream values significantly. These maximum rates of abstraction, however, will not affect maximum daily abstraction from the Core Allocation proposed for each river or stream.

Table 11: Possible abstraction criteria and water availability under the Core Allocation.

Water course	Available Core Allocation (m^3/day)	Proposed maximum abstraction (m^3/day)	Remaining Core Allocation (m^3/day)	Current Minimum Flow (L/s)	Abstraction rate assuming 10% of minimum flow (L/s)	Daily abstraction volume assuming 10% of minimum flow (m^3)
Koputaroa (at McDonald Road)	351	231	120	11*	1	86
Ohau	409	409	0	820	82	409
Waikawa	4,498	2,998	1,500	220	22	1901
Manakau	156	102	54	40	4	102
Waitohu	3,240	2,160	1,080	140	14	1,210
Total	***8,654***	5,900 (but limited to a maximum of ***3,900****)*	***2,754***			**3,708**

Note: ***Estimated by scaling flows from Tavistock Road.***

10 Conclusions

The above review and analyses allow for the following conclusions:

- As part of the investigations for the Ō2NL Project, the potential to abstract 'construction water' from surface water sources has been reviewed. Water could come from several potential sources, including the Ohau River, and the Waikawa, Manakau, Koputaroa and Waitohu Streams. To meet the peak demand, and to minimise any risk to both the Project and the environment, it is likely that water from several sources would need to be used in combination.
- Peak water demand for construction activities is likely to occur during summer and autumn, a period that coincides with the higher risk of prolonged low flows in the potential water sources.
- Peak abstraction has been estimated at 3,900m^3/day i.e., 45L/s if abstracted continuously from the various rivers and streams.
- There is 5,414m^3/day of water currently available from the Core Allocation from the Lower Ohau River (Ohau_1b), Waikawa (West_9a), Manakau (West_9b) and Koputaroa (Mana_13e) management unit sub-zones. The Waitohu Stream has an additional 3240m^3/day available. This provides a maximum possible available core allocation of 8,654m^3/day. Abstraction of 3,900m^3/day to support construction of the Project would represent 45% of this available allocation.
- The lowest mean daily flows recorded at the various sites range from 0.009m^3/s (Manakau Combined) to 0.585m^3/s (Ohau at Rongomatane). If this maximum abstraction of 45L/s was 'distributed' across all potential sites, this would be less than 1% of the lowest flows ever recorded.

- There are minimum flows, below which any abstraction from the Core Allocation is restricted, for each of the potential water sources. These minimum flows have been derived from hydrometric sites on the Ohau at Rongomatane (Ohau River), Waikawa at North Manakau Road (Waikawa Stream), Manakau at SH1 Bridge (Manakau Stream) and Manawatū at Teachers College (Koputaroa Stream). Horizons has set minimum flows for these rivers and streams in the One Plan. The minimum flow restriction for the Waitohu Stream has been set by GWRC and is related to flows measured in the Waitohu at Water Supply Intake.
- In general, flows drop below the minimum flows relatively infrequently. However, periods below the minimum flow, when abstraction would be restricted, are not randomly distributed. These periods are likely to coincide with the construction season and therefore represent a significant risk to continuous abstraction.
- The maximum number of consecutive days when flows have fallen below the minimum flow ranges from nine (Waikawa at North Manakau Road, in 2013/14) to 28 (Manawatū at Teachers College, in 2012/13).
- The return periods of these events range from 22-years (21-day event at Manakau Combined) to 100-years (25-day event at Ohau at Rongomatane). Such events therefore have relatively low probabilities of occurring during construction of the Ō2NL Project but do represent a risk that must be managed.
- To mitigate any potential adverse hydrological effects, abstraction from the Core Allocation should be at relatively low rates but over longer periods. This would also likely avoid any stress on the instream environment. Advice regarding the maximum pumping rates for the various rivers and streams should be should from the Project Aquatic Ecologist.
- The potential impact of periods of restricted abstraction on construction activities can be managed to some extent through the provision of storage along the route. This storage will ensure security of water supply and mitigate any effect of restricted abstraction during short periods of low flow in any of the potential water sources.
- The ability to replenish the storage ponds following periods of restricted abstraction requires slightly higher rates of both instantaneous and daily abstraction than the average rate of water demand.
- The One Plan provides for a Supplementary Allocation, above the Core Allocation considered in this report, of up to 10% of any flow in a river or stream above the median. This option could also be used to mitigate the risk of periods of low flow and restricted abstraction by ensuring that all storage ponds are full prior to a low flow event.

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