Volume 1: Command Area Analysis and Refinement

Northland Water Storage and Use Project

NORTHLAND REGIONAL COUNCIL

WWLA0156 | Rev. 5

27 March 2020

Northland Water Storage and Use Project

Project no:	WWLA0156
Document title:	Volume 1: Command Area Analysis and Refinement
Revision:	5
Date:	27 March 2020
Client name:	Northland Regional Council
Project manager:	Chris Frost
Author(s):	WWLA et. al.,
File name:	G:\My Drive\Projects\NRC\WWLA00156\Consortium\Deliverables\1 Command Area\Report Vol1_Command Area Analysis and Refinement_Rev5.docx

Williamson Water & Land Advisory

19 Broadway
Kaikohe
New Zealand
T +64 21 337453

Document history and status

Rev	Date	Description	By	Review	Approved
1-2	29 Oct 2019	Internal review	WWLA SET Censeo Water Matters Agfirst	various	
3	13 Nov 2018	First draft for client review	WWLA	Jon Williamson	Jon Williamson
4	21 Feb 2020	Updated following client and peer review feedback	WWLA	WWLA	Jon Williamson
5	27 Mar 2020	Updated following client and peer review feedback	WWLA		Jon Williamson

Distribution of copies

Rev	Date issued	Issued to	Comments
3	08 Nov 2019	Northland Regional Council	First draft flor client review
4	21 Feb 2020	Northland Regional Council	Updated following client and peer review comments
5	27 Mar 2020	Northland Regional Council	Updated following client and peer review comments

Contents

Table of Figures

1. Introduction

Williamson Water & Land Advisory (WWLA) was commissioned as the lead contractor with partners RILEY Consultants and a number of other experts by Northland Regional Council (NRC) in August 2019 to undertake the Northland Water Storage & Use Project: Pre-feasibility Demand Assessment and Design Study.

NRC has previously undertaken two studies that identified areas worthy of further investigation. These were the Mid-North, and Kaipara areas. These areas are being investigated in conjunction with the Far North District Council (FNDC) and Kaipara District Council (KDC) respectively, with support from the Provincial Growth fund.

This Pre-feasibility Demand Assessment and Design Study is the next phase in the investigation of viable water storage and water use infrastructure within these areas

The goal of the project is to allow environmental improvement and economic development to occur within the water use Command Area with a net positive socio-economic impact to the surrounding local communities.

The following suite of reports will be completed to determine the viability of potential schemes to further:

1. ***Volume 1*****:** Command Area and Refinement (this report);
2. ***Volume 2*****:** Water Resources Assessment;
3. ***Volume 3*****:** Conceptual Design and Costing; and
4. ***Volume 4*****:** Analysis and Recommendations.

1.1 Report Objectives and Structure

This report details the Command Area analysis and refinement component of the project. The primary objectives and structure of this report comprises discussion and identification of:

- planning and policy considerations (**Section 2**);
- sites of significance within the Command Area (**Section 3**);
- environmental considerations (**Section 4**);
- major land owners (**Section 5**);
- existing infrastructure of relevance (**Section 6**);
- land resources within the Command Area (**Section 7**);
- identification of horticultural soils (**Section 8**);
- irrigation demands for different land uses (**Section 9**); and
- refinement of Command Area (**Section 10**).

1.2 Existing Command Areas

The previous two studies identified Command Areas within the Kaipara and Mid-North as shown in **Figure 1** and **Figure 2** respectively.

These Command Areas were comprised through following key features such as road and parcel boundaries that broadly encompassed the higher quality soils as derived from readily available GIS information.

In understanding that these Command Area are a starting point only our discussion herein will consider adjacent landholdings, in particular in the mid-north where the five distinct Command Areas will be considered as one.

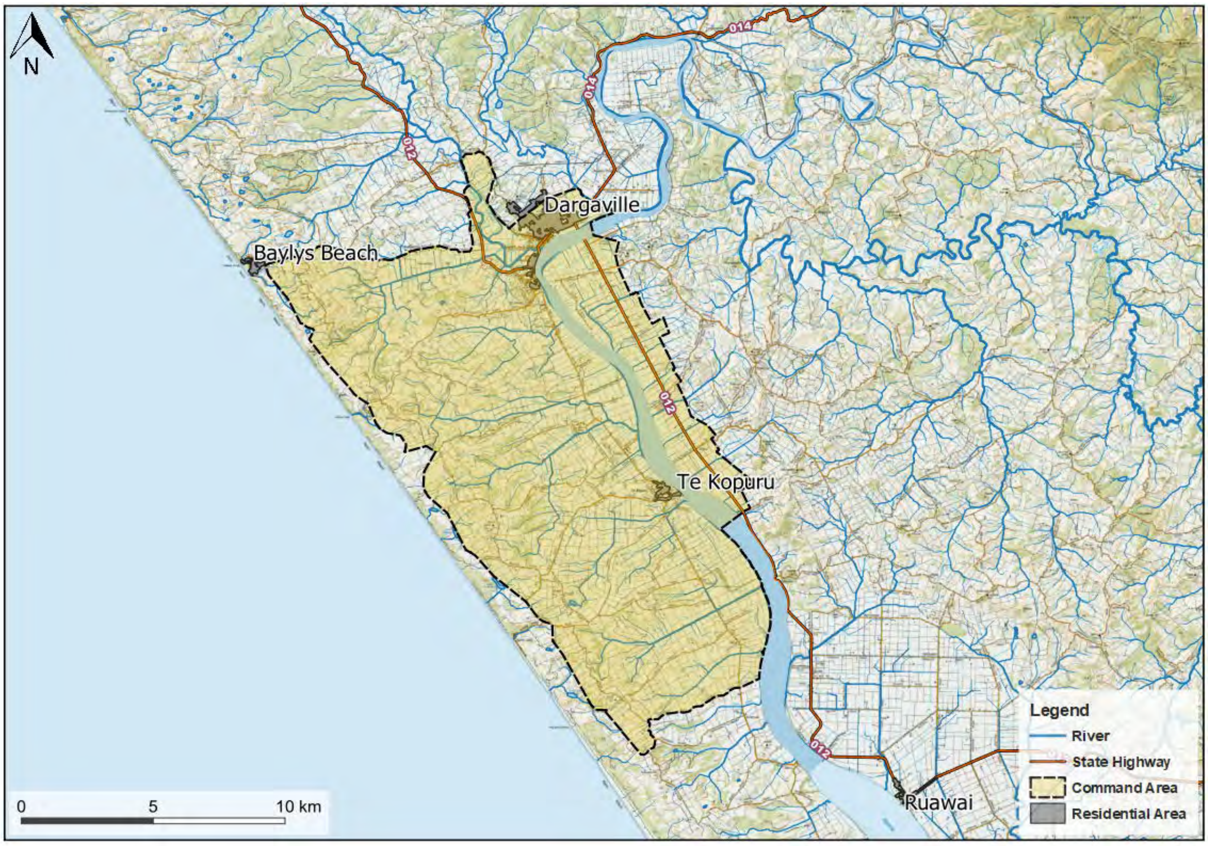


Figure 1. Kaipara Command Area.

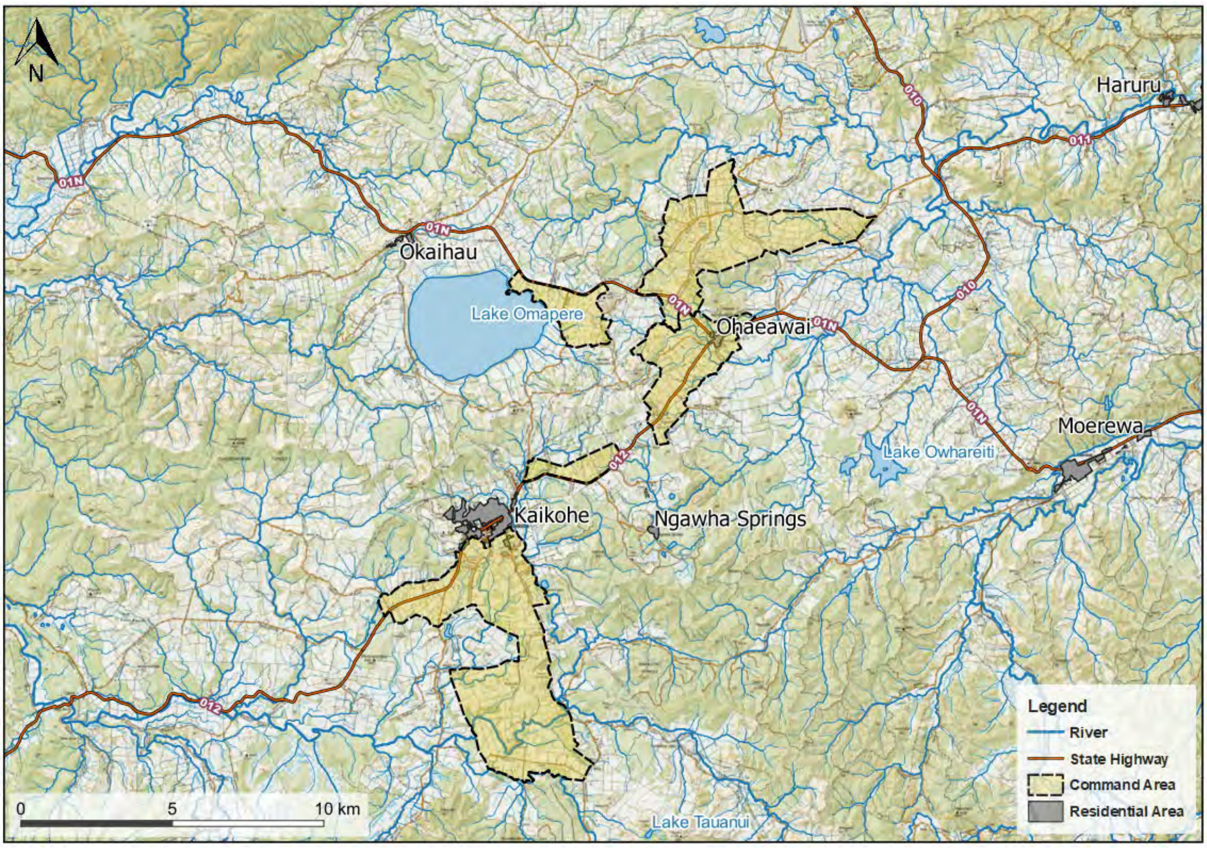


Figure 2. Mid-North Command Area.

2. Planning and Policy

This section sets out to understand high level implications the current or future regulatory environment may have on the ability for land owners to contemplate a change in land use should water become available.

This analysis does not address the like of water allocation rules, or the storage aspects of water, which are addressed in **Volume 2 – Water Resources Report.**

2.1 Northland Regional Council

Northland Regional Council oversees the use and allocation of water in the Northland Region. That use and allocation is governed by directives from Central Government (including the Resource Management Act (RMA)) which are translated into regional planning documents. The main regional document is the Operative Regional Policy Statement for Northland ('RPS') and a series of Regional Plans. At the current time, the Regional Council is transitioning from an existing set of regional plans to one consolidated Regional Plan for Northland (RPN). That transition is nearly complete.

The RPS document sets an overall direction for the region while the RPN implements the direction through a series of objectives, policies, and rules. The combination of the two documents sets out the planning and policy matters that are directly relevant to water storage and use in Northland. With regard to use and allocation of freshwater, these documents are required to give effect to national policy statements. In this case, that includes the National Policy Statement for Freshwater Management 2017. It is understood that both the RPS and RPN will require further amendments in order to give effect to this National Policy Statement.

In general, the regional planning documents do not direct activities on land. However, they are central instruments to consider when addressing the use of water as a resource. At the RPS level, the document states:

'The key pressures on Northland's fresh and coastal water resources are:

a) *Increasing demand for surface and ground water resources in some catchments;*
b) *Climate change;*
c) *Elevated levels of fine sediments, nutrients, and faecal pathogens in freshwater bodies, estuaries, and harbours, mainly from diffuse run-off and leaching from land used for primary production, eroding beds and banks of streams and rivers, historical human induced erosion, and in some areas discharges of untreated and poorly treated wastewater and stormwater.*
d) *Drainage and diversion of wetlands;*
e) *Water temperature outside of its natural ranges mainly due to the reduced extent and quality of riparian plant cover, and altered flows in streams and rivers in productive and urban environments; and*
f) *Dissolved oxygen outside of its natural ranges due to reduced riparian plant cover, excessive aquatic plant and algae growth, elevated levels of organic matter from discharges and run-off, and altered flows.*'

While these pressures on freshwater resources are identified, the RPS recognises the need to better respond to demand and use of resources as stated below:

'Northland has not effectively and sustainably managed its natural and physical resources to fully realise its economic potential and social wellbeing. Limiting factors include:

a) *Common natural resources not being used and allocated efficiently, particularly where there is significant demand;*
b) *Subdivision, use and development, particularly residential development, that compromise either:*
    i. *existing and future productive activities and use of land; or*

ii. regionally significant infrastructure;

c) *Regionally significant infrastructure not available or sufficient to support development and community needs;*

d) *Poor security of energy supply;*

e) *Degraded state and availability of natural resources;*

f) *Regulation and compliance costs deterring investment; and*

g) *Unjustified and inconsistent application of the Resource Management Act 1991 in district and regional plans.*'

These matters inter alia form the basis for the response through the Council's planning documents by way of objectives, policies, and rules. The RPN is the Regional Council's vehicle for implementing sustainable management of resources, including freshwater.

The RPN contains a number of provisions that control the use and allocation of freshwater. These include objectives addressing freshwater water quantity and quality as directed by the National Policy Statement for Freshwater Management 2017. Policies and rules in the RPN address the following relevant matters:

- Damming and diverting water;
- Taking and use of water;
- Discharges to land and water (including production land discharges); and
- Landuse and disturbance activities (including earthworks and vegetation clearance).

In reading these rules collectively, the RPN provides clear direction as to areas that should be avoided when considering water storage and allocation activities and possibly horticultural land use (in some instances). These areas are mapped and therefore easily defined, and include:

- Outstanding Natural Character Areas;
- Outstanding Natural Features;
- Sites or Areas of Significance to tangata whenua;
- Outstanding Freshwater Bodies; and
- Significant Wetlands.

It is important in the context of regional and local government to understand that there is a hierarchy. Under the Resource Management Act, any regional council planning document (such as the RPS and RPN) are required to be consistent and give effect to any national policy statement. In turn, any district council planning document is required to be consistent and given effect to any regional planning document. This emphasises the importance of getting the high-level directions contained in any National Policy Statement implemented (in both intent and action) through both the regional and district planning documents.

2.2 Far North District Council

The Far North District Council ('FNDC') has responsibility for managing land use activities. It does so through the Far North District Plan which contains objectives, policies and rules that direct both subdivision and land use activities.

The FNDC has no direct impact on water storage and use. Rather, the land use implications associated with water storage and use (such as earthworks for dam construction and associated infrastructure development, and reverse sensitivity issues associated with land use) generally fail to be considered under the District Plan.

Currently, the Far North District Plan zones much of the rural land as Rural Production Zone, which is intended to provide for rural production and horticultural activities. The exception to this is an area around Waimate North, which is encompassed within the Mid-North Command Area. A 'Waimate North Special Zone' currently covers an area around Waimate North and is defined as an area with heritage and landscape values and provides for some limited rural lifestyle subdivision. While there is no specific limitation on horticultural activities or potential water storage and use, it is an area where reverse sensitivity and/or heritage values may limit potential development.

In addition to zones, the Plan includes a number of areas and rules that address high value areas such as landscapes, natural features and indigenous vegetation. Much of these areas are mapped and readily available to view by way of Far North Maps available at https://www.fndc.govt.nz/services/fndc-maps. These are identified areas where new horticultural activities and any associated water storage and use would be more difficult to establish.

These areas need to be viewed in conjunction with those identified in the Regional planning documents as identified above. In some cases, the regional and district documents identify different areas as having the same values – where this occurs the regional planning documents take precedent at this time.

It should be noted that while the District Council does identify some sites of heritage significance and/or sites of significance to Maori in the District Plan, it is neither an exhaustive list nor necessarily accurate at the scale defined on the planning maps. The District Plan should therefore not be relied on as anything more than indicative for these areas of value. Where any land area is not shown as subject to any heritage or archaeological sites, this does not imply that such sites do not exist.

The Far North District Council is currently commencing a review of its District Plan. Information available to date indicates that this process will formally commence by way of release of a proposed District Plan in mid-2020. That process will allow an opportunity to make submissions on proposed Plan provisions and will allow an opportunity to refine existing provisions or include new ones that assist in land development and associated water storage and use. In addition, it is possible that matters such as the existing 'Waimate North Special Zone' will be removed from the Plan.

Some suggestion has been made regarding the possible inclusion of a horticulture zone although no information is available as to how that may be defined or developed at this stage. Advocating for a suitable zone that reflects a number of parameters including water available for productive land use may be an approach to pursue in conjunction with this project.

2.3 Kaipara District Council

The Kaipara District Council ('KDC') has similar responsibilities to the FNDC as a District Council. The current District Plan provisions are not highly refined in terms of mapping of high value areas such as landscapes and heritage areas.

Currently, the Kaipara District Plan identifies the majority of the Kaipara District as being zoned Rural, including the Kaipara Command Area. This zone is general in the sense that it covers both rural production and rural lifestyle development areas. There are no special zones or rural lifestyle / rural transition zones as provided for in the Far North District Plan. Reliance is therefore placed on the rules relating to the zone to control landuse, including such matters as earthworks and building development.

In considering areas where horticultural development and associated water storage and use may not be viable, reliance should be placed on the Regional planning maps to identify high value areas that should be avoided, as identified above. It is noted that, apart from the coastal margins, there are very few high value areas identified within the Kaipara Command Area. While a soil may not be versatile because it is suited to only a very narrow range of uses, it may be valuable for one or more specialist uses. Identification of these special values and protection of these soils for that purpose should form part of the 'Kaipara Kai' project.

While the Kaipara District Council does identify heritage sites on its planning maps, like Far North District Council those should not be relied on as anything more than indicative.

Advice has been sought and received from the Kaipara District Council regarding an intended review of its District Plan. That advice indicates that a review will commence in April 2020. An initial indication is that the Council may adopt a Rural Production zone with a separate zone identified for rural living / lifestyle development. Any rural living zone would likely apply on the east coast area (Mangawhai) rather than being located anywhere within the Kaipara Command Area.

Like Far North District Council, a horticulture zone has been mooted and is linked to the 'Kaipara Kai' project funded through the Provincial Growth Fund. This is an approach that should be pursued.

2.4 Central Government

Whilst at the time of this report being written feedback was being sought on proposed proposals, it is clear that the direction taken by Government will significantly influence the prospects for horticultural land use and in turn this project.

2.4.1 New Format NPS Freshwater 2019 (Replace 2017)

As expected, the NPS and in combination the NES takes freshwater management in a new direction. Economic values have been firmly placed in a lower priority position and the value of water to land has been removed from the NPS 2019.

Effectively, any growth (including urban growth) will need to be met within current attribute states everywhere, even if iwi and the local demonstration of Te Mana o Te Wai (TMOTW) suggest a growth objective is appropriate given the state of water. The only different track is for the named hydro systems and any natural exception. The structure of the NPS seems to in some way's "reward" more developed catchments as the more degraded catchments have more development options. The concept of maintaining or improving within a band has been removed.

Attention to Iwi rights and interests has been significantly elevated in the NPS 2019. It is unclear what the final content of the tangata whenua related provisions are; as an Act is required to implement this, and there will be a separate process that goes through Select Committee for some of this. The key change relates to the reinterpretation of TMOTW reflecting governance as mana whakahaere (power and authority) as opposed to kawanatanga. It is very unlikely however that there will be any ability for tangata whenua to argue a state that is lower than the existing state for any water quality parameter.

The NPS is accompanied by a draft NES. There seems to be a significant change in terms of benchmarking current or existing footprint. It is unclear how this will affect previously set benchmarks in plans. Because this translates through to the NES it will be further discussed when that instrument is discussed.

Water quality is far more comprehensive than water quantity, particularly given the content of the NES and the merging of all Objectives in prior policy statements on freshwater. There are no longer strong links requiring the adoption of limits to be efficient and effective. There are some good changes in relation to groundwater linking take limits to compulsory flows and levels to be set. This will be a challenge for many existing plans.

There are many changes to the National Standards Framework (NOF). The most significant relate to new nitrogen standards, incorporation of habitat and riparian margins, inclusion of both native and aquatic plants and fish, and new primary contact sites (e. coli). In general, it is likely that the cost of monitoring and reporting alone is likely to be a significant increase. This will fall on the community, and the NES makes it clear this monitoring and associated costs covers permitted activities as well.

There are also significant changes to the scope of application of the NPS; as marine and estuarine environments are included as receiving environments bringing the New Zealand Coastal Policy Statement into play more directly. The NPS and NES also now include wetlands and there is an effective prohibition on any destruction of wetlands or streams. Natural Resource Accounting gets increased recognition but no minimum standard. It is clear that the Government is still grappling with this key issue.

2.4.2 Proposed NES for Freshwater Management 2019

The NES provides a detailed regulatory pathway for any activity impacting a wetland or stream; and many farming activities. The application of the NES in most cases only affects activities established post commencement date of the NES.

National Rules are laid out as bottom lines. There are new rules for pastoral farming; compulsory farm plans and potentially nitrogen benchmarking. Strict control is placed on stream and wetland management (drainage, damming, diversion, take and use of water, discharge, filling, culverting, fish passage). Very large buffers from wetlands are required for many activities. Some activities such as dairy farming and intensive grazing practices are strongly regulated. Land disturbance activities have strict controls and will impact on any project not part of the exceptions framework.

Nationally significant infrastructure (tending to be facilities managed by government or highly regulated) and hydroelectric facilities are not required to meet the same conditions as other activities. There is an exemption pathway provided that allows for degradation with “offsetting” Public drainage networks and flood protection activities.

Effectively there is a strong signal that intensification of farming is to be avoided. Wetlands and streams are to be either maintained or enhanced. The definition of intensification picks certain activities as signals of intensification. These include dairy farming; intensive sheep and beef, increases in scale of irrigation and intensive stock regimes.

For horticulture the signals are as follows:

- A pathway is provided as one option for increased commercial vegetable production with consent. The other option proposed is no increase. The Government is seeking feedback on which option to choose.
- For commercial vegetable production, if a “no increase” framework is picked, a nitrogen assessment will probably be required.
- The increase of irrigation area beyond 10 hectares requires consent as a discretionary activity under the proposal. Increase will require a FEP and will need to meet other conditions.
- Construction of schemes may be impacted by the land disturbance and wetland rules if they are not signalled as projects deserving national significance or exception.
- There is no clear regulatory pathway for land use change to permanent horticulture. It is unclear how the NES applies to these conversions.
- There is still a clear signal that allocation of water quality (in particular nitrogen discharges is a next step the Government wishes to take.

3. Sites of Significance

Command areas in both the Kaipara and the Mid North are dotted with sites of significance that need to be considered in the development of a scheme. These include, but are not limited to:

- Culturally Significant Sites;
- Archaeological Sites;
- Marae;
- Cemeteries;
- QEII Covenanted Land; and
- Top Wetlands.

Figure 3 (Kaipara) and **Figure 4** (Mid North) show these sites spatially in respect to the command areas.

Figure 3. Sites of Significance Map for Kaipara. (Refer A3 attachment at rear).

Figure 4. Sites of Significance Map for Mid-North. (Refer A3 attachment at rear).

It is clearly evident that there are significantly more sites of significance in the Mid-North than the Kaipara which could pose challenges of unknown magnitude at this point in time. This being said, given the size of the command areas, there is no reason to expect that any sites of significance could not be duly respected by land owners during the land development and undertaking of general farming practices so as not to cause disturbance.

Whilst there are legislative requirements around environmental impacts, and water quality (such as setbacks from water bodies or wetlands) there is minimal control on the aesthetics or farming and horticulture developments outside of buildings i.e. pergola structures for kiwifruit could very quickly cover a large area but not require any permissions.

Water storage may or may not be development within the command areas. Care would need to be taken to avoid where at all possible inundation of any sites of significance regardless of location and would need to be a key consideration of any consenting process.

4. Environmental Opportunities

It is important to realise that the provision of a reliable water supply for the primary purpose of irrigation does not instantly mean a decrease in water quality and or availability during summer months.

There are a number of environmental benefits that may be enabled by the carefully planned development of a community water storage scheme and the change in land use that is enabled. These may arise through several direct or indirect pathways, including;

- the physical presence of the water storage features (e.g. increase in aquatic habitat or changes in water table);
- switching water takes from sensitive systems (e.g. dune lakes) to the water storage features; and
- changes in land management, including retiring marginal areas and planting shelterbelts.

NRC currently have several projects, or initiatives, underway targeting positive water quality and biodiversity that could be directly aligned with development within the Command Areas of interest, namely;

- Farm Environment Plans;
- Farm Water Quality Improvement Plans;
- Waimā Waitai Waiora;
- Kaipara Hill Country Erosion Project; and
- Dune Lake Restoration Projects.

Figure 5 and **Figure 6** provide an overview of key environmental features with the Command Areas.

Figure 5. Environmental Features Map for Kaipara. (Refer A3 attachment at rear).

Figure 6. Environmental Features Map for Mid-North. (Refer A3 attachment at rear).

4.1.1 Water Storage Features

The physical presence of water storage features within the Command Areas, whether it be scheme storage or on farm storage, provide permanent and temporary habitats for aquatic species. The location of the water demand areas could be considered favourable in this regard as they are surrounded by wetland systems some of which have high biodiversity values as identified by NRC.

For example, the Kaipara Command Area is located between the Manganui River Complex and the wetland areas of Kaihu Forest, Lakes Taharoa and Waikere, and the Maitaihi and Awakino Wetlands. Similarly, the Mid-North Command areas are encircled by a series of wetland habitats, including Rakautao Bush, Ngawha Geothermal Area and the Titihuatahu Wetland to the south, Lake Omapere immediately to the north, with the headwater wetlands of the Hokianga Harbour and Puketi Wetland further north.

Many of these wetlands were ranked highly in an assessment of Northland's wetlands (Wildland Consultants, 2011) and the aquatic habitat provided by water storage features would provide two potential benefits for wetland species in these areas. First, the wetlands provide new freshwater habitat that extends the areas of aquatic habitat that may be permanently used by aquatic species. Second, the new freshwater features would serve as corridors or staging points to facilitate the movement of aquatic species between different aquatic habitats.

Together these two benefits may begin to address the loss and fragmentation of wetland habitats, which has been linked to the decline of wetland species across New Zealand. In particular, there are several threatened bird species found in Northland's wetlands that could benefit from an increased extent and connectivity between aquatic habitats. These include the 'Nationally Critical' Australasian bittern and grey duck, the 'At Risk' spotless crake, marsh crake and North Island fernbird along with several species of lower conservation interest.

In addition to the habitat that would be provided by the water storage features, the presence of the features would also contribute to positive changes in the water table for nearby aquatic habitats. Changes to the hydrological regime of wetlands is the biggest threat to such ecosystems (Kingsford et al, 2016), which are manifested through lowered water tables and reductions in wetted extent. This is a recognised issue for Northland's dune lakes, including those on the Poutō Peninsula, where water levels are monitored to help manage lake levels and the associated environmental effects (NRC, 2017).

4.1.2 Maintenance of Low Flow

One of the key opportunities that could arise from the development of appropriately sized storage is a more constant minimum flow regime that is less subject to the extreme low flow conditions associated with drought.

The maintenance of a higher minimum flow can result in more stable habitat for the downstream aquatic ecosystems, enabling a healthier and richer aquatic ecosystem biodiversity to thrive.

If streams or rivers are utilised for conveyance of water i.e. flow augmentation it may be possible to increase these flows in localised areas only without specifically having water allocated for environmental reasons.

These opportunities generally will require the construction of additional storage capacity specifically to support these environmental flows. Whilst not allowed for within this phase of the project, these opportunities could be an important consideration in gaining future community buy in and required consents.

4.1.3 Water Takes

The potential switching of water takes from sensitive natural systems to purpose built water storage infrastructure would reduce some of the stress on the natural systems currently impacted by water takes. This includes the dune lakes, but also wetlands and rivers that may be have water takes in their catchments.

Northlands dune lakes are currently the most accessible source of water for "permitted" takes, such as stock drinking water, however NRC monitoring is showing some lakes with declining trends in water level (NRC, 2017a).

4.1.4 Land Use Change and Management

The presence of more secure water sources may enable changes in land management practices that could provide positive environmental effects, for example:

1. A more secure source of water could lead to a high value land use, which in turn on the basis of whole-of-farm profitability often means a lesser requirement to utilise every area of land for production. A more selective use of land, whereby the productivity of land with a high suitability for production is maximised, whilst retiring marginal or sensitive land, could see overall productivity maintained or increased while providing for environmental improvements. This could lead to wider buffers around sensitive waterbodies, and the retiring of 'critical source areas' (CSA).

   Much research in agricultural landscapes has focussed on identifying these areas, from which a disproportionate contamination load is observed compared with the surrounding landscape. Identifying these areas and retiring them can potentially significantly reduce contaminant loads, whilst allowing production to be maximised on the more suitable land around them (McDowell *et. al.*, 2019). The security of a water supply could allow more flexibility to retire CSAs, which in turn would reduce sediment and nutrient losses to nearby aquatic systems. This is a key issue in the freshwater habitats of Northland, with elevated nutrients occurring in a number of lakes and rivers monitored by NRC (2017a; 2017b), including non-compliance with bottom lines described in the National Policy Statement: Freshwater Management (2017). The retirement of these CSAs could also provide for biodiversity benefits if the areas were re-vegetated with native plantings.

2. Changes in land management associated with new productive uses or areas could see the creation of shelterbelts. While the primary purpose of shelterbelts is to protect pasture, crops and stock from the elements, they can provide a range of secondary benefits. These include benefits related to the productive use of land (i.e. habitat for beneficial insects that pollinate crops or predate on agricultural pests), but also to wider biodiversity outcomes. For example, shelterbelts with mixed native plantings can provide significant biodiversity benefits in agricultural landscapes through habitat provision and migration pathways for native insects and birds (Brown et al, 2012; Blackwell et al, 2008; Norton & Miller, 2000).

5. Land Ownership

In both of the Command Areas there is a mix of ownership (privately owned, company owned, or publicly owned) and title types i.e. General Titles or Maori Freehold Land (MFL), as shown in **Figure 7** and **Figure 8**. Of particular note is the difference in numbers of MFL in the Mid-North compared to the Kaipara.

Figure 7. Land Ownership Map for Kaipara. (Refer A3 attachment at rear).

Figure 8. Land Ownership Map for Mid-North. (Refer A3 attachment at rear).

5.1 General Title Land

General title land and ownership makes up the majority of the land holdings in both the Kaipara and the Mid-North Command Areas, 95% and 70% respectively.

Within the Kaipara approximately 80% of this resides within the largest 100 land owners, ranging in size from 50 ha to 760 ha.

Similarly, in the Mid-North over 80% of the General Title land, ranging in size from 14 ha to 650 ha, is owned by the largest 70 land owners. Over 50% of the total land holdings is in the largest 20 land owners. This indicates that there is a select group of larger land owners that will potentially have a significant effect on scheme uptake and subsequent scale and shape.

5.2 Maori Freehold Land

One of the key investment principles of the PGF in this project is that water storage will help address disparities in Māori access to water for land development.

Analysis of the Command Area indicated that there was only one significant block of MFL in the Kaipara Command Area - OTUREI M10C, which is slightly under 300 ha in area.

The Mid-North however is very different with approximately 1000 ha of MFL in over approximately 600 trusts or individual ownership. It should be noted there is one significant land owner in the form of Omapere Rangihamama Trust, who own over half of this area just south of Kaikohe, and have over 3,000 shareholders.

The other most significant concentration of MFL is located to the south west of Kaikohe, where land parcels are not large on their own, but collectively may provide scale.

In 2015 a report was commissioned by MPI that considered opportunities to bring MFL into production within both a 30 km and 50 km radius of Kaikohe. The study stated that:

"providing opportunities for the future development of Maori freehold land in the Mid-North is the initial step required to create an environment that will enhance the health, wealth and wellbeing of the whenua and the local community".

Within this document, water and associated infrastructure were specifically identified as a key to this being achievable. It is understood that delivering water into this area as part of this project is potentially a priority, however it needs to be acknowledged that water is only a piece of the "puzzle" and should not be considered a "silver bullet". Water however will provide these land owners with opportunities that did not exist or were constrained previously.

5.3 Discussions with Land Owners

Discussions have been had with many of the larger General Title landowners identified above, and local horticultural industry participants, to gauge interest in this project and better understand the community's position on this project and the potential opportunities perceived.

The following outlines the key messaging taken from the discussions that occurred in October and November 2019:

- There appears to be genuine interest of the potential that could be realised within communities from the majority of land owners should a water storage scheme be progressed successfully.
- This potential for horticulture growth in Tai Tokerau has been ratified by the comments and feedback received from discussions with the industry, which is generally willing to help.
- Expansion of Kiwifruit, Avocado, Berries and Market Gardening industries appear most likely in the short term should water be available. Of particular note is the belief in the suitability of the potential for Avocado in the Kaipara, and Kiwifruit in Kaikohe.
- There was a general consensus that those currently on the land would unlikely be the "users" of the water should it be available, with water bringing the need for significant capital and skills that would need to come from "off farm".
- Whilst most parties indicated they would undertake due diligence on any opportunity, there was quite a number who would never sell, but would consider developing in partnership or leasing their land to someone who has the "capital and skills".
- There is a trend of existing grower entities becoming bigger and that capital will be coming from outside of Northland. There is evidence of this through recent land sales and through discussions with real estate agents. This being said, participation of local iwi in the industry, particularly in the mid north, is seen important moving forward by most.
- The parties identified that are close to potentially being "ready to go" are spatially fragmented. For example, there is an equity partnership at the eastern end of Waimate North and a large corporate owned farm 8 kms south of Kaikohe, both currently considering horticulture options on their property that expressed a real interest in collaboration on this project.
- In almost every instance, the availability of a reliable water source was seen as a mechanism to not only future proof their farming enterprise, but as a means to allow options and diversification to be considered.
- In the Kaipara, most land owners had contemplated how water could change their farming system and many have "had a look" on their own property before, albeit historically for pastoral irrigation. This was not the case in the Mid-North unless they were actively involved in, or seeking to enter, the horticulture sector.
- In the Kaipara, the ability to utilise water to guarantee the production of existing farming enterprises is seen as a key enabler to allowing transitional change of land use over time. It was clear in land owner thinking that this does not mean more cows but the ability to guarantee crop establishment and guarantee a certain amount of pasture.

Discussions with landowners were still commencing at the time of this report being compiled. **Volume 4** provides further detail and analysis in regards to uptake potential and demand.

6. Existing Infrastructure and Potential Co-benefits

"Fresh water resources are essential for the growth of Northland. Drought and flood events are becoming increasingly common and there is a need to be able to manage these extremes whilst supporting the development of industries to which water is essential including agriculture and horticulture" (Tai Tokerau Northland Economic Action Plan, 2016).

6.1 Kaipara

Dargaville is the main urban centre of the Kaipara District, and has a need for an adequate water supply for urban residential (potable) use, and urban commercial and industrial use. The demand for urban water for residents is unlikely to increase significantly unless there is increase in industrial or commercial activity in Dargaville in future.

A key point raised by stakeholders in the Kaipara District is the need for a larger, more secure water supply for Dargaville (including Baylys Beach).

The existing raw water supply is surface water from the Waiparataniwha Stream and the larger Kaihu River in the drier months. However, this scheme arrangement often leads to a restricted water take when the Kaihu River flows fall below consented trigger levels commencing at 755 L/sec.

The Dargaville raw water main also includes untreated raw water connections to approximately 116 rural landowners along its approximately 22 km route, providing a valuable source of water for agriculture purposes.

The largest industrial user of water in Dargaville is the Silver Fern Farms (SFF) cattle slaughter and processing plant, which uses approximately 25% of the water demand for Dargaville.

Other wet industry includes kumara packing facilities, which together with SFF and the current residents, consume all of the currently available potable water. During dry periods, demand exceeds the available supply resulting in the imposition of water saving initiatives and restrictions by Council. This places additional pressure on SFF whose demand generally increases during these dry periods as farmers send their stock to the freezing works due to lack of water and feed.

The ability of Dargaville in the future to provide the quantity of water at sufficient quality to retain and if possible, attract additional industries is an important consideration. Water is a key enabler for providing a viable outlet for primary producers in the area, as well as providing employment opportunities for the people in the town and surrounding areas.

Figure 9. Kaipara Existing Infrastructure Map. (Refer A3 attachment at rear).

6.1.1 Kaipara District Council Infrastructure

The Kaipara Command Area includes Council-owned public infrastructure that needs to be considered when assessing the location of any new water storage infrastructure.

The Dargaville and Te Kopuru urban area has a formed roading network (includes State highways and local roads), and underground reticulated water supply, wastewater and stormwater infrastructure. Other above and below-ground utility infrastructure such as power and telecommunications are also present.

Dargaville has well developed flood protection infrastructure in the form of stopbanks with outlet structures and tidal gates, predominantly parallel to the Northern Wairoa River and also along the tidally influenced tributaries.

The rural area within the Kaipara Command Area has a formed roading network (includes State highways and local roads), and other above and below-ground utility infrastructure such as power and telecommunications.

This rural area also includes Council-maintained land drainage schemes with associated land drainage infrastructure that includes a network of open drains, stopbanks and outlet structures with tidal gates. These stopbanks and outlet structures are predominantly parallel to the Northern Wairoa River on both the east and west banks, and with some stopbanks running inland along the tidally influenced tributaries. The network of open channels drain to the outlet structures.

6.1.2 Mutually Beneficial Opportunities

The following mutually beneficial opportunities have been identified:

- Greater quantity of volume drought proof raw water supply for Dargaville and Baylys Beach, preferably located as close to Dargaville as possible.
- Community water supply scheme raw water source for Te Koporu.
- Any modelling of the Kaihu River flows (taking into account climate change predictions) could provide information to support a Council application for an increased raw water take during low-flow periods, and also assist in quantifying future risks to the water source e.g. increased periods of drought, changes to the Kaihu River's fresh/salt water interface due to increased sea levels, etc.
- Recreational use of water storage dams and adjoining margins r e.g. picnicking, and water activities such as fishing, swimming, sailing, kayaking, waka ama, water skiing etc. noting that powered water craft are limited to only one lake (Lake Taharoaat the Kai Iwi lakes). One of the Environment objectives of the 'Reserve Management Plan Kai Iwi Lakes (Taharoa Domain) 2016' is 'To stop the release of exotic fish (trout) by 2018 into Lakes Taharoa and Waikare, but consider re-releasing trout if native species numbers are seen to decline in their absence'. This is currently under review and may in future lead to the prohibition of trout being released into the lakes. An alternative water storage dam/s could provide alternative trout fishing opportunities.
- Whilst not a primary design element in this project, water storage dams can be designed to provide mitigation of downstream flooding from large storm events.

6.1.3 Municipal Water Demand

Dargaville's population increased from 4,251 in 2013 to 4,794 in 2018 (Stats NZ) i.e. 2.43% growth per annum. Peak water demand recorded by KDC in Dec/Jan 2016/17 was 3,930 m^3/day.

Allowing for continued growth, and an additional allowance for future commercial and industrial demand, potable water demand could rise to 8,000 m^3/day in 2069. This includes an allowance of 2,700 m^3/day for future commercial/industrial use.

Assuming no surface water was available due to a significant drought, it is estimated that a storage volume of 700,000 m^3 would be required to ensure an unrestricted water supply to Dargaville in 2069, or alternatively an estimated storage volume of 530,000 m^3 would be required assuming water restrictions were to be imposed.

The above assumption is considered conservative, as to our knowledge KDC has not had to cease taking water from the Kaihu River before.

6.1.4 Long Term Plan Budgets

Kaipara District Council's (KDC's) Long Term Plan 2018/2028's (LTP) Water Supply Activity Statement identifies the key risks and issues, which include the following:

- 'Dargaville water supply has drought risks and the security of supply for Dargaville is challenging during dry years.'
- The option to construct a raw water pipeline (estimated cost $2.8 million) from the Waiatua Dam (Opanake Road) to Dargaville to improve security of supply for the Dargaville and Baylys community during moderate droughts has been included in Council's Infrastructure Strategy 2018/2048. Variations to the existing water take resource consents would be required to support this initiative.

KDC's LTP (page 111) includes a total of $3.016M (escalated) in the 2021/22 ($1.490M) and 2022/23 ($1.526M) financial years for level of service (LoS) improvements to mitigate these risks, as shown in **Figure 10**.

Prospective Infrastructure Strategy Costs - Water Supply - adjusted for inflation

For the year ended: 30 June	Budget 2018-2019 $'000	Budget 2019-2020 $'000	Budget 2020-2021 $'000	Budget 2021-2022 $'000	Budget 2022-2023 $'000	Total Budget 2018-2023 $'000	Budget 2023-2024 $'000	Budget 2024-2025 $'000	Budget 2025-2026 $'000	Budget 2026-2027 $'000	Budget 2027-2028 $'000	Total Budget 2023-2028 $'000
Operating expenditure												
Total operating expenditure	2,317	2,365	2,412	2,376	2,510	11,980	2,642	2,674	2,721	2,768	2,821	13,627
Capital expenditure												
Capital Expenditure - Growth	0	0	0	0	0	0	0	0	0	0	0	0
Capital Expenditure - LoS	13	13	13	1,490	1,526	3,054	14	14	15	15	16	74
Capital Expenditure - Renewal	1,866	1,825	1,471	1,443	762	7,366	3,407	2,793	3,802	2,333	3,551	15,886
Total capital expenditure	1,878	1,838	1,485	2,932	2,288	10,420	3,421	2,808	3,817	2,348	3,567	15,960
Total expenditure	4,195	4,203	3,896	5,309	4,797	22,400	6,063	5,481	6,538	5,117	6,388	29,587

Figure 10. KDC water supply planned capital expenditure.

Subject to KDC's approval, the funds indicated in **Figure 10** could be reallocated to jointly fund a reservoir and any associated raw water pipeline that would provide security of supply to the Dargaville and Baylys Beach communities for the foreseeable future.

The volume of water that KDC would be requiring could be approximately 5% of the total scheme storage which means, assuming that the contribution to capital cost would be a pro-rata contribution, that the currently allocated funds may be sufficient i.e. if the scheme cost $60m, 5% of this would be $3m.

6.2 Mid-North

The Kaikohe Water Supply is owned by Far North District Council (FNDC) and currently sourced from bores in a volcanic cone and a stream fed small dam, which is recognised as inadequate to support current peak demands.

The Kaikohe Water Supply Scheme also supplies Ngawha Prison, which has increased its water demand (the prison includes water-intensive programmes such as horticultural) and thereby exacerbating the water supply demand pressures.

Top Energy, a local electricity generation and lines network company, is intending on expanding geothermal energy generation at its existing Ngawha power station site. The development of complementary businesses adjacent to the power site is likely i.e. Ngawha Park. It is anticipated that these businesses may be high energy users such as wood processing, which will have a need for a reliable water supply.

FNDC is keen to support the proposed industrial park as it would provide obvious economic benefits to the region including employment opportunities for the locals. They have also indicated an interest in any co-benefits that water storage infrastructure would provide to supply Kaikohe, but would need to have inclusive ownership to ensure an agreed priority of supply.

Figure 11. Mid-North Existing Infrastructure Map. (Refer A3 attachment at rear).

6.2.1 Far North District Council Infrastructure

The Mid-North Command Area includes Council-owned public infrastructure that would need to be considered when assessing the location of any water storage infrastructure.

The Kaikohe urban area has a formed roading network (includes State highways and local roads), and underground reticulated water supply, wastewater and stormwater infrastructure. Other above and below-ground utility infrastructure such as power and telecommunications are also present. The wastewater treatment plant servicing Kaikohe discharges to a natural waterbody that flows through the Command Area to the west coast. There is also an airfield south of Kaikohe within the Command Area.

The rural area has a formed roading network (includes State highways and local roads), and other above and below-ground utility infrastructure such as power and telecommunications.

6.2.2 Mutually Beneficial Opportunities

The same mutual benefits as identified for the Kaipara Command area apply to the Mid-North Command Area, with the exception of fishery opportunities associated with the Kai Iwi lakes

The specific additional demand worth noting is that of the proposed Ngawha Innovation and enterprise park being development by Far North Holdings Limited (FNHL). Discussions with FNHL have indicated that 200,000 m3 would be considered sufficient to meet the parks immediate needs.

6.2.3 Municipal Water Demand

Kaikohe's population is predicted to decrease (Stats NZ). Peak water demand recorded by FNDC was 2,888 m^3/day in 2018.

Conservatively assuming the domestic demand stays the same, and allowing an additional nominal allowance of 1,500 m^3/day for future commercial and industrial growth, this could rise to approximately 4,500 m^3/day by 2069.

Assuming no ground or surface water was available due to a significant drought, it is estimated that a storage volume of 550,000 m^3 would be required to ensure an unrestricted water supply to Kaikohe in 2069, or alternatively an estimated storage volume of 280,000 m^3 would be required assuming water restrictions were to be imposed.

6.2.4 Long Term Plan Budgets

FNDC's Long Term Plan 2018/2028's (LTP) Infrastructure Strategy identifies 'Resilience and climate change' (page 43) as one of the key infrastructure issues, and state the following (pages 44 & 45):

- *'Council operates a number of water takes that rely on small surface water sources. These are extremely sensitive to dry weather, and climate change may result in an increased risk of drought related water shortages. Larger schemes will also start to come under pressure in terms of their capacity to service the* *district, particularly in areas that are experiencing population growth or are significant tourist destinations (e.g. Kerikeri and Paihia). Increased demand from direct water connections during dry conditions is not just a tourist or growth related issue. Households that rely on roof water collection are also reliant on bulk water tanker supplies at times when water supplies are already under pressure from dry conditions.'*

Council's strategy is to support economic growth by (page 47):

- *'Continuing to investigate the role Council can play in the delivery of investment into irrigation schemes at strategic locations, particularly in and around Kaikohe.'*

As noted above, any water storage infrastructure providing both a secure raw water supply for the Kaikohe Water Supply Scheme, and for irrigation purposes would be mutually beneficial.

FNDC's current Long-Term Plan (LTP) has recognised managing potable water peak demand associated with growth around Kerikeri, and the construction of a new water treatment plant for Pahia as high priorities. At the current time, there is no funding allocation to provide a more secure raw water source for Kaikohe. Any funding proposed would need to be included in the next 2022-32 LTP for Council's consideration as part of the triennial review of its LTP.

7. Land Resources

7.1 Soils

Given the wide variety in soil types and complex distribution across Northland, a greater level of detail is required than from the readily available fundamental soils layer (FSL) and NZMS 1 series maps

The level of detail required needs to be 1:10,000 rather than 1:100,000, which is considered suitable for broad scheme planning, design purposes, or determination of irrigable areas. Brief field surveys have been undertaken by AgFirst, in accordance with the mapping methods described in the Land Use Capability Survey Handbook, to enable soil use data to be generated to this level of detail.

Table 1 and **Table 2** (in the following sections) outline the soil types within the Command Area as mapped by AgFirst compared to the soils identified from the FSL during the previous studies. As these Command Areas will be further refined during this study, the field work was undertaken to the outer extremity of the more suitable soils and topography for horticulture.

Section 8 discusses the implication of these soil types for horticulture.

7.1.1 Kaipara

In the Kaipara Command Area:

- Kaipara Clay and Clay Loam account for approximately 27% of the area in both the FSL and mapped soil surveys.
- Te Kopuru Sand was also found to be prevalent in both surveys, however more so in the FSL soil layer, whereas the AgFirst found some of this area to be Tangitiki Sandy Loam and Sand, or frequently a combination of the two. These two soil types together accounted for approximately 45% of the Command Area in the AgFirst survey and 38% of the area in the FSL soils layer. As indicated above, the implication of this difference is discussed in **Section 8**.
- The Red Hill Sand and Red Hill Sandy Loam accounted for 16% and 17% of the land area in the AgFirst and FSL soil surveys, respectively.

Table 1. Soil types in the Kaipara Command Area as mapped by AgFirst and as defined in the Fundamental Soils Layer.

Soil Description	AgFirst Mapped		FSL	
	Area (Ha)	Percent of Area	Area (Ha)	Percent of Area
Parore Peaty Sand	1,415.4	7.2%	1,735.4	8.4%
Tangitiki Sandy Loam and Sand	4,361.4	22.1%	2,248	10.8%
Pinaki Sand	1,57	0.8%	186.9	0.9%
Kaipara Peaty Clay Loam	6,22.3	3.2%	636.1	3.1%
Te Kopuru Sand, wet phase	4,463.4	22.7%	5,622.2	27.1%
Pinaki Sand/ Tangitiki Sandy Loam and Clay	21.8	0.1%	0	0.0%
Kaipara Clay and Clay Loam	5,346.3	27.1%	5,667.8	27.3%
Red Hill Sand	3,148.2	16.0%	2,856	13.8%
Red Hill Sandy Loam	0	0.0%	650.3	3.1%
Waitemata Silt Loam	10	0.1%	0	0.0%

Soil Description	AgFirst Mapped		FSL	
	Area (Ha)	Percent of Area	Area (Ha)	Percent of Area
Kara Silt Loam	25.3	0.1%	23.8	0.1%
Sand over Parore Peaty Sand	0.9	0.0%	0	0.0%
Coastal Cliffs	0	0.0%	0	0.0%
Pinaki Sand and Dune Sand 1960s	60.1	0.3%	0	0.0%
Okaka Clay and Silty Clay	3.6	0.0%	5.6	0.0%
Kaipara Clay and Clay Loam Urban	58.6	0.3%	0	0.0%
Sand over Parore Peaty Sand 1970s	2.6	0.0%	0	0.0%
Rockvale Clay	0	0.0%	25.3	0.1%
Town	0	0.0%	269.3	1.3%
River	0	0.0%	793.5	3.8%
Bedrock	0	0.0%	16.6	0.1%

Figure 12 provides the FSL map for the Kaipara Command Area and by way of comparison **Figure 13** provides and updated soils map using the ground truth work undertaken by AgFirst. The later forms the basis of ongoing analysis.

Figure 12. FSL Map for Kaipara. (Refer A3 attachment at rear).

Figure 13. Ground truthed soils map for Kaipara. (Refer A3 attachment at rear).

7.1.2 Mid-North

In the Mid-North Command Area:

- Waiotu Friable Clay is the most prevalent soil type in both the AgFirst survey (21%) and FSL soil layer (28%).
- Kiripaka Bouldery Silt Loam, which in some areas consisted of compact subsoil and large boulders, accounted for 20% and 22% of the focus area in AgFirst survey and FSL layer, respectively.
- Waimate Clay Loam accounts for 19% and 17% in AgFirst survey and FSL layer, respectively.
- Other prominent soil types were Ohaeawai Silt Loam and Whakapai Clay Loam (combined with Whakapai Friable Clay in the AgFirst survey).

Table 2. Soil types in the Mid-North Command Area as mapped by AgFirst and as defined in the Fundamental Soils Layer.

Soil Description	AgFirst Mapped		FSL	
	Area (Ha)	Percent of Area	Area (Ha)	Percent of Area
Aponga Clay	34.7	0.7%	78.1	1.5%
Kamo Clay and Loam	5.8	0.1%	1.8	0.0%
Kara Silt Loam	0	0.0%	41.8	0.8%
Kiripaka Bouldery Silt Loam	579.9	11.4%	638.7	12.4%

Soil Description	AgFirst Mapped		FSL	
	Area (Ha)	Percent of Area	Area (Ha)	Percent of Area
Kiripaka Bouldery Silt Loam with Compact Subsoil and Large Boulders	444.9	8.7%	500	9.7%
Mangakahia Mottled Clay Loam	12	0.2%	8.6	0.2%
Ohaeawai Shallow Bouldery Silt Loam	5.9	0.1%	10.3	0.2%
Ohaeawai Silt Loam	829.2	16.3%	768.7	14.9%
Okaihau Gravelly Friable Clay	0	0.0%	0	0.0%
Otonga Peaty Clay Loam	8.6	0.2%	12.5	0.2%
Papakauri Silt Loam	14.6	0.3%	3.7	0.1%
Parahaki Fine Sandy Loam and Silt Loam	0	0.0%	0.4	0.0%
Ruatangata Friable Clay	49	1.0%	33.9	0.7%
Waimate North Clay Loam	961.6	18.9%	878.8	17.0%
Waiotu Friable Clay	1,056.5	20.8%	1,418.5	27.5%
Waipu Clay	0	0.0%	4.3	0.1%
Whakapai Clay Loam	67.5	1.3%	594.2	11.5%
Whakapai Clay Loam + Whakapai Friable Clay	479.1	9.4%	0	0.0%
Wharekohe Silt Loam	1	0.0%	2.5	0.0%
Mangakahia Clay	0	0.0%	21.1	0.4%
Okaka Clay and Silty Clay	18.6	0.4%	4.4	0.1%
Town	0	0.0%	87.9	1.7%
Wharekohe Sandy Loam	0	0.0%	0	0.0%
Puketitoi Sandy Loam	0	0.0%	13.2	0.3%
Hukerenui Silt Loam	0	0.0%	37.8	0.7%
Lake	0	0.0%	2	0.0%
Apotu Friable Clay	17	0.3%	0	0.0%
Hukernui Silt Loam	46.9	0.9%	0	0.0%
Kiripaka Bouldery Silt Loam - Urban	169.2	3.3%	0	0.0%
Mangakahia Silt Loam and Clay Loam	86.2	1.7%	0	0.0%
Otaha Clay	22.9	0.4%	0	0.0%
Waipapa Clay	2.1	0.0%	0	0.0%
Wetland	1.8	0.0%	0	0.0%
Whakapara Mottled Clay Loam	5	0.1%	0	0.0%
Undefined	171.4	3.4%	0	0.0%

Figure 14 provides the FSL map for the Mid-North Command Area and by way of comparison **Figure 15** provides and updated soils map using the ground truth work undertaken by AgFirst. The later forms the basis of ongoing analysis.

Figure 14. FSL Map for Mid-North. (Refer A3 attachment at rear).

Figure 15. Ground truthed soils map for Mid-North. (Refer A3 attachment at rear).

7.2 Landcover

7.2.1 Kaipara

Land cover over the Kaipara Command Area, as defined in the New Zealand Land Cover Database, is shown in **Figure 16** and summarised in **Table 3**. High Producing Exotic Grassland is the dominant land cover, accounting for 80% of the land area. The second most prevalent land cover is Short Rotation Cropland, covering approximately 8% of the focus area.

Figure 16. FSL Map for Kaipara Command Area. (Refer A3 attachment at rear).

Table 3. Land cover classifications in Kaipara Command Area.

Land Cover Classification	Area (ha)	Percentage of Total Area
High Producing Exotic Grassland	16,625.5	80.2%
Surface Mine or Dump	1.8	0.0%
Exotic Forest	504.4	2.4%
Lake or Pond	28.2	0.1%
Herbaceous Freshwater Vegetation	77.8	0.4%
Built-up Area (settlement)	336.6	1.6%
Urban Parkland/Open Space	63.6	0.3%
River	659.4	3.2%
Short-rotation Cropland	1,696.3	8.2%
Estuarine Open Water	162.9	0.8%
Low Producing Grassland	78.7	0.4%
Gorse	64.6	0.3%
Manuka and/or Kanuka	184.8	0.9%
Broadleaved Indigenous Hardwoods	69.4	0.3%
Mixed Exotic Shrubland	44.1	0.2%
Matagouri or Grey Scrub	8.4	0.0%
Deciduous Hardwoods	17.3	0.1%
Indigenous Forest	113.3	0.5%
Orchard, Vineyard or Other Perennial Crop	0.0	0.0%
Forest - Harvested	0.0	0.0%
Total	20,737.1	100%

7.2.2 Mid-North

Land cover for the Mid-North Command Area, as defined in the New Zealand Land Cover Database, is shown in **Figure 17** and summarised in **Table 4**. The High-Producing Exotic Grassland is the dominant land cover, accounting for 83% of the Mid-North Command Area. The second most prevalent land cover type is Indigenous Forest, covering approximately 5% of the focus area.

Figure 17. FSL Map for Mid-North Command Area. (Refer A3 attachment at rear).

Table 4. Land cover classifications in Mid-North Command Area.

Land Cover Classification	Area (ha)	Percentage of Total Area
High Producing Exotic Grassland	4,277.7	82.8%
Surface Mine or Dump	2.6	0.1%
Exotic Forest	119.9	2.3%
Lake or Pond	10.4	0.2%
Herbaceous Freshwater Vegetation	3.7	0.1%
Built-up Area (settlement)	64.7	1.3%
Urban Parkland/Open Space	86.5	1.7%
River	0.0	0.0%
Short-rotation Cropland	92.4	1.8%
Estuarine Open Water	0.0	0.0%
Low Producing Grassland	3.2	0.1%
Gorse	103.5	2.0%
Manuka and/or Kanuka	6.8	0.1%
Broadleaved Indigenous Hardwoods	19.4	0.4%
Mixed Exotic Shrubland	4.7	0.1%
Matagouri or Grey Scrub	0.0	0.0%
Deciduous Hardwoods	10.6	0.2%
Indigenous Forest	280.8	5.4%
Orchard, Vineyard or Other Perennial Crop	72.5	1.4%
Forest - Harvested	4.1	0.1%
Total	5,163.4	100%

7.3 Slope

LIDAR information supplied by NRC was utilised to determine land elevation and slope at a 1 m grid cell resolution for the purpose of improving the accuracy of assessing land for potential horticultural value. This was then based upon slope groups as per the LUC handbook.

7.3.1 Kaipara

Figure 18 shows slope over the Kaipara Command Area as determined from the LiDAR data, and **Table 5** summarises this data within four slope categories. Over half of the land area had a slope of under three degrees and approximately 75% of the land area was under 7 degrees slope, which implies that the area is mainly flat with vast tracts of land of an appropriate contour for horticulture.

Table 5. Distribution of slopes in the Kaipara Command Area.

Slope Class (degrees)	Area (ha)	% of area
0 to 3	10,892	52.8%
3 to 7	4,434	21.5%
7 to 15	3,524	17.1%
15+	1,784	8.6%

Figure 18. Slope Map for Kaipara Command Area. (Refer A3 attachment at rear).

7.3.2 Mid-North

Figure 19 shows slope over the Mid-North Command Area as determined from the LiDAR data, and **Table 6** summarises this data. Approximately half of the land area had a slope of under three degrees and approximately 79% of the land area was under 7 degrees slope.

Table 6. Distribution of slopes in the Mid-North Command Area.

Slope Class (degrees)	Area (ha)	% of area
0 to 3	2,536.7	49.4%
3 to 7	1,504.4	29.3%
7 to 15	791.2	15.4%
15+	304.5	5.9%

Figure 19. Slopes map for Mid-North Command Area. (Refer A3 attachment at rear).

8. Identification of Horticultural Soils

Each of the command areas, and adjacent land, has a myriad of different soil types albeit with common physical properties and characteristics.

The following sub-sections summarise the key soil groups identified, and detailed descriptions of the groups are provided in **Appendix A** and **Appendix B** for the Kaipara and Mid-North respectively.

8.1 Kaipara

Soils suitable for horticulture in the Kaipara Command Area include those developed on three ages of dune sand, compacted sand terraces, alluvial and estuarine flats and terraces, and peat.

There are seven groups of soils within the vicinity of the Kaipara Command Area on which some form of commercial horticulture could be practiced providing there is access to irrigation water. Each of these as identified below are described in the following section:

- **K-1**: Very free-draining sands (**Appendix A.1**);
- **K-2**: Stable and free-draining sand, sandy loam and associated sandy peat soils (**Appendix A.2**);
- **K-3**: Sandy peat soils (**Appendix A.3**);
- **K-4**: Alluvial and estuarine soils (**Appendix A.4**);
- **K-5**: Sandy soils with weak topsoil structure and impeded drainage (**Appendix A.5**);
- **K-6**: Tangitiki sandy loam and sand to Te Kopuru sand (**Appendix A.6**);
- **K-7**: Gleyed Alluvial Soils and Terrace soils (**Appendix A.7**);

Whilst considered potentially suitable, groups K-5 through to K-7 are less preferable, and K5 Only after extensive pan and sandstone breaking, mixing sand and associated peaty material. The main challenges are associated with soil structure and drainage.

Whilst this study is unlikely to target delivery of water to these areas it does not preclude them being supplied should the demand exist. It should be noted that if a large area of these soils were proposed to be irrigated, this could change volume of water storage required significantly albeit not necessarily the command area. The most likely instance of this occurring would be if water was allowed to be utilised for pastoral farming as these Te Kopuru soils have a pan very close to the surface, resulting in them being the first to dry out and the likely biggest beneficiary of irrigation.

Figure 20. Horticultural soils map for Kaipara. (Refer A3 attachment at rear).

The definition of this Command Area has been based on the practicality of water harvesting and distribution within reasonably close proximity to Dargaville. There are similar sandy soils north of Baylys Beach Road and south of Te Kopuru which are suited to horticultural development, just as there are alluvial and estuarine soils further upstream and downstream on the Wairoa River and its tributaries which are suited to vegetable growing, arable farming and horticulture.

The soils that have developed on sand range in 'age' (soil development) from dune sand that has only been stabilised in the last 50 to 60 years and on which soils are still developing, to mature podzols, terrace sands on which generations of kauri forest and heathland have formed mature podzols, 'gumland sand' which is generally unsuited to horticulture in its natural state. Because the 'sand soils' are in places distributed as a mosaic, reflecting the distribution and density of old kauri forests, these largely unsuitable soils have been included in and described along with the better soils within the command area. On the Aupouri Peninsula in the Far North some of these unsuitable soils have been completely reconstituted to create a growing medium suited to horticulture, the extra cost being justified by the very favourable climate for avocado, presence of groundwater underneath, and because they constitute only part of the total area of orchards under development.

These areas of unfavourable soils scattered amongst more favourable ones provide opportunities of 'non-soil' based horticulture (hydroponics) and support infrastructure without impinging on highly productive soils.

Table 7. Horticultural soil in the Kaipara Command Area.

Group	Soil Types	Horticultural Uses
Group K1 Very free-draining sands	• Pinaki sand (PN) • dune sand	• Forestry • Avocado • (Special crops in sheltered areas) • (Currently dairy and beef run-offs, beef farming, forestry and wasteland/protection areas)
Group K2 Stable, free-draining sands, sandy loams and peat pockets	• Redhill sand (RLa) • Redhill sandy loam (RL) • Younger Tangitiki sandy loam and sand (TT) • Pockets Parore peaty sand (PZ)	• Avocado, tamarillo, citrus, kiwifruit, vegetables but possibly many other horticultural crops • (Currently used for dairy, pastoral farming, forestry)
Group K3 Sandy peats	• Parore peaty sand (PZ) • Kaipara peaty clay loam (KPy)	• Vegetables, kiwifruit, blueberry • (Currently used for dairy, pastoral farming, vegetables, finishing lambs over winter)
Group 4 Alluvial and estuarine soils	• Mangakahia silt loam and clay loam (MF) • Whakapara silt loam and clay loam (WF) • Kaipara clay (KP) • Kaipara peaty clay loam (KPy)	• Kumara, squash, maize/corn, vegetables, kumara • Not suited to winter cultivation or crop harvesting • (Currently as dairy, pastoral farming, kumara, vegetables, maize/corn, finishing lambs over winter)
Group 5 Sandy soils with weak topsoils structure and/or impeded drainage	• Tangitiki sandy loam and sand (TT) • Te Kopuru sand (TEK)	• Avocado on deeper soils, kiwifruit, citrus, other tree crops • (Currently dairy, pastoral farming and forestry) • ['Salad greens' in the Far North]
Group 6	• Tangitiki sandy loam and sand (TT) • Te Kopuru sand (TEK)	• Much less horticulture opportunity than Group 5, some areas suited to winter growing of salad greens and similar. Includes flat land suited to non-soil-based horticulture. • (Currently dairy, pastoral farming and forestry) • ['Salad greens' in the Far North]

Group 7 Gleyed alluvial soils and terraces	• Mangakahia mottled clay (MFm) • Whakapara mottled clay (WFm) • Kohumaru clay (KM) • Waipuna clay (WU) • Waitemata silt loam (WE) • Albany silt loam (AB) • Coatesville silt loam (CV)	• High flood risk on MFm and WFm soils, meaning late cultivation and short growing season crops only (maize), still at risk of being flooded. • Some areas of higher terrace soils KM, WU, etc.) suitable for kiwifruit.

8.2 Mid-North

The volcanic soils suited to horticulture (field crops, vines and trees) within the Mid-North Command Area have developed on:

- basaltic lava flows;
- basaltic scoria, ash and lava cones;
- debris fan deposits from the collapsed sides of scoria cones; and
- alluvium from both sedimentary and volcanic rock catchments.

There are **five groups** of soils within the Mid-North (Kaikohe-Okaihau-Waimate North) Command Area on which some form of commercial horticulture could be practiced providing there is access to irrigation water:

- MN-1: Deep, free draining, volcanic (**Appendix B.1**);
- MN-2: Shallower and/or heavier, less free-draining, moderately leached volcanic (**Appendix B.2**);
- MN-3: Moderately to strongly leached Brown and Red Loams (**Appendix B.3**);
- MN-4: Strongly to very strongly leached Brown Loams, ‘ironstone soils’ (**Appendix B.4**); and
- MN-5: Miscellaneous soils (**Appendix B.5**).

Table 8. Horticultural soils in the Mid-North Command Area.

Group	Soil Types	Horticultural Uses
MN-1 Deep, free draining volcanic	• KB Kiripaka bouldery silt loam • OW Ohaeawai silt loam • PK Papakauri silt loam • MU Maunu silt loam	• Avocado • Tamarillo • Market gardens (where not too stony) • Kiwifruit, citrus • Berries
MN-2 Shallower, less free-draining, moderately leached volcanic	• WP Whakapai clay loam • WM Waimate North clay loam • KPe Kiripaka bouldery silt loam with compact subsoil • KE Kerikeri friable clay	• Market gardens/vegetables • Arable crops • Tree nurseries • Kiwifruit • Citrus • Persimmon • Berries
MN-3 Moderately to strongly leached Brown and Red Loams	• WPe Whakapai friable clay • YO Waiotu friable clay • MC Matarau friable clay • RT Ruatangata friable clay • AT Apotu friable clay	• Arable crops • Tree nurseries • Kiwifruit • Citrus • Persimmon • Marginal for market gardens
MN-4 Strongly to very strongly leach Brown Loams	• PG Pungaere gravelly friable clay • OD Otaha clay • ODg Otaha gravelly clay loam • OK Okaihau gravelly friable clay	On areas of deeper soil: • Arable field crops • Kiwi fruit • Citrus
MN-5	• KO Kamo clay loam • WF Whakapara silt loam and clay loam	Where at low risk of flooding: • Melons

Group	Soil Types	Horticultural Uses
Miscellaneous soils	• MF Mangakahia silt loam and clay loam • OG Otonga peaty clay loam	• Arable field crop (maize, sugar beet)

9. Land Use Irrigation Demand

To provide an envelope of potential water use requirements for the Kaipara and Mid-North Command Areas, an irrigation demand analysis was undertaken for four representative land use/crop types (pasture, citrus, avocados, and kiwifruit), and the four soil types best suited for horticultural production in each Command Area, respectively.

The soil types that were assessed for each Command Area are those referred to as soil Group K-1 to K-4 defined for the Kaipara in **Section 8.1** and MN-1 to MN-4 for the Mid-North in **Section 8.2**.

The irrigation module of the Soil Moisture Water Balance Model (SMWBM_Irr) was applied to determine the optimum peak irrigation application rates required to maintain soil moisture levels above the crop wilting point during the peak of summer, while minimising water use requirements. Model results also provided an estimate of monthly and annual water use for each crop type and soil type.

The model interface is shown in **Figure 21**, and a summary description of each model parameter and the values assigned provided in **Appendix C**.

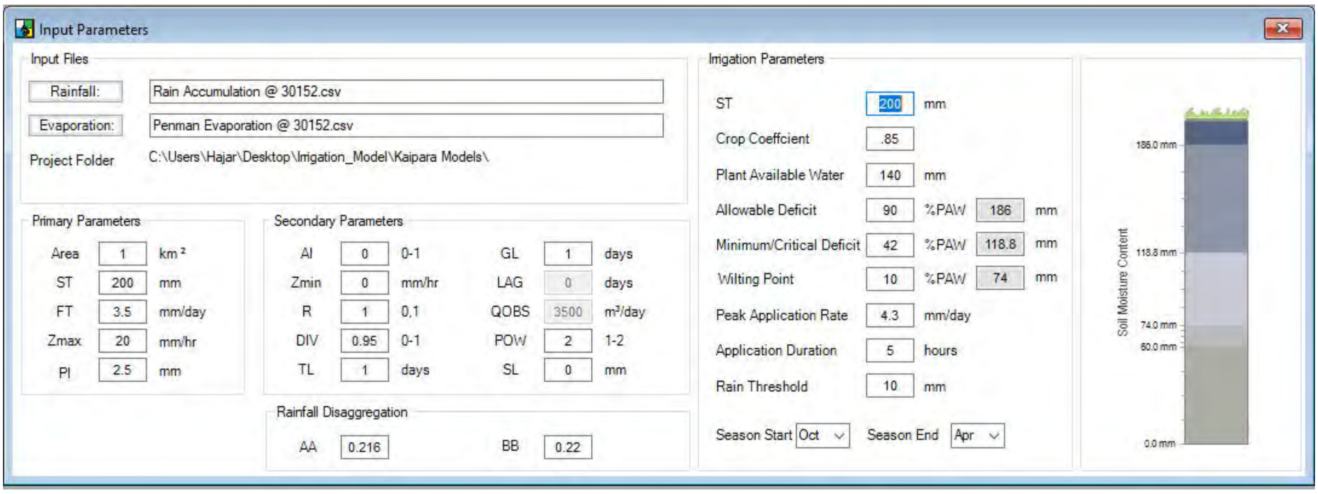


Figure 21. SMWBM interface with irrigation parameters.

The model was simulated using historical daily rainfall and evaporation data sourced from the virtual climate station network (VCSN) operated by NIWA. Station #30152 was used for the Kaipara models and Station #21418 was used for the Mid-North models. Irrigation demand was simulated for each combination of crop / land cover and soil type for the period January 1972 to December 2018.

For a more nuanced understanding of irrigation demand, daily water requirements for each irrigation cycle were calculated using the SMWBM. In essence, the model informs the irrigation return period given the prescribed application depth and criteria for wilting point, minimum allowable soil moisture (or soil moisture deficit), and allowable soil moisture deficit where irrigation ceases (fill point). The irrigation return period is typically greater in the shoulder periods than during peak summer months. A schematic diagram of SMWBM inputs is shown in **Appendix B**.

The model was run using the optimisation feature, which seeks the minimum irrigation peak application rate (PAR) required, while still maintaining soil moisture levels above the crop wilting point throughout summer up to a 1 in 10-year drought condition. By minimising the PAR, water use efficiency is maximised.

The model parameters used to generate the optimised peak application rate for each combination is presented in **Appendix B**, while **Table 9** shows the optimised peak irrigation rates as determined by the model simulations and **Table 10** shows the optimised annual irrigation rates for a 1 in 10-year drought for the Kaipara and Mid-

North Command areas, respectively. An example time series of irrigation and unirrigated soil moisture profiles is shown in **Figure 22**.

The irrigation demand models were developed with the aim of achieving daily and annual irrigation rates that are representative of the water use in highly productive orchards. This means that simulated water requirements are toward the upper end of the range of typical water use. The Critical Deficit (CD) parameter defines the level of soil moisture where irrigation is initiated. The definition and application of this parameter varies in different irrigation demand models. In the SMWBM_Irr model, CD is varied such that the model generates realistic daily and annual irrigation demand.

It should be noted that the water use values reported in this document are representative of mature crops that consume water at their peak potential. Earlier stages of crop development would require less water and therefore less water would be required at the outset of developing an orchard, provided that the peak water requirements would be available at an appropriate point in the crop's life cycle.

Table 9. Proxy crops and their peak irrigation requirements.

Crop Type	Soil Group Peak Irrigation Requirements (mm/day)							
	Kaipara				Mid-North			
	K-1	K-2	K-3	K-4	MN-1	MN-2	MN-3	MN-4
Pasture	4.7	4.3	4.1	3.9	4.2	4.1	3.7	3.7
Citrus	-	4.1	3.7	3.8	4.1	3.4	3	3
Avocado	4.4	4.2	-	-	4.2	-	-	-
Kiwifruit	-	4.4	4.1	4.2	4.4	3.8	3.6	3.6

Table 10. Proxy crops and their 10-year return interval annual irrigation requirements.

Crop Type	Soil Group Peak Irrigation Requirements (m^3/year)							
	Kaipara				Mid-North			
	K-1	K-2	K-3	K-4	MN-1	MN-2	MN-3	MN-4
Pasture	4,800	4,390	4,340	4,230	4,170	3,670	3,520	3,410
Citrus	-	3,590	3,320	3,200	3,540	2,620	2,500	2,530
Avocado	4,390	4,200	-	-	3,860	0	0	0
Kiwifruit	-	4,140	3,840	3,700	4,120	3,590	3,430	3,340

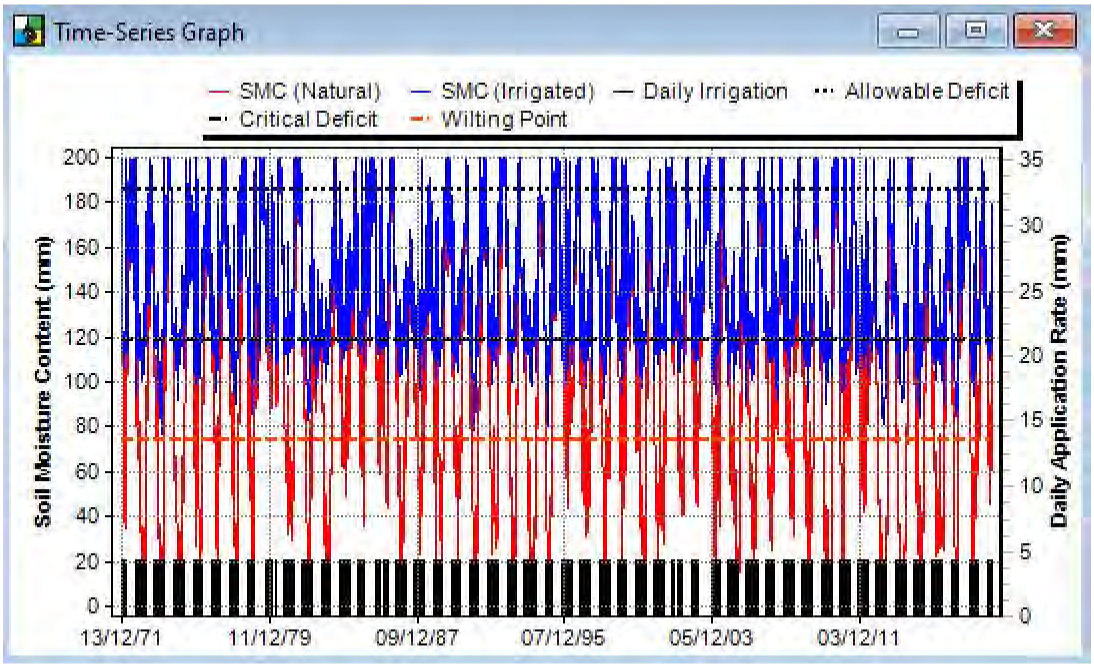


Figure 22. Example irrigation demand time series output for Kiwifruit on Kaipara Command Area soil group K-2 type soil.

9.1 Seasonal Water Usage

The irrigation models were simulated from 1972 to 2018 to define the seasonal pattern of irrigation demand, including mean and maximum monthly volumes and annual volumes. An analysis of the irrigation demand for a 1 in 10-year return interval for the four crop types and soil types is provided in **Table 11**. Full results are provided in **Appendix B**.

High level conclusions drawn directly from the irrigation model results include the following:

- Kaipara requires more irrigation than Mid-North (i.e. it is drier);
- Pasture requires the most irrigation; and
- Citrus requires the least irrigation.

Table 11. Kaipara and Mid-North Command Area monthly irrigation demand frequency statistics for 1 in 10-year return interval.

Command Area	Soil Group	Crop type	1 in 10 Year Irrigation Demand (mm)							
			Jan	Feb	Mar	Apr	Oct	Nov	Dec	Total
Kaipara	K-1	Pasture	128	101	90	46	39	94	119	480
		Avocados	121	101	92	44	30	85	111	439
	K-2	Pasture	122	99	83	40	25	79	111	439
		Citrus	112	88	75	34	0	48	94	359
		Avocados	122	98	90	42	19	72	108	420
		Kiwifruit	123	97	84	40	17	70	112	414
	K-3	Pasture	123	98	82	37	7	75	111	434
		Citrus	111	88	78	33	0	37	83	332

Command Area	Soil Group	Crop type	1 in 10 Year Irrigation Demand (mm)							
			Jan	Feb	Mar	Apr	Oct	Nov	Dec	Total
		Kiwifruit	119	94	80	33	0	57	98	384
	K-4	Pasture	117	94	78	35	6	70	109	423
		Citrus	110	89	72	28	0	19	84	320
		Kiwifruit	115	88	71	29	0	44	97	370
Mid-North	MN-1	Pasture	115	101	92	44	25	73	119	417
		Citrus	108	94	88	43	6	59	106	354
		Avocados	111	94	87	51	25	73	109	386
		Kiwifruit	119	101	88	44	19	70	118	407
	MN-2	Pasture	115	92	75	36	10	66	107	367
		Citrus	99	83	76	39	0	34	80	262
		Kiwifruit	110	95	81	40	9	61	100	359
	MN-3	Pasture	107	90	68	34	0	56	101	352
		Citrus	88	78	67	34	0	13	62	250
		Kiwifruit	106	94	66	32	0	46	97	343
	MN-4	Pasture	107	90	67	33	0	46	100	341
		Citrus	88	78	69	32	0	8	61	253
		Kiwifruit	109	93	64	29	0	42	96	334

9.2 Potential Implications from Climate Change

The potential implications from climate change on water availability (rainfall and subsequently streamflow) for Northland are summarised in **Volume 2 – Water Resources Analysis**. Key conclusions drawn by Pearce (2018) for Northland are Summarised as follows:

- the number of days exceeding 25°C may increase from 25 days now, to 99 days by 2090;
- frosts may decline from one frost every two years, to one frost every ten years;
- rainfall changes are small by 2040, with up to 10% decrease in spring rainfall in some areas;
- by 2090 further reduction in spring rainfall (up to 20%), and increased rainfall in autumn/summer; and
- increased risk of drought is highest for east and west coasts and southern inland areas of Northland.

The general consensus is reduced precipitation in winter and spring and only a slight increase in summer. Given the generally lower annual rainfall, hotter summer temperatures, and thus likely increased evapotranspiration, it is expected soil moisture deficits will increase. Larger and longer duration soil moisture deficits will require more frequent irrigation to generate similar levels of reliability and/or productivity (bulk mass e.g. fruit) as at present.

It is recommended during the next phase (feasibility assessment) of the Northland Water Storage and Use Project, the potential effects of climate change on irrigation demand are investigated further.

10. Refinement and Analysis

10.1 Command Area Prioritisation

An overview of the Command Areas utilised for analysis within this report has been based upon the previous studies undertaken. The Kaipara area is shown in **Figure 23,** and the Mid-North area shown in **Figure 24**.

To assist in identifying areas suitable for horticulture development, an analysis of soil characteristics, land cover, slope, aspect, natural habitat, historic features, exclusion and buffer zones has been undertaken. Details of this analysis are provided in the following sections.

Figure 23. Horticultural Suitability Map for Kaipara. (Refer A3 attachment at rear).

Figure 24. Horticultural Suitability Map for Mid-North. (Refer A3 attachment at rear).

10.1.1 Exclusion Zones

Certain areas were determined to be inappropriate for development based on current land use, vegetation type, or because they are water bodies. The following land cover types were excluded from the potential horticultural areas:

- Native vegetation;
- Urban areas;
- Conservation land; and
- Water bodies and wetlands (20m m buffer applied).

10.1.2 Buffer Zones

Features within Command Areas where horticultural development would not be appropriate were identified and removed from each Command Area. In each case, a 100 m buffer was applied to ensure that development would not likely have a detrimental effect on these features. The following features were removed from the potential horticultural development areas within the Kaipara and Mid-North Command Areas.

- Outstanding natural character areas;
- Outstanding natural features;
- Sites or Areas of significance to Tangata Whenua;
- Outstanding freshwater bodies;
- Significant wetlands; and
- Residential areas.

10.1.3 Prioritisation Based on Slope/Aspect

Slope and aspect are important considerations in determining suitability for horticultural development. Flatter areas are more well suited for farming and horticulture, while slopes greater than 15 degrees are too steep for development for horticultural land use to be practical.

North facing slopes are more optimal because they receive more hours of sunlight relative to other aspects, although this effect is minimised on flat terrain.

For these reasons, the landscape was evaluated based on a combined assessment of slope and aspect. Slope was classified into four categories based on suitability for horticulture. The impact of aspect, favouring northerly facing land, was then added to the assessment to better classify development suitability as summarised in **Table 12**.

Table 12. Classification of horticultural suitability based on slope and aspect.

<table>
<tr><th>Slope</th><th>Aspect</th><th>Horticultural suitability</th></tr>
<tr><td>0 to 3 degrees</td><td>Any</td><td rowspan="2">Very suitable</td></tr>
<tr><td>3 to 7 degrees</td><td>N, NE, NW</td></tr>
<tr><td>3 to 7 degrees</td><td>S, W, E</td><td rowspan="2">Moderately suitable</td></tr>
<tr><td>7 to 15 degrees</td><td>N, NE, NW</td></tr>
<tr><td>7 to 15 degrees</td><td>S, W, E</td><td>Less suitable</td></tr>
<tr><td>15+ degrees</td><td>Any</td><td>Not suitable</td></tr>
</table>

10.2 Delineation of Zones

A combination of streams, roads and property boundaries have been utilised to sub-divide each zone into smaller units that can potentially be “mixed and matched” to align with possible water sources, groups of stakeholders, and or infrastructure needs. Where possible the zones were also delineated with regard to soil classifications as defined in **Sections 7** and **Section 8**.

This resulted in the Kaipara area being sub-divided in to 15 zones and the Mid-North area sub-divided in to 14 zones.

The area to the eastern side of the Northern Wairoa River in the Kaipara has been trimmed based upon the fact it is isolated from the balance of the area of interest and that it is not dissimilar to the large area of land on the western side.

Figure 25. Zones Map for Kaipara. (Refer A3 attachment at rear).

Figure 26. Zones Map for Mid-North. (Refer A3 attachment at rear).

Based upon the homogeneity of soil types, areas of exclusion, and desirable slope/aspect, smaller more succinct zones and have been delineated to enable further definition to be given to the shape and scale of the potential irrigable areas. The extent of potential horticultural areas classified by soil group and slope/aspect suitability is shown in terms of area within each zone in **Table 13** and **Table 14**.

Table 13. Kaipara Zone Slope Analysis

Zone #	Soil group -->		K-1 (Ha)				K-2 (Ha)				K-3 (ha)				K-4 (Ha)				Undefined (Ha)			
	Total area (ha)	Area with Exclusions (ha)	Very Suitable	Moderately Suitable	Less Suitable	Not Suitable	Very Suitable	Moderately Suitable	Less Suitable	Not Suitable	Very Suitable	Moderately Suitable	Less Suitable	Not Suitable	Very Suitable	Moderately Suitable	Less Suitable	Not Suitable	Very Suitable	Moderately Suitable	Less Suitable	Not Suitable
1	990.6	908.3	0.0	0.0	0.0	0.0	55.3	80.8	82.3	31.7	14.7	3.3	3.5	3.7	0.0	0.0	0.0	0.0	0.1	0.3	0.3	0.0
2	754.7	700.5	4.3	6.3	7.9	3.7	186.3	214.8	191.3	68.4	0.1	0.1	0.2	0.0	0.0	0.0	0.0	0.0	6.3	4.0	2.5	0.8
3	684.6	660.9	9.7	16.0	16.6	6.4	148.5	193.5	173.5	64.6	0.0	0.1	0.2	0.1	0.0	0.0	0.0	0.0	3.1	4.9	10.1	7.1
4	410.3	345.7	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	267.7	6.8	2.0	0.5	54.3	2.4	0.2	0.0	3.9	2.8	2.0	1.1
5	485.1	402.1	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	132.8	6.8	3.9	0.7	227.6	7.5	1.4	0.3	11.0	4.3	2.9	0.8
6	729.7	646.3	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	181.0	4.4	0.8	0.0	419.3	11.7	2.7	0.9	16.7	3.9	1.4	0.2
7	641.8	541.9	11.7	22.6	23.2	10.5	129.2	150.3	123.9	47.3	13.6	2.1	3.0	0.8	0.0	0.0	0.0	0.0	0.2	0.3	0.2	0.1
8	638.8	541.3	0.0	0.0	0.0	0.0	2.1	1.5	1.6	0.4	143.0	5.8	2.7	0.7	351.9	18.0	4.9	1.3	3.0	0.9	0.5	0.0
9	710.2	653.0	0.6	1.2	1.1	0.3	169.9	200.4	171.6	79.7	15.0	4.2	3.9	2.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
10	1161.3	1117.7	0.1	0.1	0.2	0.1	446.6	344.7	224.3	72.9	7.4	2.7	1.8	0.2	0.0	0.0	0.0	0.0	7.4	2.9	0.8	0.1
11	662.9	598.1	0.0	0.0	0.0	0.0	0.1	0.0	0.0	0.0	82.9	5.6	2.6	0.2	481.3	15.6	3.8	0.5	1.6	0.3	0.2	0.0
12	756.3	711.4	19.6	27.7	36.4	30.1	168.1	192.5	157.3	71.9	0.4	0.6	0.5	0.2	0.0	0.0	0.0	0.0	0.5	1.0	0.8	0.3
13	442.9	416.9	11.9	27.8	43.9	20.9	88.3	107.1	77.8	26.8	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.7	2.0	3.7	4.0
14	723.0	647.6	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	137.1	21.2	11.1	3.0	435.2	17.9	3.7	0.7	3.1	5.1	4.3	1.7
15	358.2	323.2	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	83.7	4.2	1.4	0.8	212.8	9.7	2.7	1.0	2.9	1.0	0.6	0.5

Table 14. Mid-North Zone Slope Analysis

Zone #	Soil group -->		MN-1 (Ha)				MN-2 (Ha)				MN-3 (ha)				MN-4 (Ha)				Undefined (Ha)			
	Total area (ha)	Area with Exclusions (ha)	Very Suitable	Moderately Suitable	Less Suitable	Not Suitable	Very Suitable	Moderately Suitable	Less Suitable	Not Suitable	Very Suitable	Moderately Suitable	Less Suitable	Not Suitable	Very Suitable	Moderately Suitable	Less Suitable	Not Suitable	Very Suitable	Moderately Suitable	Less Suitable	Not Suitable
1	569.9	445.9	283.7	78.9	26.4	3.1	29.1	6.4	1.1	0.2	0.1	0.5	0.0	0.0	0.0	0.0	0.0	0.0	8.7	2.0	0.7	0.0
2	582.4	488.7	131.3	88.7	33.8	9.3	44.4	59.3	29.6	7.3	13.7	10.2	3.0	0.0	0.0	0.0	0.0	0.0	19.8	19.7	12.7	3.1
3	579.2	514.6	34.5	12.2	2.6	0.3	205.7	126.7	54.1	8.6	34.0	18.4	11.3	3.3	0.0	0.0	0.0	0.0	0.2	0.2	0.0	0.0
4	230.7	221.1	0.0	0.0	0.0	0.0	151.3	39.1	14.2	2.1	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	2.4	3.8	5.8	1.3
5	268.9	253.3	0.0	0.0	0.0	0.0	125.2	72.9	21.9	2.7	14.4	10.2	4.5	0.2	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
6	401.7	364.8	29.2	35.3	27.6	6.4	133.6	79.3	40.8	8.0	0.4	0.5	0.6	0.1	0.0	0.0	0.0	0.0	0.2	0.3	0.2	0.0
7	223.8	170.4	0.0	0.0	0.0	0.0	115.5	40.0	11.7	1.2	0.3	0.3	0.1	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
8	431.7	369.6	205.1	64.5	28.8	6.5	14.3	15.7	10.1	2.8	2.7	4.0	2.3	0.2	0.0	0.0	0.0	0.0	9.1	1.2	0.2	0.1
9	404.9	314.3	47.8	17.9	2.7	0.1	131.9	29.3	5.4	0.5	35.9	9.9	0.9	0.0	0.0	0.0	0.0	0.0	20.2	8.0	2.0	0.2
10	350.8	328.3	0.0	0.0	0.0	0.0	247.0	35.8	6.3	1.7	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	22.3	6.8	4.3	0.5
11	234.5	216.5	72.9	7.3	0.8	0.2	0.0	0.0	0.0	0.0	78.4	17.7	4.1	1.1	0.0	0.0	0.0	0.0	19.4	6.8	1.5	0.1
12	700.8	596.3	0.0	0.0	0.0	0.0	283.3	55.7	27.5	5.8	116.8	35.9	22.3	8.5	0.1	0.1	0.2	0.2	1.7	1.0	0.6	0.7
13	442.9	397.1	1.0	1.1	2.5	4.0	4.0	1.1	0.3	0.0	217.1	101.5	45.8	7.3	0.0	0.0	0.0	0.0	0.5	1.1	2.0	1.8
14	593.8	526.9	414.9	76.4	24.5	7.0	0.0	0.0	0.0	0.0	0.1	0.0	0.1	0.0	0.0	0.0	0.0	0.0	0.6	0.3	0.2	0.0

10.3 Water Requirements

The potential water demands for each zone is affected by a variety of factors. **Section 9** set outs the requirements for various proxy crops and with the exception of Ngawha Enterprise and Innovation Park, there is not perceived to be major additional consumptive demands outside of the Dargaville and Kaikohe Municipal supplies. As such, the predominant factors seen as influencing water demand are:

- ***Canopy ha or effective irrigable area*** – This is area of the farm, or orchard, that requires water rather than the total property area which includes unproductive areas.
- ***Uptake*** - this willingness or ability to take up irrigation on an enterprise, change land use, etc.
- ***Diversity*** – This takes into account a myriad of factors that can impact upon uptake or demand for water at a given point in time, which to give a sense of this could include the following:
  - localised rainfall patterns;
  - crop development phase and/or rotation;
  - annual leave, illness, or other absentee of the irrigation manager;
- **System Losses** – This takes into account potential losses though the likes of supply efficiency, leakages and evaporation.

These factors will change from zone to zone and property to property, as well as being dependent on individual growing or farming systems. Typically, within an orchard growing a permanent tree crop the canopy hectare could be expected to be approximately 60 to 80% of the total orchard area.

Similarly, the complex fabric that our rural communities are cut from will mean that not every land owner is interested in pursuing horticultural development. Initially assuming 70% as the uptake factor would be a prudent assumption without building unnecessary conservatism into calculations that could ultimately suggest an unrealistic demand.

Typically, an allowance can be made for scheme diversity in determining scheme water requirements. For example, with smaller areas (<500 ha) the peak could be 100%. Areas greater than 500 ha could be 90% or greater, and for areas over 5,000 ha it could be 80%.

As indicated in **Section 9**, regardless of crop type, the peak water requirement would be approximately 4 mm per day. The total annual volume, however, will be dependent on the level of reliability sought.

Similarly, an allowance needs to be made for system losses which given this is likely to be predominately a piped scheme are likely to be minimal. As such it has been determined as prudent to allow for an annual requirement of water, inclusive of these, of 4,000 m^3 per irrigable ha.

As such, it could be assumed that 50% of a zone may in fact be developed and subsequently require irrigation water. As the scheme progresses into future stages sensitivity analysis should be undertaken upon these various factors.

Table 15 and **Table 16** below provide an estimate of the potential water volumes that may be required for each zone (defined in **Section 10.2**) assuming different annual requirements in general alignment with proxy crops for comparative purposes.

Table 15. Kaipara Water Requirements with 70% uptake.

Zone	Area (Ha)		Peak Daily Requirement (m^3)	Annual Requirement per ha			
	Total (with Exclusions)	Effective (50% of Total)		3,400 m^3	3,600 m^3	3,800 m^3	4,000 m^3
				Total Requirement (m^3)			
1	908.3	454.2	18,167	1,544,194	1,635,029	1,725,864	1,816,699
2	700.5	350.2	14,009	1,190,800	1,260,847	1,330,894	1,400,941
3	660.9	330.4	13,218	1,123,501	1,189,589	1,255,678	1,321,766
4	345.7	172.8	6,913	587,627	622,193	656,759	691,326
5	402.1	201.1	8,043	683,620	723,833	764,046	804,259
6	646.3	323.2	12,926	1,098,721	1,163,352	1,227,983	1,292,613
7	541.9	270.9	10,838	921,194	975,382	1,029,570	1,083,757
8	541.3	270.7	10,826	920,246	974,378	1,028,510	1,082,643
9	653.0	326.5	13,060	1,110,138	1,175,441	1,240,743	1,306,045
10	1117.7	558.9	22,355	1,900,142	2,011,915	2,123,689	2,235,462
11	598.1	299.0	11,962	1,016,756	1,076,565	1,136,374	1,196,184
12	711.4	355.7	14,228	1,209,385	1,280,526	1,351,666	1,422,806
13	416.9	208.5	8,339	708,799	750,493	792,188	833,882
14	647.6	323.8	12,952	1,100,923	1,165,683	1,230,443	1,295,204
15	323.2	161.6	6,464	549,452	581,773	614,093	646,414

Table 16. Mid-North Water Requirements with 70% uptake.

Zone	Area (Ha)		Peak Daily Requirement (m^3)	Annual Requirement per ha			
	Total (with Exclusions)	Effective (50% of Total)		3,400 m^3	3,600 m^3	3,800 m^3	4,000 m^3
				Total Requirement (m^3)			
1	445.9	223.0	8,918	758,030	802,620	847,210	891,800
2	488.7	244.4	9,774	830,790	879,660	928,530	977,400
3	514.6	257.3	10,292	874,820	926,280	977,740	1,029,200
4	221.1	110.6	4,422	375,870	397,980	420,090	442,200
5	253.3	126.7	5,066	430,610	455,940	481,270	506,600
6	364.8	182.4	7,296	620,160	656,640	693,120	729,600
7	170.4	85.2	3,408	289,680	306,720	323,760	340,800
8	369.6	184.8	7,392	628,320	665,280	702,240	739,200
9	314.3	157.2	6,286	534,310	565,740	597,170	628,600
10	328.3	164.2	6,566	558,110	590,940	623,770	656,600
11	216.5	108.3	4,330	368,050	389,700	411,350	433,000
12	596.3	298.2	11,926	1,013,710	1,073,340	1,132,970	1,192,600
13	397.1	198.6	7,942	675,070	714,780	754,490	794,200
14	526.9	263.5	10,538	895,730	948,420	1,001,110	1,053,800

In the Kaipara, assuming an annual water requirement of between 3,400 m^3 and 4,000 m^3 for approximately 4,600 ha, the total volume of water required for irrigated land use could be expected to be between 15.7 Mm^3 and 18.5 Mm^3. This is based up the assumption of 70% canopy ha and a diversification factor of a constant 70%.

Similarly utilising these same assumptions in the Mid-North the total volume of water required for 2,600 ha of irrigated land use could be expected to be between 8.9 Mm^3 and 10.5 Mm^3 per annum.

The peak daily requirements for the Mid-North and Kaipara are 105,000 m^3/day and 185,000 m^3/day, respectively.

For comparative purposes, an approach utilising a variable diversification factor has been utilising assuming a flat 4,000 m^3 per irrigated ha of land. The variability in uptake has been subjectively determined based upon versatility of soil, potential land use options, land ownership and conversations undertaken within the community and horticultural industry as part of this project.

Table 17 and **Table 18** below provide an estimate of the potential water volumes that may be required for each zone assuming potential uptake ranged between the bounds of 30% (lower) and 70% (upper).

Table 17. Kaipara water requirements with variable uptake.

Zone	Total Area with Exclusions (Ha)	Assumed Uptake	Effective Area (Ha)	Peak Daily Requirement (m^3)	Annual Requirement (m^3)
1	908	30%	191	7,630	762,972
2	701	50%	245	9,807	980,700
3	661	50%	231	9,253	925,260
4	346	30%	73	2,904	290,388
5	402	30%	84	3,378	337,764
6	646	30%	136	5,429	542,892
7	542	50%	190	7,587	758,660
8	541	30%	114	4,547	454,692
9	653	50%	229	9,142	914,200
10	1118	50%	391	15,648	1,564,780
11	598	30%	126	5,024	502,404
12	711	50%	249	9,960	995,960
13	417	50%	146	5,837	583,660
14	648	30%	136	5,440	543,984
15	323	30%	68	2,715	271,488

Table 18. Mid-North water requirements with variable uptake.

Zone	Total Area with Exclusions (Ha)	Assumed Uptake	Effective Area (Ha)	Peak Daily Requirement (m^3)	Annual Requirement (m^3)
1	446	70%	218	8,740	873,964
2	489	50%	171	6,842	684,180
3	515	50%	180	7,204	720,440
4	221	50%	77	3,095	309,540
5	253	70%	124	4,965	496,468
6	365	50%	128	5,107	510,720
7	170	30%	36	1,431	143,136
8	370	50%	129	5,174	517,440
9	314	70%	154	6,160	616,028
10	328	50%	115	4,596	459,620
11	217	70%	106	4,243	424,340
12	596	30%	125	5,009	500,892
13	397	30%	83	3,336	333,564
14	527	70%	258	10,327	1,032,724

In the Kaipara this alternative weighted approach results in a total volume of water required for 2,600 ha of irrigated land use could be expected to be in the order of 10.4 Mm^3, assuming an annual requirement of 4000 m^3 per canopy or irrigated ha.

Similarly utilising these same assumptions in the Mid-North, the total volume of water required for 1,900 ha of irrigated land use could be expected to be in the order of 7.6 Mm^3 per annum.

The peak daily requirements for the Mid-North and Kaipara are 76,000 m^3/day and 104,000 m^3/day, respectively

11. Summary

There are numerous regulatory challenges that are going to be faced in diversification of land from the status quo. In principle however, the majority of these will be able to be overcome through avoiding sensitive areas, robust orchard/farm development planning, and the adoption of best farming practices.

As well as the obvious economic and socio-economic benefits that could be expected through a change to higher value land use, there are apparent mutually-beneficial opportunities available, in particular to address the reliability of the municipal water supplies to Dargaville and Kaikohe, and supply water to the proposed Ngawha Park.

From an environmental perspective the provision of a reliable water supply would be envisioned to remove reliance on sensitive water bodies such as dune lakes for water, and through land use change provide land owners with the ability to retire sensitive parts of properties to a higher level of production on the better land.

Land holding size in the Mid-North is considerably more fragmented that in the Kaipara. The predominant reason for this is the considerable amount of Maori Freehold Land and number of lifestyle blocks. Both of these will create challenges in terms of commercially viable scale of developments as well as reverse sensitivity challenges.

Discussions with land owners to date as part of this project did not identify any bulk group or groupings of landowners that were spatially clustered and considered ready to uptake irrigation water immediately, however there are definitely property owners, particularly in the Mid-North, actively evaluating their current assets in terms of horticulture potential.

The majority of the landholdings in both areas are currently used for pastoral farming, however it is evident that there is a variety of soils highly suitable for horticulture should a reliable water supply be available. There are other challenges, such as shelter, but once again nothing that should not be possible to address with sound development planning in terms of timing and spatial localities.

It was clear that the communities did not favour any particular crop with the understanding that water would provide them a variety of options.

Irrigation demand analysis confirmed that while the various crop types had slightly differing demand profiles, assuming 4,000 m^3/ha per annum, with a peak demand of 4 mm per day, was an appropriate average for the purposes of a pre-feasibility study and would ensure that a variety of crop demands could be realised in the future. It should be noted that a lesser volume may be acceptable and justifiable, depending on land use in future stages, particularly in the Mid-North.

Ultimately the main purpose of this report was to better define the shape, size, and water requirements of the two Command Areas, which in turn will form the premise or basis of design on the required scheme infrastructure.

The previous stage, undertaken by Opus in 2017, identified a Command Area of 19,000 ha in the Kaipara with and irrigable area of 6,300 ha requiring 25.2 Mm^3 water to supply an adequate level of reliability. Similarly, the area in the Mid-North identified an area of 5,100 ha, with an irrigable area of 3,300 ha requiring 12.2 Mm^3 water to supply an adequate level of reliability.

Utilising soil mapping undertaken as part of this project to determine the most suitable horticulture soils, LIDAR information for slope analysis, and removing sensitive areas, the Command Areas were further refined from the Opus work described above, effectively dividing into smaller more manageable areas, or zones, which ultimately reduced the scale of the schemes and allowing more targeted effort.

Table 19 below summaries the refined scheme details to be progressed forward to conceptual design in the Volume 3 report.

Table 19. Summary of refined scheme areas.

District	Area (ha)			Irrigation Water Requirement	
	Total	Total (with Exclusions)	Proposed Irrigable Area	Peak Daily (m^3)	Annual (Mm^3)
Kaipara	10,150	9,215	2,607	104,298	10.4
Mid-North	6,016	5,208	1,906	76,231	7.6

In addition to the irrigation requirements shown in **Table 19**,other consumptive water demands such as Municipal and Ngawha Park need to be allowed for. In summary, this means that the indicative potential water requirements derived for the Kaipara are 11 Mm^3 to 12 Mm^3 and 8 Mm^3 to 9 m^3 in the Mid-North.

The total proposed irrigable area of approximately 4,500 ha is considerably smaller than what was proposed previously. It should be noted that the total property area that is irrigated may in fact be considerably greater than this assuming that some of the irrigable land is utilised for rotational crops.

Similarly, the 4,500 ha is the canopy area of an orchard or effective irrigable area. This would likely amount to closer to 6,500 ha of total orchard or farm area which is considerable larger than the current combined area of the two irrigation schemes in Northland.

Whilst the total proposed irrigable area is proposed to be reduced substantially the project is still of the scale that it will have a significant impact upon the immediate and wider communities of interest.

12. References

Blackwell, et al., 2008. Room for everyone? Refugia and native biodiversity in New Zealand's agricultural landscapes. New Zealand Journal of Agricultural Research, 51:473-476.

Brown, et al., 2012. Landscape preferences in the Canterbury Region. Landcare Research Report LC1151.

Cox, J.E. 1988. The Location of Free Draining Soils in Northland, DSIR Soil Bureau, Whangarei

Harmsworth, G.R. 1996. Land Use Capability classification of the Northland region. A report to accompany the second edition (1:50,000) NZLRI worksheets. Landcare Research Science Series 9. Lincoln, Manaaki Whenua Press, 269p.

Kingsford, et al., 2016. Wetlands: conservation's poor cousins. Aquatic Conservation: Marine and Freshwater Ecosystems 26:892-916

McDowell, *et. al.*, 2019. Why are median phosphorus concentrations improving in New Zealand streams and rivers? Journal of the Royal Society of New Zealand, 49:143-170.

Norton & Miller, 2000. Some issues and options for the conservation of native biodiversity in rural New Zealand. Ecological Management and Restoration, 1:26-34.

NRC. 2017a. Poutō Catchment Management Plan

NRC. 2017b. Waitangi Catchment Management Plan

NZLRI (New Zealand Land Resource Inventory), Landcare Research - Manaaki Whenua, Lincoln, New Zealand https://lris.scinfo.org.nz/layer/76-nzlri-land-use-capability/

Pearce, P.R., 2017. Northland Climate Change Projections and Impacts. NIWA Client Report for Northland Regional Council, 2017027AK.

Sutherland, C.F., Cox, J.E., Taylor N.H., Wright, A.C.S. 1980: Soil map of Mangakahia-Dargaville area (sheets P06/07), North Island, New Zealand. N.Z. Soil Bureau Map 186.

Wildland Consultants, 2011. Ranking of top wetlands in the Northland Region Stage 4 – Rankings for 304 wetlands.

Appendix A. Descriptions of Kaipara Horticultural Soils

A.1 Group K-1: Very Free-Draining Sands

The K-1 Group soils are recent to very recent sands on dunes, some of which were only stabilised in the 1960's and 70's and which are still high-risk wind erosion areas. Soils developed on Pinaki sand (**Figure 27** and **Figure 28**) have accumulated some organic matter in the surface horizon, but generally these 'soils' are raw sand, and naturally low in nutrients. There are well suited to avocado, subject to establishing adequate shelter from prevailing salt laden south-westerly winds, particularly as these tend to be the western-most and generally highest dunes. These soils are very free draining and with no clays or any other minerals to bind elements, are prone to leaching, a potential threat within the catchment of dune lakes. Contour varies from flat to undulating to steep rolling.

Figure 27. Pinaki sand (Photo: Pouto Peninsula).

Pinaki Sand – Soil Profile:	
0 to 15 cm	golden fine to medium sand, loose to very weakly developed root-bound crumb structure
15 to 30 cm	dark grey brown to very dark brown, loose fine to medium structureless sand.
>30 cm	light olive brown loose medium sand.

Figure 28. Pinaki sand profile.

A.2 Group K-2: Stable and Free-Draining Sand and Sandy Loam

The K-2 Group soils comprise Red Hill sand (RLa), Red Hill sandy loam (RL) and some more mature but not strongly podzolised Tangitiki sandy loam and sand (TT). These soils form on consolidated dunes that have largely retained their rounded shape (**Figure 29**). Landform ranges from very gentle basins to strongly rolling, with Parore peaty sand (PZ) in some basins and old lake beds. There may also be patches of podzolised soil where kauri have been growing in sheltered basins.

The K-2 Group soils are free-draining with reasonable soil structure, and are well suited to arable, market garden and orchard use, including avocado. They tend to be a mosaic of younger and older soils, some even podzolised, with peaty basins. They are susceptible to wind erosion and to sheet erosion when cultivated and left bare of vegetation. There has been sufficient weathering and leaching in the soil to cause clay to accumulate in the soil profile and for thin lenses of cemented iron to form. These iron pans are easily fractured by ripping during development for orcharding. These same accumulations of iron and clay reduce the rate of leaching and trap nutrients that would have been leached to groundwater under younger soils.

Figure 29. Red Hill soils (Photo: landscape, Rehutai).

Red Hill Soils – Soil Profile:	
0 to 17 cm	very dark brown loamy sand, very weak soil structure; indistinct boundary.
17 to 65 cm	yellowish brown to strong brown sandy loam, some iron-coated clay nodules.
65 to 88 cm	reddish yellow sandy loam, very weak soil and ped structure, slightly sticky.
>88 cm	brownish yellow loamy sand and sand, very compact sandstone that breaks to single grain structure.

Figure 30. Red Hill soils profile.

A.3 Group K-3: Sandy Peat Soils

The K-3 Group soils includes Parore peaty sand (PZ) which merges into Kaipara peaty clay loam KPy) where it meets alluvial and estuarine sediments deposited along the banks of the Kaihu, Awakino and Wairoa Rivers. These alluvial deposits have trapped tributary valleys, causing peat swamps to develop. Sand washing off old sand terraces and some dune sand has combined with peat in the upper valleys. The Parore peaty sand is a highly variable soil with more and less proportions of sand, sometimes evenly distributed through the peat, and in other places spread as layers. Some sections of the valleys have a high incidence of sunken kauri logs while other parts have very little. This peaty sand is used for vegetable growing in some of the valleys to the west of Dargaville.

Figure 31 shows a photograph taken at Mangatara of pasture in the foreground on Paroroe peat sand where vegetables are grown in rotation with pasture.

Figure 31. Parore peaty sand (Photo: Mangatara).

<table>
<tr><td rowspan="4"></td><td colspan="2">Ruakaka Peaty Sand – Soil Profile:
Note: In the absence of a photogrpah and profile description of Parore peaty sand, this photograph and profile description are of Ruakaka peaty sand, the East Coast equivalent soil</td></tr>
<tr><td>0 to 15 cm</td><td>Black fine sandy peaty loam</td></tr>
<tr><td>15 to 60 cm</td><td>Black to reddish brown fine sandy peaty loam</td></tr>
<tr><td>>60 cm</td><td>Black loamy peat, with wood fragments and ash layers where the swamp has been burnt and then peat has developed on top.</td></tr>
</table>

Figure 32. Ruakaka peaty sand (east coast equivalent) profile.

A.4 Group K-4: Alluvial and Estuarine Soils

The K-4 Group soils are Mangakahia silt loam and clay loam (MF), Whakapara silt loam and clay loam (WF) Kaipara clay and clay loam (KP), and Kaipara peaty clay loam (KPy).

This group includes recent soils formed on alluvium along the Kaihu, Awakino and Tangowahine River valleys, which in places are deep and relatively free draining silt loams, but in other areas heavier clay loams. They are classified as 'Recent' soils because sediment is still being deposited in major floods and the soil is still forming. Unfortunately, because of the narrowness of the floodplain, there is no cost-effective means of reducing flood risk so farming systems must cope with periodic flooding. These soils are suited to field crops like maize for silage or for grain.

The extensive areas of Kaipara clay loam and Kaipara peaty clay loam along the Wairoa River from Tangowahine to the river mouth south of Ruawai have formed on old estuarine deposits. Some areas are below spring tide level but are protected from flooding by community-managed stopbanks, with flood-gated outfalls into the tidal rivers. Unlike the floodplain soils described above, silt is not being deposited on these estuarine areas. Instead, soil structure is improving as land drainage controls the soil water table, ensuring it is aerated year-round. These soils are well suited to arable field crops with over 90% of New Zealand's kumara being grown in this district (**Figure 33**). Kaipara peaty clay loam is used for vegetable growing in several valleys near Dargaville. They would also be suited to kiwifruit and, the peaty phase soils in particular, to blueberries.

Figure 33. Kumara on Kaipara estuarine soils, Dargaville.

Mangakahia – Soil Profile:	
0 to 25 cm	Dark greyish brown to dark brown silty clay loam, with indistinct boundary.
25 to 150 cm	Brown silty clay loam-clay loam, with an indistinct boundary.
>150 cm	Brown to dark yellowish-brown silty clay loam-clay loam, mottling and iron staining.

Figure 34. Mangakahia soil profile.

Kaipara clay and clay loam – Soil Profile:	
0 to 15 cm	100 mm dark-grey clay, merging into
15 to 40 cm	Grey and brown mottled clay, with iron staining and nodules **NB** Kaipara clay soils are highly variable with more or less mottling, the subsoil varying from mottled white clay, through grey to the brownish-orange in this profile, depending on the texture of the estuarine sediments at that particular location (which can include sand-banks), and the depth to which the soils have been drained, that is, the extent to which the fluctuating water table has been controlled.

Figure 35. Kaipara clay and clay loam soil profile.

A.5 Group K-5: Sandy Soils with Weak Topsoil Structure

The K-5 Group soils are on land only marginally suited to horticulture or arable use due to steep or broken contour, susceptibility to erosion when cultivated, heavily podzolised soil and/or a dense sandstone basement which impedes both drainage and root penetration.

These soils occur on the inland edge of the old dune systems and still retain some of their dune shape, and comprises some rolling and some low, undulating land. They often occur as a mosaic of undulating to gently rolling old dunes with podzolised basins that impede drainage. These soils are unsuited to deep-rooting plants like avocado due to the impeded drainage, but better areas could be suited to citrus, kiwifruit, vegetables and field crops. They are further inland, sheltered by higher and more recent dunes, so less exposed to salt-laden winds.

Topsoils will vary from a sand or sandy loam on Tangitiki (TT) soils to a peaty sand layer on grey silica sand on Te Kopuru (TEK) sand. The basins tend to be wet in winter (TEK soils) and the ridges (TT soils) dry out in summer. The pan under the Te Kopuru soils is usually thin enough to be broken by ripping with tines on a bulldozer.

Figure 36. Steeper Tangitiki soils suited to more extensive orcharding

	Tangitki Sandy Loam and Sand on late Quaternary dunes – Soil Profile:	
	0 to 15 cm	Very dark grey loamy sand, very weak soil structure.
	15 to 30 cm	Pale brown to grey brown loamy sand.
	30 to 70 cm	Yellowish brown sandy loam, weakly to moderately developed fine nut structure, some iron nodules and hard sandstone fragments.
	>70/100 cm	Consolidated, cemented and weathered sand.

Figure 37. Tangitiki sandy loam and sand soil profile.

Figure 38. Tangitiki sandy loam and sand and Te Kopuru sand mosaic (horizontal distribution) .

The predominant soil type in **Figure 38** is Tangitiki sandy loam and sand, the brown soil in the foreground. To the right is Te Kopuru sand, the light grey soil.

A.6 Group K-6: Tangitiki sandy loam and sand to Te Kopuru sand

The K-6 Group soils are Tangitiki (TT) soils and Te Kopuru (TEK) sand, which are more mature soils formed on old cemented sand terraces on the inland side of Pouto Peninsula south of Maunganui Bluff. Eroded remnants also occur further eastwards on the left (east) bank of the Kaihu, Awakino and Wairoa Rivers. Te Kopuru soils are on the flatter terrace tops and Tangitiki soils on the steep, eroded terrace edges.

This is land unsuitable for 'in soil' horticulture in its present form.

Re-contouring to manage surface water, help break up the cemented sand pan and mix the peat with underlying sand appears to have been successful in developing land for vegetables (potato and melons) and salad greens in the Far North. The challenge is to not dry and lose the peaty organic matter during this development work. Care is also required to avoid over-watering plants as the cemented sand pan remains at depth and will continue to impede drainage. The 'soil' created is naturally very infertile, requiring all nutrients to be added to sustain plant growth (a sandy 'potting mix').

Careful management of the structureless soil and of runoff water is necessary to avoid sheet and rill erosion when the land is under cultivation.

Figure 39 shows a photograph of Tangitiki sandy loam and sand in the upper slopes, with lower slopes comprising Te Kopuru sand, similar to land on which salad greens are being grown in the Far North.

Figure 39. Tangitiki sandy loam and sand (upper slopes) and Te Kopuru sand (lower slopes).

Tangitki Sandy Loam and Sand, shallow phase– Soil Profile:	
0 to 15 cm	Very dark grey loamy sand, very weak soil structure.
15 to 30 cm	Pale brown to yellowish brown loamy sand.
30 to 50 cm	Yellowish brown sandy loam, weakly to moderately developed fine nut structure, some iron nodules and hard sandstone fragments.
>50 cm	Brownish yellow, strongly consolidated weathered sands.

Figure 40. Tangitiki Sandy Load and Sand profile.

Figure 41. Te Kopuru sand terrace tops, shallow Tangitiki sides.

	Te Kopuru Sand– Soil Profile:	
	0 to 15 cm	Grey loamy sand.
	15 to 40 cm	White sand, loose single grain structure.
	40 to 50 cm	Black cemented sand, massive, very hard.
	50 to 80 cm	Brownish yellow to red iron-cemented sand.
	>80 to 110 cm	Brownish yellow 'sandstone'.

Figure 42. Te Kopuru sand profile.

Figure 43. Worst case example of Te Kopuru Soils.

Figure 43 provides a poorly drained Te Kopuru soil example. This is land unsuitable for 'in soil' horticulture in its present form, but with development work to break the hardpan and mix with peaty topsoil, has successfully produced a 're-constituted' soil medium in the Far North suitable for vegetable growing.

A.7 Group K-7: Gleyed Alluvial Soils and Terrace Soils

The K-6 Group soils are Mangakahia mottled clay loam (MFm), Whakapara mottled clay loam (WFm), Kohumaru clay (KM), Waipuna clay (WU), and a complex of Waitemata silt loam (WE), Albany silt loam (AB) and Coatesville silt loam (CV).

The Mangakahia and Whakapara soils are found in basins, along the outer edges of wider floodplains and on narrow floodplains, all areas where ponding floodwaters drop fine silts and clays. The higher terrace soils are more weathered and leached, while the ‘complex’ soils are terraces formed with a mix of alluvium from sedimentary rocks and airfall ash.

The Kohumaru and Waipuna clays, and Waitemata, Albany and Coatesville are all found on higher river terraces.

All these soils are suited to an occasional field crop as part of a pasture renewal rotation. There is, however, a serious flood risk on the floodplain soils and the soils are only dry enough for cultivation in late November/December, meaning only short-season crops can be grown. Some more free-draining areas of terrace soils would be suitable for kiwifruit.

Figure 44 shows a typical landform comprising Whakapara clay loam on the floodplain and Waipuna clay on the terrace.

Figure 44. Whakapara clay loam (floodplain) and Waipuna clay (terrace).

Kohumaru Clay – Soil Profile	
0 to 15/19 cm	Very dark brown to dark brown granular silty clay loam.
15/19 to 30/35 cm	Brown to dark yellowish brown compact silty clay.
30/35 to 60/65 cm	Dark yellowish brown to yellowish brown silty clay or clay, small manganese concretions.
>60/65 cm	Strong brown to yellowish brown clay, strong iron mottling, manganese concretions.

Figure 45. Kohumaru clay soil profile.

A.8 Considerations on Sandy Soils

Erodibility and Shelter

Soils developed on sand and suited to horticulture range in age from recent dune systems through to old stable dunes. The recent dunes, some still moving inland in the 1960s, are closer to the coast and at the greatest risk from re-mobilisation. Easier basins are well suited to crops favouring free-draining soils, but will need extensive shelter, both to prevent soil erosion and to protect crops from salt-laden winds. There is a strong argument in favour of a strip of shelter plantings, possibly a combination of indigenous and exotic tree species, extending 300-500 m inland from the cliff tops to provide community shelter rather than trying to establish shelter on individual properties.

Redhill and Tangitiki soils on older, stabilised dune systems inland of the recently active dune systems, are less likely to remobilise as dunes, but are at risk of wind erosion. Erosion of topsoil, either by wind or water, will expose a clay and/or iron-rich subsoil, an iron or clay-pan which can be difficult to revegetate. Soil structure will need to be carefully managed to encourage infiltration, and runoff controlled to prevent sheet, rill and gully erosion. Channelled water needs to be carefully managed over gully edges to prevent the deep gullies previously common in this district.

Soil Structure

Sandy soils have a low organic matter content and a relatively weak topsoil structure, which can be broken down by over-cultivation or compaction, both when wet and when dry. A structureless surface layer increases the risk of wind erosion and causes water to runoff rather than infiltrate, further increasing the risk of sheet, rill and gully erosion. Lack of infiltration lowers soil moisture levels and increases the volumes that must be supplied by infiltration.

Soil Mosaics

As is common in Northland, due to terrain and the density of ancient kauri trees, the Redhill and Tangitiki soils tend to be mosaics of more and less leached and podzolised soils, and also contain basins with soils containing more clay and some with peat. Some areas will need to be ripped to break thin iron pans and some will need to be drained.

Nutrient Status

The recent dune and Pinaki sand soils have low nutrient status, and no clay and little organic matter to manage nutrient levels, particularly phosphorus (P). Horticulture on these soils is akin to hydroponics. Redhill soils have developed from dunes containing more iron sand and behave in a similar manner to Taranaki ring-plain soils. At low pH they will fix P so liming will be important, but the iron will prevent P leaching to groundwater. They are also naturally low in potassium (because of the source of their parent material) and essential nutrient of fruiting crops. Tangitiki sand, developed on sand of similar origin to the most recent dunes, has higher potassium levels and less iron, so nutrient management should be easier than on Redhill soils.

Land Use Capability Units

Under the NZ Land Resource Inventory, soils on sand are within a suite of land use capability units including Class 3e5, 3s4, 4e9, 6e6 and 7e9 and 7e10. 3e5, 3s4 and 4e9 are given this rating because of their erosion risk and drought prone nature, risks that would be considerably reduced by irrigation and shelter. The LUC Classification system enables the classification of land on floodplain, peat and estuarine soils serviced by community flood control schemes and community irrigation schemes to be raised. Some of the Redhill soils and better Tangitiki soils could, for example, be raised from Class 3 to Class 2 if they have access to a community water scheme.

Contamination of Groundwater

The Regional Plan for Northland recognises the threat to dune lakes from both nutrient runoff and leaching, and has restricted land uses within some lake catchments. The sand deposits from Maunganui Bluff to Pouto contain at least three layers of lignite, effective aquicludes which are tilted westward resulting in water draining over layers in the coastal cliffs. While volumes of water used in spray irrigating a vegetable crop, for example, may result in nitrates being leached to groundwater, such leaching is unlikely under trickle-irrigated or fixed-tree spray irrigated horticultural crops. Concentrations of iron and clay in the subsoil of Redhill soils should be sufficient to prevent P leaching to groundwater. Any areas where peat is present will provide carbon source and anaerobic conditions suitable for nitrate reduction.

Wetlands and Dune Lakes

Early settlement of this area resulted in extensive draining of wetlands and even of lakes to enable recovery of kauri gum and development for farming. In more recent years, further wetlands have been lost during recovery of swamp kauri. The remaining wetlands and dune lakes are now protected in the Regional Plan for Northland and may have even greater protection under a National Environmental Standard for Freshwater and biodiversity legislation. The effects of water storage, land development and irrigation within the catchments of remnant wetlands and dune lakes will require special consideration in furthering this project.

A.9 Considerations on Alluvium, Estuarine Deposits and Peat Soils

Erodibility and Shelter

While there is little risk of wind erosion of alluvial and estuarine soils, particularly when irrigated, persistent salt-laden winds will desiccate and reduce crop production and cause more water to be used than would be the case if there is adequate shelter. Shelterbelts across the valleys will be required to provide protection from wind funnelling down the valleys towards the Kaihu River and across the Wairoa River.

Sandy peat soils in the valleys will be at greater risk from wind erosion and this exposure will increase oxidation of the peat, lowering the land surface and upsetting drainage systems. These areas too will require effective shelter. The upper valley systems would be protected by afforestation of the broken and eroded Class 7e9 land towards the heads of the valleys.

Soil Structure and Drainage

While the sandy peat soils provide an excellent growing medium and can be cultivated in most seasons of the year providing the water table is well managed, the alluvial and estuarine soils are at times too wet and heavy to allow year-round machine access and cultivation. Soil structure is easily lost if cultivated or when, for example, kumara or maize are harvested when too wet.

Peat is almost impossible to re-wet when over-drained, hence it is important to manage the water table.

Each of the valleys draining from the coastal sand to the Wairoa and Kaihu Rivers has peaty soils in the upper valley, some have peaty estuarine soils in the lower middle reaches and estuarine soils along the rivers. All these side valleys within the Command Area are within community land drainage districts and have flood-gated outfalls to the rivers. Water flowing down the valleys can only discharge when the tide in the rivers is low enough to allow the flap-gates to open. Over time, the peat in these valleys 'shrink', reducing their water content and oxidising, causing the surface to settle.

Settlement can be uneven, causing water to lie in low spots after heavy rain. It also makes it more difficult to clear floodwaters between tides. This problem will increase as more land is cultivated and the peat oxidises and settles, and the floodgates are open for a lesser period during each tidal cycle as sea level rises. Pumping may eventually be required to effectively drain this land.

Water storage behind embankments in upper valleys would not only provide water for irrigation and other abstractive uses but may reduce the volume of water to be discharged through the floodgates/pumped to the river. An alternative to pumping the drain water to the river could be to pump drainage water back to storage.

Land Use Capability Units

Under the NZ Land Resource Inventory, soils on alluvial deposits, Mangakahia silt loam and clay loam can be class 2w1, 3w1, 4w1, 6w1 or 7w1, depending on frequency of flooding and land drainage. Mangakahia mottled clay loam would include the same LUC Units (except Class 2w1) but would be of a different Class. For example, land which has Mangakahia silt loam and clay loam may be Class 2w1 whereas Mangakahia mottled clay alongside, because it is a heavier soil and more difficult to work year-round, would be Class 3w1.

Soils on estuarine deposits are Class 2w2 and 3w2, and more detailed mapping would identify as Classes 4w, 6w and 7w. The peat soils, Parore peaty sandy loam and Kaipara peaty clay loam, are Class 3w4, but with more detailed mapping would include Class 4w3, 6w3 and 7w2, and could include a new Class 2w unit.

The terrace soils will generally be Class 3w, 3s or 4w because the heavy clay soils are less suited to cultivation and suitable for a lesser range of orchard crops.

Contamination of Groundwater

Because of their high organic matter (carbon) levels and anaerobic conditions, the peat soils are unlikely to leach large quantities of nitrates. Nitrates can be lost from the alluvial and estuarine soils via subsurface drainage mole and tile drains, hence nutrient management measures will be an important part of the sustainable land and water management on orchards and cropping land that have alluvial and estuarine soils. Recent research and modelling work suggest that the columnar cracking of heavier clay subsoils may increase the quantities of nitrogen leached from these alluvial soils.

Appendix B. Descriptions of Mid-North Horticultural Soils

B.1 Group MN-1: Deep Free-Draining Volcanic Soils

The MN-1 Group soils consist of weakly to moderately leached Brown Loam soils that have developed under broadleaf forest on relatively recent lava flows, Kiripaka bouldery silt loam (KB) (**Figure 46** and **Figure 47**) and Ohaeawai silt loam (OW), both of which have more or less rock/boulders. Also included in this group are soils formed on basaltic scoria and lava cones, including Papakauri silt loam (PK) (**Figure 48**), a weakly to moderately leached silt loam which has developed under broadleaf forests on 'recent' basaltic scoria cones. This latter soil is a Red Loam and does not have boulders/rock.

The MN-1 Group soils are deep, free draining, weakly to moderately leached Brown and Red Loams 'volcanic' soils that are well suited to avocado and tamarillo. While some of these volcanic soils, or areas within them, may be stony (bouldery), there are no significant soil pans, clay layers or other impediments to tree/plant root penetration or which can trap water within the tree rooting zone.

Figure 46. Kiripaka soil (foreground) and Papakauri soil (background) (not within Command Area).

Kiripaka Silt Loam – Soil Profile: The Ohaeawai Silt Loam is similar.	
0 to 15 cm	Dark greyish brown friable silt loam.
15 to 50 cm	Dark reddish-brown friable silt loam, with small scoriaceous basalt rocks.
50 to 100 cm	Dark reddish-brown friable clay loam with scoriaceous basalt.

Figure 47. Kiripaka Silt Loam soil profile.

Papakauri Silt Loam – Soil Profile:	
0 to 12 cm	Dusky red friable silt loam.
12 to 22 cm	Dusky red, weak red and red friable silt loam.
22 to 50 cm	Red silt loam with small scoria fragments.
>50 cm	Red, heavier silt and clay loam.

Figure 48. Papakauri Silt Loam soil profile.

B.2 Group MN-2: Shallower Heavier Less Free-Draining Volcanic Soils

The MN-2 Group soils include moderately leached brown and red loam ‘volcanic soils’ of the Whakapai clay loam (WP), Waimate North clay loam (WM), Kiripaka bouldery silt loam with compact subsoil (KBe), and the Kerikeri friable clay (KE).

The Whakapai clay loam, Waimate North clay loam and Kiripaka bouldery silt loam have a higher clay content or a clay accumulation in the soil profile because of their greater age and weathering than some of the younger soils. Soil drainage is slightly slower because of the higher clay content; hence this restricts their use to shallower rooting crops as the deeper-rooted and less disease-tolerant crops such as avocado and tamarillo may find conditions too wet for much of the year.

Whakapai clay loam (WP) has developed on an outwash fan of material deposited when the side of a lake-filled crater collapsed. While listed as Brown Loams, it should, perhaps be a Red Loam as it has formed on basaltic scoria and ash. While not well suited to avocado and tamarillo, these soils are well suited to cultivation and harvesting of vegetable and field crops throughout most of the year and to orchard crops like kiwifruit, citrus and persimmon.

Also included in this group, while technically ‘older’, more leached, is Kerikeri friable clay (KE). Rather than just a ‘clay pan’, the Kerikeri soil has an accumulation of iron and aluminium nodules in the subsoil, which impedes root penetration.

The MN-2 Group soils are the equivalent of the Pukekohe market garden soils.

B.3 Group MN-3: Moderately to strongly leached Brown and Red Loams

The MN-3 Group soils include Whakapai friable clay (WPe), Waiotu friable clay (YO) (**Figure 50**), Ruatangata friable clay (RT) and Apotu friable clay (AT) (**Figure 51**). These soils consist of moderately to strongly leached brown and red loams, which are older, more mature ‘volcanic soils’ with an even greater accumulation of clay in the subsoil than the Group MN-2 soils.

The MN-3 Group soils are suited to arable cropping and vegetables due to their often gently undulating landform and relative absence of rock/boulders (**Figure 49**), however their higher clay content makes them less suited to winter cultivation and harvesting.

Figure 49. Typical landforms of the Waiotu and Ruatangata soils.

<table>
<tr><td rowspan="4"></td><td colspan="2">Waiotu friable clay – Soil Profile:</td></tr>
<tr><td>0 to 15 cm</td><td>Dark grey friable clay.</td></tr>
<tr><td>15 to 50 cm</td><td>Yellowish brown compact crumbly clay with alumina concretions.</td></tr>
<tr><td>50 to 80cm</td><td>Reddish yellow sticky waxy clay with many pieces of weather basalt.</td></tr>
</table>

Figure 50. Waiotu friable clay soil profile.

	Apotu friable clay – Soil Profile:	
	0 to 20 cm	Reddish grey friable clay.
	20 to 40 cm	Reddish orange friable clay.
	40 to 100 cm	Light reddish grey to purple clay.

Figure 51. Apotu friable clay soil profile.

B.4 Group MN-4: Strongly to very strongly leached Brown Loams, 'ironstone soils'

The MN-4 Group soils include Pungaere gravelly friable clay (PG), Otaha clay (OD), Otaha gravelly clay loam (ODg), and Okaihau gravelly friable clay (OK) (**Figure 52**). These soils consist of strongly to very strongly leached brown loams, and contain mature 'ironstone soils', which have dense concentrations of subsoil iron and aluminium nodules.

Where a friable topsoil remains, the MN-4 Group soils are suited are suited to orcharding, particularly shallow-rooted crops such as kiwifruit and citrus. They are also suited to occasional summer field crops, such as maize, vegetables or fodder beet, usually within a pastoral farming rotation. In places, however, the topsoil has been completely removed by erosion, leaving a very gravelly surface layer of exposed subsoil high in aluminium and iron.

Okaihau Gravelly Friable Clay – Soil Profile:	
0 to 10 cm	Dark greyish brown gravelly silt loam, medium columnar structure.
10 to 50 cm	Brown clayey gravel (up to 60 mm diameter) of hard concretions.
50 to 90 cm	Dark yellowish-brown gravelly clay loam, few fine concretions.
>90 cm	Dark grey-brown friable clay.

Figure 52. Okaihau gravelly friable clay.

B.5 Other Soils

Scattered amongst the volcanic soils and soils on sedimentary rocks that are not suited to horticulture, are small pockets of soil that may be of value for horticulture. These include:

- **Floodplain deposits** – these include Whakapara silt loam and clay loam (WF) (**Figure 53** and **Figure 54**), Mangakahia silt loam and clay loam (MF), and the mottled phase of these two soil types (WFm, MFm). These tend to be narrow floodplains, still subject to occasional flooding so, depending on the probability/frequency, velocity and duration of flooding, crops grown would need to be able to withstand occasional inundation and/or siltation. All these soils benefit from subsurface drainage.
- **Higher alluvial terraces** – These are older, more strongly leached and heavier soils such as Whareora clay (WO) and Waipu clay (YU). Also included is Otao silt loam (C1), a terrace soil formed on alluvial ash deposits, terraces formed during a time when volcanic (rhyolitic) ash was falling or had recently fallen across the catchment. These soils are similar to those in the Kumeu area north of Auckland, and are found mainly in the Hupara area north of Moerewa-Kawakawa. All these soils would be suited to kiwifruit and summer cropping (melons, vegetable crops, etc.).
- **Soils on basaltic alluvium** – These alluvial deposits have come from almost entirely basaltic ash, scoria and lava sediments, in most cases trapped in a basin. They include Kamo clay loam (KO), Kamo silt loam (KOl) and Waipapa clay (YF). There may be a gravel pan in the subsoil, ‘bog iron’, formed by bacterial action on the iron-rich sediments. Where the groundwater levels are controlled and the iron pan shattered, some areas of these soils will be suited to field crops and to kiwifruit. Some may however be seasonally, too wet.

Figure 53. Whakapara silt loam and clay loam on narrow alluvial floodplain.

	Recent Soil – Soil Profile: Whakapara Silt Loam and Clay Loam	
	0 to 18 cm	Dark greyish brown to dark brown silty clay loam, with indistinct boundary.
	18 to 25 cm	Brown silty clay loam-clay loam, with an indistinct boundary.
	>25 cm	Brown to dark yellowish brown silty clay loam-clay loam. ***Note:*** *the lack of profile development in this very recent (Whakapara) soil on an active floodplain.*

Figure 54. Recent soil (Whakapara Silt Loam and Clay Loam).

B.6 Considerations for Mid-North Soils

Erodibility

All these ‘volcanic’ soils have a friable topsoil, but most are technically ‘clays’ and require careful management to maintain soil structure, infiltration of rainfall and to avoid soil erosion, particularly during high intensity rainstorms while under cultivation. If the relatively thin topsoil is eroded, the exposed subsoil of older soils has poor structure, a higher clay content and is often unsuited to arable use. Market gardens should be managed according to an ‘environmental management plan’ which sustains or improves soil structure and organic matter, retains soil in situ and traps any detached sediment and nutrients before reaching water bodies.

Soil Structure

Soil particles in the topsoil have strength when moist and are most at risk of degradation when compacted or over-cultivated when very dry. The particles break down to form a ‘dust mulch’, a layer of fine dust on the soil surface which repels water. This characteristic, a feature of red tropical soils, causes rain or irrigation water to run off, rather than soak in, resulting in sheet and rill erosion of cultivated (and grass) land.

Orchardists, who are forced to follow the same wheel tracks during spraying and harvesting are encouraged to avoid using machinery during very wet weather, use low pressure tyres and/or shallow rip track lines every few years to reduce compaction and encourage infiltration.

As the soils become more mature, clay leached from the topsoil accumulates in the subsoil where it impedes drainage and the penetration of plant roots, hence the order of the soil groups and land uses described above and below.

Ironstone Soils/Laterites

In this intense sub-tropical leaching or laterisation process, aluminium and iron accumulate in the subsoil as hard nodules, creating a gravelly pan. While usually only approximately 300 mm thick under the ‘ironstone soils’, mineable deposits (of bauxite) several metres thick exist in parts of the Command Area. Where a deep friable topsoil remains, these ‘old’ soils will support a field crop of vegetables, maize or fodder beet, and are suited to kiwifruit and citrus. Plant roots cannot, however, penetrate the hard and toxic aluminium accumulations, making these soils very drought-prone and crops need regular irrigation.

Orchard development involving deep earthworks, deep enough to bring iron and aluminium-rich material to the surface or within the rotting zone of plants, should include heavy applications of agricultural lime worked into the disturbed material, as discussed in the following sub-section.

Nutrient Status

The subsoils of these laterised volcanic soils are naturally very acidic. At low pH, there are free ions of iron (Fe) and aluminium (Al) which ‘fix’ or bond to nutrients such as P to render the P permanently unavailable as a plant nutrient. That is, not only is Al toxic to plant roots, it also deprives the plants of macro and micro-nutrients, which renders only shallow-rooted plants suitable on these mature ironstone soils. However, shallow rooted plants without irrigation die off in dry seasons and are very susceptible to cyclonic gales.

Trials have been conducted at Plant and Food Research into ways of encouraging deeper root penetration, including injecting lime to depth in the soil to raise pH to a level where there is less ‘free’ Fe and Al.

Land Use Capability Units

The land resource inventory and land use capability survey, from which the NZLRI database has been compiled, was conducted at a time of the year when the land ‘looked its best’ and by surveyors who did not fully understand the limitations of some of these soils. Consequently, some of the classifications could be considered ‘optimistic’ and are inconsistent with similar soil types in Whangarei District. This is not a fatal flaw as the general descriptions of the LUC units are still appropriate, but some land at Waimate North assessed as

Class 1c1 should instead be 2c1 or 2s1 and some older (Waiotu and Ruatangata) soils assessed as Class 2s1 should instead be Class 3s1 or 3e1. The NZLRI data is only indicative at its mapped 1:50,000 scale and any anomalies can be corrected in more detailed surveys.

Bouldery Land

Soils tend to be much more bouldery towards the edges of lava flows and on ridges pushed up in the lava flows where the molten rock cooled more quickly. There are also strips of boulders down the sides of old, broader shield volcanoes like at Waimate North and in gullies cut into the weathered volcanoes and lava flows. These areas are too bouldery to be economically developed for horticulture, orchards or tree crops, except for hardy species such as olives. The density of exposed surface boulders would generally prevent any opportunity for mechanisation. This land could, however, be used for non-productive support services such as dwellings, packing sheds, implement sheds, process areas, etc., leaving the less bouldery land for production.

Climate and Shelter

The Mid-North Command Area lies across a saddle, 200 to 250 metres above mean seal level (mAMSL) between the Hokianga Harbour and Bay of Islands through which the prevailing, cooler, south-westerly wind is funnelled. While wind shelter would be a distinct advantage for most crops, shelter needs to be designed and managed to ensure that it does not trap cold air, including frosts in winter (i.e. say 50% permeable shelter for example). There is scope for community shelter or strategically planted woodlots on fingers of stony land, or on sedimentary clay soils within the Command Area. The original community shelter for Kerikeri included woodlots of durable timber eucalypt species.

Contamination of Groundwater

These volcanic rocks beneath these soils are important groundwater aquifers, tapped for domestic and stockwater supplies, small-scale irrigation and some municipal supplies. They also feed puna or springs within and around the fringes of the volcanic areas, sustaining baseflows in streams. Spring-fed streams within the area are prime sources of water cress and are habitat for kura and a range of indigenous fauna.

One of the few areas in Northland recorded as having elevated N levels in groundwater is a market gardening area on free-draining Maunu silt loam (MU) near Whangarei, which is similar to the Kiripaka bouldery silt loam. The risk of contamination is greater on free-draining, younger soils than on the older soils with a clay or peaty subsoil.

Appendix C. Irrigation Demand Modelling

The following tables summarise the parameters used in the Soil Moisture Water Balance Irrigation Model.

Table A1. Summary of irrigation module parameters.

Parameter	Description	Value range	Basis of Values
Maximum Soil Moisture Content (ST)	The capacity of water in mm in the soil at field capacity.	200	Estimated from potential rooting depth (PRD) and macroporosity (n).
Plant Available Water (PAW)	The amount of water physically accessible by the plants in the root zone in mm.	See Table A3	Table 22 of Crop Evapotranspiration – Guidelines for Computing Crop Water Requirements (FAO website), lists percentages of Total Available Water (interpreted as equivalent to ST) that can be depleted before each crop suffers stress.
Allowable Deficit (AD)	Soil moisture level where irrigation ceases.	90	Previous experience.
Maximum / Critical Deficit (CD)	Percentage of PAW at which further drying of the soil would start to have an impact on plant grown rates, and hence CD represents the soil moisture level where irrigation commences.	See Table A3	Previous experience, and rule of thumb for CD is 50% of PAW.
Wilting Point	The minimum soil moisture level required for the plant not to wilt.	See Table A3	Irrigation NZ – Water holding capacities and soil textures.
Application Duration	Duration in hours over which the peak application depth is applied	5	Previous experience.
Rainfall Threshold	Daily rainfall total in mm when a farmer would choose not to irrigate.	10	Judgement.
Season	Irrigation season start and finish	October – April	General irrigation season length.

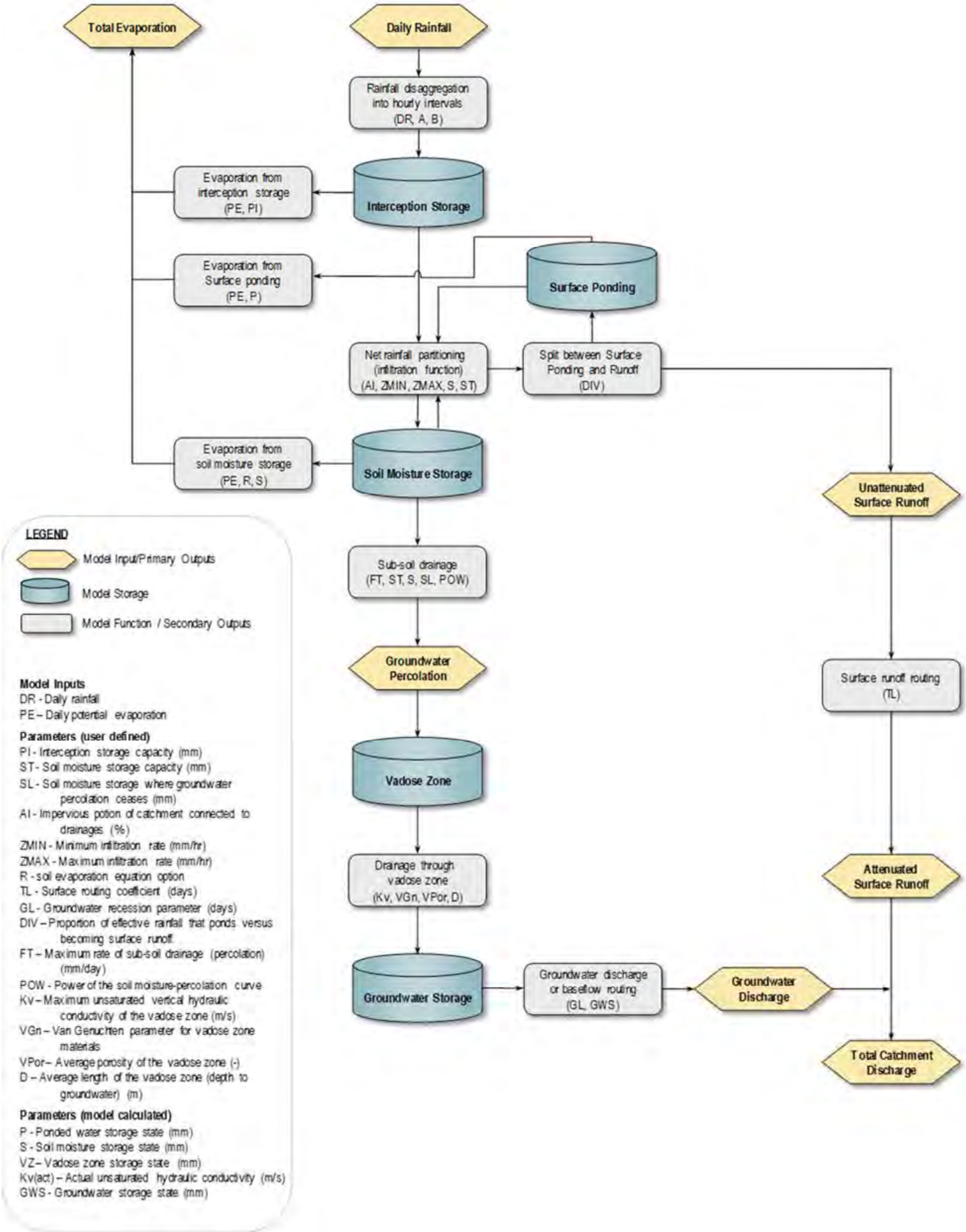


Figure 55. Schematic structure of the SMWBM.

Table A2. SMWBM parameters.

SMWBM Parameter	Name	Value
ST (mm)	Maximum soil water content	200
FT (mm/day)	Sub-soil drainage rate from soil moisture storage at full capacity	See Table A3
Zmax (mm/hr)	Maximum infiltration rate	
PI (mm)	Interception storage capacity	2
AI (0-1)	Impervious portion of the catchment	0.1
Zmin (mm/hr)	Minimum infiltration rate	0
R (0, 1)	Evaporation - soil moisture relationship	0
DIV (0-1)	Fraction of excess rainfall allocated directly to pond storage	0.9-1
TL (days)	Routing coefficient for surface runoff	1
GL (days)	Groundwater recession parameter	5
POW (1-2)	Power of the soil moisture-percolation equation	2
SL (mm)	Soil moisture content where drainage ceases	0.216
AA, BB	Coefficient for rainfall disaggregation	0.22

Table A3. Calibrated SMWBM soil parameters by crop type.

Soil	Crop Type	Kaipara						Mid-North					
		FT (mm/day)	Zmax (mm/hr)	Crop Coeff.	PAW (mm)	Critical Deficit (% of PAW)	Wilting Point (% of PAW)	FT (mm/ day)	Zmax (mm/hr)	Crop Coeff.	PAW (mm)	Critical Deficit (% of PAW)	Wilting Point (% of PAW)
A	Pasture	4.5	30	1	144	20	4	4	20	1	130	30	5
	Citrus	-	-	-	-	-	-	4	20	0.6	140	37	15
	Avocado	4.5	30	0.68	147	25	10	4	20	0.68	140	35	15
	Kiwifruit	-	-	-	-	-	-	4	20	0.85	140	35	15
B	Pasture	3.5	20	1	144	20	5	1.5	15	1	120	40	12
	Citrus	3.5	20	0.6	150	25	10	1.5	15	0.6	130	50	20
	Avocado	3.5	20	0.68	150	30	13	-	-	-	-	-	-
	Kiwifruit	3.5	20	0.85	150	23	10	1.5	15	0.85	130	50	20
C	Pasture	1.2	6	1	130	22	5	1	3	1	150	28	12
	Citrus	1.2	6	0.6	140	35	12	1	3	0.6	160	42	22
	Avocado	-	-	-	-	-	-	-	-	-	-	-	-
	Kiwifruit	1.2	6	0.85	140	28	10	1	3	0.85	160	40	20
D	Pasture	1	3	1	150	20	8	0.9	2.5	1	155	25	12
	Citrus	1	3	0.6	150	27	12	0.9	2.5	0.6	160	40	20
	Avocado	-	-	-	-	-	-	-	-	-	-	-	-
	Kiwifruit	1	3	0.85	150	20	9	0.9	2.5	0.85	160	36	18

Appendix D. Irrigation Requirements by Crop Type

Table B1. Kaipara Command Area irrigation requirements.

Soil Group	Crop type	Percentile	Irrigation Requirement (mm)							
			Jan	Feb	Mar	Apr	Oct	Nov	Dec	Total
A	Pasture	25	48.4	52.8	17.6	0.0	0.0	33.0	41.8	244
		Median (50th)	74.8	66.0	48.4	17.6	8.8	44.0	70.4	326
		75	114.4	85.8	68.2	30.8	26.4	63.8	90.2	416
		90	127.6	101.2	89.8	45.8	38.7	94.2	118.8	480
		95	130.7	117.9	99.9	59.0	59.0	96.8	126.3	531
		99	132.0	123.2	113.1	73.1	75.9	108.3	132.4	592
	Avocados	25	30.8	35.2	4.4	0.0	0.0	17.6	24.2	196
		Median (50th)	66.0	61.6	44.0	17.6	0.0	35.2	61.6	268
		75	105.6	79.2	63.8	30.8	15.4	57.2	88.0	387
		90	120.6	101.2	92.4	44.0	29.9	85.4	110.9	439
		95	127.6	116.6	99.9	54.6	48.8	88.0	118.8	500
		99	132.0	123.2	115.5	72.8	69.4	104.3	128.0	563
B	Pasture	25	38.7	43.0	12.9	0.0	0.0	21.5	32.3	204
		Median (50th)	68.8	64.5	38.7	12.9	0.0	34.4	64.5	297
		75	107.5	77.4	62.3	25.8	12.9	60.2	86.0	376
		90	122.1	98.9	83.4	40.4	24.9	79.1	110.9	439
		95	124.7	115.2	93.3	53.3	40.4	86.0	119.1	486
		99	127.0	120.4	106.2	66.8	56.9	101.6	125.0	549
	Citrus	25	8.2	22.6	0.0	0.0	0.0	0.0	8.2	119
		Median (50th)	45.1	49.2	20.5	4.1	0.0	8.2	45.1	184
		75	92.2	65.6	55.3	18.5	0.0	30.8	63.5	287
		90	112.3	87.7	75.4	34.4	0.0	48.4	94.3	359
		95	117.7	107.4	90.2	46.7	13.9	66.0	98.4	410
		99	123.0	114.8	109.8	66.3	37.9	91.2	112.9	468
	Avocados	25	21.0	33.6	4.2	0.0	0.0	8.4	18.9	172
		Median (50th)	63.0	63.0	37.8	8.4	0.0	25.2	58.8	256
		75	100.8	77.7	65.1	27.3	6.3	52.5	84.0	357
		90	121.8	98.3	89.9	42.0	18.5	72.2	108.4	420
		95	126.0	112.6	99.5	56.3	35.3	82.7	116.3	478
		99	128.3	117.6	118.6	69.8	57.9	101.8	126.3	538
	Kiwifruit	25	30.8	35.2	4.4	0.0	0.0	11.0	24.2	176
		Median (50th)	66.0	61.6	35.2	8.8	0.0	26.4	61.6	260
		75	103.4	74.8	59.4	26.4	4.4	50.6	83.6	354
		90	123.2	96.8	83.6	39.6	16.7	69.5	111.8	414
		95	123.2	116.6	91.1	50.2	32.6	83.6	118.8	469

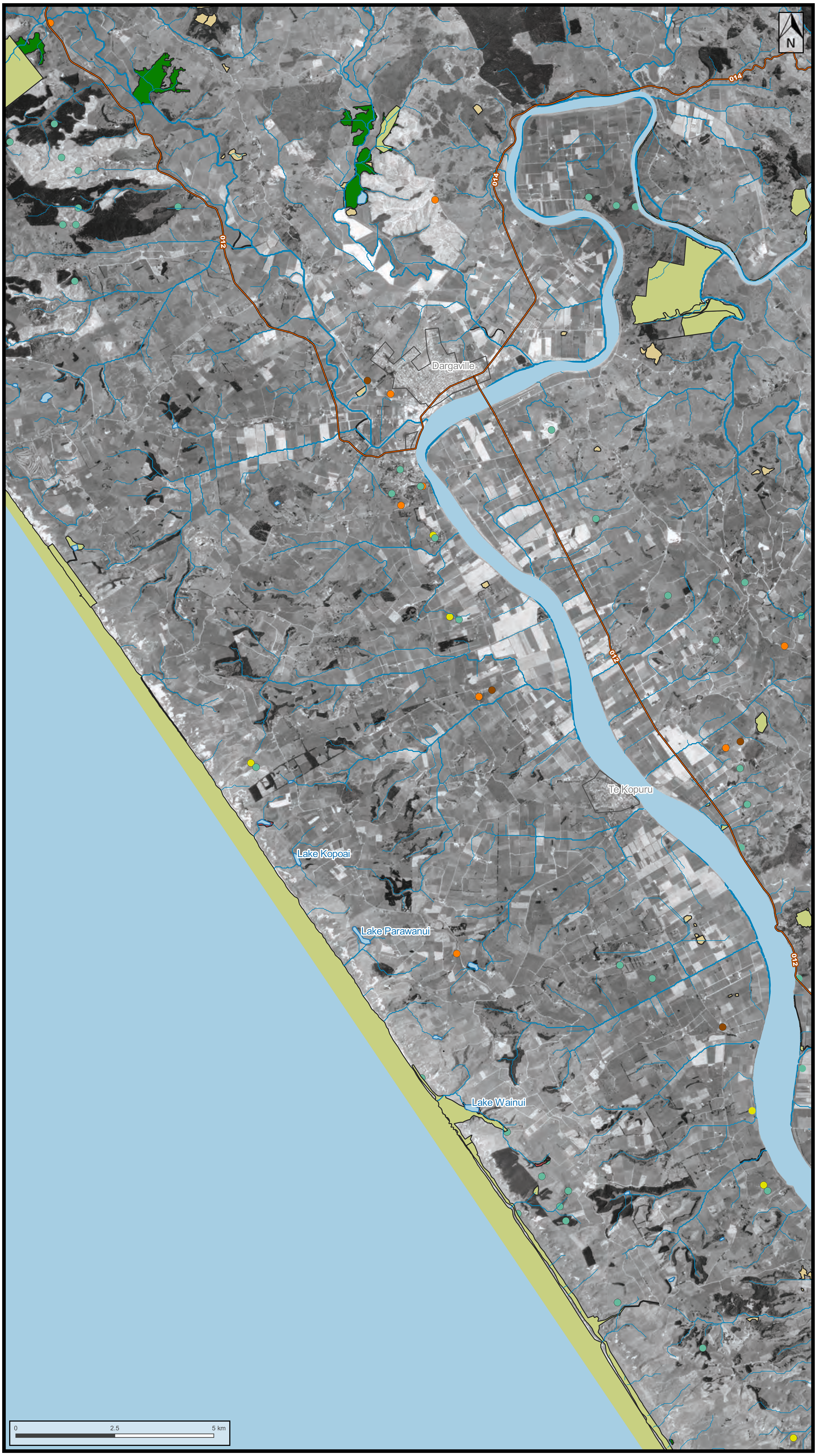
Soil Group	Crop type	Percentile	Irrigation Requirement (mm)							
			Jan	Feb	Mar	Apr	Oct	Nov	Dec	Total
		99	130.0	123.2	106.7	66.4	49.5	97.5	130.3	531
C	Pasture	25	49.2	51.2	16.4	0.0	0.0	18.5	38.9	213
		Median (50th)	77.9	65.6	45.1	16.4	0.0	32.8	69.7	299
		75	106.6	82.0	63.5	24.6	0.0	53.3	88.1	371
		90	123.0	98.4	82.0	36.9	7.4	74.6	110.7	434
		95	123.0	111.1	86.1	49.6	19.3	82.0	117.7	471
		99	125.2	114.8	103.5	61.8	33.8	93.1	123.3	525
	Citrus	25	13.0	27.8	0.0	0.0	0.0	0.0	3.7	93
		Median (50th)	48.1	51.8	22.2	0.0	0.0	0.0	33.3	159
		75	86.9	68.5	53.7	16.7	0.0	9.3	57.4	268
		90	111.0	88.1	77.7	33.3	0.0	37.0	82.9	332
		95	111.0	101.4	88.8	44.8	0.0	40.7	87.7	377
		99	114.7	103.6	109.6	55.8	4.0	60.4	100.5	437
	Kiwifruit	25	30.8	39.0	4.1	0.0	0.0	0.0	22.6	152
		Median (50th)	65.6	57.4	32.8	8.2	0.0	8.2	57.4	234
		75	98.4	73.8	55.3	20.5	0.0	32.8	75.8	320
		90	118.9	94.3	79.5	32.8	0.0	56.6	98.4	384
		95	121.8	109.9	84.9	42.6	2.9	61.5	108.2	425
		99	123.0	114.8	105.7	55.8	15.2	81.1	119.2	485
D	Pasture	25	54.6	52.7	19.5	0.0	0.0	15.6	44.9	232
		Median (50th)	78.0	66.3	50.7	15.6	0.0	31.2	70.2	285
		75	103.4	80.0	60.5	23.4	0.0	54.6	85.8	371
		90	117.0	93.6	78.0	35.1	5.5	70.2	109.2	423
		95	117.0	105.7	81.9	44.5	13.3	76.8	111.9	445
		99	120.9	109.2	96.6	56.7	27.9	88.5	115.2	506
	Citrus	25	20.9	32.3	3.8	0.0	0.0	0.0	11.4	110
		Median (50th)	57.0	53.2	26.6	3.8	0.0	0.0	38.0	156
		75	87.4	68.4	51.3	15.2	0.0	5.7	60.8	266
		90	110.2	88.9	72.2	28.1	0.0	19.0	83.6	320
		95	114.0	103.0	77.5	38.4	0.0	30.4	86.3	349
		99	114.0	106.4	96.2	45.9	0.0	42.1	97.7	412
	Kiwifruit	25	37.8	44.1	12.6	0.0	0.0	0.0	29.4	166
		Median (50th)	67.2	54.6	37.8	8.4	0.0	4.2	58.8	223
		75	96.6	71.4	54.6	16.8	0.0	29.4	77.7	315
		90	115.1	88.2	71.4	29.4	0.0	43.7	97.4	370
		95	120.5	105.4	75.6	39.5	0.0	56.3	109.2	401
		99	124.1	117.6	88.9	50.7	6.8	65.6	118.3	464

Table B2. Mid-North Command Area irrigation requirements.

Soil Group	Crop type	Percentile	Irrigation Requirement (mm)							
			Jan	Feb	Mar	Apr	Oct	Nov	Dec	Total
A	Pasture	25	14.7	31.5	0.0	0.0	0.0	0.0	14.7	172
		Median (50th)	54.6	58.8	33.6	8.4	0.0	29.4	42.0	239
		75	98.7	73.5	63.0	31.5	6.3	56.7	77.7	355
		90	115.1	100.8	92.4	43.7	25.2	73.1	119.3	417
		95	120.5	109.2	106.7	61.7	32.3	86.9	121.8	433
		99	124.1	117.6	124.1	78.9	49.1	109.5	128.3	524
	Citrus	25	2.1	16.4	0.0	0.0	0.0	0.0	0.0	109
		Median (50th)	36.9	45.1	20.5	0.0	0.0	4.1	16.4	168
		75	77.9	61.5	47.1	22.6	0.0	26.7	69.7	293
		90	108.2	93.5	87.7	42.6	5.7	59.0	105.8	354
		95	113.6	101.3	101.3	61.5	13.9	64.4	114.8	364
		99	121.1	114.8	121.1	77.0	33.8	90.9	123.0	460
	Avocados	25	10.5	31.5	4.2	0.0	0.0	6.3	12.6	158
		Median (50th)	50.4	54.6	25.2	4.2	0.0	29.4	46.2	218
		75	90.3	65.1	54.6	27.3	10.5	54.6	73.5	334
		90	110.9	94.1	87.4	51.2	25.2	73.1	109.2	386
		95	120.5	103.7	99.5	61.7	39.9	84.0	117.6	453
		99	128.3	115.7	124.1	84.7	46.2	106.0	124.1	549
	Kiwifruit	25	8.8	26.4	0.0	0.0	0.0	0.0	6.6	147
		Median (50th)	44.0	57.2	30.8	0.0	0.0	22.0	30.8	216
		75	96.8	68.2	57.2	26.4	0.0	46.2	77.0	341
		90	118.8	101.2	88.0	44.0	19.4	70.4	117.9	407
		95	125.0	110.0	104.3	60.3	25.1	79.2	123.2	412
		99	130.0	121.2	128.0	80.3	42.7	108.7	127.6	512
B	Pasture	25	14.4	36.9	2.1	0.0	0.0	4.1	12.3	148
		Median (50th)	49.2	49.2	24.6	0.0	0.0	28.7	41.0	205
		75	96.3	61.5	51.2	18.5	0.0	47.1	73.8	318
		90	114.8	91.8	75.4	36.1	9.8	65.6	106.6	367
		95	117.7	101.3	91.8	48.0	22.1	68.5	113.6	423
		99	125.2	109.1	108.8	68.1	33.1	93.4	118.9	509
	Citrus	25	0.0	10.2	0.0	0.0	0.0	0.0	0.0	70
		Median (50th)	20.4	30.6	13.6	0.0	0.0	0.0	17.0	126
		75	62.9	52.7	32.3	15.3	0.0	17.0	52.7	231
		90	98.6	83.0	75.5	38.8	0.0	34.0	79.6	262
		95	98.6	87.4	88.7	50.0	2.4	39.8	94.5	311
		99	103.8	93.6	102.0	70.1	10.7	75.1	102.3	437
	Kiwifruit	25	13.3	32.3	0.0	0.0	0.0	0.0	7.6	137
		Median (50th)	45.6	49.4	22.8	0.0	0.0	26.6	41.8	194

Soil Group	Crop type	Percentile	Irrigation Requirement (mm)							
			Jan	Feb	Mar	Apr	Oct	Nov	Dec	Total
		75	87.4	64.6	49.4	19.0	0.0	45.6	70.3	308
		90	110.2	95.0	80.6	40.3	9.1	60.8	99.6	359
		95	110.2	101.5	95.4	49.4	22.0	64.6	109.1	410
		99	116.1	106.4	112.3	71.1	30.7	92.4	114.3	504
C	Pasture	25	25.9	38.9	7.4	0.0	0.0	0.0	24.1	155
		Median (50th)	59.2	55.5	29.6	0.0	0.0	14.8	44.4	207
		75	92.5	64.8	46.3	18.5	0.0	35.2	70.3	303
		90	107.3	90.3	68.1	34.0	0.0	55.5	101.4	352
		95	109.9	95.1	85.5	43.3	0.0	58.1	103.6	391
		99	113.0	100.2	96.5	57.8	0.0	77.2	111.3	455
	Citrus	25	4.5	15.0	0.0	0.0	0.0	0.0	0.0	65
		Median (50th)	33.0	39.0	15.0	0.0	0.0	0.0	18.0	114
		75	72.0	54.0	42.0	13.5	0.0	1.5	51.0	216
		90	88.2	78.0	67.2	33.6	0.0	13.2	62.4	250
		95	90.0	81.0	87.3	46.2	0.0	19.2	76.2	287
		99	90.0	84.0	91.6	57.2	0.0	37.0	90.0	378
	Kiwifruit	25	21.6	37.8	5.4	0.0	0.0	0.0	18.0	140
		Median (50th)	54.0	54.0	28.8	0.0	0.0	10.8	39.6	194
		75	91.8	66.6	48.6	18.0	0.0	32.4	68.4	295
		90	105.8	93.6	66.2	31.7	0.0	46.1	97.2	343
		95	108.0	97.2	91.8	41.0	0.0	52.9	99.7	385
		99	109.9	100.8	104.7	58.2	0.0	71.5	104.4	453
D	Pasture	25	25.9	37.0	7.4	0.0	0.0	0.0	24.1	148
		Median (50th)	55.5	51.8	29.6	0.0	0.0	7.4	44.4	203
		75	92.5	62.9	44.4	16.7	0.0	27.8	70.3	294
		90	107.3	90.3	66.6	32.6	0.0	45.9	99.9	341
		95	107.3	92.5	81.8	39.6	0.0	50.7	102.5	376
		99	113.0	100.2	92.8	54.1	0.0	69.5	109.3	436
	Citrus	25	6.0	21.0	0.0	0.0	0.0	0.0	0.0	72
		Median (50th)	36.0	42.0	18.0	0.0	0.0	0.0	18.0	123
		75	73.5	57.0	43.5	16.5	0.0	0.0	52.5	222
		90	88.2	78.0	69.0	32.4	0.0	8.4	61.2	253
		95	90.0	81.0	87.3	44.1	0.0	17.1	75.3	292
		99	90.0	84.0	91.6	55.6	0.0	33.7	87.2	377
	Kiwifruit	25	25.9	35.2	7.4	0.0	0.0	0.0	20.4	141
		Median (50th)	55.5	55.5	25.9	0.0	0.0	7.4	44.4	192
		75	92.5	64.8	46.3	18.5	0.0	25.9	66.6	289
		90	108.8	92.5	64.4	28.9	0.0	42.2	96.2	334
		95	111.0	98.8	86.9	39.6	0.0	47.0	98.8	379

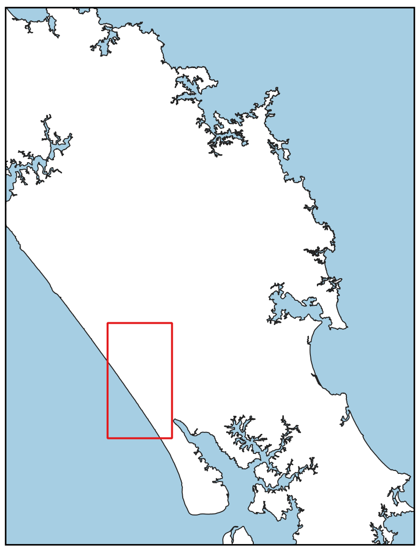
Soil Group	Crop type	Percentile	Irrigation Requirement (mm)							
			Jan	Feb	Mar	Apr	Oct	Nov	Dec	Total
		99	113.0	101.9	100.5	54.1	0.0	67.5	103.6	440



Map Title:
Kaipara Command Area Sites of Significance

Project:
Northland Water Storage Pre-Feasibility Study

Client:
Northland Regional Council



Legend

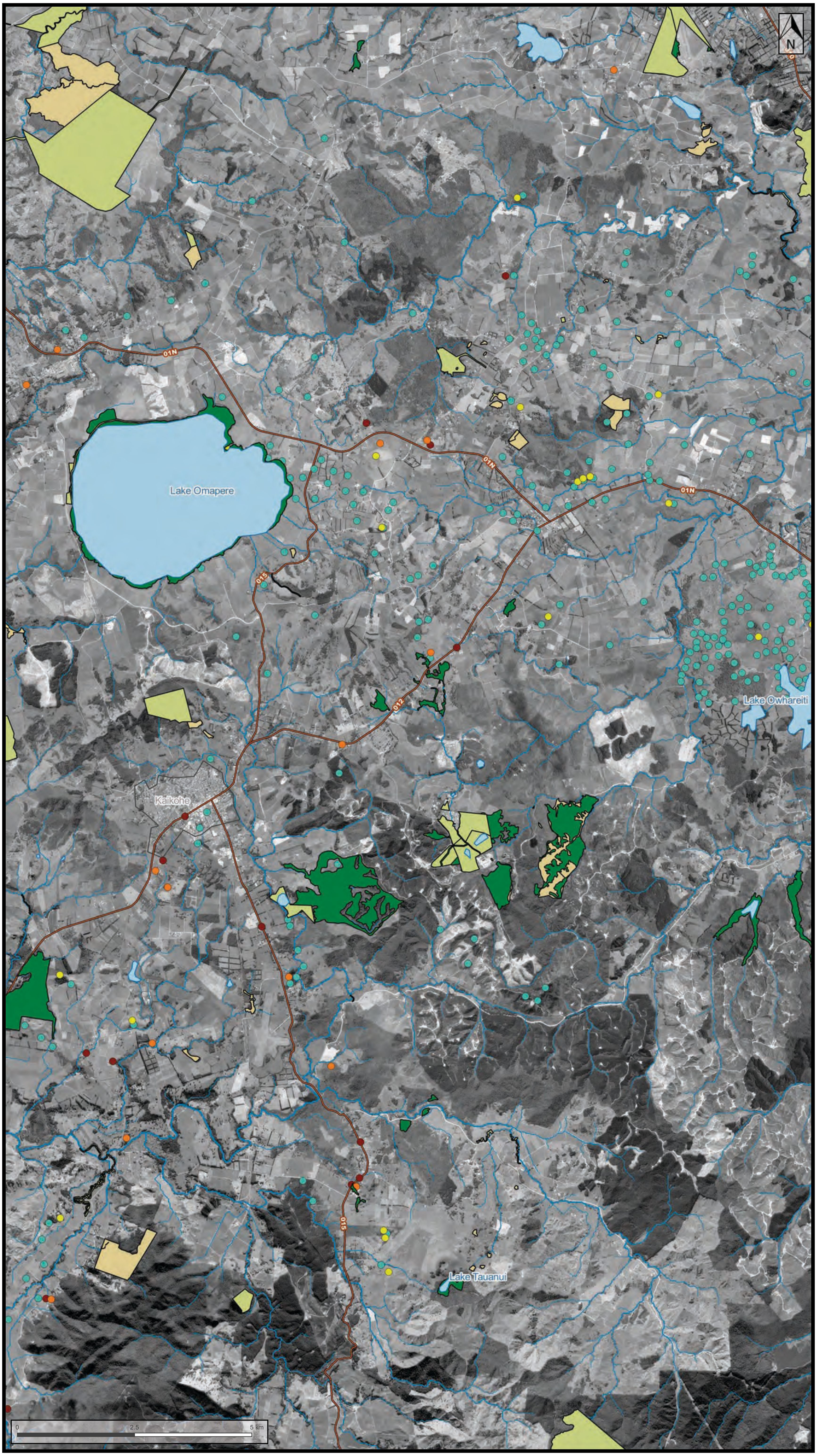
- Highway
- River
- Lake
- Urban Area
- Cemetery
- Marae
- Archaeological Sites
- Pa Site
- High Natural Character
- Protected Area
- Wetlands Top 150
- QEII Area

Data Provenance

Northland 0.4m Rural Aerial Photos (2014-2016), Topographic Data, Cemetery and Pa Site Locations derived from Land Information New Zealand. Crown Copyright Reserved.
Planning and Policy data from Northland Regional Council.
Archelogical Sites from New Zealand Archaeological Association.
Marae Locations from Māori Maps.

WILLIAMSON
WATER & LAND ADVISORY

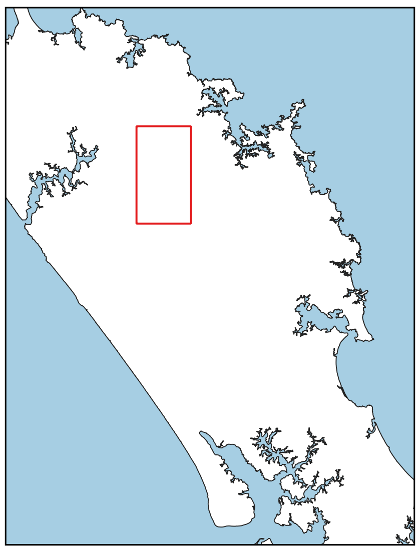
Figure 3.



Map Title:
Mid North Command Area Sites of Significance

Project:
Northland Water Storage Pre-Feasibility Study

Client:
Northland Regional Council



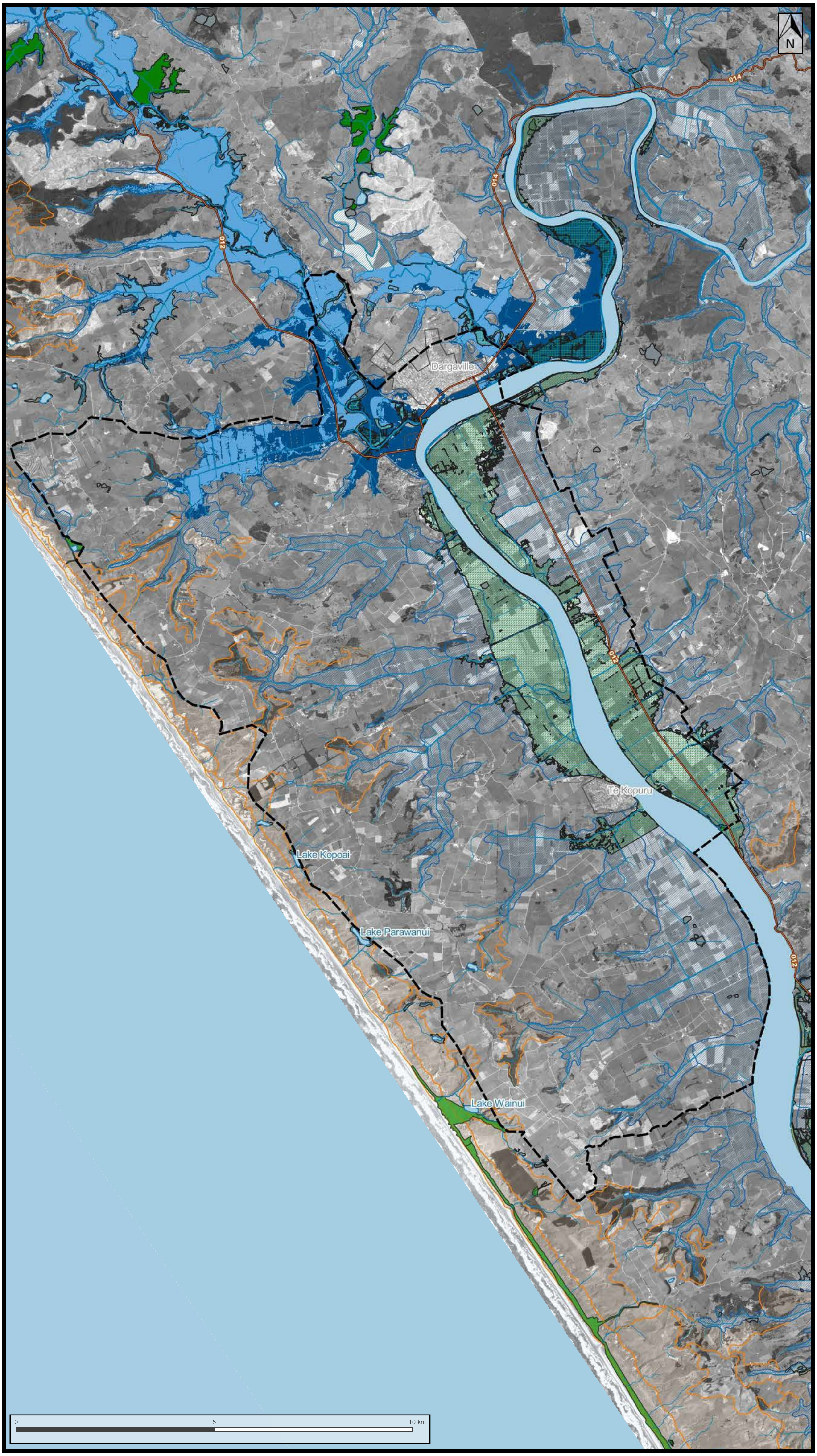
Legend

- Highway
- River
- Lake
- Urban Area
- Archealogical Site
- Cemetery
- Marae
- Pa Site
- QEII Area
- Protected Areas
- Wetlands Top 150

Data Provenance
Aerial Imagery, Cemetery and Pa Site Locations derived from Land Information New Zealand.
Crown Copyright Reserved.
Planning and Policy data from Northland Regional Council.
Archaeological Sites from New Zealand Archaeological Association.
Marae Locations from Māori Maps

WILLIAMSON WATER & LAND ADVISORY

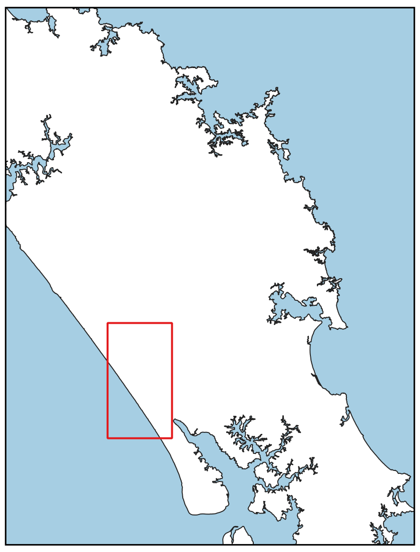
Figure 4.



Map Title:
Kaipara Environmental Features

Project:
Northland Water Storage Pre-Feasibility Study

Client:
Northland Regional Council



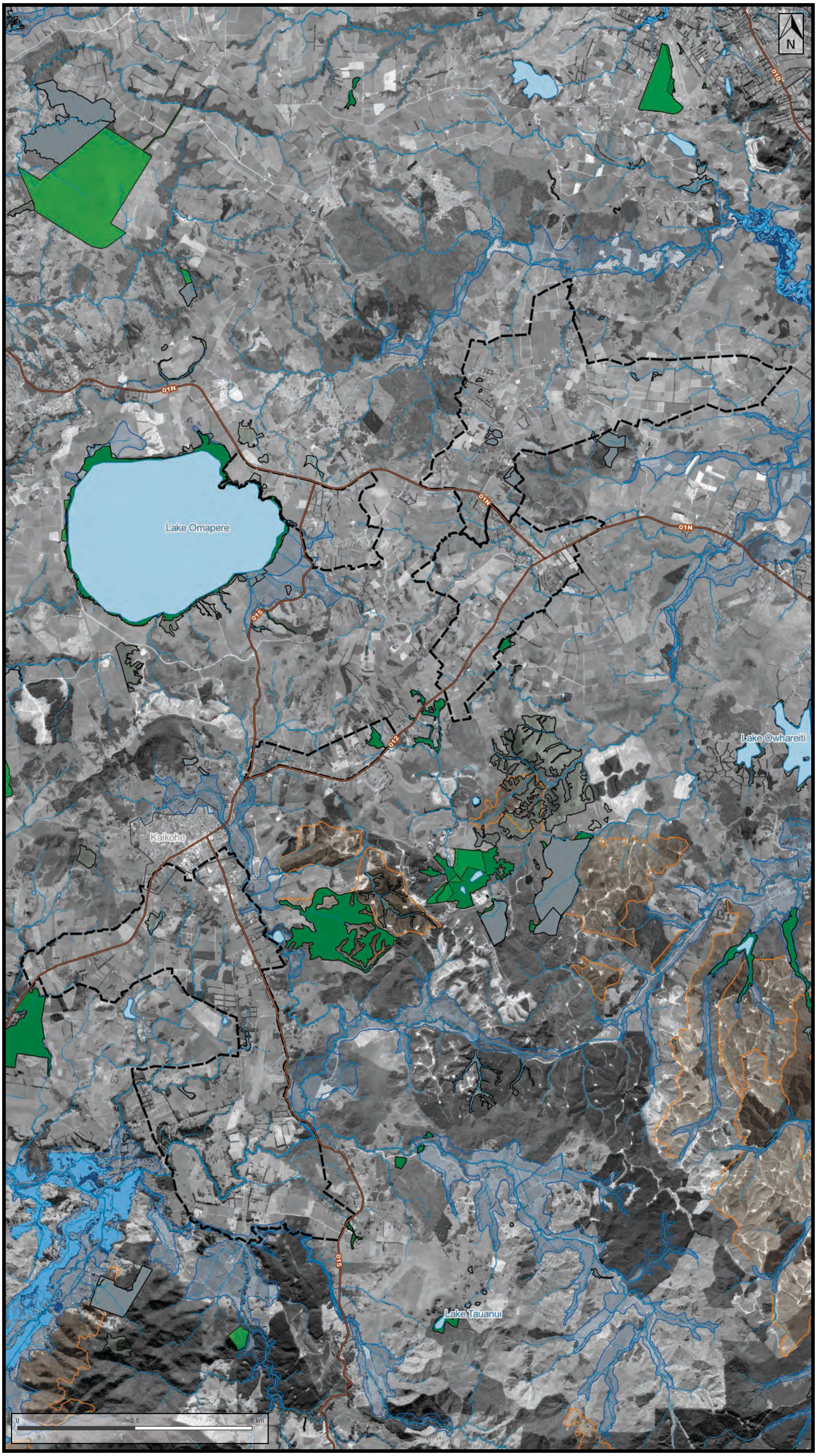
Legend

- **Highway**
- **River**
- **Lake**
- **Urban Area**
- **Kaipara Command Area**
- **Erosion Prone Land**
- **Flood Susceptible Land**
- **Priority Rivers 10 year Flood Extent**
- **Priority Rivers 100 year Flood Extent**
- **Coastal Flood Hazard Zone**
- **DOC Land**
- **Wetlands**
- **Wetlands Top 150**
- **QEII Land**

Data Provenance
Northland 0.4m Rural Aerial Photos (2014-2016) from Land Information New Zealand. Crown Copyright Reserved.
Flood Extent and Land Classification data from Northland Regional Council.

WILLIAMSON WATER & LAND ADVISORY

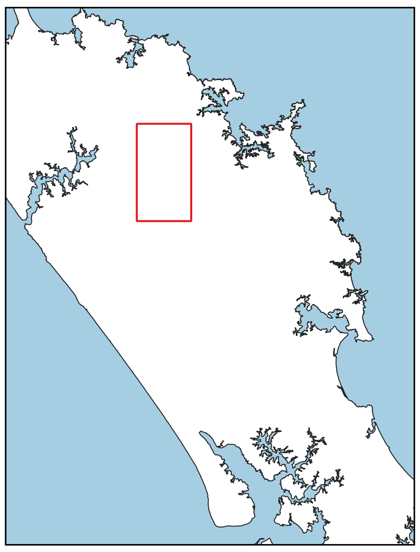
Figure 5.



Map Title:
Mid North Environmental Features

Project:
Northland Water Storage Pre-Feasibility Study

Client:
Northland Regional Council



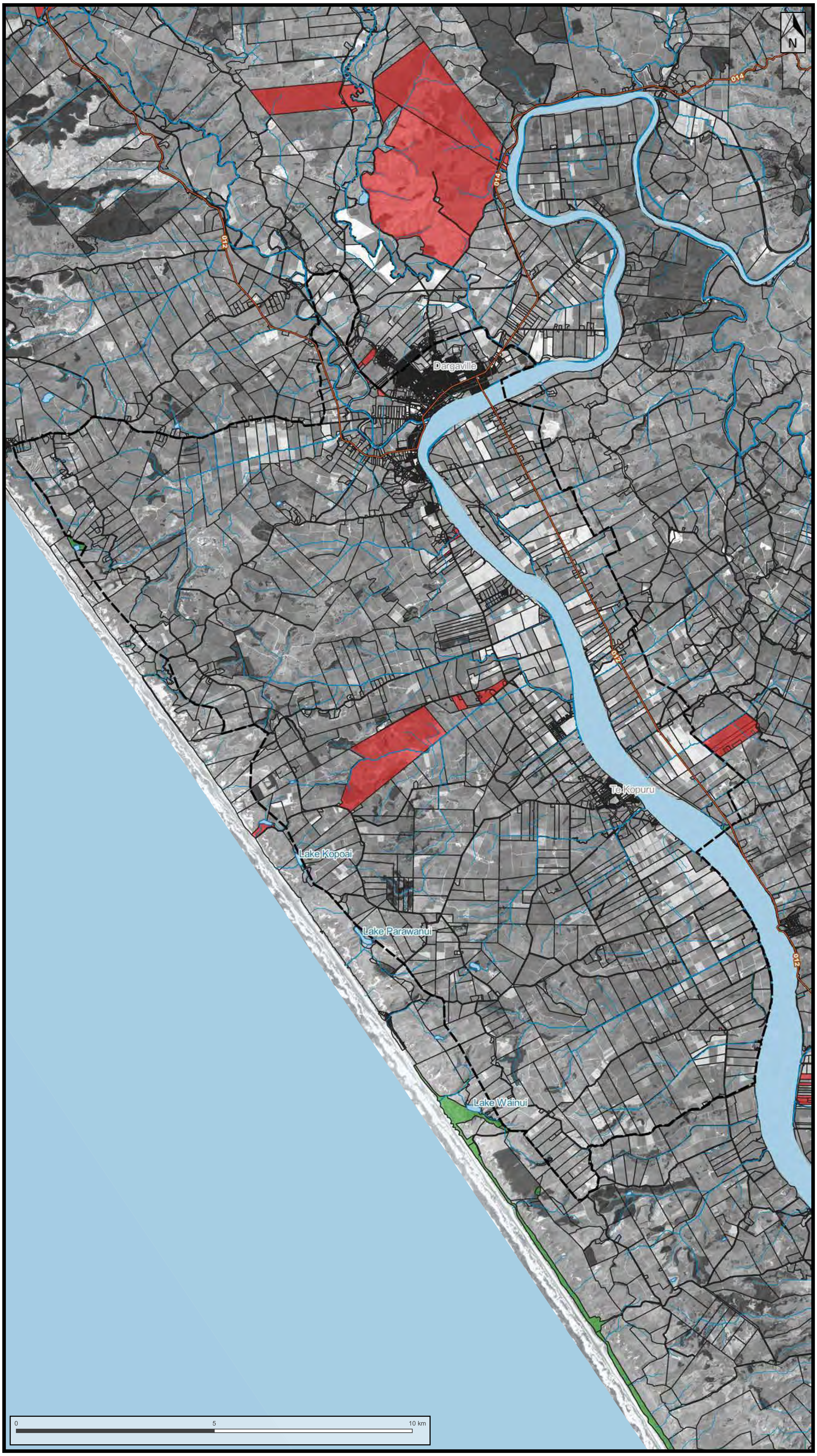
Legend

- Highway
- River
- Lake
- Urban Area
- Mid-North Command Area
- Erosion Prone Land
- Flood Susceptible Land
- River 10 year Flood Extent
- River 100 year Flood Extent
- DOC Land
- Wetlands
- Wetlands Top 150
- QEII Land

Data Provenance
Northland 0.4m Rural Aerial Photos (2014-2016) from Land Information New Zealand. Crown Copyright Reserved. Flood Extent and Land Classification data from Northland Regional Council.

WILLIAMSON WATER & LAND ADVISORY

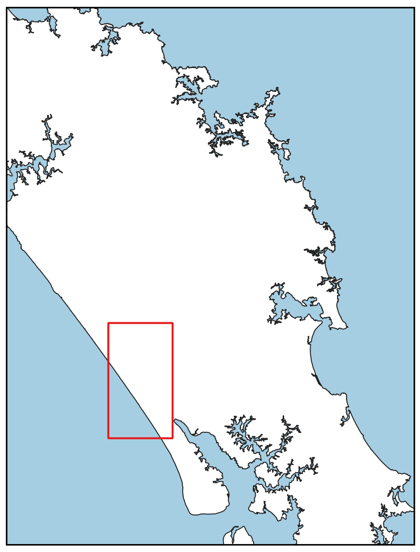
Figure 6.



Map Title:
Kaipara Command Area Land Ownership

Project:
Northland Water Storage Pre-Feasibility Study

Client:
Northland Regional Council



Legend

- Highway
- River
- Lake
- Kaipara Command Area
- Property Boundary
- Maori Owned Land
- DOC Land

Data Provenance

Northland 0.4m Rural Aerial Photos, property boundaries from Land Information New Zealand Crown Copyright Reserved. DOC land data from Northland Regional Council.

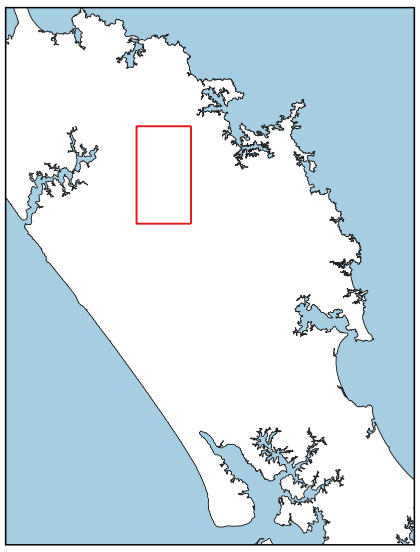
WILLIAMSON WATER & LAND ADVISORY

Figure 7.

Map Title:
Mid-North Command Area Land Ownership

Project:
Northland Water Storage Pre-Feasibility Study

Client:
Northland Regional Council



Legend

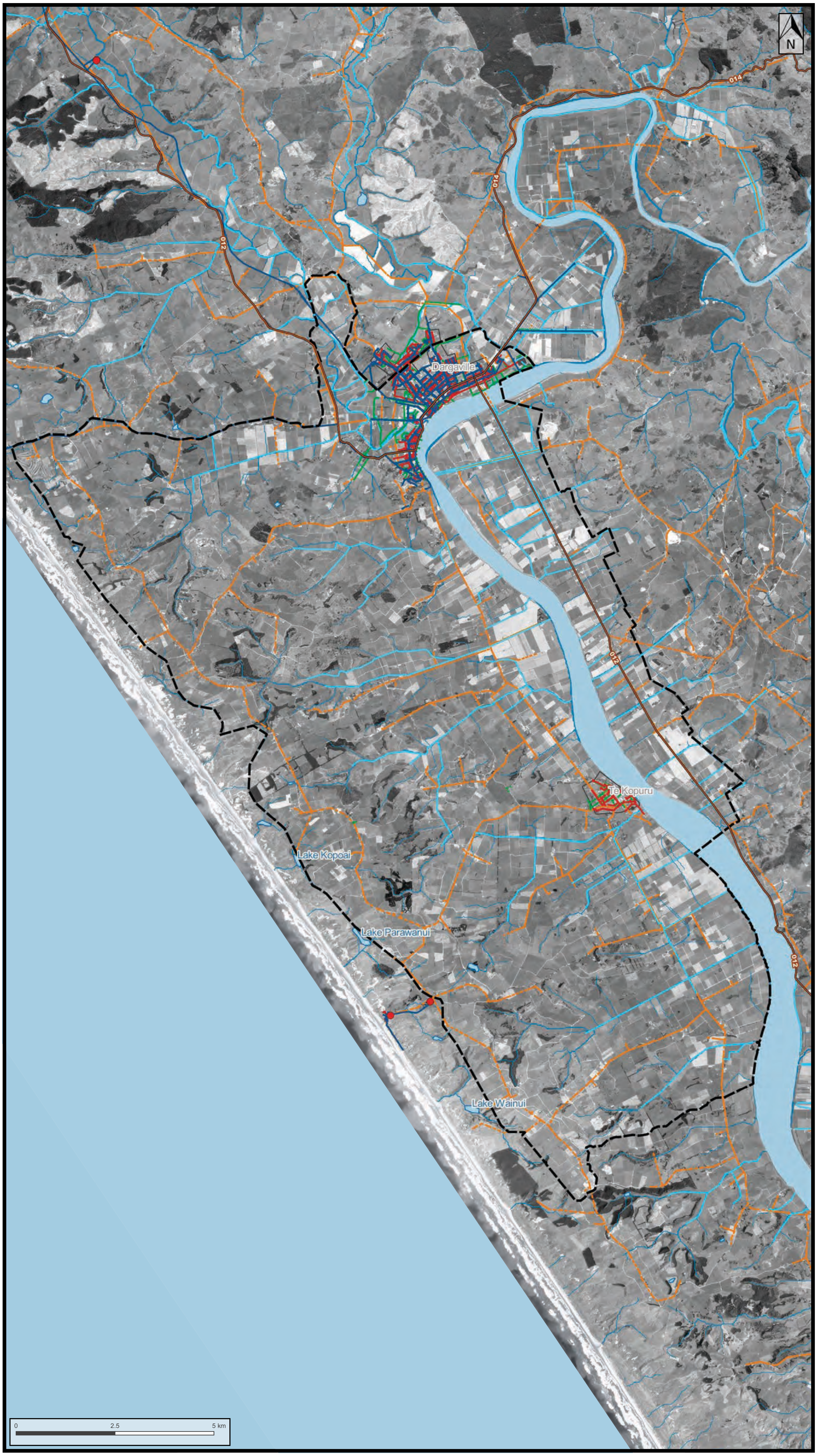
- Highway
- River
- Lake
- Mid-North Command Area
- Property Boundary
- Maori Owned Land
- DOC Land

Data Provenance

Northland 0.4m Rural Aerial Photos, property boundaries from Land Information New Zealand Crown Copyright Reserved.
DOC land data from Northland Regional Council.

WILLIAMSON WATER & LAND ADVISORY

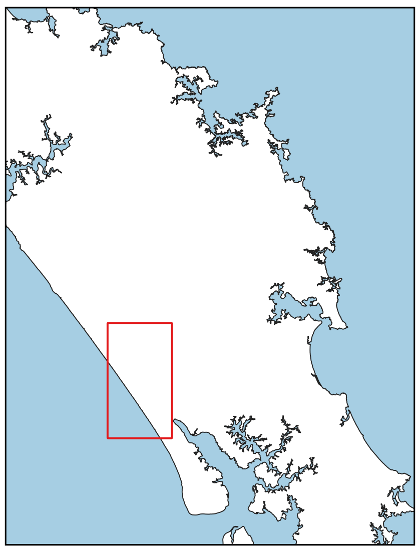
Figure 8.



Map Title:
Kaipara Command Area Existing Infrastructure

Project:
Northland Water Storage Pre-Feasibility Study

Client:
Northland Regional Council



Legend

- Highway
- River
- Lake
- Kaipara Command Area
- KDC Consented Take
- Drainline
- Stormwater
- Wastewater Line
- KDC Water Services

Data Provenance

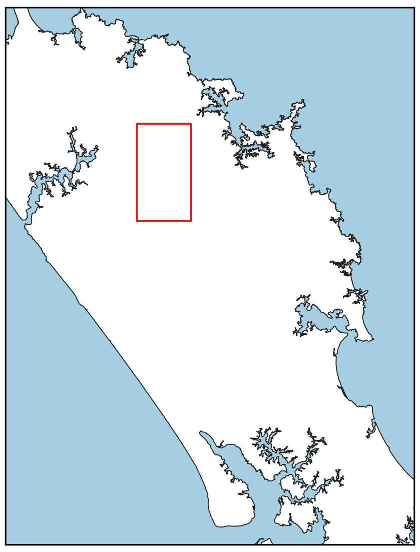
Aerial Imagery 0.4m Northland (2014-2016) from Land Information New Zealand. Crown Copyright Reserved.
Infrastructure data from Northland Regional Council.

Figure 09.

Map Title:
Mid North Command Area Existing Infrastructure

Project:
Northland Water Storage Pre-Feasibility Study

Client:
Northland Regional Council

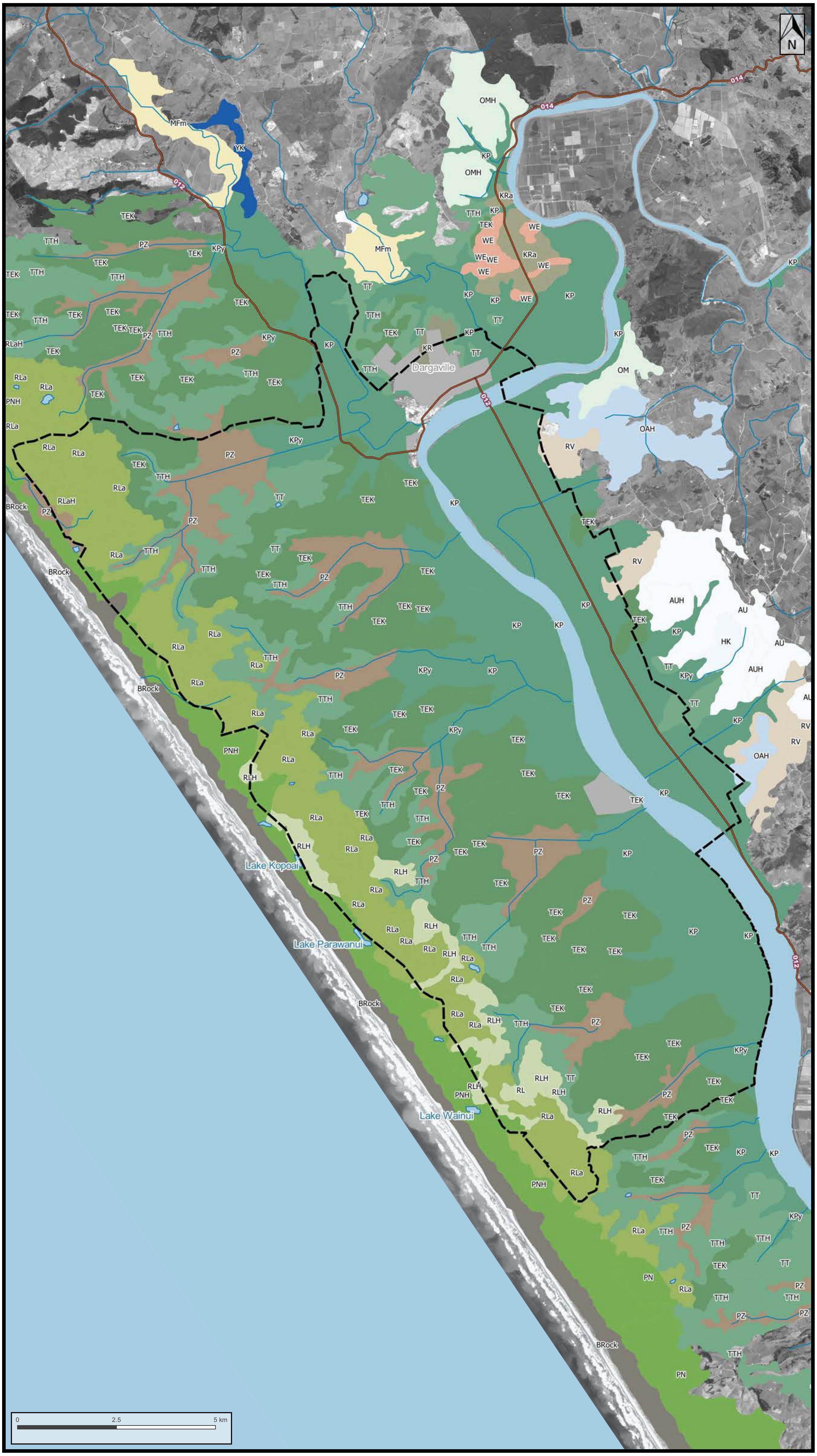


Legend
- Highway
- River
- Lake
- Mid-North Command Area
- FNDC Consented Take
- Power Conductor
- Wastewater Line
- Storm Water Line
- Water Services

Data Provenance
Aerial Imagery 0.4m Northland (2014-2016) from Land Information New Zealand. Crown Copyright Reserved.
Infrastructure data from Northland Regional Council.

WILLIAMSON WATER & LAND ADVISORY

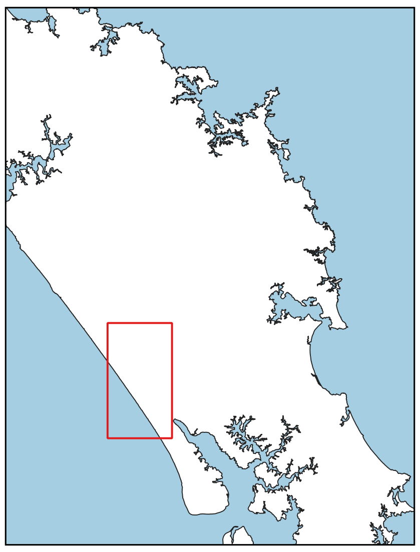
Figure 11.



Map Title:
Kaipara Command Area Soil Type

Project:
Northland Water Storage Pre-Feasibility Study

Client:
Northland Regional Council



Legend

- Highway
- River
- Lake
- Urban Area
- Kaipara Command Area

Soil Types

- AU/AUH - Arapohue Clay
- BRock - Bedrock
- HK - Hukerenui Silt Loam
- KP - Kaipara Clay and Clay Loam
- KPy - Kaipara Peaty Clay Loam
- KR - Kara Silt Loam
- KRa - Kara Sandy Loam
- MFm - Mangakahia Mottled Clay Loam
- OAH - Okaka Hill Clay
- OM/OMH - Omu Clay Loam
- PN/PNH - Pinaki Sand
- PZ - Parore Peaty Sand
- RL/RLH - Red Hills Sandy Loam
- RLa/RLaH - Red Hill Sandy Clay Loam
- RV - Rockvale Clay
- TEK - Te Kopuru Sand, wet phase
- TT/TTH - Tangitiki Sandy Loam and Sand
- WE - Waitemata Silt Loam
- YK - Waikare Silt Loam

Data Provenance

Aerial Imagery 0.4m Northland from Land Information New Zealand. Crown Copyright Reserved.
Soil Data from Landcare Research. Crown Copyright Reserved

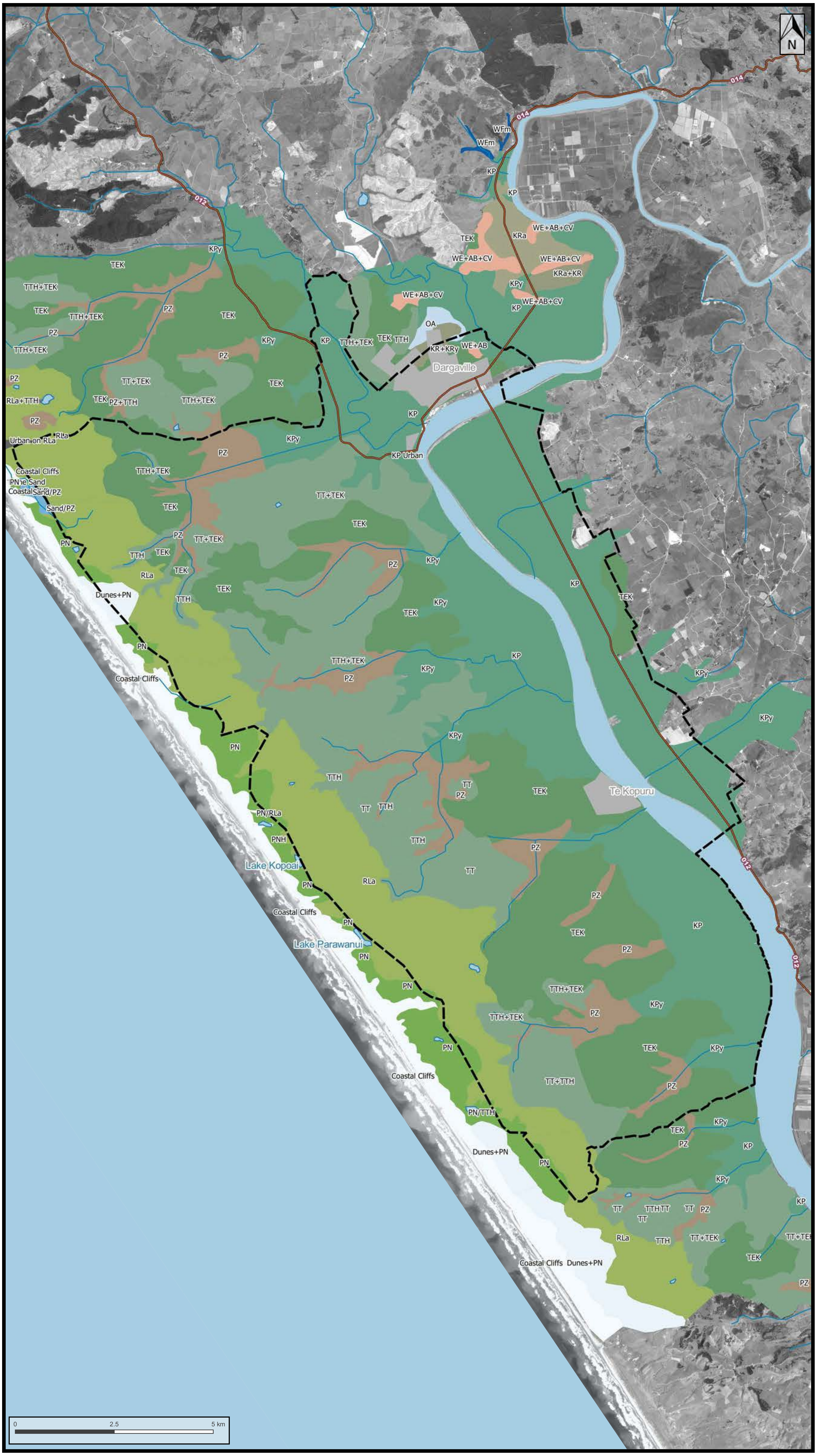
WILLIAMSON WATER & LAND ADVISORY

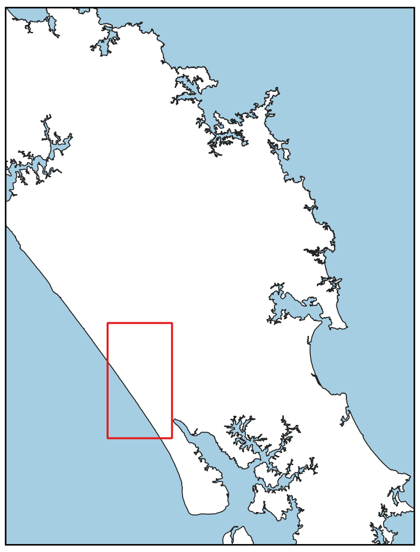
Figure 12.

Map Title:
Kaipara Command Area Soil Type

Project:
Northland Water Storage Pre-Feasibility Study

Client:
Northland Regional Council





Legend

- Highway
- River
- Lake
- Urban Area
- Kaipara Command Area

Soil Types

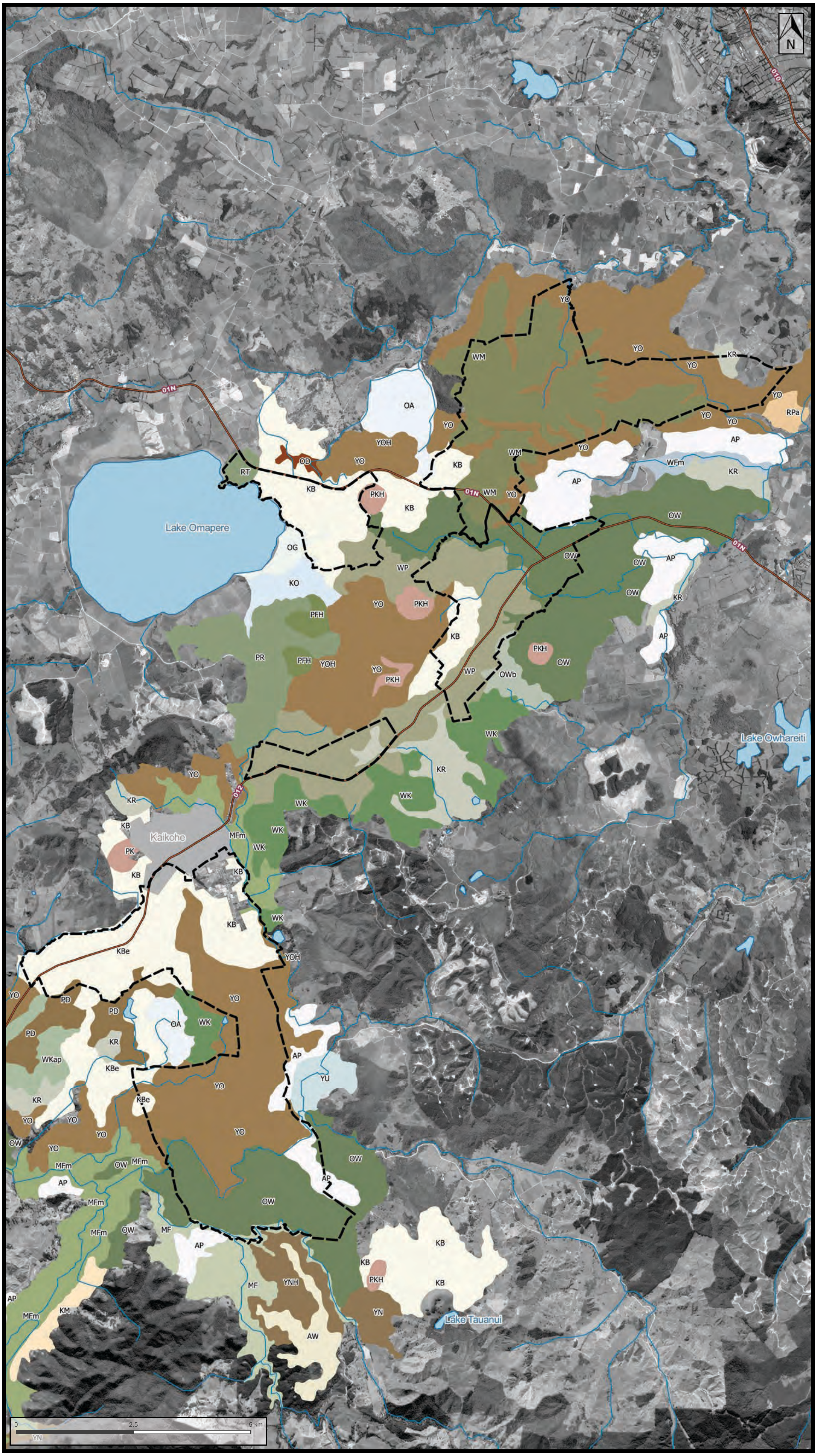
- Coastal Cliffs
- Dune Sand
- Dunes + PN
- KP - Kaipara Clay and Clay Loam
- KPy - Kaipara Peaty Clay Loam
- KR - Kara Silt Loam
- KRa - Kara Sandy Loam
- OA - Okaka Clay and Silty Clay
- PN/PNH - Pinaki Sand
- PZ - Parore Peaty Sand
- RLA/RLaH - Red Hill Sand
- TEK - Te Kopuru Sand, wet phase
- TT/TTH - Tangitiki Sandy Loam and Sand
- WE - Waitemata Silt Loam
- WFm - Whakapare Mottled Clay Loam

Data Provenance

Aerial Imagery 0.4m Northland from Land Information New Zealand. Crown Copyright Reserved.
Soil Data provided by AgFirst Consultants NZ Ltd.

WILLIAMSON WATER & LAND ADVISORY

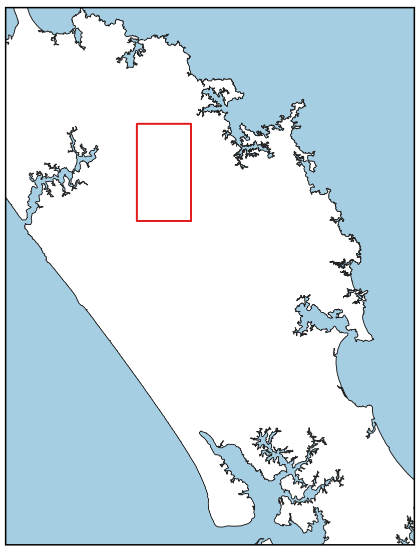
Figure 13.



Map Title:
Mid North Command Area Soil Type

Project:
Northland Water Storage Pre-Feasibility Study

Client:
Northland Regional Council



Legend

- **Highway**
- **River**
- **Lake**
- **Urban Area**
- **Mid-North Command Area**

Soil Types

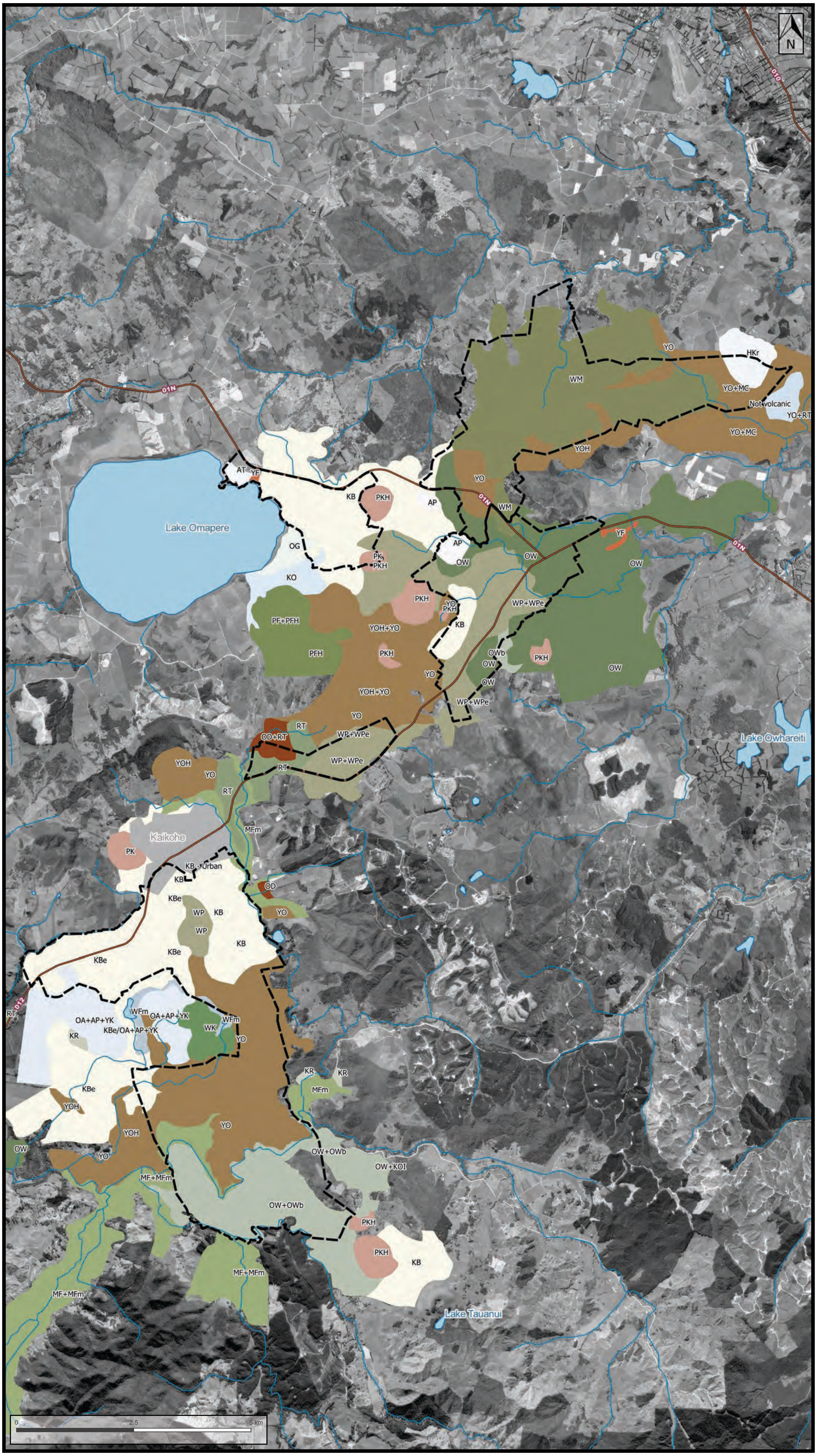
- **AP - Aponga Clay**
- **AW - Awarua Clay**
- **KB - Kiripaka Bouldery Silt Loam**
- **KBe - Kiripaka Bouldery Silt Loam with Compact Subsoil and Boulders**
- **KM - Kohumaru Clay**
- **KO - Kamo Clay and Loam**
- **KR - Kara Silt Loam**
- **MF - Mangakahia Clay**
- **MFm - Mangakahia Mottled Clay Loam**
- **OA - Okaka Clay**
- **OD - Otaha Clay**
- **OG - Otonga Peaty Clay Loam**
- **OW - Ohaeawai Silt Loam**
- **OWb - Ohaeawai Shallow Bouldery Silt Loam**
- **PD - Puketitoi Sandy Loam**
- **PFH - Piroa Clay**
- **PK - Papakauri Silt Loam**
- **PKH - Papakauri Silt Loam**
- **PR - Parahaki Fine Sandy Loam and Silt Loam**
- **RPa - Riponui**
- **RT - Ruatangata Friable Clay**
- **WFm - Whakapara Mottled Clay Loam**
- **WK - Wharekohe Silt Loam**
- **WKap - Warekohe Sandy Loam**
- **WM - Waimate North Clay Loam**
- **WP - Whakapai Clay Loam**
- **YN/YNH - Waimatenui Clay**
- **YO/YOH - Waiotu Friable Clay**
- **YU - Waipu Clay**

Data Provenance

Aerial Imagery 0.4m Northland from Land Information New Zealand. Crown Copyright Reserved.
Soil Data from Landcare Research. Crown Copyright Reserved.

WILLIAMSON WATER & LAND ADVISORY

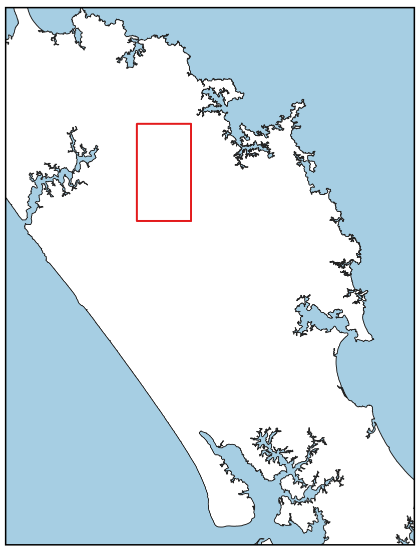
Figure 14.



Map Title:
Mid North Command Area Soil Type

Project:
Northland Water Storage Pre-Feasibility Study

Client:
Northland Regional Council



Legend

- Highway
- River
- Lake
- Urban Area
- Mid-North Command Area

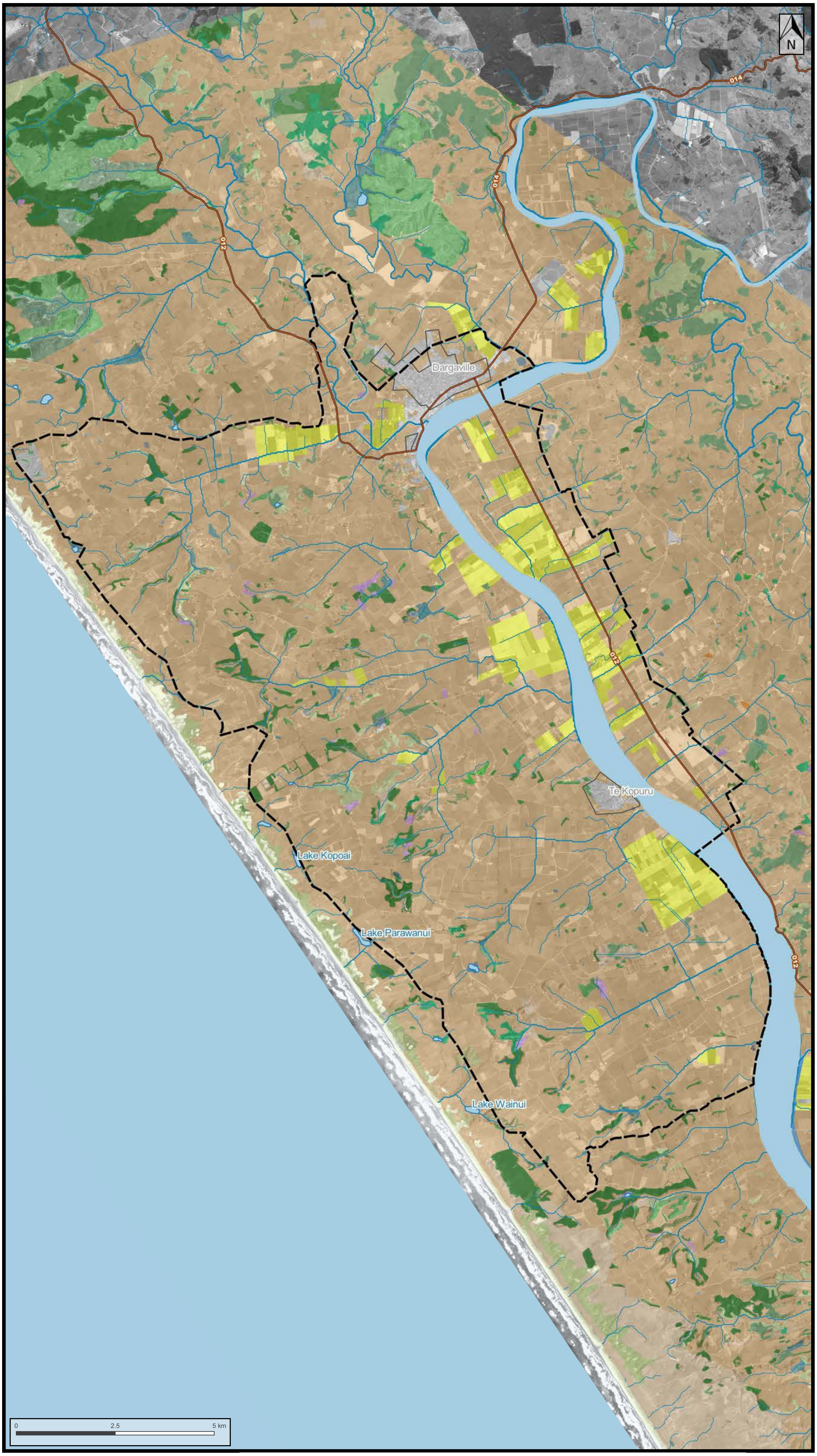
Soil Types

- AP - Aponga Clay
- AT - Apotu Friable Clay
- HKr - Hukernui Silt Loam
- KB - Kiripaka Bouldery Silt Loam
- KBe - Kiripaka Bouldery Silt Loam with Compact Subsoil and Boulders
- KO - Kamo Clay and Loam
- KR - Kara Silt Loam
- MF - Mangakahia Silt Loam and Clay Loam
- MFm - Mangakahia Mottled Clay Loam
- OA - Okaka Clay
- OD - Otaha Clay
- OG - Otonga Peaty Clay Loam
- OW - Ohaeawai Silt Loam
- OWb - Ohaeawai Shallow Bouldery Silt Loam
- PF/PFH - Piroa Clay
- PK/PKH - Papakauri Silt Loam
- RT - Ruatangata Friable Clay
- WFm - Whakapara Mottled Clay Loam
- WK - Wharekohe Silt Loam
- WM - Waimate North Clay Loam
- WP - Whakapai Clay Loam
- YF - Waipapa Clay
- YO - Waiotu Friable Clay

Data Provenance
Aerial Imagery 0.4m Northland from Land Information New Zealand. Crown Copyright Reserved.
Soil Data provided by AgFirst Consultants NZ Ltd.

WILLIAMSON WATER & LAND ADVISORY

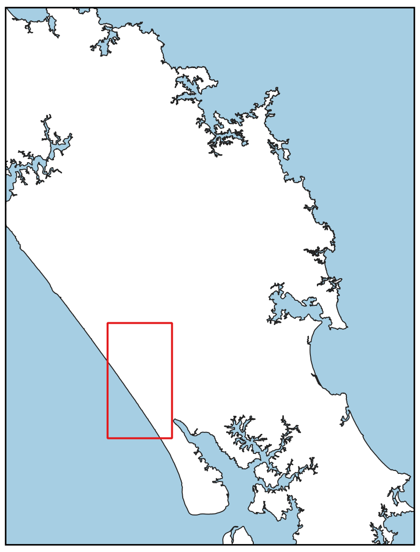
Figure 15.



Map Title:
Kaipara Command Area Land Use Capacity

Project:
Northland Water Storage Pre-Feasibility Study

Client:
Northland Regional Council



Legend

- Highway
- River
- Lake
- Urban Area
- Kaipara Command Area

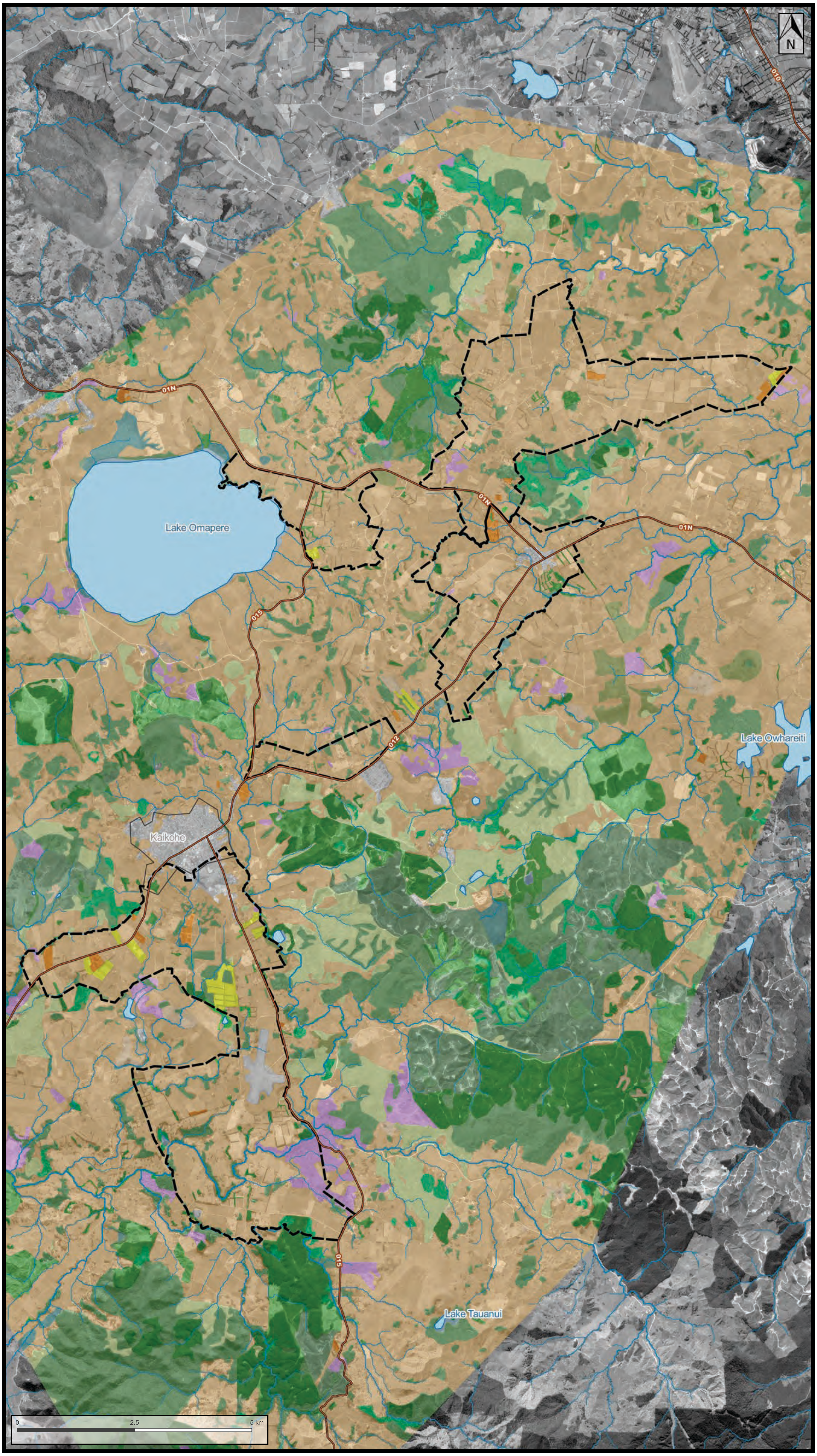
Land Cover

- Broadleaved Indigenous Hardwoods
- Built-up Area (settlement)
- Deciduous Hardwoods
- Exotic Forest
- Fernland
- Forest - Harvested
- Gorse and/or Broom
- Herbaceous Freshwater Vegetation
- High Producing Exotic Grassland
- Indigenous Forest
- Lake or Pond
- Low Producing Grassland
- Manuka and/or Kanuka
- Matagouri or Grey Scrub
- Mixed Exotic Shrubland
- Orchard, Vineyard or Other Perennial Crop
- River
- Short-rotation Cropland
- Surface Mine or Dump
- Urban Parkland/Open Space
- Estuarine Open Water
- Flaxland
- Mangrove
- Sand or Gravel

Data Provenance
Aerial Imagery 0.4m Northland from Land Information New Zealand. Crown Copyright Reserved.
Landcover data from Northland Regional Council.

WILLIAMSON WATER & LAND ADVISORY

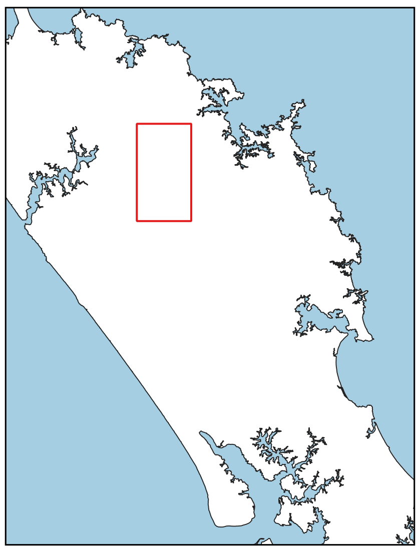
Figure 16.



Map Title:
Mid North Command Area Land Cover

Project:
Northland Water Storage Pre-Feasibility Study

Client:
Northland Regional Council



Legend

- Highway
- River
- Lake
- Urban Area
- Mid-North Command Area

Land Cover

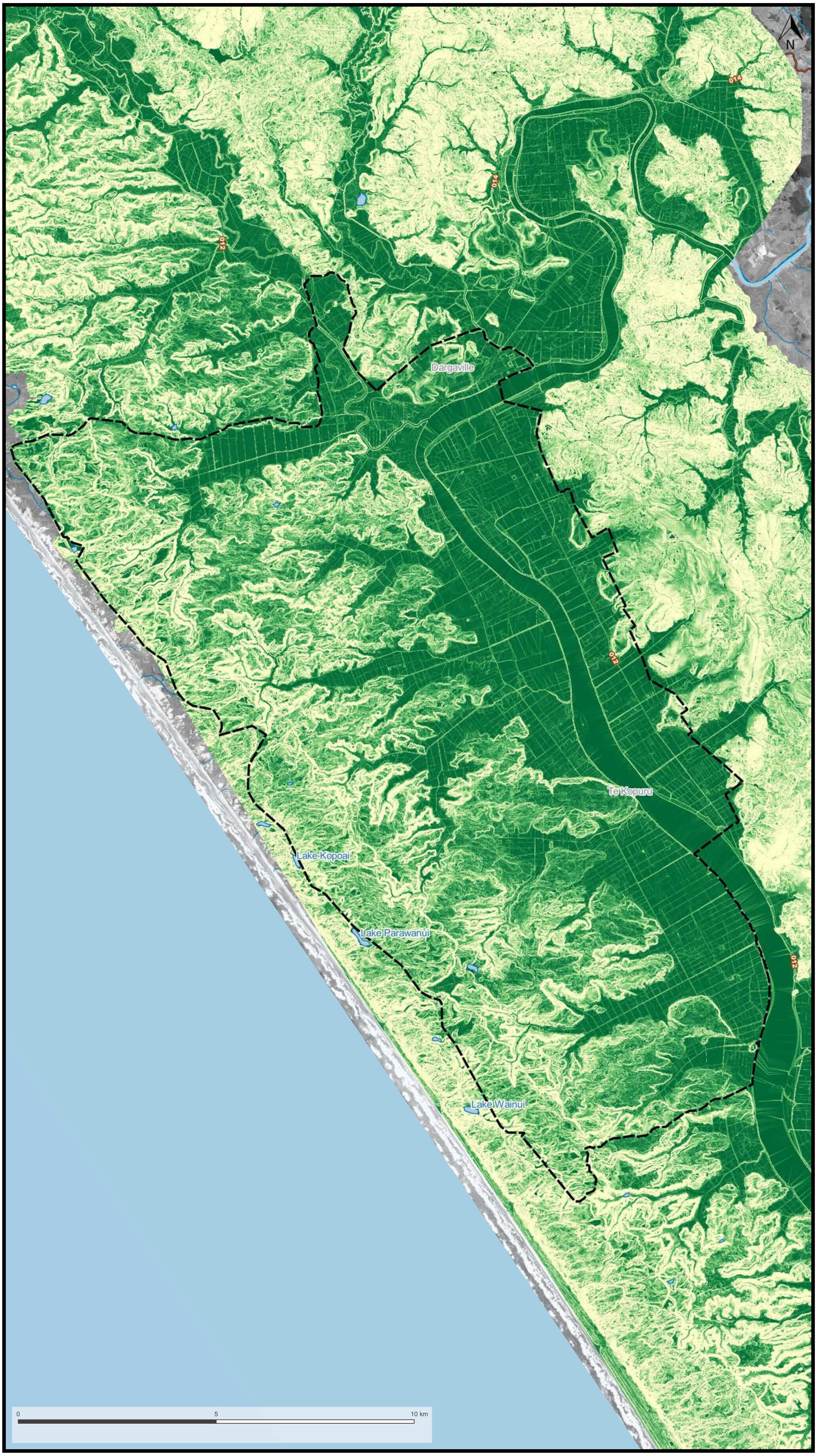
- Broadleaved Indigenous Hardwoods
- Built-up Area (settlement)
- Deciduous Hardwoods
- Exotic Forest
- Fernland
- Forest - Harvested
- Gorse and/or Broom
- Herbaceous Freshwater Vegetation
- High Producing Exotic Grassland
- Indigenous Forest
- Lake or Pond
- Low Producing Grassland
- Manuka and/or Kanuka
- Mixed Exotic Shrubland
- Orchard, Vineyard or Other Perennial Crop
- Short-rotation Cropland
- Surface Mine or Dump
- Urban Parkland/Open Space
- Flaxland
- Sand or Gravel

Data Provenance

Aerial Imagery 0.4m Northland from Land Information New Zealand. Crown Copyright Reserved.
Landcover data from Northland Regional Council.

WILLIAMSON
WATER & LAND ADVISORY

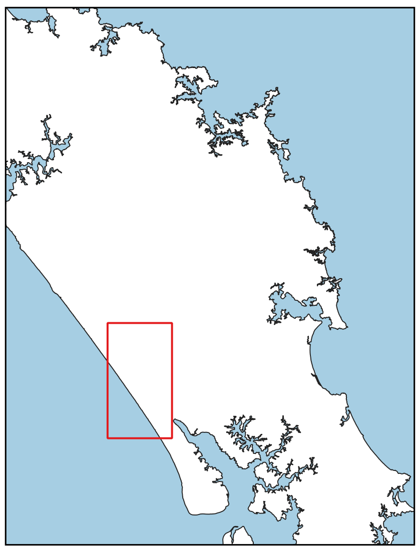
Figure 17.



Map Title:
Kaipara Command Area Slope

Project:
Northland Water Storage Pre-Feasibility Study

Client:
Northland Regional Council



Legend

- **Highway**
- **River**
- **Lake**
- **Urban Area**
- **Kaipara Command Area**

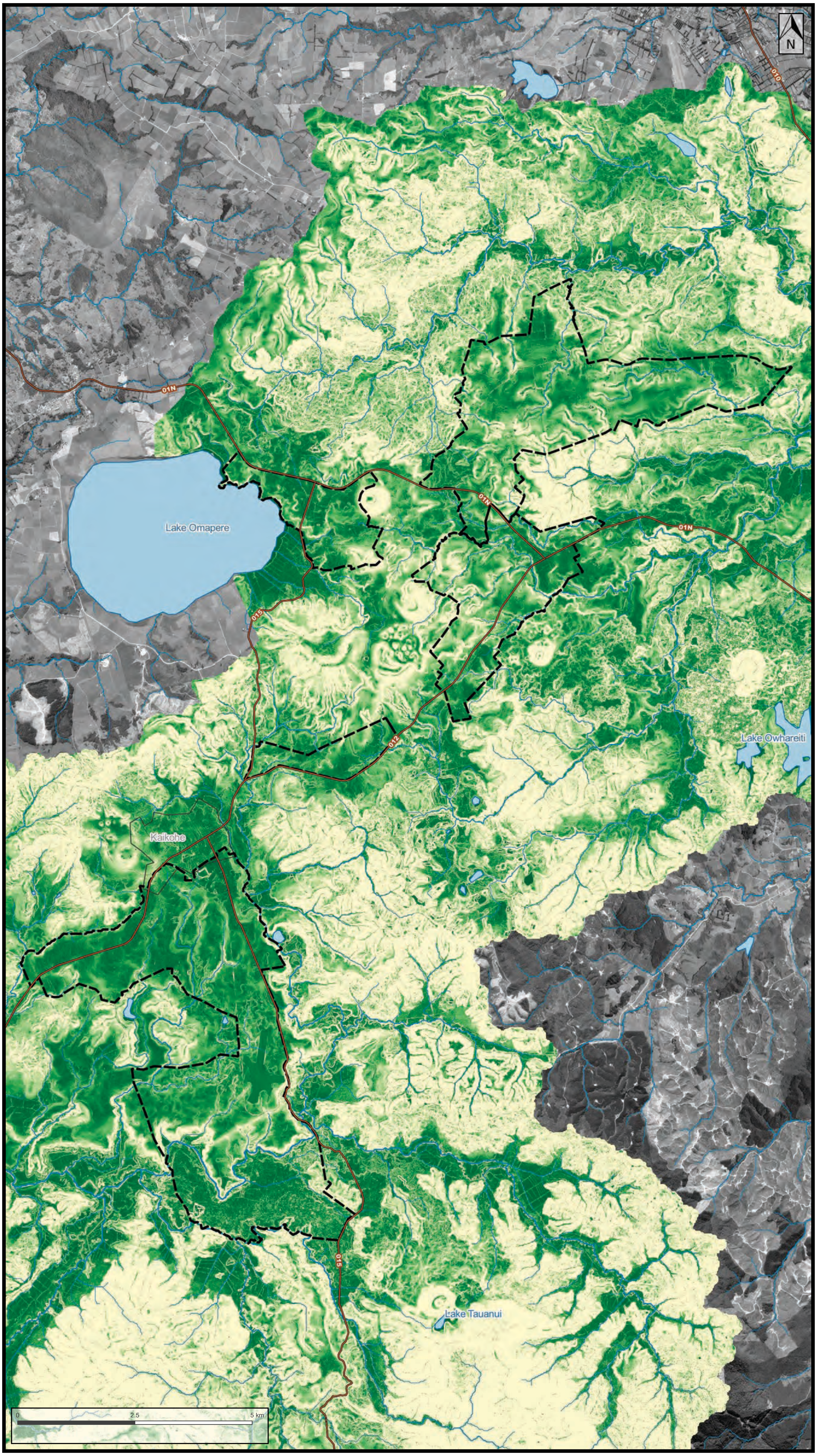
Slope (Degrees)

- **0**
- **3**
- **7**
- **15+**

Data Provenance
Topographic Data derived from Land Information New Zealand
Crown Copyright Reserved. Planning and Policy data from Northland Regional Council.

WILLIAMSON WATER & LAND ADVISORY

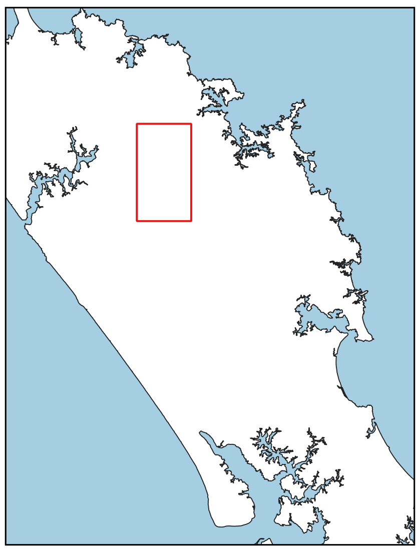
Figure 18.



Map Title:
Mid North Command Area Slope

Project:
Northland Water Storage Pre-Feasibility Study

Client:
Northland Regional Council



Legend

- Highway
- River
- Lake
- Urban Area
- Mid-North Command Area

Slope (Degrees)

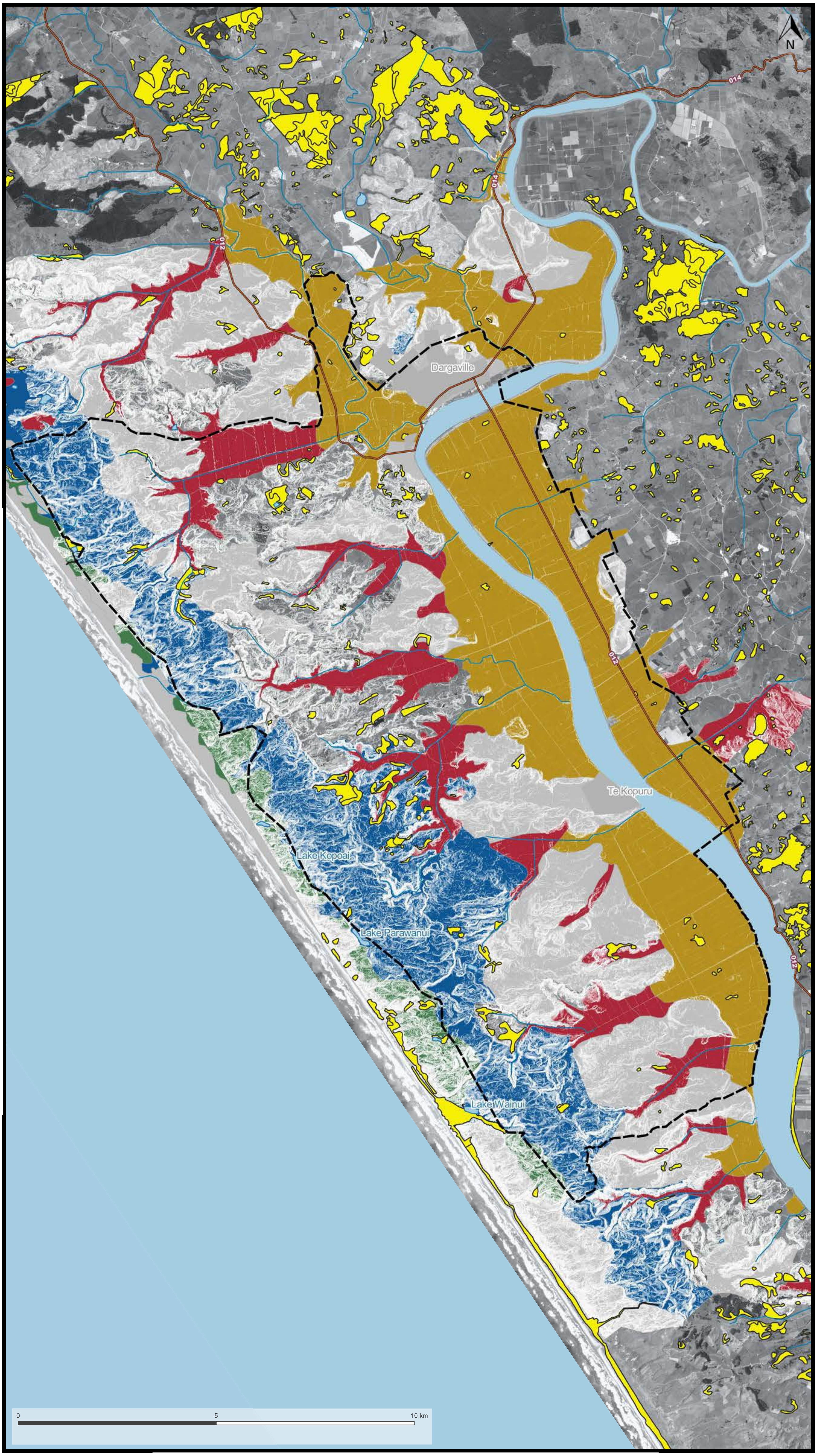
- 0
- 3
- 7
- 15+

Data Provenance

Slope derived from LiDAR from Northland Regional Council 2019.

WILLIAMSON WATER & LAND ADVISORY

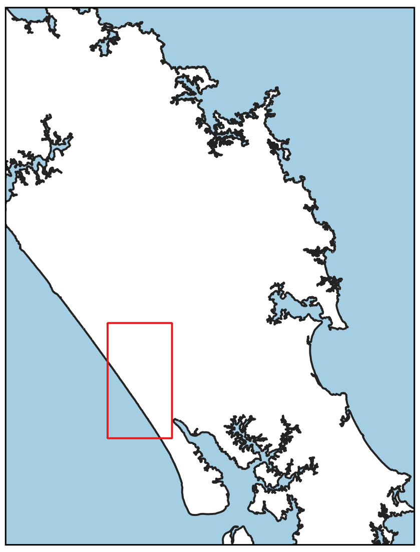
Figure 19.



Map Title:
Kaipara Command Area Soil Group Classifications

Project:
Northland Water Storage Pre-Feasibility Study

Client:
Northland Regional Council



Legend

- **Highway**
- **River**
- **Lake**
- **Urban Area**
- **Kaipara Command Area**

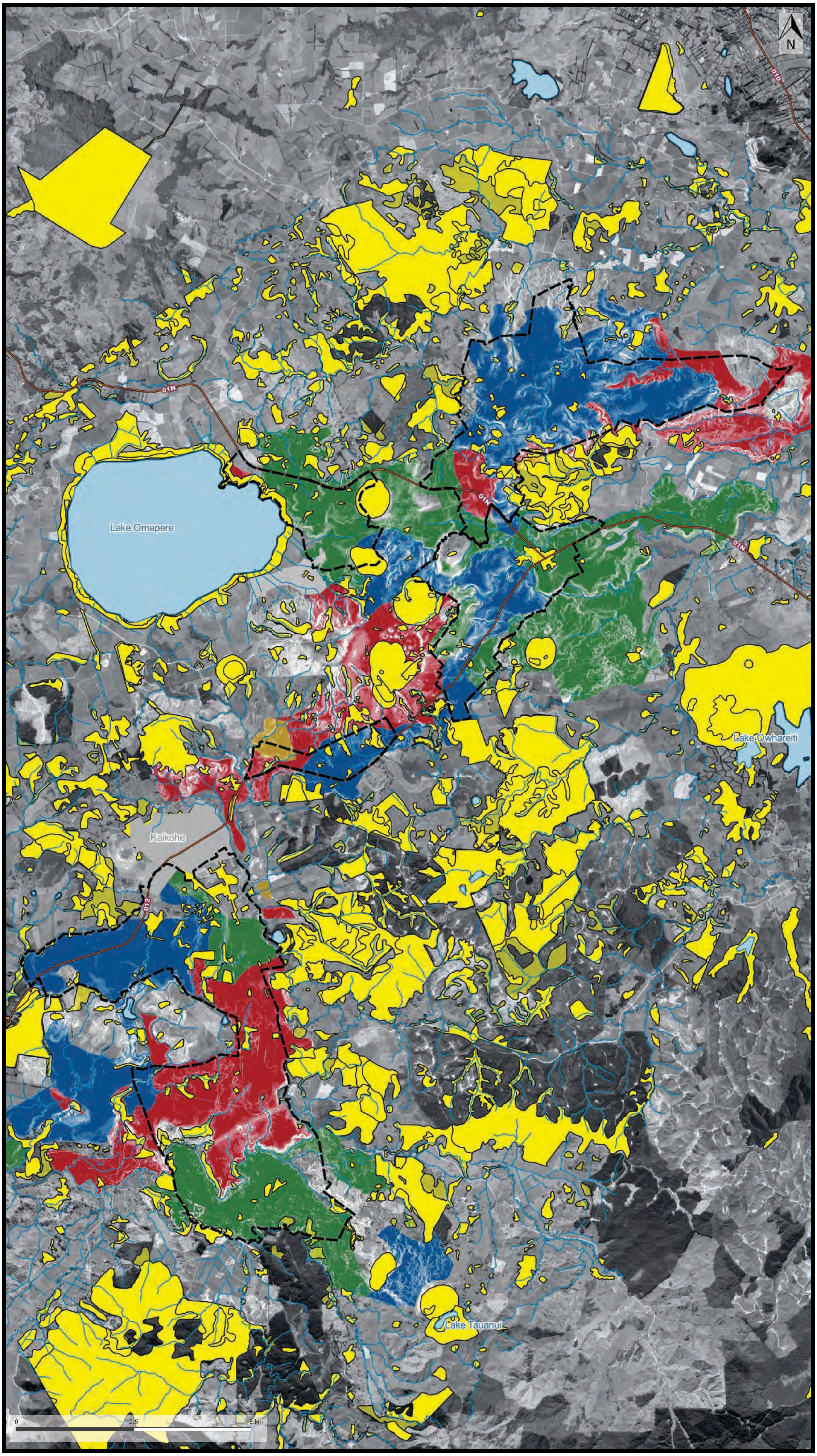
Kaipara Command Area Soil Group Classifications

- **K-1**
- **K-2**
- **K-3**
- **K-4**
- **Other soils**

Data Provenance
Aerial Imagery derived from Land Information New Zealand
Crown Copyright Reserved.

WILLIAMSON WATER & LAND ADVISORY

Figure 23.



Map Title:
Mid North Command Area Horticultural Suitability Analysis

Project:
Northland Water Storage Pre-Feasibility Study

Client:
Northland Regional Council

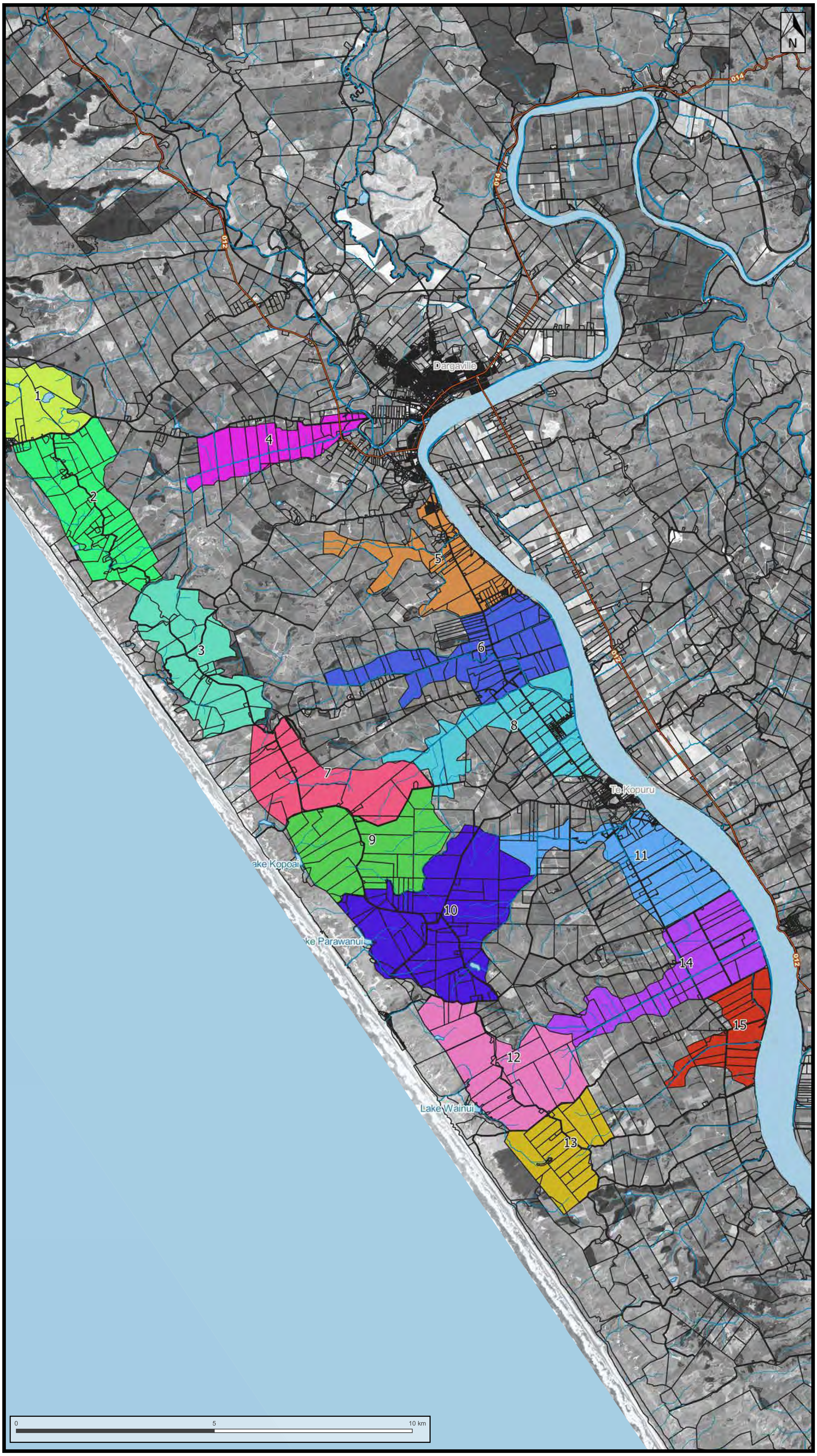
Legend
- **Highway**
- **Lake**
- **Urban Area**
- **Mid-North Command Area**

Mid-North Command Area Soil Group Classifications
- **MN-1**
- **MN-2**
- **MN-3**
- **MN-4**
- **Other soils**
- **Farm development exclusion areas**

Data Provenance
Aerial Imagery derived from Land Information New Zealand. Crown Copyright Reserved.

WILLIAMSON WATER & LAND ADVISORY

Figure 24.



Map Title:
Kaipara Command Area Zones

Project:
Northland Water Storage Pre-Feasibility Study

Client:
Northland Regional Council

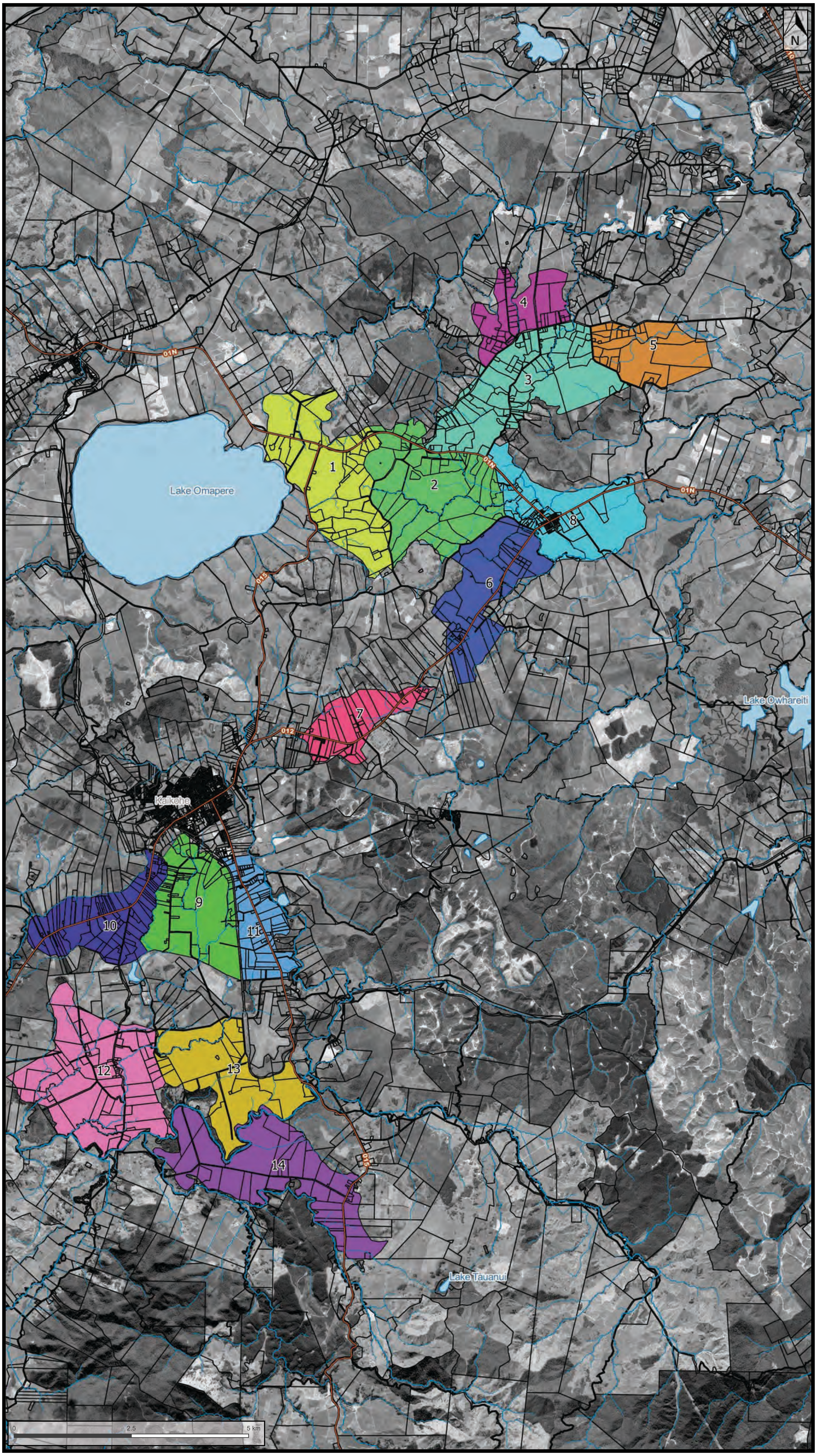
Legend
- Highway
- River
- Property Boundary
- Urban Area
- Lake

Kaipara Zones
- 1
- 2
- 3
- 4
- 5
- 6
- 7
- 8
- 9
- 10
- 11
- 12
- 13
- 14
- 15

Data Provenance
Topographic Data derived from Land Information New Zealand

WILLIAMSON WATER & LAND ADVISORY

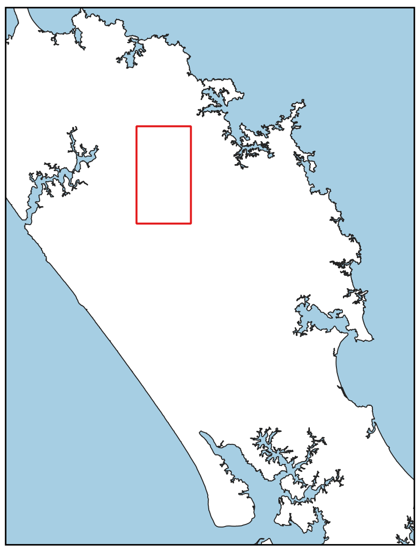
Figure 25.



Map Title:
Mid-North Command Areas

Project:
Northland Water Storage Pre-Feasibility Study

Client:
Northland Regional Council



Legend

- **Highway**
- **River**
- **Lake**
- **Urban Area**
- **Property Boundary**

Mid North Command Areas

- **1**
- **2**
- **3**
- **4**
- **5**
- **6**
- **7**
- **8**
- **9**
- **10**
- **11**
- **12**
- **13**
- **14**

Data Provenance
Aerial Imagery derived from Land Information New Zealand. Crown Copyright Reserved.

WILLIAMSON
WATER & LAND ADVISORY

Figure 26.