Northland Strategic Irrigation Infrastructure Study

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Glossary

Term	Description
amsl	Above mean sea level
Command area	Total geographical area within an irrigation scheme. This area includes net irrigated areas and non-irrigable areas such as buildings and roads etc.
Evapotranspiration (ET) or Potential Evapotranspiration (PET)	Water lost by soil evaporation and crop transpiration (mm/day).
Field capacity	Maximum level of soil water available for plant extraction after gravitational drainage from a saturated condition falls to a rate that is insignificant (i.e., generally a rate of ≤ 1 mm/day) (dimensionless, often expressed as a percentage respect to the depth of the soil profile).
GDP	Gross Domestic Product is the value of a country's overall output of goods and services at market prices, excluding net income from abroad
IRR	Internal Rate of Return is the average annual return earned through the life of an investment
Irrigation system capacity	Depth of irrigation water applied ÷ minimum return period (mm/day).
Irrigation application efficiency or Irri-efficiency	Average depth of water retained within the root zone ÷ average depth of water applied through the irrigator during a single irrigation event. Losses include wind drift, interception losses, run-off, and deep drainage (dimensionless, often expressed as a percentage).
MCA	Multi-Criteria Decision Analysis, is commonly used tool that is applied to help solve problems that are characterized as a choice among alternatives.
Plant Available Water (PAW)	PAW reflects the soil's capacity down to the rooting depth of the crop to hold water that is available for the crop to use (mm)
Return period	Minimum time between irrigation events in the same paddock (days).
SWOT	SWOT Analysis is a technique for understanding Strengths and Weaknesses faced, as well as identifying both the Opportunities and Threats posed.

Executive Summary

Strategic water management including its related infrastructure is a significant part of the future economic, social and environmental community decision making process for Northland's communities. The implications of water management strategies and policies influence and assist the many and varied community aspirations and desired outcomes. Progress in this area will require effective collaboration with likely compromise and investment of time and capital by many stakeholders.

This document presents the findings of the Strategic Irrigation Infrastructure Study undertaken by Opus International Consultants with consortium partners of Aqualinc and BERL for Northland Regional Council (NRC). Bob Cathcart assisted the project team to provide additional local perspectives on existing and potential irrigation and land use.

The primary focus of the study is on the opportunities presented by managing a reliable water supply to primary productive capable land. The report aims to provide relevant information to support strategic decision making in regards to water management across the entire Northland region but focused down onto definable areas of interest. The study has addressed specific challenges faced by the region and evaluates the potential use of productive agriculture to grow the economy whilst recognising the social and environmental impacts of intensive land use. This has been achieved by analysis of the region to determine areas suitable for irrigation, a review of the capability of the area to support and develop water infrastructure and assessment of the economic impacts of implementing systems locally.

As a starting point the study has considered the existing irrigated land use in Northland. This established the current irrigated areas, whether consented or not, irrigation methods used and effectiveness of these. The study reviewed the two existing large irrigation schemes, Kerikeri and Maungatapere, and found their strengths lie within security of supply and good community engagement. Opportunities for growth were also identified in these areas.

Other historic initiatives and proposals were reviewed to ensure that lessons could be taken from the decision criteria applied to previous potential developments.

A small number of key stakeholders were consulted via an online survey at the commencement of the study. These stakeholders represented a cross section of land and water users, community interests and regulators. Their feedback was used to frame the weighting of decision making criteria used in this report. The response indicated that there was a strong interest in the issues with water availability and land use impacting Northland and the process of this study. It is clear that there is a strong underlying community appetite for progress in the area of water resource management, particularly irrigation development. In keeping with New Zealand's rural social fabric individuals are likely to support initiatives that benefit the wider community rather than just themselves. But it is recognised that the pace of community decisions may not meet individual objectives especially around timing of investment or farm succession planning. The risk is that a positive community outcome could be diminished if fragmented development occurs outside an obvious collective model.

The Northland regional topography, meteorological and climate characteristics and geographical features were assessed to determine suitable locations for irrigation. This resulted in 18 command areas containing over **186,282** hectares (ha) of potentially irrigable land.

A water balance assessment was undertaken for these areas to determine what water is needed and what is available spatially, seasonally and year by year to meet a reliability target that would support land use management decisions with a degree of confidence.

The water balance information allowed the rationalisation of the 18 command areas into four clusters. This indicated that the provision of a combination of surface water storage and allocable ground water could provide irrigation support to an area of over 91,000 hectares in Northland.

- Far North (7,193 ha)
  - Aupouri Peninsula
  - Awanui Plains
- Mid North (16,224 ha)
  - Kerikeri
  - Waimate North
  - Kaikohe
- Whangarei and Surrounds (34,159 ha)
  - Hikurangi
  - Glenbervie
  - Mangakahia
  - Maungatapere
  - Maungakaramea
- Kaipara (34,339 ha)
  - Hoanga
  - North Kaipara
  - Kaihu
  - Ruawai

The advantage Northland has with being able to grow sub-tropical fruit could see the irrigated area of orchards increase from about 2,000 hectares at present to about 14,000 hectares and the area of vegetables from about 400 hectares at present to about 5,000 hectares. This leaves a balance area of 73,000 hectares of potentially irrigable land to be utilised for pastoral agriculture including about 4,800 hectares irrigated at present. All of these areas are inclusive of existing irrigated land.

The main economic benefit to Northland from increased irrigation is a significant increase in employment opportunities. Any increase in area of land converted into irrigated horticultural production generates a major increase in the direct employment, due to the high amount of labour per hectare required in the production process.

If water management policy and storage/distribution infrastructure for irrigation was implemented through the four clusters identified above, there is the potential for nearly 3,400 additional people to be directly employed within Northland in both horticulture and pastoral agriculture. This is a significant increase on the 5,049 people recorded as employed in these industries in 2014.

The analysis has also shown that the total increase in GDP from developing the full irrigation potential, taking account of margins for suppliers and local spending, is about $250 million per year, expressed in 2014 prices. The 2014 total GDP for Northland is estimated by Infometrics as $5,905 million in 2010 prices, which is $6,487 million in 2014 prices. The total GDP contribution from the irrigation would therefore be equivalent to 3.9% of current total GDP.

The figures above are based upon conservative assumptions around the allocable and harvestable water resources, and the project team understands that NRC is still in the process of developing water management policies and allocation rules in this space.

The potential increase in employment in the Mid North cluster gives renewed importance to improving transport and communication between the labour-rich Kaikohe/Hokianga area and the increased production in the Okaihau/ Waimate North and Kerikeri/Waipapa areas.

A multi-criteria analysis (MCA) to refine the areas of interest further has been conducted by a selected panel and the results of this informed the conclusions and recommendations in the report. Following this high level and limited MCA, it is highly recommended that a wider stakeholder panel be engaged using the multi-criteria analysis framework presented. This will further enable identification of co-benefits and challenges.

The study has highlighted a number of recommendations set out in Section 11 for further analysis. Further work should focus on the cluster areas for any detailed investigation and should include clarification of potential “irrigation water storage and supply scheme” options for these areas as well as possible global management of water allocation consents within the areas of interest. Where existing schemes are in operation in these areas, these could be upgraded, extended or redeveloped to optimise these schemes to support additional production and therefore economic potential.

In addition to cluster level investigations, subsequent studies should also include case studies at a farm level in order to demonstrate the effect of full and partial irrigation and/or land use change. This includes assessment of the effectiveness of current irrigation and the adoption of advanced irrigation methods, including an element of education required. This will assist with community decision making and the uptake potential that often hinders progress in this sector.

If irrigation infrastructure development or management rules are deemed suitable for all or part of the cluster areas, a suitable allocation model will need to be used, or the SPASMO model corrected. It is recommended that further, more detailed studies utilise a model that simulates pragmatic regional irrigation management practices and produces accurate daily outputs for the water balance calculations.

It is necessary to use, where available, a clear policy processes to support water management initiatives. The best decisions on water resource management will occur in a policy environment that reflects not only economic and employment drivers but also the complex and sometime competing community requirements for environmental flows, water quality standards and cultural (iwi) rights and interests.

1 Introduction

1.1 Background

Northland Regional Council (NRC) commissioned Opus International Consultants, with consortium partners of Aqualinc and BERL, to produce a Strategic Irrigation Infrastructure Study for the Northland region. In addition, Bob Cathcart assisted the project team to provide local insight into existing and potential irrigation development.

The Tai Tokerau Northland Economic Growth Study identified a wide range of important considerations that will assist NRC to develop its strategic thinking on water management as well as address specific challenges faced by productive agriculture in the growth of the region's economy.

The Executive Summary of that document states, "Northland has significant untapped economic potential. The region's people and industries are currently not making the most of existing advantages, limiting economic growth. However, there is no silver bullet initiative or industry that will transform the Northland economy. Growing the Northland economy will require a coordinated effort across a range of industry and cross-cutting opportunities".

A document issued by the Ministry for Primary Industries (MPI) in October 2013 titled "Northland - Potential for primary industry growth" stated "For New Zealand to build a more productive and competitive economy, we need all our regions to achieve their potential".

The implication of water management strategies and policies cut across many and varied community aspirations and desired outcomes. Progress in this area will require collaboration, compromise and investment of time and capital by many parties.

This study provides the information to show that strategic water management including its related infrastructure is a significant part of the future economic, social and environmental solution for Northland. It analyses the Northland region's suitability for irrigation infrastructure and explores the potential of benefitting economic growth.

Opus and our project partners strongly believe that this study is a stepping stone to achieving authentic community outcomes which in turn will provide a social licence for the development of infrastructure to effectively manage water, in turn helping Northland reach its potential.

1.2 Location and landuse

Northland (Te Tai Tokerau) is the northern most region in New Zealand. It covers approximately 13,000 square kilometres, approximately 5% of the country's total area, and is often referred to as the winterless north due to its mild climate. The boundary of NRC is shown in Figure 1.1.

Figure 1.1 - Northland Locality Map

Northland is constrained to the west by the Tasman Sea and to the east by the Pacific Ocean, and is predominately rolling hill country. Northland has many harbours with a coastline of over 3,200km long. No point on land within Northland is more than 40km from the ocean.

Farming and forestry occupy over half of the land and are two of the major industries in the region (Table 1.1). Land use/cover data is collected from various statistical dataset inputs and is presented here to provide some context of the Northland percentage cover of each category. However the monitoring and measurement of land cover is fraught with difficulty. In particular for our report purposes we have noted the difference in area of horticulture land coverage (10,463 ha or 0.8%) with data obtained from Statistics New Zealand and direct canvassing by HortNZ (5,477 ha). Therefore, in this report we have adopted the Statistics New Zealand data as more representative of the actual planted area for calculation purposes (see Table 8.1). The most reliable statement from the land cover statistics would be that Pasture is still the predominant land cover (approx. 50%) and Horticulture is less than 1% of total land cover.

Table 1.1 - Land cover in Northland

Land Cover	Class Hectares	Percentage cover (%)
Pastoral	608,121	48.7%
Indigenous Forest	247,813	19.8%
Planted Forest	186,182	14.9%
Shrubland	152,813	12.2%
Coastal Sands	13,819	1.1%
Horticultural	10,463	0.8%
Inland Wetland	8,373	0.7%
Urban Areas	7,943	0.6%
Inland Water	6,064	0.5%
Coastal Wetland	3,485	0.3%
Mangrove	1,677	0.1%
Urban Open space	1,635	0.1%
Mines and Dumps	683	0.1%
Bare Ground	17	0.0%
Tussock	0	0.0%
	1,249,089	100.0%

Source: Land Cover Database 4 Table compiled by Policy Information Group, MPI.

1.3 Physical characteristics

The dominant rock types over large parts of Northland are sedimentary rocks of the Northland Allochthon. They include sandstone, mudstone, claystone/shale and argillaceous (muddy) limestone. These rocks store very small quantities of water and streams draining from them often go dry in the summer.

Northland has a very complex pattern of soils with over 230 distinct soil types, each having differing soil moisture characteristics. Most Northland soils are clay loam or clay soils with seasonally impeded drainage, in most cases due to elevated clay levels in the subsoil. The subsoil of a mature soil has a distinct columnar structure, water draining down the cracks between the columns. Development and maintenance of these cracks depends on the soils being allowed to dry out in autumn, allowing the clay to shrink, open the cracks and, over time, organic matter to flow down the cracks and develop more permanent 'preferential flow paths'.

1.4 Climate and seasonal variability

Northland has a highly variable climate. Its exposure to subtropical weather systems means rainfall can come in 'big lumps' interspersed with dry spells, and varies significantly season to season, year to year and in geographical distribution.

The different physical characteristics across the region, combined with variable rainfall, results in large variations in plant and pasture growth and productivity each year. This variability makes it difficult to match grazing management to feed supplies resulting in a conservative approach to stocking rates. Winter-spring calving cows reach their peak of production in the spring and early summer, coinciding with the peak of temperate pasture production. The aim is to maintain both pastures and animals at peak production for as long into the summer as possible. Once either have dropped back, it is difficult to return cows to that high level of production.

It is a common assumption that irrigation will help 'smooth' out the seasons and provide more consistent pasture growth, and that adding water over summer will increase overall pasture production. Although this is true, irrigation is most efficient in areas with consistently very low rainfall where the farmer has almost total control over soil moisture levels.

The need for seasonal climate stability also includes the common 'dry spell' in September, October and/or November. This sometimes results in more productive ryegrass-dominant pastures undergoing a drought response to this dry weather in which they go to seed and stop growing.

Additionally January, February, March and even April can be hot and dry, particularly in those seasons when there are no tropical north-easterly weather systems or in parts of Northland sheltered from those systems. At this time air and soil temperatures will generally be beyond the optimum for temperate pasture species.

1.5 Community stakeholder profile

The community interests and stakeholders in the Northland region are extremely diverse. We therefore considered it important to engage with a selection of key stakeholders at the commencement of the project to provide focus for the report and subsequent discussions. This is discussed further in Section 2.7.

2 Current situation of irrigation in Northland

2.1 Estimation of irrigated areas

This section summarises the status of current irrigation in Northland. Section 3 outlines the further irrigation potential along with appropriateness of climate, soils and topography to achieve irrigation benefits within the region.

2.1.1 Areas currently irrigated

The actual area of current irrigation is generally smaller than the consented irrigated area. This occurs as some consent applicants may have applied for water for aspirational future areas, and it is possible that some of the areas are not currently fully developed. For example, NRC compliance records show the Maungatapere Irrigation Scheme currently irrigates only 664 hectares. However, the consented irrigated area is 1,500 hectares. The current irrigated area within the Kerikeri Irrigation Scheme, the largest scheme in the region, is estimated to be approximately 2,500 hectares of the consented area of 2,600 hectares.

Table 2.1 presents a comparison of the irrigated area by territorial authority (TA) as determined from the NRC consent database and the Statistic New Zealand 2012 Agricultural Census. The census total irrigated area (7,795 hectares) is approximately 26% lower than the consented irrigated area. This is because of a difference in approach and methodologies. The consented irrigated area represents a potential upper gross irrigated area for a property and includes a safety factor for future development. In comparison, the census area is based on the reported irrigated area, as per census questionnaire. The census is a simple approach which is reliant on the accuracy and completeness of information supplied by landholders. The reported area probably reflects the area of installed irrigation and regularly irrigated. However, it is interesting that the irrigated area reported in the census for the Kaipara District is considerably higher than the consented area. This discrepancy may have resulted from the level of accuracy of census data supplied by landholders.

Table 2.1 - Comparison of irrigated area by territorial authority

Territorial authority	Irrigated area (hectares)		
	Consented[#1]	Agricultural Census 2012[#2]	Percent difference (%)
Far North District	5,382	2,965	-44.9%
Kaipara District	1,399	2,046	46.2%
Whangarei District	3,818	2,784	-27.1%
Total	**10,599**	**7,795**	**-26.5%**

[#1] **Source: NRC consent database**

[#2] **Source: Statistics NZ**

Taking these discrepancies into account, a best estimate is that overall actual irrigated area is probably on the order of 80% of consented area. On this basis the actual total irrigated area would be approximately 8,500 hectares.

2.1.2 Current irrigation consents

According to the NRC consent database as at 13 July 2015, there are 488 resource contents for taking water within the region. Of these 488 consents, 321 are issued for irrigation, as shown in Table 2.2. Groundwater takes account for most irrigation takes (48% or 153 consents). The total consented irrigated area is approximately 10,600 hectares; of that approximately 70% of the area (7,337 hectares) is sourced water from run-of-stream.

Table 2.2 - A summary of current irrigation consents

Source	Number of consents (No.)	Net take rate (l/s)	Daily volume (m^3/d)	Irrigated area (hectares)
Bore	153	314	27,134	1,284
Dam	42	2,814	243,161	1,962
Lake	3	6	479	16
Run-of-stream	123	2,830	244,517	7,337
Total	**321**	**5,964**	**515,290**	**10,599**

Source: NRC consent database

Table 2.3 shows the use of irrigation consents as reported in the council consent database. This shows current irrigated area is dominated by horticulture, followed by pasture. Further analysis is presented in Appendix B.

Table 2.3 - Current irrigated areas by use type (hectares)

Use type	Area (hectares)	Percentage (%)
Horticulture	6,282	59%
Pasture	4,077	38%
Recreational/Sports	107	1%
Arable/Crop	94	1%
Vegetables/Market Garden	21	0.2%
Floriculture	10	0.1%
Nursery	7	0.1%
Total	**10,599**	**100%**

Source: NRC consent database

2.2 Current irrigation systems

2.2.1 Current methods

A range of irrigation systems are being used within Northland. The horticulture industry predominately uses drip or micro-spray irrigation systems but there are also a small proportion of solid-set sprinklers. Pastoral irrigators mainly utilise sprinkler irrigation systems such as long-laterals and K-line systems[1].

Irrigators generally choose the most appropriate irrigation method considering crop type, initial cost, running cost, required labour input, land properties (size, shape and slope), land ownership or lease, water source, general local conditions such as wind, cost-benefits and their previous experience. All irrigation systems have advantages and disadvantages. For some farms, especially large areas, there is no single best method. The irrigation efficiency mainly depends on the irrigation system being used and the irrigation management (i.e. irrigator's discipline). Accordingly, it is important that NRC promote, educate and work in conjunction with farmers to improve the irrigation efficiency for overall regional benefits.

Irrigators in areas of Northland may also need to take waterlogging issues into account in irrigation development. The soil types with low infiltration characteristics (e.g. clay soils) are likely to result in waterlogging following high-intensity rainfall events. This is more prominent in relatively flat lands. Surface or subsurface drainage systems need to be developed to enhance water drainage through the soil profile. Construction of a drainage system increases the overall cost of irrigation.

2.2.2 Current irrigation effectiveness

NRC currently allocates irrigation water sufficient to meet an irrigation application efficiency of 80% or better. This can be interpreted as the net irrigation of 80% of the amount applied. For example, 200m^3 abstracted from a source for irrigation application on a hectare represents a gross application depth of 20mm (i.e. 20mm over one hectare [10,000m^2] equates to 200m^3). At 80% efficiency, the net effective irrigation is 16mm (i.e. 20 x 80%). The efficiency value of 80% value is now widely accepted as a standard figure for water allocation throughout New Zealand. Irrigation systems with application efficiencies greater than 80% will, in terms of production, will have an advantage over systems with less than 80% efficiency.

Virtually all spray and drip irrigation systems should be capable of achieving 80% efficiency, provided that they are properly designed and managed. The expectation is that systems will be designed according to the Irrigation New Zealand codes of practice and standards.

While not widely used in the region, the surface irrigation systems (border, contour) find it more challenging and in some cases unrealistic to reach an 80% application efficiency. This will mean production losses.

With all systems, application of the best knowledge and modern technology will be required to achieve high efficiency. Irrigators will need to understand their soil and crop characteristics as well as:

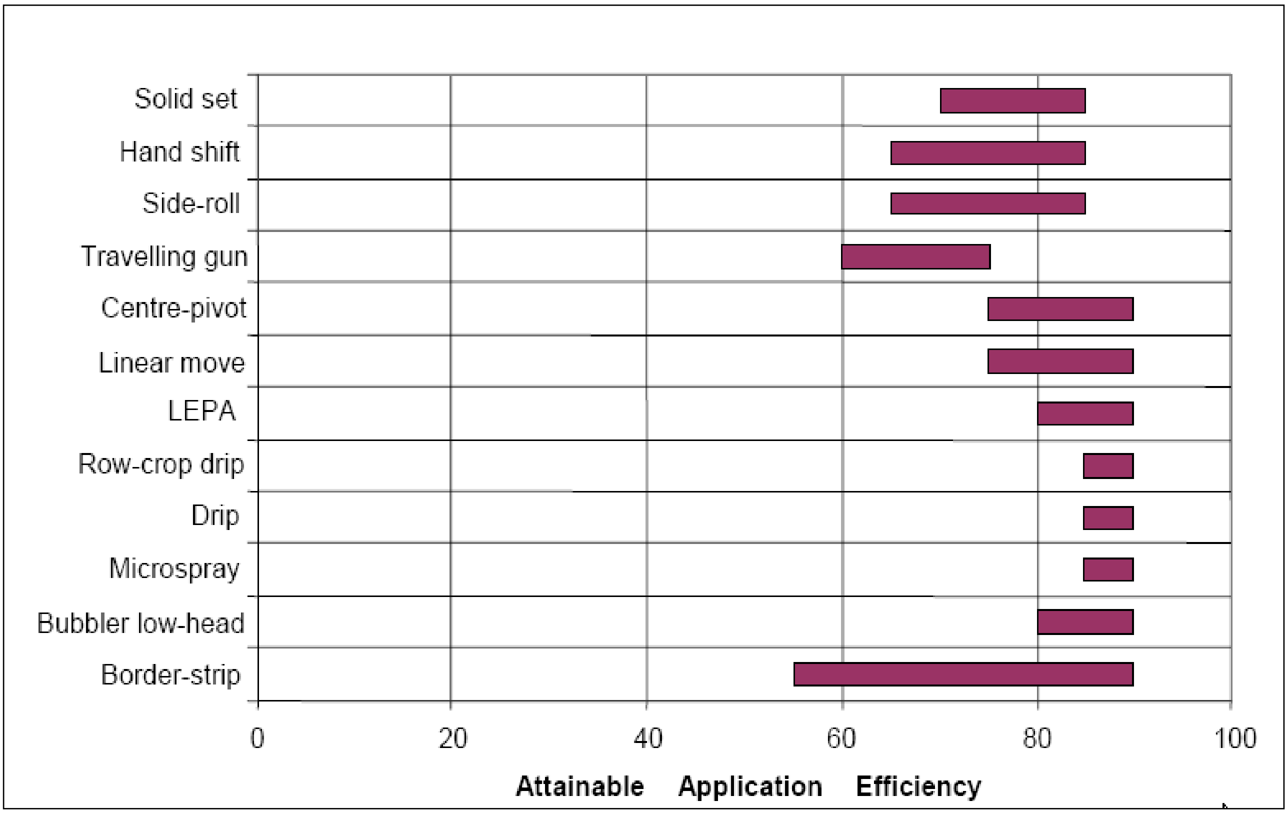
- ensure that they have an irrigation system that is realistically able to apply the required depth of water when it is needed,
- know how much water to apply, and
- monitor irrigation performance.

[1] Long-lateral irrigation systems typically have sprinklers mounted on a moveable stand, connected to permanently buried mainlines and hydrants by a long polythene pipe. Each sprinkler is generally moved manually around 6-10 positions to cover approximately 0.4 to 0.8 hectares. K-Line irrigation systems comprise a series of small, tough plastic pods protecting a small sprinkler firmly attached to low density poly pipe. The small, flexible, lightweight lines are generally shifted using a four-wheeled motor bike by driving across the paddock.

Technology such as variable rate irrigation (known as VRI), used on centre-pivots and lateral move irrigators to turn individual sprinklers on and off, is an example of equipment that can be used to improve performance. However, the method of application is only one factor that needs to be considered.

Aqualinc (2006) summarised the typical range of irrigation application efficiencies for a range of system types, as shown in Figure 2.1. The long-laterals and K-line systems fall into 'hand shift' category. These hand shift systems require a high labour input to achieve efficiency of 80% or over. Figure 2.1 indicates that the irrigation systems that are currently used for horticulture, i.e. drip or micro-spray, generally able to attain high efficiency, when managed properly.

Figure 2.1 - Attainable application efficiencies for different system types



Source: Aqualinc, 2006

Water use efficiency is also dependent on the water delivery (conveyance) method; pipes are generally more efficient than canals. Water losses occur in canals through evaporation and leaks, if not lined properly and not well maintained. In pipe conveyance, there are also losses through leaks. More water lost can be expected in large irrigation schemes than in small schemes due to long conveyance networks. Accordingly, it is important that large schemes use the best methods and maintenance techniques to minimise water lost.

Irrigation efficiency is an output resulting from the conditions occurring at the time of an irrigation event and differs widely under different systems at different times. It depends on the design of irrigation systems and how well they are managed.

There are many benefits to improving irrigation efficiency, including both environmental and economic. Improving irrigation efficiency will:

- Mean less stress on water resources, less losses of water and nutrients to groundwater and surface water resources;
- Minimise irrigation inputs while continuing to maintain/improve production and overall profits;
- Potentially allow a greater area to be irrigated with a given volume of water.

2.3 Existing large irrigation schemes

In the 1970s the Ministry of Works and Development investigated a number of areas in Northland that had soils suited to horticultural development but would need water storage to facilitate full development (Kirkland et al., 1980). These were areas of volcanic soils, particularly the more free-draining brown loam soils on basalt lava flows around Kaikohe, Waimate North, Kerikeri and Pakaraka in the mid-north and Kauri, Glenbervie, Kiripaka, Matarau-Ruatangata, Three Mile Bush-Ngararatunua, Maunu Maungatapere and Maungakaramea around Whangarei. Irrigation schemes were eventually built at Kerikeri and Maungatapere

This section briefly investigates the economic, social and environmental impacts of these two schemes, and identifies improvement opportunities and lessons that can be applied more widely to regional water management. Using his extensive knowledge of the schemes and land-use in Northland, Bob Cathcart provided substantial input into the following summarisations.

2.3.1 Maungatapere Irrigation Scheme

The Maungatapere Irrigation Scheme was completed in 1990 and has the potential to provide water to at least 1,500 hectares. A total of 1,180 hectares are planted within the serviced area. Of this, 205 horticultural properties are supplied and a total of 711 hectares are irrigated currently with water supplied by the scheme.

The Maungatapere Irrigation Scheme is governed and managed by a co-operative company, Maungatapere Water Company Limited (MWCL). There are six board members who report to 128 shareholders.

There are 502 shares in the company valued at a nominal $3,000. Shares are allocated per hectare (minimum of two per property) with each share entitling the property to 25m^3 over a 24hr period. The annual capacity fee for each share is $805 which covers an initial allocation of 387m^3 of water. Water is charged at 49c per m^3 thereafter which is relatively high compared to other schemes nationally. Non-shareholders on the scheme also pay an annual capacity fee of $805 for an initial allocation of 387m^3 of water. However they then pay $2.08 per m^3 thereafter, and supply to shareholders takes precedence over non-shareholders.

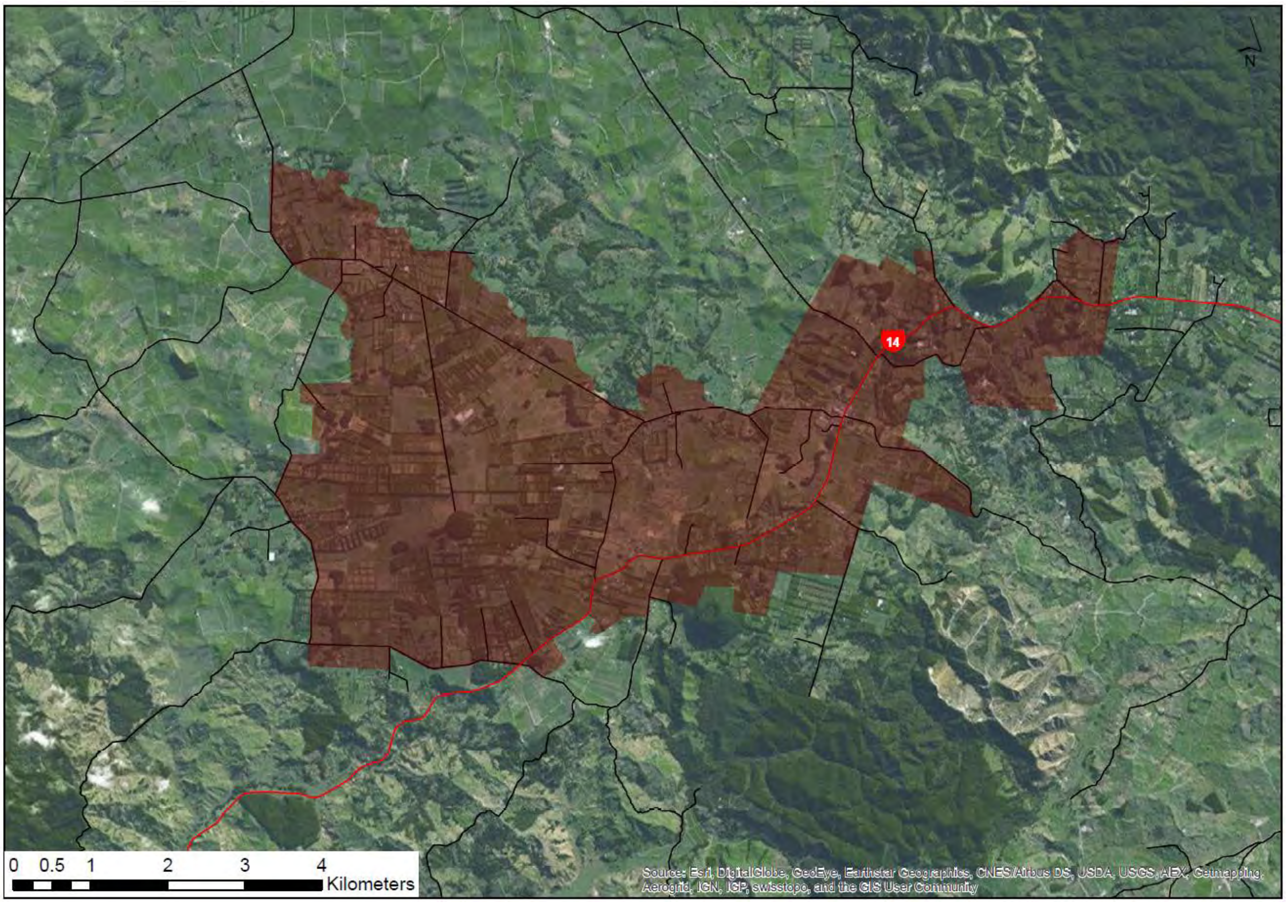
There are also a number of private orchard irrigation takes within, and immediately adjoining, the scheme drawing on groundwater and spring-fed lake storage. These private takes explain some of the difference between 711 hectares currently served by the scheme and the estimated planted area of 1,180 hectares. Part of this difference will also be made up of un-irrigated horticulture.

The relatively free-draining volcanic brown loam soils are well suited to avocado which is the main crop in this area, followed by kiwifruit and tamarillo.

Water is taken from the Poroti Springs, Wairua River, and a dam at Millington Road in Maunu, and has intake structures, pipe infrastructure, pumping stations and storage tanks currently in place. The scheme consists of 55km of main reticulation pipelines feeding a similar service network to individual properties. Seven pumping sheds reticulate the water. The scheme is computer controlled, and all water pumped and supplied is measured by water meters at the pump sheds and at the boundaries of individual properties.

Until recently the limited duration of scheme resource consents impacted upon security of supply. The current consent expires 2044. The consent from Poroti Springs is for 3,000 m³/day and water is also taken from the Wairua River if additional water is required. Historically, the collective daily take is about 3,455 m³/day due to demand. However the quantity can vary due to a water-sharing agreement between Whangarei District Council, Zodiac Holdings, and Maungatapere Water Company Limited. Figure 2.2 indicates the area which the Maungatapere Irrigation Scheme services.

Figure 2.2 - Maungatapere Irrigation Scheme Extent



The company promotes water use efficiency and wise water management to ensure adequate supplies and to comply with the conditions of its consent. To some extent this is self-regulating as excess water use results in waterlogging and an increase in the incidence of fungal root-rot diseases (*Phytophthora*) which is common within the predominant avocado crops.

Cathcart also believes that the scheme has delivered environmental benefits through the planting of tree crops like avocado which reduces runoff and increases groundwater recharge of Whatitiri mountain increasing spring flow and better sustaining stream low flows.

Le Page (1987), commissioned by Ministry of Works and Development (MWD) Whāngārei, indicated a total capital cost of about $30 million for the development of the scheme, including on-farm infrastructure. Applying the Statistics NZ Capital Expenditure Price Index this amounts to a figure today of $66 million.

A feasibility report by MWD (1982) estimated that developing an 80 hectare dairy farm into kiwifruit, assuming a 2,000 hectare irrigation scheme, would yield an Internal Rate of Return (IRR) of 24.3% and realise a payback (discounting at 10%) in the tenth year. This report also concluded that "*implementation of an irrigation scheme in the Maungatapere area would confer substantial gains to the nation*".

The above report also stated that "*an additional consideration is the extra employment which would be generated in the vicinity of Whangarei city, the centre of the Northland Region which has one of the highest rates of unemployment in New Zealand at the present time*". Whilst economics will have changed, the above statement around unemployment is still current. Regardless of this, it is still very likely that positive social impacts have been felt within the community due to increases in employment opportunities as the scale of production has increased and a range of crops and orchard-based work opportunities has moved the industry from a part-time or casual employer to a full-time employer.

Horticulture within the Maungatapere irrigation scheme area is estimated to currently contribute $17 million GDP per annum to the regional economy, and it provides employment to over 360FTEs in the region. (BERL Estimates, based on 1,180 planted hectares, gross margins from AgFirst *Value of irrigation in New Zealand* and industry sources, and regional multipliers from Butcher Partners). Whilst this cannot solely be attributed to the Maungatapere Irrigation scheme, this scheme has provided a level of certainty in the horticulture industry to encourage investment and subsequent development in the location.

It is envisioned that an increase in uptake of water supplied through the Maungtapere Irrigation Scheme, and subsequent optimisation use of land within the scheme area for productive purposes, a substantial benefit could be realised in terms of GDP and employment. This is discussed further in subsequent sections of this report.

Table 2.4 summarises the current situation as well as drivers in the future for the Maungatapere Water Company Limited.

Table 2.4 - SWOT Analysis of Maungatapere Irrigation Scheme

Strengths	**Weaknesses**
1. Security of water supply with recent resource consent renewal. 2. Soils generally fit for purpose. 3. Community scheme with stable shareholding and governance. 4. Group shelter due to contiguous orchard development. 5. Scheme and off-orchard facilities (packhouses, contractors, labour, marketing, etc.) all established	1. The scheme was completed around the same time as the market for kiwifruit dropped severely. Many orchards were cleared of vines. This reduced confidence in horticulture and slowed the establishment of alternative crops. 2. Lack of subdivision control has resulted in lifestyle and residential block intrusion onto land suited for horticulture, both occupying elite soils and placing (reverse sensitivity) restrictions on large-scale development of horticulture. 3. Competition for water between District Council municipal (Whangarei city), commercial bottled water and Iwi has, until recently, restricted access to and certainty of supply.

Opportunities	Threats
1. Ability to increase irrigated area of scheme using existing infrastructure with minimal, if any, capital costs through new orchards, currently non-irrigated orchards, and/or relinquishment of alternative water sources and relevant consents. 2. Increased employment opportunities as the scale and range of crops and orchard-based work opportunities moves the industry from a part-time/casual employer to a full-time employer.	1. Continued lifestyle block intrusion into prime horticulture land. 2. Low utilisation of scheme and resultant high cost of water units at gate. 3. Profitability of horticulture. 4. Aging infrastructure.

2.3.2 Kerikeri Irrigation Scheme

The Kerikeri Irrigation Scheme was built by MWD, completed in 1982, and supplies water to an area of approximately 2,800 hectares. Currently approximately 2,500 hectares of land is irrigated with water supplied from the scheme, which supplies 450 commercial properties and 1,000 lifestyle users.

The Kerikeri Irrigation Scheme is governed and managed by a co-operative company, Kerikeri Irrigation Company Limited (KICL). There are seven board members who report to 360 shareholders.

The company requires all commercial users to hold 40 shares per irrigable hectare of land which entitles the user to take 3,000m^3 per hectare annually. This is charged using a mixed charge system involving an annual cost per hectare as well as a per cubic metre rate.

In addition to the Kerikeri Irrigation Scheme there are several private schemes supplying two or more orchards or farms within or immediately adjoining the Kerikeri Irrigation Scheme area (Lupi, Wiroa Holdings, and others).

Kerikeri soils are much older volcanic brown loam soils than the soils on more recent lava flows around Kaikohe and Whangarei. They are less free-draining, often having a subsoil layer of ironstone and aluminium nodules overlying a layer of clay. Together these layers can impede drainage, and the high concentrations of iron and aluminium both fix phosphorus and impede or discourage root penetration. Kiwifruit and citrus are the main crops in this area, with land also in vineyards, persimmon, tamarillo, other minor crops, nurseries and floraculture.

Water is stored in two main catchment and stream fed storage reservoirs (named Lake Waingaro and Lake Manawai) that supply water via 140km of pipe infrastructure and pumping stations. The scheme is a pumped scheme with supply measured by water meters at pump sheds and at boundaries of individual properties.

The on-farm irrigation systems across the area are variable, but the company ‘encourages’ water use efficiency to ensure adequate supplies and to comply with the conditions of its consent.

The current consent is to abstract 660 l/second from Lake Waingaro, 600 l/sec from Lake Manuwai and 420 l/sec from Waipapa stream. This consent expires in 2020 and is fully allocated.

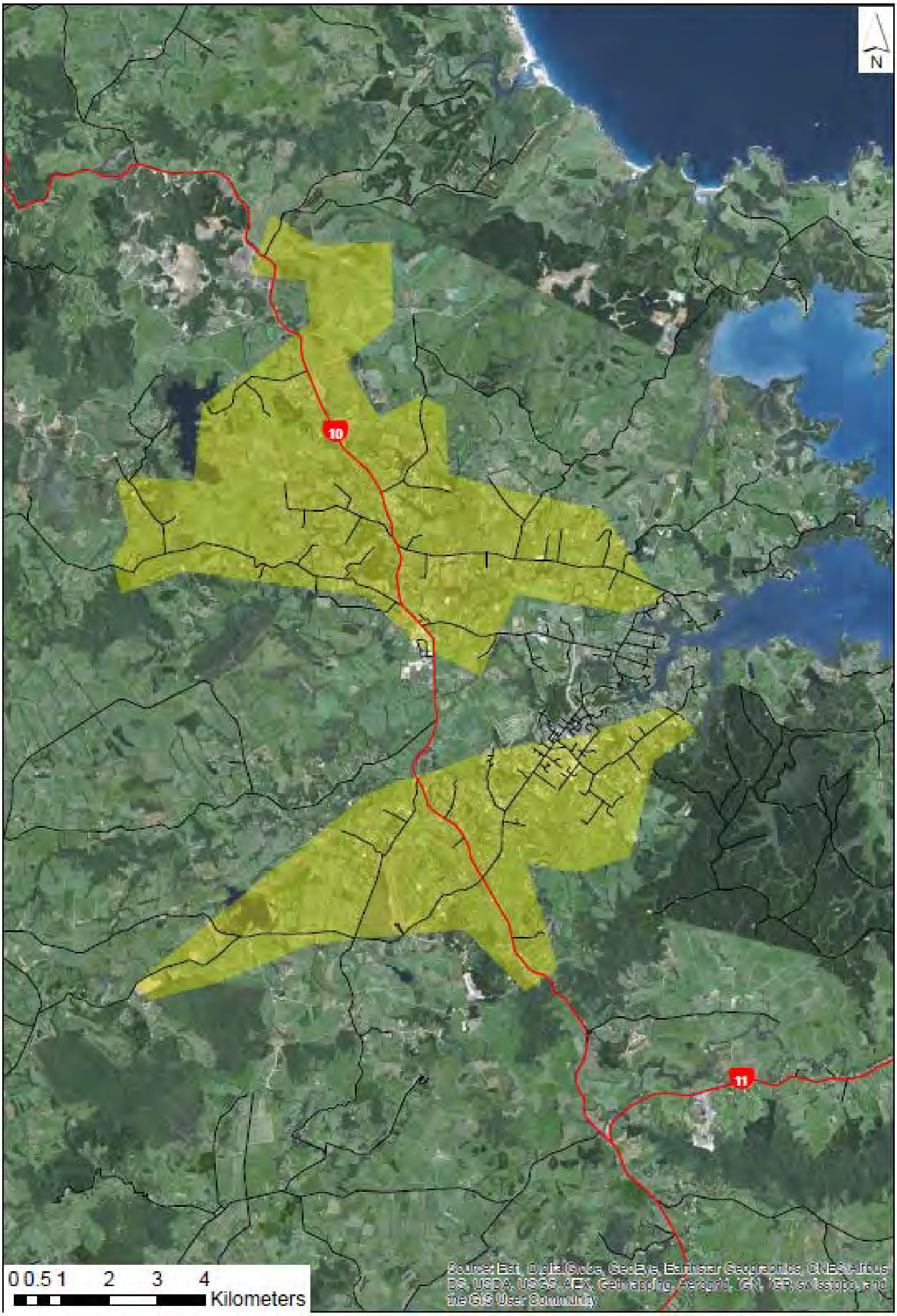
MWD (1982) produced a report for the Kerikeri Irrigation and Horticulture Development titled "The Economy" indicated a total capital cost of about $16 million for the development of the scheme, including on-farm infrastructure. Applying the Statistics NZ Capital Expenditure Price Index this amounts to a figure today of $42 million.

The Kerikeri Irrigation scheme has delivered a number of benefits to the area through increased employment opportunities as scale and a range of crops and orchard-based work opportunities moves the industry from a part-time/casual employer to a full-time employer. It also provides the urban water supply for the townships within the catchment.

Horticulture within the Kerikeri irrigation scheme area is estimated to currently contribute $36 million GDP per annum to the regional economy, and it provides employment to over 650 FTEs in the region. (BERL Estimates, based on 1,700 planted hectares, gross margins from AgFirst *Value of irrigation in New Zealand* and industry sources, and regional multipliers from Butcher Partners.) Whilst this cannot solely be attributed to the Kerikeri Irrigation scheme, this scheme has provided a level of certainty in the horticulture industry to encourage investment and subsequent development in the location.

Figure 2.3 indicates the area which the Kerikeri Irrigation Scheme services.

Figure 2.3 - Kerikeri Irrigation Scheme Extent



Cathcart (2012) estimated in "Soils suited to Horticulture in Northland" that the potential area suitable for horticulture or irrigated pastoral farming in the vicinity of the Kerikeri Irrigation Scheme (Kerikeri-Waipapa district) is 6,700 hectares.

Cathcart (2012) also then estimates that there are 5,000 hectares within this area that is not currently developed in horticulture including 2,750 of which is classed as suitable for horticulture and irrigated pastoral farming if water was made available.

It should be noted that much of the land outside of the current scheme extents is at a higher altitude than the existing scheme reservoirs. A water storage supply higher than the existing lakes would be preferable, of which there are likely suitable dam sites higher in the Kerikeri and Waipapa River catchments not on streams associated with the existing reservoirs.

It is envisioned that should the consented water take, and surrounding land resource be better utilised that substantial benefit could be realised with regard to GDP and employment. This is discussed further in subsequent sections of this report.

Table 2.5 summarises the current situation as well as drivers in the future for the Kerikeri Irrigation Scheme.

Table 2.5 - SWOT Analysis of Kerikeri Irrigation Scheme

Strengths	Weaknesses
1. Security of water supply. 2. Soils generally fit for purpose. 3. Community scheme with good liaison between growers, promoting wise water management and sharing crop management experience. 4. Group shelter due to contiguous orchard development. 5. Scheme and off-orchard facilities (packhouses, contractors, labour, marketing, etc.) all established.	1. A large proportion of the existing development was underway in anticipation of a scheme. While shelterbelts were planted, delays in planting crops and the collapse of the kiwifruit industry resulted in extensive areas not being fully developed. 2. Lack of controls over or council encouragement of fragmentation resulted in lifestyle and residential block intrusion onto land suited to horticulture, both occupying soils suited to horticulture and placing (reverse sensitivity) restrictions on large-scale development of horticulture.
Opportunities	**Threats**
1. Construction of additional dams within the catchments of the Waipapa and Kerikeri Rivers would assist in reducing flood risk in Waipapa in particular and could supply the remaining 1,500 hectares of irrigable land in the area, much of this being in existing dairy farms. 2. Expansion and supply of orchards currently under private irrigation schemes, ensuring greater security for the wider horticulture industry. 3. Increased employment opportunities as scale and range of crops and orchard-based work opportunities moves the industry from a part-time/casual employer to a full-time employer. 4. The District Council seeking an alternative town supply source would free up a small amount of water for some of the development of the remaining 1,000 hectares of land within the scheme area.	1. The urbanisation of the scheme is creating issues as user priorities are different. 2. Profitability of horticulture.

2.4 Historic water management initiatives and proposals

There have been numerous historic water management initiatives and proposals in Northland. Using his extensive knowledge of the area, Bob Cathcart has summarised the major ideas and schemes for the region that did not eventuate.

2.4.1 Northland Dairy Cooperative promotion of pasture irrigation

In response to dry summers in the mid-1990s and following a visit to Tasmania by a group of farmers and company representatives, the Northland Co-operative Dairy Company began promoting spray irrigation of pasture from on-farm storage dams. Approximately 32 earth dams were built within the Northland region and a few in the Tomarata area of the Auckland region. However not all went on to supply water for pasture irrigation. In some cases dams were built but irrigation was not followed through either because the property sold or 'normal' rainfall in subsequent years discouraged irrigation.

Similarly some farmers in the Mangakahia River Valley applied, separately and in small groups, to take water from the river for pasture irrigation. As the volume sought far exceeded the available run-of-stream resource, they were encouraged to work together and to develop a practical roster. Two of the larger applicants subsequently built dams instead.

The dairy company's aim was to raise the level of production generally by increasing overall pasture production or sustaining it at early summer levels right through the production season rather than use the water strategically. Of those still taking water for dairy farm irrigation, most appear to be using the water more strategically, particularly to grow maize or other fodder crops to reduce the volume of bought-in supplements.

All of the dairy farm irrigation systems were designed for and constructed within single farms, that is, they are not community irrigation schemes. This is normal within Northland except for several dairy farms which are buying water from the Kerikeri Irrigation Company.

A specific type of irrigation was promoted as part of this initiative that is by present day standards considered labour intensive and not overly efficient in regards to water usage. The implication that a system of this nature had upon operational costs (labour and machinery) and the overall farm system may impact upon generating farmer interest towards present day irrigation possibilities in Northland.

If a similar project was launched now, it is likely that farmers would have irrigation management support from DairyNZ and Fonterra.

2.4.2 Northern Wairoa Barrage

The concept of a barrage on the northern Wairoa River has been looked at several times. The most recent was a prefeasibility study carried out by BECA on behalf of the Northland Cooperative Dairy Company in 1995 (BECA, 1995). Earlier studies also considered reclamation of parts of the harbour. The costs of such schemes far outweighed the benefits so they went no further than 'discussion'.

With the current forecasts of sea level rise, the feasibility of such a project would need to have regard to and be an integral part of a scheme to protect the existing land and resources, rather than primarily a way of storing water for irrigation.

The Raupo drainage scheme is due for another review, having greater regard for sea level rise than the previous review in 1988. A combination of land settlement due to drainage in respect of the pockets of peat in valleys west of the river, and sea level rise will be reducing the time during which drainage water flows to the river/harbour.

Further, the current sediment load in the river, despite claims that the river was clear before bush within the catchment was felled, belies the fact that the extensive northern Wairoa and Ruawai flats are formed from alluvial and estuarine material brought down by this river. This catchment, which drains one-third of Northland, has tropical clay soils and there has always been a significant fine sediment load in the river. Unless a cost-effective way of flocculating and/or filtering this sediment can be found, the water in the reservoir will be unsuitable for irrigation.

Currently no irrigation infrastructure is available. While those farmers adjoining the river could simply take from the reservoir, a channel distribution system is proposed to distribute water further away from the river. Extreme care would be required in siting, building and maintaining an irrigation race network and the modified land drainage system.

Development of a scheme of this type will carry a large cost due to the potential relocation of the drainage network to enable building of water reticulation. There are possible conflicts with an increased cost of the drainage network if drainage water has to be pumped to get it past irrigation canals.

Environmental impacts could potentially be high with regard to water quality issues with sediment loads and transport. The effect of the barrage on the ecology of the river will also need to be reviewed as previous studies have not focused on biodiversity values, fish passage and the ecology of the Kaipara Harbour.

There are other benefits and opportunities available outside of irrigation. Water supplies would be increased for stock, municipal and processing uses (if sediment can be removed). Additionally, electricity generation could be explored.

This is a very water-short area however the project did not get off the ground effectively because of the limited number of droughts in the following years and the economic benefits meant that increase in alternatives to pasture irrigation would be required and the cost were too high for Northland to finance.

2.4.3 Hikurangi Swamp Major Scheme

The Hikurangi Swamp is an old lake bed within the catchment of the Wairua River. Unstable land and concern at the risk of increased flooding of farmland and roads downstream of the Swamp restricts the outflow to about one-third of flood inflow.

Stage I, which was built by the Northland Catchment Commission between 1968 and 1974, stores floodwaters between widely spaced stopbanks and in a >1 in 5-yr event allows water to overflow at control points. Pump stations in seven isolated 'pockets' pump this stored water back once river levels have dropped below the overflows. The objective is to clear overflow water from farmland within three days in summer before the warm water kills pasture. These works were designed in the 1970s and 80s and provide protection up to a 1 in 25-year flood. The standard of protection has not been assessed subsequently.

The original concept plan for Hikurangi Swamp Major Scheme, described in 1966, designed three stages:

Stage I – as built, approved by the National Water and Soil Conservation Authority/Minister of Works and Development and currently operating;

Stage II – Hillwater canals which would collect local runoff and small streams within the seven stopbanked 'pockets', conveying it to gravity outfalls to the main channel before floodwater arrived from the upper catchment. Only two short hillwater canals were built, one in Te Mata pocket and the other in Ngararatunua (and which has since been infilled). Only preliminary survey and no design work was undertaken for the other canals, they remained purely a concept;

Stage III – Flood detention dams within the upper catchment. This went no further than a concept.

The Stage III concept proposal envisaged these dams as multi-purpose reservoirs in upper catchment areas, storing floodwaters and so increasing the level of protection provided by Stages I and II of the scheme. Other possible benefits included prevention of flooding and closure of SH1, hydro-electricity generation, and water supplies for municipal and farm water (stock, dairy sheds and irrigation).

The landform has the potential to provide adequate storage, with extensive valley systems with flat grades. This is mainly greywacke country providing firm foundations and suitable dam-building material. Reticulation does not exist and each farm relies on local water sources and in-farm reticulation for stock water and dairy sheds. Rather than reticulating water from the storage dams to farm boundaries, the dams could be used to supplement river flows during late spring and summer.

Apart from a small number of farms with storage dams, there is little or no pasture or crop irrigation within the Hikurangi Swamp catchment. Fonterra has an extensive in-farm reticulation system for irrigating factory wash and waste-water on land from Kauri to Jordan Valley.

There are several small horticultural ventures irrigating from bores and small dams at Whakapara, Kauri, Apotu Road, Matarau and Ruatangata, not all of which have resource consents. A larger kiwifruit venture has consents and takes from two dams at Ruatangata, downstream of the lower end of the Hikurangi Swamp proper. Many of these ventures will have their access to water reduced or removed under stricter water allocation rules.

2.4.4 Kaihu River Dam Investigations

In the 1970s the North Auckland Electric Power Board (now Northpower) investigated building a dam on the Waima River, near its confluence with the Kaihu River, upstream of the gorge.

The water level in the dam would have been high enough to channel flows through to Aranga and spill the flow through penstocks which, after generating electricity, discharged to the Tasman Sea near Maunganui Bluff at the northern end of Ripiro Beach.

This dam would have created a reservoir that extend well back up the Waima River valley. As well as inundating the settlement of Donnelly's Crossing and access roads traversing the valley, the lake would have flooded a significant part of Trounson Kauri Park.

As well as generating electricity, this dam could have had several other benefits: reduced flood peaks in the Kaihu River valley would likely be achievable as the valley is narrow and the flood flows too large to be effectively managed with stopbanks, as well as the lower section of the river being affected by the tide.

It would also have provided water for irrigation, farm water supplies and municipal use in the Kaihu and Awakino valleys, the sand country between the Kaihu-Northern Wairoa River and the coast and the greater Northern Wairoa-Ruawai Flats including Dargaville, possibly the most water-short part of Northland.

Reduced flood peaks would also ensure SH12 remained open whereas it currently closes south of Mamaranui during flood events.

Hobson County Council managed the Kaihu River flood control scheme; Dargaville Borough Council managed the piped town supply water from near Kaihu; and Northland Catchment

Commission had an overview of flood management and was the regional water board (Water and Soil Conservation Act 1967).

All parties supported the concept. However, they were not at a stage when they wished to upgrade their respective flood management and water supply schemes meaning it would have been only a hydro-electricity scheme. The fact that the scheme was judged to be only marginally economic and that Trounson Kauri Park would have been destroyed resulted in the proposal being abandoned.

Tonkin and Taylor (1974) identified that "*the total rural area capable of benefitting from water supply by improve framing or by crop irrigation in the Dargaville-Ruawai area is approximately 70,000 acres*"

As substantial investigations were completed into this initiative there are many historic reports available for this initiative.

2.4.5 Opouteke River

Carter Holt Harvey (CHH) supported the establishment of a flow recorder site in the gorge of the Opouteke River, west of Pakotai in the 1970's. The Opouteke, a major tributary of the Mangakahia River, drains the high rainfall area on the eastern slopes of the Tutamoe Range.

CHH planned to build a dam, generate electricity and pipe water down to a planned processing plant alongside the Dargaville racecourse. Plans later changed and they established the LVL plant at Marsden Point and purchased the TDC sawmill in Whangarei.

The Opouteke dam site, which has significant storage, is 30km from Dargaville compared with 28km from a possible Kaihu River site.

Water from an Opouteke River dam could have also been used to supplement flow in the Mangakahia River, improving summer water quality, support pasture irrigation relying on river takes and reduce flood peaks in the Opouteke.

2.5 Other water management considerations

Using his extensive knowledge of the region, Bob Cathcart has discussed below some examples of challenges Northland towns and communities are facing in regards to water management and how it may be able to be managed moving forward.

2.5.1 Flood risks

In many areas, high quality potential and existing farmland is located in areas at risk of flooding. This does not necessarily mean that these areas should be discounted when considering irrigation as schemes can be implemented such that they address flood risk to farmland and downstream settlements.

The following points discuss examples of where this integration could be explored:

- Current work on the Awanui River scheme is expected to raise/restore the Awanui River flood reduction scheme to its design 1 in 25-year standard. The scheme only protects Kaitaia and the Awanui Flats north of the town, not the extensive area of alluvial land south of Kaitaia. These southern flats, some of which have more recent, freer-draining and more fertile soils than those on the Awanui Fats, are inundated to a depth of one or more metres with fast flowing floodwaters several times each year. There are several tributaries of the Awanui River which could be dammed to regulate the depth and timing of floodwaters on the floodplain upstream of Kaitaia and reduce the frequency of stopbank overflows downstream of Kaitaia on the Awanui Flats. This would increase the level of protection/reduce the risk to more intensive farming systems.

- The Oruru River flows on a narrow floodplain from Peria to Taipa. Soils are fertile and the area well sheltered from winds but frequent flooding limits the intensity of land use on the best soils. Channel works or installation of stopbanks would likely not be cost effective. Flood peaks and frequency of flooding could be reduced by damming either the main river or one or more of its upper-catchment tributaries. This would give protection to Peria Road, an arterial root through to the foot of the Mangamuka's on the northern side.

- The channel and stopbank work recently completed on the Kaeo River within Kaeo township is about all that can be done on this part of the river to reduce damage during the frequent floods that are typical of this valley. A dam upstream of the Waiare Gorge could both reduce flood peaks and provide a more secure water supply for the town.

- The irrigation reservoirs upstream of Kerikeri and Waipapa, the fastest growing part of the Far North District, are already helping to regulate flood flows. There are more sites suited to damming and the additional reservoirs would supply water for pasture/crop and horticulture irrigation, stock water, industry (particularly further processing of primary products) and urban development.

- The Hikurangi Swamp and Wairua River area is also relatively water short with a limited volume of water having to assimilate waste from both farming operations and the Hikurangi municipal oxidation ponds. Flows in tributary streams from Three Mile Bush-Ngararatunua, Matarau and Apotu areas of volcanic soil are fully committed to lifestyle and horticultural units drawing on spring and groundwater resources. Stage III of the original Hikurangi Swamp Scheme was to be flood retention dams in the tributary catchments. Only Stage I has been built and in the 40 years since its completion, land drainage and development in the catchment has dramatically reduced the time of concentration and increased flooding at Whakapara (SH1) in particular.

- In the 1970s, CHH Forests jointly funded a hydrological station in the gorge of Opouteke Stream, a major tributary of the Mangakahia. At that stage CHH planned to build a dam near that site to supply water and electricity to a processing plant on land it owned beside the Dargaville racecourse. The Northland Catchment Commission supported the concept because such a dam could have a significant effect on flood flows in a valley where there are no other practical means of reducing flood peaks and frequency. Deep and fast flowing floodwaters frequently flood farmland and shut Mangakahia Road, a major arterial route, where the Opouteke flows across Mangakahia Road immediately north of Pakotai and again a couple of kilometres south of Pakotai.

- The Tangowahine Stream and the Awakino and Kaihu Rivers all flow on narrow but fertile and potentially highly productive floodplains. Major arterial roads traverse each of these valleys and access is frequently disrupted. While there are channel maintenance schemes on the lower valley of each and stopbanking on the tidal reaches, it is not cost-effective to do much more just to control flooding.

- The Manganui River has the biggest catchment area of all the northern Wairoa River tributaries. It has little high country and tributaries have very flat grades. Many of the swamps in these tributary valleys have been drained and floodwaters concentrate more quickly in the extensive wetlands in the lower reaches of the Manganui before it joins the Wairoa. Roads in the upper catchment often follow the narrow floodplains as much of the hill country has unstable sedimentary rocks where it is difficult to maintain roads. These roads are often flooded, causing traffic to be diverted around very long detours.

  Apart from a narrow band of greywacke along the eastern, Mareretu-Ruarangi section of the catchment boundary, the sedimentary rock hill country of the Manganui River catchment yields very little water in summer, a high proportion of streams going completely dry. Stock water has been sourced from mainly small dams, most of which are insufficient for current stocking rates.

  The landform within the Manganui River catchment is suitable for constructing large ponding areas which would supply much needed quality stock water and help offset the effect of draining the wetlands. They could also be used to supplement summer flows in streams in which indigenous biodiversity has been adversely affected by land development.

2.5.2 Urban and small town water supplies

Most urban and coastal areas in the Far North and Kaipara Districts, apart from Kerikeri and Kawakawa-Moerewa, rely on run-of-stream supplies and are either water-short in most dry summers or do not have sufficient water to support growth. Work is in progress to supply Kaitaia, which currently relies on a small dam and a take from the Awanui River, from the Aupouri groundwater aquifer. However, even with that connection, there may not be sufficient water to support urban growth, industry and food processing (adding value to primary produce), particularly as the groundwater resource comes under pressure from irrigators of both pasture and horticulture.

The following points discuss examples of where town water supply could be explored alongside irrigation:

- Small towns and rural dormitory areas like Paparoa, Kaiwaka, Matakohe, Waiotira and Ruawai cannot rely on stream flow or groundwater and will depend on stored water. Ruawai and Te Kopuru have relied on bore water of poor quality. Maungaturoto township and the dairy factory have a reliable supply because of an irrigation dam on land behind Bald Rock. The residents of 'resort' towns like Tinopai, Whakapirau and Pahi will demand a more reliable water supply than roof water as these settlements grow. Farm water supplies in these same areas will require more reliable supplies as dairy herd sizes increase, sheep and beef farms are converted to dairying, and beef farming becomes more intensive.

- Kaikohe is supplied from bores in a volcanic cone and a small dam which is barely adequate to support its current needs, let alone sufficient to encourage forestry or food processing.

- Kerikeri-Waipapa has an adequate supply because it is able to draw from the irrigation dams. It is, however, the fastest growing urban area in the Far North District and any growth in horticulture will result in competition for this valuable resource.

- Doubtless Bay (Mangonui, Coopers Beach, Cable Bay and Taipa) is supplied by a private water supply scheme that draws both from bores and from the Oruru River just upstream of the limit of tidal influence. Many houses still use roof tank supplies and there is a risk that the reticulated system would not be able to cope with the demand should all the existing houses switched to the Doubtless Bay Water Company system. The system would also have difficulty coping with any significant growth. While Carrington Estate on Karikari Peninsula has sufficient water to support its current hotel complex, vineyards and golf course, this supply will be stretched if the complex is expanded as planned. Adjoining Whatuwhiwhi and Tokerau Beach and nearby Rangiputa all depend on roof water.

- There is a large number of developed but yet to be built on sections and, particularly around Mangonui-Coopers Beach, more houses are occupied year-round rather than just in the holiday season. This area does not have reliable run-of-stream supplies and only limited groundwater, which is at risk of salt water intrusion if overdrawn. It is likely that the area will eventually require significant storage.

- Houhora-Hukatere also relies on roof water and small bores. It has no stream flows and is at the northern end of the Aupouri groundwater system. Any public supply takes from groundwater would compete with established, expanding and very successful avocado production.

- The Opononi-Omapere water supply is a take from behind a weir on a small stream adjacent to Waiotemarama Gorge Road. While the rocks of the Tangihua volcanics sustain a reasonable stream low flow, the supply is inadequate for the Opononi-Omapere township over most summers due to insufficient storage. Waimamaku would benefit from a reticulated water supply. Alternatives include wells in the gravels adjacent to the Waimamaku River or a dam to create storage.

- Opua, Paihia and Waitangi rely on a take from the Waitangi River immediately upstream of Haruru Falls. With the expansion of the Bay of Island settlements the security of supply will be at risk.

- Small coastal settlements from Russell, up to Rawhiti and Hauai and down the east coast to Sandy Bay rely mainly on roof water with some bore water. The bores are at risk of saltwater intrusion and, in some places, being partly recharged by septic tank soakage fields. With people expecting higher standards, using more water and many living permanently in these settlements, they demand a more reliable water supply.

2.6 Council Long Term Plans (LTP's)

All four councils in Northland including Whangarei, Far North, Kaipara District Councils and the Northland Regional Council are required to complete Long Term Plans (LTPs) as a statutory requirement.

Water supply, flood protection infrastructure and stormwater management are an important part of LTPs from both an operational and capital expenditure perspective. Councils are responsible for ensuring the resiliency of this infrastructure so it can manage natural hazards, cater for the effects of climate change, and continue to support the local community and economy.

The LTPs in their entirety can be accessed from the Council websites; however the following are examples drawn from the LTPs that could be considered complimentary to water storage for primary production:

- Significant decisions are required around capital expenditure on Awanui, Kaeo/Whangaroa, and Kerikeri/Waipapa River Schemes (NRC)
- Hikurangi Swamp Flood protection scheme which offers positives for the local economy (WDC)
- An alternative water source investigation is planned for Dargaville and Bayleys (KDC)
- Options are being investigated for improved water sources and security for Paihia, Kaitaia, Opononi/Omapere, and Rawene/Omania (FNDC)

The above is by no means a comprehensive review of the LTPs. However the examples show the importance of a catchment wide approach to ensure that potential competing water uses are considered in unison from both a practical and affordability perspective.

2.7 Stakeholder engagement responses

Selective engagement with stakeholders was undertaken during the first phase of this study. Affected and suitable organisations, groups, or individuals, were chosen to help gauge the level of interest, their thoughts on the importance of water and water management, and their requirements on a regional or sector basis. This holistic view was imperative for the study to determine the potential areas of demand, and the needs of the Northland region without preconceived ideas or focus on benefits for individuals.

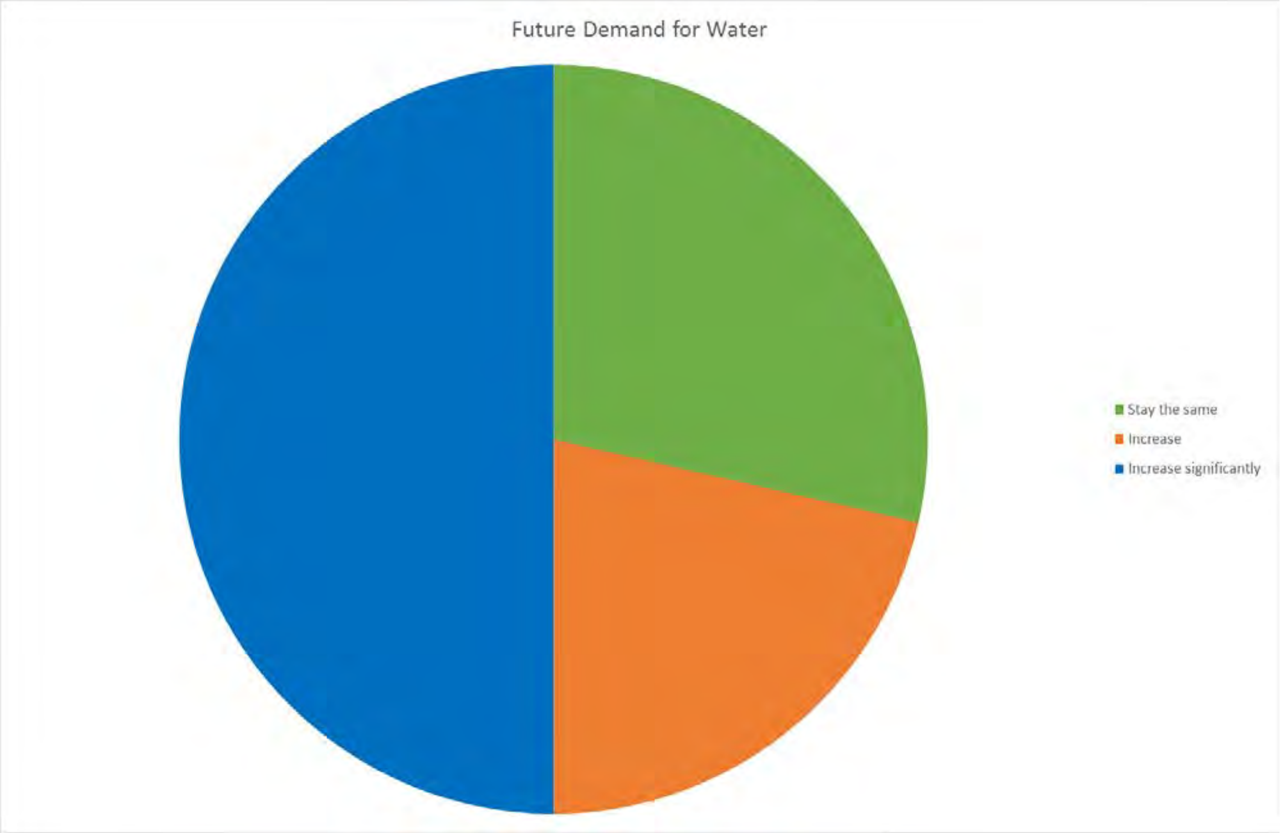
The current response from stakeholders has shown that communities, organisations and individuals are extremely interested in the subject of water infrastructure in Northland. A survey was sent to the people listed in Appendix A with a response rate of 53%.

Approximately 85% of respondents indicated that they were willing to engaged in the investigation process. 65% said they had a high level of interest in this study and would be very supportive to investment.

A reliable water supply which users can access during peak water demand periods was considered to be the most vital benefit to supporting a water infrastructure scheme, with one respondent saying *"Our higher value systems would flourish in a water reliable climate given the demands* *for fruit categories; but also potential development of the vegetable sector particularly kumara and fresh vegetable products".*

Figure 2.4 shows that the majority see personal demand increasing over the next 20 years. Therefore, alongside potential climate change factors "*water storage creates opportunities where they aren't present now, by creating a resource it will allow the community to adapt and evolve in the face of future challenges*".

Figure 2.4 - The future demand for water perceived by stakeholders



Source: Stakeholder engagement survey, Opus (2015)

Respondents were asked what they considered to be the influence of improved water infrastructure. Economic outcomes was top followed by cultural interests, environmental protection and social benefits. The responses have been used to determine a suitable weighting for important criteria (see Section 9.1).

Further engagement with specific communities, organisations and iwi, should be undertaken in future stages once areas are identified as having financial and technical merit for further investigation. Figure A.1 shows the questions posed to the stakeholders.

3 Demand analysis

3.1 Irrigation potential

The Northland region benefits from a subtropical climate, providing a largely frost free environment, and rich versatile soils. Relatively warm climate conditions enable growing crops at different times of year compared with other regions, which results in economic benefits. The region also consists of good versatile soils suitable for a variety of horticulture and agriculture crops. While NRC has not determined the limits of resources, it is possible that a few water bodies, primarily run-of-stream resources are fully allocated or nearly fully allocated (Osbaldiston, personal communication, 2015). Therefore, it is considered that potential for further direct abstractions from these resources for irrigation is low. Accordingly, this report makes a strategic assessment on areas that can be irrigated for higher returns while identifying options for enhancing water resource availability.

The two important questions in determining potential irrigable areas are:

1) whether land is physically able to be irrigated, and
2) whether land is worth irrigating.

Whether land is physically able to be irrigated depends primarily on topographical features; whereas whether land is worth irrigating depends on climate and land use capabilities. The following subsections assess these important physical and economic-related factors affecting the choice of irrigation.

3.2 Topography

The potential irrigable areas can be identified based on land elevation, slope and aspect. It is unlikely that irrigation will be practical at elevations greater than 400m amsl due to practical difficulty in accessing sufficient quantities of water at a viable cost. The high altitude areas in the region are also associated with high slopes. Analysis of the NRC consent database reveals that the highest elevation where irrigation currently occurs is 314m amsl.

Irrigation on pastoral land is generally limited to slopes less than 15°. However, drip and micro irrigation for horticulture can occur on steeper slopes i.e. parts of the current orchard irrigation within the region takes place on slopes up to ~20°. Therefore, the areas with a slope up to 20° have been included in selecting potential irrigable areas.

Given the warm climate within the region, it was considered that aspect (i.e. compass direction that a slope faces) would not be a vital factor in determining potential irrigable area at this high level study, therefore, it has not been included in these determining characteristics.

3.3 Climate

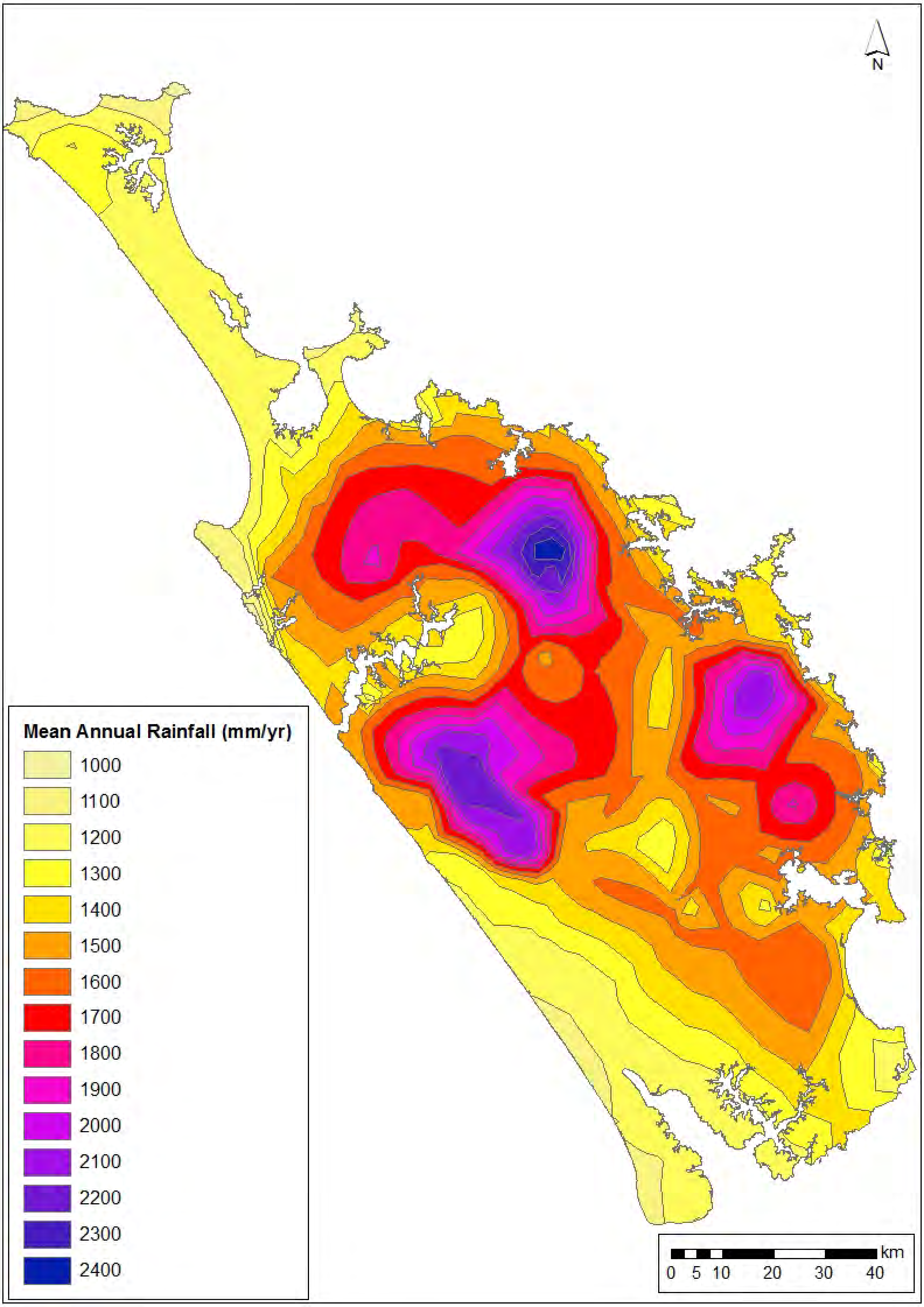
Climate conditions have a significant impact on agriculture and horticulture. The type of crops that can be grown in particular areas depends on climate; generally, warmer subtropical climate conditions allow the growth of a wide range of crops. Warm temperatures, sunshine and solar radiation generally increase crop production. However, certain crops grown in a sunny and warmer climate need more water per day than the same crop grown in a cloudy and cooler climate.

Apart from sunshine and temperature, other climatic factors such as humidity and wind speed also influence crop water requirement. When it is dry, the crop water needs are higher than when it is humid. In windy conditions, the crops will use more water than in calm conditions. Accordingly, in determining crop water requirements, in addition to rainfall, the likely daily evapotranspiration (ET) of a crop should be taken into account.

Figure 3.1 shows that Mean Annual Rainfall (MAR) is highly variable within the region. The economic return of irrigation is usually lower in high rainfall areas. The general practice is to exclude high rainfall areas when identifying potential irrigable areas. For example, Aqualinc (2015) excluded the areas which receive more than 1,200 mm/year within the Otago region from the potentially irrigable area. However, analysis of the NRC consent database reveals that nearly 20% of the total irrigation abstraction by take rate is accounted for consents within areas that have a MAR higher than 2,000 mm/yr. This indicates that summer drought is possible in these high annual rainfall areas, at least in some years. Northland is also recognised as a region with many micro climates. Therefore, MAR was not used in this analysis to eliminate potential irrigable areas.

The distribution of Potential evapotranspiration (PET) (Figure 3.2) differs between 300 and 1,000 mm/yr. PET also effects the irrigation water demand calculations in Section 4. The benefits of irrigation, i.e. converting from dryland to irrigated, vary due to rainfall and PET. The benefits would be lower in areas which receive high rainfall and experience low summer PET.

Figure 3.1 - Distribution of mean annual rainfall (MAR) within the region



Source: National Institute of Water and Atmospheric Research's (NIWA) MAR isohyets

Figure 3.2 - Distribution of mean annual PET within the region

Source: NIWA's PET contours

3.4 Land capability

Not all land is productive in terms of agriculture and/or horticulture production. Accordingly, the potential irrigation return varies between land types. The Land Use Capability (LUC) is a hierarchical classification (i.e. classes) identifying capability to sustain continuous production, the land's general versatility for productive use, the factor most limiting to production, and a general association of characteristics relevant to productive use (Landcare, 2008). Class 1 land, known as the 'elite' soils, are highly versatile with virtually no limitations for arable agriculture or horticulture. Classes 2 and 3 ('prime' land) are also productive agricultural and horticultural land with slight to moderate limitations for arable use. Class 4 has moderate limitations for arable use but suitable for occasional cropping, pasture and forestry. A breakdown of LUC classes 1-4 in Northland and New Zealand is presented in Table 3.1. A description of all LUC classes is given in Appendix C.

As shown in Table 3.1, just over 10% of the region is classified within classes 1-3. Approximately 25% of the region is classified as class 4. A list of areas for all LUC Classes is given in Appendix C. It is likely that most future agriculture and horticulture developments will happen in LUC classes 1-4. However, the project team, decided to include all classes (i.e. 1-8) for this pre-feasibility study. This was primarily due to the existence of many classes within most areas that are physically suitable (e.g. slope and elevation) for water infrastructure development. Further detailed analysis may need to exclude some of the low fertile areas such as LUC classes 7-8.

Table 3.1 - Areas (hectares) of Land Use Capability (LUC) classes in Northland

LUC Class	Area (hectares)	Area as a percentage (%)	
		Within the region	All New Zealand
1	435	0.03	0.7
2	36,126	2.9	4.5
3	91,166	7.3	9.2
4	301,772	24.2	10.4

Source: Landcare (2008)

The land area that is unlikely to develop for farming such as towns, built-up areas and indigenous forests were excluded from the potential irrigable areas. However, current forestry areas have been selected to be available for future irrigation development as it is possible that some of these lands would be converted to agriculture or horticulture after the next forest rotation logged. This was assessed based on Land Cover Database version 4 (LCDB v4.0) (Landcare, 2014).

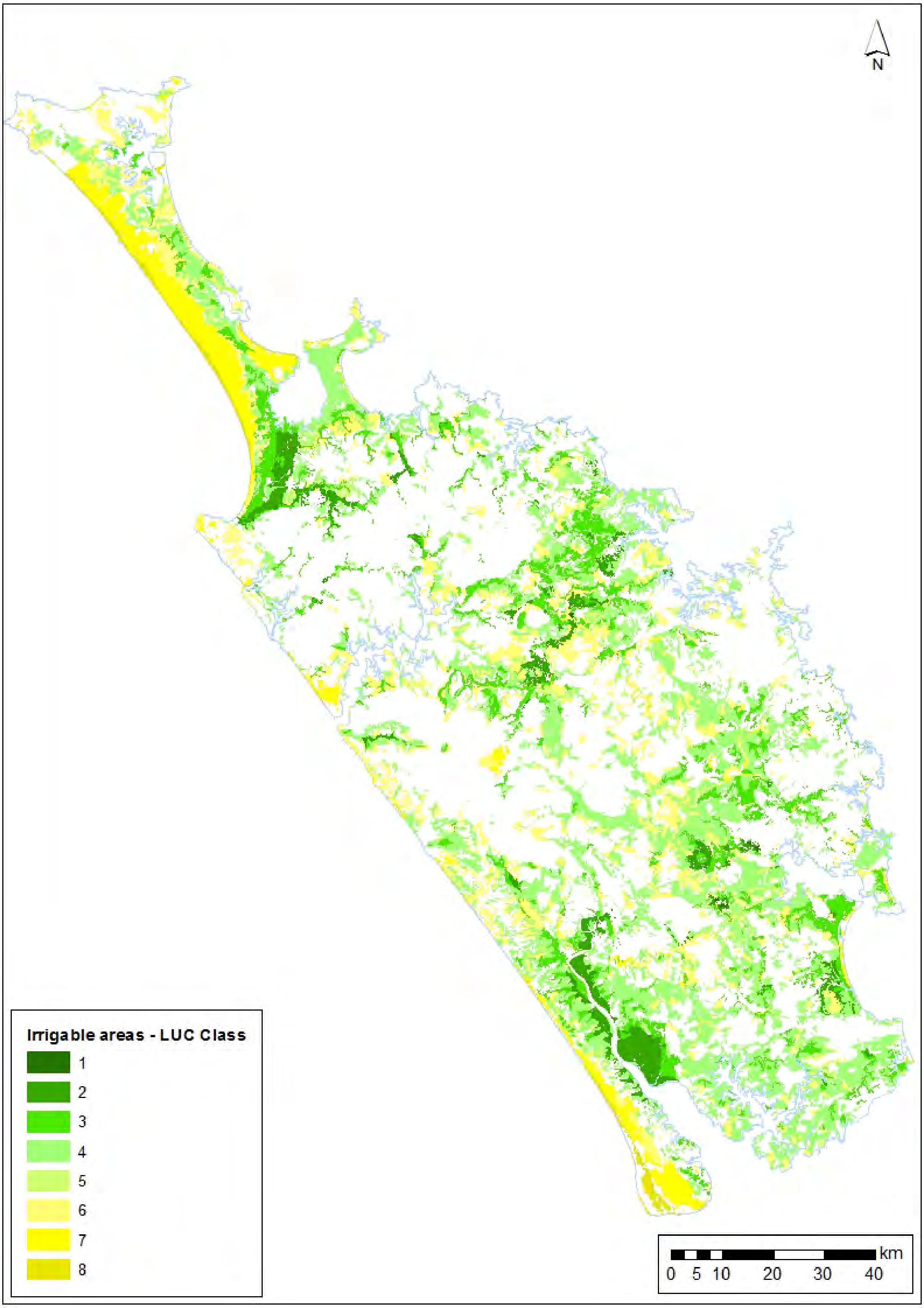
3.5 Selected irrigable areas

Table 3.2 summaries the criteria, which are described from Section 3.2 - Section 3.4, used for selecting irrigable areas. The selected irrigable areas based on these criteria are shown in Figure 3.3. The high LUC classes (darker green areas) represent more versatile land with less limitation for agriculture and horticulture production whereas the low LUC classes (yellow areas) represent severely limiting land.

Table 3.2 - Criteria for selecting irrigable areas

Parameter	Criteria
Elevation	≤400 m amsl
Slope	≤20°
Aspect	Not incorporated in this study
Mean annual rainfall	Not incorporated in this study – considered though, due to high seasonal variation in rainfall (i.e. dry summers) and the current irrigation in the region.
LUC	Classes 1-8
LCDB	Excluded areas which are unlikely to develop for farming such as towns, build-up areas and indigenous forests

Figure 3.3 - Identified irrigable areas by LUC Classes



3.6 Potential command areas for further consideration

Based on the identified potential irrigable areas in Section 3.5, 18 potential irrigation scheme command areas have been selected. The command area represents the total gross geographical area within an irrigation scheme. However, the actual irrigable area would be less than the command area due to non-irrigable areas such as buildings and roads, and lands that are unsuitable for agriculture (e.g. due to their slope). The selected areas are listed in Table 3.3 and shown in Figure 3.4. This command area selection considered the areas that include larger potentially irrigable areas of better soils within a reasonable proximity so that water can be practically delivered from the source (i.e. from run-of-stream or dam[s]). This assessment also considered the surface water catchment boundaries as it is generally difficult and not economical to transport water from one catchment to another. This study largely focuses on assessing the feasibility of developing larger-scale water infrastructure for a community of users rather than for individual farms. The advantages of a community-based water infrastructure scheme include:

- Water availability; access to water is a constraint on many properties without a river or stream boundary, or where allocable resources are limited as on the smaller streams. Water infrastructure development would be able to deliver water to lands that are not adjacent to rivers or streams.
- Water reliability; run-of-stream takes are subject to low flow restrictions, and it is uneconomical or impractical for many land owners to develop storages individually.
- Equitable water management; a scheme approach would provide all property owners with equal access to water, and hence could be regarded as a more equitable allocation of resources.
- Negotiating power; a community based scheme is likely to have stronger negotiating power when it comes to allocation and financial issues.
- Proven benefits; the production, farm management and financial benefits are well understood in the region (e.g. Kerikeri Irrigation Scheme), making the "selling" of the concept easier to the farming community.
- Improve capital value; the development of a scheme is likely have a positive impact on land values, as the reliability of water supply is seen as a key factor in improving production and returns (or alternatively reducing risk).
- Cost effective water supply; scheme development is more likely to produce, in the longer-term, a more cost effective source of water.
- High future demand; population in neighbouring Auckland region is projected to increase by 50%, from current level of 1.5million to 2.2million by 2040 (Auckland Council, 2012). While this increased population will need more food, most high productive areas in the Auckland region such as Pukekohe is under threat from planned greenfield developments. Therefore, there is a high potential that farmers will look into relocating to the areas that climate and soils are suitable for growing, and water would not be a constraint.

The total irrigable area would generally not be available for development. Within typical existing large irrigation schemes, 20% of the potentially irrigable area would not be irrigated because owners choose not to irrigate. However, there are further potential constrains for irrigation development in Northland due to other demands such as rural residential and lifestyle blocks (e.g. Glenbervie and Mangawhai) and impact on environment (e.g. water flow to sustain ecological values, impact on significant wetlands). Accordingly, the percentage of the potentially irrigable area has been adjusted for some schemes as shown in column 5 in Table 3.3. It has been assumed that the net irrigable area (estimated scheme development area) is evenly distributed throughout the command area.

Table 3.3 shows that over 26,000 hectares (equivalent to 13%) of the total potential irrigable area is within the Aupouri Peninsula. Most of the current irrigated area (87%) in the region lies within the selected irrigable areas. This is excepted as the criteria used for identifying the irrigable areas is similar to what farmers generally use to determine whether land is physically able to be irrigated.

As shown in Figure 3.4, a large proportion of the Aupouri Peninsula command area is covered with lower versatile soils (i.e. LUC classes 5-8). As described in Section 3.5, availability of surface water is also limited within the Peninsula. However, this area is overlain on a reasonably high yielding aquifer. Accordingly, this area could potentially be developed through the use of many small schemes rather than a single large scheme, with specific crops that are suitable for the climate and available soils using groundwater resources.

Figure 3.5 shows the soils throughout Northland with LUC class 1-4. More detailed maps are shown in Appendix J.

Table 3.3 - Summary of selected water infrastructure command areas based on irrigable areas

No.	Area	Command area (hectares)	Total irrigable area (hectares)	Estimated scheme area as a percentage of total irrigable area (%)	Estimated scheme development area (hectares)	Current consented irrigated area (hectares)	Future development potential (hectares)
1	Aupouri Peninsula	49,865	44,294	60	26,576	499.6	26,076
2	Awanui Plains	27999	22,991	75	17,243	1,410.5	15,833
3	Kerikeri	14,213	13,215	80	10,572	2,887.7	7,684
4	Waimate North	29,422	21,657	80	17,325	124.4	17,201
5	Kaikohe	31,090	22,111	80	17,689	226.0	17,463
6	Waimamaku	5,096	3,824	80	3,059	-	3,059
7	Hikurangi	41,824	30,614	60	18,369	625.1	17,744
8	Glenbervie	5,404	3,958	60	2,375	135.3	2,240
9	Mangakahia	12,938	9,941	60	5,965	494.0	5,471
10	Maungatapere	16,576	12,478	80	9,983	1,844.1	8,139
11	Maungakaramea	22,688	18,480	75	13,860	190.7	13,669
12	Ruakaka	6,434	5,859	80	4,687	6.5	4,681
13	Waipu	10,756	8,307	80	6,646	116.5	6,530
14	Kaihu	5,498	4,580	80	3,664	40.0	3,624
15	Hoanga	3,768	3,086	80	2,469	-	2,469
16	North Kaipara	37,564	26,218	75	19,663	510.0	19,153
17	Ruawai	13,833	13,059	80	10,447	20.0	10,427
18	Mangawhai	11,521	8,226	60	4,936	115.9	4,820
	Total	**346,489**	**272,899**		**195,528**	**9,246**	**186,282**

Figure 3.4 - Selected water infrastructure command areas

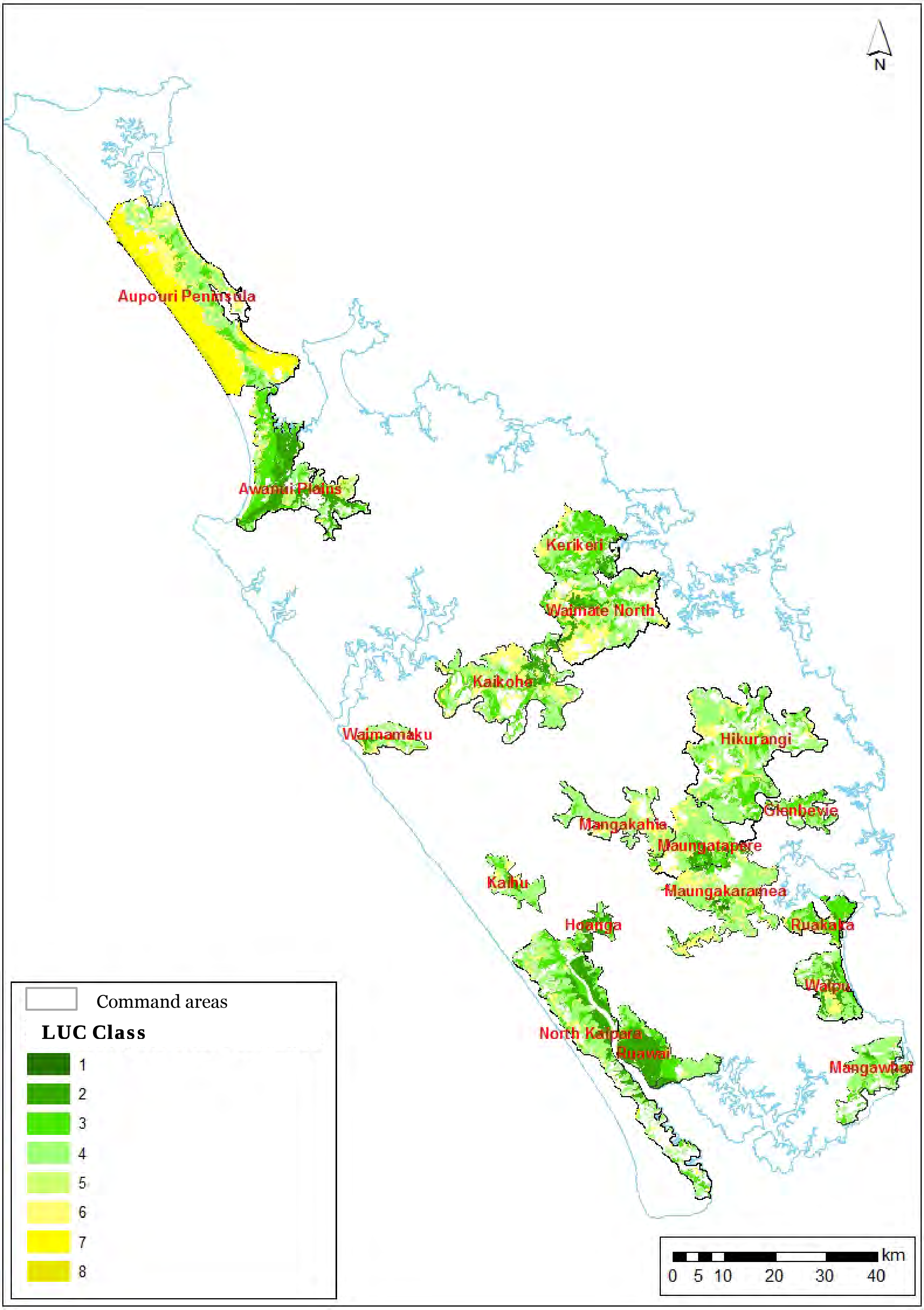
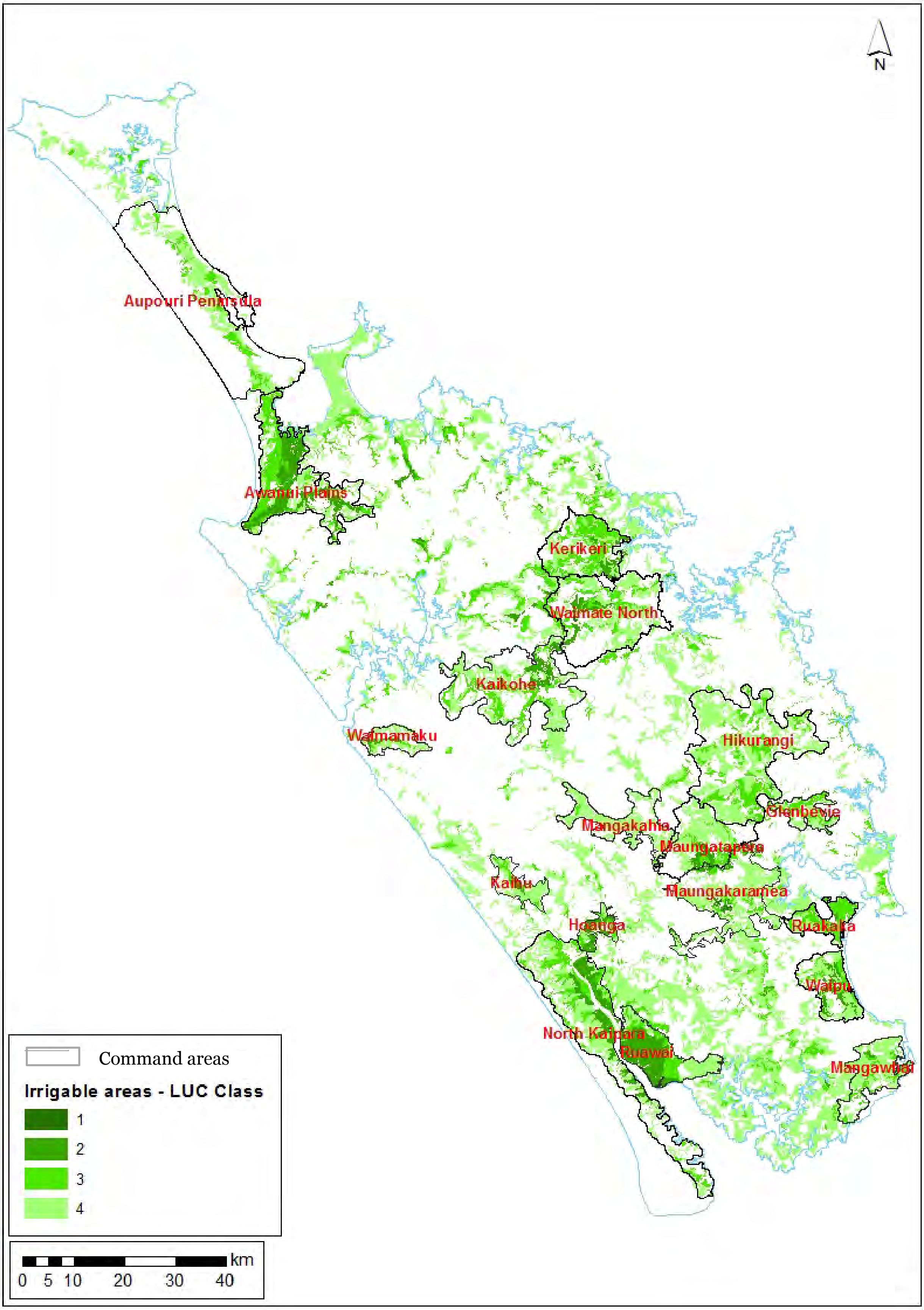


Figure 3.5 - Areas with LUC Class 1-4 throughout Northland



3.7 Potential challenges and limitations

There are many potential challenges in the development of large irrigation projects. Abstracting run-of-stream flows or groundwater, or diverting stream flow into reservoirs causes environmental and/or social disturbances. Reduction in stream flow changes flood plain hydrology and ecology, and can cause salt water intrusion in the stream and into the groundwater of adjacent lands. Harvesting stream flows for irrigation reduces the water availability for downstream users. A reduction in stream base flow decreases the ability of flows to dilute municipal and industrial wastes added downstream. The use of groundwater for irrigation can result in the lowering of the water table and saltwater intrusion in coastal areas such as Aupouri Peninsula. The effect of saltwater intrusion can be exacerbated due to predicted future sea level rise (MfE, 2015), reduced recharge due to land use change and future rainfall patterns. These affects will need to be analysed by each command area in the next stage when environmental effects are assessed. However, there are two clear challenges to development of land for large-scale water infrastructure schemes in the region, flooding and erosion.

3.7.1 Flooding

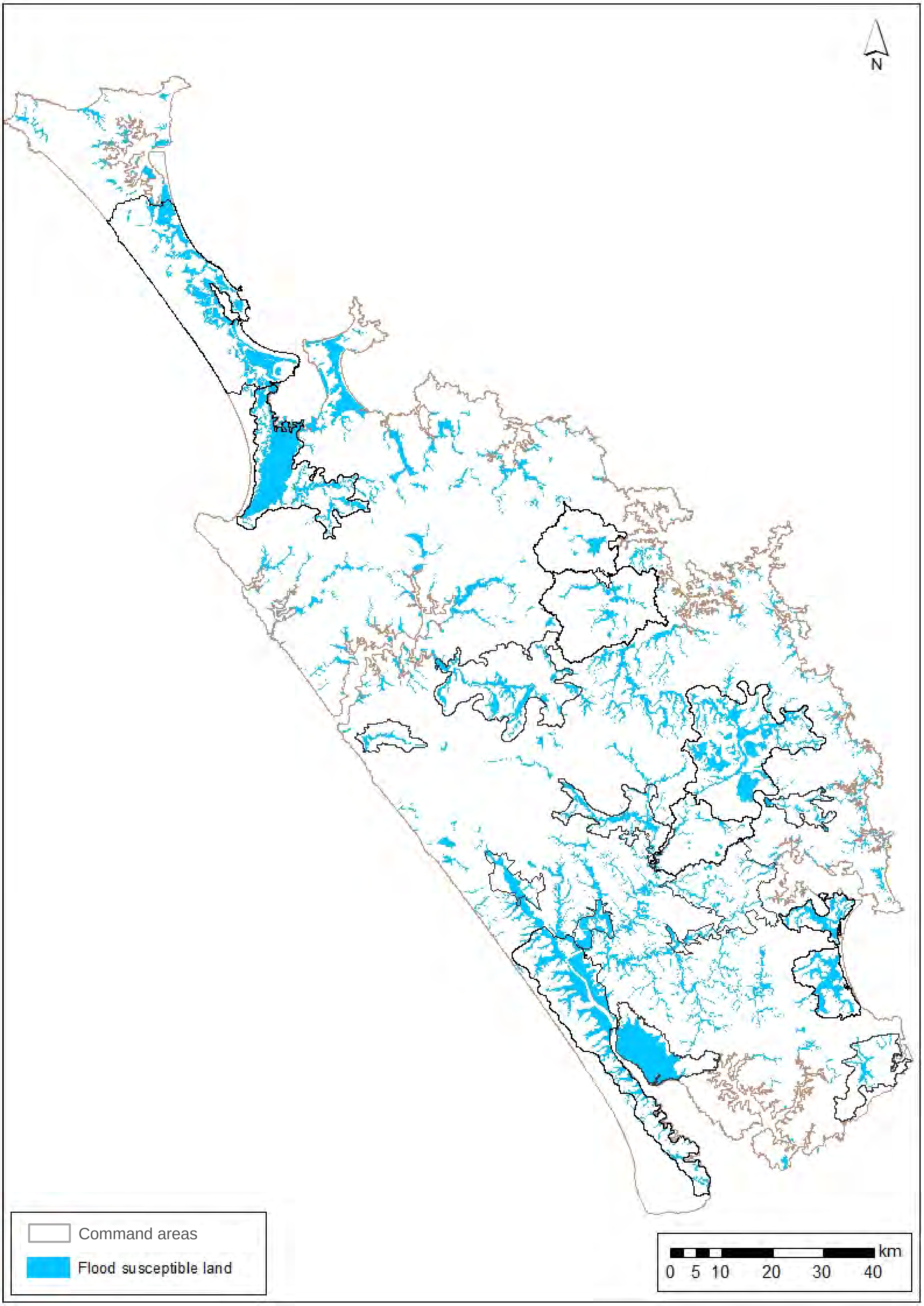
Flooding is a major concern in most parts in Northland. NRC is currently investigating 26 river catchments, which are identified as priorities for flood risk planning (NRC, 2015). Table 3.4 and Figure 3.6 shows the flood susceptible areas with the identified irrigation command areas from this current study). Almost all the command areas are susceptible to floods. This is to be expected as soil quality on flood plains is generally high, and flat or gentle sloping plains are highly suitable for irrigation. As described in Section 4.2, it is likely that more heavy rainfall events due to climate change will increase the risk of flooding in the future. Accordingly, preventing or minimising the occurrence of flooding in the command area is paramount for future agriculture or horticulture development.

A carefully designed water storage reservoir for irrigation can also be used for flood protection to achieve multiple objectives. The dams and reservoirs can be operated to reduce the peak flows entering a flood prone area. Therefore, in essence, despite flooding being a major challenge for the development of water infrastructure in the region, a well-planned water management strategy may be able reduce flood risks while increasing supply security and reliability.

Table 3.4 - Flood susceptible land in the command area

No.	Command Area	Command Area (hectares)	Flood prone land in command area (hectares)	% Command Area
1	Aupouri Peninsula	49,865	11,878	23.8%
2	Awanui Plains	27,999	14,498	51.8%
3	Kerikeri	14,213	989	7.0%
4	Waimate North	29,422	2,367	8.0%
5	Kaikohe	31,090	5,617	18.1%
6	Waimamaku	5,096	721	14.2%
7	Hikurangi	41,824	11,608	27.8%
8	Glenbervie	5,404	965	17.9%
9	Mangakahia	12,938	3,177	24.6%
10	Maungatapere	16,576	1,275	7.7%
11	Maungakaramea	22,688	3,204	14.1%
12	Ruakaka	6,434	2,863	44.5%
13	Waipu	10,756	3,733	34.7%
14	Kaihu	5,498	1,679	30.5%
15	Hoanga	3,768	2,426	64.4%
16	North Kaipara	37,564	11,880	31.6%
17	Ruawai	13,833	8,778	63.5%
18	Mangawhai	11,521	1,048	9.1%
	Total	**346,489**	**88,706**	**26%**

Figure 3.6 - Flood susceptible areas in Northland



3.7.2 Erosion

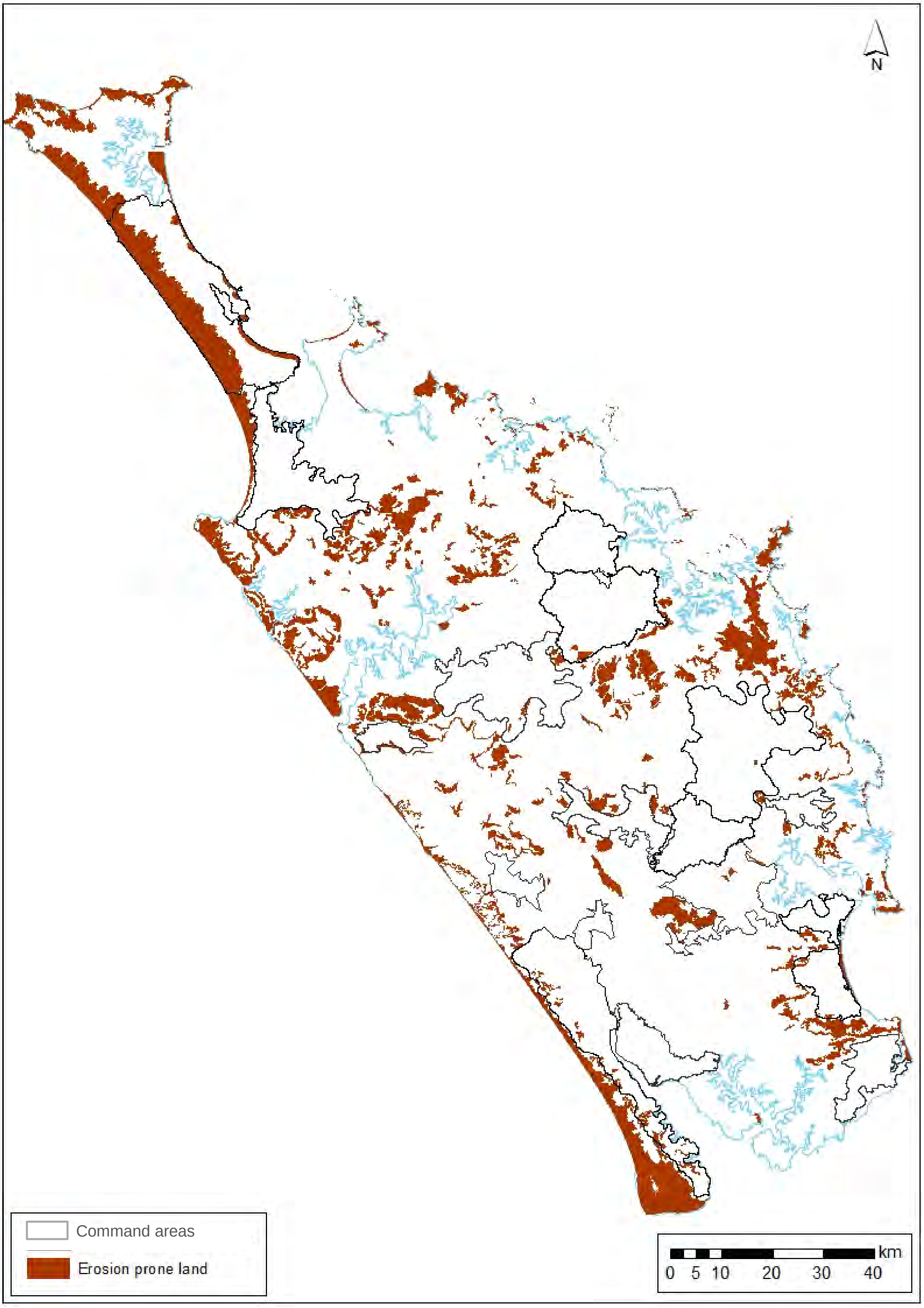
Erosion is another threat for farming within Northland. Erosion removes the rich topsoil, degrading soil quality and reducing its ability to be used for food production. Predicted future high rainfall events could increase the likelihood of erosion. Figure 3.7 illustrates the extent of erosion prone land within the region. Table 3.5 shows that the proportion of erosion prone land within the identified command areas is not significant with the exception of the Aupouri Peninsula.

The intensification of agriculture using irrigation has the potential for increased erosion, particularly on land with a slope greater than 15°. Therefore, a specific detailed analysis may need to be undertaken for command areas during the irrigation design phase.

Table 3.5 - Erosion Prone land by command area

No.	Command Area	Command Area (hectares)	Erosion prone land in command area (hectares)	% Command Area
1	Aupouri Peninsula	49,865	21,696	43.5%
2	Awanui Plains	27,999	243	0.9%
3	Kerikeri	14,213	0	0.0%
4	Waimate North	29,422	473	1.6%
5	Kaikohe	31,090	297	1.0%
6	Waimamaku	5,096	133	2.6%
7	Hikurangi	41,824	105	0.3%
8	Glenbervie	5,404	41	0.8%
9	Mangakahia	12,938	109	0.8%
10	Maungatapere	16,576	0.2	0.0%
11	Maungakaramea	22,688	246	1.1%
12	Ruakaka	6,434	5	0.1%
13	Waipu	10,756	413	3.8%
14	Kaihu	5,498	3	0.1%
15	Hoanga	3,768	0	0.0%
16	North Kaipara	37,564	2,665	7.1%
17	Ruawai	13,833	0	0.0%
18	Mangawhai	11,521	9	0.1%
	Total	**346,489**	**26,439**	**7.6%**

Figure 3.7 - Erosion prone lands in Northland



4 Water demand assessment

This section estimates the water demand within the 18 identified irrigation command areas. As water is a finite resource it is important that all water demands, including those other than irrigation, are considered to assess the future water availability for irrigation in each area, and what strategic developments are necessary to increase the water availability.

Apart from irrigation within water infrastructure command areas, the other primary water use categories are:

i) Domestic consumption (i.e. household water consumption) with two sub-categories:
- Reticulated supply; and
- Non-reticulated.

ii) Agriculture and horticulture:
- Livestock, inclusive of drinking water for all stock including rural residential units and dairy shed wash-down requirements. Dairy shed wash-down requirements are not permitted as of right under the RMA, so these must comply with permitted volumes under the Regional Plan;
- Frost protection;
- Rural residential; water demand for non-commercial agricultural activities (excluding domestic component and livestock demand) such as irrigation of gardens, shelter belts, part-time horticulture and plant nurseries.

iii) Recreational (such as demands for sports fields, bowling greens, swimming pools etc. as well as water remaining in rivers for canoeing/kayaking etc);

iv) Industrial and commercial use.

Water demands for fire-fighting are not considered in this assessment as it is difficult to quantify.

4.1 Consented water takes

Table 4.1 lists a summary of all consented water takes within command areas. Some command areas cover only a part of the catchment. However, it is possible that certain water takes that are outside of the command area but within the catchment will affect the water availability for the command area. In these circumstances, those takes outside of the command area are also included into the assessment.

Table 4.1 - Summary of consented water takes within each command area

Command Area	Use type	Source	Take rate (l/s)	Daily volume (m^3/d)
Aupouri Peninsula	Drinking	Bore	4.9	421
		Lake	4.7	410
	Irrigation	Bore	114.6	9,901
		Lake	0.6	49
		Run-of-stream	16.3	1,410
Awanui Plains	Drinking	Bore	47.0	4,059
		Run-of-stream	73.6	6,356
	Industrial	Bore	2.6	225
		Run-of-stream	1.1	91
	Irrigation	Bore	112.4	9,710
		Dam	12.7	1,100
		Run-of-stream	233.0	20,131
	Other	Bore	6.4	550
Kerikeri	Drinking	Bore	0.8	69
		Run-of-stream	24.3	2,100
	Irrigation	Dam	1362.3	117,703
		Run-of-stream	456.2	39,418
Waimate North	Drinking	Run-of-stream	50.7	4,383
	Irrigation	Bore	0.5	42
		Dam	303.0	26,175
		Run-of-stream	23.0	1,985
	Other	Dam	20.0	1,726
		Run-of-stream	145.0	12,528
Kaikohe	Drinking	Bore	10.0	861
		Run-of-stream	15.0	1,296
	Industrial	Bore	0.6	52
	Irrigation	Bore	2.2	194
		Dam	116.0	10,022
		Run-of-stream	3.6	308
	Other	Bore	0.5	43
Waimamaku	Drinking	Run-of-stream	2.3	199

Command Area	Use type	Source	Take rate (l/s)	Daily volume (m^3/d)
Hikurangi	Drinking	Bore	1.0	82
	Industrial	Bore	1.0	89
		Run-of-stream	71.0	6,134
	Irrigation	Bore	9.6	825
		Dam	370.2	31,984
		Run-of-stream	48.4	4,182
	Other	Bore	0.7	60
Glenbevie	Drinking	Run-of-stream	116.0	10,022
	Irrigation	Bore	8.9	768
		Dam	2.4	208
		Run-of-stream	47.8	4,133
Mangakahia	Irrigation	Dam	138.8	11,996
		Run-of-stream	587.0	50,717
Maungatapere	Drinking	Run-of-stream	444.9	38,439
	Irrigation	Bore	14.3	1,237
		Dam	10.0	864
		Run-of-stream	702.4	60,688
	Other	Run-of-stream	30.0	2,592
Maungakaramea	Drinking	Bore	2.7	230
		Run-of-stream	36.4	3,145
	Irrigation	Bore	13.1	1,131
		Dam	27.2	2,350
		Run-of-stream	23.3	2,013
Ruakaka	Drinking	Run-of-stream	43.0	3,715
	Industrial	Bore	1.1	98
		Dam	0.6	50
		Lake	5.8	499
	Irrigation	Bore	2.5	217
	Other	Bore	0.8	70
Waipu	Drinking	Run-of-stream	81.0	6,998
	Irrigation	Dam	33.6	2,900
		Run-of-stream	35.9	3,101
Kaihu	Drinking	Run-of-stream	51.6	4,458
	Industrial	Run-of-stream	0.7	60
	Irrigation	Run-of-stream	23.0	1,987
Hoanga				
North Kaipara	Irrigation	Bore	2.0	169
		Lake	1.7	145

Command Area	Use type	Source	Take rate (l/s)	Daily volume (m^3/d)
		Run-of-stream	225.0	19,443
	Other	Bore	0.8	70
Ruawai	Drinking	Bore	5.2	449
	Industrial	Bore	2.3	199
	Irrigation	Run-of-stream	0.7	60
Mangawhai	Drinking	Bore	4.1	353
		Run-of-stream	11.7	1,007
	Industrial	Bore	0.7	60
	Irrigation	Bore	13.4	1,154
		Dam	30.0	2,592
		Run-of-stream	1.7	144
Total			**6,451**	**557,404**

Source: NRC consent database

4.2 Impact of climate change

Climate change will likely affect both the water availability and water demand in the future. The global data shows that the number of extreme climate events, which exceed up to 10% variation of long term records, have increased since 1950. While the annual occurrence of cold nights has significantly decreased, the annual occurrence of warm nights has considerably increased. These warm extremes entail an increased frequency of heat waves (IPCC, 2007). IPCC (2007) also details a number of increased extremes including extremely wet periods and drought frequency.

The number of strong hurricanes has increased significantly, with the number of category 4 and 5 hurricanes increasing by about 75% since 1970. The El Niño-Southern Oscillation affects the location and intensity of tropical storms around the world (IPCC, 2007). It is likely that the wind patterns and their strength will change in New Zealand due to global phenomenon such as the El Niño.

Future hydrological conditions will be different from the historical data primarily due to a reduction in rainfall, and change in temperature and solar radiation, and in turn evaporation. It is possible that the available inter-annual water resources are more variable and harder to predict due to unpredictable extreme weather patterns (MfE, 2015). Without a detailed study, it is also difficult to assess the changes to stream low flow allocation regimes required to meet in-stream ecological requirements due to overall climate change effects. However, with respect to the future impact of climate change on Northland, MfE (2015) predicts that *"More heavy rainfall will increase the risk of flooding, which could become up to four times as frequent by 2090. Changes to flood plains resulting from a higher number of floods may damage infrastructure"*. Potentially, water available from both surface water, primarily in summer, and groundwater will be reduced.

It is expected that water requirements for the crops grown outside will be higher due to the lower rainfall in the future. However, water requirements for glasshouse operations (i.e. indoor irrigation) will not likely change. It is also possible that water demands for livestock and rural residential may also increase.

The impact of climate change will vary within Northland. Not only are there different current climate patterns between east and west coast areas within the region, but different areas in the region also have micro climates. There is a possibility that variation within the region (i.e. micro climates etc.) may intensify in the future. Therefore, it is important that more specific climate forecasts for each command area be generated and analysed to identify the impact of climate change in water availability and demand (e.g. crop water requirements). More specific data can be developed using global climate models or general circulation models (both abbreviated as GCM) and statistical downscaling techniques. However, such detailed analysis is not within the scope of this current study. It is recommended that impact of climate change for each command area is assessed in the next stage of the study.

4.3 Irrigation demand

Irrigation water demand for the 18 command areas identified in Section 3 has been estimated using a soil-water balance modelling. The following sections describe the soil-water balance model SPASMO along with the key parameters used for the modelling.

4.3.1 Soil-water balance model

Crop water requirements for different combinations of climate-soil-crop have been determined using NRC's in-house soil-water balance model SPASMO. This model uses a paddock scale daily soil water balance modelling approach to calculate the irrigation water requirements for crops. Model outputs are based on daily simulations for 38 years; from 1 January 1972 through to 31 December 2009. Potential limitations of using SPASMO for this assessment are discussed in Section 10.4.

The following sections describe the data used for modelling and the basis of selecting crop-soil-climate model combinations.

4.3.2 Soils

Irrigation demand varies for different soils. The key soil property for irrigation is the plant available water at field capacity (PAW). PAW is the amount of water that soil can store and is available for plants to use. Soils with high PAWs can store more water and therefore have more capacity to take advantage of rainfall than soils that have a lower PAW. Accordingly, irrigation water demand would be typically less for high PAW soils than that for low PAW soils. However, the production benefits of converting dryland to irrigation will generally be higher on low PAW soils, as the percentage production increase is higher.

Given the same soil, PAW differs between crops because different plants have different rooting depths and therefore, have the ability to access water from different depths. Thus, it is important to determine representative soil-water reservoir depth for each crop type and estimate the PAW.

PAW values for different crops associated with different soil types are available within NRC's soil-water balance model SPASMO. These PAW values are given for a 1 m depth. The S-map (Landcare Research, 2015) coverage is currently incomplete for the region. Therefore, to identify the soil types present within each command area, the New Zealand Fundamental Soils Layer (FSL) (Landcare Research, 2000) has been analysed. To simplify the analysis, the soils that have similar PAW were grouped into five classes as shown in Table 4.2. A summary of soil PAW class distribution within each of the 18 command areas is given in Appendix D.

The areas that consist of more areas with a lower PAW range (e.g. 70 mm/m) will require more water to irrigate than an area that has high PAW soils, if climate and coverage of both areas are similar.

Table 4.2 - Soil PAW classes

PAW range (mm/m)	PAW Class (mm/m)
60 – 80	70
80.1 – 120	100
120.1 – 140	130
140.1 – 160	150
>160	200

4.3.3 Crops

The SPASMO model has the ability to model a number of crops. The project team has identified the crops that are grown within each command area or likely to grow in the future. If the identified crops are not available within SPASMO, another similar crop that is available has been used as a proxy, if possible. Where no proxy is available within SPASMO, pasture has been modelled. This approach is conservative as pasture generally has the greatest seasonal water use of all standard crops grown in the region. In the absence of model's ability to model all the crops grown in the region, it is considered this approach is appropriate for this initial study. The modelled crops for each command area are listed in Table 4.3. The predicted potential area distribution of crops within each command area is listed in Appendix F.

Table 4.3 - Crops modelled for each command area

Command Area	Crop
Aupouri Peninsula	Avocado, Citrus, Pasture, Potato
Awanui Plains	Pasture, Potato, Citrus, Lettuce
Kerikeri	Kiwifruit, Citrus, Pasture, Grapes
Waimate North	Citrus, Kiwifruit, Potato, Pasture
Kaikohe	Avocado, Citrus, Kiwifruit, Potato, Pasture
Waimamaku	Pasture
Hikurangi	Pasture
Glenbevie	Avocado, Citrus
Mangakahia	Pasture
Maungatapere	Avocado, Kiwifruit, Citrus
Maungakaramea	Avocado, Potato, Kiwifruit
Ruakaka	Pasture
Waipu	Pasture
Kaihu	Pasture
Hoanga	Pasture, Kumara
North Kaipara	Pasture, Potato, Kumara, Avocado
Ruawai	Pasture, Kumara
Mangawhai	Avocado, Grapes, Olives

4.3.4 Climate

The SPASMO model uses 12 climate stations to determine the irrigation water requirements for different locations in the region. The closest and representative climate station for each area has been selected. The selected climate stations are listed in Appendix E. Climate data is available from 1 January 1972 through to 31 December 2009, i.e. 38 years. It is considered that climate data over a 38 year period is a sufficiently long period to model crop water requirements for this feasibility study. Generally, 38 years' data represents climate variation due to longer term effects such as Inter-decadal Pacific Oscillation (IPO) and El Niño/Southern Oscillation (ENSO). However, a recent drought assessment identified that, on average, three summers between 2009 and 2012 were the driest summers in Northland over the forty-year period 1972-2013 (MPI, 2013). Therefore, SPASMO model will need to be updated with recent climate data to analyse the impact of these dry summers on crop water requirements during the next stage to develop specific water demands for selected areas.

4.3.5 Irrigation water demand

A summary of model outputs of 90^{th} percentile annual irrigation demands for command areas is given in Table 4.4. The estimated irrigation demands by soil PAW classes and crops are presented in Appendix F.

The 90^{th} percentile annual irrigation demand is estimated to be sufficient to meet 9 in 10-years crop water requirement based on the period modelled. The SPASMO model uses a gross application depth of 18.8mm for all crops, except for grapes. The application depth for grapes is 6.2mm. As shown in SPASMO outputs, these high application depths have resulted in high peak daily demands – frequently 9.4mm/day. These peak daily demands can be high and it may be necessary to optimise the daily demand values for future detailed analysis. It is possible that some crops in certain areas, particularly that are on deeper soils (i.e. with high PAW), would be able to service with lower daily water depths, i.e. system capacities. This is particularly important for the areas that are supplied by run-of-stream flows. The total allocable run-of-stream resource is entirely dependent on the instantaneous flow rate (l/s). If the optimum crop water demand is lower than 5mm/day, potentially that allows a greater area be irrigated from the same stream. Therefore, strategic irrigation water allocation based on optimum system capacity may be important to maximise the total economic benefits that can be attained from use of run-of-stream resource.

Table 4.4 - Estimated irrigation demands for the identified areas

Area	90th percentile annual demand (Mm³/year)
Aupouri Peninsula	190.9
Awanui Plains	98.0
Kerikeri	36.9
Waimate North	73.0
Kaikohe	60.4
Waimamaku	14.9
Hikurangi	91.7
Glenbevie	7.1
Mangakahia	19.7
Maungatapere	31.9
Maungakaramea	53.9
Ruakaka	15.1
Waipu	21.1
Kaihu	20.5
Hoanga	11.9
North Kaipara	118.0
Ruawai	53.0
Mangawhai	17.4

4.4 Industrial demand

Industry in Northland has two main components to its spatial pattern. There are a relatively small number of large industrial production units, and a number of places with a mix of smaller production units, the latter being in effect 'industrial estates'.

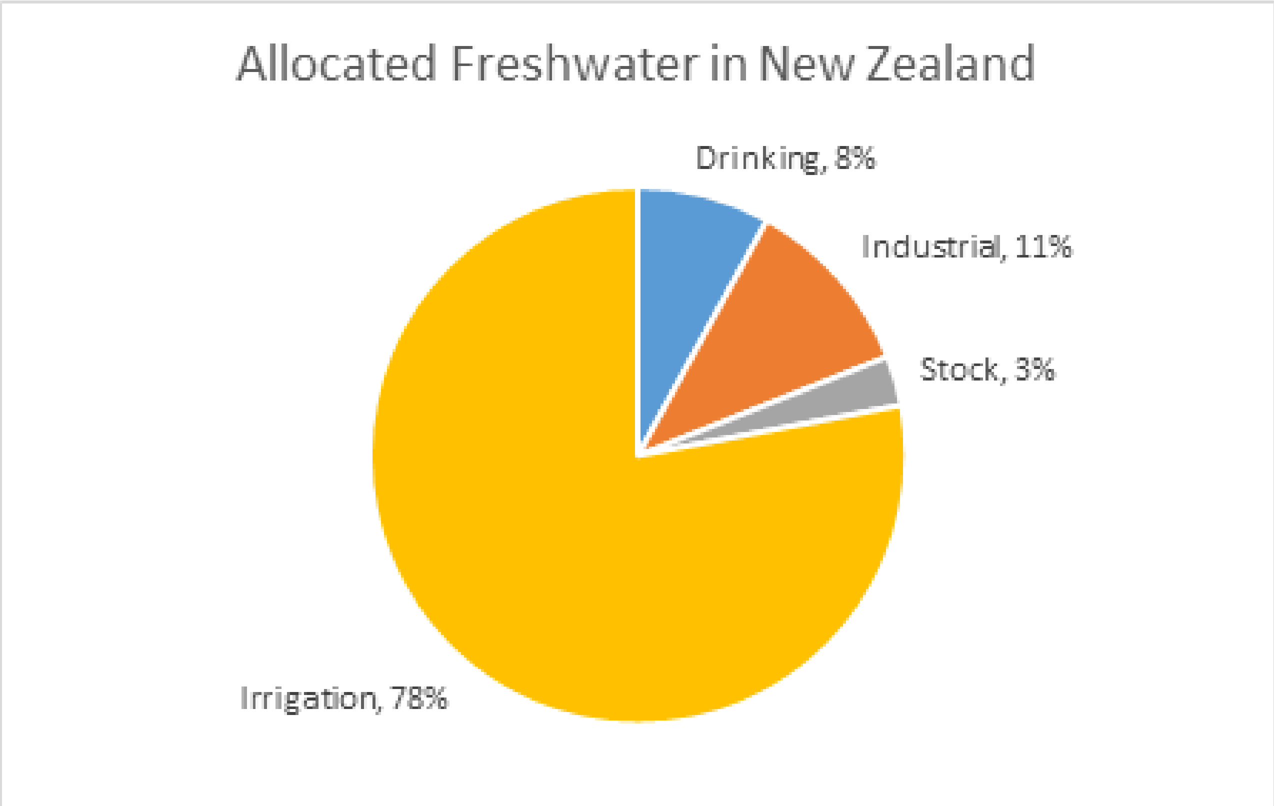
This section will describe the location of these separately, and also provide indications of expected industrial expansion by 2031 under two scenarios: a Business as Usual (BAU) scenario and a Growth scenario.

There are currently over 20,500 consented freshwater takes in New Zealand of which around 200 consents are for hydro generation. Most of the hydro generation takes are termed *non-consumptive*, because this water, after hydro-power generation, generally returns to rivers and downstream storage lakes and can be used again by other water users. Of the remaining allocated water the majority is for agricultural irrigation and stock water with only a relatively small percentage allocated to human drinking water (8%) and industrial use (11%).

Whilst this report has identified a number of industrial activities within the Northalnd region these are scattered across several districts and urban centres. As such there are not concentrated water demand points. Therefore in the overall water resources management context the industrial demand compared to the demand for agriculture and stock in Northalnd is likely to be small. Further, in many instances these industrial demands will be spread more evenly across the calendar year in alignment with more uniform industrial outputs as opposed to the seasonal peak demands associated with agriculture. It is assumed for this report that whilst not insignificant that most industrial demand will be met from either existing water supply allocations or as minor add-ons to future managed agricultural water supply schemes. Examples of this have occurred in other regions such as provisions contemplated for Alexandra and Clyde from future water supply schemes in the Central Otago Manuherikia Valley Scheme.

Additional to this many industrial process are currently not overly efficient in terms of water use and waste water discharges. Continued scrutiny of industrial activities especially where discharges cause deterioration of receiving water body quality will help ensure future water use efficiency gains are made such as water recycling. A practical example within the wine industry is the use of freshwater for fermentation vat flushing. Where cold freshwater is used the volume expending on this task tended to be generous and somewhat inefficient. Changing to heated water helped staff recognise the value of the energy used to heat the water and as a result much less was used. A final saving occurred when innovative and alternative methods were adopted such as flushing with CO_2 gas as a sterilizer instead of hot or chlorinated water. It is this sort of thought process that can be considered and encouraged within a regional water allocation and management framework for industrial users.

Figure 4.1 - Freshwater Allocation in New Zealand



Ref adapted from Freshwater use in New Zealand, Current issues for the 50th Parliament: Freshwater use in New Zealand December 2011

4.4.1 Large industrial units in Northland

Table 4.5 shows a list of large industrial units in Northland, as identified from the CoreLogic (QV) database. The location is given by Census Area Unit (CAU), which has enabled us to estimate the employment at these plants, deriving employment from the Statistics NZ databases as revised by BERL. CAU locations are shown in Appendix F.

Our fieldwork indicated that the plant shown as being in Herekino, may in fact be in Kaitaia East, although it is not the TriBoard mill. This has not been explored further.

Table 4.5 - Location and industry of large industrial units in Northland

Census Area Unit	Industry: Actual or *Presumed*	Employment Number	Ha.
Far North District			
Herekino	*We believe this is an error*	?	149
Kaitaia East	C14 Wood Product Manufacturing	250	11
Moerewa	C11 Food Product Manufacturing	220	10
Waitangi	C14 Wood Product Manufacturing	70	69
Pokere-Waihaha	?	?	4
Waihou Valley Hupara	F33 Basic Material Wholesaling	20	5
	F36 Grocery, Liquor and Tobacco Product Wholesaling	15	
Whangarei District			
Marsden Ruakaka	C17 Petroleum and Coal Product Manufacturing	360	141
Wharekohe Oakleigh	?	?	504
Pataua Whareora	?	?	9
Springs Flat	C11 Food Product Manufacturing	350	166
	C14 Wood Product Manufacturing	55	
Abbey caves	C14 Wood Product Manufacturing	50	10
Kaipara District			
Kaipara Coastal	*C14 Wood Product Manufacturing*	45	5
Dargaville	C11 Food Product Manufacturing	280	10
	C22 Fabricated Metal Product Manufacturing	20	
Maungaturoto	C11 Food Product Manufacturing	15	20
Rehia Oneriri	*C14 Wood Product Manufacturing*	45	4
TOTAL			**1,117**

4.4.2 Mixed industrial 'estates' in Northland

Table 4.6 is a list of the seven main CAUs in Northland which have a mix of industrial activities. To that extent they could be characterised as having 'industrial estates'. They generally include light industry, some industry services and some warehousing, storage and transport.

Table 4.6 - Industrial activities in Northland

Census Area Unit with industry mix	Occupied Industrial land 2013 (Hectares)	Vacant Ind. Land (Hectares)	Total Industrial land (Hectares)
Far North District			
Kaitaia East	33.3	10.7	44
Kerikeri	26.2	1.4	28
Sub Total Far North	**59.5**	**12.1**	**72**
Whangarei District			
Marsden Ruakaka	247.4	438.2	686
Springs Flat	198.9	12.6	212
Whangarei Central	23.3	2.2	25
Port- Limeburners	167.1	100.7	268
Sub Total Whangarei	**636.7**	**553.7**	**1,190**
Kaipara District			
Dargaville	46.9	8.4	55
Sub Total Kaipara	**46.9**	**8.4**	**55**
TOTAL Mixed Industry CAUs	**743.1**	**574.1**	**1,317**
Total in all CAUs	**1,703.8**	**802.1**	**2,506**

4.4.3 Scenario rates of industry growth to 2031

BERL, working with regional and district council staff, completed a projection of two scenarios of industrial growth in Northland to 2031: a BAU scenario and a Growth scenario.

The overall industrial growth projected in each district is shown in Table 4.7.

Table 4.7 – Industrial growth projection

Scenario growth to 2031	BAU (%)	Growth (%)
Far North District	33	51
Whangarei District	32	54
Kaipara District	33	48

4.4.4 Ngawha Industrial Development

Top Energy, a local electricity generation and lines network company, is intending on expanding geothermal energy generation at its existing Ngawha power station site. This expansion project, utilising available geothermal resources, in expected to be commissioned in 2020.

The development of complementary businesses adjacent to the power site is likely. 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.

It is understood that preliminary plans include for an unknown quantity of water storage as part of the proposed development.

4.5 Other demands

There are a number of demands other than irrigation and water supply for development that should be considered when providing an area with an increased reliability of water. Additional demands such as stock water, potable water and emergency supplies for firefighting will have to be included in demand allocation when designing a scheme in any of the areas. These demands have not been considered at this stage.

Additional complementary activities such as recreation, aquaculture and hydroelectric power generation could bring benefits to communities and the region as a direct result of an increasingly reliable water supply.

At this stage, each areas will be considered for the local potential and willingness of a community to embrace these benefits. Potential for future land use and social activity changes will be a major factor in demand allocation. These considerations will form part of the multi-criteria analysis.

In order ensure a level of environmental protection, and likely to adhere to resource consents, there is potential for additional environmental demands to supplement low flows and for sediment removal.

NRC are currently developing an allocation framework which will determine minimum environmental flows on each of their water management units. As this work will be more accurate than any estimates made by this study, this has not been undertaken.

5 Availability of water

This section summarises the available water resources to supply water to the identified command areas based on available data. The source of data includes previous water studies, estimates of allocable groundwater resources, flow records and flow statistics (e.g. mean annual low flow (MALF), mean flow) - all have been supplied by NRC. Water resources within most command areas include both surface and groundwater. The volume of water available, as compared to the size of a resource, must be cognisant of NRC's current and/or proposed allocation rules and extraction limits for the different water resources. NRC is in the process of drafting a new proposed regional plan. Therefore, some allocation rules, which are required to be used for this study, are not currently available within the current regional plan. In such circumstances, necessary rules have been adopted in consultation with NRC; these rules have been stated where appropriate within the following sub sections.

5.1 Run-of-stream

Northland consists of numerous small surface water catchments. These catchments are generally short and of even slope (Roke, 1986). Mean annual rainfall ranges between 1,100 to over 2,400mm/year for different areas within the region (Figure 3.5). Most of the rain events occur in the winter; summers are generally dry. Most of the high rainfall events result in floods due to the catchment characteristics (e.g. slope). Therefore, base flows of rivers and streams are generally small, particularly in summer.

5.1.1 Flow data

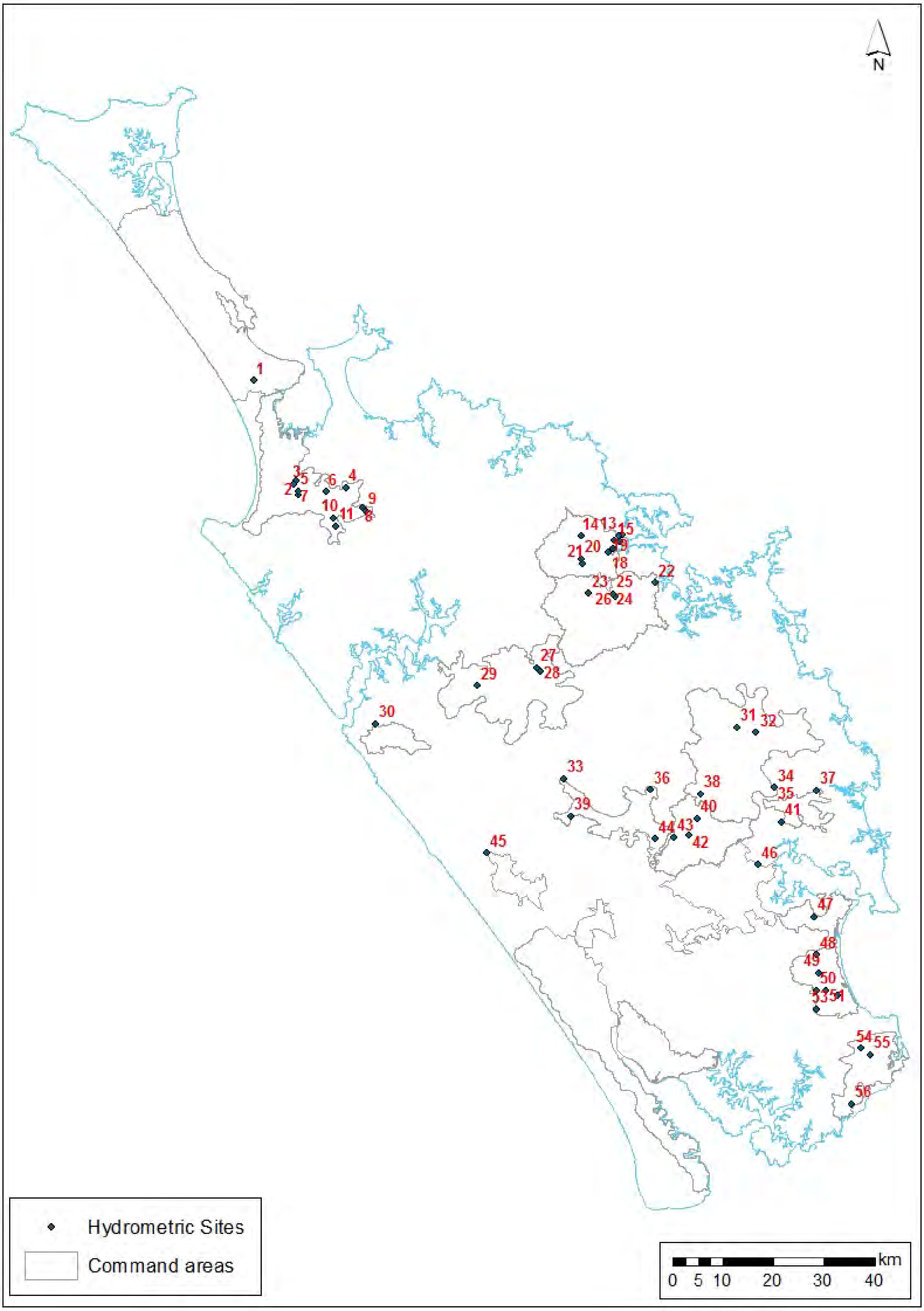
The available flow data has been supplied by NRC. The locations of the flow measurement sites (hydrometric sites) that are used for this study are shown in Figure 5.1. To be consistent with the time unit used for the irrigation demand analysis (i.e. daily), mean daily flow data has been extracted from the NRC database. The period that data is available varies considerably between sites. In addition there are significant gaps within the records. The period of data available and number of data gaps is given in Appendix G. The daily flow data has been extended and gap-filled for the period from 1 January 1972 through to 31 December 2009, which is the same period that the soil-water balance modelling has been carried out to determine irrigation water demand. The extension and gap-filling of flow data was necessary to assess the water balance on a daily basis by comparing daily irrigation demand against water availability.

The flow data extension and gap-filling was carried out through correlation using available flow data from nearby representative catchments. As average stream flows vary seasonally, correlation of monthly flows was used. It is considered that 'lumping' all the data together for correlation purposes would result in masking the monthly or season variability of flow patterns.

While correlation of flow has been carried out using available data from nearby streams, there is inherent uncertainty associated with flow correlation. This uncertainty may have also been compounded due to climate variability within short distances in the region; as described in Section

3.3, Northland has many micro climates. However, in the absence of measured data, we consider that the level of representativeness of the correlated flow data is sufficient for this high-level study.

Figure 5.1 - Hydrometric sites used for the study

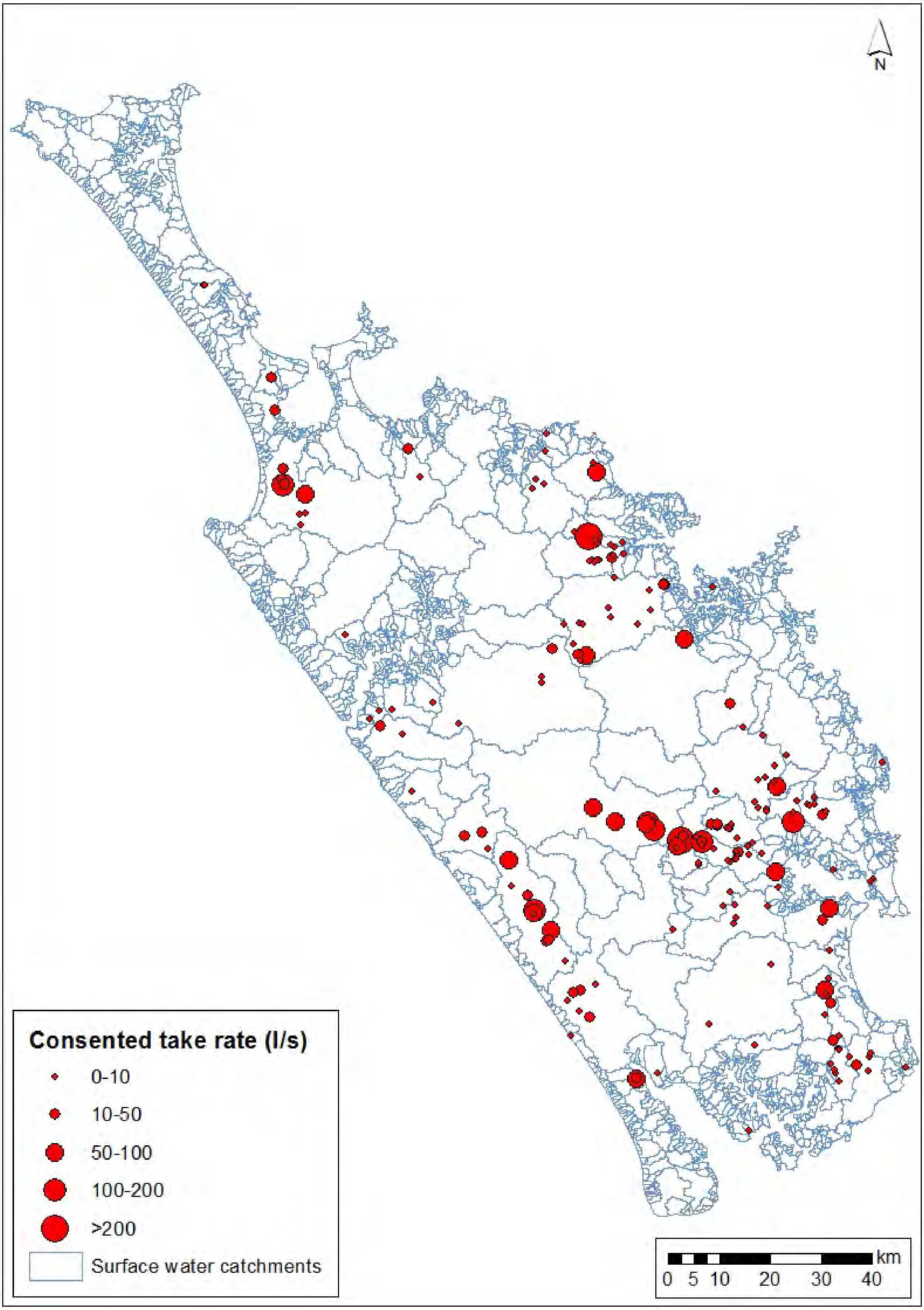


Source: NRC hydrometric site database
Note: Details of the sites are given in Appendix G

5.1.2 Allocable resources

NRC is in the process of determining the instream minimum flow requirements and allocable flows for the region's streams. Accordingly, allocable flows are not currently available for this stage of the project. NRC has advised that some of the streams with high flows are considered to be highly allocated, for example the Wairua catchment. Figure 5.2 shows the surface water catchments and current consented take rates for surface water takes. This shows that the consented take rates from some large catchments are high. The NRC consent database shows that 5,964l/s has been allocated from run-of-stream resources. In consultation with NRC, it has been decided that no run-of-stream resources will be considered for this high level study. This is a reasonable approach because large schemes require high flow rates during dry low flow conditions and the region's allocable run-of-stream resources (i.e. primary allocations) are not large. Accordingly, it is unlikely that most available run-of-streams, if any, would be sufficient to provide reliable irrigation water to large schemes during dry summer months.

Figure 5.2 - Consented surface water takes and surface water catchments

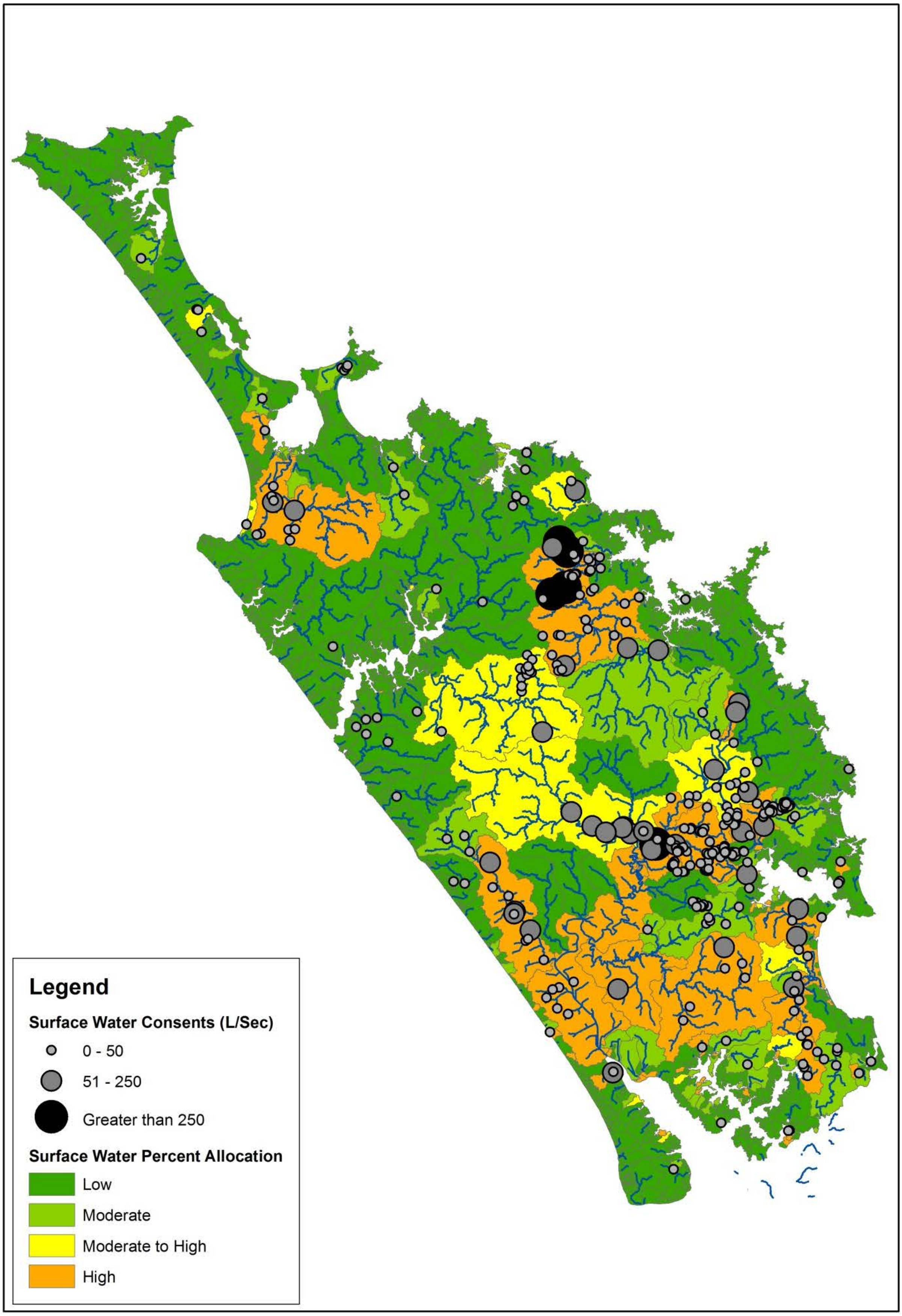


Source: NRC consent database

5.1.3 Current level of allocation

As previously discussed, NRC is in the process of drafting allocation limits for a revised draft Regional Plan. In the interim, NRC has compared the current level of allocation with interim allocation levels of 30% of the 7-day Mean Annual Low Flow (MALF). This approach has provided the council with a general indication of the level of allocation in catchments across Northland and does not necessarily indicate levels of over allocation. Refer to Figure 5.3 for an indication of surface water allocation.

Figure 5.3 –Indication of the level of run-of-stream allocation



Source: NRC database

5.2 Groundwater

Northland is not rich in groundwater resources when compared with other regions in New Zealand. The NRC consent database shows 260 consented groundwater takes within the region. Total consented annual groundwater volume is in the order of 8.7 million cubic metres per year (Mm^3/year), which is approximately 25% of the total annual consented volume. Not all groundwater systems within the region have been investigated to date. Therefore, current knowledge of the total available groundwater resources is limited. However, NRC has investigated the aquifer systems that are considered to have high yield or have high or potential demand. The aquifer systems, where characteristics have been investigated within the region, are shown in Figure 5.4.

A summary of the annual allocable groundwater resources (i.e. sustainable aquifer yields) and current consented volumes within identified command areas are listed in Table 5.1. It should be noted that there can be considerable variation in yields between wells within a localised area, and therefore groundwater may not be available everywhere.

Table 5.1 shows that overall groundwater use is not high within command areas. The highest allocable groundwater resource is within the Aupouri Peninsula command area. Only 3.9% of the 43Mm^3/yr available resource is currently allocated. Groundwater is a vital resource in the Aupouri Peninsula for future irrigation development. Due to thin shape of the Peninsula, surface water catchments are small and there are no significant run-of-stream resources available. The nature of small catchments also attributes to the lack of potential for large storage capacities. Given that current use is small, there are considerable prospects for developing a network of groundwater well fields within the Peninsula to operate as a scheme or support individual farmers or farmer groups.

Shallow groundwater near the coast, particularly within the thin Aupouri Peninsula, should not be considered suitable for abstraction of high volumes. This is because surface water base flows connected to these resources will probably reduce and saltwater intrusion can occur from pumping of wells in shallow aquifers near the coast. Therefore, we recommend that only deeper groundwater should be considered, and that the abstraction does not affect the base flow in any connected surface water resources and saltwater intrusion does not occur.

The degree of resource development of an aquifer is largely dependent on its water quality for consumptive use, cost for well construction, and well yields. These important aspects should be evaluated during the next stage of the study.

Figure 5.4 – Investigated consented groundwater takes and aquifers

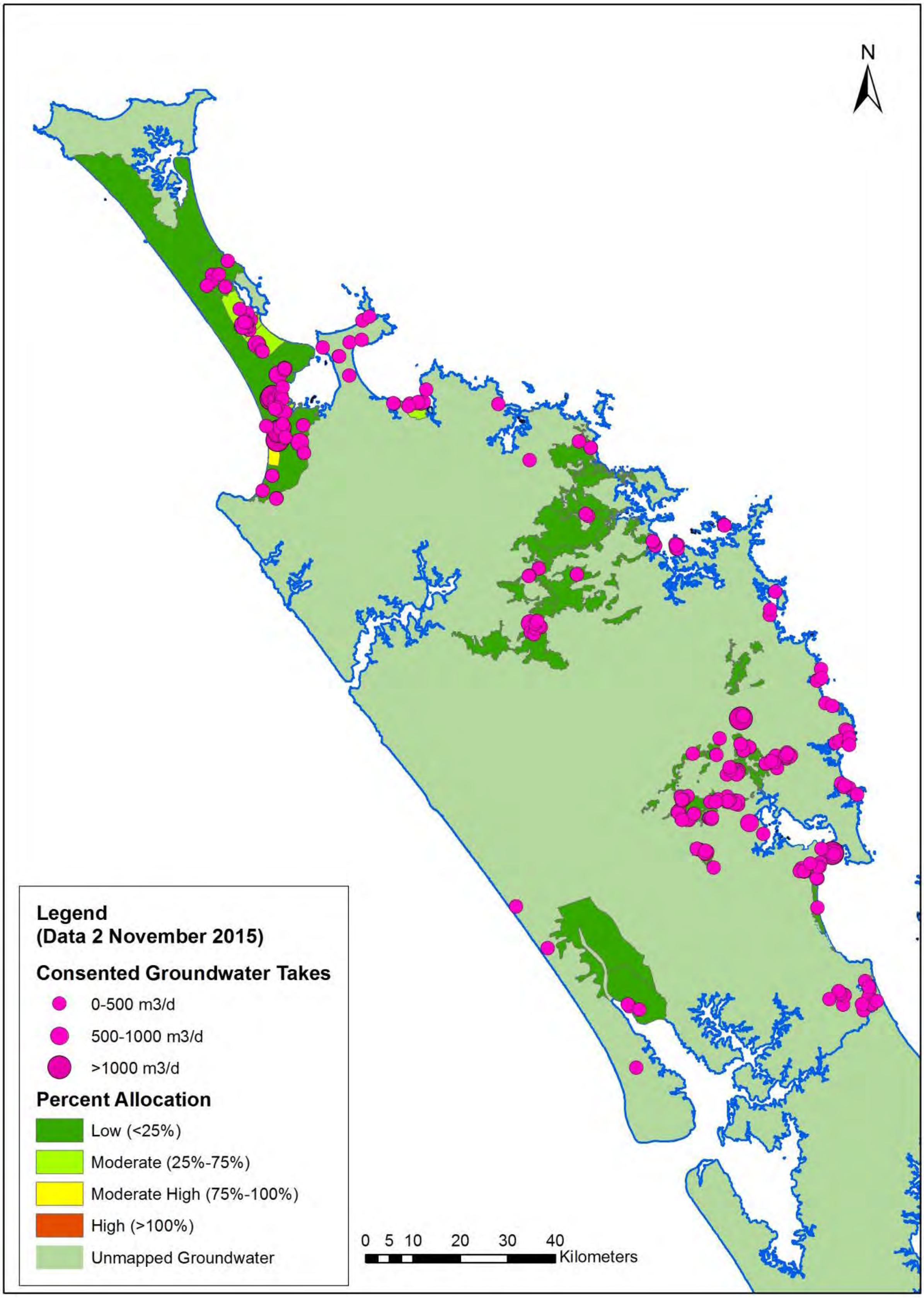


Table 5.1 - Summary of allocable groundwater resources and consented groundwater use

Command Area	Volume available (1000' m³/yr)	Consented volume (1000' m³/yr)	% currently consented
Aupouri Peninsula	43,114	1,679	3.9%
Awanui Plains	15,218	5,352	35.2%
Kerikeri	14,506	26	0.18%
Waimate North	9,596	14	0.1%
Kaikohe	7,986	293	3.7%
Waimamaku	Unknown		
Hikurangi	6,551	188	2.9%
Glenbervie	2,323	137	5.9%
Mangakahia	Unknown		
Maungatapere	3,832	359	9.4%
Maungakaramea	2,722	285	10.5%
Ruakaka	757	100	13.3%
Waipu	461	36	7.8%
Kaihu	Unknown		
Hoanga	Unknown		
North Kaipara	4,333		
Ruawai	1,500	151	10.1%
Mangawhai	316	130	41.1%

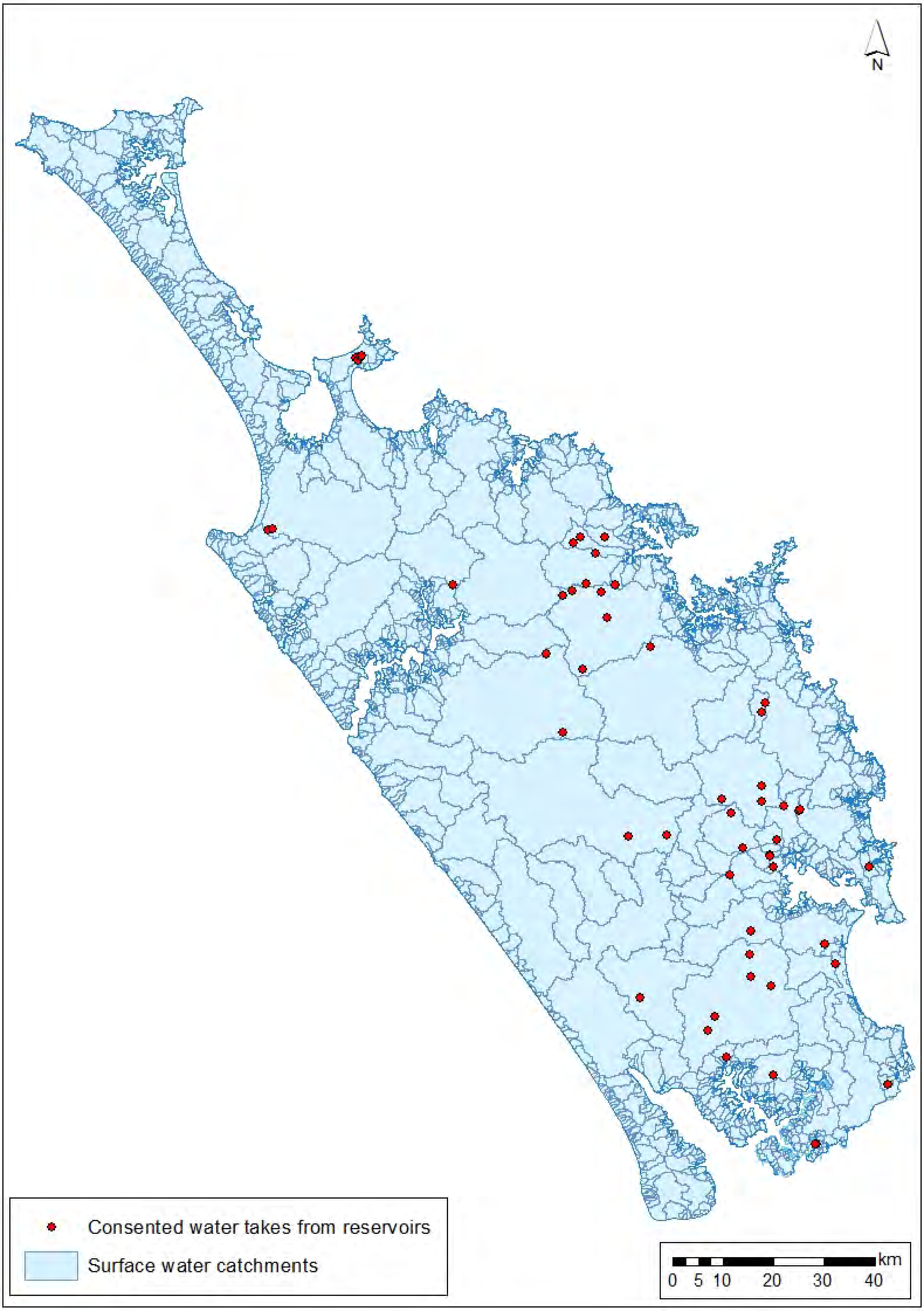
Source: NRC groundwater resource availability GIS shapefiles and associated database as at 8 September 2015

5.3 Reservoirs and harvesting high flows

Northland experiences reasonably high annual rainfall with a mean annual rainfall between 1,100 to over 2,400mm/year. Thus, there is potential for harvesting high flows and storage within many catchments. The volumes that can be harvested during high flows varies due to variation in rainfall and size of the catchment. Further, due to the variability of inter-annual rainfall, it is possible that flow events in some dry winters are insufficient to fill storage. This may result in sufficient quantities of stored water not being available for irrigation during the following summer. The stream flows within small catchments are generally low and not suitable for harvesting and storing large volumes.

The NRC consent database (as at 13 July 2015) shows that there are 57 consented water takes from reservoirs, of which 47 are primarily for irrigation takes. The locations of the consented takes are shown in Figure 5.5. It is possible that many other reservoirs exist within the region, possibly constructed prior to the Resource Management Act (RMA) as farm and stock water supplies. Reservoirs are a major source of water for livestock, particularly in areas with limited availability from run-of-stream and shallow groundwater sources. However, these non-consented reservoirs are likely to be small in size.

Figure 5.5 - Consented water takes from dams



Source: NRC consent database

Based on economics of supply, it is likely that the order of preference for water sources is run-of-stream, groundwater and storage. This reflects the higher costs associated with constructing a reservoir and various other constraints such as social, environmental and engineering design costs.

However, as described in Section 5.1, it is likely that some run-of-stream resources are highly allocated. Therefore, the prospect of sufficient run-of-stream quantities of reliable water being available to meet irrigation demands for large schemes is not high. Furthermore, as outlined in Section 5.2, groundwater availability within the region is also limited in some areas. Accordingly, the region will need to invest in storage to increase the reliability of water supply. Furthermore, this current study primarily focuses on assessing the feasibility of developing water infrastructure for the region rather than for individual farms. In the absence of the availability of large run-of-stream resources, reservoirs will likely provide the best practical means of water supply for areas.

In addition to supplying reliable water into command areas, storage reservoirs may help to alleviate flood hazards in the region.

There are no current NRC policies for harvesting high stream flows, i.e. over and above the "primary allocations". However, NRC has advised that they are considering drafting policy to enable harvesting high stream flows (per. comm., Osbaldiston, S., NRC). Other regions have adopted policies for harvesting high stream flows (e.g. Waikato, Auckland and Horizons), which essentially states:

> *In addition to the primary allocable flows, provide for surface water harvesting at an amount up to 10% of the flow in the river or stream, at times when the flow is greater than the median flow immediately upstream of the point of the take.*

Such a policy generally promotes maintaining the natural flow variability of streams. Accordingly, this study has used a harvesting threshold of 10% of the flow above the median flow for assessing flow availability for harvesting and storage. The estimated flow statistics using correlated flow data (i.e. extended and gap-filled flow data) for the approximate flow harvesting locations in the streams used for this study are given in Appendix G.

As outlined in Section 3.7.1, the region experiences a few high rainfall events resulting in flood damage. Accordingly, analysis was completed to determine the potential for abstracting a higher percentage of flow when flow is higher, e.g. abstracting 20% of the flow when flow is greater than twice the median, if quality of water permits such abstraction. This is further discussed in Section 10.5. Abstracting a larger proportion (e.g. 20%) during high flows will alleviate flood risk; however, the remaining 80% of flow will maintain the natural flow variability.

The sizing of storage reservoirs has been undertaken to meet a specific level of irrigation supply-demand reliability. The size of the storage is dependent on timing of the flow availability as well as timing of the irrigation demand. It is incorrect to design a storage reservoir that has the capacity to store water to meet the full annual demand. The reservoirs are continuously replenished through all available high flows during the irrigation season. Therefore, time series analysis of daily irrigation demand and mean daily flows (i.e. supply) were assessed to determine the optimum size of reservoirs. Details of storage sizing by area is given in Section 6.2.

6 Water balance

A summary of the water demand and resource availability has been presented in previous two sections of this report. This section assesses the water availability against the resource demand predictions. This water balance forms the basis of assessment of the status of the water demand and availability by areas. This assessment is based on the integration of the water resource and demand assessment components. This assessment is important as it indicates whether there is likely to be a significant imbalance between demand and supply. The water balance assessment by area will importantly highlight the proportion of total irrigable area, which has been identified in Section 3, which can be reliably supplied through available resources.

The capacity of a reservoir and its cost are generally not directly proportional. Apart from the economic factors, there are other aspects that need to be considered in determining storage sizing. These aspects include availability of water to fill the reservoir, geology, engineering challenges, availability of construction material, environmental and social factors. Accordingly, the final sizing of a storage reservoir is an iterative process that assesses these multi-dimensional factors to determine the appropriate capacity. However, as a “first-cut” within this high level feasibility study, the approach is essentially to match the storage sizes to meet irrigation water demand for an area that can reliably be supplied within each area. The supply reliability is dependent on the storage capacity, i.e. a larger reservoir stores more water to increase the reliability of supply. However, the volumes that can be harvested is finite due to stream flow volumes and regional policies. Therefore, storage sizing is primarily based on evaluating three aspects:

i) Irrigation demand. The maximum demand for irrigating the total irrigable area is listed in Section 4.3. This water balance assessment determines whether water resource is available to meet the demand for the full area, or what proportion of the area can reliably be supplied.

ii) Water availability within the NRC policy to fill the reservoir. This will determine the potential for available flow to replenish the reservoir (i.e. storage capacity).

iii) Irrigation supply-demand reliability.

The irrigation supply-demand reliability criteria used in the storage sizing assessment is presented in Section 6.1.

6.1 Reliability of irrigation water

Four key factors have to be considered to quantify reliability of supply-demand. These are:

- Severity – size or amount of restriction;
- Frequency – how often the restrictions occur;
- Duration – how long the restrictions last; and
- Timing – when restrictions occur.

On any day during the irrigation season, the supply of water available can be compared with the demand for irrigation on that day. If available supply from the storage equals or exceeds demand, reliability is 100%. If demand exceeds supply, reliability is calculated by dividing supply by demand to give a supply/demand ratio. The daily ratios can be combined into weekly, monthly, seasonal (spring, summer, autumn), irrigation season or annual figures. Irrigation season values are often used to indicate the overall reliability of a particular supply.

As a general guide, the following average irrigation season reliability assessments apply:

100%	Very good reliability
94-99%	Good reliability
87-94%	Marginal reliability
<87%	Poor or very poor reliability.

This study has adopted the following two indicators to determine the irrigation water supply reliability. It is assumed that for the irrigation water supply to be reliable, both of the following conditions are met:

- Mean irrigation-season average supply-demand ratio to be greater than 95%. Given that this preliminary assessment has not considered potential water losses such as distribution losses, we consider that an average supply-demand reliability of 95% is appropriate.
- Periods of restrictions exceeding 10 consecutive days will occur in no more than 10% of the irrigation seasons modelled.

For storage-based systems, the second indicator will tend to determine the overall reliability, as restrictions occur when the storage volume is depleted. The reliability criteria can therefore be loosely interpreted as the storage emptying once every 10 years on average. As described in Section 4.3, irrigation water demand has been modelled for 38 years. Accordingly, the number of restrictions exceeding 10 consecutive days have been limited to four events within this period.

6.2 Command area water balance

This section outlines the water balance by command area. As run-of-stream availability is not considered for this study, area water balance is basically grouped into two resource types: storage-based and groundwater supply.

It should also be noted that surface water – groundwater interaction or stream depletion due to groundwater abstraction is not assessed in this high level regional study. These aspects need to be assessed at local scale during future stages.

Table 6.1 presents a summary of potential storage capacity, the irrigable area using the storage, supply-demand reliability and days of restrictions. The irrigable area using the groundwater resource is provided in Section 5.2. These two assessments can potentially be combined to determine the total irrigable area within each area.

6.2.1 Storage based schemes

Water supplies from stored water, i.e. from reservoirs, will be the major source of resource for irrigation schemes within the region in the future. Table 6.1 lists a summary of the storage-based water balance by command area. Appendix H presents the locations of stream intakes or instream reservoirs considered for each reservoir. These intake locations have been considered largely to match the available flow records from hydrometric stations. Therefore, these locations only represent ‘rough’ locations in terms of water availability. Appendix H also presents storage volume hydrographs and consecutive irrigation deficit days by scheme.

The available water flows within some catchments are not large enough to harvest and store for servicing large irrigated areas. This is primarily due to size of the catchments, which are generally small in many parts in the region. However, some command areas can be serviced by harvesting flows from more than one location along a stream or from many catchments (i.e. many intakes and reservoirs). Accordingly, the storages for a number of schemes were assessed using two reservoirs: Kerikeri, Waimate North, Hikurangi and Mangakahia.

While the two reservoirs in Kerikeri and Mangakahia schemes are fed in through flows from two different catchments, for the Waimate North and Hikurangi schemes, the two different flow intake locations have been used along the same river. The flows at the lower intake location within the Waimate North and Hikurangi schemes increase with many small streams flowing into the stream in between the two intakes. It is also considered that these catchments (Waimate North and Hikurangi) are sufficiently large to use two intake locations. The distance between these intakes is assumed to be large enough to provide sufficient downstream flow variability and adequate to meet the ecological requirements of the river. The assumptions we have made will need to be assessed within the next stage of the study.

The North Kaipara and Ruawai schemes have been assessed together to determine the storage sizing. The locations of the schemes and topography lends itself to treat these schemes jointly, at least in terms of water storage. These two areas lie in a relatively flat area at the downstream end of the large Wairoa River catchment (the largest surface water catchment in Northland). Therefore, it is pragmatic to locate the reservoir in the upper catchment (i.e. above the scheme area) and use the river to convey the water from the reservoir to the scheme intakes. The location of the Hoanga scheme and its topography also has the potential to join the North Kaipara and Ruawai schemes to utilise the same reservoir as the water source. However, there is sufficient flow in the Tangowahine Stream to be able to harvest and store flows to independently service the scheme.

The potential for further development of surface water resources for irrigation within the Kerikeri scheme area will be limited. Table 6.1 shows the total irrigable area from reservoir supplies is 1,455 hectares. However, most of the Kerikeri Irrigation Scheme (Section 2.3.2) falls within this command area. Therefore, it is unlikely that additional water or land resources would be available for further large scale irrigation development within the command area.

Development of irrigated areas above a reservoir within any area would potentially be limited due to high pumping costs into irrigated areas. It is common to initially supply water to areas that can be supplied by gravity or little pumping to reduce operating cost. Therefore, it is likely that the difference between the total irrigable area and reliably irrigable area, i.e. the resulting areas that would not be developed, will largely be located in higher altitudes within the command area.

Table 6.1 - Potential storage capacity, irrigable areas and supply-demand reliability

Area – Storage		Total irrigable area[#1] (hectares)	Storage capacity[#2] (Mm^3)	Average supply/ demand ratio	No. of periods of 10 days or more consecutive restrictions (1972-2009)	Irrigable area with available resource (ha)	Percentage irrigable area
Aupouri Peninsula		44,338	No flow data available				
Awanui Plains		23,017	12	98.7%	4	3,222	14%
Kerikeri	Puketotara	13,226	3.7	98.7%	4	860	6.5%
	Waipapa		3.9	98.8%	4	595	4.5%
Waimate North	Upper	21,675	5.6	97.8%	4	1,257	5.8%
	Lower		14	98.9%	4	3,685	17%
Kaikohe		22,133	25	99.2	4	7,746	35%
Waimamaku		3,829	10	98.2%	4	2,374	62%
Hikurangi	Upper	30,637	18	98.9%	4	4,289	14%
	Lower		31.9	99.0%	4	7,353	24%
Glenbervie		3,960	4	99%	4	2,376	60%
Mangakahia	East	9,950	5	98.4%	4	3,383	34%
	West		8	98.3%	4	4,179	42%
Maungatapere		12,488	24	98.8%	4	9,990	80%
Maungakaramea		18,494	11	99.2%	4	2,589	14%
Ruakaka		5,862	1.7	97.6%	4	821	14%
Waipu		8,312	3.5	96.8%	4	2,202	26.5%
Kaihu		4,585	15	99%	4	2,384	52%
Hoanga		3,089	12	99.3%	3	2,471	80%
North Kaipara		26,242	105	98.8%	4	29,484	75%
Ruawai		13,070					
Mangawhai		8,230	3.5	98.9%	3	888	10.8%
Total		**273,137**	**317**			**92,148**	

[#1] The total irrigable area as listed in Table D.1
[#2] This storage volumes exclude storage capacity requirements for dead water (i.e. water would not available for abstraction).

There are many factors to determine whether a reservoir is economically viable for a given area. One of the key indicators is the area that can be irrigated from a volume of stored water. The last column of Table 6.2 lists the irrigable area (hectares) that can be serviced with one million cubic metres (Mm^3) of stored water. The irrigable area from a unit volume of stored water ranges from 153 to 677 hectares. This range (i.e. irrigable area per unit volume) primarily highlights the nature of catchment hydrology due to its size and rainfall. The Opuha reservoir in Canterbury services 16,000 hectares using 74 Mm^3 of stored water (Opuha, 2015), i.e. 216 hectares/Mm^3. It is expected that a higher area should be able to be irrigated in Northland than in Canterbury as average annual rainfall in Canterbury is significantly lower (approximately three times). Therefore, it is likely that storages with lower irrigable area per unit volume, say less than 250 hectares, will be economically less attractive. The economic analysis of these aspects are described in Section 8.

Table 6.2 - A summary of storage volumes and irrigable areas by areas

Area-Storage	Storage volume available (Mm^3)	Irrigable area (hectares)	Irrigable area from a unit storage volume (ha/Mm^3)
Awanui Plains	12	3,222	269
Kerikeri - Puketotara	3.7	860	232
Kerikeri - Waipapa	3.9	595	153
Waimate North - Upper	5.6	1,257	224
Waimate North - Lower	14	3,685	263
Kaikohe	25	7,746	310
Waimamaku	10	2,374	237
Hikurangi - Upper	18	4,289	238
Hikurangi - Lower	31.9	7,353	231
Glenbervie	4	2,376	594
Mangakahia - East	5	3,383	677
Mangakahia - West	8	4,179	522
Maungatapere	24	9,990	416
Maungakaramea	11	2,589	235
Ruakaka	1.7	821	483
Waipu	3.5	2,202	629
Kaihu	15	2,384	159
Hoanga	12	2,471	206
North Kaipara Ruawai	105	29,484	281
Mangawhai	3.5	888	254

Water availability for areas that are located in downstream areas will be affected by the amount of water taken from the upper catchments. For instance, availability for the North Kaipara area will be dependent on many other potential takes in upstream catchments; these areas are Hikurangi, Maungatapere, Mangakahia and Maungakaramea. The assessment in Table 6.2 is based on the assumption that that all upstream abstractions have taken place and resulted in a reduction in water availability for the downstream takes.

The effects of storage requirements and supply reliability for the downstream takes, if no upstream takes were in operation, have also been assessed (Table 6.3). The results show that the stored volume or irrigable area does not increase significantly when there are no upstream takes, apart from Kaipara North-Ruawai joint storage. This is primarily due to the change in flow will also result in change in the median flow; as the threshold for flow harvesting is the median flow, which increases with increased flows result in little overall change in harvesting volumes. However, there is a considerable decrease in storage size in Kaipara North-Ruawai, from 105 to 92Mm^3. This is because the frequent availability of higher flows within this large catchment compared to the other catchments within the region.

It should also be noted that other rivers are available for harvesting and storage for servicing some areas than what has been used in this study. The selected rivers are considered to be the most appropriate sources to irrigate maximum irrigable areas within the areas. However, on completion of the economic and other relevant analysis, if it is found that irrigating a smaller area will have better overall benefits, then other rivers can be considered, if they are more suitable to achieve overall local and regional objectives.

Table 6.3 - Storage capacity, irrigable areas and supply-demand reliability (no flow redution)

Area - Storage	Total irrigable area (hectares)	Storage capacity (Mm^3)	Avg. supply/ demand ratio	No. of periods of 10 days or more consecutive restrictions (1972-2009)	Irrigable area with available resource (ha)	Percentage irrigable area
Waimate North - Lower	21,675	15	98.9%	4	3,902	18%
Hikurangi - Lower	30,637	32.5	99.0%	4	7,506	24.5%
Maungatapere	12,488	24	98.6%	4	9,990	80%
North Kaipara	26,242	92	98.4%	4	29,484[#1]	75%
Ruawai	13,070					

[#1] Estimated maximum irrigation development area, i.e. 75% of the total irrigable area.

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6.2.2 Groundwater supplied areas

While groundwater is available within most command areas, the available volumes are not significant enough to be considered as a resource suitable for a scheme, apart from Aupouri Peninsula, Awanui Plains and Kerikeri. Table 6.4 summarises the potential irrigable area from potentially available groundwater resources. Only one-half of the allocable resource has conservatively been considered for this water balance assessment. This is because shallow groundwater near the coast should not be abstracted at high volumes, to prevent saltwater intrusion. It is also likely that groundwater within the whole area would not be able to developed for scheme supplies due to potential practical limitations (e.g. land ownership).

These conservative estimates need to be assessed and updated via NRC groundwater models (e.g. Aupouri Peninsula) and taking NRC's policy on stream depletion effects into account.

Table 6.4 - Summary of potential irrigable area using groundwater resource

Area	Average 90th percentile irrigation demand#1 (m^3/yr/ha)	Future allocable groundwater resource for schemes#2 (000 m^3/yr)	Potential irrigable area using groundwater resource (ha)	Percentage irrigable area
Aupouri Peninsula	7,176	20,718	2,887	6.5%
Awanui Plains	5,675	4,933	869	3.8%
Kerikeri	3,483	7,240	2,079	15.7%

#1 See Appendix F

#2 See Table 5.1. Only 50% of the allocable resource is considered for areas, as shallow aquifers near the coast should not be developed for abstraction of high volumes to prevent saltwater intrusion.

7 Rationalisation of areas of interest

The indicative volume of water available for irrigation of these areas previously identified is now understood which enables the possible irrigable area from the available resource to be determined.

To enable the economic impact and a multi-criteria analysis to be carried out, the target areas identified have been rationalised and clustered.

This rationalisation reduces the list or, in some cases, combines adjacent areas that could benefit from the same water supply, enabling a stronger focus upon the regional benefits irrigation may bring.

7.1 Long list

The study has highlighted the following 18 areas that have the potential as an irrigation infrastructure command area:

- Aupouri Peninsula
- Awanui Plains
- Kerikeri
- Waimate North
- Kaikohe
- Waimamaku
- Hikurangi
- Glenbervie
- Mangakahia
- Maungatapere
- Maungakaramea
- Ruakaka
- Waipu
- Kaihu
- Hoanga
- North Kaipara
- Ruawai
- Mangawhai

7.2 Short list (clustering)

The long list above was evaluated and rationalised into clusters to enable further assessment, taking into account the following:

- Source and connectivity of water resources
- Locality of towns/ service centres / communities of benefit
- Spatial location
- Local authority boundaries

Table 7.1 and Figure 7.1 show these 'cluster' areas.

Figure 7.1 - Cluster location map

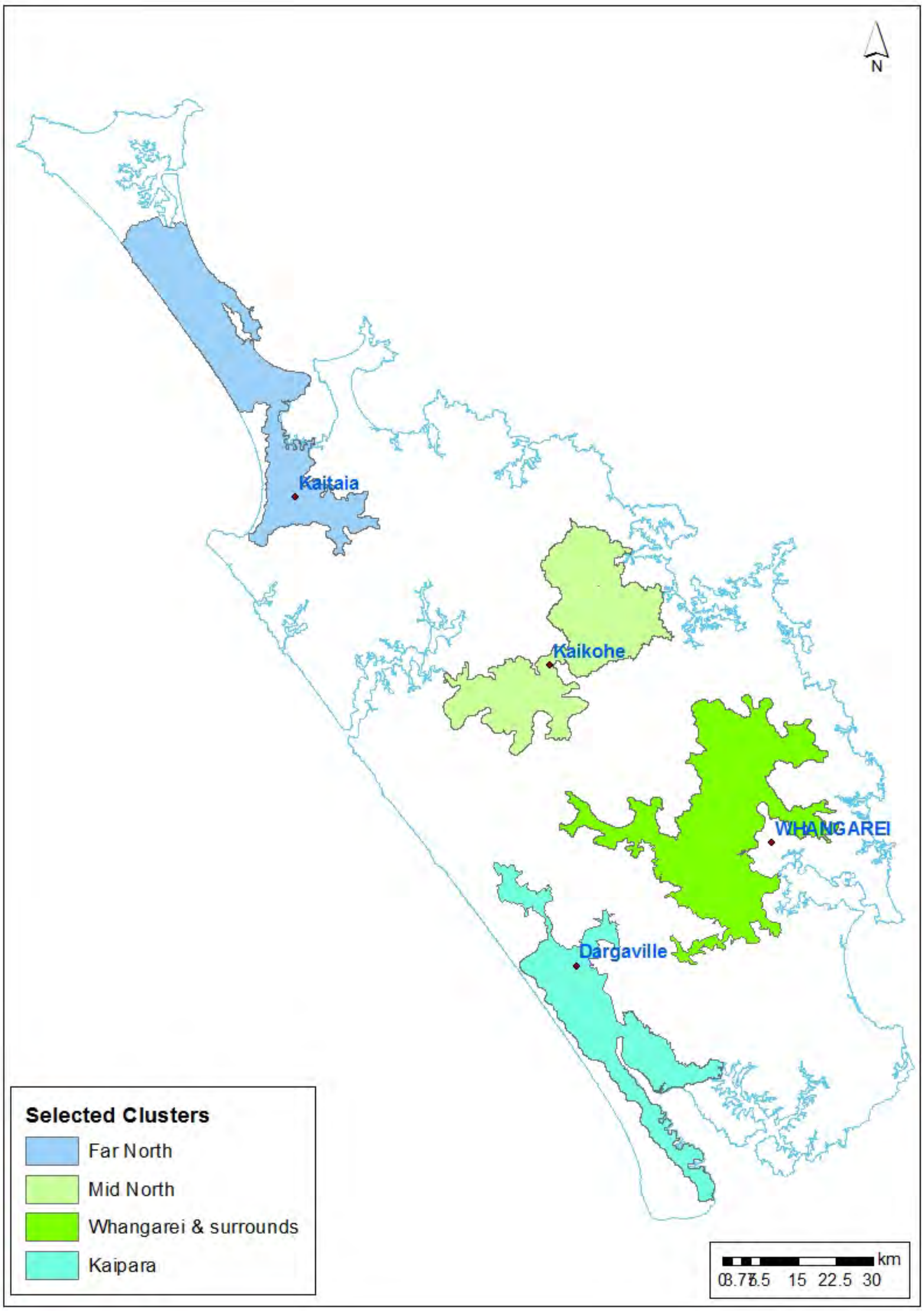


Table 7.1 - Cluster descriptions and areas

Cluster Name	Included Areas of Interest	Total Area of Irrigable Land (hectares)
Far North	• Aupouri Peninsula • Awanui Plains	7,193
Mid North	• Kerikeri • Waimate North • Kaikohe	16,224
Whangarei and Surrounds	• Hikurangi • Glenbervie • Mangakahia • Maungatapere • Maungakaramea	34,159
Kaipara	• Kaihu • Hoanga • North Kaipara • Ruawai	34,339

It should be noted that the majority of the Whangarei and Surrounds cluster is in the upper reaches of the wider Kaipara Harbour catchment. This means that water utilised or harvested in this area will have an impact upon water availability for the downstream Kaipara cluster.

7.3 Excluded areas of demand

The following areas were excluded from the above clusters, or not included as a cluster of their own, due to the size of demand area, spatial locality, and/or characteristics of the water source:

- Waimamaku
- Ruakaka
- Waipu
- Mangawhai

This does not necessarily exclude these locations from further analysis, or suggest that it is not viable for these communities to develop infrastructure to better manage the available water resources. Opportunities and pathways for these smaller "local" areas, rather than "regional" areas are discussed further in Section 10.

It is possible that upon further investigation and engagement with industries and affected parties, the clustered areas identified upon the short list may subsequently become smaller areas such as those above.

8 Economic Impact of Irrigation

This section provides an overall regional perspective on land use, potential land use change, and potential economic impacts of irrigation in Northland. We initially describe the current land use in Northland including the irrigation component. In order to determine the specific differences and strengths of land use in Northland, the land use pattern is compared with the profile of land use over the whole North Island.

Having indicated the comparative advantages which Northland appears to have in main land uses, the section then provides a Northland-wide description of the land use changes if irrigation was developed in the four clusters. The perspective is completed with an analysis of the extent and importance of the economic impacts on regional employment and on regional GDP.

Following the description of change at the regional level, the analyses drill down into the four clusters and the areas of interest within these clusters. In that drill-down we provide some description of possible land use and other impacts from adoption of irrigation on the land found to be irrigable.

It is important to stress here that this initial overview of the land use economics has not had the resource to explore possible issues of profitability, investment and other matters encountered in adopting irrigation practises in-orchard and on-farm.

8.1 Current regional land use and irrigation

The total land area of Northland is just over 1.33 million hectares. Statistics NZ in their agricultural data by Regional Council show that in 2012, the 4,671 farm holdings in Northland had a total land area of 765,155 hectares. However by 2014 the numbers have declined to 4,425 farm holdings with a total land area of 711,077 hectares. The total area of rural land in 2014 is recorded by QV/CoreLogic as just 509,000 hectares and of this Statistics New Zealand's Agricultural Census 2012 indicates that approximately 36% of the region's land, namely 483,600 hectares is in pasture, tussock and feed crops used for pastoral farming.

The recording of land areas in the different measures provide only a relatively general appreciation of actual land use. The final figure of 483,600 hectares in pastoral farming is closest to the estimate of total land use obtained from other sources and shown in Table 8.1 at a little over 470,000 hectares.

The area shown in Table 8.1 as irrigated is also somewhat different from the areas given in Table 2.1 which is 10,999 hectares consented, and 7,795 hectares given in the 2012 Agricultural Census.

Northland utilised land is about 10% of all utilised land in the North Island. The main land uses in which it has more than 10% of North Island's land are avocados and tamarillos (37%), forestry (16%), dairy (13%), and the smaller under-cover horticulture (26%). This reflects the nature of its climate, and the large area of stabilised sand country suitable for avocados and plantation forests.

Current irrigation accounts for approximately 1.5% of utilised land in Northland and the dominant land use is in dairying, with considerable areas also in orchards, vegetables and crops.

Current land use patterns indicate that Northland has relative advantages for production of subtropical orchard crops, vegetables and for dairying. These land uses also benefit from increased certainty of water as provided by irrigation. It can be expected that availability of irrigation in Northland would increase the area and productivity of these land uses.

Table 8.1 - Northland current land use and irrigation

Northland						
Current land use		***Non-irrigated (Ha)***	**Irrigated (Ha)**	**Total**	**Irrigation share (%)**	***Share of North Island land (%)***
Horticulture						
	Avocado, tamarillos	1,638	1,211	2,849	43%	37%
	Kiwifruit, citrus	896	756	1,652	46%	7%
	Vegetables, crops	2,821	418	3,239	13%	8%
	Stonefruit, grape, apple & pear, berries	351	0	351	0%	2%
	Other outdoor, nursery, flowers	214	64	278	23%	9%
	Under cover horticulture	539	85	624	14%	26%
	Horticulture Total	**6,459**	**2,534**	**8,993**	**28%**	**9%**
Agriculture and forestry						
	Dairy	175,544	4,171	179,715	2%	13%
	Beef, beef/sheep, deer	261,208	665	261,873	0%	10%
	Sub-total main pastoral	*436,752*	*4,836*	*441,588*	1%	*11%*
	Sheep, horse other livestock	22,043	18	22,061	0%	3%
	Forestry	7,794	0	7,794	0%	16%
	Crop +/- livestock	7,085	0	7,085	0%	7%
	Agriculture and forestry Total	**473,674**	**4,854**	**478,528**	**1%**	**10%**
Total utilised land		**480,133**	**7,388**	**487,521**	**2%**	**10%**

Sources: Statistics NZ; Value of irrigation in New Zealand, MPI 2014; Opus and BERL analyses

8.2 Projected additional Northland irrigated land use

The current strategic study is tasked with making a high-level assessment of the possible impacts of availability of irrigation in a number of areas of interest in Northland.

The areas of interest have been arranged into four clusters, generally titled Far North, Mid North, Whangarei and surrounds, and Kaipara. Our initial description shows the increase in assessed levels of irrigated land uses in each of these clusters and in Northland as a whole.

The total irrigable area is the irrigable area based on water availability, i.e. for which there would be sufficient water with surface water storage and/or future allocable ground water. This assessment indicates that there is a potential for the area under irrigation to be increased to over

91,000 hectares irrigated in Northland, a significant increase on the 7,400 hectares irrigated at present.

8.2.1 Horticulture land use profile

A detailed and useful assessment of potential horticulture land uses was completed by Cathcart (2012) for Horticulture NZ. In his assessment he concluded that there could be a potential maximum uptake for avocado orchards and other orchards of approximately 15,000 hectares. The assessments of the current planted area, the gross suitable area and the assumed maximum uptake are shown in Table 8.2.

Table 8.2 - Horticulture NZ estimates of additional irrigated land use

Land use suitability	Nature of soils	Gross suitable	Planted now	Remainder	Assumed maximum uptake	Maximum uptake share of remainder
		Hectares				
Avocado and tarmarillo orchards	Free-draining volcanic and sandy soils	14,515	1,958	12,557	6,348	51%
Citrus and other orchard crops	Other volcanic, some alluvial, some sandy peat soils	17,484	1,935	15,549	7,720	50%
Crops, vegetables and grains	Alluvial land and peat soils	13,432	1,584	11,848	Unknown	
Total of significant areas for horticulture	**As above**	**45,431**	**5,477**	**39,954**	**14,818**	

Source: Horticulture NZ, Cathcart (2012)

These assessments by Cathcart (2012) appear to be conservative in that the maximum assumed uptake of the land suitable for each main orchard use was only about 50% of the remaining land which is assessed to be suitable for that orchard crop. The assessment also covered only significant areas and parcels of land that would be suitable for commercial horticultural development.

The area suitable for uptake for crops and vegetables is noted to be unknown until the flood risk on the Ruawai flats and Northern Wairoa is mitigated.

Cathcart (2012) notes that "*There are extensive areas of alluvial and peat soils in other parts of Northland but the risk of flooding is too great, given the inadequate level of protection currently provided under the Awanui River Management Plan and the Hikurangi Swamp Major Scheme, in particular.*"

In total Cathcard (2012) listed seventeen locations where there was suitable land for one or other of these horticultural uses. Exploration of this work would be very useful in extending the analyses of the detail of the potential for expanded irrigation.

8.2.2 Pastoral irrigated land increase

The assessment of a total irrigable area of 91,000 hectares, and of horticultural potential use of about 20,000 hectares implies an irrigated area supporting pastoral dairy and beef of about 70,000 hectares. This area is only about one-sixth of the 436,752 hectares at present in non-irrigated pastoral land use for dairy and beef.

Analyses of district level changes in Northland dairy production from 1996 to 2014 indicates that there has been some reduction in land used for dairy production and in the number of dairy cows over this period (Appendix I). There would therefore appear to be land capable of re-introduction to dairying if and when irrigation water availability made it feasible and profitable

Due to the inhibited drainage on many of the soils in Northland, the adoption of intensive dairying under irrigation is likely to be possible to only a limited extent. It is generally accepted that irrigation on dairy farms in Northland would be mainly to mitigate periodic drought conditions and enable some increase in productivity.

8.2.3 Potential irrigated land use in Northland clusters

The analyses indicate that of the over 91,000 hectares potentially irrigable, about 18,000 to 19,000 hectares could be irrigated for horticultural orchards and vegetables, taking into account soils and topography. This includes the 14,818 hectares assumed maximum uptake for orchards as shown in Table 8.2, and an allowance of about 5,000 hectares for vegetables and crops as shown in Table 8.3. In pastoral production, a further 62,000 hectares could be irrigated to support dairy production, and about 11,000 hectares for beef/sheep and dairy support as also shown in Table 8.3.

The assessment is that the provision of surface water storage and future allocable ground water would increase the provision of irrigation support on a total area of over 91,000 hectares in Northland.

The advantage Northland has in sub-tropical fruit growing could see the irrigated area of the orchards increase to about 14,000 hectares and the area of vegetables to about 5,000 hectares. As indicated above these numbers include judgement elements including in the assumptions made as to the uptake of the remaining land suitable for each use. For that reason totals may vary in different analyses. This would leave capacity for about 73,000 hectares in pastoral agriculture to have irrigation support.

Judgement has been applied to the potential for increased vegetable production in Northalnd soils based on recent high profile media discussion around land use change occurring on prime South Auckland (Pukekohe) volcanic soils. *Reference RadioNZ National Country Life "Housing vs Horticulture" 11 December 2015.* Previously known for its high value production capacity there is increasing pressure for the Pukekohe district to accommodate up to 50,000 new homes on the Auckland peri-urban margins. The lost productive capacity will have to be replaced to meet local and international consumption demands and Northland is ideally placed to meet this demand.

Table 8.3 - Irrigated land use potential in Northland cluster areas

Irrigated land uses in Clustered Areas of Interest	Clusters				Northland Total
	Far North	Mid North	Whangarei surrounds	Kaipara	
	Hectares				
Total irrigable area	**7,193**	**16,225**	**34,159**	**34,339**	**91,916**
Avocado, tamarillo	1,950	780	2,118	1,500	6,348
Kiwifruit, citrus	1,650	5,380	690	0	7,720
Vegetables, crops	500	0	0	4,346	4,846
Sub-total Horticulture	***4,100***	***6,160***	***2,808***	***5,846***	***18,914***
Sub-total Pastoral *Of which:*	***3,093***	***10,065***	***31,351***	***28,493***	***73,002***
Dairy	2,629	8,555	26,648	24,219	62,052
Beef/sheep, dairy support	464	1,510	4,703	4,274	10,950

Source: Horticulture NZ, Bob Cathcart, Opus/BERL estimates.

8.3 Benefits of Northland irrigation in-orchard and on-farm

The number of hectares that would be converted from dryland production to irrigated production in the same land use has been estimated. Where there was still additional irrigable capacity we assumed that land was converted from pastoral agriculture into irrigated land uses.

Table 8.4 shows the increased value of margins from Northland irrigated land uses. Note that this table ignores three of the minor horticulture categories from Table 8.1 being 'stonefruit', 'outdoor nursery' and 'under cover horticulture'.

The likely margin was derived between the value per hectare generated by the previous land use and the value per hectare generated by the potential future land use supported by irrigation.

It should be noted that some of the crop value margins are aggregated figures under some of the categories. For instance Kiwifruit is an aggregate of both green and gold varieties based on information from various industry sources. Whilst there is an understanding of different margins occurring from these crops at farm gate level, the year to year variations due to a number of local and international market drivers make any further breakdown of the figures of limited value in this study.

Table 8.4 - Increased value of margins from Northland irrigated land uses

Northland							
Irrigated land uses in Areas of Interest		**Land with irrigation**	**New irrigated land obtained from:**		**Irrigated margin over dryland**	**Irrigated margin over pastoral**	**Total annual margin to new land irrigated**
			Dryland (non-irrigated)	**Land use change**			
		Hectares			*Gross Margin $/hectare per Year*		*$million*
Horticulture							
	Avocado, tamarillos	6,348	1,638	3,499	$2,500	$5,500	$23.30
	Kiwifruit, citrus	7,720	896	6,068	$7,116	*$10,500*	$70.10
	Vegetables, crops	4,846	2,821	1,607	$893	$2,247	$6.10
	Horticulture	**18,914**	**5,355**	**11,174**			**$99.60**
Pastoral agriculture							
	Dairy	62,052	57,881		$1,034		$59.80
	Beef/sheep, dairy support	10,950	10,285		$726		$7.50
	Pastoral agriculture	**73,002**	**68,166**				**$67.30**
	Total utilised land	**91,916**	**73,521**	**11,174**			**$166.90**

Sources: Horticulture NZ, Bob Cathcart; Value of irrigation in New Zealand, MPI 2014; Opus and BERL analyses

The assessment has shown that 5,355 hectares currently in dryland (non-irrigated) horticulture will be converted to irrigated production, and 11,174 hectares currently in pastoral agriculture will be converted to irrigated horticulture. This includes horticulture areas currently utilising irrigation.

Approximately 68,000 hectares currently in dryland pastoral production will be converted to having irrigation support.

The margins per hectare at irrigated orchard-gate are much higher than at dryland pastoral farm gate. The land use change from pastoral land uses to irrigated orchards would increase Northland's farm gate margin by $93 million per year. Irrigation support on 58,000 hectares of dairy land could increase Northland's farm-gate margin by a further $60 million per year.

8.4 Northland economic impacts from irrigation

The main economic benefits to Northland from increased irrigation are significant increases in employment opportunities, especially in orchards. The amount of work required per hectare of horticultural production is much greater than per hectare of pastoral production. Consequently the increased area of land potentially in irrigated horticultural production generates a major increase in the direct employment.

The analysis has shown that the total GDP contribution, taking account of margins for suppliers and local spending, is about $250 million per year, expressed in 2014 prices. The 2014 total GDP for Northland given by Infometrics as $5,905 million in 2010 prices, which is $6,487 million in 2014 prices. The total GDP contribution from the irrigation would therefore be equivalent to 3.9% of current total GDP.

The value of production and also the margin which contributes to GDP is also greater per hectare from horticulture than from pastoral agriculture.

It is common economic methodology to use GDP calculation for each of these activity categories. The value of output is back-calculated from the GDP by applying BERL's regional coefficients. At this regional study level output values are not normally calculated by product yield multiplied by commodity price as these are too variable for anything other than farm gate scale analysis.

Table 8.5 shows the results of irrigation in Northland on employment and GDP. The column titled 'GDP direct' holds the values estimated for 'Total annual margin to new land irrigated' in Table 8.4.

Table 8.5: Northland increased employment and GDP from irrigation

Irrigated land use	Value of output	GDP Direct	GDP Total	Employment Direct	Employment Total
	$ Mn	*$ Mn*	*$ Mn*	*FTEs*	*FTEs*
Avocado, tamarillo	$47.60	$23.30	$35.70	439	782
Kiwifruit citrus and olive	$143.00	$70.10	$107.20	1,018	1,813
Vegetables,crops	$11.40	$6.10	$8.90	81	108
Total horticulture	**$202.00**	**$99.60**	**$151.90**	**1,538**	**2,703**
Dairy	$110.80	$59.80	$83.20	378	608
Beef/sheep, dairy support	$16.20	$7.50	$12.30	68	115
Total pastoral	**$127.00**	**$67.30**	**$95.50**	**446**	**723**
Economic increase from Irrigation	**$329.10**	**$166.90**	**$247.40**	**1,984**	**3,426**

Source: BERL analysis

The analysis suggests that horticulture would employ a further 1,500 Fulltime Equivalent Employed persons (FTEs) as a result of the increased irrigation. Pastoral agriculture would employ a further 450 FTEs, giving increased direct employment in-orchard and on-farm by about 2,000 FTEs. Taking account of the increased employment by suppliers to the orchards and farms, and the employment generated by these people spending their earnings in the local community, the total increase in employment would be over 3,400 FTEs. These estimates of total GDP and total employment generated by suppliers to the orchards and farms, and the employment generated by these people spending their earnings in the local community are estimated based on multipliers estimated for Northland. These multipliers are a common method used to estimate indirect economic impacts and are specific to different industries and different regions. In general in New Zealand multipliers fall in the range from about 1.5 to about 3.

The significance of these increases in employment is:

- Nearly 2,000 additional people directly employed in horticulture and pastoral agriculture.
- Nearly 40% increase on the 5,049 people recorded as employed in these industries in 2014.
- Increased development of contract supply of local seasonal workers to horticulture.
- The total increase by 3,400 FTEs is about 6% of the total employment in all industries and occupations in Northland in 2014.

- The direct contribution to regional GDP at orchard- and farm-gates is over $160 million per year.
- The total contribution, taking into account of margins for suppliers and local spending is about $250 million per year.

8.5 Increased land use margins in Northland clusters

The distribution of the benefits of increased margins earned at orchard-gate and farm-gate are of a similar order of magnitude in total for each of the four clusters. Each would contribute significantly to strengthening their area's economy. For example the Mid North cluster could see increased production in areas across the peninsula between Kaikohe and Kerikeri, generating some additional producer income which can be invested in increased production and economic activity across this area. Table 8.6 shows irrigation margins for producers in each of the 'cluster areas'.

Table 8.6 - Producers' margins from irrigation in Northland clusters

Irrigated production margins (Direct GDP)	Far North	Mid North	Whangarei surrounds	Kaipara	Northland
	$Mn	*$Mn*	*$Mn*	*$Mn*	*$Mn*
Avocado, tamarillo	$7.20	$2.90	$7.80	$5.50	$23.30
Kiwifruit, citrus	$15.00	$48.80	$6.30	$0.00	$70.10
Vegetables, crops	$0.60	$0.00	$0.00	$5.50	$6.10
Horticulture	**$22.80**	**$51.70**	**$14.10**	**$11.00**	**$99.60**
Dairy	$2.50	$8.20	$25.70	$23.40	$59.80
Beef/sheep, dairy support	$0.30	$1.00	$3.20	$2.90	$7.50
Pastoral	**$2.90**	**$9.30**	**$28.90**	**$26.30**	**$67.30**
Total increased margins	**$25.60**	**$61.00**	**$43.00**	**$37.30**	**$166.90**

Source: BERL estimates

8.6 Employment generated by irrigation in clusters

Similar the total employment generated on orchard and farm and the indirect impacts are reasonably well distributed across the clusters. They will each make a significant impact on employment in the areas. The increased employment in the Mid North cluster gives renewed importance to improved transport and communication between the labour-rich Kaikohe/Hokianga area and the increased production in the Okaihau/ Waimate North and Kerikeri/Waipapa areas.

Some of the increased production in some areas including the Whangarei surrounds cluster include some Maori Freehold Land. Depending on the ownership status, this may or may not be of interest to Te Tumu Paeroa (The Maori Trustee) to co-ordinate some developments in these areas. Table 8.7 provides the impact of irrigated production in clusters on total employment for each 'cluster area'.

Table 8.7 - Total employment impact of irrigated production in clusters

Total employment increase from irrigated production	Far North	Mid North	Whangarei surrounds	Kaipara	Northland
	FTEs	*FTEs*	*FTEs*	*FTEs*	*FTEs*
Avocado, tamarillo	240	96	261	185	782
Kiwifruit, citrus	387	1,263	162	0	1,813
Vegetables, crops	11	0	0	97	108
Horticulture	**639**	**1,359**	**423**	**282**	**2,703**
Dairy	26	84	261	237	608
Beef/sheep, dairy support	5	16	50	45	115
Pastoral	**31**	**100**	**311**	**282**	**723**
Total employment increase	**669**	**1,459**	**733**	**564**	**3,426**

Source: BERL estimates

8.7 Realising development of irrigable land

The investigations of hydrological conditions, the agronomy, the soils and the high-level economics have indicated the desirability of the potential for increased irrigated production in the four clusters in Northland. In particular, there is a very strong potential for increased employment to be generated by the expansion of irrigated horticultural production.

The next step to realising these potential increases is to explore the specific commercial viability of the in-orchard and on-farm investment and production.

8.7.1 The 'lifestyle' land use phenomenon

One specific potential limiting factor for at least some of the orchard potential is the subdivision into lifestyle blocks. However, where there is a potentially profitable use this situation could be explored to test the feasibility of people adopting a form of share cropping on some of this land.

There is another aspect of 'lifestyle' land especially of relevance to small parcels of Maori Freehold Land. Work which BERL has done in relation to utilisation of Maori Freehold Land (MFL) has shown that considerable areas of land in unutilised titles which are too large for residential use, and too small for productive use in the primary sector are classified by the land valuers as 'lifestyle' use. In many cases these properties have no attraction as 'lifestyle blocks' in the normal sense being neither close to urban areas, nor necessarily of suitable aspect etc. In a high-level scan of the Far North District we identified about 1,600 such blocks covering a total area of 14,500 hectares. Of these about 1,200 blocks covering 10,600 hectares were of LUC Class 1 to 4, and thus suitable for arable, horticulture or quality pastoral uses.

At a total regional level, the BERL property database, with base information from QV/CoreLogic shows that in Northland in 1997 there was 46,000 hectares of land classified 'lifestyle', and that by

2014 this has increased to 114,000 hectares. Much of this may well be in true 'lifestyle blocks' and consequently have a land value now which makes it uneconomic for conversion to fully primary productive use. However, this aspect does require exploration as many 'lifestyle blocks' have under-utilised land, which in other regions is often utilised by contract lessees for pastoral, share-cropping or horticultural use.

8.7.2 Land not on farm holdings

There is a further 560,000 hectares (1.33 million hectare total area less 765,000 on farms) which is in 'other cover'. This will include indigenous forests, scrub and regenerating bush, and presumably some sand country.

The high level implication is that the land area of Northland is not currently intensively utilised. Some of this land shall be used in production either directly or indirectly, when or if primary production intensifies, by expanded irrigation or otherwise. Other land will be retired once use of the more suitable land is intensified.

8.8 Specific impacts of expanding current irrigation schemes

The main existing irrigation schemes are the Kerikeri and the Maungatapere schemes. Cathcart (2012) identified the main horticultural impacts on these schemes as detailed in Section 8.8.1 and Section 8.8.2. The following estimates appear to be conservative, if the economics of production is favourable.

8.8.1 Kerikeri

For Kerikeri, the current area planted is 1,694 hectares, with maximum additional uptake of 2,780 hectares. This is approximately 55% of the remainder of suitable land in the area.

These figures indicate a potential increased area of citrus and kiwifruit of 2,780 hectares. This is about 45% of the total additional irrigated area for this land use assumed within the six potential schemes. This implies that if Kerikeri were expanded, that land use would generate an additional $40million regional GDP, and additional employment of over 600 FTEs

8.8.2 Maungatapere

The current area planted within Maungatapere Scheme is 1,172 hectares, with maximum additional uptake of 1,600 hectares. This is approximately 62% of the remainder of suitable land in the area.

The Maungatapere figures indicate a potential increased area of avocado area of 1,600 hectares. This is only about 16% of the total additional irrigated area for this land use assumed within the six potential schemes. This implies that if Maungatapere Irrigation Scheme were to be expanded, the new supply land would generate an additional $11million regional GDP, and additional employment of over 240 FTEs.

9 Multi-criteria analysis

This study has identified four 'cluster areas' within Northland that could be suitable for irrigation infrastructure development. NRC need to establish prioritisation of these areas for further consideration to ensure money is spent efficiently with most return for the regional economy.

A multi-criteria analysis (MCA) provides a useful tool to rapidly assess the areas and assist NRC to determine the priority of areas. It is undertaken by asking a number of respondents answer a series of questions and score the areas based on the scoring framework provided. These questions are combined and weighted according to the priority for the criteria. This provides a final value for each area that can be directly compared to each of the other areas.

The benefit of comparing areas with the results of an MCA score is that, using answers from a range of respondents should smooth out any conscious or unconscious bias that would be applied to an area. Additionally, important factors can be weighted accordingly but less important factors are not completely ignored.

9.1 Weighting the criteria

The weighting of each of the decision making criteria that will feed into the multi-criteria analysis was formally agreed with NRC. Table 9.1 details the important points and weighting based on previous experience and engagement with local stakeholders.

At this stage, the weightings have been determined using feedback from the stakeholder engagement survey, the findings from this report and local knowledge. This can be refined if different priorities emerge during subsequent stages.

Ultimately the cost of a scheme will govern whether it can be implemented in an area. However the cost cannot currently be considered as the specific details of such schemes are unknown. Therefore the following criteria shown in Table 9.1 have been reviewed without considering costs.

Table 9.1 - Decision making criteria to refine the long list

Criteria	Description	Weighting (%)
Cultural	Cultural considerations will be an important part of all of the criteria and independently. The level of understanding of cultural values within the cluster area will be evaluated.	12
Reliability of Water	Certain schemes and areas will provide a greater security of supply locally and for the region. The importance of this will be greater in some areas.	10
Productivity/profitability	Increased reliability of water eventually leads to increased productivity and profitability as the land use is altered or optimised as a results of irrigation.	13
Environmental impacts	Changing the hydrological behaviour of a catchment has many implications for the environment. In some areas they may be managed effectively to provide environmental benefits.	10
Economic Impacts	The potential improvements to the Northland economy is a major driver for this strategic study. The impacts locally and regionally should be considered.	20
Social impacts	Investment in irrigation could lead to increased skilled workforce and increased permanency of employment.	10
Potential for flood risk reduction	If planned effectively and feasible, schemes could be combined with flood alleviation projects.	7
Risk of uptake	For most of the areas there will be the risk of uptake of the available water due to financial or operability constraints.	10
Complementary activities	Additional complementary activities such as electricity generation and leisure activities may provide benefits to a wider range of people.	3
Preparation for future changes	Increased urban development and industry in Northland, combined with changing climate factors may result in changing needs in some areas.	5

9.2 Questioning

A question has been phrased around each of the criteria and Table 9.3 shows the form of questioning. The respondent answers the questions focusing on the word in **bold**. Each of the questions should be considered on a local, as well as a regional level for each area.

For each of the questions, the respondent provided an appropriate answer on the following scale shown in Table 9.2.

Table 9.2 - Scale for answers to the multi-criteria analysis

None	Least				High
0	1	2	3	4	5

Table 9.3 - Multi-criteria Analysis question format

Criteria	Question	Area 1 Far North		Area 2 Mid North		Area 3 Whangarei & Surrounds		Area 4 Kaipara	
		Local	Regional	Local	Regional	Local	Regional	Local	Regional
Cultural	How **clearly understood** are culturally significant localities and values understood in this area should water management infrastructure be developed? *For example, consider current understanding by the community of known significant areas and values; plus potential for unknown impacts and the ability to manage them locally/regionally.*								
Reliability of Water	What is the **importance** of an increased security of supply to this area? *For example, consider current access to water supply for productive and domestic use, and potential population growth and future uses locally/regionally.*								
Productivity/ profitability	What is the **potential** to increase productivity/profitability of the land in this area? *For example, consider possibilities for farm expansion, willingness to change land use, and opportunities to adopt more efficient management practices locally/regionally.*								
Environmental impacts	What is the **potential** for mitigating risks to the environment by changing the hydraulic behaviour of the catchment to accommodate water infrastructure development in this area? *For example, consider ability to positively influence low stream flows, ecologically significant areas, sediment transportation and water quality locally/regionally.*								
Economic Impacts	What is the **importance** of improvements to the economy? *For example, consider the potential level of improvement to the current situation and the impact this would have locally/regionally.*								
Social impacts	What is the **potential** for the development of strategic water infrastructure to increase the demand for a skilled workforce? *For example, consider the requirement for further training for employment, increased permanency of employment, level of education and potential for seasonal worker increase. Consider impacts on an individual and community level locally/regionally.*								
Potential for flood risk reduction	What is the **significance** of reducing flood risk in this area if it is feasible? *For example, consider historical flood events with respect to safety of residents, reduced access restrictions and impact on primary industry locally/regionally.*								
Risk of uptake	What is the **potential** for community interest, support and uptake in this area? *For example, consider local interest, community versus individual interest, willingness and financial situation alongside opportunity for policy and funding models, and perceived timeframes of interested parties locally/regionally*								
Complementary activities	What is the **potential** to develop additional complementary activities alongside water infrastructure in this area? *For example, consider activities such as electricity generation, municipal water supply, industrial use, aquaculture, leisure activities and tourism locally/regionally.*								
Preparation for future changes	How **important** is strategic water infrastructure development in this area to meeting future needs? *For example, consider factors such as supporting industrial/commercial development, population growth, climate change and regulatory environment locally/regionally.*								

9.3 MCA process

Members of the project team, and representatives from NRC and Northland Inc undertook the multi-criteria analysis in November 2015. The aim of this exercise was to ensure that questions were understood and a framework could be developed for use with a further refined list or extended to other stakeholders.

The respondents completed the process individually and honestly. Each answered each of the questions considering the criteria on a local, as well as a regional level for each area.

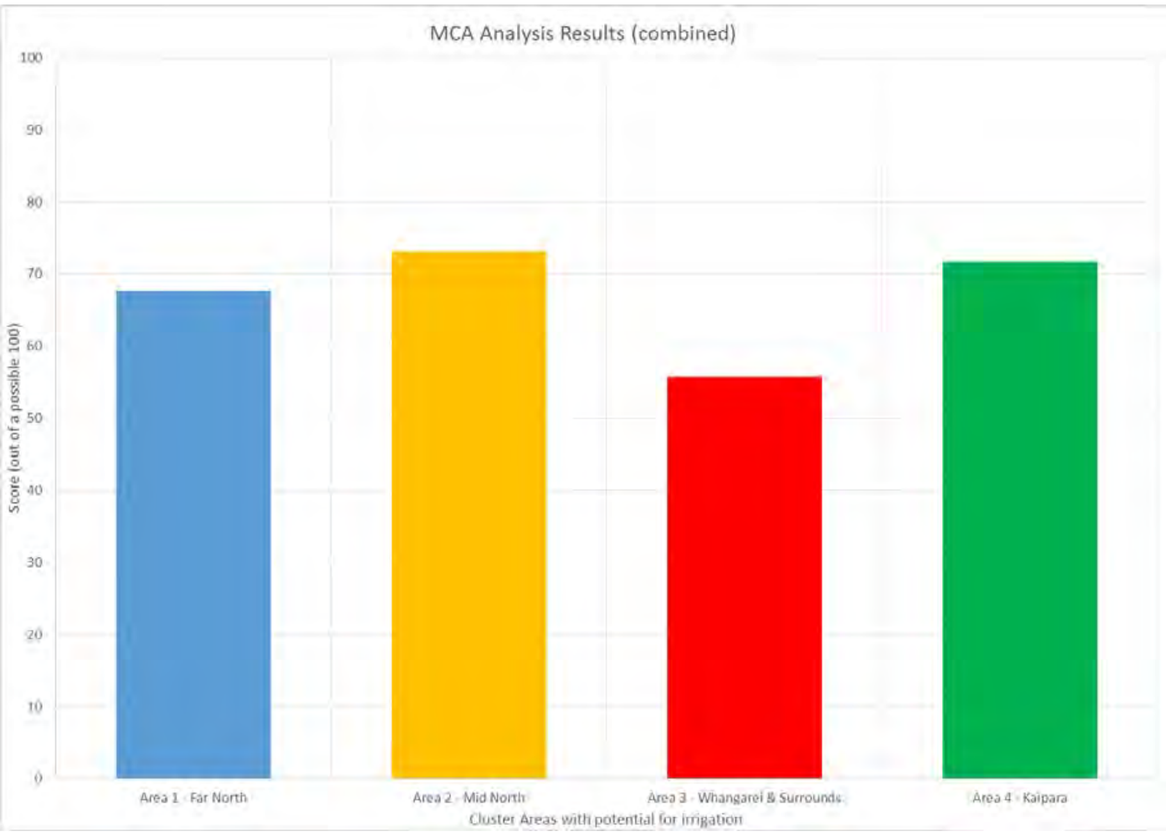
It is important to note that this process has not specifically involved any stakeholders due to project time commitments. However once the priorities have been established, it is recommended that subsequent MCA processes are inclusive of a wide range of local stakeholders.

9.4 MCA Results

The results of this exercise showed that respondents considered all areas to be important. All scored over 50 (of a possible 100) for both local, regional and combined (averaged) benefits and Mid North (Area 2) and Kaipara (Area 4) scored over 70 (of a possible 100).

The results showed that respondents rated the development of the Whangarei and Surrounds cluster area (Area 3) as the lowest of the four areas. However, the high scoring results for all four cluster areas highlighted that none should not be omitted from all future consideration. Figure 9.1 shows the combined local and regional (averaged) results of the multi-criteria analysis.

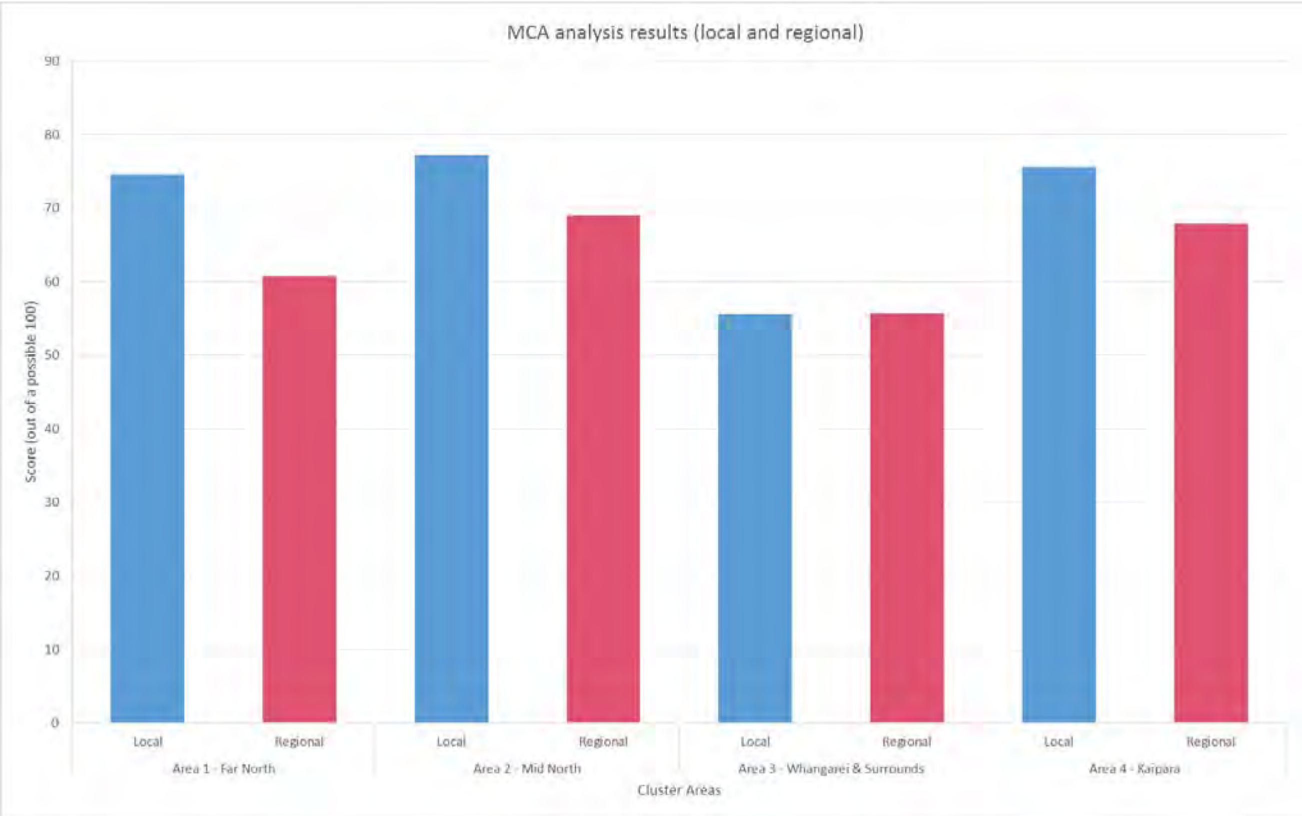
Figure 9.1 - MCA results of local and regional scores combined



At a local level, the cluster areas of Far North (Area 1), Mid-North (Area 2) and Kaipara (Area 4) scored in excess of 70, with Mid-North marginally the highest (Figure 9.2). This shows the importance of irrigation infrastructure development for Northland.

A review from a regional perspective provided a way to distinguish between the three highest scores. From a regional perspective, the results also showed that Mid-North (Area 2) and Kaipara (Area 4) have the potential to contribute to the wider Northland region more readily than the other areas (Figure 9.2).

Figure 9.2 - Local and regional MCA results



At both a local and regional level, Mid-North (Area 2) is leading with potential for benefits throughout the cluster area and the region, with Kaipara (Area 4) close behind.

The results of this exercise showed that although all areas were considered to be important, Mid-North and Kaipara have the potential to contribute more regional benefits.

10 Discussion

10.1 Key findings

Strategic water management including its related infrastructure is a significant part of the future economic, social and environmental solution for Northland. The implication of water management strategies and policies influence and assist the many and varied community aspirations and desired outcomes. Progress in this area will require effective collaboration with likely compromise and investment of time and capital by many stakeholders.

The primary focus of the study is on the opportunities presented by providing a reliable water supply to primary productive capable land. The report aims to provide relevant information to support strategic decision making in regards to water management across the entire Northland region but focused down onto definable areas of interest. The study has addressed specific challenges faced by the region and evaluates the potential use of productive agriculture to grow the economy whilst recognising the social and environmental impacts of intensive land use.

This has been achieved by analysis of the region to determine areas suitable for irrigation, a review of the capability of the area to support and develop water storage infrastructure, and an assessment of the economic impacts of implementing systems locally.

As a starting point the study considered the existing irrigated land use in Northland. This established the current irrigated areas, whether consented or not, irrigation methods used and effectiveness of these. The study reviewed the two existing large irrigation schemes, Kerikeri and Maungatapere, and found their strengths lie within security of supply and good community engagement. Opportunities for growth were also identified in these areas.

Other historic initiatives and proposals were reviewed to ensure that lessons could be taken from the decision criteria applied to previous potential developments.

A small number of key stakeholders were consulted in the form of an online survey at the commencement of the study. These stakeholders represented a cross section of land and water users, community interests and regulators. Feedback was used to frame the weighting of the multi-criteria analysis used in this study report. The response indicated that there was a strong interest in the issues with water availability and land use impacting Northland and the process of this study. It is clear that there is a strong underlying community appetite for progress in the area of water resource management, particularly irrigation development. In keeping with New Zealand's rural social fabric individuals are likely to support initiatives that benefit the wider community rather than just themselves. But it is recognised that the pace of community decisions may not meet individual objectives especially around timing of investment or farm succession planning. The risk is that a positive community outcome could be diminished if fragmented development occurs outside an obvious collective model.

The regional topography, meteorological and climate characteristics and geographical features were assessed to determine suitable locations for irrigation. This resulted in 18 potential irrigation scheme command areas containing over 91,000 hectares of potentially irrigable land.

A water balance assessment was undertaken for these areas to make sense of what water is needed and what is available spatially, seasonally and year by year to meet a reliability target that would support land use management decisions with a degree of confidence.

The water balance information allowed the rationalisation of the 18 localised areas into four aggregated clusters. This indicated that the provision of a combination of surface water storage and allocable ground water could provide irrigation support to an area of over 91,000 hectares in Northland.

- Far North (7,193 ha)
    - Aupouri Peninsula
    - Awanui Plains
- Mid North (16,224 ha)
    - Kerikeri
    - Waimate North
    - Kaikohe
- Whangarei and Surrounds (34,159 ha)
    - Hikurangi
    - Glenbervie
    - Mangakahia
    - Maungatapere
    - Maungakaramea
- Kaipara (34,339 ha)
    - Hoanga
    - North Kaipara
    - Kaihu
    - Ruawai

The advantage Northland has in sub-tropical fruit growing could see the irrigated area of the orchards increase to about 14,000 hectares and the area of vegetables to about 5,000 hectares. This leaves a balance area of 73,000 hectares of irrigable land to be potentially utilised for pastoral agriculture. These areas are inclusive of existing irrigated land.

The main economic benefit to Northland from increased irrigation is significant increases in employment opportunities. Any increase in area of land converted into irrigated horticultural production generates a major increase in the direct employment, due to the high amount of labour per hectare required in the production process.

If water management policy and storage/distribution infrastructure for irrigation was implemented through the four clusters identified above, there is the potential for nearly 3,400 additional people to be directly employed within Northland in both horticulture and pastoral agriculture. This is a significant increase on the 5,049 people recorded as employed in these industries in 2014.

The analysis has also shown that the total increase in GDP contribution resulting from an expansion in irrigation, taking account of margins for suppliers and local spending, is about $250 million per year.

There is considerable upside potential in the figures above as they are based upon conservative assumptions around the allocable and harvestable water resources and the project team understands that NRC is still in the process of developing water management policies and allocation rules in this space.

The analysis has provided additional evidence that irrigation management policies and new infrastructure will make a significant impact on employment in the cluster areas. The potential ncrease in employment in the Mid North cluster gives renewed importance to improved transport and communication between the labour-rich Kaikohe/Hokianga area and the increased production in the Okaihau/ Waimate North and Kerikeri/Waipapa areas.

A MCA to refine the areas of interest further was conducted by a selected panel and the results of this informed the conclusions and recommendations in this report. Following this high level and limited MCA, it is highly recommended that a wider stakeholder panel be engaged using the multi-criteria analysis framework presented. This will further enable identification of co-benefits and challenges.

10.2 Stakeholder engagement

A small number of local stakeholders were consulted at the commencement of this study via an electronic survey. The important findings of this have shaped both the focus of the MCA and the weighting criteria, and have been critical to the development of this study.

It is important to note that the MCA process has not involved stakeholders at this stage. However once the priorities have been established, it is recommended that subsequent stages are inclusive of stakeholders.

10.3 Cultural considerations

It is acknowledged that Northland is one of the most culturally diverse regions in New Zealand. As such, cultural considerations are going to be of paramount importance in the development of irrigation within the region.

The importance of cultural considerations is reflected by the inclusion of it as a highly weighted component within the MCA, and also within the small selection of stakeholders that were engaged with – specifically Maori Agriculture Forum and Iwi CE Forum.

As such, it is suggested that one of the first steps moving forward is to commit time and resources to clarifying how the development of irrigation infrastructure fits culturally in Northland i.e. a regional perspective. This will then support more targeted investigation in specific areas in addressing cultural impacts through the implementation of appropriate avoidance, remedial or mitigation measures. It will also be very important to clearly distinguish the difference between cultural and environmental matters.

It is acknowledged that irrigation within the areas of interest requires up-front engagement with Iwi is absolutely necessary as Kaitiaki (Guardians) of the sky, sea and land.

10.4 Potential limitations and uncertainties

Given the preliminary nature of this study, there are a number of uncertainties associated with various elements of the study. These uncertainties are present in both water availability and water demand assessments. Accordingly, it is likely that the water balance, which has been completed by integration of the water availability and demand assessment components, also contains uncertainties.

Availability of continuous measured flow data is limited within many catchments. To enable the daily supply analysis, the flow data has been extended and gap-filled (see Section 5.1.1). The correlated data has some fundamental uncertainty. Therefore, to reduce the uncertainty, we recommend that frequency of flow data availability be improved for the schemes that are identified as having the greatest potential for further investigation.

To determine the irrigation water demand, NRC's in-house soil-water balance model SPASMO has been used. However, the initial model supplied was only capable of producing monthly and annual outputs. While NRC was working with the SPASMO model developers to obtain an updated version of the model, which produced daily demand outputs, the existing model was used to obtain annual demands. This was necessary to produce water demand calculations by schemes to facilitate the other member of the project team (e.g. economic analysis) proceeding with their respective analysis to meet the project timeline.

The updated SPASMO model was run again to obtain daily irrigation requirements (i.e. system capacities) for various crop-soil-climate combinations. At 80% irrigation efficiency, the SPASMO model uses a gross application depth of 18.8mm for all crops, except for grapes, where it is set at 6.2mm. The model uses a strategy of irrigating these fixed amounts (i.e. 18.8 or 6.2mm) when soil-moisture deficit reaches the trigger point (e.g. 50% of PAW for pasture). However, the model does not use minimum return periods between irrigation events. This has resulted in irrigation system requirements with very high daily demands – as high as 18.8mm/day on some occasions (i.e. irrigation in two consecutive days at 18.8mm depth), and frequently at 9.4mm/day at two day return periods. This does not represent what actually occurs on farms. In particular, when hand-shift irrigation systems are used, it is not practical for irrigators to operate under one or two day return periods; a minimum of approximately 7-day return periods are common with those irrigation systems. Further, it is extremely unlikely that irrigators will invest in an irrigation system to meet such a high system capacity as 9.4mm/day. However, NRC advised that the scope under which SPASMO was developed was to estimate annual demands, not daily. Accordingly, daily demands may not represent reality. However, daily water application depth affects annual volumes (Rajanayaka *et al*., 2015). Therefore, there is potential for annual volumes, which have been produced by the SPASMO soil-water balance model, to be incorrect due to unrealistic irrigation system capacities.

In the light of the above, NRC advised that the project team may consider using another model that is more suitable for the project, or modify the SPASMO model parameters. However, after careful evaluation, we decided that the available project resources were not adequate to use another model to determine irrigation demands. Due to circumstances beyond the control of the project team, both funding and time were insufficient to determine the irrigation demand using another model. A considerable input of resources is needed to develop and format model input files, carry out the modelling and analyse the outputs. Similarly, modifying SPASMO model parameters and re-running the model was not viable within the available project resources, due to uncertainty of the suitability of the SPASMO outputs for the project as described below.

To evaluate the uncertainty of the SPASMO outputs, the results for pasture irrigation within the Hikurangi scheme were compared with Irricalc (Aqualinc's in-house soil-crop-water balance model) results. Demand using Irricalc was modelled for system capacities of 5.0, 4.0 and 3.5mm/day for 70, 130 and 200 mm PAW classes (see Section 4). The irrigation parameters for Irricalc were selected to meet the generally accepted following two criteria:

1. 90% of the time soil-water content should be more than 50% of PAW; and

2. 99% of the time soil-water content should be more than 25% of PAW.

For the Hikurangi scheme, the comparison showed that SPASMO demand is approximately 30% higher than Irricalc for 70mm PAW class (i.e. shallow soils) over the model period (1972 to 2009). However, SPASMO underestimated water requirements, as compared to Irricalc, by 20% and 14% for 130 and 200mm PAW classes (heavy soils). While it is not possible to examine these differences in detail within the scope of this current study, scrutiny of a few periods indicates that SPASMO over-irrigates light soils. For example, SPASMO irrigation water use for the period 17 – 31/12/2009 is 150.4mm (i.e. eight times 18.8mm events). Assuming 80% of that was effective, crop irrigation is 120.3mm. However, crop water evapotranspiration demand (ET_c) for the period was only 86.1mm – i.e. SPASMO irrigation water use was approximately 40% higher than the crop demand. It should be noted that this period was selected as it is unlikely that rainfall or soil-water storage would have affected the water balance assessment.

On the other hand, SPASMO appears to under-irrigate heavy soils. For 106mm PAW soils, it is expected that irrigation would occur when soil-moisture falls below 53mm (i.e. 50% trigger). However, no irrigation has been predicted by SPASMO for the period 19/1 – 6/2/2008 until the deficit falls to 79.8mm – a difference of 26.8mm (79.8-53). It is highly likely that the soil profile is at field capacity following heavy rainfall at beginning of the selected period, and there was no further rainfall following that.

As discussed above, it should be understood, that while SPASMO outputs are appropriate for a feasibility study such as this, it is conceivable that the irrigation daily demands are not precise for some scheme areas. For example, comparison of irrigation demand estimates for the Hikurangi scheme using SPASMO, produced results that were significantly higher for shallow soils and lower for heavy soils, as compared to Irricalc. This means that the demand for Aupouri Peninsula which is dominated by shallow soils may have been overestimated. However, as a full comparison of SPASMO and Irricalc over the entire region was not undertaken, it may be incorrect to directly translate these differences between the two models to other scheme areas with a different climate, as this may change the observed differences. We recommend that a model that simulates pragmatic regional irrigation management practices and produces accurate daily outputs for the water balance calculations are used in the future stages of the project.

10.5 Regulatory Considerations

This report has not considered the current regulatory environment in significant detail due to the current Regional Water and Soil Plan (RWSP) being under review. With the new plan currently in development the opportunity should be taken to ensure that the likely increase in demand and reliability of water is addressed in a manner which will be clearly navigated though by a potential Water Storage Initiative.

Clarity and potential interpretation of rules and regulations is likely to have a major influence on how easily initiatives can be progressed. Likewise this updated plan and its subsequent requirements will have an impact upon the many factors that are considered key for agriculture and horticulture, namely availability of water, and requirements and restrictions place upon land based activities.

There is an opportunity here to ensure a clear concise regulatory environment for irrigators and water infrastructure development through drawing upon lessons and examples from around the rest of New Zealand where applicable to Northland.

The section below highlights an example of where policy could potentially support and stimmy irrigation in an area.

10.5.1 Strategies to enhance irrigation development

The water balance analysis highlights that full potential of irrigation development (i.e. irrigation of all irrigable areas) is unlikely to be realised under the current or proposed policies in many areas due to insufficient water resources. Is likely that the predominant water source for water infrastructure development will be from reservoirs. There is a significant potential for further harvesting and storage of high surface flows within some catchments.

The water balance analysis was undertaken on the basis of harvesting of up to 10% of the flow in a river or stream, when the flow is greater than the median flow (see Section 6.2.1). However, the region experiences significant high flow events that are considerably higher than the median flow – they can be over two magnitudes higher in some catchments. These high flow events also cause flood damage. Therefore, it is recommended that NRC investigates the impact of harvesting a higher percentage of flow at times when flow is greater (subject to the practical limitations of harvesting higher flows). Impact on water availability and irrigable area with harvesting higher flows, as an example for the Awanui scheme, is shown Table 10.1. This shows that harvesting potential and the area that can be reliably irrigated can be substantially enhanced through adopting the proposed policy in Table 10.1.

Table 10.1 – Potential allocation regimes for Awanui area

Allocation policy	Reliable irrigable area (hectares)	Storage capacity (Mm³)
Proposed policy (10% above median)	3,222	12
10% above median + (20% above 2 x median)	6,215	26
10% above median + (20% above 2 x	8,746	40

median) + (30% above 3 x median)		

As only 20% and 30% of the flow is proposed to be harvested when the flow is above twice and thrice the median, respectively, there is sufficient water left in a water body to maintain natural flow variability. Some other regional councils currently use a 1:1 flow sharing of high flows, i.e. abstracting up to 50% of the flow. Given that, we consider that it is important that NRC examines the potential for abstracting high flows up to 30% (3:7 flow sharing). Detailed ecological work needs to be undertaken to assess whether these allocation regimes are appropriate in Northland.

10.6 Individual or Localised Irrigation Initiatives

It is important to understand that this report does not infer that land located outside of the large clustered areas is not suitable for irrigation. The report simply identifies larger areas more likely to deliver wider benefits to the region due to scale.

These smaller areas may support community based schemes or the ability for individual land owners to develop their own infrastructure. There were four distinct areas outside of the later clusters indicated in this report as having potential demand and water availability for irrigation. There will also be other smaller pockets of land scattered across the region as well that could be considered irrigable.

Similarly to the above there may be individual land owners, or communities within the larger clustered areas which elect to develop their own infrastructure or try to source water for irrigation purposes. This may occur due to several reasons however care needs to be taken to ensure that fragmentation does not preclude the development of a larger scheme at a later date.

Understanding the process to investigate and develop potential irrigation infrastructure, whether from an Individual or community basis, is likely to be difficult and unclear. Providing a clear process for interested parties could be of benefit in supporting the smaller opportunities to be developed and benefits realised.

11 Recommendations

This study has shown there is strong evidence that positive economic and authentic social outcomes could eventuate from the tactical application of water resources into primary production in Northland through both infrastructure development and collaborative water management policies. The following recommendations are made for the Northland region.

11.1 Stakeholder engagement

The predominant areas of interest shown from the initial project team panel multi-criteria analysis (MCA) point to initial best likelihood of success in the Mid North and Kaipara districts. In particular, benefits will arise from labour intensive horticultural land use options built on the back of the successful current sector activities.

Recommendation 1:
A wider community stakeholder panel should be engaged for a further MCA round to enable more in-depth identification of co-benefits and challenges within and between the areas of interest and to establish community ownership of future water management solutions.

11.2 Detailed investigations needed

It is necessary to consider the timescale over which developments could occur which is primarily driven by uptake – a measure of the number of water users that connect to a scheme and commit to land use change to utilise the water supply. A slow uptake is likely to mean a delay in reaching a positive return on the investment and that will affect investor appetite to take on risk.

To better match infrastructure investment to uptake it may be necessary to consider a method of staged development whereby only the parts are built that match the rate of demand. This may be a less efficient method and hence more expensive overall but might make the difference between a scheme being developed or not.

To achieve this staged development, a "masterplan" style of reasoning should be adopted which facilitates small sections or individual development needs without risking fragmentation leading to the failure of achieving an optimum community outcome.

Recommendation 2:
Undertake a further level of investigation prioritised into the indicated areas of interest to determine a provisional development masterplan. This will build on current project phase to investigate:

- Potential "irrigation water storage and supply scheme" options i.e. plumbed together;
- Possible "global management of water allocation consents" i.e. managed together;

- Existing schemes that could be upgraded, extended or redeveloped; and
- Increasing land use uptake with e.g. share-cropping variant.

Recommendation 3
Limitations associated with elements of study have been identified – e.g. quality of the input data and the NRC SPASMO model. Need to adopt a suitable allocation model to be used for future water management, or the SPASMO model needs to be corrected.

11.3 Case studies at a farm level

Uptake often hinders progress. To assist individual water user uptake decisions processes to maximise optimum water management potential a number of case studies could be prepared or model farms established to determine benchmark data.

These will demonstrate the effect of full or partial irrigation or land use change in horticulture and pastoral situations. They will include assessment of effectiveness of current irrigation against the adoption of advanced irrigation methods.

Recommendation 4:
Undertake case studies on selected indicator farms.

Recommendation 5:
Establish model irrigated farm and report on benchmarking data.

11.4 Prioritisation of water use and regulatory framework

It is necessary to establish, where absent, or use, where available, a clear policy processes to support water management initiatives. After human consumption and environmental flow requirements it will be necessary to allocate water according to the potential to provide the social and economic benefits to the local and regional community.

The best decisions on water resource management will occur in a policy environment that considers regional level or community level issues and avoids allocation and management decisions based solely on individuals' priorities.

The wider water resource policy environment will need to consider the specific issues of irrigation storage and distribution infrastructure development. There is the opportunity to adopt and adapt NZ best practice from other schemes.

Water management policy will necessarily reflect not only the economic and employment drivers indicated in this report as key outcome for Northland but also the complex and sometime competing community requirements for environmental flows, water quality standards and cultural (iwi) rights and interests. These complex interfaces between water, land and the people who value the resource have been widely debated and commented on by the Land and Water Forum. The recently released 4th LaWF Report (Nov 2015) encapsulates a number of strong recommendations to Central Government on freshwater management and a national objectives framework aimed to help inform local and regional policy development.

Recommendation 6:
Review current or draft water management policies and future review to reflect long term community outcomes, adopting a multi-criteria analysis for economic, community, environmental and cultural factors that properly considers the utilisation of irrigation infrastructure and/or collaborative water management units as tools.

11.5 Funding and development entity models

It is necessary to consider in principle the investment required in any significant scale infrastructure necessary as an instrument to allow the economic and social benefits to be realised.

Based on knowledge of similar developments in New Zealand and Australia it can be assumed that water supply and storage schemes in Northland may cost in the order of $10-20,000 per hectare and on-farm infrastructure in the order of $5,000 per hectare.

This represents a significant sum if the whole of 19,000 hectares of new horticultural land and a proportion of the pasture land is funded – possibly up to a combined total of $500M.

This “one off” investment of course needs to be seen in the light of the estimated annual GDP return of around $200M per annum.

The reality is that a one off investment of that magnitude would be difficult to fund solely by the main recipients i.e. the water users themselves, despite being the initial primary benefactors.

The social benefit and likely environmental benefit could be argued to have a wider community obligation that extends to consideration by both central and regional government to be partners in any future development.

If a combination of public and private equity is to be called upon, whether supported by debt funding or not, the infrastructure development(s) will require eventual consideration of organisational structure, governance and financial models that recognise the risks allocation and benefits to all parties.

A number of models have been attempted in New Zealand irrigation schemes to lesser or greater levels of success in the past and recently.

These include historic total government funded schemes but more recently the models are more likely to be farmer lead companies which attract share investment or equity partnerships including public sector investments.

Recommendation 7:
Undertake an ‘options analysis’ to determine possible funding and entity models to meet the likely capital intensive first phases of any community scheme solutions.

11.6 Employment ready workforce

There will be some challenges to overcome with future developments not the least being the preparation of the yet-to-be-employed labour force to meet the seasonal and long term requirements at both skilled and non-skilled levels.

This will present opportunities for skills development programmes and other employment support initiatives including improving the transport and communication links between the labour source and the demand areas.

Given the community make-up in Northland this is likely to need to include the skills and resources offered from iwi as development partners.

It is assumed an element of education will be required for the owner/manager of any infrastructure required.

Recommendation 8:
Undertake a skills audit and corresponding 'preparation for employment' study to match the workforce to the likely sector requirements and establish any necessary training programmes, transportation linkages and incentives programmes.

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Appendix A Stakeholder Engagement

Table A.1 – Stakeholder engagement

Organisation	Point of Contact
Agri-specialists	Rod Hodgson
Dairy NZ	Chris Neil
Federated Farmers	Rodger Ludbrook
FNDC	Kathryn Ross
Fonterra	Carly Robinson
Hikurangi Plains Water	Evan Smeath
Horticulture NZ	Chris Keenan
Individual	Harry Burkhardt
Individual	Ben Dalton
Individual	Peter Cooper
Individual	Naida Glavish
Individual	Jim Peters
Individual	Haami Piripi
Individual	Allan Pivac
Individual	Rawson Wright
Individual	Mike Stevens
Irrigation NZ	Andrew Curtis
Kauri Coast Water	Allister McCahon
KDC	Anna Curnow
Kerikeri Irrigation Limited	Bill hunter
Landcorp	Gordon Williams
Maungatapere Irrigation Limited	John Wiessing
MSD	Eru Lyndon
Northash	Hamish Davidson
Northland Agriculture Forum	Julie Jonker
Northland Aquaculture working group	Andrew Forsythe
Northland Dairy Development Trust	Penny Smart
Northland Economic Action Group	Graham Dawson
Northland Horticulture Forum	Patrick Malley

Organisation	Point of Contact
Northland Inc	David Wilson
Northport	John Moore
Northpower	Russell Watson
Rabobank	Tafi Manjela
Rural Support Trust	Julie Jonker
Te Taitokerau Maori Agriculture Forum	Hemi Toia
Top Energy	Russell Shaw
Vegetables New Zealand	Andre Burns
WDC	Jude Thompson
Westpac	Rod Pakinson

Figure A.1 – Stakeholder engagement questionnaire

NORTHLAND STRATEGIC WATER INFRASTRUCTURE STUDY STAKEHOLDER QUESTIONNAIRE

OPUS

NORTHLAND REGIONAL COUNCIL

Opus has been commissioned to undertake a region wide strategic water infrastructure study on behalf of Northland Regional Council, in conjunction with the Ministry of Primary Industries (MPI) Irrigation Acceleration Fund (IAF). The purpose of the study is to determine where improved water infrastructure (including water storage and distribution networks) could support tactical water use in agricultural production while achieving authentic community outcomes.

While the study has a primary focus on irrigable land, it will consider other potential areas of demand and benefits in those proximities. The combination of these uses of water will be used to identify spatial locations of one or more areas that have technical, environmental and financial merit for further investigation.

In undertaking this initial region wide assessment, we would like your help. Your opinion is a first step on a long consultation journey which will ultimately result in effective collaboration and engagement.

Respondent Details

Respondent:

Email:

Phone:

What is your organisation's, or sector you represent, particular use(s) of water, e.g. agriculture, drinking water, industry, etc.?

How important is a reliable water supply to your organisation's, or sector you represent, particular uses?

1 (low) ○ 2 ○ 3 ○ 4 ○ 5 ○ 6 ○ 7 ○ 8 ○ 9 (high) ○

What level of reliability of supply is required by your organisation's, or sector you represent, particular uses, expressed in terms of the ability to access water over the peak water demand periods?

60% ○ 65% ○ 70% ○ 75% ○ 80% ○ 85% ○ 90% ○ 95% ○ 100% ○

To what extent do you believe demand for your organisation's, or sector you represent, particular uses of water is going to change over the next 20 years?

Reduce ○ Stay the same ○ Increase by 25% ○ Increase by 50% ○ Double or more ○

Would your organisation, or sector you represent, support investment to improve water infrastructure in Northland?

1 (low) ○ 2 ○ 3 ○ 4 ○ 5 ○ 6 ○ 7 ○ 8 ○ 9 (high) ○

If yes (to the previous question), please describe the possible ways in which you perceive your organisation, or sector you represent, would likely support such investment.

To what extent do you think improving water infrastructure to increase the availability and reliability of the water resource will influence Northland in regards to:

Economic outcomes?	1 (low) ○	2 ○	3 ○	4 ○	5 ○	6 ○	7 ○	8 ○	9 (high) ○
Social objectives?	1 (low) ○	2 ○	3 ○	4 ○	5 ○	6 ○	7 ○	8 ○	9 (high) ○
Cultural interests?	1 (low) ○	2 ○	3 ○	4 ○	5 ○	6 ○	7 ○	8 ○	9 (high) ○
Environment protection?	1 (low) ○	2 ○	3 ○	4 ○	5 ○	6 ○	7 ○	8 ○	9 (high) ○

What specific benefits can you see for your organisation, or sector you represent, from improving water infrastructure in Northland?

What specific benefits can you see for the wider Northland community resulting from water infrastructure in Northland?

What challenges and/or road blocks do you perceive to improving water infrastructure in Northland?

Any other comments?

Please indicate your level of interest in this study and willingness to be engaged in the investigation process?

1 (low) ○ 2 ○ 3 ○ 4 ○ 5 ○ 6 ○ 7 ○ 8 ○ 9 (high) ○

SUBMIT SURVEY

Or please return to Chris Frost at Opus International Consultants Limited
e. Chris.Frost@opus.co.nz
t. 02108156443

Appendix B Water Take Consents

This Appendix presents breakdown of consents, particularly irrigation consents by source, use type, and consented take rate and volumes.

Table B.1 – Current consent number by purpose and source

Purpose	Consent numbers (no.)						Total
	Bore	Dam	Diversion	Geothermal	Lake	Run-of-stream	
Drinking	74	8			3	51	136
Industrial	18	3			1	9	31
Irrigation	153	42			3	123	321
Other	15	8	15	1		8	47
Total	**260**	**61**	**15**	**1**	**7**	**191**	**535**

Table B.2 – Allocated water for current consents by purpose

Water demand category	Consent numbers	Daily volume (m^3/d)	Take rate (l/s)
Drinking	136	154,672	1,790
Industrial	31	25,563	296
Irrigation	321	515,290	5,964
Other	47	19,028	220
Total	**535**	**714,554**	**8,270**

Table B.3 – Allocated irrigation water by source

Source	Rate (l/s)	Daily volume (m^3/d)
Bore	314	27,134
Dam	2,814	243,161
Lake	6	479
River/stream/spring	2,830	244,517
Total	**5,964**	**515,290**

Table B.4 – Allocated irrigation water by type

Type of crop/irrigation	Rate (l/s)	Daily volume (m^3/d)
Arable/Crop	65	5,583
Floriculture	10	840
Frost Protection	7	605
Horticulture	3,232	279,227
Nursery	5	437
Pasture	2,548	220,177
Recreational/Sports	82	7,067
Vegetables/Market Garden	16	1,356
Total	**5,964**	**515,290**

Appendix C Land Use Capability

Table C.1 – Description of Land Use Capability (LUC) classes

LUC Class	Description*
1	Land with virtually no limitations for arable use and suitable for cultivated crops, pasture or forestry
2	Land with slight limitations for arable use and suitable for cultivated crops, pasture or forestry
3	Land with moderate limitations for arable use, but suitable for cultivated crops, pasture or forestry
4	Land with moderate limitations for arable use, but suitable for occasional cropping, pasture or forestry
5	High producing land unsuitable for arable use, but only slight limitations for pastoral or forestry use
6	Non-arable land with moderate limitations for use under perennial vegetation such as pasture or forest
7	Non-arable land with severe limitations to use under perennial vegetation such as pasture or forest
8	Land with very severe to extreme limitations or hazards that make it unsuitable for cropping, pasture or forestry

* As given in Landcare (2008)

Table C.2 - Areas (ha) of Land Use Capability (LUC) classes in the Northland Region

LUC Class	Area (ha)	Percentage area
1	435	0.03%
2	36,126	2.9%
3	91,166	7.3%
4	301,772	24.2%
5	8,292	0.7%
6	614,430	49.2%
7	153,956	12.3%
8	30,183	2.4%
Other	11,616	0.9%
Total area (ha)	**1,247,977**	**100%**

Table C.3 - Areas (ha) of Land Use Capability (LUC) classes by command area.

No.	Command Area	Area (ha)								
		LUC Class								Total irrigable area
		1	2	3	4	5	6	7	8	
1	Aupouri Peninsula	-	-	3,245 (7.3%)	10,128 (22.9%)	-	8,764 (19.8%)	19,072 (43.1%)	3,085 (7%)	44,294
2	Awanui Plains	-	7,697 (33.5%)	7,713 (33.5%)	5,134 (22.3%)	716 (3.1%)	1,588 (6.9%)	142 (0.6%)	-	22,991
3	Kerikeri	-	1,222 (9.2%)	5,796 (43.9%)	4,744 (35.9%)	163 (1.2%)	1,289 (9.8%)	-	-	13,215
4	Waimate North	92 (0.4%)	1,709 (7.9%)	4,211 (19.4%)	9,138 (42.2%)	64 (0.3%)	6,443 (29.7%)	-	-	21,657
5	Kaikohe	-	2,123 (9.6%)	4,897 (22.1%)	8,760 (39.6%)	848 (3.8%)	5,483 (24.8%)	-	-	22,111
6	Waimamaku	-	464 (12.1%)	227 (5.9%)	2,392 (62.6%)	-	740 (19.3%)	-	1 (0.03%)	3,824
7	Hikurangi	-	66 (0.2%)	6,690 (21.9%)	19,786 (64.6%)	-	3,442 (11.2%)	630 (2.1%)	-	30,614
8	Glenbervie	-	-	1,824 (46.1%)	1,997 (50.4%)	-	137 (3.5%)	-	-	3,958
9	Mangakahia	-	-	385 (3.9%)	7,619 (76.6%)	-	1,933 (19.4%)	4 (0%)	-	9,941
10	Maungatapere	-	1,218 (9.8%)	1,726 (13.8%)	6,604 (52.9%)	320 (2.6%)	2,475 (19.8%)	136 (1.1%)	-	12,478
11	Maungakaramea	162	1,218	1,942	10,570	-	4,588	-	-	18,480

No.	Command Area	Area (ha)								
		LUC Class								Total irrigable area
		1	2	3	4	5	6	7	8	
		(0.9%)	(6.6%)	(10.5%)	(57.2%)		(24.8%)			
12	Ruakaka	-	100 (1.7%)	4,077 (69.6%)	1,211 (20.7%)	-	467 (8%)	4 (0.1%)	-	5,859
13	Waipu	-	1,828 (22%)	1,571 (18.9%)	3,906 (47%)	-	984 (11.8%)	18 (0.2%)	-	8,307
14	Kaihu	-	347 (7.6%)	696 (15.2%)	2,949 (64.4%)	-	588 (12.8%)	-	-	4,580
15	Hoanga	-	1,534 (49.7%)	688 (22.3%)	840 (27.2%)	-	24 (0.8%)	-	-	3,086
16	North Kaipara	-	5,139 (19.6%)	5,648 (21.5%)	12,911 (49.2%)	-	2,361 (9%)	158 (0.6%)	-	26,218
17	Ruawai	-	6,471 (49.5%)	2,729 (20.9%)	3,700 (28.3%)	44 (0.3%)	116 (0.9%)	-	-	13,059
18	Mangawhai	-	114 (1.4%)	1,896 (23.1%)	6,116 (74.4%)	-	68 (0.8%)	25 (0.3%)	7 (0.08%)	8,226
Note: The values in brackets show the LUC class as a percentage of total irrigable area of the command area										

Appendix D Soils

Table D.1 - Soil PAW Classes

No.	Area	Area (ha)					
		PAW Class (mm/m)					Total irrigable area
		70	100	130	150	200	
1	Aupouri Peninsula	22,019	16,749	2,477	-	3,093	44,338
2	Awanui Plains	5,028	5,917	-	-	12,072	23,017
3	Kerikeri	-	1,279	-	-	11,947	13,226
4	Waimate North	1,946	3,363	4,216	-	12,151	21,675
5	Kaikohe	796	4,525	-	1,417	15,394	22,133
6	Waimamaku	-	1,499	-	-	2,329	3,829
7	Hikurangi	8,256	-	6,063	-	16,318	30,637
8	Glenbervie	-	413	773	-	2,775	3,960
9	Mangakahia	-	1,494	-	-	8,456	9,950
10	Maungatapere	-	-	3,132	-	9,356	12,488
11	Maungakaramea	1,127	2,353	-	1,063	13,951	18,494
12	Ruakaka	-	-	272	-	5,590	5,862
13	Waipu	-	-	-	-	8,312	8,312
14	Kaihu	777	1,477	-	-	2,332	4,585
15	Hoanga	224	2,115	-	-	750	3,089
16	North Kaipara	7,314	18,928	-	-	-	26,242
17	Ruawai	-	10,557	-	-	2,513	13,070
18	Mangawhai	868	2,301	-	-	5,061	8,230

Note: The areas given above for the total irrigable area. These values may not exactly match with the values listed in Column 4 in Table 3.3. This is because the spatial areas within different GIS layers (e.g. soils, LUC, LCDB) used for this study contain minor inconsistencies.

Appendix E Climate Stations

Table E.1 - Climate station used for different areas

Area	Climate station
Aupouri Peninsula	Houhora
Awanui Plains	Kaitaia
Kerikeri	Kerikeri
Waimate North	Kerikeri
Kaikohe	Kaikohe
Waimamaku	Hokianga
Hikurangi	Hikurangi
Glenbevie	Hikurangi
Mangakahia	Whangarei
Maungatapere	Whangarei
Maungakaramea	Whangarei
Ruakaka	Whangarei
Waipu	Whangarei
Kaihu	Dargaville
Hoanga	Dargaville
North Kaipara	Dargaville
Ruawai	Ruawai
Mangawhai	Leigh

Appendix F Irrigation Water Demand

Table F.1 – Northland census area unit locations

Table F.2 – 90th percentile annual irrigation demands by crop and soil type

Area	Total irrigable area (ha) PAW Class (mm/m)					Net irrigable area (%)	Crop	% crop area (%)	90th percentile annual demand (mm/yr) PAW Class (mm/m)					90th percentile annual area demand (Mm³/yr)
	70	100	130	150	200				70	100	130	150	200	
Aupouri Peninsula	22,019	16,749	2,477		3,093	60	Avocado	40	907	581	529	562	511	190.9
							Citrus	30	601	529	453	479	390	
							pasture	20	1,094	636	626	627	576	
							Potato	10	996	754	736	699	652	
Awanui Plains	5,028	5,917		-	12,072	75	Pasture	40	946	522	510	513	453	98.0
							Potato	30	877	676	651	603	549	
							Citrus	20	493	423	351	373	276	
							Lettuce	10	868	701	698	606	590	
Kerikeri	-	1,279		-	11,947	80	Kiwifruit	40	683	541	484	527	455	36.9
							Citrus	30	423	361	297	318	237	
							Pasture	20	869	460	443	442	385	
							Grapes	10	238	222	129	197	85	
Waimate North	1,946	3,363	4,216		12,151	80	Citrus	40	423	361	297	318	237	73.0
							Kiwifruit	30	683	541	484	527	455	
							Potato	20	806	620	593	555	506	
							Pasture	10	869	460	443	442	385	
Kaikohe	796	4,525		1,417	15,394	80	Avocado	35	655	375	320	350	295	60.4
							Citrus	25	372	312	236	266	186	
							Kiwifruit	20	645	481	437	469	407	
							Potato	10	747	551	544	500	437	
							Pasture	10	813	403	394	389	325	
Waimamaku		1,499	-	-	2,329	80	Pasture	100	1,004	524	512	514	462	14.9
Hikurangi	8,256		6,063		16,318	60	Pasture	100	818	437	428	425	364	91.7
Glenbervie		413	773	-	2,775	60	Avocado	60	673	400	358	382	324	7.1
							Citrus	40	403	345	276	300	214	

Area	Total irrigable area (ha) PAW Class (mm/m)					Net irrigable area (%)	Crop	% crop area (%)	90th percentile annual demand (mm/yr) PAW Class (mm/m)					90th percentile annual area demand (Mm³/yr)
	70	100	130	150	200				70	100	130	150	200	
Mangakahia		1,494		-	8,456	60	Pasture	100	795	397	386	383	318	19.7
Maungatapere			3,132	-	9,356	80	Avocado	60	675	363	320	348	287	31.9
							Kiwifruit	30	655	476	425	466	403	
							Citrus	10	375	308	234	300	178	
Maungakaramea	1,127	2,353		1,063	13,951	75	Avocado	50	675	363	320	348	287	53.9
							Potato	30	735	535	530	491	435	
							Kiwifruit	20	655	476	425	466	403	
Ruakaka		-	272	-	5,590	80	Pasture	100	795	397	386	383	318	15.1
Waipu				-	8,312	80	Pasture	100	795	397	386	383	318	21.1
Kaihu	777	1,477		-	2,332	80	Pasture	100	969	508	503	505	456	20.5
Hoanga	224	2,115		-	750	80	Pasture	60	969	508	503	505	456	11.9
							Kumara	40	496	456	423	423	269	
North Kaipara	7,314	18,928		-		75	Pasture	30	969	508	503	505	456	118.0
							Potato	30	867	643	627	589	540	
							Kumara	30	496	456	423	423	269	
							Avocado	10	798	481	433	454	410	
Ruawai		10,557	-		2,513	80	Pasture	60	1,013	552	542	539	491	53.0
							Kumara	40	524	492	462	455	306	
Mangawhai	868	2,301	-	-	5,061	60	Avocado	50	837	511	457	488	439	17.4
							Grapes	30	295	282	180	249	133	
							Olives	20	367	333	263	290	148	

Note: The water demands shown above are for irrigating the total irrigable area within a command area, if water is not a constraint. Table 6.1 lists a summary of potential irrigable area based on available water resources to meet the required irrigation supply-demand reliability.

Appendix G Flow data availability and correlation

This Appendix lists a summary of available flow data and estimated flow statistics.

Table G.1 – Flow data availability by hydrometric station

Site number[#1]	Hydrometric station	Record start day	Record end day	Number of records (days)	Number of gaps (days)
1	Selwyn Swamp at Big Flat Rd (Aupouri)	-	-	0	-
2	Whangatane at Spillway	2/02/2007	10/09/2015	3,141	2
3	Awanui at Waikuruki	5/04/1990	5/02/1992	628	44
4	Te Puhi at Meffin Rd	14/08/2009	10/09/2015	2,216	3
5	Awanui (NIWA) at School Cut	14/07/2000	10/09/2015	5,431	106
6	Victoria at Double Crossing	5/04/1990	23/04/1992	728	22
7	Tarawhataroa at Puriri Place	2/02/2007	10/09/2015	3,139	4
8	Victoria at Thompson Br.	1/04/1990	23/04/1992	754	-
9	Victoria at Victoria Valley Road	18/08/2006	10/09/2015	3,299	12
10	Takahue at Diggers Valley Rd Br	28/06/1990	28/05/1994	795	636
11	Takahue at Grays	14/08/2009	10/09/2015	2,203	16
12	Rangitane at Tubbs	16/07/1977	30/10/2001	7,966	907
13	Rangitane at Stirling	11/07/2007	10/09/2015	2,967	17
14	Waipapa at Pungaere Rd	20/09/1975	26/06/1996	1,308	6,278
16	Waipapa at Landing	15/07/1977	3/03/1981	1,328	-
17	Kerikeri at Peacock Garden	21/11/2001	11/09/2015	4,242	801
20	Maungaparerua at Tyrees Ford	19/11/1999	11/09/2015	5,040	736
21	Puketotara at Backblocks	11/09/1975	31/01/1989	4,168	724
22	Waitangi at Wakelins	21/11/2001	11/09/2015	5,007	36
23	Waitangi at Waimate North Rd	2/10/2011	11/09/2015	1,429	12
24	Waitangi at SH10	21/05/2014	10/09/2015	440	38
26	Waiaruhe at Puketona	3/02/1984	12/05/2014	6,448	4,609
27	Waikaka at Totara Trees Weir	12/01/1989	30/10/1996	2,796	53
28	Te Tunaotemaku at Rock Weir	7/01/1989	25/11/1992	1,418	1
29	Punakitere at Taheke	3/10/1999	11/09/2015	5,767	56
31	Waiotu at SH1 Br	16/07/2006	11/09/2015	3,343	2
32	Whakapara at Cableway	28/02/2002	11/09/2015	4,930	14
33	Mangakahia at Gorge	19/11/1999	11/09/2015	5,551	225
35	Mangahahuru at County	29/07/2006	11/09/2015	3,330	2

Site number[#1]	Hydrometric station	Record start day	Record end day	Number of records (days)	Number of gaps (days)
	Weir				
36	Hikurangi at Moengawahine	8/09/2006	11/09/2015	3,281	10
37	Ngunguru at Kiripaka	20/10/2011	6/11/2014	1,114	-
38	Wairua at Purua	22/04/2009	11/09/2015	2,320	14
39	Opouteke at Suspension Br	3/10/1999	11/09/2015	5,767	56
40	Mangere at Knights Rd	12/11/2006	11/09/2015	3,221	5
41	Hatea at Whareora Rd	19/09/2007	11/09/2015	2,913	2
42	Waipao at Draffins Rd	15/11/2006	10/09/2015	3,212	10
43	Wairua at Wairua Br	8/09/1961	1/09/2014	19,148	204
44	Mangakahia at Titoki Br	3/10/1999	11/09/2015	5,759	64
45	Kaihu at Gorge	3/10/1999	11/09/2015	5,785	38
46	Otaika at Kay	29/01/2011	11/09/2015	1,665	22
47	Ruakaka at Flyger Rd	14/10/2006	11/09/2015	3,132	123
48	North at Applecross Rd	3/10/1999	11/09/2015	5,806	17
49	Millbrook at Millbridge Rd	19/11/1982	4/12/1984	684	63
50	Ahuroa at Braigh Flats	3/10/1999	11/09/2015	5,745	78
51	Waihoihoi at St Marys Rd	10/12/2007	10/09/2015	2,798	34
52	Waionehu at McLean Rd	14/10/2006	18/06/2015	3,149	21
53	Ahuroa at Durham Rd	1/05/1981	27/06/1997	5,568	334
54	Hakaru Trib. at Brown S.3	7/05/1988	24/04/1995	2,544	-
55	Hakaru Trib. at Pacific Orchard S.16	12/05/1988	22/04/1993	1,807	-
56	Hakaru at Topuni Creek Farm	2/10/2013	8/09/2015	497	210
	Awanui (NIWA) Back Up Water Level	12/02/2013	11/09/2015	940	2
	Kaihu at Rotu	1/06/1977	15/09/1980	1,164	39
	Kirikiri at Cheviot St Footbridge	3/07/2014	10/09/2015	420	15
	Waipapa at Forest Ranger	1/12/2001	11/09/2015	4,984	49
	Waipoua at SH12	1/06/2007	14/05/2013	2,145	30

[#1] Locations of the hydrometric sites are shown in Figure 5.1

Table G.2 – Estimated flow statistics at approximate intake locations for reservoirs

Area - Storage		Approximate location	NZ Reach number#1	Flow (m^3/s) Mean	Flow (m^3/s) Median
Awanui Plains		Awanui River above school	1003890	5.45	3.97
Kerikeri	Puketotara	Puketotara at Backblocks	1006712	1.08	0.75
Kerikeri	Waipapa	Waipapa at Pungaere Rd	1005752	0.60	0.46
Waimate North	Upper	Waitangi at Waimate North Rd	1008074	1.66	0.99
Waimate North	Lower	Confluence of Waitangi and Waiaruhe	1008048	6.59	3.27
Kaikohe		Punakitere above Taheke	1011883	4.77	2.69
Waimamaku		Waimamaku	1014196	3.61	1.92
Hikurangi	Upper	Confluence of Waiotu and Whakapara	1014436	10.7	6.9
Hikurangi	Lower	Wairua above Purua	1016617	21	12.5
Glenbervie		Hatea above Whareora Rd	1017464	1.3	0.75
Mangakahia	East	Hikurangi below Moengawahine confluence	1016863	5.9	2.8
Mangakahia	West	Confluence of Opouteke and Mangakahia	1016892	15.4	8.9
Maungatapere		Wairua at Wairua Br	1018572	19.6	11.9
Maungakaramea		Maungakaramea catchment	1020820	1.16	0.89
Ruakaka		Ruakaka at Flyger Rd	1021503	0.95	0.35
Waipu		Confluence of Ahuroa-Millbrook	1023446	1.51	0.87
Kaihu		Kaihu at Gorge	1019201	4.0	2.52
Hoanga		Hoanga East catchment above scheme	1020608	5.0	2.7
North Kaipara		Confluence of Wairua and Hikurangi	1019899	44.8	26.4
Ruawai		Confluence of Wairua and Hikurangi	1019899	44.8	26.4
Mangawhai		Hakaru above Topuni Cr Farm	1026117	1.2	0.55

Appendix H Storage

This Appendix presents the approximate locations of the intake or instream reservoirs considered along with storage volume hydrographs and consecutive irrigation deficit days.

Awanui Plains Area

Figure H.1 – Approximate location of intake for water harvesting or instream dam for the Awanui Plains Area

Figure H.2 – Storage hydrograph for the Awanui Plains Area

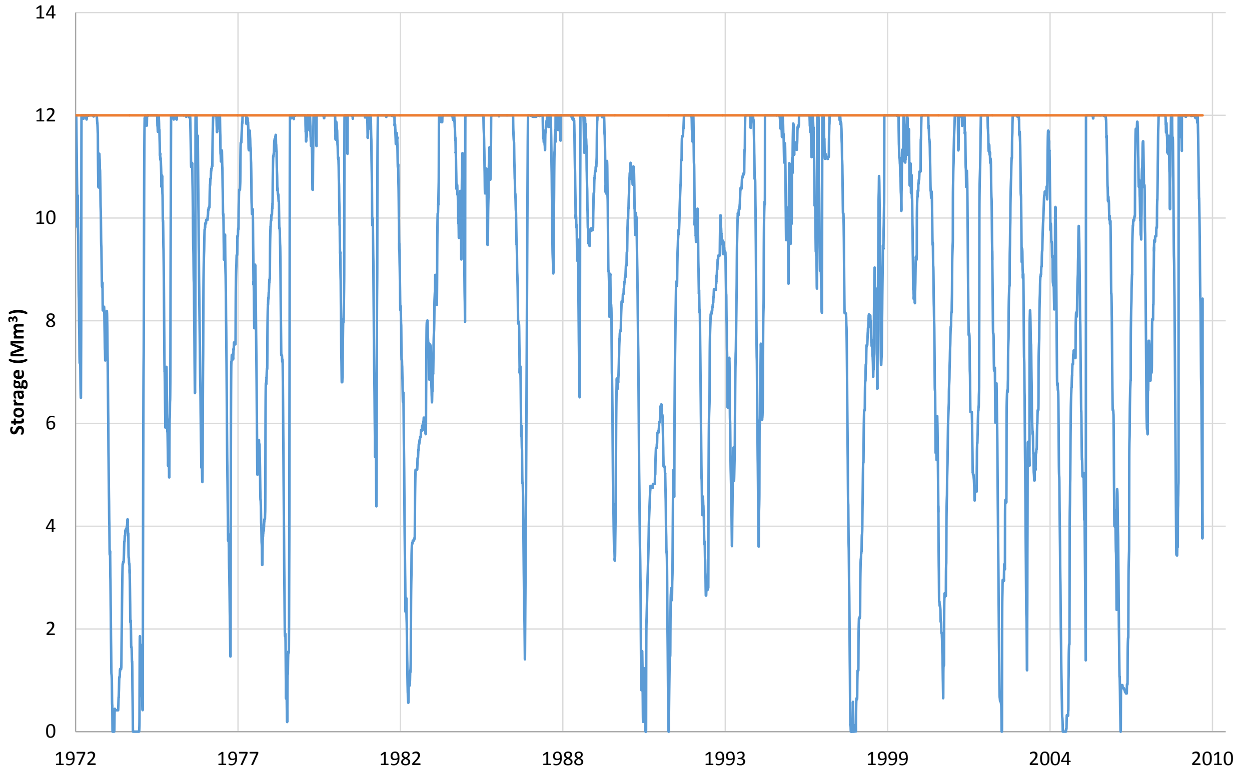
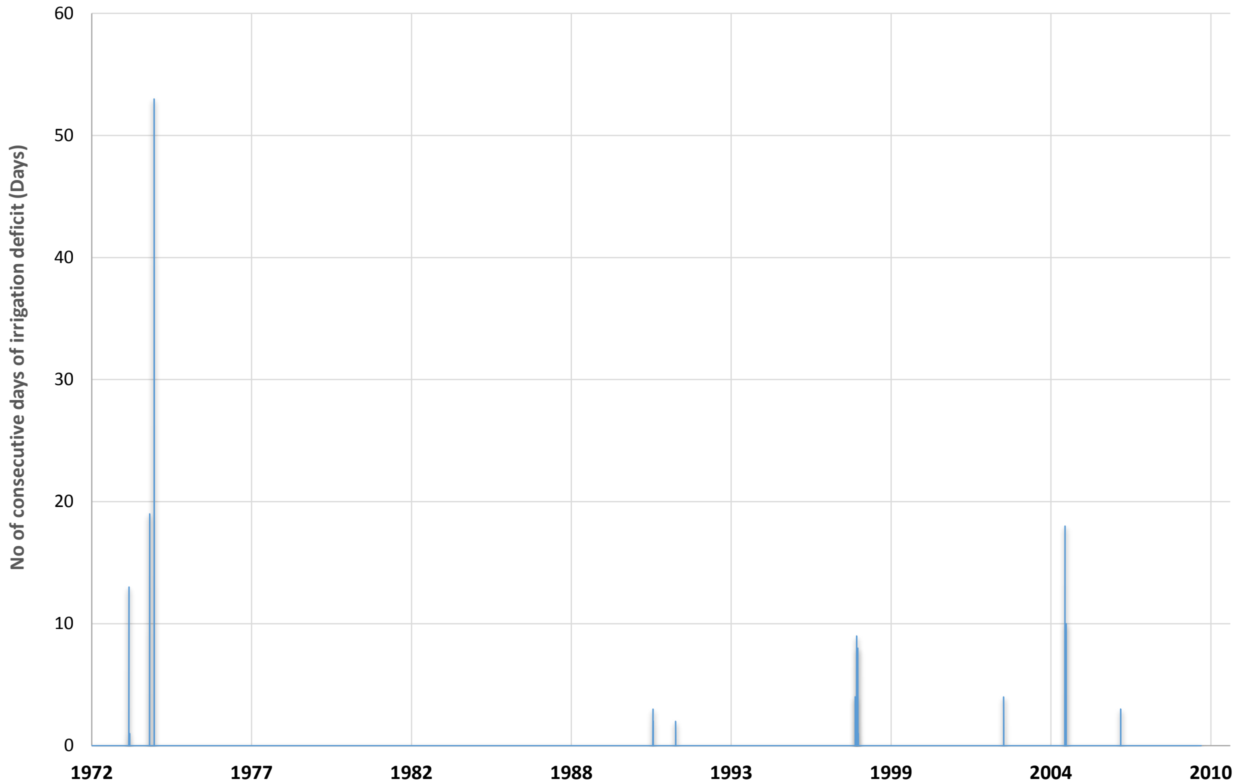


Figure H.3 – Irrigation supply deficit days for the Awanui Plains Area



Kerikeri Area

Figure H.4 – Approximate locations of intakes for water harvesting or instream dams for the Kerikeri Area

Figure H.5 – Puketotara storage hydrograph in the Kerikeri Area

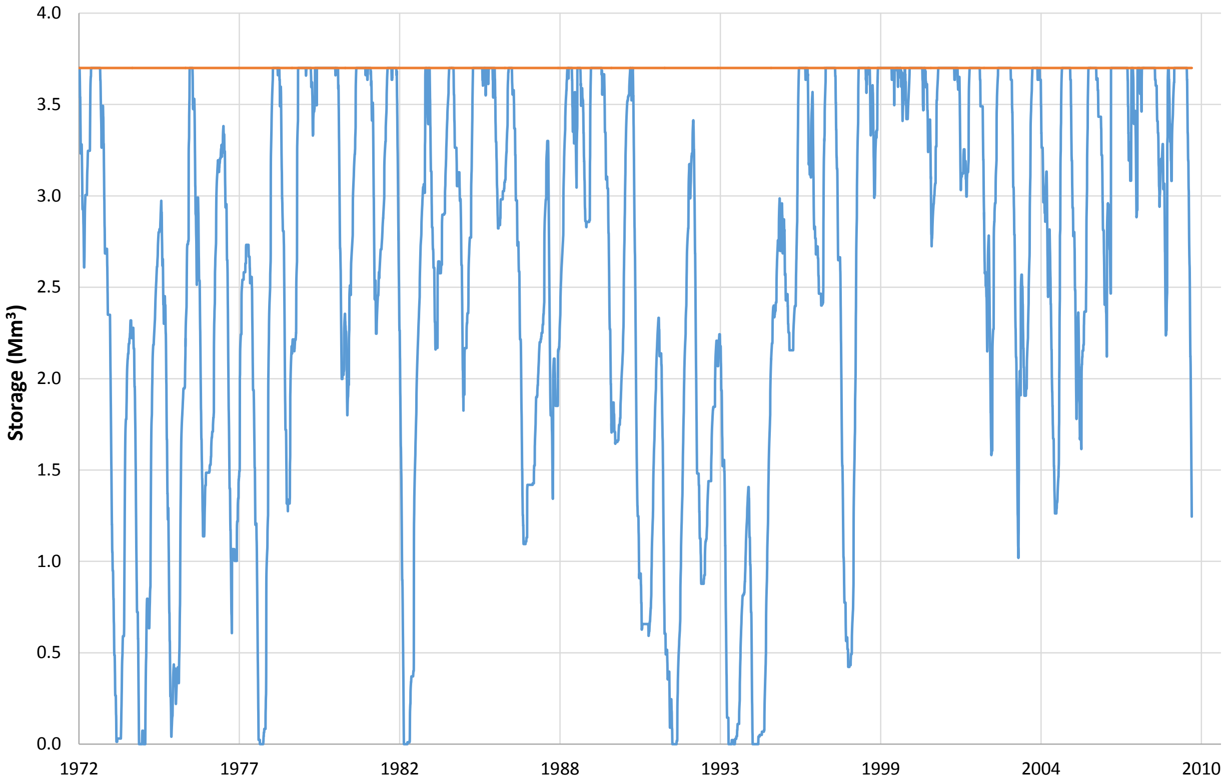


Figure H.6 – Waipapa storage hydrograph in the Kerikeri Area

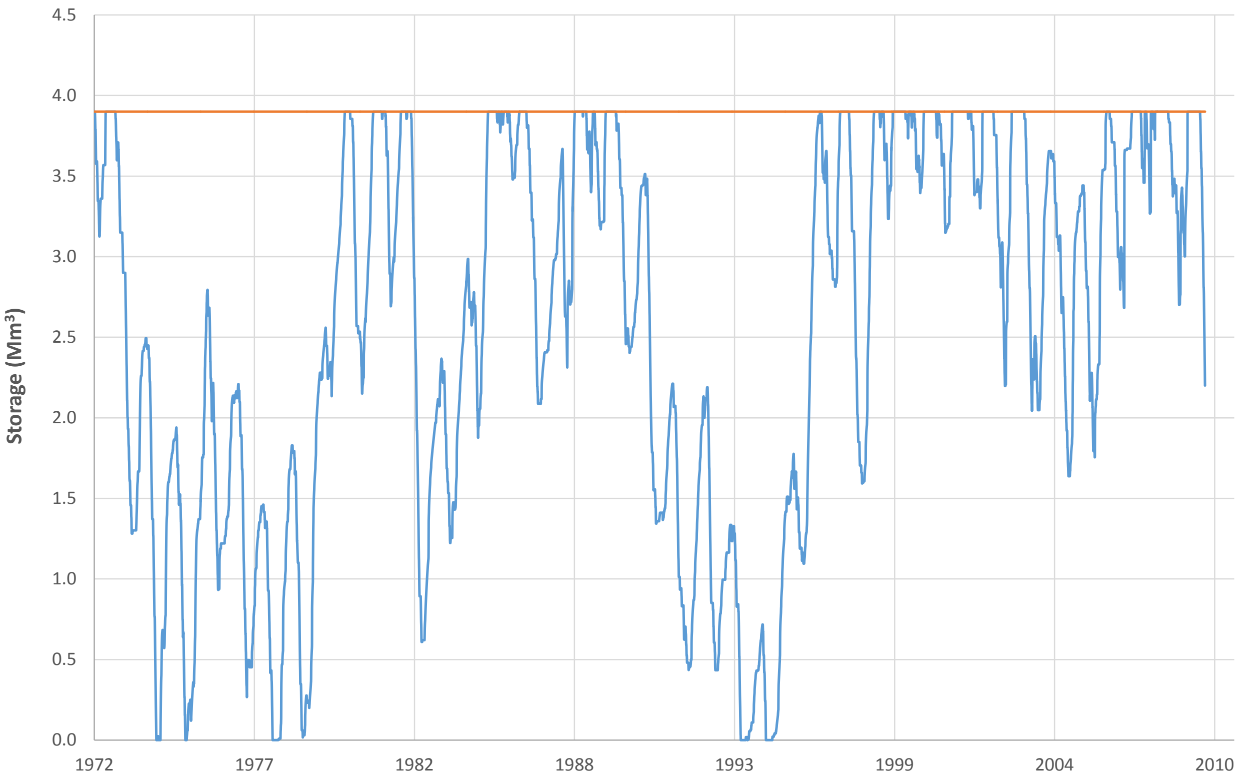


Figure H.7 – Irrigation supply deficit days for the area supplied by the Puketotara storage in the Kerikeri Area

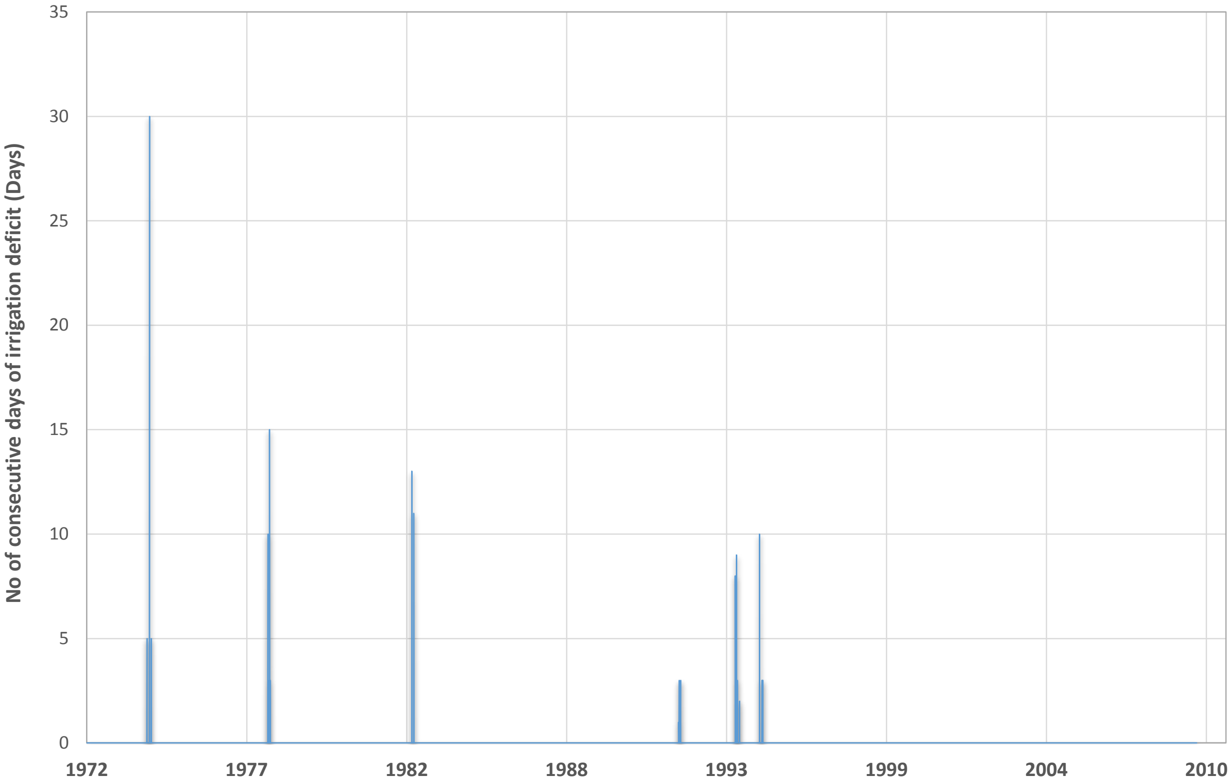
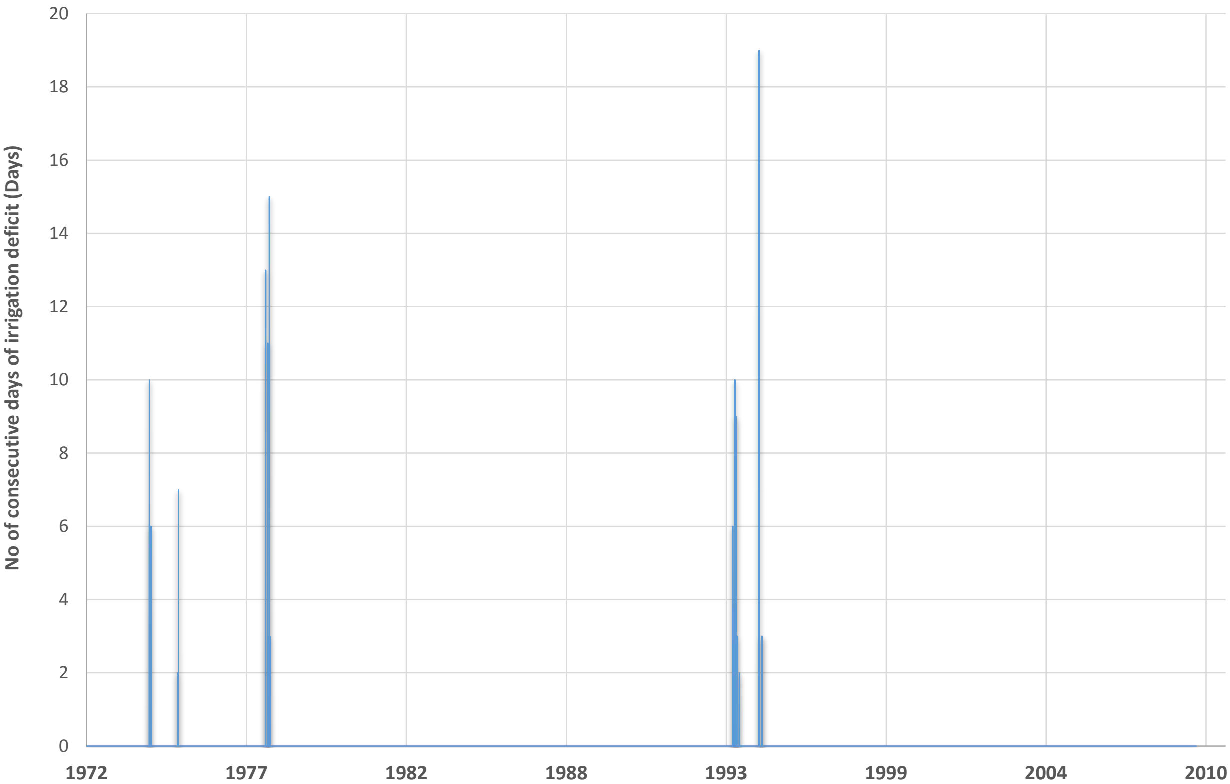


Figure H.8 – Irrigation supply deficit days for the area supplied by the Waipapa storage in the Kerikeri Area



Waimate North Area

Figure H.9 – Approximate locations of intakes for water harvesting or instream dams for the Waimate North Area

Figure H.10 – Upper storage hydrograph in the Waimate North Area

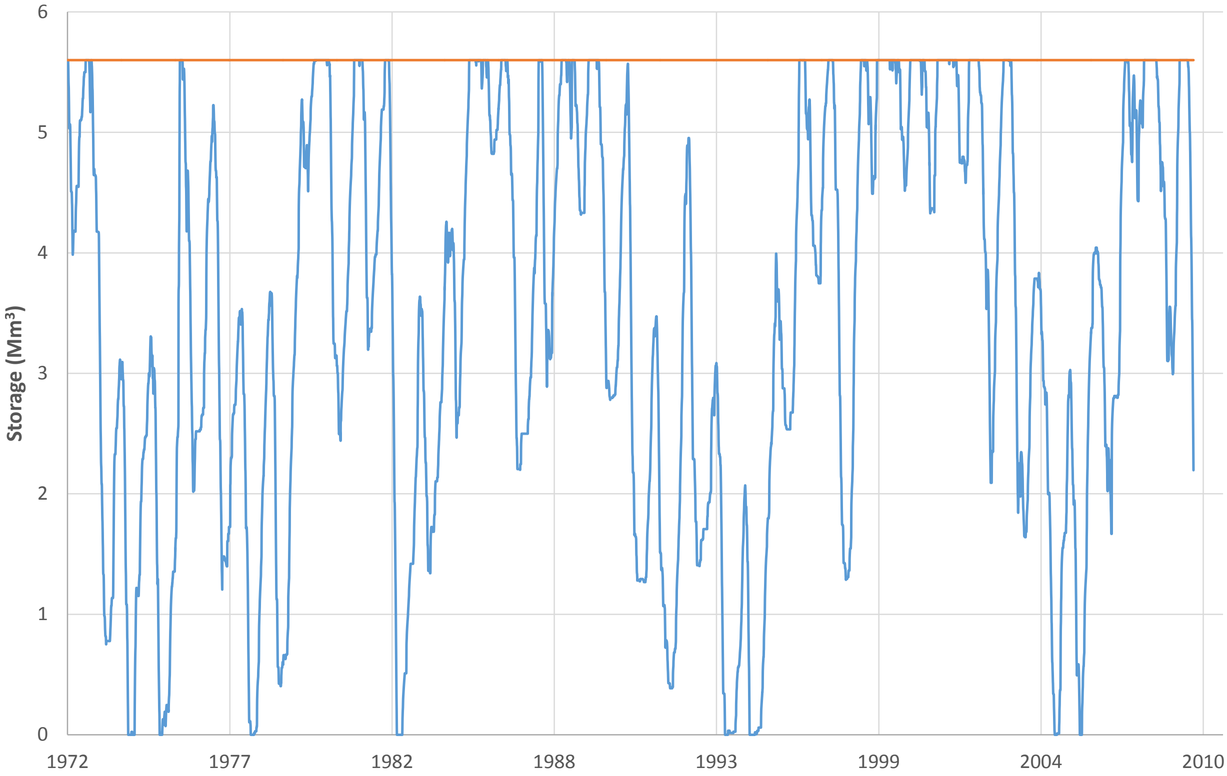


Figure H.11 – Lower storage hydrograph in the Waimate North Area

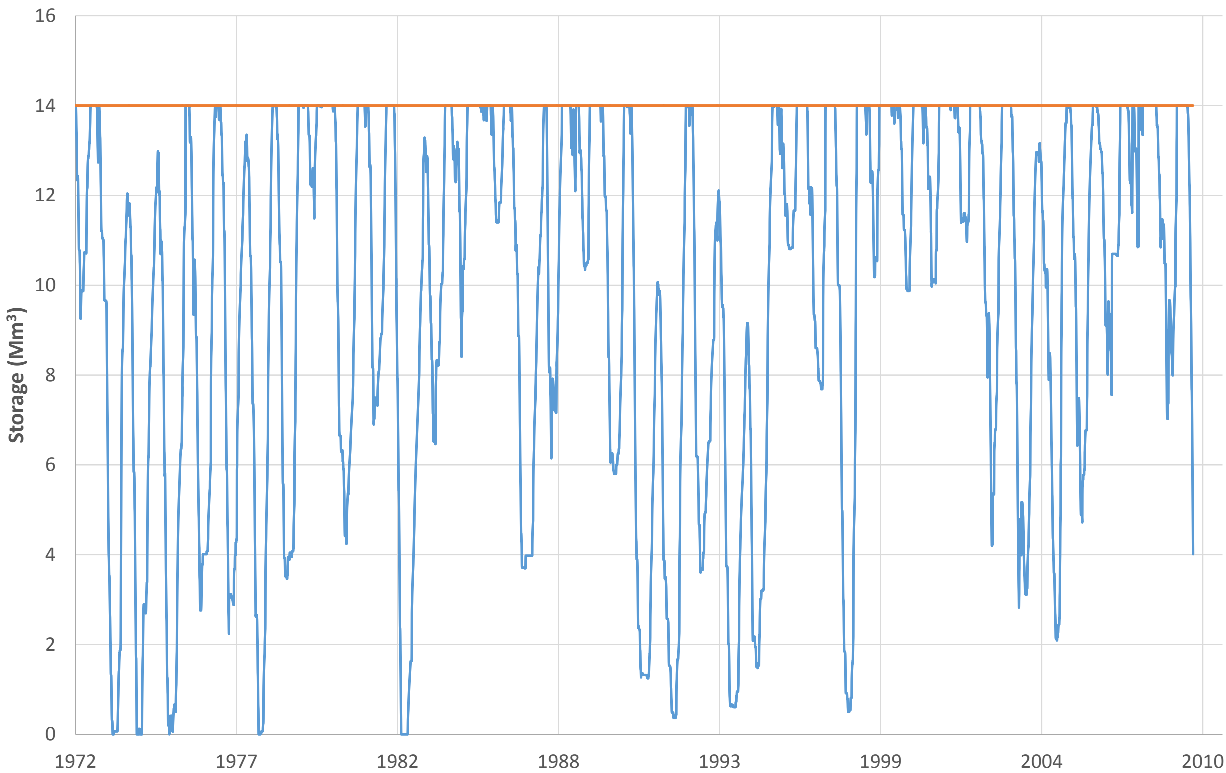


Figure H.12 – Irrigation supply deficit days for the area supplied by the upper storage in the Waimate North Area

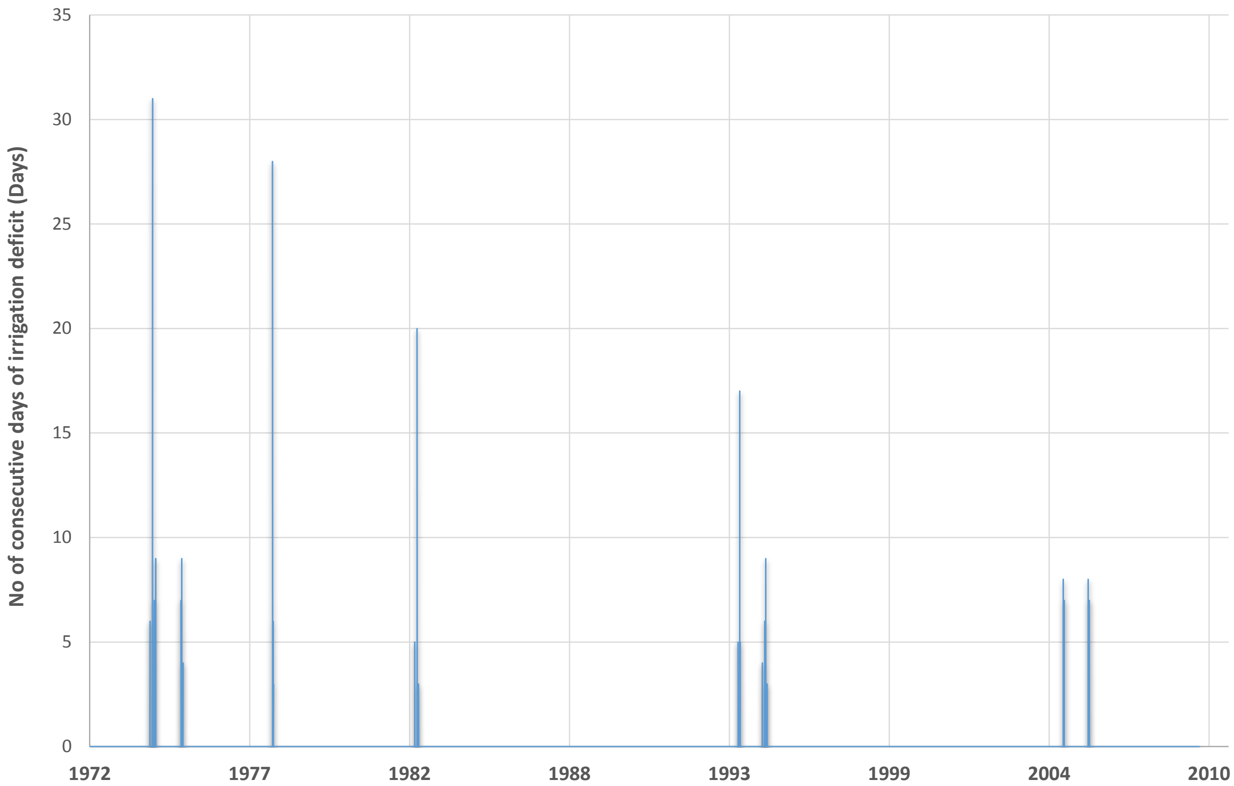
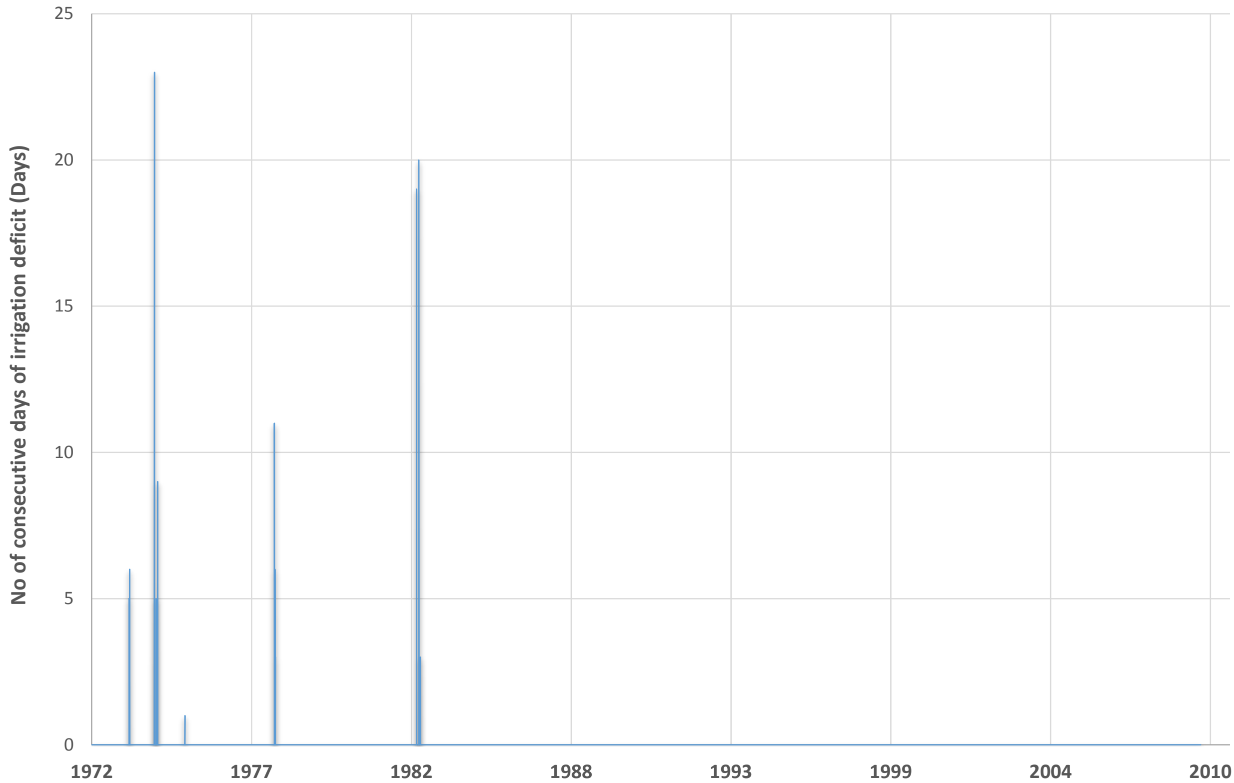


Figure H.13 – Irrigation supply deficit days for the area supplied by the lower storage in the Waimate North Area



Kaikohe Area

Figure H.14 – Approximate location of intake for water harvesting or instream dam for the Kaikohe Area

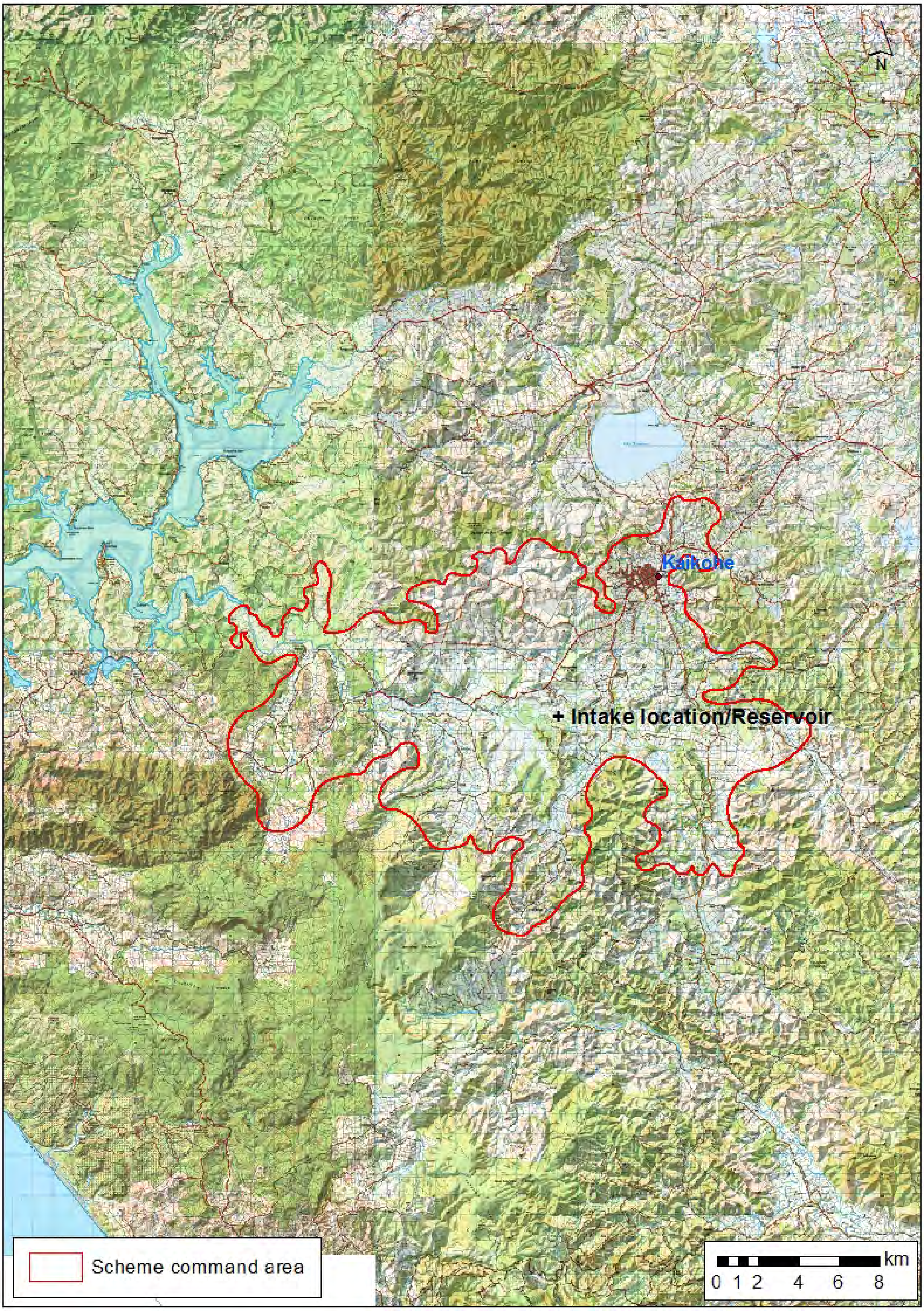


Figure H.15 – Storage hydrograph for the Kaikohe Area

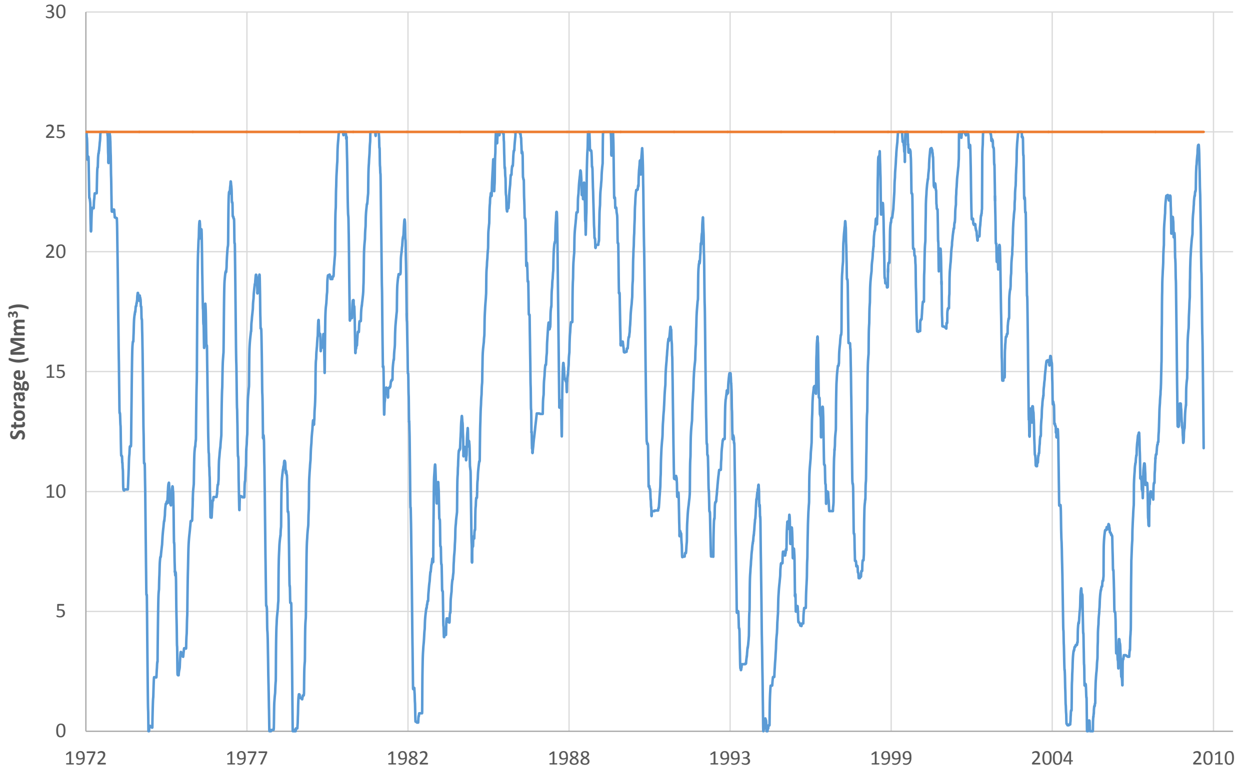
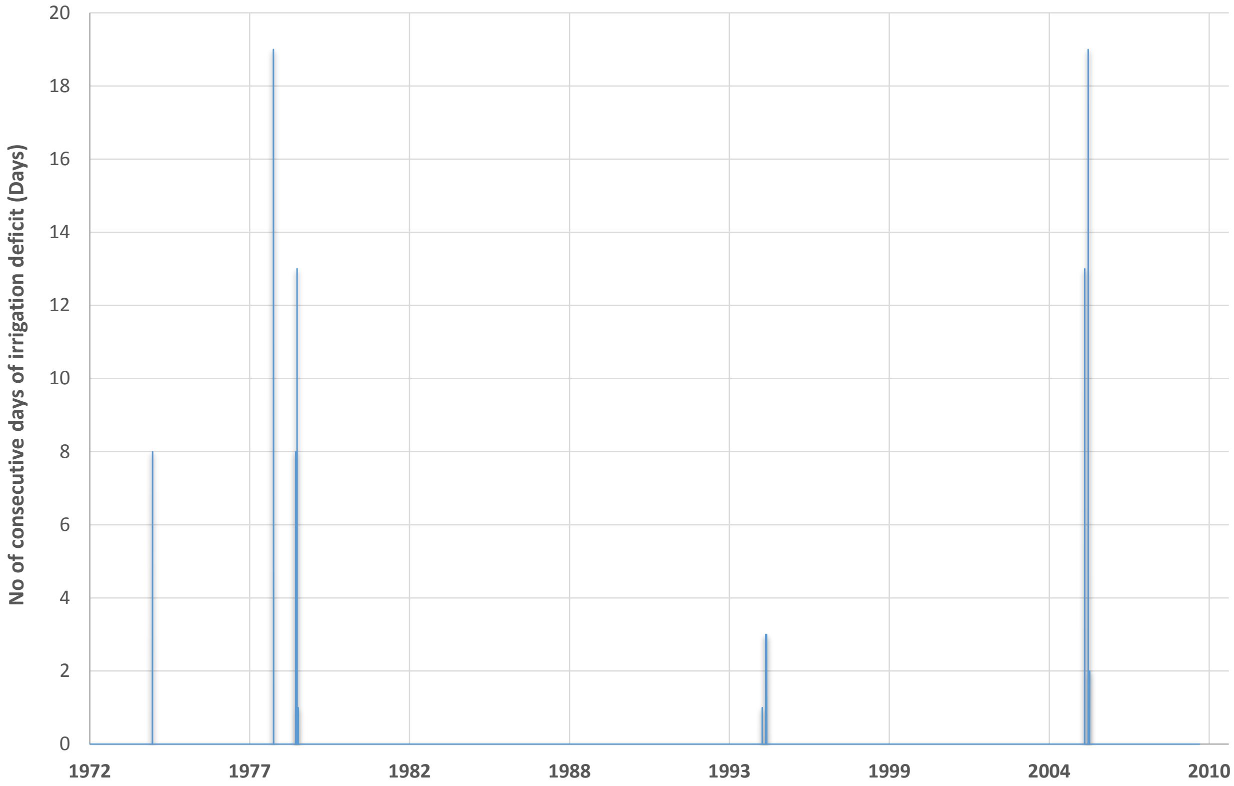


Figure H.16 – Irrigation supply deficit days for the Kaikohe Area



Waimamaku Area

Figure H.17 – Approximate location of intake for water harvesting or instream dam for the Waimamaku Area

Figure H.18 – Storage hydrograph for the Waimamaku Area

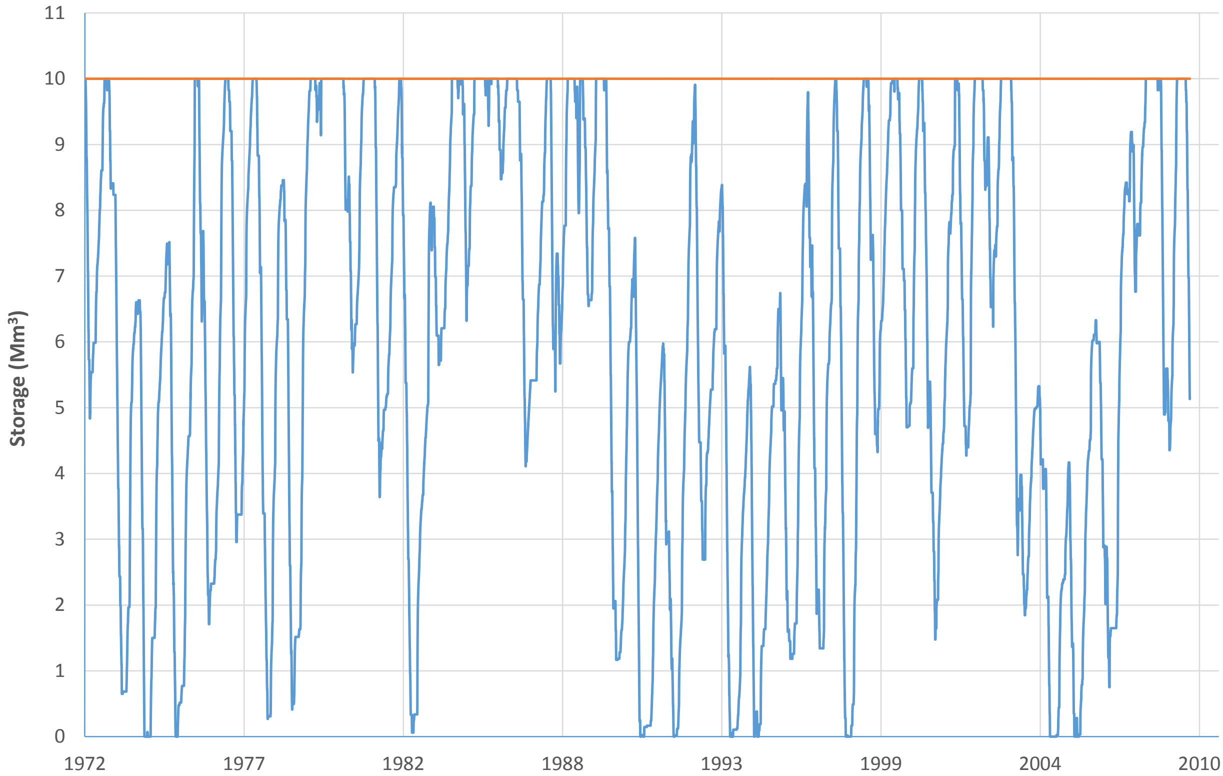
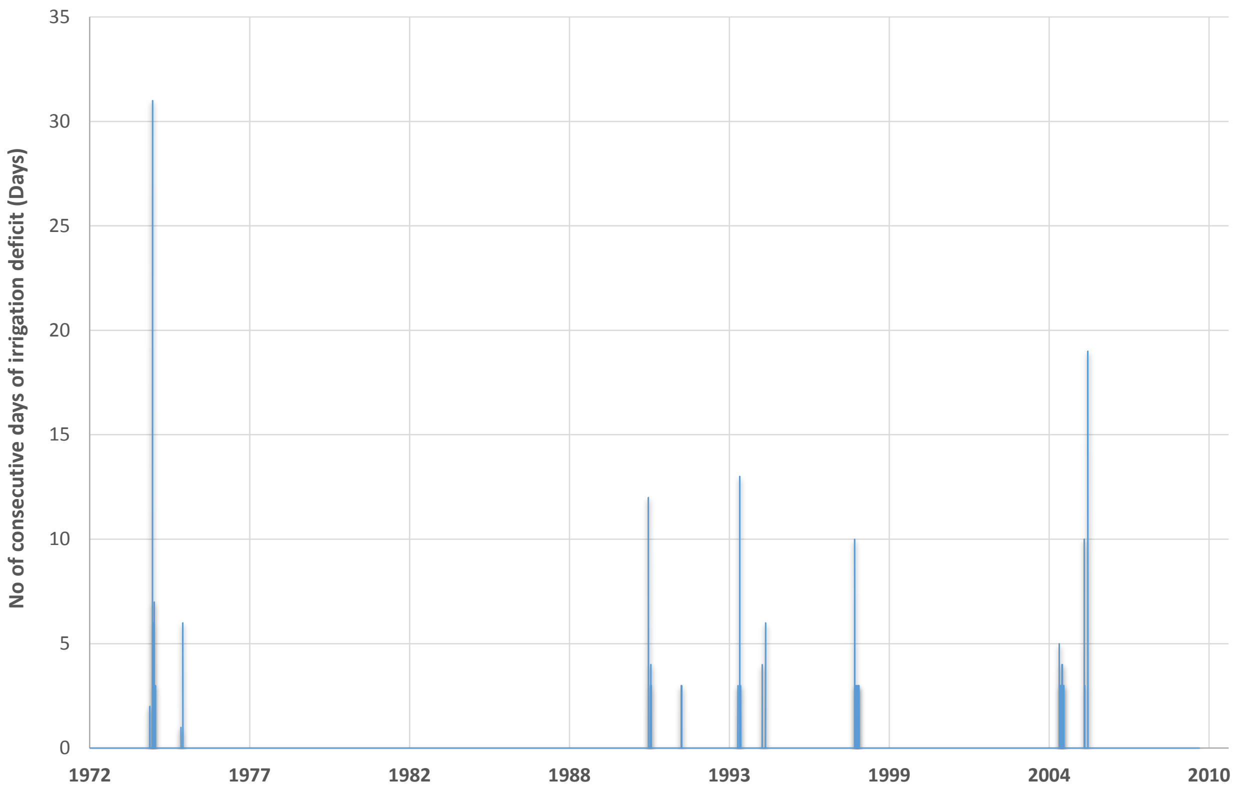


Figure H.19 – Irrigation supply deficit days for the Waimamaku Area



Hikurangi Area

Figure H.20 – Approximate locations of intakes for water harvesting or instream dams for the Hikurangi Area

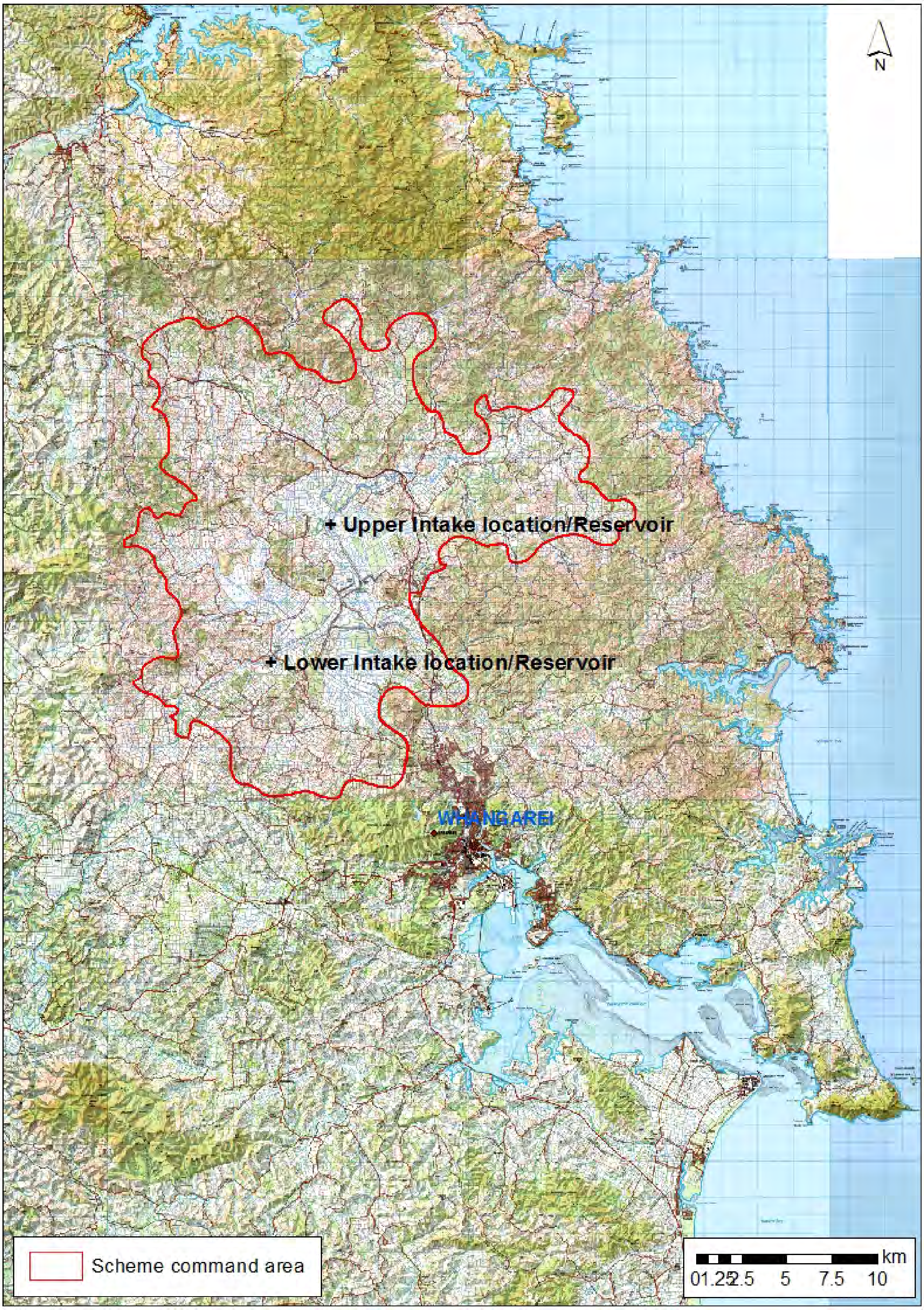


Figure H.21 – Upper storage hydrograph in the Hikurangi Area

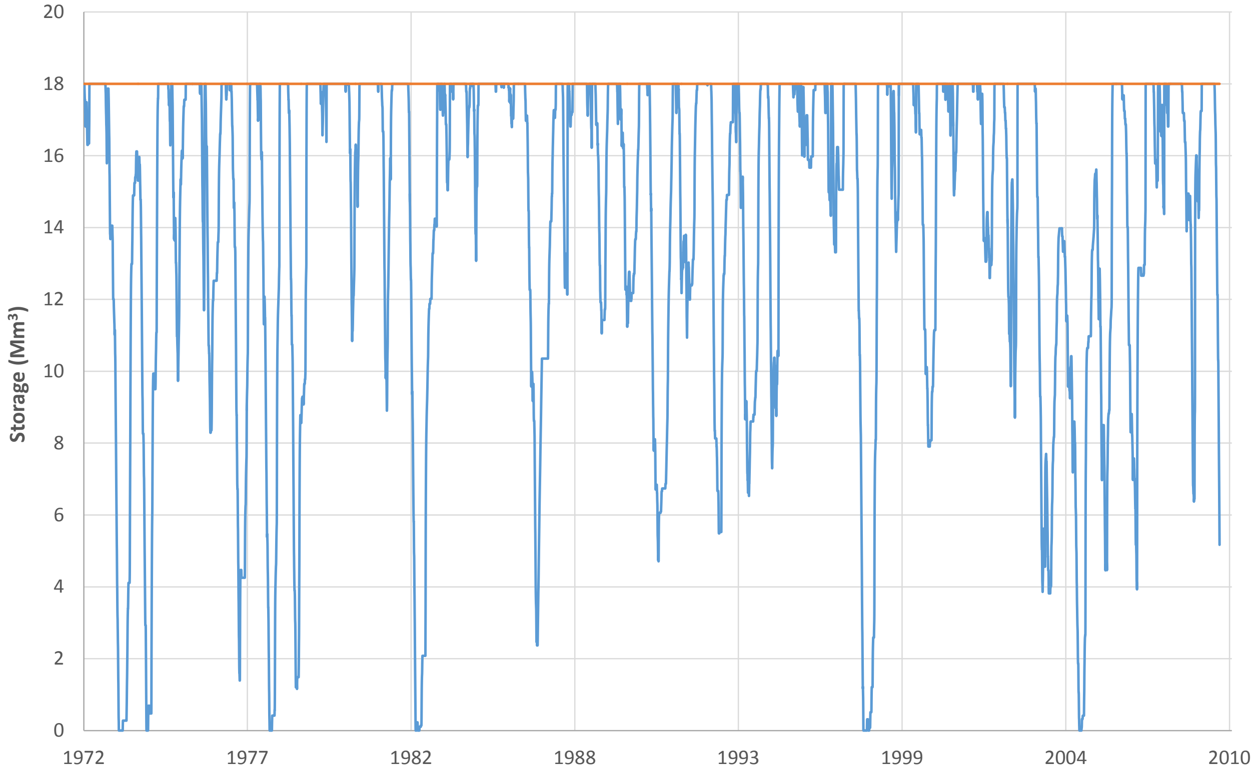


Figure H.22 – Lower storage hydrograph in the Hikurangi Area

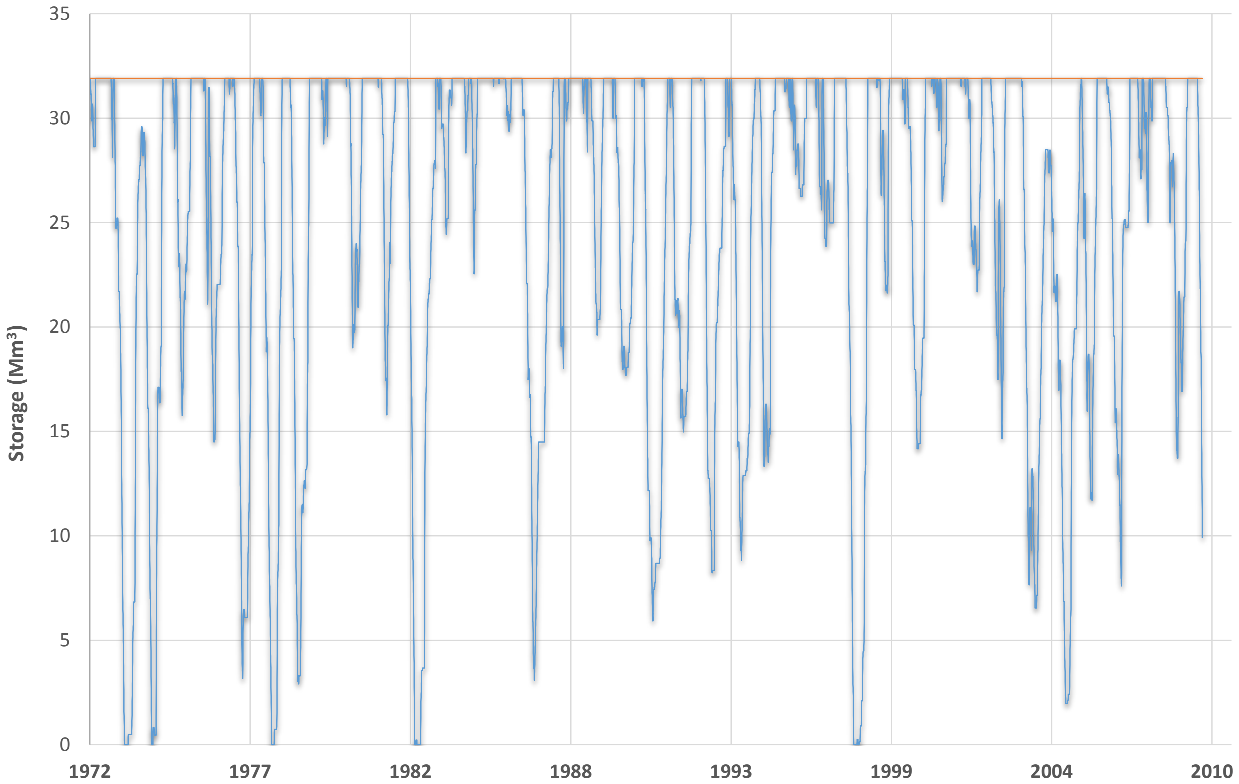


Figure H.23 – Irrigation supply deficit days for the area supplied by the upper storage in the Hikurangi Area

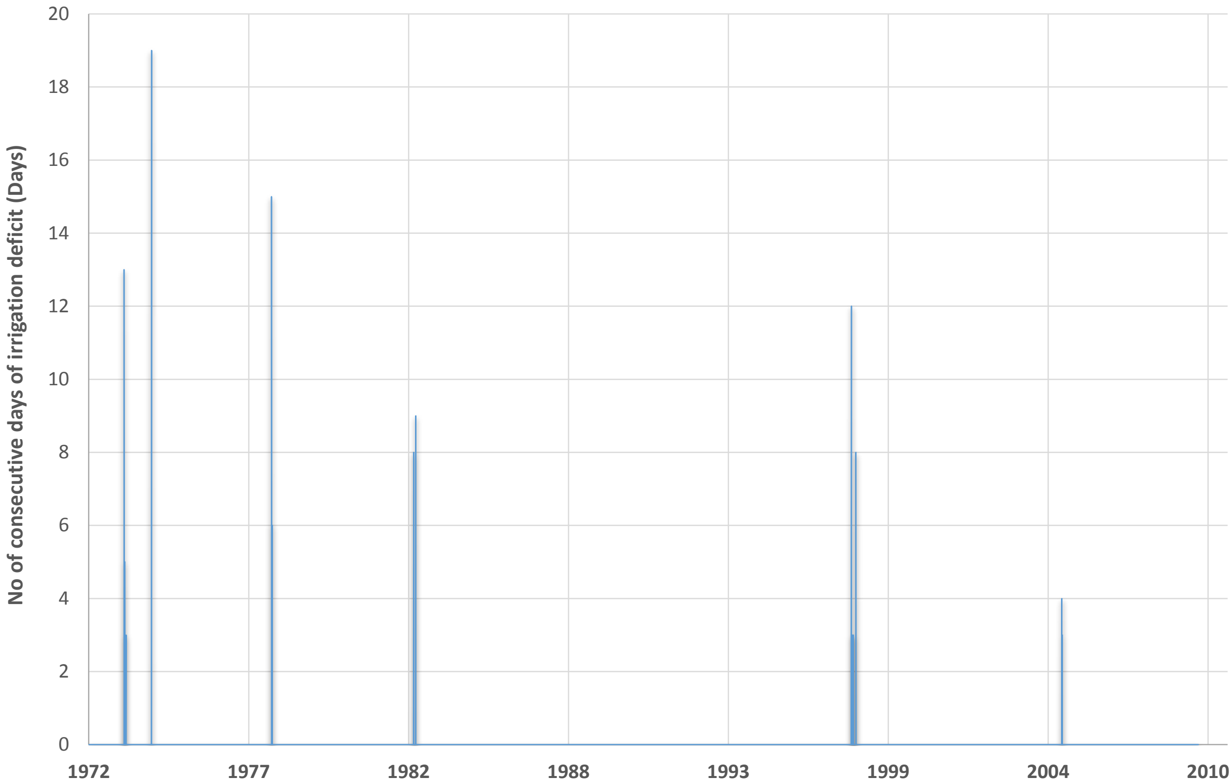
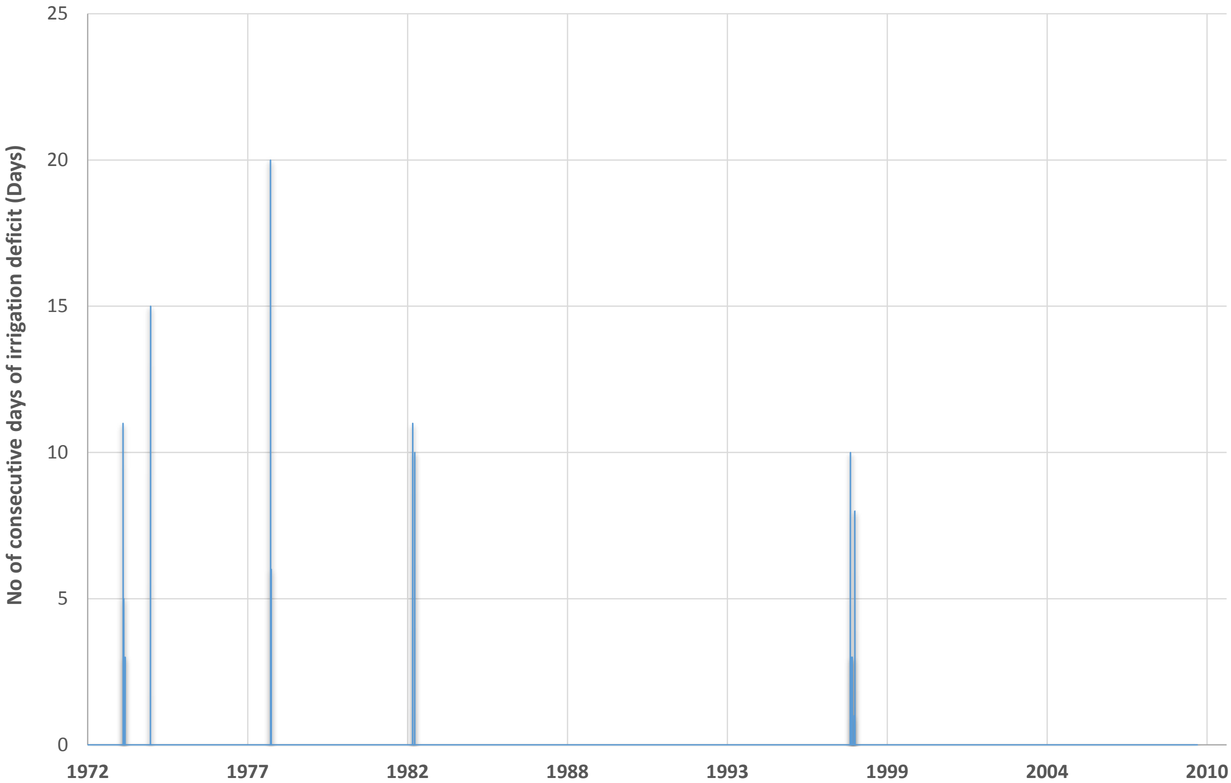


Figure H.24 – Irrigation supply deficit days for the area supplied by the lower storage in the Hikurangi Area



Glenbervie Area

Figure H.25 – Approximate location of intake for water harvesting or instream dam for the Glenbervie Area

Figure H.26 – Storage hydrograph for the Glenbervie Area

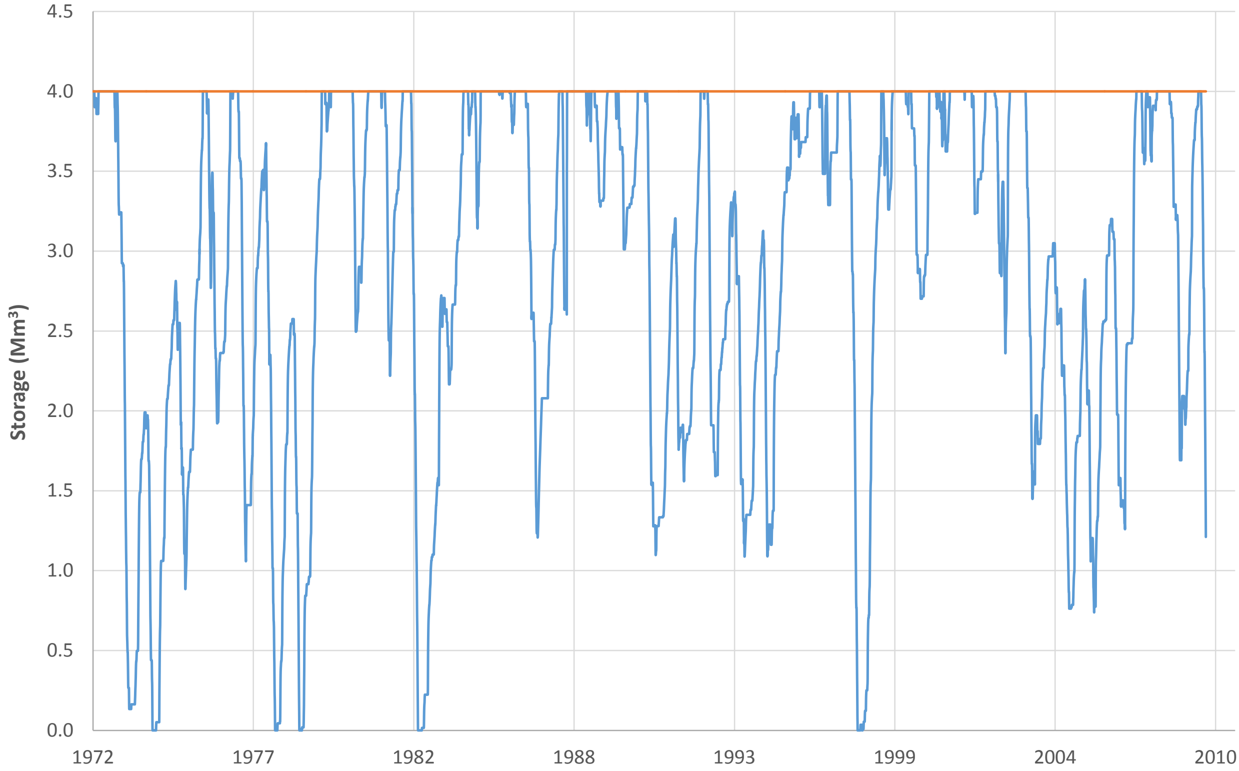
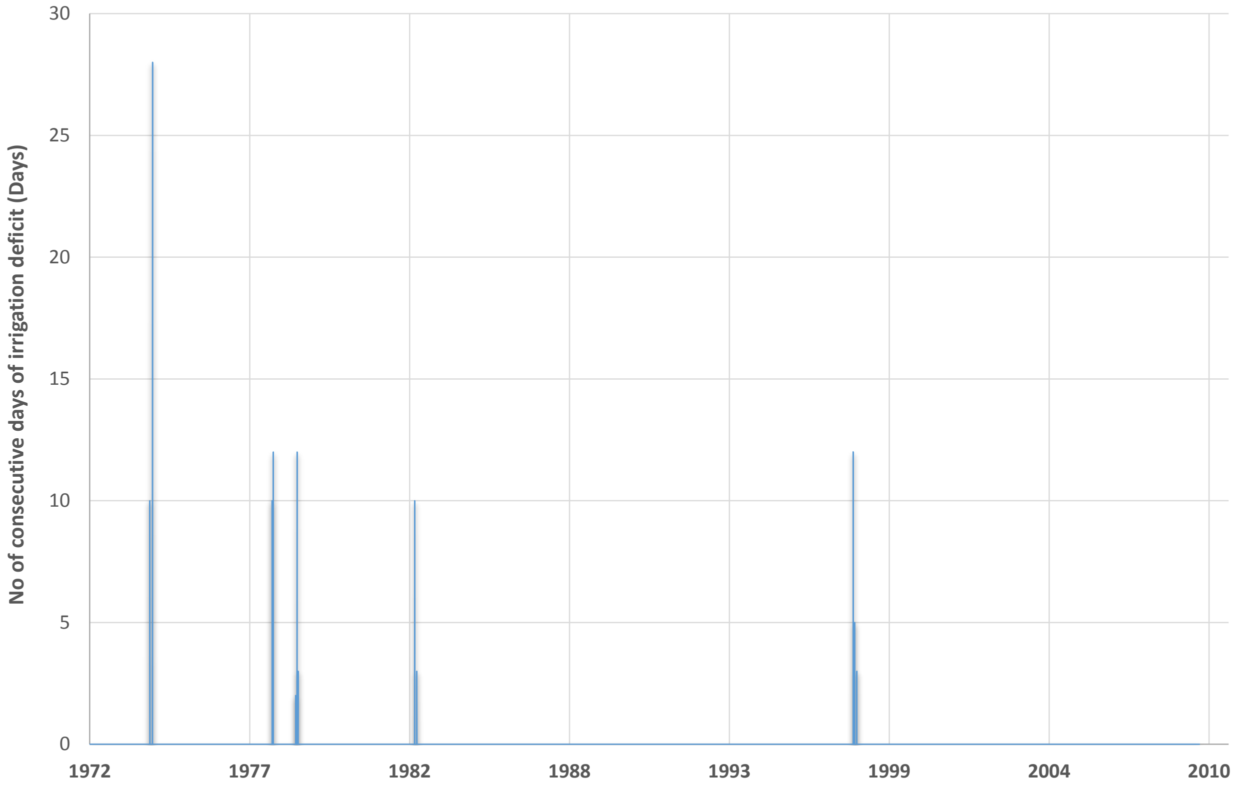


Figure H.27 – Irrigation supply deficit days for the Glenbervie Area



Mangakahia Area

Figure H.28 – Approximate locations of intakes for water harvesting or instream dams for the Mangakahia Area

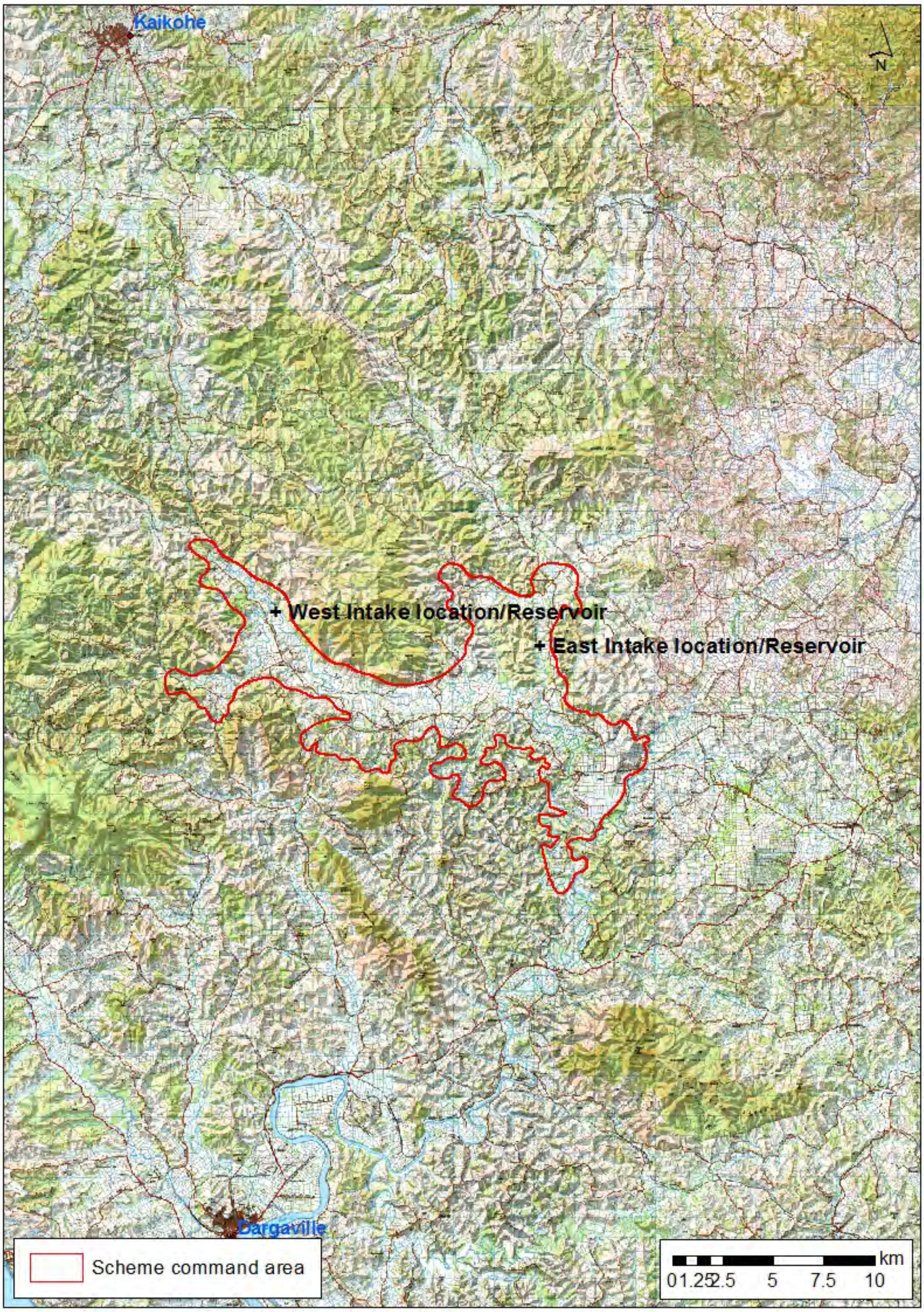


Figure H.29 – West storage hydrograph in the Mangakahia Area

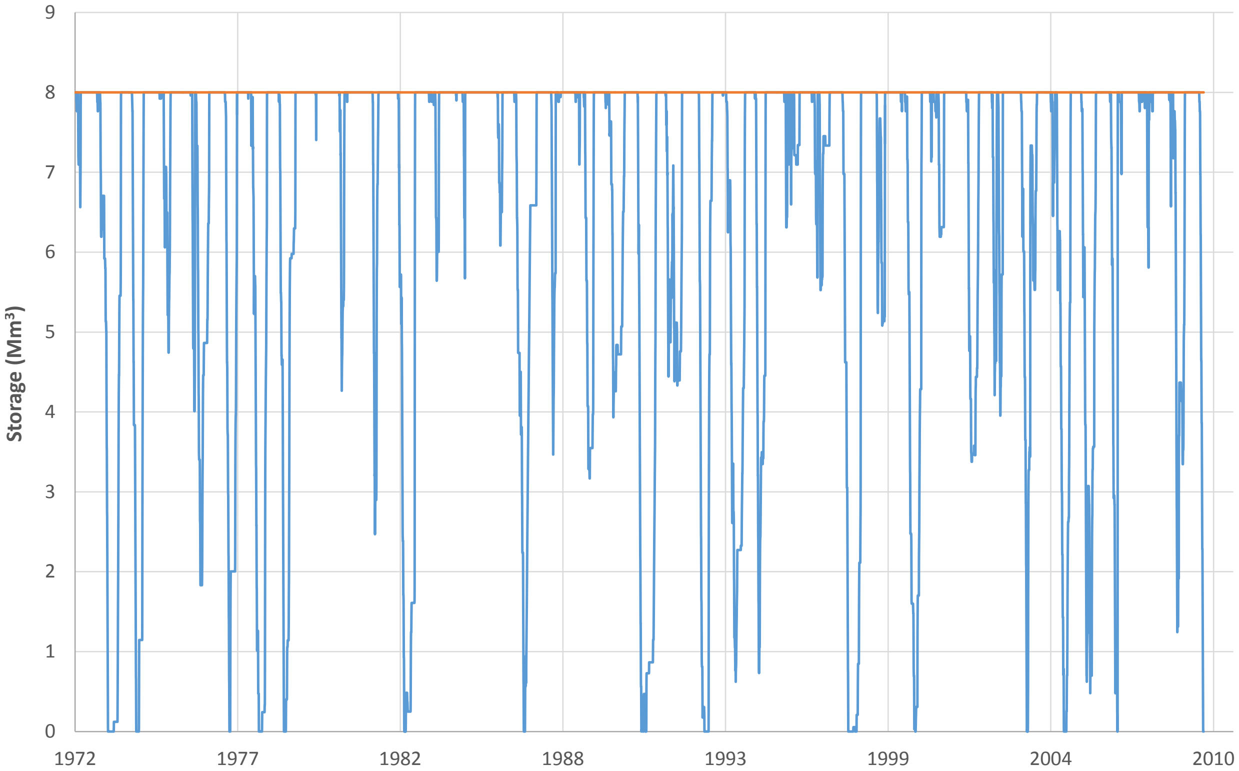


Figure H.30 – East storage hydrograph in the Mangakahia Area

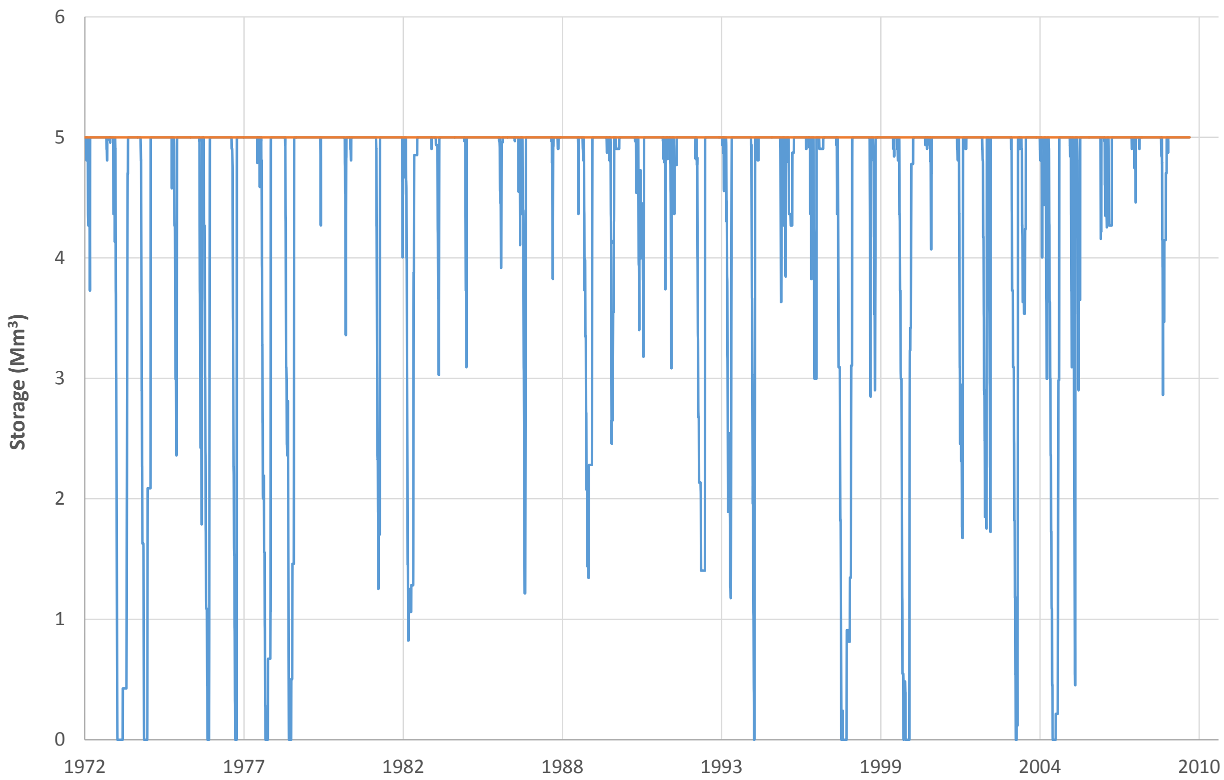


Figure H.31 – Irrigation supply deficit days for the area supplied by the West storage in the Mangakahia Area

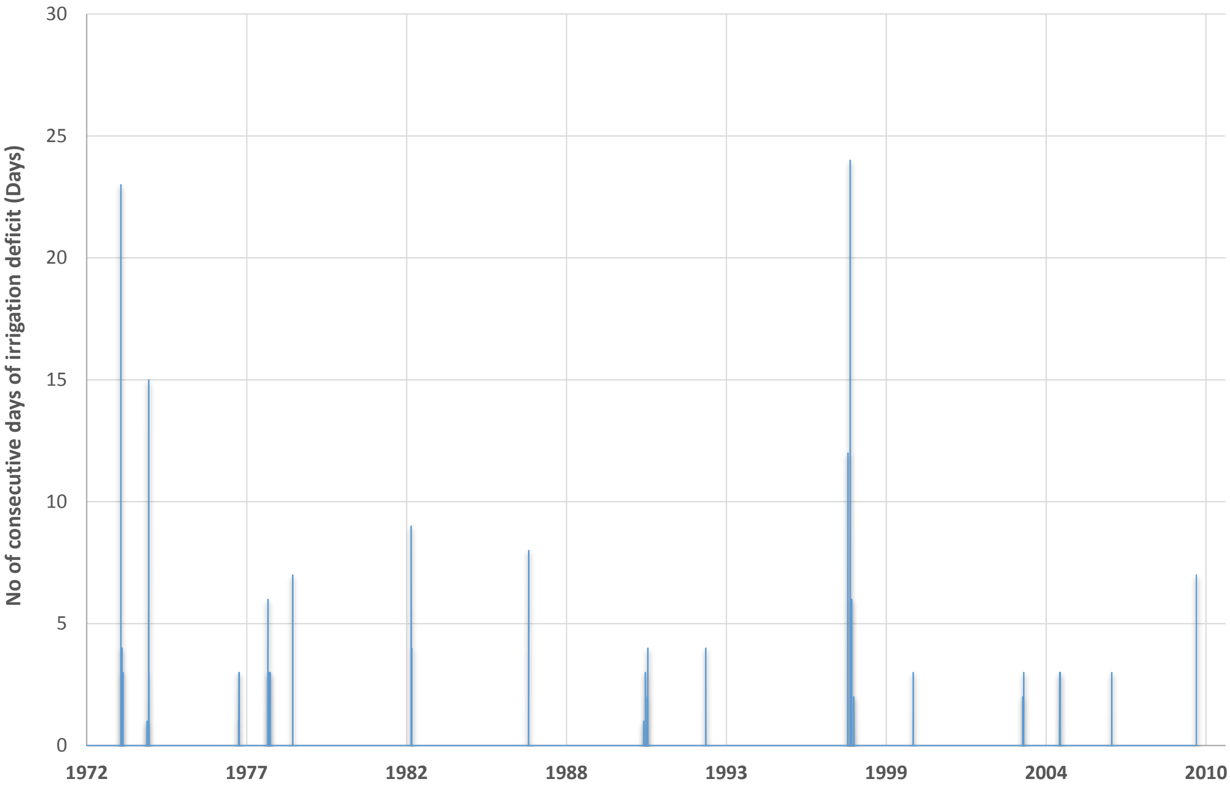
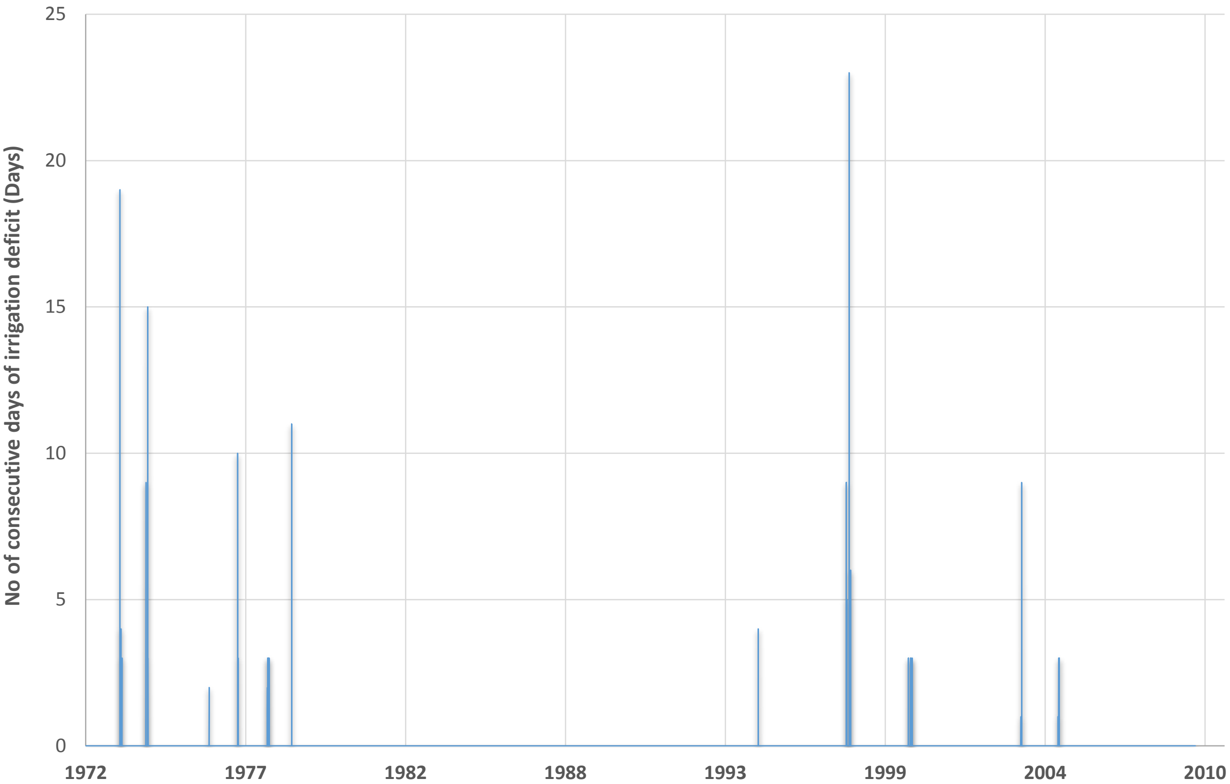


Figure H.32 – Irrigation supply deficit days for the area supplied by the East storage in the Mangakahia Area



Maungatapere Area

Figure H.33 – Approximate location of intake for water harvesting or instream dam for the Maungatapere Area

Figure H.34 – Storage hydrograph for the Maungatapere Area

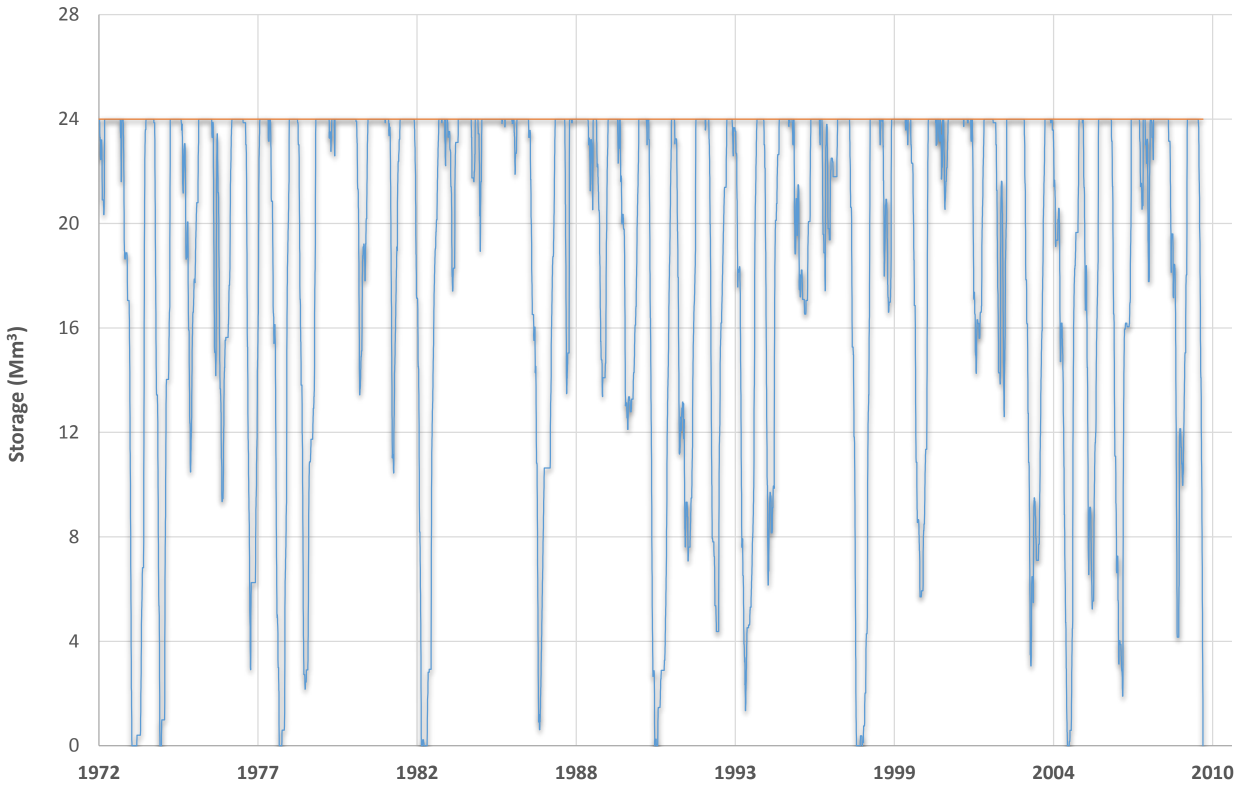
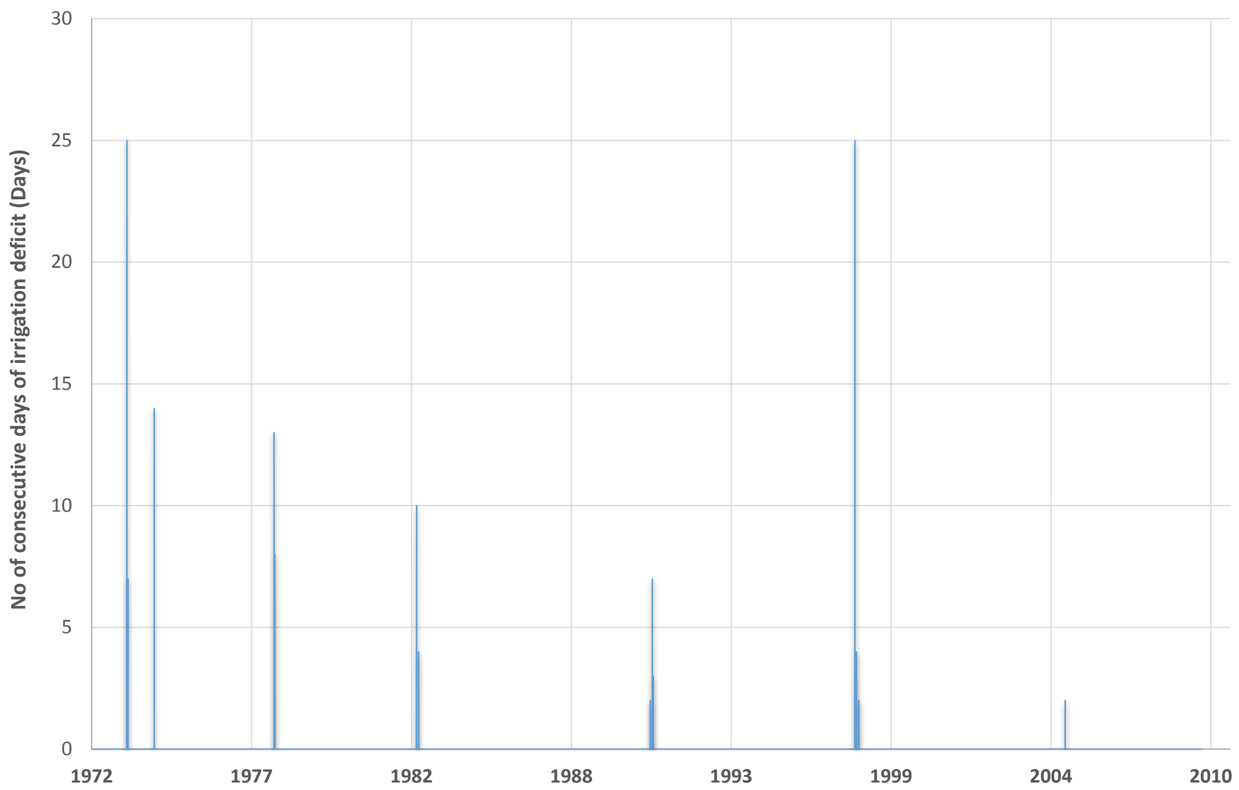


Figure H.35 – Irrigation supply deficit days for the Maungatapere Area



Maungakaramea Area

Figure H.36 – Approximate location of intake for water harvesting or instream dam for the Maungakaramea Area

Figure H.37 – Storage hydrograph for the Maungakaramea Area

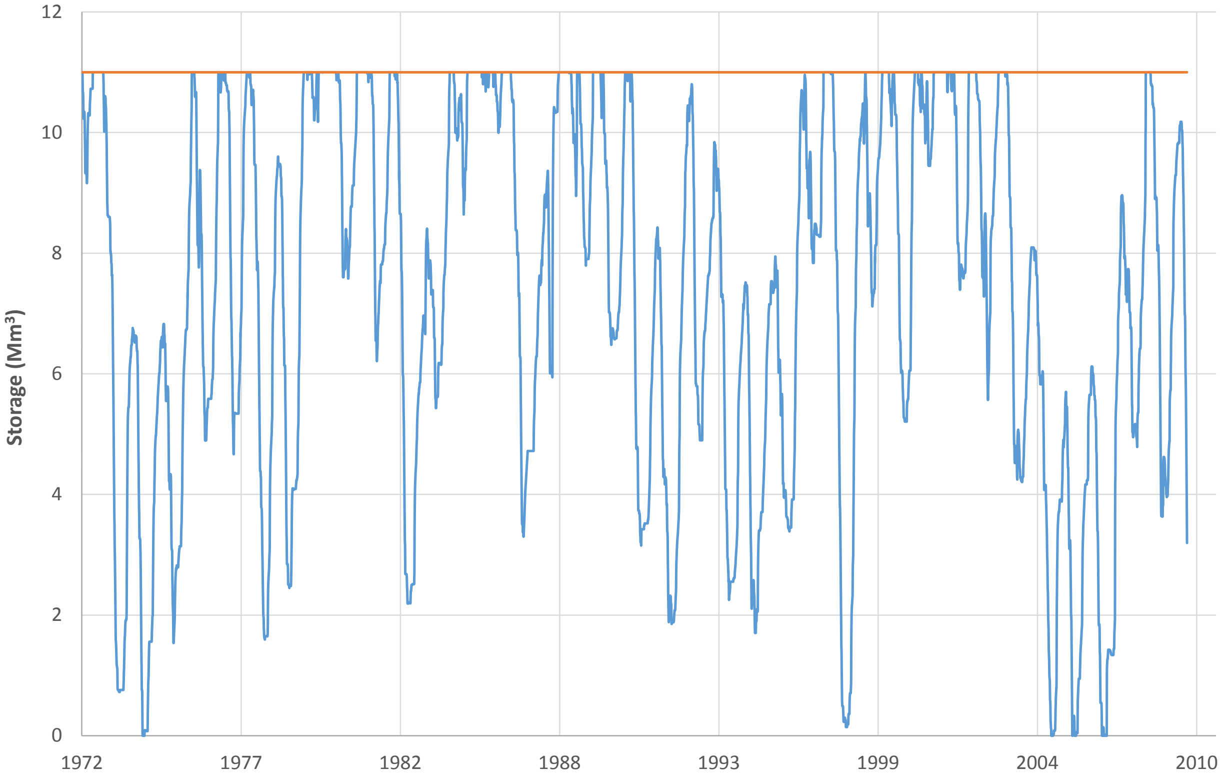
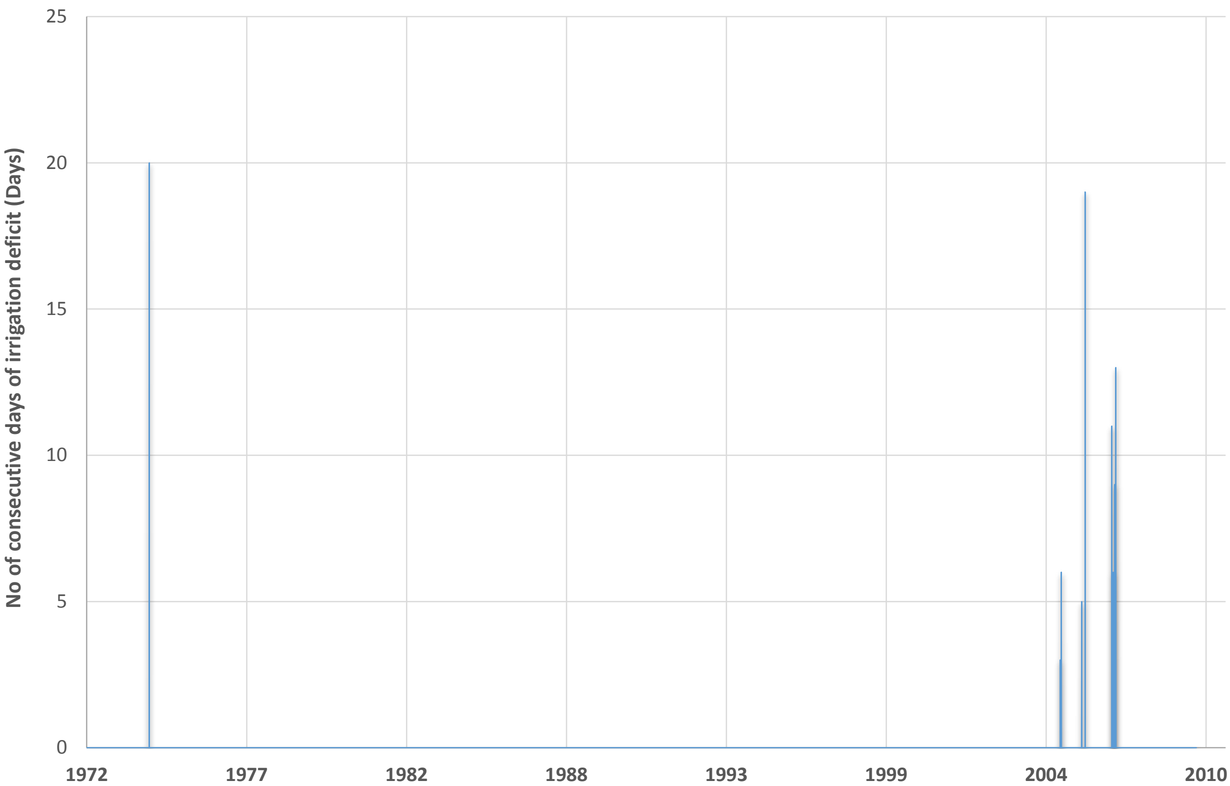


Figure H.38 – Irrigation supply deficit days for the Maungakaramea Area



Ruakaka Area

Figure H.39 – Approximate location of intake for water harvesting or instream dam for the Ruakaka Area

Figure H.40 – Storage hydrograph for the Ruakaka Area

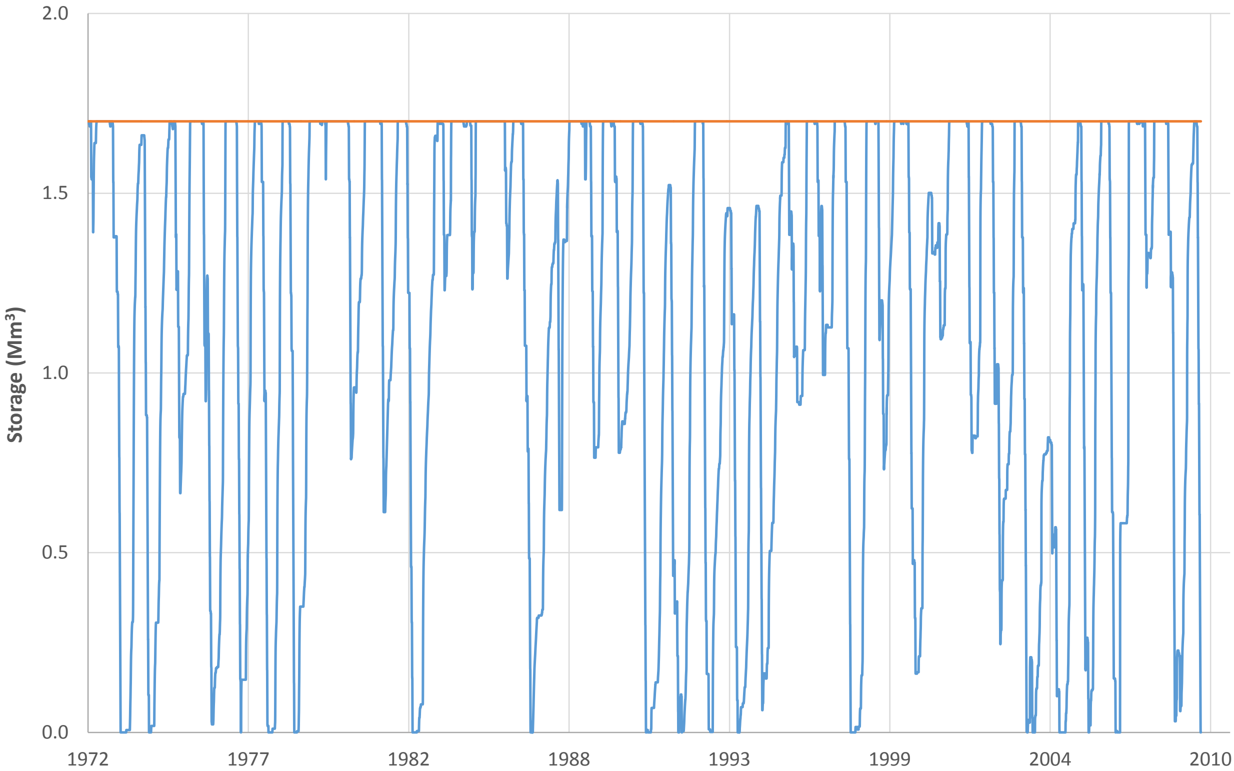
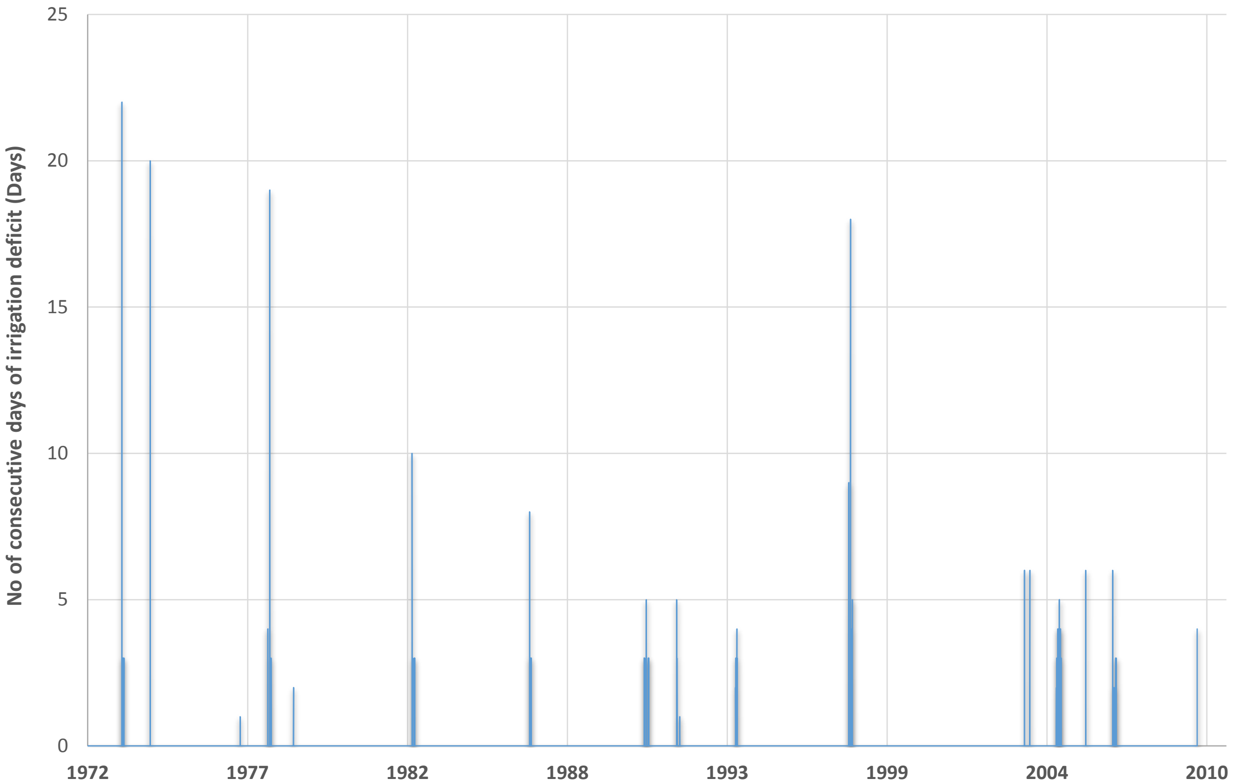


Figure H.41 – Irrigation supply deficit days for the Ruakaka Area



Waipu Area

Figure H.42 – Approximate location of intake for water harvesting or instream dam for the Waipu Area

Figure H.43 – Storage hydrograph for the Waipu Area

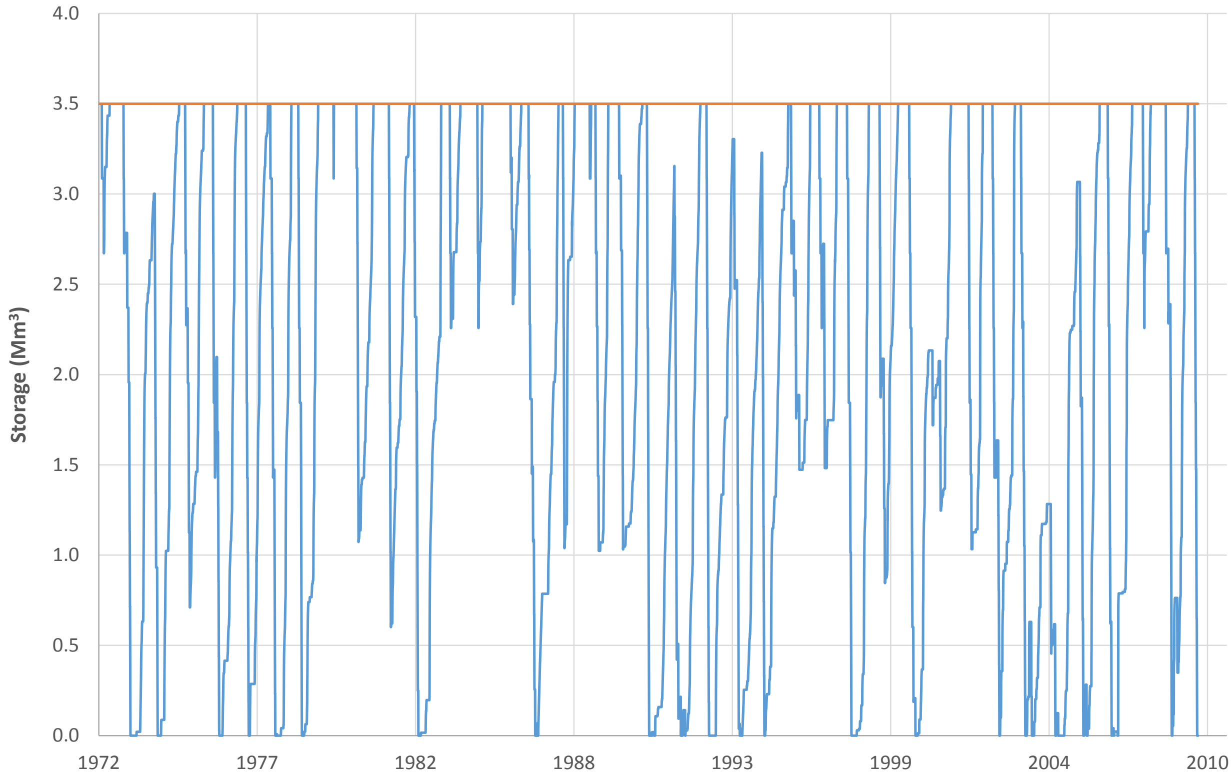
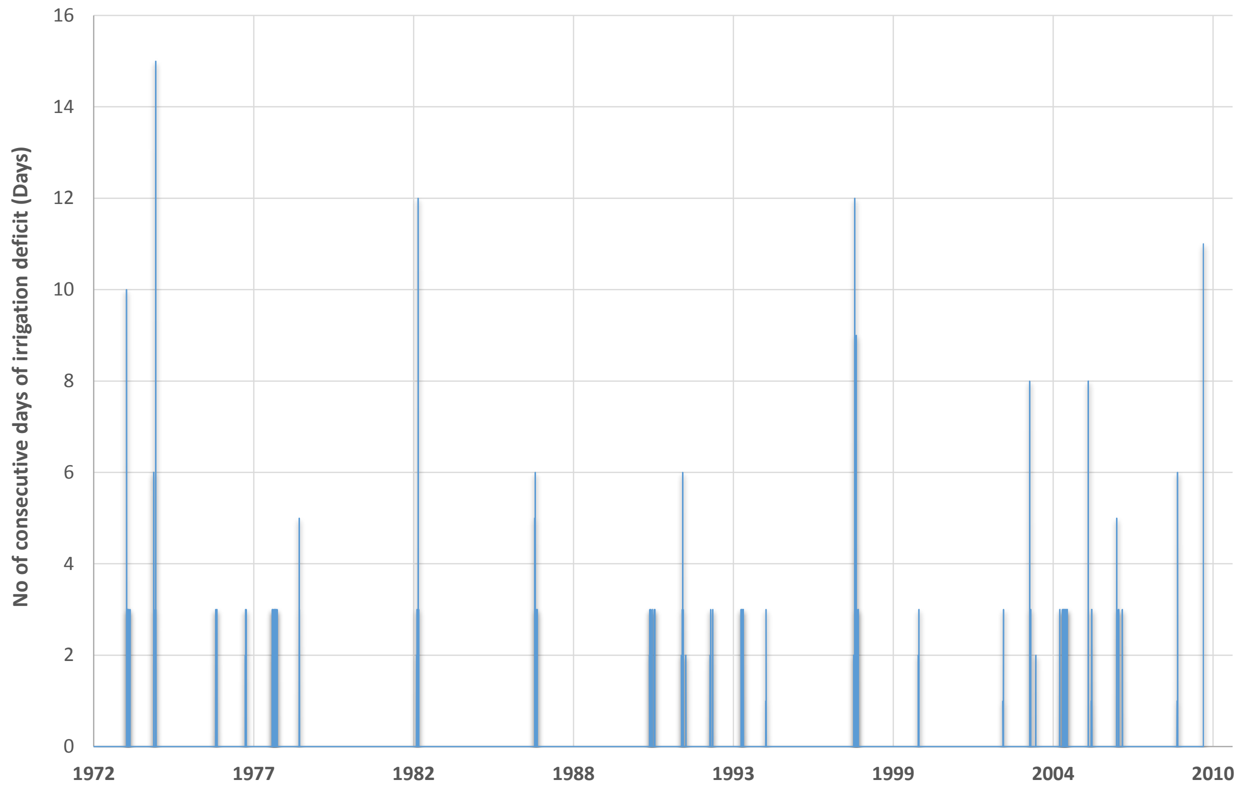


Figure H.44 – Irrigation supply deficit days for the Waipu Area



Kaihu Area

Figure H.45 – Approximate location of intake for water harvesting or instream dam for the Kaihu Area

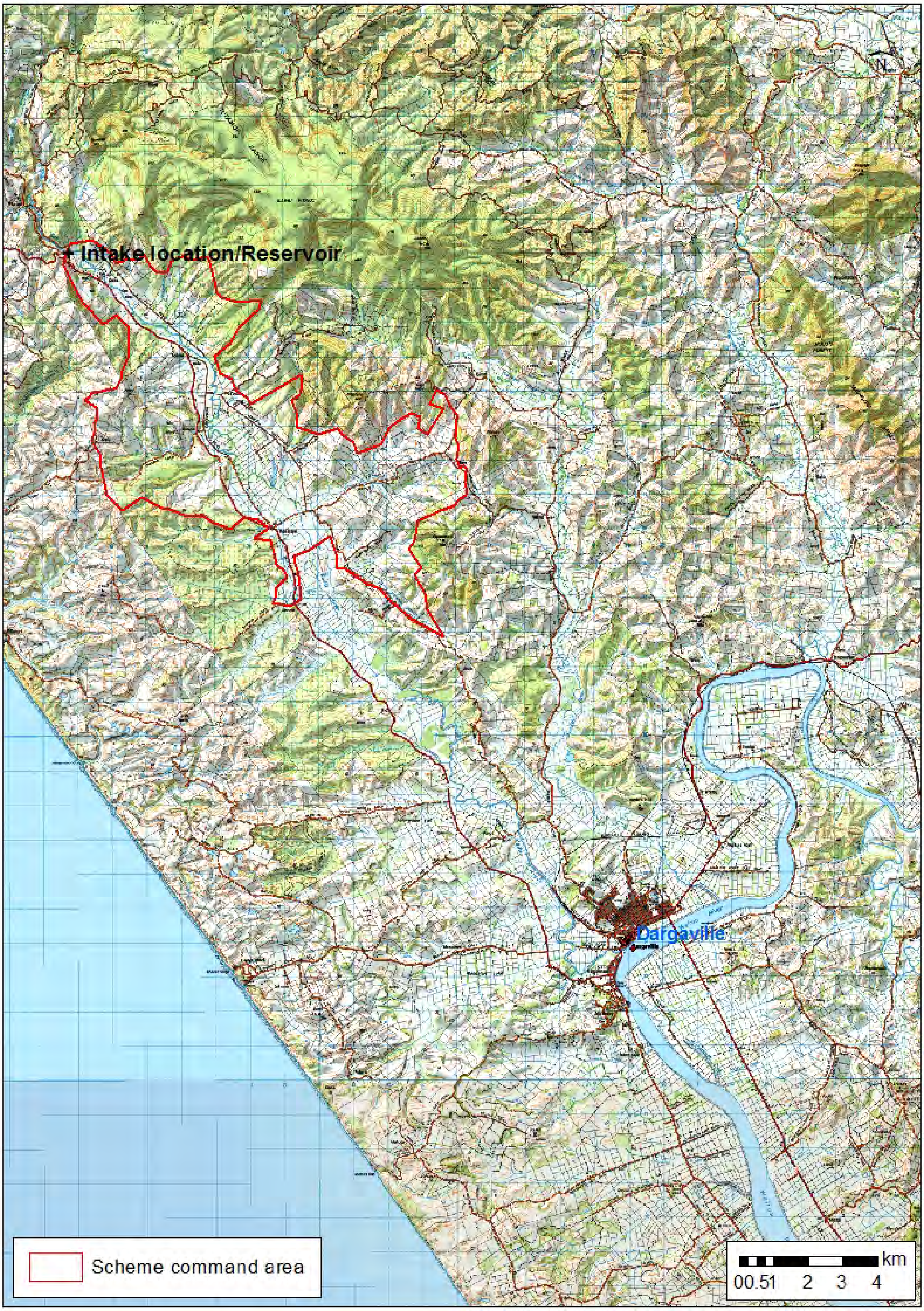


Figure H.46 – Storage hydrograph for the Kaihu Area

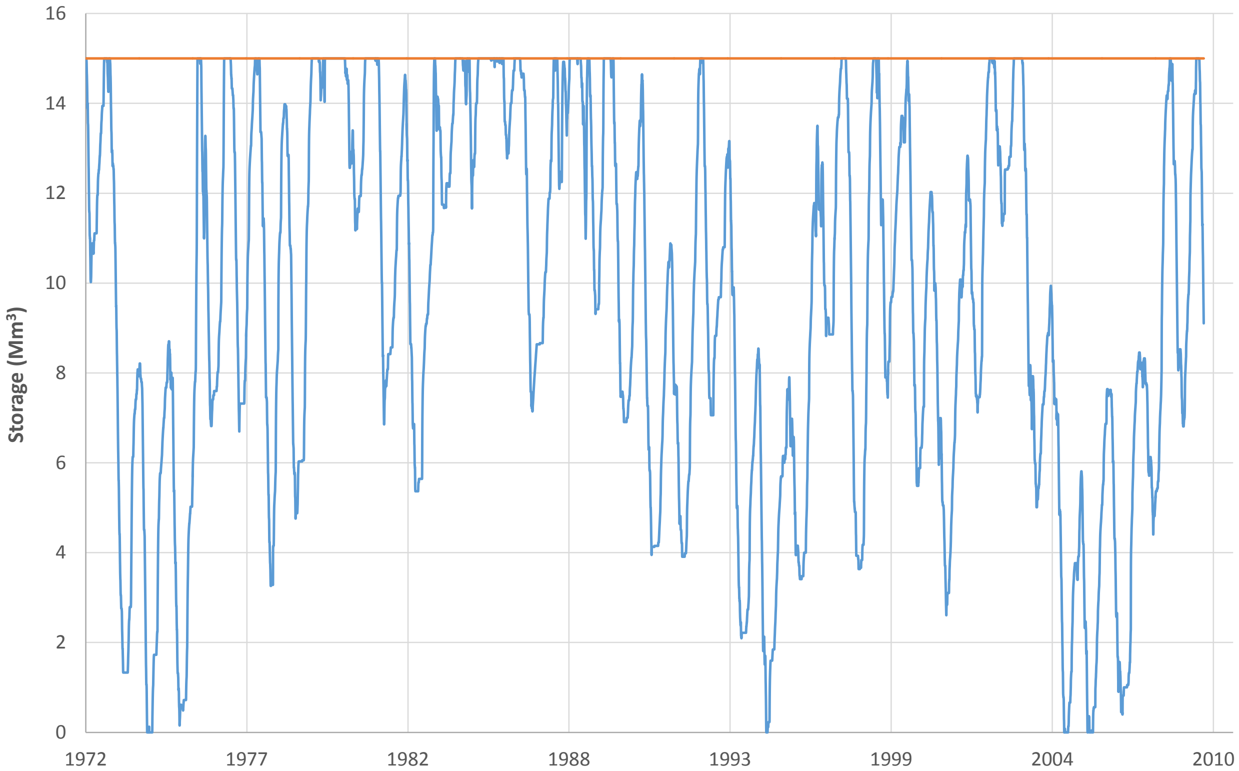
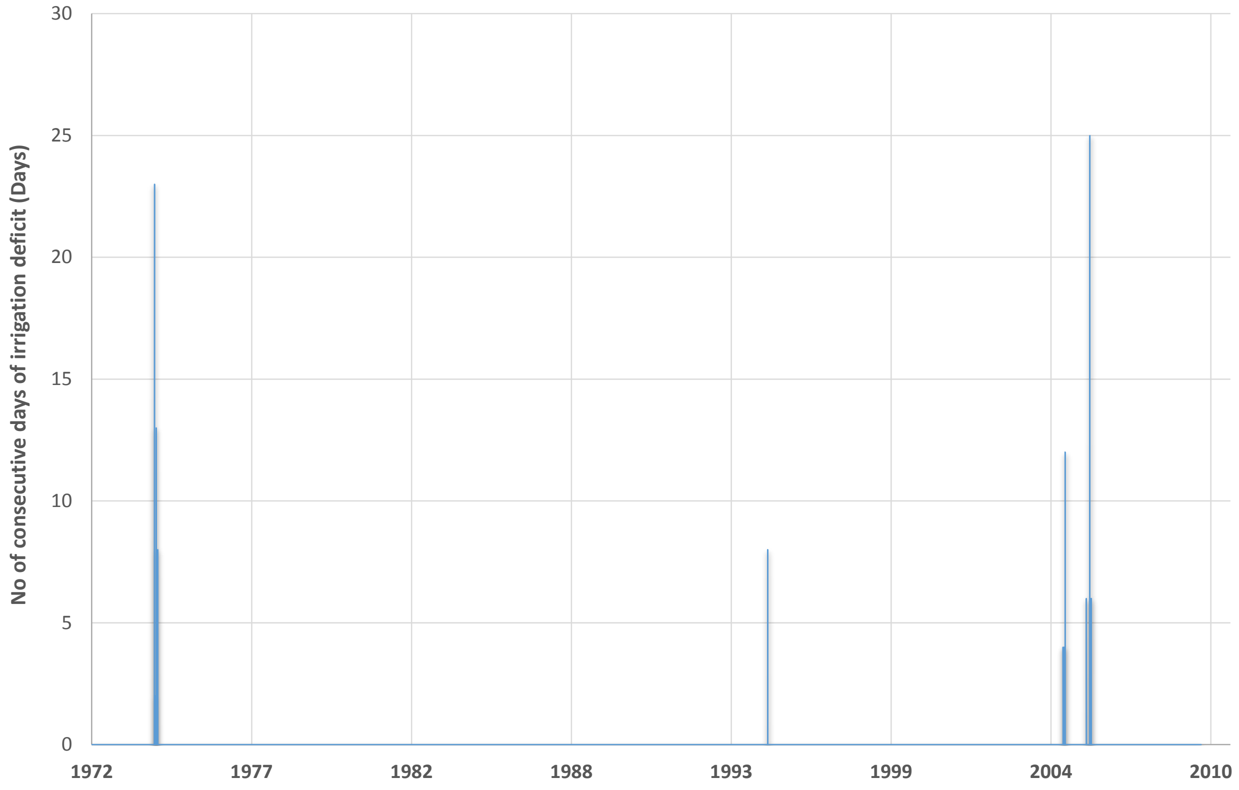


Figure H.47 – Irrigation supply deficit days for the Kaihu Area



Hoanga Area

Figure H.48 – Approximate location of intake for water harvesting or instream dam for the Hoanga Area

Figure H.49 – Storage hydrograph for the Hoanga Area

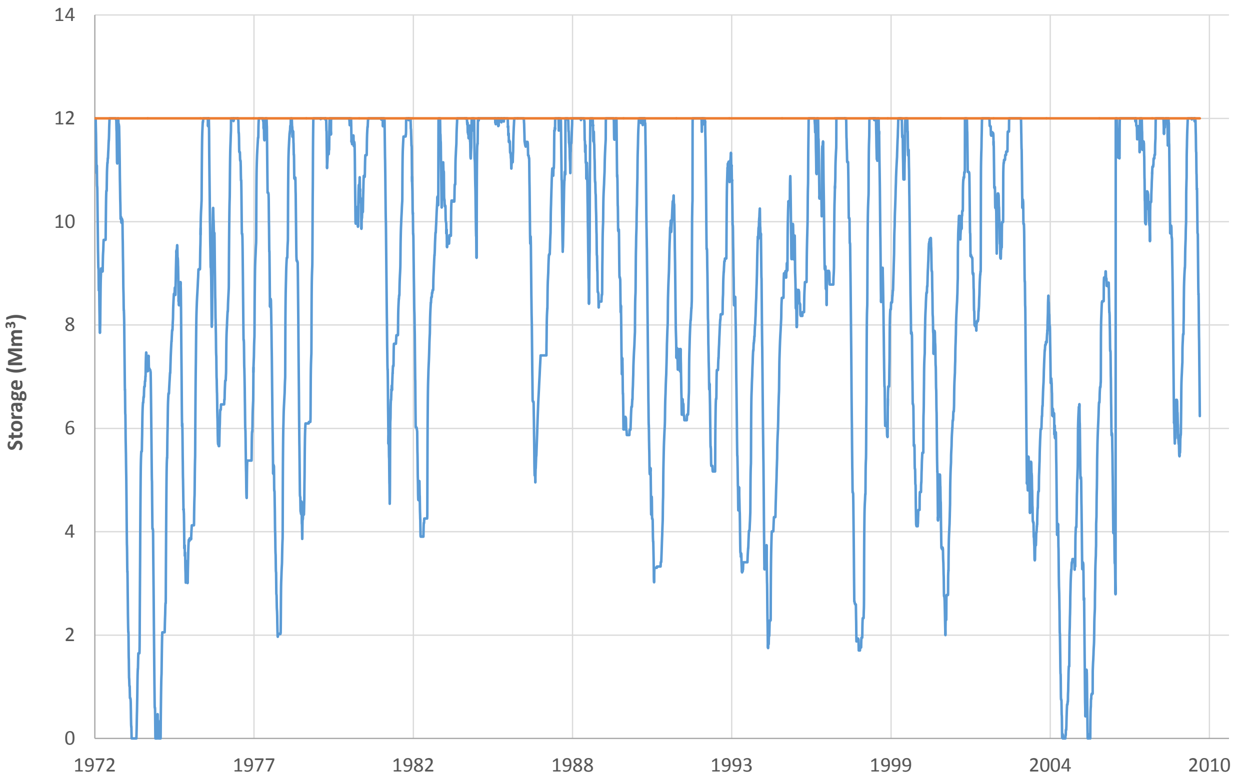
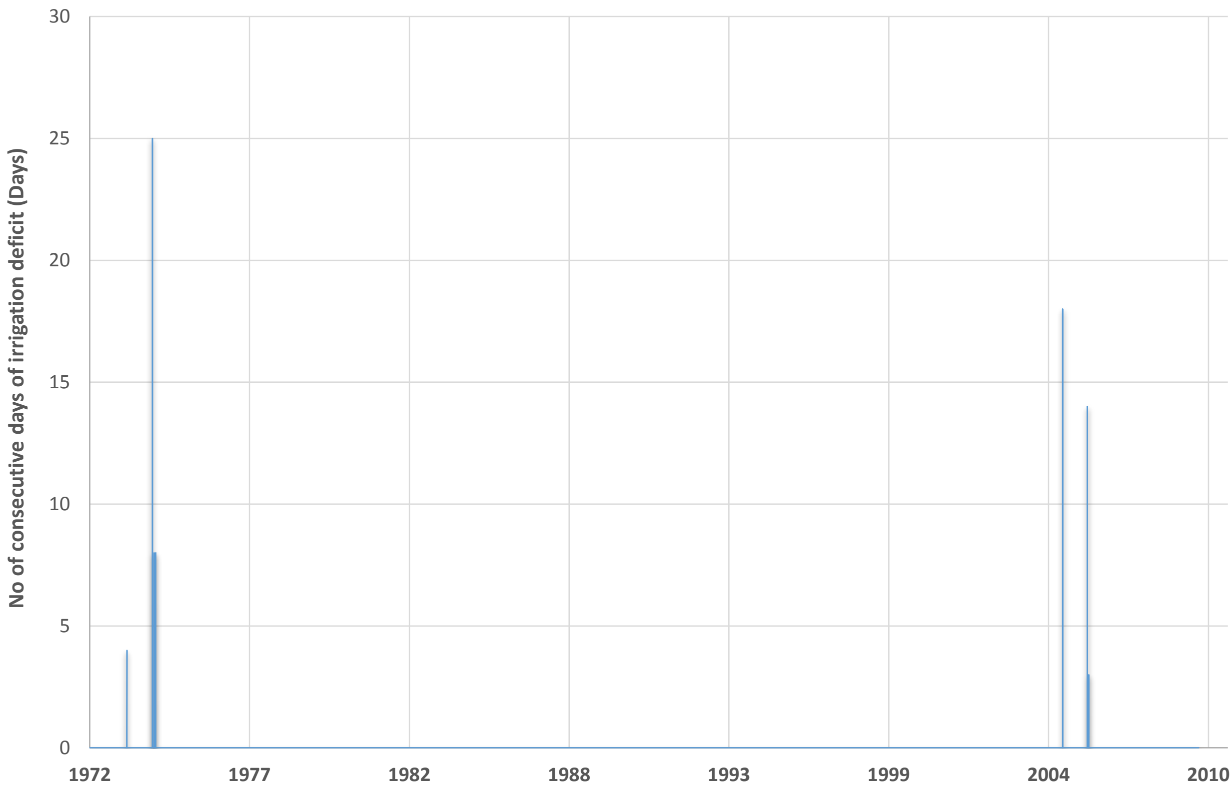


Figure H.50 – Irrigation supply deficit days for the Hoanga Area



North Kaipara and Ruawai Area

Figure H.51 – Approximate location of intake for water harvesting or instream dam for the North Kaipara and Ruawai Areas

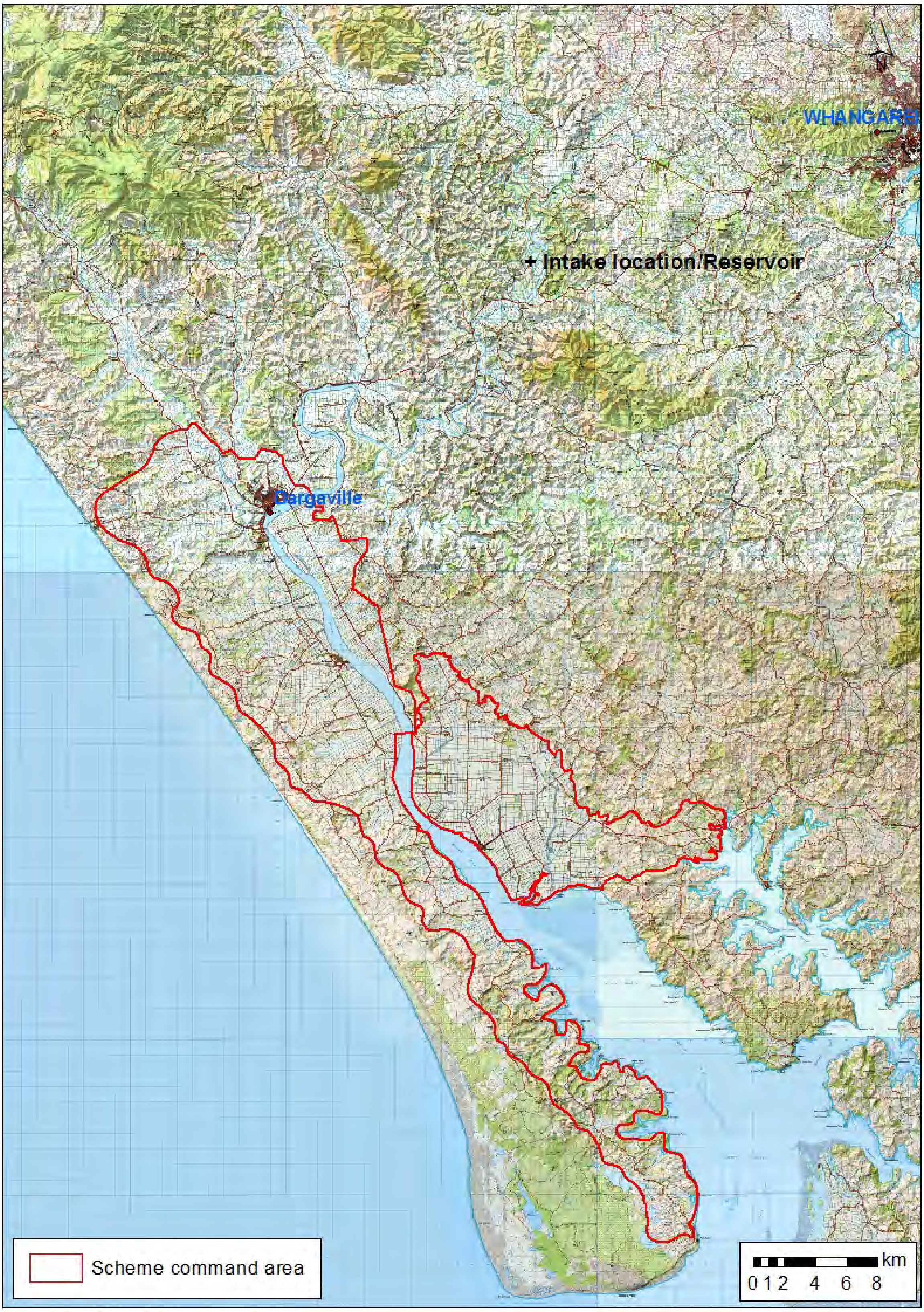


Figure H.52 – Storage hydrograph for the North Kaipara and Ruawai Areas

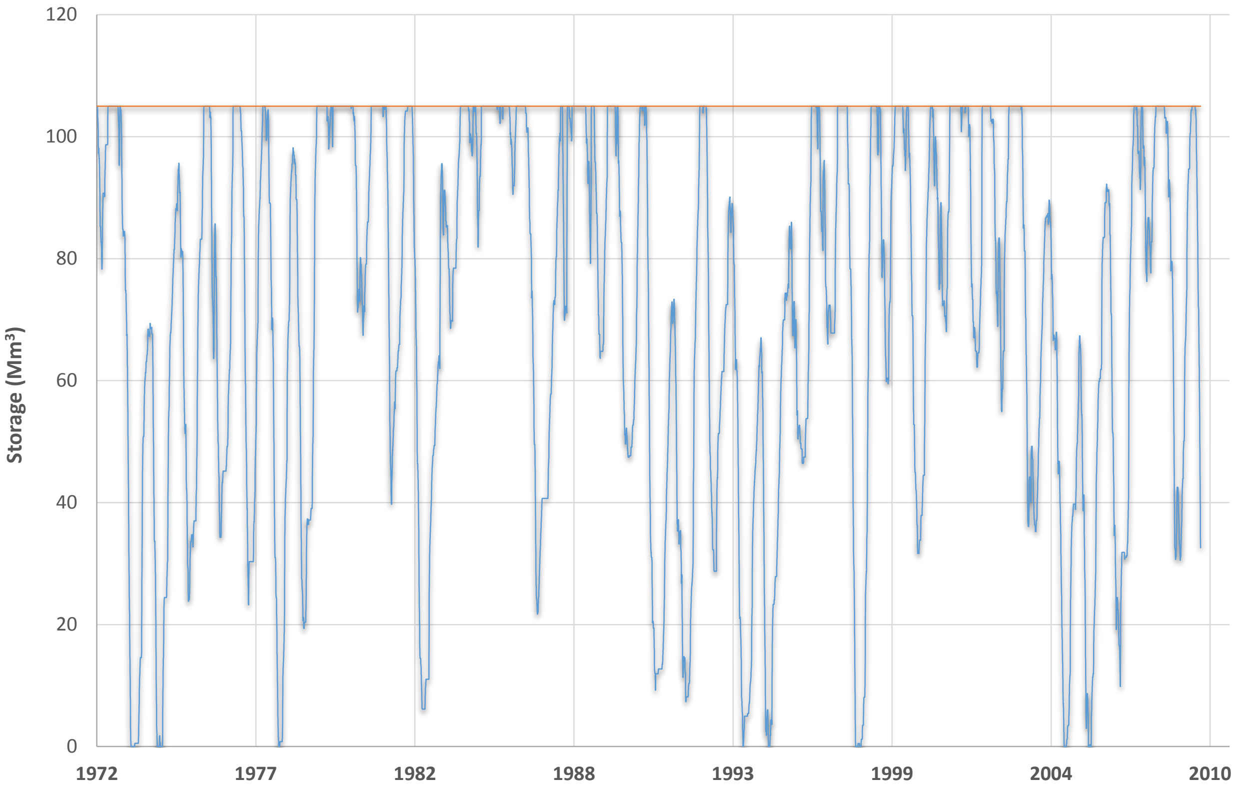
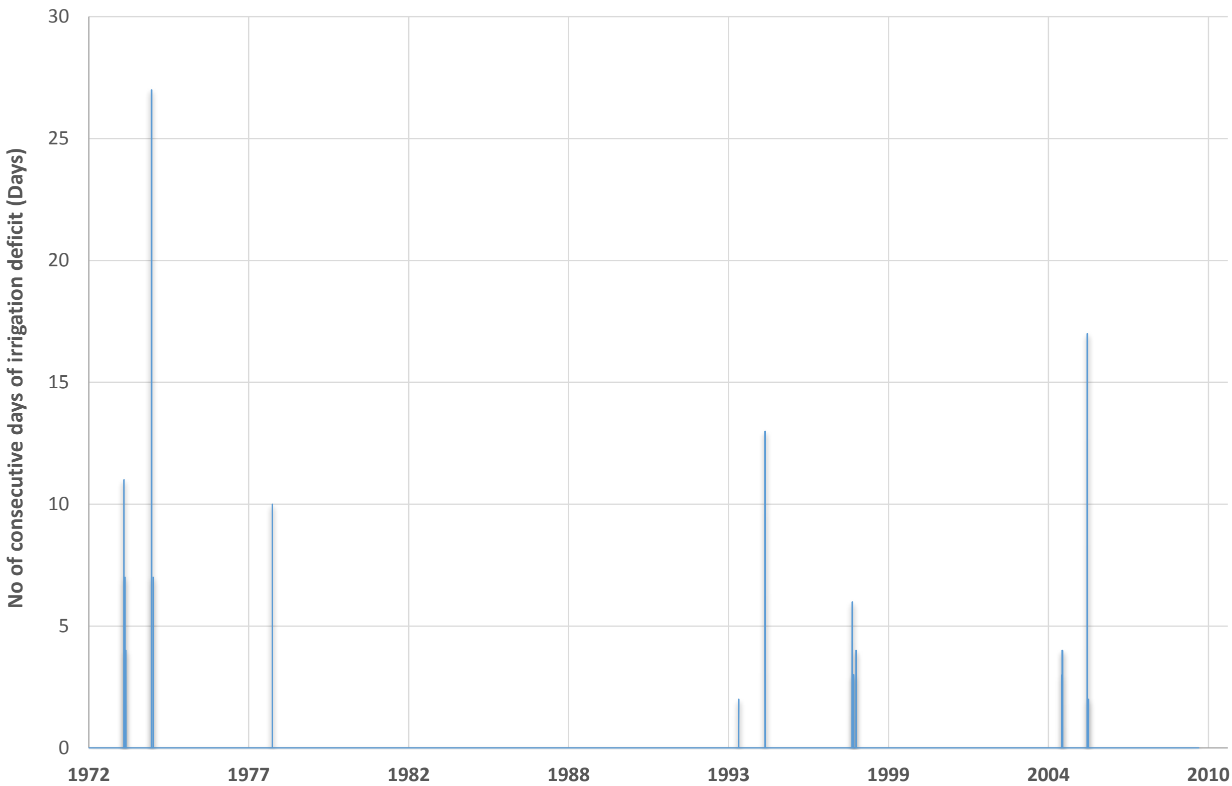


Figure H.53 – Irrigation supply deficit days for the North Kaipara and Ruawai Areas



Mangawhai Area

Figure H.54 – Approximate location of intake for water harvesting or instream dam for the Mangawhai Area

Figure H.55 – Storage hydrograph for the Mangawhai Area

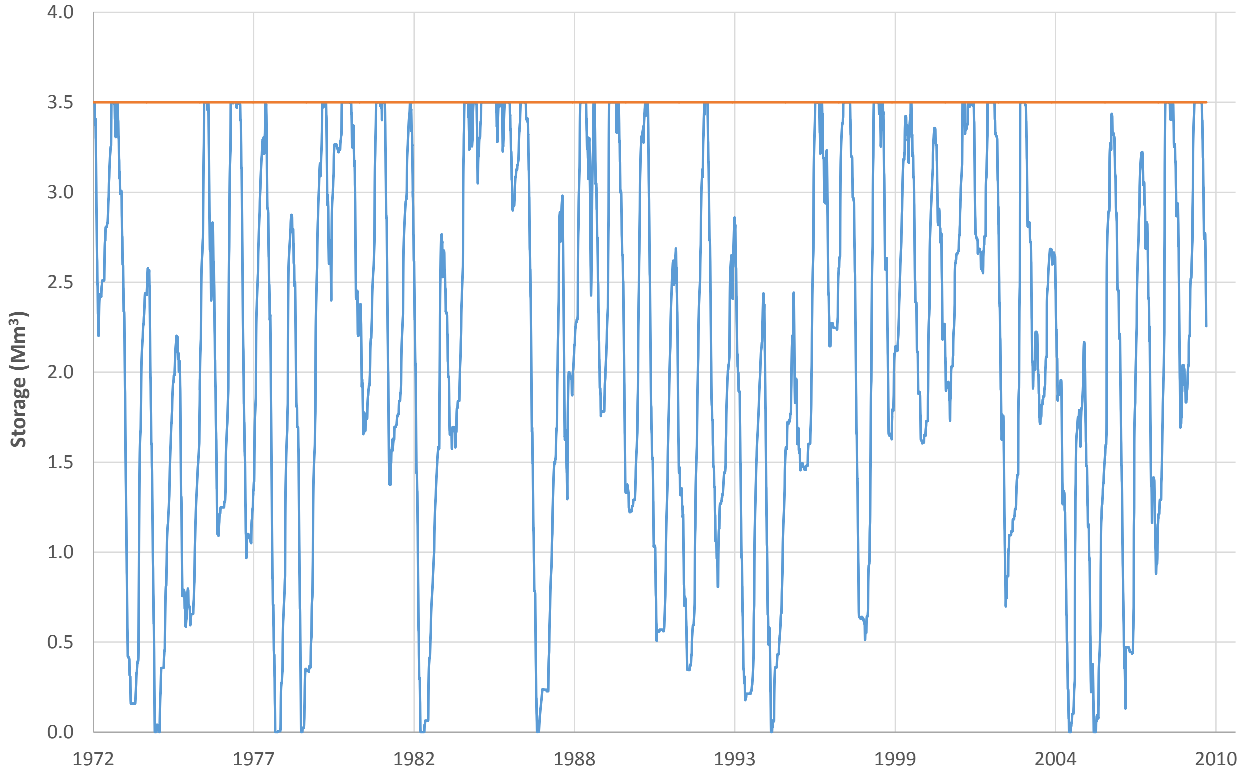
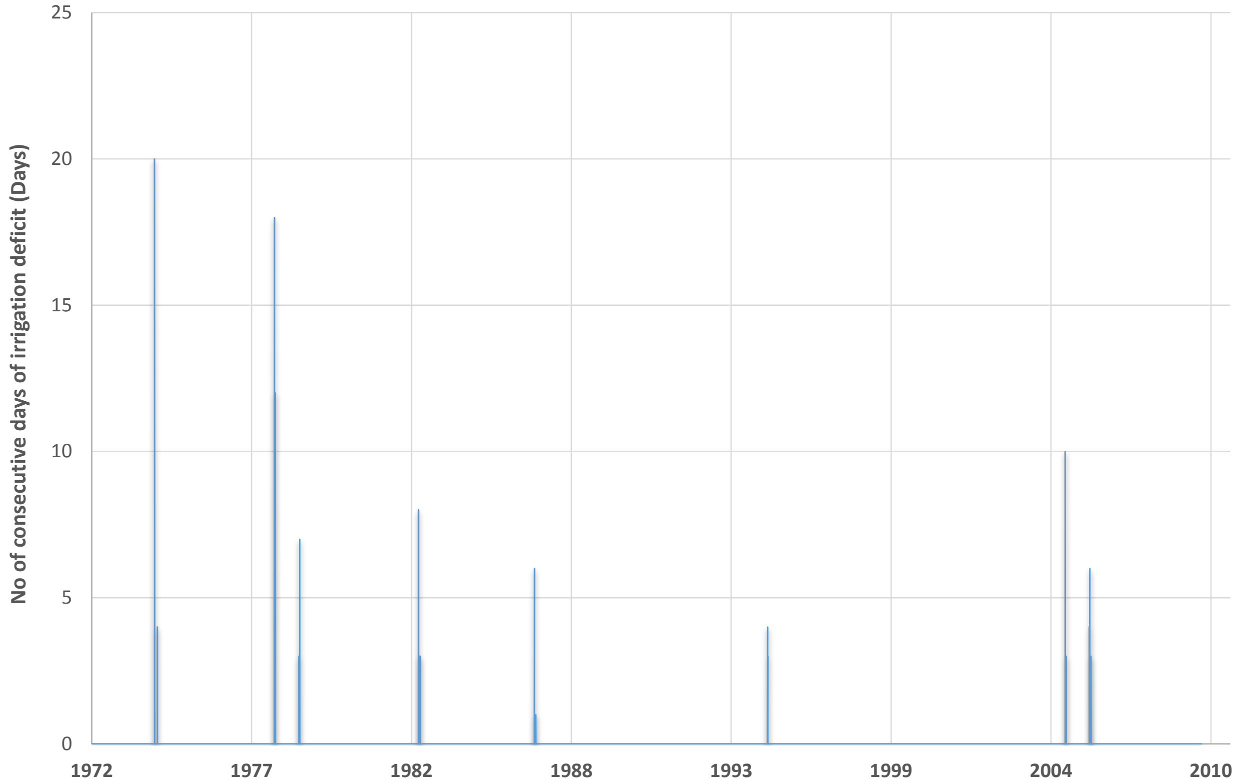


Figure H.56 – Irrigation supply deficit days for the Mangawhai Area



Appendix I Dairy performance and irrigated potential

Dairy performance and irrigated potential

Much of Northland's land has impeded drainage, so is not as well-suited to intensive irrigation as alluvial land in Canterbury. The function of irrigation in Northland on many of the soil types will therefore be to maintain production in dry seasons, including true drought mitigation, rather than to change to fully intensive irrigated dairy production. Some idea of the reality of the potential for increased production from irrigated dairy farming is gained by tracking dairying changes in Northland and relevant other regions over the past twenty years.

Dairy current production

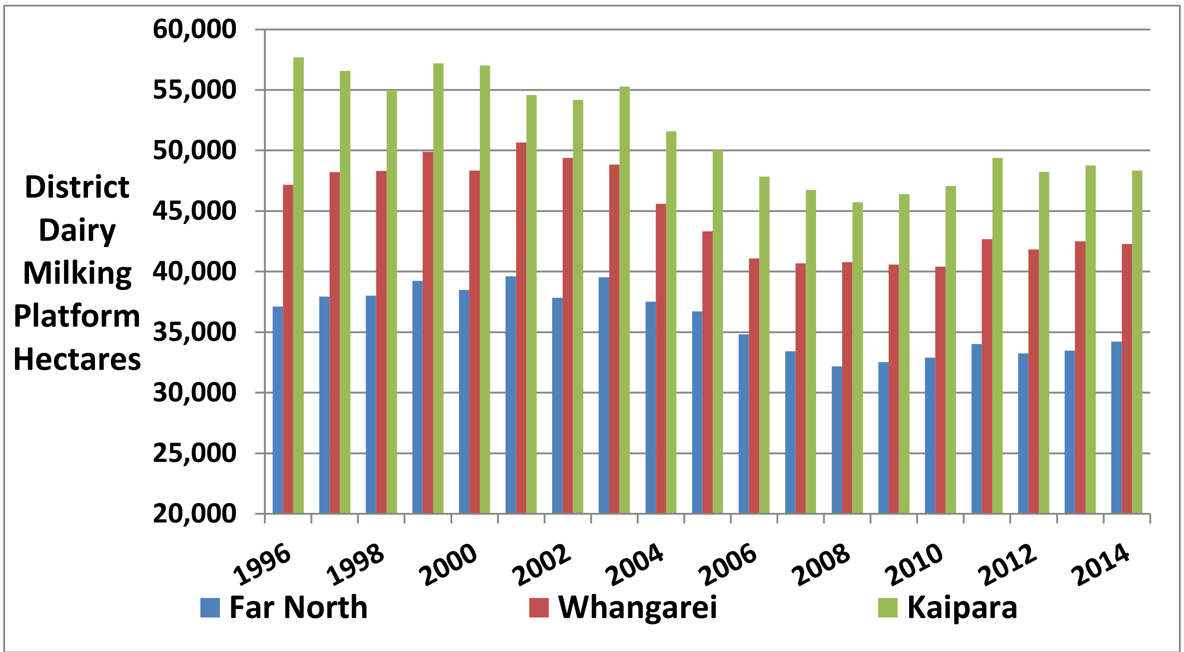
This section tracks changes in the districts of Northland from 1996 to 2014 in the areas of land used for dairy milking platforms, in the number of cows, and in the productivity per hectare of land used in the dairy milking platforms.

Dairy land use

Dairy statistics indicate that in the last twenty years the land in dairy milking platforms or 'Total effective hectares' in dairy as recorded by DairyNZ and LIC on farms in Northland peaked at 145,000 hectares in 1999 to 2001. It then steadily declined to around 119,000 hectares in 2008 and 2009, and has since firmed to about 125,000 hectares. This is a total area about 12% less than used in 1996.

The fluctuation in hectares in dairy production in each of the three Northland districts followed the same track over this period.

Figure I.1 - Dairying land area in Northland districts 1996-2014



Work by BERL at the national level including studies such as Analysis of the value of pasture to the New Zealand economy, editions in 2007 and 2011 for the Pasture Renewal Charitable Trust have indicated that this area usually constitutes a serious under-estimate of the area of land applied to dairy industry use. In effect this area is the milking platforms from functioning dairy farms. It does not necessarily include areas in gullies, shelter belts, and run-offs and certainly does not include land used in dairy support growing out replacement dairy stock off the core dairy farm.

As an example as recorded in the Statistics New Zealand Census of Agricultural Production, at a national level the total dairy cattle numbers on dairy farms in 2012 were recorded as 75% of all dairy cattle. This share was down from 79% of all dairy cattle in 2007, just five years earlier. The cows and heifers not in-calf, and the cows that were NOT on dairy farms in 2007 were 47% of these classes of animals, and the share had increased to 54% of these animals by 2012. This gives the indication that a significant amount of land other than the dairy farm milking platform land is being used in the dairy industry.

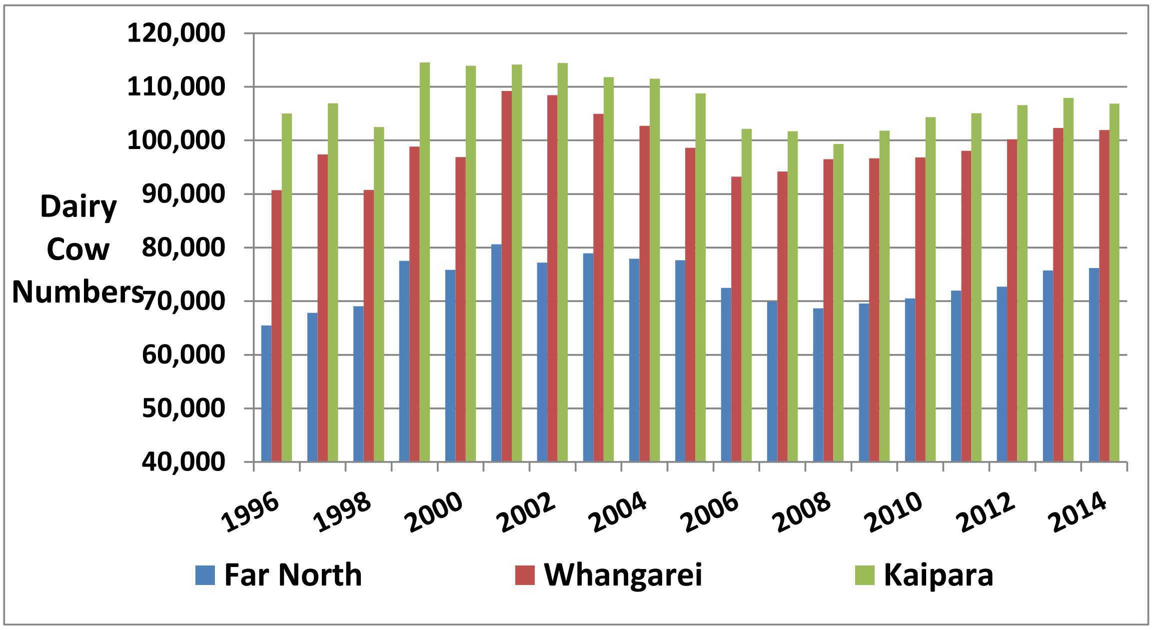
In fact at a national level, the stock units carried off the dairy farms in 2007 was an additional 22% of the number of stock units on the dairy farms, and in 2012 had increased to 26% additional to the stock units on the dairy farms.

The implications are that in Northland the current land used by the dairy industry is likely to be of the order of 155,000 to 160,000 hectares. Some of the 30,000 hectares currently used for dairy support could well be suitable for dairying, with irrigation, and land used for other livestock rearing could be used in dairy support. **The implication is that there could well be land potentially capable of increased irrigated dairy production.**

Dairy cow numbers

The number of cows in Northland has not increased as strongly as nationally. There were 261,000 in 1996, these increased to 300,000 in 2001 – 2002, and then declined to 265,000 in 2007, and have firmed to 285,000 by 2014. Over the whole period, cow numbers in Northland increased by 9%. Over the same period New Zealand dairy cow numbers increased from 2.9 million to 4.9 million, and increase by 68%. The fluctuation in cow numbers in each of the three Northland districts followed the same track over this period.

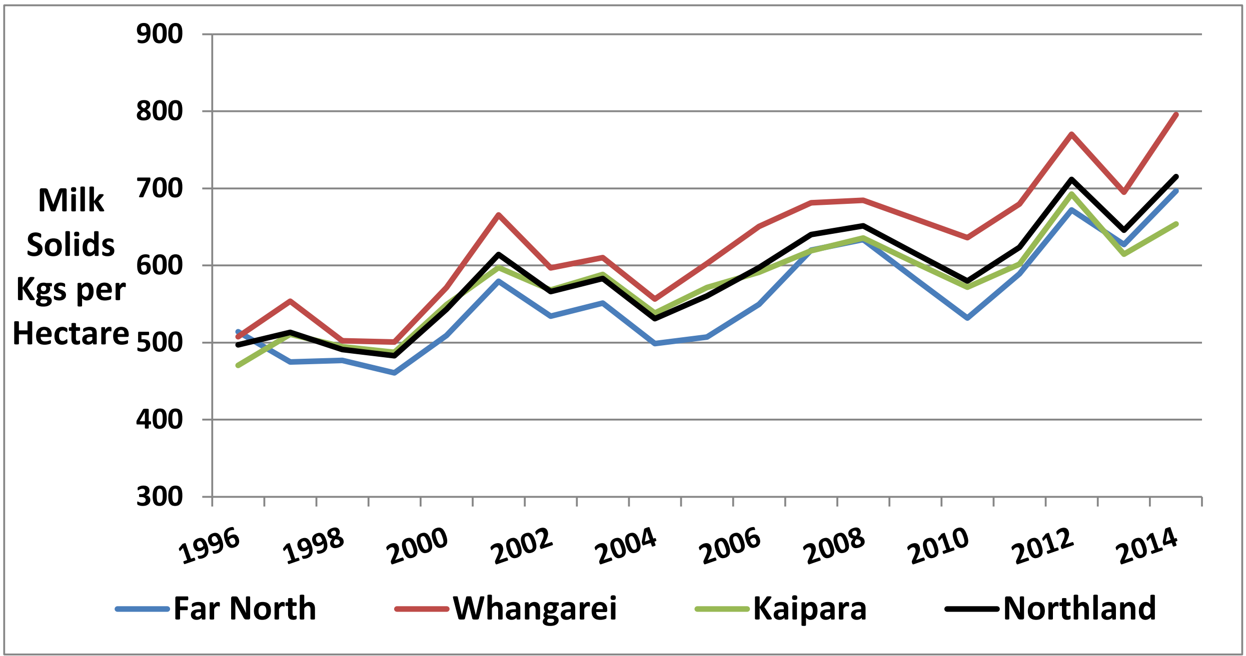
Figure I.2 - Dairy cow numbers in Northland districts 1996-2014



Dairy land productivity

The production of milk solids (MS) over this period increased in Northland by 27%. Given that the total milking platform declined by 12%, this indicates an increase in production of MS per hectare. Once again, the fluctuation in production of MS per hectare in each of the three Northland districts followed the same track over this period.

Figure I.3 - Dairy Milk Solids per hectare in Northland districts 1996-2014



The other key aspect which this track of production per hectare shows is that the production from season to season has wide fluctuations, with differences between peak and trough of 120 kg MS per hectare to 150 kg MS per hectare.

Irrigation to mitigate drought in dairying

There are two main potential impacts of irrigation on dairy productivity:

- first the reduced fluctuation as discussed above, and
- second, the straight increase in production per hectare.

That first potential impact of irrigation would substantially reduce fluctuations in productivity as between seasons. By tracking the upper modal production per hectare over the period 1996 to 2014 and assuming that in the lower production years that level could be achieved, these estimates indicate that if fluctuations in production per hectare could have been largely eliminated over that period in Northland, total production would have increased by 10%.

The first indication is that irrigation could mitigate dry seasons and increase production by 10%.

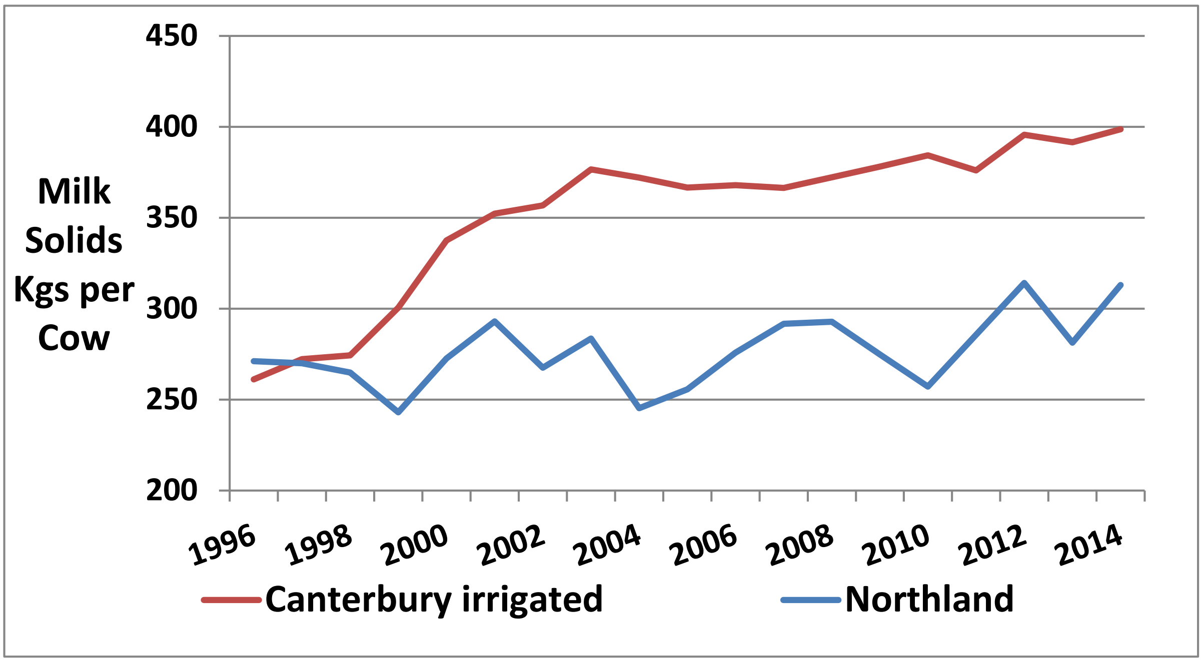
Irrigation for a step-change in dairy productivity

Where land type is suitable for intensive irrigation the greatest potential production increase further exceeds the 10% noted above where irrigation is just used to mitigate dry seasons. Intensive irrigation undertaken on free-draining alluvial soil stimulates both increased production per cow and increased stocking rate per hectare. The resultant cumulative effects causes production per hectare to increase strongly.

This change can be illustrated by tracking productivity in two Canterbury districts, Selwyn and Ashburton, over the period 1996 to 2003 when they were adopting intensive irrigation, and continuing on to the present. There is also likely some parallel investment occurring in these regions in both animal genetics and grass species to help achieve this productivity lift.

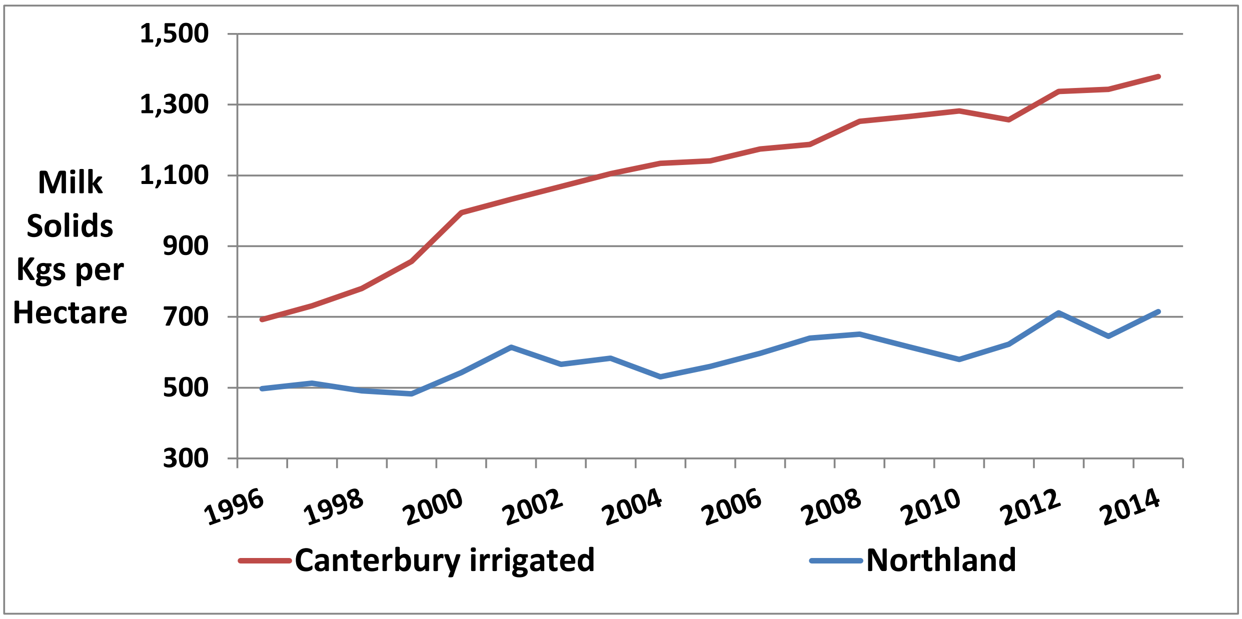
The two Canterbury districts had similar productivity of MS per cow to Northland at the beginning of the period. This rapidly increased to being about 35% greater than Northland. Thereafter it remained relatively steadily at approximately 35%.

Figure I.4 - Milk Solids per cow in Northland and Canterbury 1996-2014



Taken together with the stocking rate increases the total production of MS per hectare in the two Canterbury districts nearly doubled from 700 kg MS per hectare initially to about 1,400 kg MS per hectare in 2014.

Figure I.4 - Milk Solids per hectare in Northland and Canterbury 1996-2014



The indication from this high-level comparison is that in areas of Northland with relatively free-draining soils and access to substantial volumes of water for intensive irrigation, the production of MS per hectare could be increased by about 50%. This assumes that productivity of dairying on free-draining soil is equal to the Northland average.

However as we have stated above, much of Northland's land has impeded drainage, so is not as well-suited to intensive irrigation as alluvial land in Canterbury. Also both of these figures are regional averages, not specific to soil type.

Appendix J Cluster area locations

Figure J.1 - Cluster Area 1 - Far North with LUC class areas

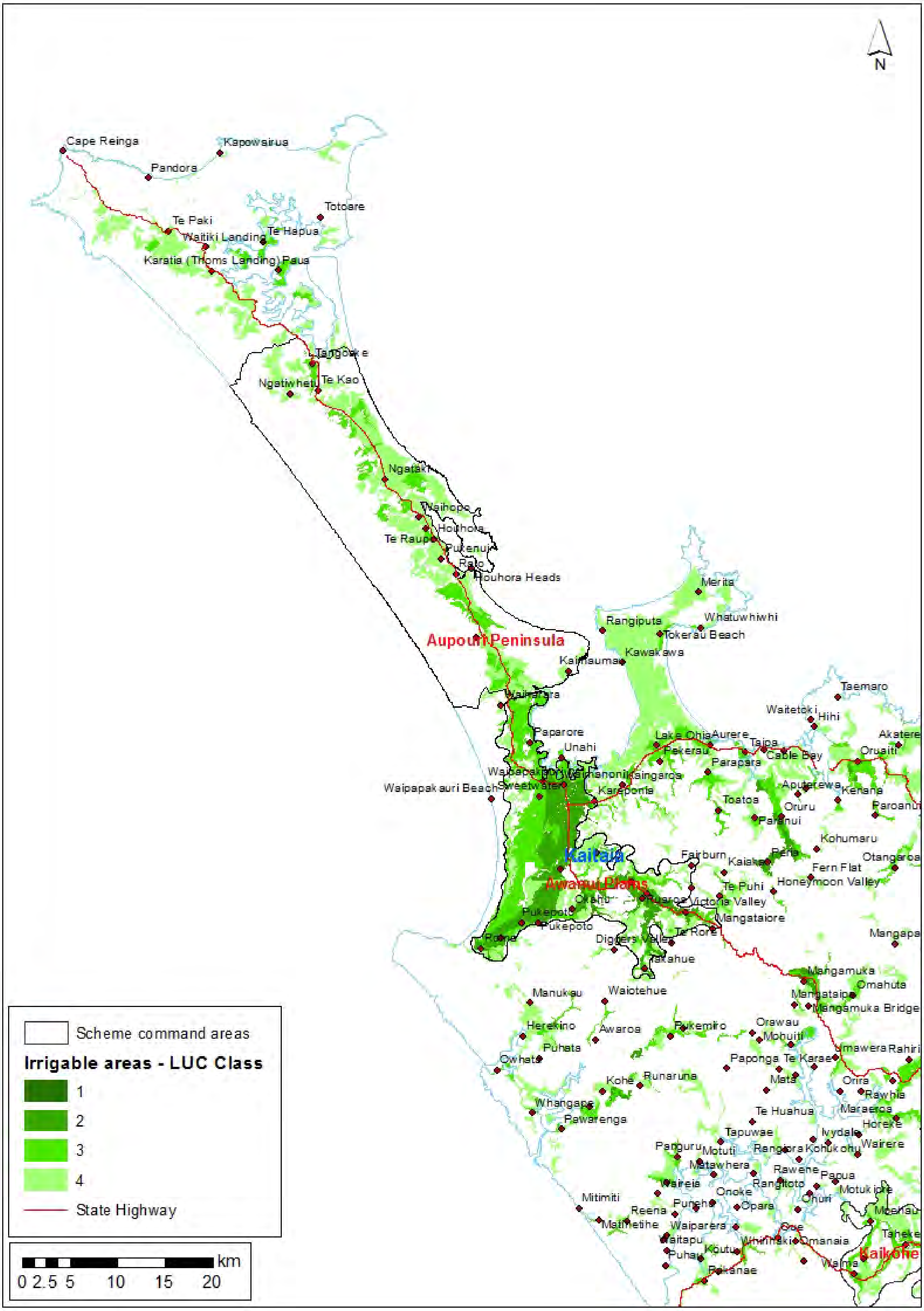


Figure J.2 Cluster Area 1 - Mid-North with LUC class areas

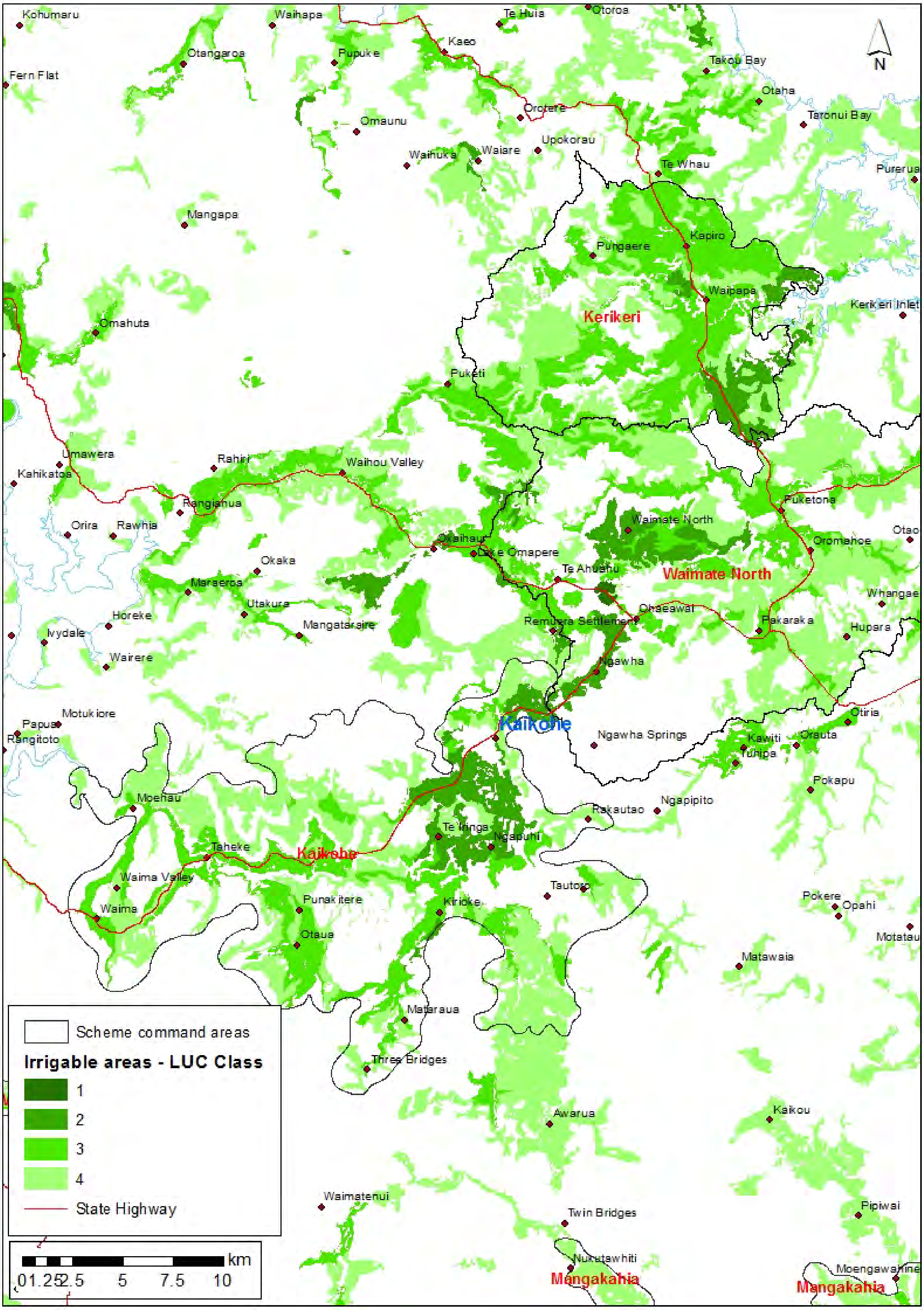


Figure J.3 - Cluster Area 3 - Whangarei and surrounds with LUC class areas

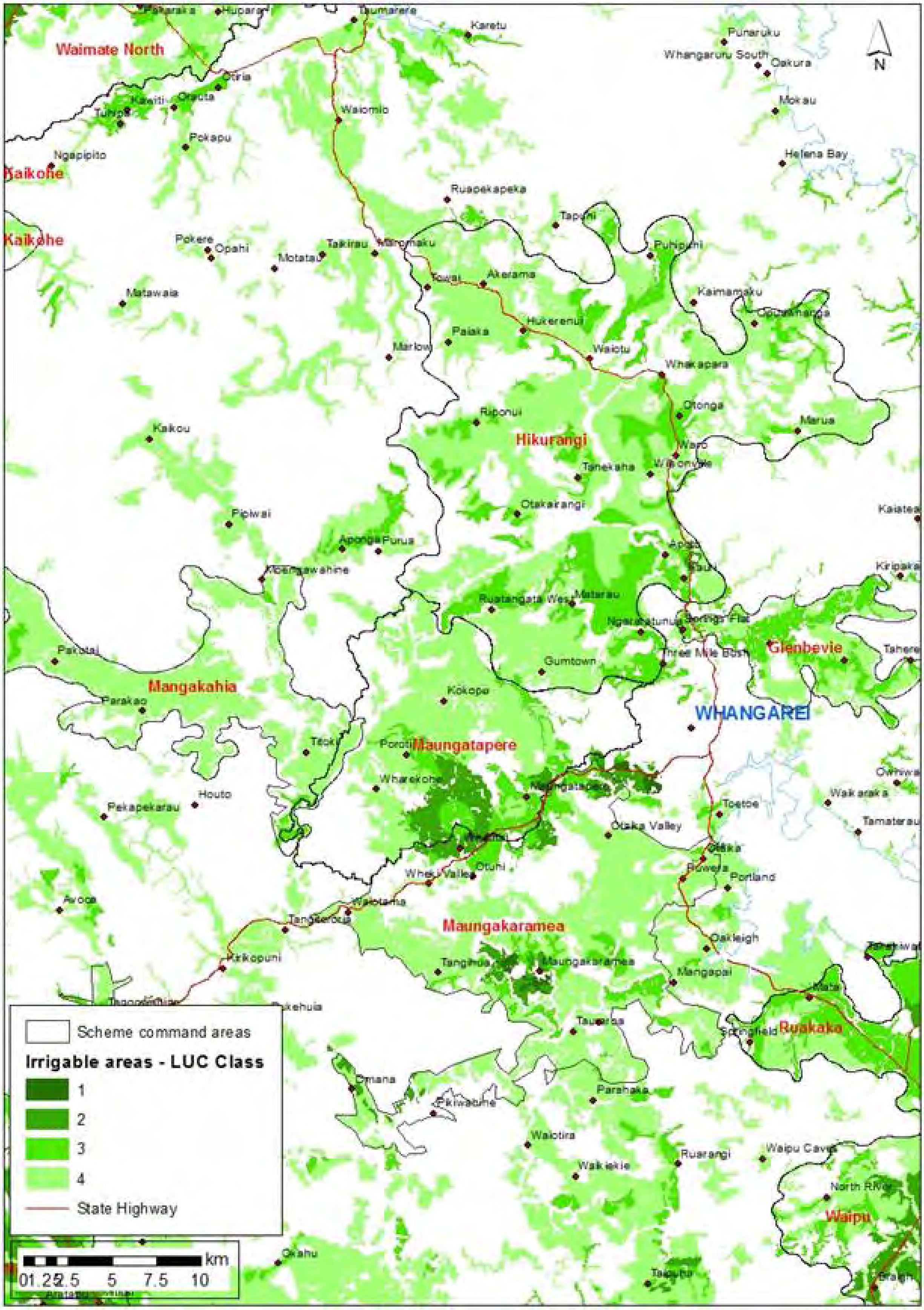
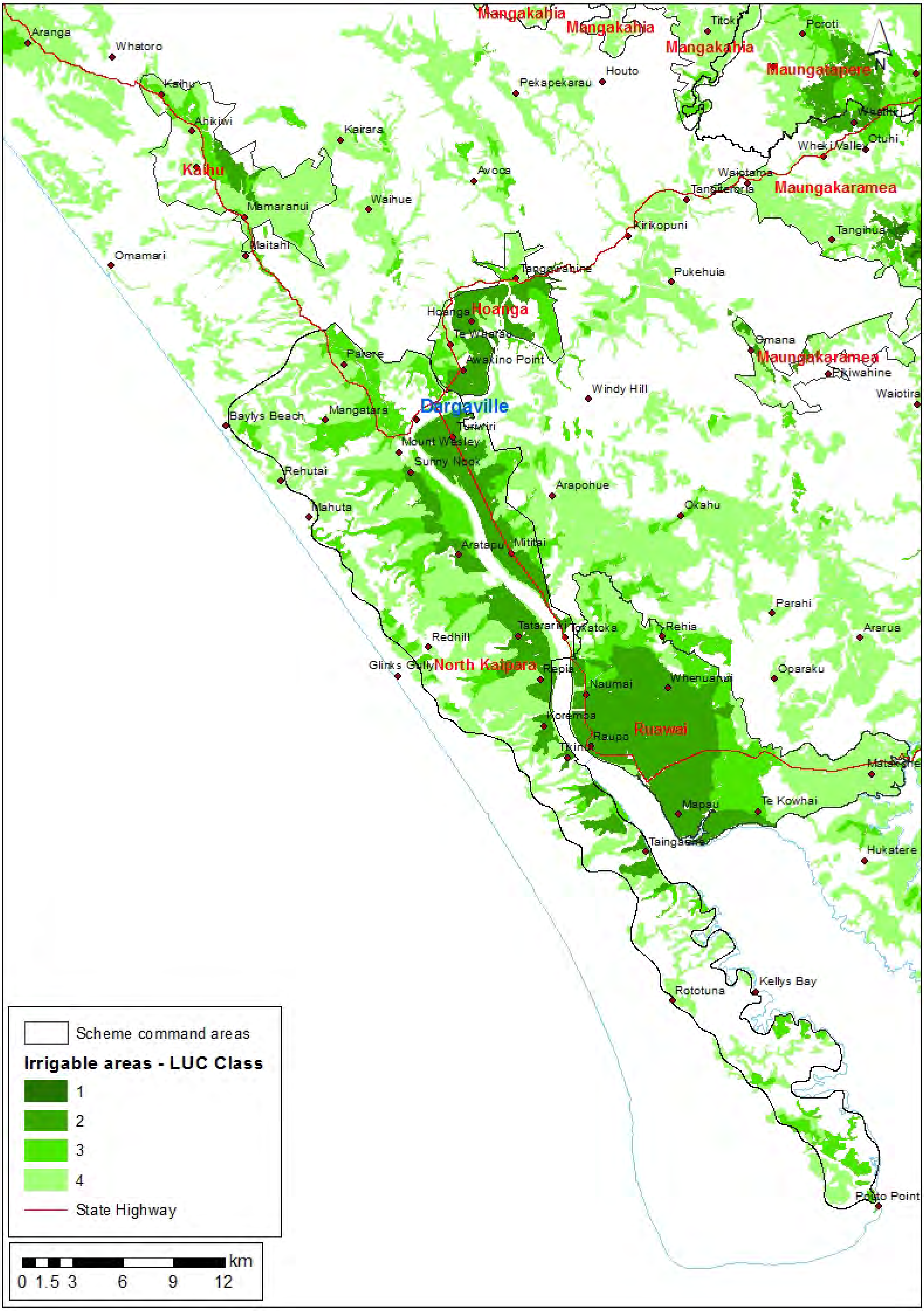


Figure J.4 - Cluster Area 3- Kaipara with LUC class areas



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