LOWER MANUHERIKIA VALLEY
WATER RESOURCES STUDY

HIGH LEVEL OVERVIEW

MANUHERIKIA IRRIGATION CO-OPERATIVE SOCIETY LTD

Lower Manuherikia Valley Water Resources Study High Level Overview

Manuherikia Irrigation Co-operative Society Ltd

Prepared By

Adrian Mahalingam
Erin Chalk,
Helli Tribe,
Sheryl Paine,
Jack McConchie

Reviewed By

Stephen McNally
Manager,
Environmental Engineering

Opus International Consultants Limited
Environmental

Level 9, Majestic Centre, 100 Willis Street
PO Box 12 003, Wellington 6144,
New Zealand

Telephone: +64 4 471 7000
Facsimile: +64 4 499 3699

Date: August 2009
Reference: 3-50705.00
Status: Final

© Opus International Consultants Limited 2009

Contents

1 Executive Summary

The water allocated in the consent to abstract from Lake Dunstan is more than sufficient to irrigate the entire irrigable area in the Lower Manuherikia Valley at an application depth of 7 mm per day for 120 days per season, which allows for the maximum foreseeable irrigation demand in the future. However, applying that depth would require impractically large storage reservoirs to store water abstracted during the months outside the irrigation season to supplement water directly abstracted during the irrigation season. Nevertheless, the use of some storage volume, with scheme-wide storage reservoirs and on-site storage dams, would be essential to allow the most efficient use of the available consented water. We propose that it is more sensible to use a lower application depth that would meet the likely current irrigation water demand while trimming the irrigable area to exclude areas where the marginal cost to supply water is expected to be significantly higher than the marginal benefits of extra revenue. The actual required application depth and irrigation season length will be verified via a water balance model in the subsequent detailed concept study.

2 Introduction

In this high level overview report, we present the first component of a Water Resource feasibility study for the Lower Manuherikia Valley and its associated rural and community activities. A primary option is to examine extending the proposed privately supported Dairy Creek Irrigation Scheme to incorporate a wider community water resources objective. Our report discusses the feasibility of combining the various irrigation and water supply schemes in the command area into a single entity with possibly a single source.

We present our estimates of the likely water demand for the Lower Manuherikia Valley and the supply capability from the existing consented allocation proposed to abstract water from Lake Dunstan at Dairy Creek.

Our scope was to conduct a desktop study of the command area in relation to foreseeable demand for water resources and relate this to available water sources, taking into account the influence of storage buffering. We also establish in broad principles the limitations on moving water up the Lower Manuherikia Valley towards Tiger Hill, a natural boundary with the water source from the Upper Manuherikia Valley. The feasibility study will establish a high-level water demand model for various agricultural, horticultural and rural residential water users for the foreseeable future up the valley to Tiger Hill.

Specifically, we present results of our analysis of the rationalisation of the irrigable land within the command area in terms of slope, soil type and local climate factors. We then present our conclusions and recommendations for review.

Following on from this high level water resources study, we will build a detailed concept study to examine engineering factors and develop a cost/benefit analysis.

This report has been jointly funded by and will be distributed to:-

- Manuherikia Irrigation Co-operative Society Ltd
- Otago Regional Council

- Central Otago District Council
- Vincent Community Board

3 Background to the Project

There is an existing consent (Consent No. 2002.725) to abstract water from Lake Dunstan for irrigation and frost fighting with an extraction point identified at Dairy Creek, approximately 1km north of the Clyde Dam. The consent allows the abstraction from 1st August to 30th May annually of a maximum of 4.53 m^3 per second and a maximum of 326,160 m^3 per day.

It needs to be noted that the daily maximum represents a peak pumping rate of 4.53 m^3 per second for only 20 hours a day. The consent does not stipulate when the extraction can occur on a daily time scale, thus the maximum daily limit could be achieved by pumping at 3.775 m^3 per second continuously for 24 hours a day. This will be further considered in terms of pump, pipes, power supply and storage sizing calculations in the detailed study.

The consent was established on 19th May 2003 for 35 years, and hence expires on 1st April 2038. A number of conditions are placed on the consent which will be discussed in later sections. However, most significantly, the conditions can be reviewed in 2013, including determining whether the allocated volume is excessive. Effectively, if no progress is made toward exercising the consent by 2013, an argument by other parties linked to the Clutha River could be mounted to 'leave' the allocated volume to the river system. The holders of the consent are aware of this condition, and as such, are undertaking this and other related studies to determine how best to utilize some or all of the consent allocation.

The command area identified in the brief of this study is for the potential irrigation of the Lower Manuherikia Valley in Central Otago, stretching from Lake Dunstan in the west to Tiger Hill in the east. It covers the existing Lower Manuherikia and Galloway irrigation schemes, the proposed Dairy Creek irrigation scheme, and other surrounding areas, some of which could potentially be irrigated.

Currently, the Lower Manuherikia and Galloway irrigation schemes are supplied from historic race systems from the Manuherikia River under mining privileges granted for 99 years. These are due to expire in 2021, and as such, there is pressure to identify alternative water sources as a contingency against unsuccessful consenting under the RMA. An alternative view is that it is simply better to fully use the Dairy Creek allocation to reduce demand pressure on the Manuherikia River which also supplies irrigated farming operations in the Upper Manuherikia Valley. A balance will need to be struck between using Manuherikia River water to meet any shortfall of water demand in the Lower Manuherikia Valley or retain the water supply for the benefit of the Upper Manuherikia Valley, nominally identified as north east of Tiger Hill.

Central Otago District Council also wants to consider options of joining a possible piped scheme to use part of the abstracted water for potable water supply for Alexandra and Clyde. Clyde has a current water supply that is satisfactory to its community, but Alexandra's community has been less than satisfied with their water supply. Therefore, there may be some benefit in supplying Alexandra with water from the irrigation mainline. Following on from that, it is sensible to consider a combined treatment system for both Alexandra and Clyde using a single supply system. Issues surrounding drinking water supply to Alexandra, Clyde and the surrounding rural residential lots will be covered in a supplementary drinking water security report.

4 Water Allocation Framework

A potential Lower Manuherikia Valley irrigation scheme has significant economic, environmental and social benefits for the wider local community, region and nation.

More than half of the command area is currently being irrigated as part of the Manuherikia, Galloway, and other irrigation schemes and private water rights. However, these water sources are at risk in the near future, as water permits expire. In addition, private water rights supply sources are likely to become less reliable as irrigation methods change from flood irrigation (that may be recharging those sources) to more efficient irrigation methods like spray and drip irrigation. There is also land that is currently not being irrigated for various reasons, for example, because of their location above the gravity-fed water races. This irrigation scheme provides reliable irrigation water to both areas currently being irrigated as well as the opportunity to irrigate these new areas. The importance of reliable water availability is the focus of this section.

At the level of individual farm owners, water availability is a limiting factor in developing farm management practices to meet global market demands which increasingly requires consistent product quality and volume. Without irrigation in this dry district, there is no reliability of water supply for crops or pasture, thus farmers would have to use conservative dry-land farming systems which probably cannot meet international market demands. Studies have shown that because irrigation allows land use changes and increases water supply reliability, irrigated areas have significantly higher farm gate output (revenue), return on capital and cash farm surplus (profit) compared to comparable non-irrigated areas. Instead of having marginal profitability, farms can earn higher and more diverse, and therefore, more resilient profits. As an example, dairy farms in Canterbury have enjoyed a 7-fold increase in gross revenue and 10-fold increase in farm cash surplus because of irrigation. Access to reliable water also increases the capital value of the land.

At a district and regional level, there are many flow-on effects from increased agricultural activity. These include:

- *direct economic impacts*, i.e. increased employment of people who work on farms and increased value of farm output sales,
- *indirect economic impacts*, i.e. increased spending by farmers of additional farming inputs to increase production, e.g. fertilizer and fuel,
- *induced economic impacts* that result from farm owners and workers earning and spending more, leading to higher income and employment in other industries, and
- *downstream impacts*, i.e. increased processing activity of farm outputs, e.g. wine, milk or meat processing.

(Categories used in Opuha Dam Ex Post Study by Harris Consulting, Aug 2006)

With regards to higher employment, a MAF report by Doak et al. calculated 10.4 more full-time equivalent (FTE) employees per 1000 hectare employed on irrigated farms compared to non-irrigated farms. A Ministry for the Environment (MfE) report by Ian Brown Consulting and Harris Consulting gave a higher estimate of 70 more FTEs employed on irrigated farms per cumec of irrigation and a ratio of 1.8 - 1.9 total FTE (including auxiliary industries) for every one FTE of direct employment (on farm).

Because of irrigation, the region also enjoys higher economic value added, which is an indicator of economic activity. The same MfE report calculated that value added was higher by $2 - 3 million per cumec of irrigation directly associated to agriculture increase, and a 2.2 - 2.3 ratio of total value added to direct value added.

Because economics is primarily concerned with the efficient allocation of scarce resources, the proposed irrigation scheme would be a step in the right direction because it involves water that has already been consented and allocated for take, but not yet used to generate benefits to the community. The irrigation scheme would also be an efficient use of water because it should bring economies of scale, reducing the cost per hectare irrigated, and also allows more farmers to access the water.

There are also social benefits to the local community. Irrigation allows otherwise unfarmed land to be used for production and the intensification of farming in existing operations, thus supporting more workers and potentially also more land owners. These extra landowners and workers may have families, with the MfE report estimating a higher population of 180 more people per cumec, attributable to irrigation. The demographics are different as well, in terms of population age structure (more younger people), education (more educated), occupation (changes with land use changes) and median household income (higher income generally). For areas where irrigation is only now being introduced, these changes are expected to be gradual and over an extended period, potentially more than a generation. With the changed demographics, the community would start to have a demand for more family-based social needs, such as schools. This is often seen as healthy growth for the community.

We believe that a potential community irrigation scheme is also in line with Otago Regional Council's principles:

- *local water first used for local use* – the use of water for irrigation and potable water supply for the local community. This applies equally to using Lake Dunstan water in the lower valley and retaining Manuherikia River water in the upper valley.
- *no area stranded dry* – the community scheme should allow areas further away from Lake Dunstan to access water in an affordable way through economies of scale, and through the incorporation of additional storage buffers, increase the reliability of supply.
- *efficient use of water resources* – the potential irrigation scheme would facilitate the use of water for the purpose it has already been consented for abstraction. The detail of how the water will be distributed and applied to various uses will need to address the consent conditions including intake management and metering.

At a national benefit level, it is important to note that agricultural production constitutes approximately 56% of New Zealand's exports which affect the national balance of payments, which in turn affects exchange and interest rates. Increased irrigation opens up new land for farming and most of this increase is likely to be exported, which would represent an economic benefit for the country.

5 Consent Requirements

Although the promoters of the Dairy Creek project hold a consent to take water from Lake Dunstan, they do not hold a consent to use the water and this matter needs addressing.

An overview of the relevant legislation that this consent to use will have to comply with is set out below.

5.1 Relevant Legislation

Freshwater resources are managed across three levels of government: national, regional, and district. There are several pieces of legislation that are relevant to freshwater management:

- Resource Management Act 1991;
- Proposed National Policy Statement for Freshwater Management 2008;
- Regional Policy Statement for Otago 1998;
- Regional Plan – Water for Otago 2004, including Proposed Plan Change 1B (Minimum Flows) and Proposed Plan Change 1C (Water Allocation and Use); and
- Central Otago District Plan (operative 2008).

In addition, there are a number of other pieces of legislation that do not relate to freshwater management but that may still have an impact on any potential irrigation activities in the Lower Manuherikia area, including:

- Historic Places Act 1993;
- Building Act 2004;
- Building (Dam Safety) Regulations 2008;
- Conservation Act 1987; and
- Reserves Act 1977.

The Resource Management Act (RMA) provides broad, overarching guidance on all planning matters in New Zealand, including the use of freshwater resources and deemed/mining privileges in relation to freshwater use.

The Proposed National Policy Statement for Freshwater Management also provides overarching guidance specifically on freshwater resources.

The Regional Policy Statement for Otago provides regional guidance on all matters related to the environment. Included within the Regional Policy Statement are objectives and policies directly related to the region’s freshwater resources.

The Regional Plan – Water for Otago provides further specific guidance on freshwater resources. In addition to objectives and policies, the Regional Plan also includes rules that guide the taking and use of the region’s freshwater resources and the use of the beds of lakes and rivers. The two proposed plan changes, Plan Change 1B and Plan Change 1C, further build on the Regional Plan. The plan changes each deal with a specific matter related to freshwater management and expand on the objectives, policies and rules of the Regional Plan.

The Central Otago District Plan provides specific standards/rules for a range of activities across the Central Otago region. The Plan provides the most localised rules and relates primarily to physical works rather than directly to freshwater management.

The Historic Places Act does not relate specifically to freshwater; however, where there is the potential for heritage features such as historic water races in an area, the Historic Places Act provides guidance and regulation.

The Building Act and the Building (Dam Safety) Regulations provide the regulatory framework for the establishment and ongoing monitoring for dams. The Act includes the specific requirements that must be undertaken in establishing a new dam.

5.2 What Legislation is Most Relevant

The relevant legislation can be split into two categories. The first, which includes the Proposed National Policy Statement for Freshwater Management and the Regional Policy Statement for Otago, provide guidance and relevant objectives and policies but do not contain rules or standards for development. The second, which includes the Regional Plan – Water for Otago, Plan Change 1B and Plan Change 1C, and the Central Otago District Plan, contain the rules and standards that govern development and dictate whether a proposed activity is permitted as a right or will require a resource consent (Regional and/or District).

Part of the focus of this high level review is to determine whether the proposed activities (including earthworks, pump-stations, underground pipes, water storage dams etc.) are permitted activities or will require resource consent. Of most importance, however, will be how the proposal meets the principles and rules contained in the Regional Plan – Water for Otago and the Central Otago District Plan.

5.3 Resource Management Act

The Resource Management Act provides that the taking, use, diversion or damming of water, except for individual consumption, is prohibited unless specifically allowed for by a rule in a regional plan or any proposed regional plan or by a resource consent.

5.4 Regional Plan – Water for Otago

Includes Proposed Plan Change 1B (Minimum Flows) and Proposed Plan Change 1C (Water Allocation and Use)

The Regional Plan – Water for Otago is currently subject to two plan changes. These plan changes are still in the development phase but still need to be considered as they may impact on future activities in the region. The Otago Regional Council (as at June 2009) is close to giving its decision on Proposed Plan Change 1C, so it is especially important to consider any impacts this proposed change could have on irrigation activities.

5.4.1 Water Use

There is an existing consent to take water from Lake Dunstan which allows the abstraction of up to a maximum of 4.53 m^3 per second and 326,160 m^3 per day and various conditions apply to this consent. However, the consent does not provide for the use of the water.

Under both the operative Regional Plan and Proposed Plan Change 1C, the use of water, in terms of the existing consent to take water, is not a permitted activity as it breaches the thresholds for permitted water use which are set out in Section 12.1.2. The use of the water would either be a restricted discretionary or discretionary activity. Therefore, a resource consent would be required to allow use of the water.

In considering an application for the use of the water, the Regional Council would take into consideration a number of factors including whether the use of the water would meet the objectives and policies of the Regional Plan and the Proposed Plan Changes. Central to the objectives and policies are ideas including:

- the development of shared water infrastructure;
- the establishment of water allocation committees or water management groups;
- to grant consent for only as much water as actually used/needed;
- to prioritise the use of water from within the area it was taken over its use elsewhere;
- to promote shared use and management of water resources;
- to ensure the efficient use of water resources.

5.4.2 Water Storage

The Regional Plan promotes the storage of water at periods of high water availability through:

- the collection and storage of rainwater; and
- the use of reservoirs for holding water that has been taken from any lake or river.

There are no rules specifically related to the construction or use of reservoirs, however both the Regional Plan and Plan Change 1C state that the provision of information will be used as a means of encouraging efficient water use, including through the use of water storage.

5.4.3 Buildings or Structures

Under the Regional Plan it is a permitted activity to erect or place any structure, other than a defence against water, within 7 metres of the bank of a river or the margin of a lake, provided that it does not result in the physical prevention or obstruction of access for works to avoid or mitigate any natural hazard, and the Otago Regional Council is notified in writing of the location and nature of the structure at least seven working days prior to commencing the erection or placement. If these conditions are not met, then the activity becomes a discretionary activity and resource consent would be required.

It is also a permitted activity to erect or place pipes in, on, under, or over the bed of a lake or river provided certain standards are met. If these standards are not met, then the activity becomes a discretionary activity and resource consent would be required.

The erection or placement of any flow or level recording device, outfall or intake structure or navigational aid structure, that is fixed in, on or under the bed of any lake or river is a permitted activity, provided certain conditions, including that the structure does not exceed two square metres in area, are met. If these conditions are exceeded, then the activity becomes a discretionary activity and resource consent would be required.

5.5 Central Otago District Plan

5.5.1 Rural Resource Area

The Lower Manuherikia Irrigation Area, generally being the entire Lower Manuherikia Valley stretching from Lake Dunstan in the west to Tiger Hill in the east, falls within the Rural Resource Area. This area is captured by the Central Otago District Plan Maps 52-53 and 56-57.

Within this area there are several features highlighted on the planning maps that may impact on what activities can be undertaken including:

- Part of the area is also classified as an Area of Outstanding Landscape;
- Part of the area is also classified as an Area of Significant Natural Value;
- Part of the area is also classified as Land Over 900 Metres; and
- There are a number of designations, heritage features, and scheduled activities.

The Central Otago District Plan is divided into a number of sections. The following sections are considered relevant:

- Section 4 – Rural Resource Area;
- Section 5 – Water Surface and Margin Resource Area;
- Section 12 – District Wide Rules and Performance Standards
- Section 13 – Infrastructure, Energy and Utilities;
- Section 14 – Heritage Buildings, Places, Sites, Objects and Trees
- Section 17 – Hazards
- Section 19 – Schedules

Under the Central Otago District Plan, ‘network utility’ includes irrigation works.

5.5.2 Underground or In-ground Utilities

The District Plan provides that all underground or in-ground network utilities, including ancillary pump stations and water supply intakes are permitted activities provided that certain standards are met. If these standards are not met, then the activity becomes a discretionary activity and resource consent would be required.

The operation, maintenance, repair, upgrading and removal of network utilities (including existing network utilities and earthworks to maintain the utility’s function) is a permitted activity.

The development of new power generation facilities, including the construction or commissioning of a power generation facility, is a discretionary activity. Therefore, resource consent would be required.

5.5.3 Earthworks and Vegetation Clearance

For areas within the Rural Resource Area further than 10 metres from a water body, there are no restrictions on the level of earthworks. Within 10 metres of a water body, earthworks can take place to the amount of 20 m^3. A higher level of earthworks may be permitted if the works are in relation to minor maintenance required for the safe and efficient operation of utility networks.

Within 10 metres of a water body, the removal of vegetation is not permitted unless it is in relation to minor maintenance required for the safe and efficient operation of utility networks.

5.5.4 Buildings or Structures

The Central Otago District Plan provides that the following structures can be established as a permitted activity:

- River monitoring and recording facilities. Such facilities may include a stilling tower and/or instrument housing not exceeding 2.5 m x 2.5 m, a catwalk directly from the adjacent river bank to the housing and associated telemetry and power supply housing.; and
- Structures necessary for the taking and carrying of water, including intake structures, races, pipelines, and associated irrigation works, pump houses and

treatment plants no larger than 9 m^2 in area and 2 metres in height and provided their design and colour blends with the environment.

A number of standards need to be met, including that the erection of structures does not:

- adversely affect public access to or along the margins of the water body
- create a disturbance to the margin of the water body that is more than minor
- compromise safe and efficient navigation

If these standards are met, the activity can be undertaken without the need for resource consent. If the standards are breached (ie. buildings are larger than the threshold size), then the activity becomes a discretionary activity and resource consent would be required.

5.5.5 Separation Distances

Separation distances apply to buildings, excavations and/or tree planting from water races and irrigation pipelines. Separation distances increase as the slope increases. However, these separation distances do not apply to the maintenance, replacement and/or reconstruction of water races and associated irrigation works.

Table 1: Activity Status for a Range of Irrigation Related Activities

Activity	Regional Plan – Water for Otago and Plan Changes	Central Otago District Plan
Water Use	Restricted Discretionary or Discretionary Activity.	N/A
Water Storage	Promoted under the Regional Plan.	N/A
Underground Pipes	Permitted Activity: NB. Conditions apply for pipes in, on, under or over bed of river or lake.	Permitted Activity: NB. Certain standards apply.
Earthworks	N/A	Permitted Activity: Provided that within 10m of water body, 20m^3 threshold unless for minor maintenance of a network utility.
Pump Station	Permitted Activity: NB. On riverbank no restrictions; in, on, or under bed of river no more than 2m^2.	Permitted Activity: Provided no larger than 9m^2 in area and 2 metres in height.
Power Generation Facility	N/A	Discretionary Activity

5.6 The Historic Places Act

The Historic Places Act applies where there are archaeological sites that pre-date 1900. If there is the possibility of archaeological features that pre-date 1900 on a site, then a number of steps can be taken. First, a desk-top archaeological assessment can be undertaken. This will include an assessment of both visible and sub-surface archaeological features. If archaeological sites are present and works will impact on the features, then an Archaeological Authority is required from the Historic Places Trust. This would need to include a full Archaeological Assessment of Effects.

5.7 The Building Act

The Building Act requires that prior to any building work being undertaken, building consent must be applied for. The building consent process for dams (including storage dams) is the same as for all building work, as set out in the Building Act.

In addition, the construction of water storage dams requires a number of further steps to be undertaken. For ‘large dams’ (a dam that retains three or more metres depth, and holds 20,000 or more cubic metres volume), the dam owner is required to classify the dam based on the potential impact if the dam fails. For dams that have medium or high potential impact, the owner is required to prepare a dam safety assurance program.

5.8 Esplanade Reserves and Esplanade Strips

There is the possibility that some activities may need to be undertaken within an esplanade reserve or esplanade strip. Any activities that are undertaken within these areas may be subject to conditions and prohibitions under the Reserves Act, Conservation Act, or specific Esplanade Strip Instruments.

6 Determination of Extent of Command Area

The command area identified in the brief of this study is for the potential irrigation of the Lower Manuherikia Valley, stretching from Lake Dunstan in the west to Tiger Hill in the east. It covers the existing Lower Manuherikia and Galloway irrigation schemes, the proposed Dairy Creek irrigation scheme, and other surrounding areas, some of which could potentially be irrigated.

This general description, however, captures a land area of approximately 15,250ha. Our study has made an attempt to identify and eliminate features not necessarily of interest for irrigation, such as the urban areas of Clyde and Alexandra, road reserves, the airport reserve, existing water bodies such as reservoirs and river beds and other rural residential structural elements. Irrigation pertaining to urban gardens and other council-operated open spaces are currently supplied from the potable supplies to Clyde and Alexandra and have been excluded from our study, albeit subject to on-going review as to the sustainability of this supply mechanism.

Of the remaining land area, several other considerations have been applied to determine the practical long-term maximum likely irrigable area of interest. In particular, some of the area is very steep, and by examining the site slopes compared to the limitations of irrigation systems to address these areas, we have been able to eliminate some impractical scenarios.

Of the land that is of acceptable slope, we have then looked at the soil types and depth to see what, if any, area should be eliminated as simply unsuitable for irrigated farming practices. We have incorporated local knowledge applied to the detailed databases available. This process has not significantly reduced the irrigable area.

Finally, we have examined the local climate factors such as rainfall relative to evapotranspiration for this region to form the basis of a detailed water demand model. Our general brief was to look at the likely maximum water demand for the foreseeable future and a figure of 7mm/day was mooted. We have used this figure as a starting point, but applied some more rigor to likely scenarios as the study has progressed to test the sensitivity of the water demand model. A significantly lower water demand was developed for the Dairy Creek project that incorporated both high intensity pastoral irrigation and a high proportion of viticulture development. This model has also been applied to the overall command area for comparison.

6.1 Slope Analysis

A combination of AutoCAD and GIS software were used to generate a map of the command area which extends from Lake Dunstan in the west to Tiger Hill on the east including 20-metre contour lines. A higher accuracy of contour data will be needed for detailed design, but at this stage, 20 m information with accurate aerial photographs are sufficient to identify significant land features.

The proposed area for the Dairy Creek Irrigation Scheme was marked out along with rough outlines for the Lower Manuherikia and Galloway Irrigation Schemes. Based on feedback from Gary Kelliher of Manuherikia Irrigation Society and Mike Kelly of the Galloway irrigation Scheme, the areas for the Lower Manuherikia and Galloway Irrigation Schemes were refined.

The GIS software was used to perform a slope analysis, i.e. determining areas with slopes of between 0-10 degrees, 10-20 degrees, 20-30 degrees, and over 30 degrees. This was done to gauge the area of irrigable land. Based on the slope analysis, we refined the area of interest to exclude the non-irrigable areas. Figure 1 and Table 2 present the results of the slope analysis.

Based on the maximum slope for the most common irrigation systems, our study will only consider areas with slopes less than 20 degrees. Table 3 presents a comparison of several typical irrigation systems. Column 2 of the table shows the maximum slope (based on mechanical limitations only and not overall limitations which include soil infiltration rates). A slope of 20 degrees roughly equals a 36% incline.

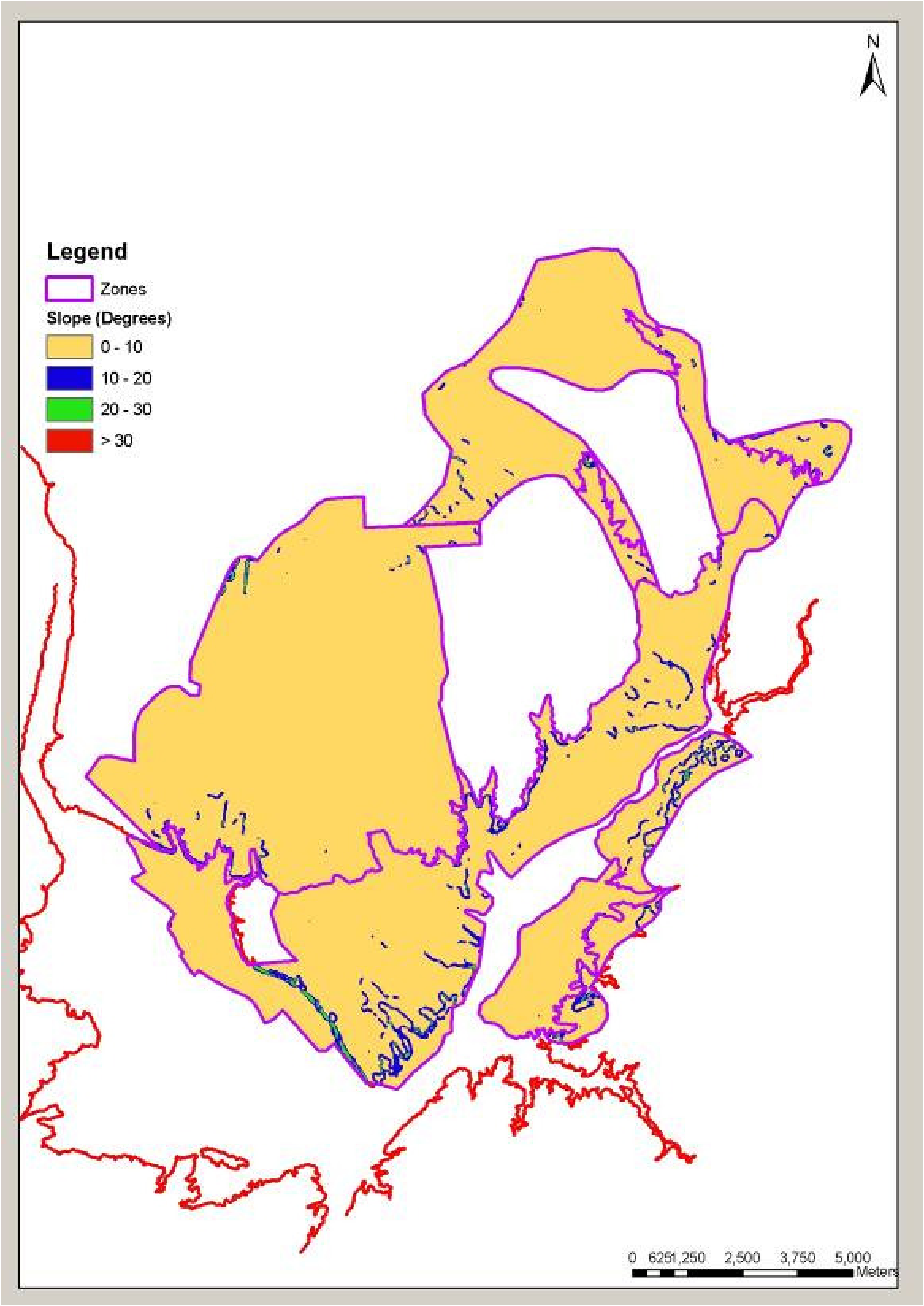

Figure 1: Slope analysis output

Table 2: Slope Analysis Output - Areas in m^2

Zones	Degrees				Total
	0-10	10-20	20-30	>30	
A	48,509,300	634,500	134,000	600	49,278,400
B	38,753,800	2,569,600	344,300	8,700	41,676,400
C	5,831,100	67,000	200	0	5,898,300
D	17,406,100	262,000	27,200	400	17,695,700
E	1,350,700	101,500	13,100	900	1,466,200
F	5,134,500	146,300	14,800	1,000	5,296,600
G	1,865,800	187,600	25,400	0	2,078,800
H	5,557,500	962,100	104,300	700	6,624,600
Total	124,408,800	4,930,600	663,300	12,300	

Table 3: Comparison of Several Irrigation Systems

System Type	Max. Slope capability (%)	Shape of Field possible	Field Surface Conditions	Max. Height of Crop (m)
Linear Move	20	Square, or Rectangular	Clear of obstructions and path for towers	2.4 - 3.0
Centre Pivot	20	Circular		
Fixed Solid Set	No limit but affected by elevation changes over about 50m	Any shape	No limit	No limit
Side Rolls	10	Rectangular	Reasonably smooth	1.2
Hand Move	20		No limit	No limit
Big Gun (Travelling or Stationary)	5	Rectangular	Safe operation for tractor and lane for boom and hose	2.4 - 3.0
K-line	20 - 30	Any shape	Clear of obstructions, Reasonably smooth, Safe operation for towing vehicle	Pasture or low lucerne
Ezi-rain	30 - 35	Any shape		
Dripline	No limit but affected by elevation changes over about 20m	Any shape	No Limit	No Limit

Table 4 presents the rationalisation of the irrigable area within the command area. We have divided the command area into 8 zones. Zones A to C are the areas covered by the Dairy Creek, Lower Manuherikia and Galloway Schemes respectively. Zones D to H are areas that are not currently irrigated, but have been identified as potential areas to be irrigated. Zone D covers the north-eastern area near Moutere-Disputed Spur Rd above 300m in elevation, whereas Zone E covers the area near Moutere-Disputed Spur Rd below 300m in elevation. Zones F and G cover the areas near Chatto Creek-Springvale Rd below and above 300m in elevation respectively. Zone H covers the area near the current Galloway Scheme.

For areas outside the Dairy Creek, Lower Manuherikia and Galloway Irrigation Schemes (which would definitely be irrigated), we have separated the areas above and below 300m in elevation. This is because the water intake point at Lake Dunstan is at approximately 195m in elevation and pumping to an elevation above 300m would require significant amounts of energy.

In Duffill Watts and King's prefeasibility assessment, the gross area for possible irrigation was reduced by 20% to estimate the irrigable area, allowing for access, farm buildings, and areas that are too steep or otherwise unsuitable for development. Because we are only considering areas with slopes below 20 degrees, we have reduced the gross area by only 10% to account for road reserves and farm buildings.

Table 4: Slope Analysis Results for the Command Area

Zone	Irrigation Scheme/Potential Area	Slope Analysis Results: Area with slope 0 – 20 degrees (ha)	Irrigable area (ha)
A	Dairy Creek Scheme	4,914	3,700
B	Lower Manuherikia Scheme	4,132	3,719
C	Galloway Scheme	590	531
D	Moutere-Disputed Spur Rd Area >300m	1,767	1,590
E	Moutere-Disputed Spur Rd Area <300m	145	131
F	Chatto Creek-Springvale Areas <300m	528	475
G	Chatto Creek-Springvale Areas >300m	205	185
H	Galloway Surrounds	652	587
Total (A through H)		12,933	10,918
Current Irrigation Schemes & Areas Below 300m in Elevation (excludes D &G)			**9,243**
Current Irrigation Schemes Only (A+B+C)			**8,050**

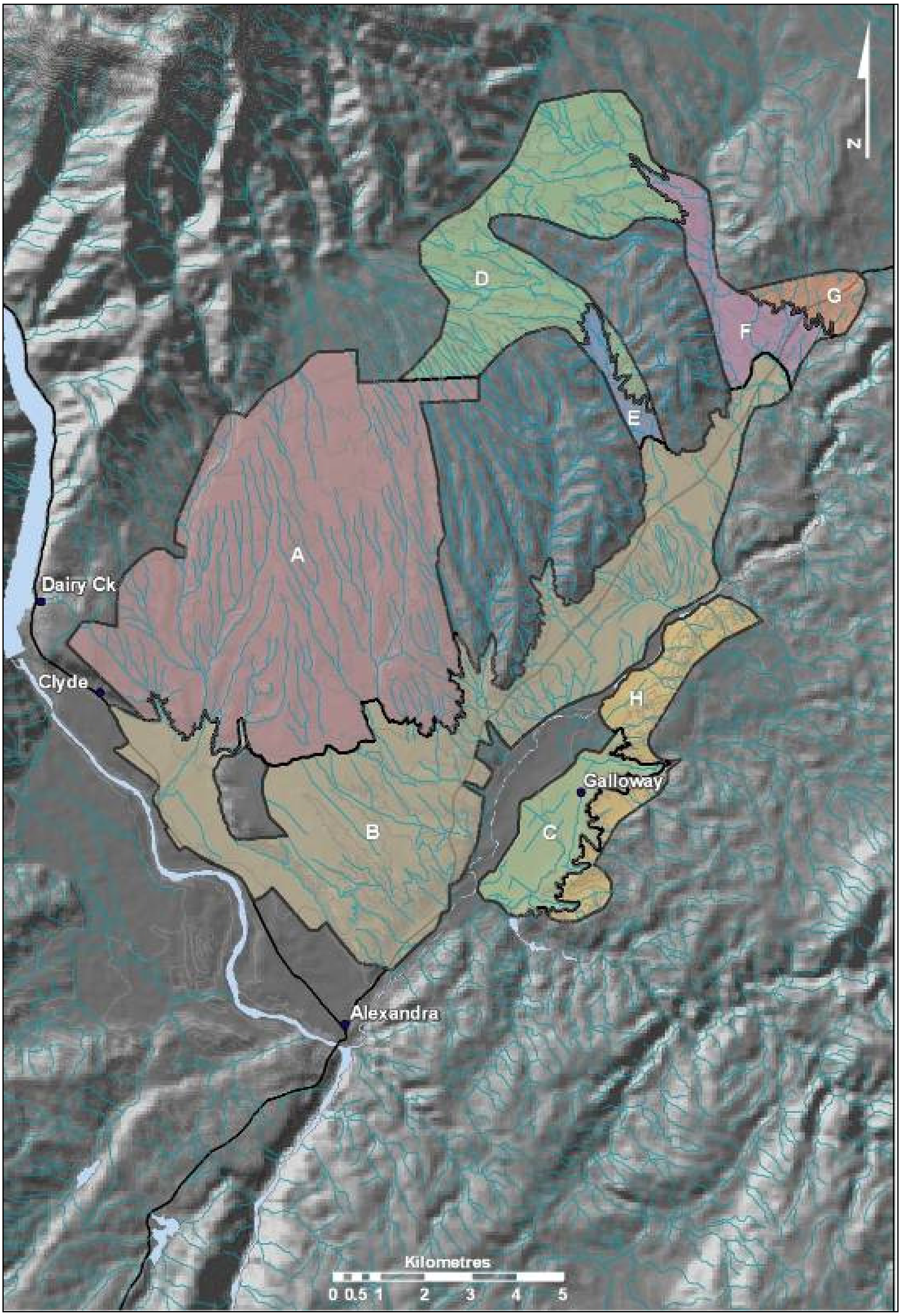

Figure 2: Location of Zones in Command Area

6.2 Soil Type Analysis

Soil type is another important factor in determining whether an area is irrigable.

While the climate of a region controls the effective precipitation, soil plays a critical role in determining the nature and amount of water available to plants. Soil moisture provides a buffer against short term climatic variability, while the size of the buffer is determined by the volume and distribution of the pores within the soil (Hawke *et al*. 2000).

Soil data were extracted from the Grow Otago Climate and Soils Maps (2004) GIS layers and the South Island Regional Land Use Capability Extended Legend from the New Zealand Land Resource Inventory (NZLRI). It should be noted that the soil maps presented are an indication of soil properties in certain areas which come from point data on the Grow Otago soil map G42 (compiled from Beecroft 1985 1:15 000; Orbell 1974 1:31 680; McCraw 1964 1:15 840; McCraw 1966a 1:31 680; Leamy & Wilde 1971a 1: 63 360; and NZ Soil Bureau 1968 1:253 440). These data were clipped to the study area and separate zones for interpretation.

Nine soil types were found in the area. The majority of the soil types were found to be semiarid; of these, most were anthropic (Figure 3). Table 5 presents the full results.

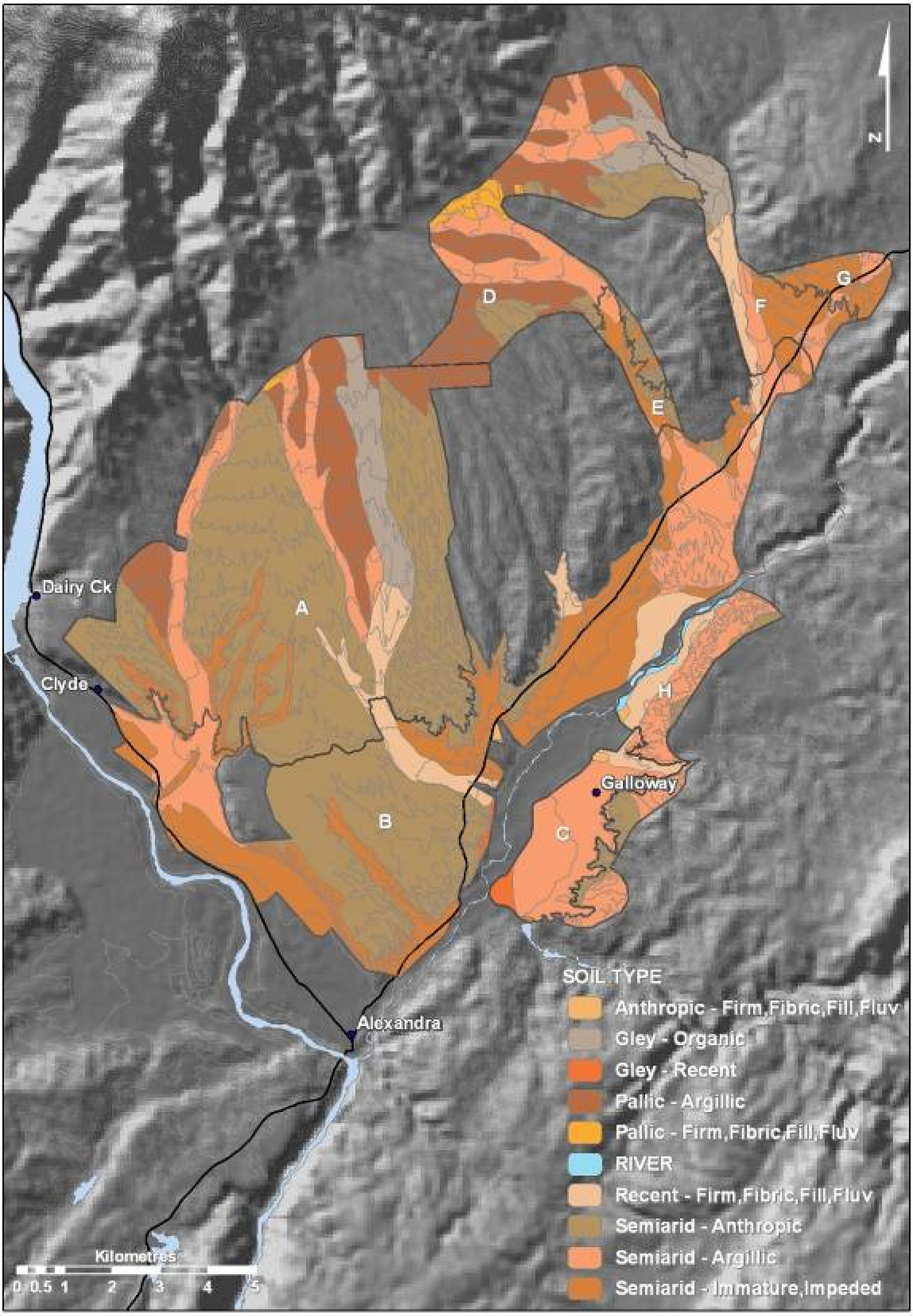

Figure 3: LINZ Soil Name classification in the study area.

Table 5: Soil Type Analysis Results of the Command Area

	SOIL TYPE (AREA IN HECTARES)										
Zone	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**	**Total**
A		323.2		727.3	11.34		164.6	2863.2	509.6	328.5	4927.7
B	6.2		16.1				341.8	1365.5	793.4	1639.9	4162.6
C	6.3		31.3				46.5		494.9	2.7	581.7
D		165.4		674.6	78.21			350.3	479.1	21.6	1769.2
E								34.3	26.2	85.9	146.4
F		119.1			0.62		112.6	16.7	118.6	160.0	527.6
G								9.7	42.6	150.8	203.2
H	5.8					25.5	96.0	121.6	413.5		662.4
Total	18.3	607.7	47.4	1401.9	90.2	25.5	761.1	4761.5	2877.8	2389.4	12980.7
% Total	0.14	4.68	0.37	10.80	0.69	0.20	5.86	36.68	22.17	18.41	100

SOIL TYPES

1) Anthropic - Firm, Fibric, Fill, Fluv
2) Gley - Organic
3) Gley - Recent
4) Pallic - Argillic
5) Pallic - Firm, Fibric, Fill, Fluv
6) River
7) Recent - Firm, Fibric, Fill. Fluv
8) Semiarid - Anthropic
9) Semiarid - Argillic
10) Semiarid - Immature, Impeded

Soil data obtained from Landcare Research

The codes on the soil maps provided depth parameters for the lowland soils only. Upland (hill) soils found mainly in zones H, C, and a fraction of Zone A had unspecified depths. . The dominant soil depth of the study area is stony (100 – 200 mm), while shallow to moderately deep (200 - 450 mm to 450 -900 mm) sub-soil pockets are present in zones B, C, D, and E. Apart from the dominant soil data, some areas also included classifications for sub-dominant soils with corresponding sub-dominant soil depths. The total combined soil depths were reclassified using the weighted average of the dominant soil depths (60%) and sub-dominant soil depths (40%). Where no sub-soil type was classified, 100% of the dominant soil type depth was used. The total combined soil depths of the study area are listed in Table 6.

Table 6: Soil depths of the specific zones.

SOIL DEPTH (AREA IN HECTARES)							
ZONE	>900 mm (deep)	450 - 900 mm (mod. deep)	200 - 450 mm (shallow)	100 - 200 mm (stony)	<100 mm (v. stony)	Unspecified	TOTAL
A	21.5	450.3	1399.2	2984.8	2.9	69.0	4927.7
B	180.6	829.5	1346.9	1734.6	70.3	4.6	4166.6
C	15.8	244.1	143.5	134.9	2.9	48.6	589.7
D		632.4	454.3	661.8			1748.5
E		38.3	98.4	9.7			146.4
F		108.9	202.0	212.7	1.1	3.2	527.9
G		51.7	122.4	29.1			203.2
H	44.2	8.2	27.5	95.5	5.1	456.2	636.6
TOTAL	262.1	2363.5	3794.3	5863.0	82.2	581.6	12946.7
% TOTAL	2.02	18.26	29.31	45.29	0.63	4.49	100.00

The results show that each specific zone within the study area has differing soil parameters.

We obtained local knowledge regarding soil types from Gary Kelliher. His opinion was that the areas which currently have been successfully irrigated include most of the different soil types identified. In all of the areas where irrigation had been trialled but then subsequently stopped, the problem was not soil type but other factors such as the topography and sub-layer porosity.

6.3 Rainfall and Evapotranspiration Results

Understanding the irrigation requirements of crops and soils in the study area and the most efficient methods of applying this water are, therefore, of critical importance to the long-term management of the water resources in this area.

A water balance or budget assesses the availability of water throughout the year. Water enters the budget in the form of precipitation and is lost through evapotranspiration. Potential evapotranspiration (PE) losses are a function of the incoming solar radiation, the vapour pressure deficit, and the wind. PE represents the maximum amount of water which will be lost if water is in unlimited supply. However, while potential evapotranspiration is the potential loss of water, this is not always attained because of limitations on the availability of the water. The actual evapotranspiration (AE) rate, therefore, represents the amount of water that is lost and is a function of both the potential evapotranspiration and the water availability. Potential evapotranspiration will use up the incoming precipitation, and if this is insufficient to satisfy the demand, then the soil moisture will be utilised (Hawke *et al.*, 2000).

Thus, the soil moisture represents a limited storage capacity within the pores of the soil. When inputs of water exceed outputs, the storage is recharged. Alternatively, when outputs potentially exceed inputs, the soil moisture acts as a buffer to reduce stress on plants.

Determining the amount of water available to sustain crops as a result of the climate is, therefore, the first step when considering the need for irrigation, and the amount of water that must be applied. Quantification of both inputs and outputs of moisture from the system (the rainfall and evapotranspiration) is required, as is the amount of water which can be held in the soil. Understanding the amount and distribution of this naturally available water is critical for efficient irrigation allocation. It represents the component of crop water which does not need to be supplied through augmentation strategies, i.e. irrigation.

Therefore, the one in five year minimum summer growing season rainfall for each site was determined (Figure 4). This analysis is based on the assumption that historical records are a reasonable model upon which future rainfall can be estimated (Pearson and Davies, 1997). The minimum one in five year growing season rainfall (Q_5) is generally accepted as a standard return period that farmers can use for planning. Analysis of data used the best of three statistical distributions to fit the data: Gumbel, GEV (Generalised Extreme Value) and Pearson 3. The Q_5 summer rainfall was then estimated from this distribution. presents the Q_5 rainfall in mm.

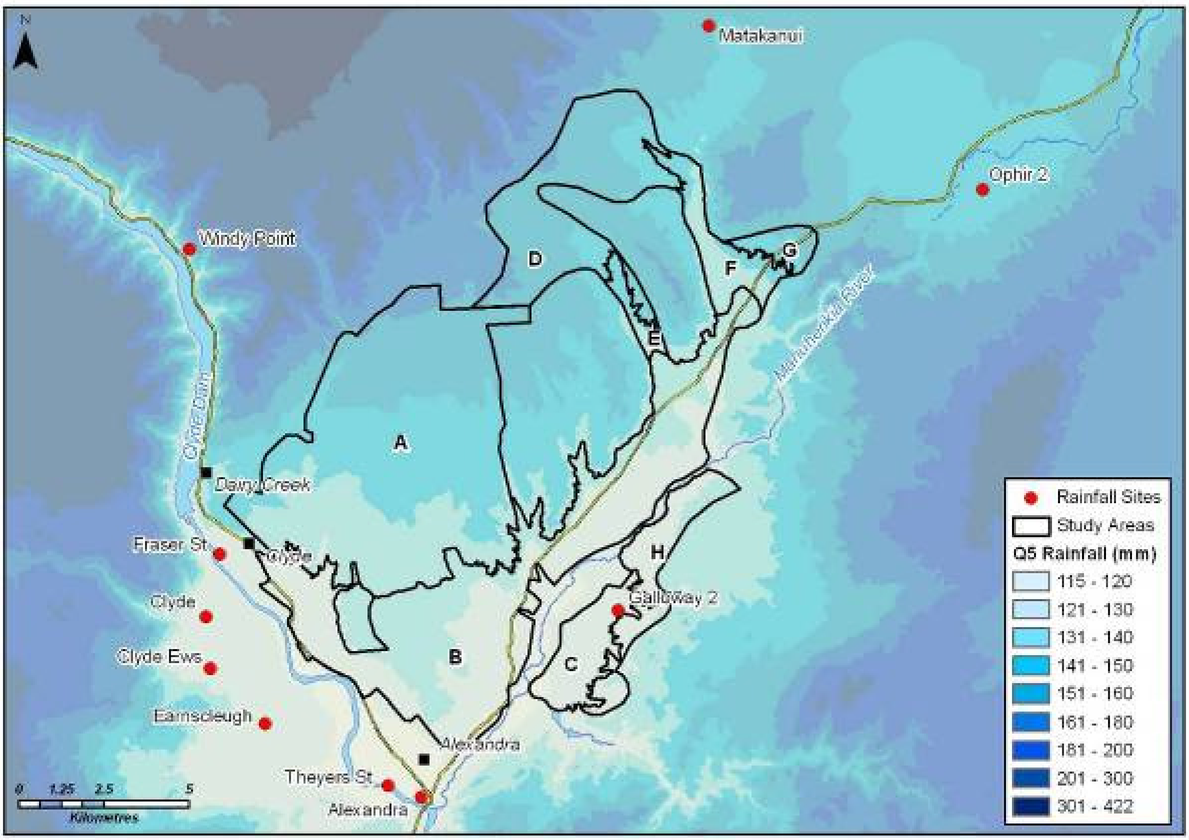

Figure 4: Q_5 or minimum one in five year growing season rainfall (mm).

The difference between the average summer growing season rainfall and the minimum one in five-year growing season rainfall (Q_5) ranged between 102.2 and 212.4 mm. The Q_5 rainfall is approximately 25% less than the average summer growing season precipitation (Table 7). The Q_5 rainfall can be used as a relatively robust measure on which to estimate naturally available precipitation. This is known as the ‘dependable rainfall’.

Table 7: The difference between average growing season rainfall and the Q_5 event.

Site Name	Site Number	Median growing season rainfall (mm)	Q_5 (mm)	Difference (mm)	Q_5 as % of median
Windy Point	590115	354.8	155.8	199.0	44
Tarras	I49841	317.0	142.4	174.6	45
Blackstone Hill	I49991	423.0	204.9	218.1	48
Cromwell 2	I59024	286.0	154.4	131.6	54
Matakanui	I59051	354.0	156.6	197.4	44
Lauder Ews	I59065	340.0	147.6	192.4	43
Clyde, Fraser St	I59131	287.0	107.3	179.7	37
Ophir 2	I59161	310.5	144.9	165.6	47
Clyde	I59235	308.0	150.1	157.9	49
Clyde Ews	I59239	257.0	113.2	143.8	44
Galloway 2	I59241	272.0	105.9	166.1	39

6.4 Evapotranspiration

Pan evaporation data, Penman open water evaporation, Penman potential evapotranspiration and Priestley-Taylor potential evapotranspiration data are recorded at a number of sites within the region. Priestley-Taylor potential evapotranspiration estimations are available at most sites providing good temporal distribution. This measure is commonly used in evaporation studies and so was used in this study also. Data showed good correlation (0.73) between elevation and evapotranspiration allowing us to create a layer showing the spatial distribution of evapotranspiration (Figure 5) over the summer growing season.

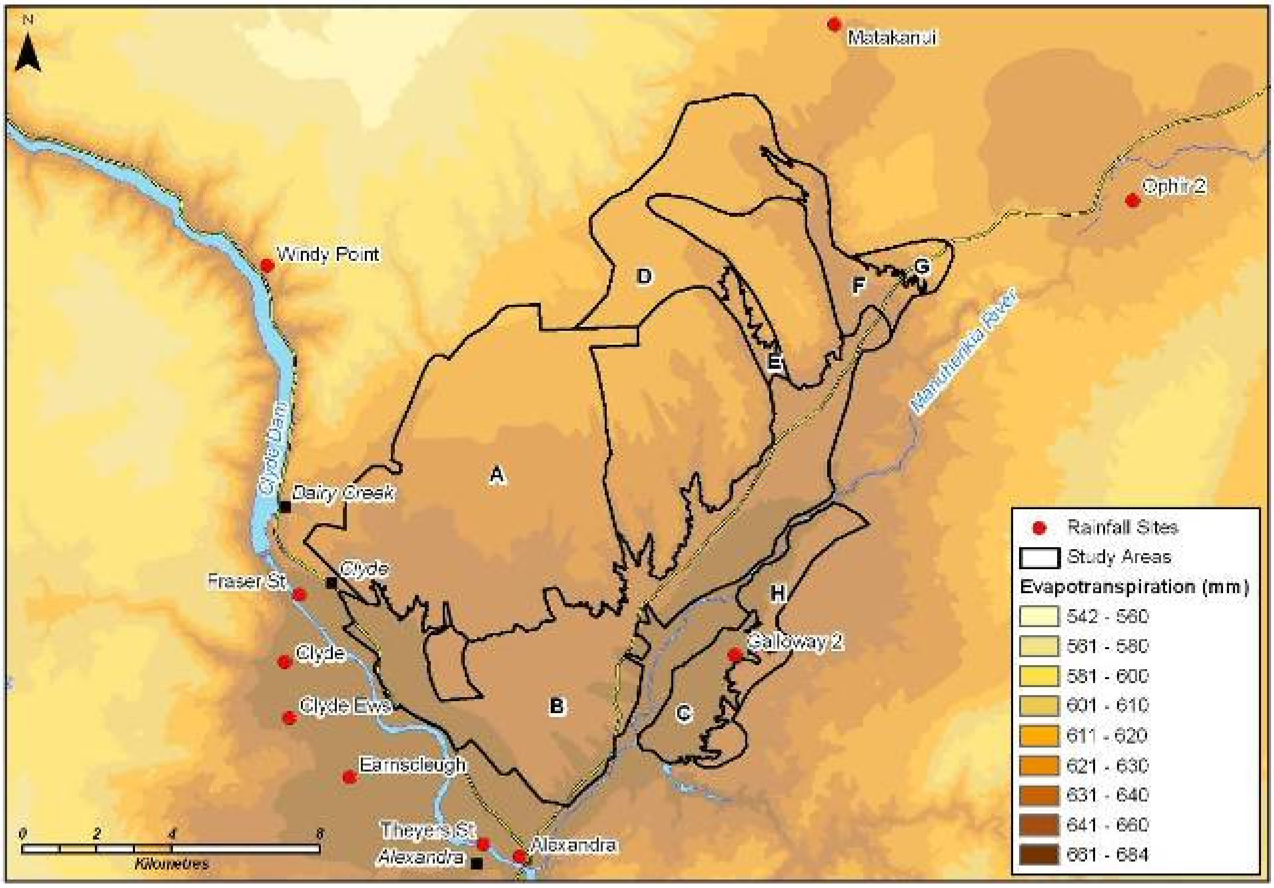

Figure 5: Growing season Priestley-Taylor potential evapotranspiration (mm).

6.5 Effective precipitation

The difference between rainfall and evapotranspiration losses determines the effective precipitation. If evaporation losses are greater than the rainfall the shortfall will be made up of any available soil moisture. If there is not enough moisture in the soil then a deficit occurs and plants will become stressed unless it is irrigated.

The southern part of the Lower Manuherikia Valley is the most susceptible to the occurrence of deficits (Figure 6) because this area receives the least amount of rain and has the highest evapotranspiration rates. In this area, evaporation losses equate to approximately 65% of average annual rainfall. An annual surplus of rainfall is needed to ensure that at some time of the year moisture is available to recharge the soil moisture storage. If soil moisture replenishment is low, or the soil has a low storage capacity, the moisture in soil storage may be depleted over the growing season resulting in water stress (Hawke *et al*, 2000).

In the valley the average summer growing season rainfall is reduced from 150 - 200mm to (-260) - (-200) mm by evaporative losses. Thus, effective precipitation is severely limited (Figure 6). During the minimum one in five-year rainfall season, not even the higher elevation areas experience an effective precipitation surplus (Figure 7).

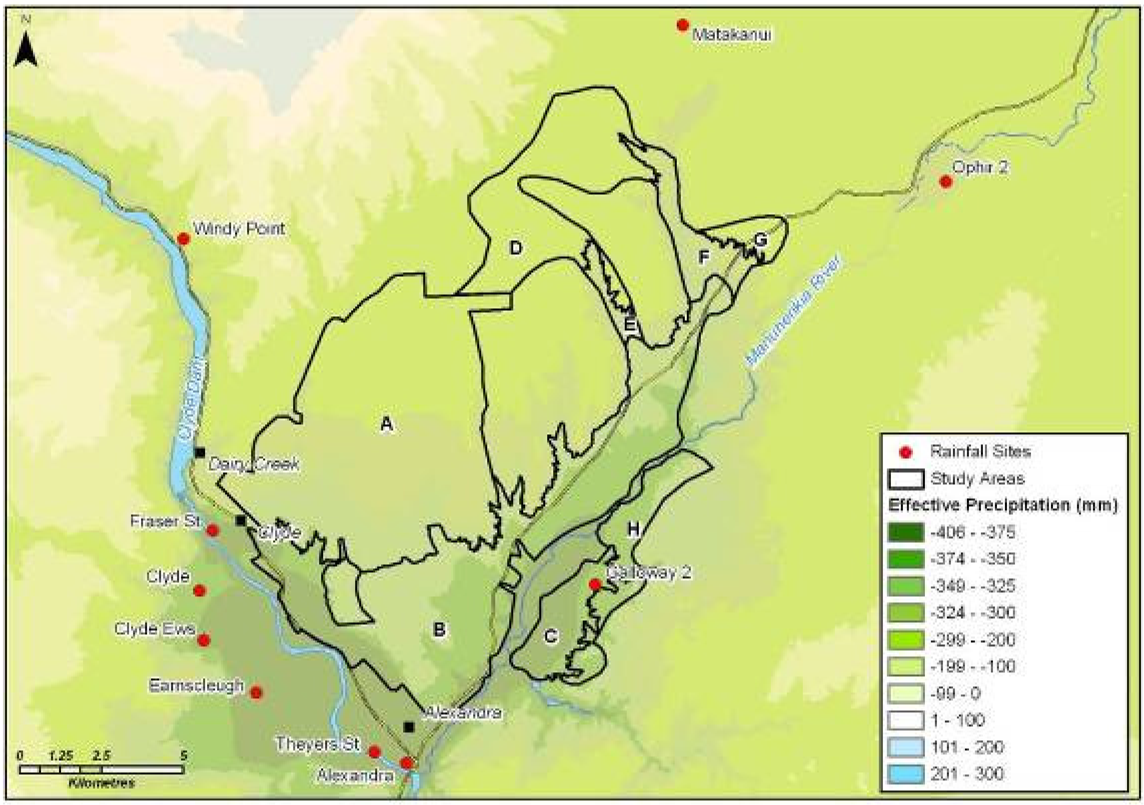

Figure 6: Growing season effective precipitation (mm).

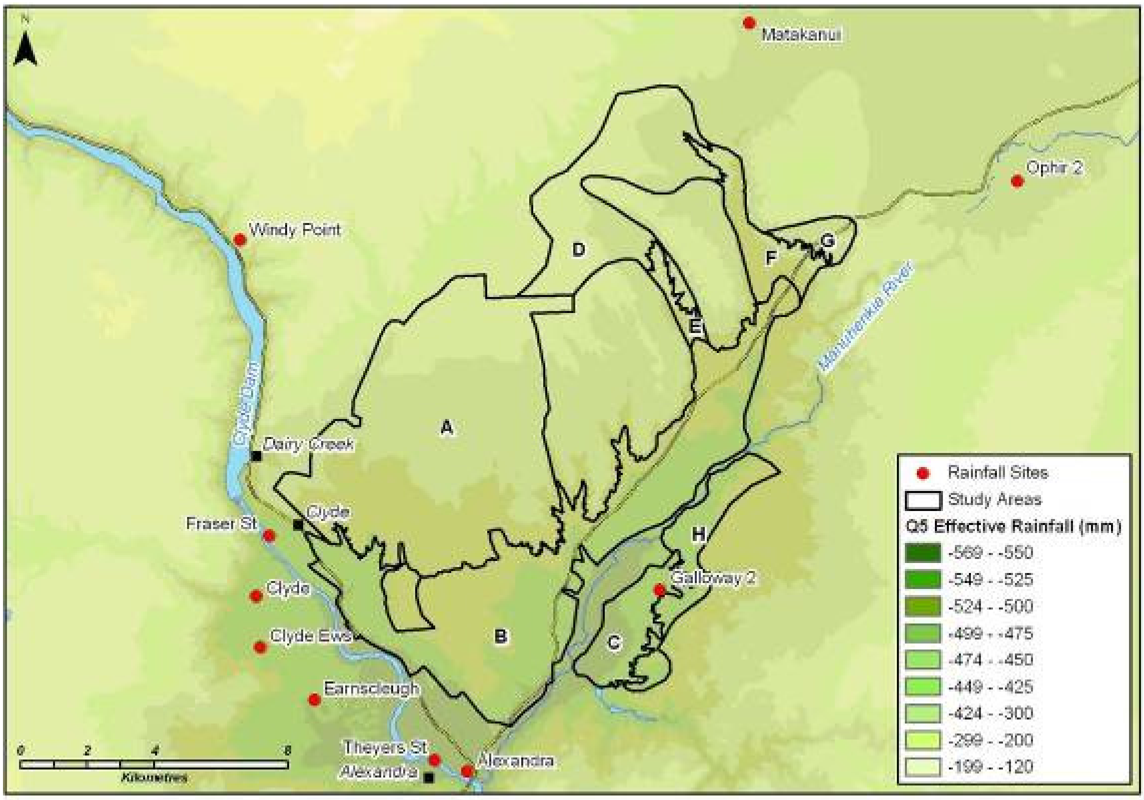

Figure 7: One-in-five year minimum growing season effective precipitation (mm).

In the detailed concept study, a full water balance model will be developed from the precipitation and potential evapotranspiration data presented here to verify the likely amount of water required for irrigation. This is important for effective utilisation of the water resource.

7 Current and Likely Future Land Use

Irrigation water demand varies with land use. The Dairy Creek Scheme proposal had been based on land use assumptions, or actual current practice records where available, giving a ratio of approximately 60% pasture farming, and 40% viticulture. For the purpose of this high level study, a ratio of 60% high intensity land use (which includes pasture farming) and 40% low-intensity land use (which include viticulture and lifestyle blocks) has been adopted as an assumption for the entire command area. This is based on the recognition that for the other areas outside the Dairy Creek Scheme, viticulture may not constitute such a large proportion, and that lifestyle blocks are also a significant part of the command area. While some lifestyle blocks are quite intensively farmed, often a significant area of the land is left unfarmed, so an assumption of low-intensity, uniform irrigation demand approximates the actual demand.

The project brief was to consider the broadest possible future demand for water, regardless of the farming practices now or in the foreseeable future. Therefore, a coarse rule of thumb could be applied that a maximum application rate from any future irrigation systems would be in the order of 7mm/day. This application rate is based on knowledge of a wide range of irrigation systems in use currently that have been designed to perform at rates up to 7mm/day, but more typically 5mm/day. To design a system with a greater precipitation rate capacity would normally lead to excessively large pumps and pipe systems that would largely be under-utilized in typical irrigation seasons.

In other dry regions around the world, a significant land use change pattern occurs following the installation of reliable water supply systems for irrigation. Most irrigation development requires intensification of land use or complete land use change to justify the investment. Landowners need to investigate the full range of land use options available to them and the likely costs and benefits from each of those land uses. In this way, they will weigh up which best meets their requirements.

Different potential land uses have different levels of water consumption and different timing requirements for the delivery of that water. History has shown that a vital element in the water demand calculation is the reliability of water supply. As irrigation has moved away from being a drought insurance tool to a productive necessity, the volume and reliability of water supply have become very important. Current experience shows that a water supply reliability of up to 98% is required to justify the very high capital investment required of some new farming systems.

The high water demand for irrigated dairy farms, for example, has put pressure on old irrigation schemes that provide less volume and less reliable water supplies as required by less intensive farming options.

The importance of identifying all parties with a potential interest in the water resource and including them in the planning process is recognized as core to the ORC Water Plan. These include recreational, environmental and cultural groups of interest. The ability to address conflicts early in the process, through effective community consultation and collaboration, will be an important part of the successful development of this scheme.

It should not be assumed, however, that land use intensification will simply result in more dairy farms. Nor should there be a direct link drawn between land use intensification and environmental deterioration. Although there are beliefs that intensive dairy leads directly to deterioration of downstream water quality, a number of factors would have to be explored such as effective water and fertilizer application management and overall farming practices. Future farming types and practices may lead to commercially viable crop or animal types as yet unexplored, and one only needs to look at the current pressure in other countries to convert to crops suitable for bio-diesel production, a situation that may not have been foreseen two decades ago. There is also an increasing focus on nutraceuticals or plant-derived pharmaceuticals born out of the demand for crops with high nutritive or medicinal values.

Having water available will simply mean that future land users will be presented with greater choice in their farming practices than if they do not have reliable water supply.

In the following section, we have estimated the potential water demand based on the potential or possible land uses in the study area.

8 Water Demand Model

Based on the information available to us and assumptions set out in this report, we have looked to see how far we could spread the Dairy Creek consented water allocation to enable the client to decide on their water resource use priorities. We have calculated the irrigation water demand based on 3 scenarios. The assumptions we have made are:

- A 120-day irrigation season per year, starting in early to mid December and running to the end of March. Although peak evapotranspiration occurs across November and December (associated with wind patterns), the soil temperatures to allow good root development (and hence justify irrigation commencing) don’t peak until after New Year. This will be verified by our hydrology team and modified to suit in the detailed concept study.
- The theoretical demand flow rates are based on 24 hour pumping, and the practical demand flow rates are based on 20 hour pumping (which allows the ability to avoid two 1.5 hour peak power charge times).
- The irrigation water demand for the proposed Dairy Creek Irrigation Scheme has been fixed at 2.00 m^3/s, which is a small modification of the flow rate calculated for the scheme in Opus’ Initial Design and Build Proposal for the scheme in October 2007. This water demand flow rate was increased with agreement with Gary Kelliher to account for extra land area included in the Dairy Creek Irrigation Scheme’s command area after the proposal was submitted.
- Frost fighting requirements for viticulture areas outside the Dairy Creek scheme have not been considered at this point because it increases the volume of the water required to be stored significantly. Alternative frost fighting measures that are not reliant on water may

need to be considered. We will revisit this assumption in the detailed phase to ensure its validity

Scenario I is based on Opus' Dairy Creek Irrigation Scheme proposal report. The Dairy Creek Scheme has a ratio of approximately 60% pasture farming and 40% viticulture. As mentioned earlier, we have assumed this same ratio of 60% high-intensity land use (which includes pasture farming), and 40% low-intensity land use (which includes viticulture and lifestyle blocks) for the entire command area. For irrigable areas designated to have low intensity land use, we have used an application rate of 2.1 mm per day, which, for viticulture, is equivalent to approximately 7 litres per plant per day, with plant spacing of 1.5 m in each row and 2.2 m between rows. For irrigation of all irrigable areas designated to have high-intensity land use, we have used a 5 mm per day application rate, which is in line with our experience and industry standard guidelines for pasture irrigation. Table 8 details our estimates for irrigation water demand for Scenario I.

Scenario II takes into account possible future needs, and is meant to be a scenario that is in between Scenarios I and III in terms of application rates. We assumed that 100% of the area could in the future be used for intensive pasture production or similar farming practice, thus a uniform application rate of 5mm/day was modelled for the entire irrigable area. Table 9 details our estimates for irrigation water demand for Scenario II.

Scenario III is based on a pragmatic look at plausible future requirements made in agreement with ORC of a uniform 7 mm/day application rate. This gives the highest demand of the three scenarios. Table 10 details our estimates for irrigation water demand for Scenario III.

The data in the tables need to be interpreted in light of the maximum rate of supply from the Dairy Creek extraction point of 4.53 m^3/s; if the practical flow rates for the "Total (A through H)" or "Current Schemes & Areas <300m (excludes D & G)" exceed this maximum, then the implication is that a storage buffer will be needed.

This is, therefore, the case for all scenarios proposed. Issues surrounding size and location of storage are discussed in a following section.

Table 8: Irrigation Water Demand for Scenario I

Zone	Scenario I (40% viticulture 2.1mm/day, 60% pasture 5mm/day)			
	Irrigation Demand Flow rates			
	Daily (m^3/day)	**Seasonal** (m^3/year)	**Theoretical** (m^3/s)	**Practical** (m^3/s)
A	144,000	17,280,000	1.67	2.00
B	142,814	17,137,640	1.65	1.98
C	20,384	2,446,060	0.24	0.28
D	61,061	7,327,314	0.71	0.85
E	5,019	602,256	0.06	0.07
F	18,250	2,190,053	0.21	0.25
G	7,097	851,586	0.08	0.10
H	22,532	2,703,809	0.26	0.31
Total (A through H)	**421,156**	**50,538,719**	**4.87**	**5.85**
Current Schemes & Areas <300m (excludes D & G)	**352,998**	**42,359,819**	**4.09**	**4.90**
Current Schemes Only (A+B+C)	307,198	36,863,700	3.56	4.27

Table 9: Irrigation Water Demand for Scenario II

Zone	Scenario II (100% pasture 5mm/day)			
	Irrigation Demand Flow rates			
	Daily (m^3/day)	**Seasonal** (m^3/year)	**Theoretical** (m^3/s)	**Practical** (m^3/s)
A	144,000	17,280,000	1.67	2.00
B	185,955	22,314,636	2.15	2.58
C	26,541	3,184,974	0.31	0.37
D	79,506	9,540,774	0.92	1.10
E	6,535	784,188	0.08	0.09
F	23,764	2,851,632	0.28	0.33
G	9,240	1,108,836	0.11	0.13
H	29,338	3,520,584	0.34	0.41
Total (A through H)	**504,880**	**60,585,624**	**5.84**	**7.01**
Current Schemes & Areas <300m (excludes D & G)	**416,133**	**49,936,014**	**4.82**	**5.78**
Current Schemes Only (A+B+C)	356,497	42,779,610	4.13	4.95

Table 10: Irrigation Water Demand for Scenario III

Zone	Scenario III (7mm/day)			
	Irrigation Demand Flow rates			
	Daily (m^3/day)	**Seasonal** (m^3/year)	**Theoretical** (m^3/s)	**Practical** (m^3/s)
A	144,000	17,280,000	1.67	2.00
B	260,337	31,240,490	3.01	3.62
C	37,158	4,458,964	0.43	0.52
D	111,309	13,357,084	1.29	1.55
E	9,149	1,097,863	0.11	0.13
F	33,269	3,992,285	0.39	0.46
G	12,936	1,552,370	0.15	0.18
H	41,073	4,928,818	0.48	0.57
Total (A through H)	**649,232**	**77,907,874**	**7.51**	**9.02**
Current Schemes & Areas <300m (excludes D & G)	**524,987**	**62,998,420**	**6.08**	**7.29**
Current Schemes Only (A+B+C)	441,495	52,979,454	5.11	6.13

At this stage of our study, we have ignored the possible potable water demand for Alexandra and Clyde. This is because it is uncertain at this stage whether they will want to use water abstracted under this consent as their potable water source as they are still studying their options. In addition, the amount of water they might need is small relative to the irrigation water demand. Alexandra and Clyde's peak potable water demand for the foreseeable future is approximately 20,000 m3 per day and 6,000 m3 per day respectively.

9 Capability to Supply

The existing consent to abstract water from Lake Dunstan allows a maximum of 326,160 m^3 per day to be abstracted everyday for the whole year except for the period between 31st May and 31st July inclusive (62 days) annually. This gives 303 days available for abstraction per year. Therefore, the maximum amount that can be abstracted from Lake Dunstan annually is 98,826,480 m^3. This suggests that the total annual amount of water consented for abstraction is sufficient to supply the annual irrigation demand based on a 7mm/day application rate for a typical 120-day irrigation season to all irrigable land within the command area.

However, the daily maximum consented abstraction of 326,160 m^3 is likely to be insufficient to meet the daily peak demand flow rate, regardless of the scenario.

It is noted that the water is required at a relatively high flow rate for only approximately 120 days in the year, whereas the water supply is available at a relatively low flow rate for 303 days in the year. Therefore, the challenge is abstracting sufficient water during the year, storing it in one or more reservoirs, and using it to supplement the water abstracted during the irrigation season.

Table 11 presents our preliminary estimation of the total dam storage required for the different scenarios, depending on whether Zones D and G which are above 300m are irrigated. The dam sizes are based on our assumption of using a single 20m deep dam. We note that four storage dams located throughout the command area would probably be more suitable (in terms of finding a location and consentability) than a single large storage dam.

Based on our estimations, 10-50% of the seasonal demand would need to be supplemented from storage, depending on the design application rate and irrigable area covered.

Table 11: Estimation of Total Dam Storage Required

	Scenario I (40% viticulture 2.1mm/day, 60% pasture 5mm/day)		**Scenario II (100% pasture 5mm/day)**		**Scenario III (7mm/day)**	
	Irrigating All (A through H)	**Irrigating all except D & G**	**Irrigating All (A through H)**	**Irrigating all except D & G**	**Irrigating All (A through H)**	**Irrigating all except D & G**
Peak Daily Demand (m^3)	421,156	352,998	504,880	416,133	649,232	524,987
Seasonal Demand (m^3)	50,538,719	42,359,819	60,585,624	49,936,014	77,907,874	62,998,420
Gross Dam Volume (m^3)	14,000,000	3,700,000	26,500,000	13,000,000	47,500,000	29,000,000
Evaporation Loss (m^3)	541,500	181,500	937,500	486,000	1,633,500	1,014,000
Dam Volume Less Evaporation Loss (m^3)	13,458,500	3,518,500	25,562,500	12,514,000	45,866,500	27,986,000
Approx. Dam Dimensions (m x m)	950x950	550x550	1250x1250	900x900	1650x1650	1300x1300
Dam Area (m^2)	902,500	302,500	1,562,500	810,000	2,722,500	1,690,000

Notes:
1. Assumes a single dam of 20m depth. In practice, this depth may not be feasible and hence a higher surface area will be required. Dam design and location factors will be further explored in the detailed part of this study.

2. Assume potential evapotranspiration total (PET) for 2 months = 100mm, thus water lost through evaporation = 0.6 m per year

3. The dam volume is estimated based on topping up from the intake and drawing down for the demand, with the minimum volume of water remaining in the dam set at no less than 15%.

4. A margin is added to the dam water surface area to give the approximate dam footprint.

10 Conclusions and Recommendations

Having applied the analysis of slope, soils and climate data to the general command area, the assumed irrigable area is approximately 11,000 ha.

Irrigating the entire irrigable area (Zones A through H) at the maximum rate of 7 mm/day for a 120-day season would require 77,907,874 m^3 each year. This translates into requiring several storage reservoirs with a total volume of 29,000,000 m^3. Not only would it be difficult to find suitable areas to store such a large volume, the dams would also likely have a high Potential Impact Classification in terms of dam failure. Such large storage structures would also significantly increase the cost of the scheme, probably to the point where costs exceed benefits.

Therefore, we recommend that the command area be trimmed down to exclude Zones D and G which are not currently marked for possible irrigation under any current scheme concept and are above 300m. The marginal cost to supply water to these zones is likely to be significantly higher than the marginal benefit of being able to irrigate these zones. It may be more practical to supply water to these zones from the Upper Manuherikia Valley, but this requires further examination, beyond the scope of this report. It is also suggested that priority be given to the supply of water for drinking purposes in Alexandra and Clyde.

Furthermore, we propose that the further work to be conducted in the detailed concept study be based on Scenario I because it is the most pragmatic scenario. This would avoid burdening the potential scheme with over-sized storage, pumps and pipes.

Irrigating all zones except Zones D and G at a rate of 2.1 mm/day for 40% of the area and 5 mm/day for the remaining 60% of the area requires 42,359,819 m^3 each year. This lower total volume translates into requiring several storage reservoirs (possibly 4 sites) with a total volume of 3,700,000 m^3, which at this stage of the study is much more practical. That is roughly 87% less storage volume required than the 7mm/day application rate.

However, it is important to remember that this is based on our preliminary assumptions about application depths and the length of the irrigation season. In the subsequent detailed concept study, our hydrology team will use a water balance model to verify the actual required application depth and the required irrigation season length against our assumptions. If a greater application depth and/or longer irrigation season is required, the resulting required storage might be impractical. If that happens, the areas to be irrigated might need to be prioritised, and certain areas might need to be irrigated from other water sources, such as from schemes in the Upper Manuherikia Valley. While the use of storage is essential to enable more efficient use of the available consented water, the availability of suitable land and the cost of construction would need to be factored into the decision surrounding the actual amount of storage to be used.

11 References

GrowOtago. (2004). *Grow Otago companion booklet.* New Zealand, Otago Regional Council.

Hawke, R.M., McConchie, J.A. and Trueman, T.P. (2000). *Wairarapa irrigation study: Moisture availability as a result of climate* (Research Report No. 6). Wellington, New Zealand: Victoria University, School of Earth Sciences.

Hawke, R.M., Watts, L.F. and McConchie, J.A. (2000). *Wairarapa irrigation study: Soil classification and characterisation* (Research Report No. 8). Wellington, New Zealand: Victoria University, School of Earth Sciences.

Hewitt, A. (1998). *New Zealand soil classification (2nd ed.).* Landcare research science series, no. 1, 133p.

Pearson, C. and Davis, T. (1997). Stochastic methods, (in) *Floods and droughts: The New Zealand experience* (eds) Mosely, M.P. and Pearson, C.P.

Resource Management Act 1991.

Proposed National Policy Statement for Freshwater Management 2008.

Regional Policy Statement for Otago 1998.

Regional Plan – Water for Otago 2004, including Proposed Plan Change 1B (Minimum Flows) and Proposed Plan Change 1C (Water Allocation and Use).

Central Otago District Plan (operative 2008).

Historic Places Act 1993.

Building Act 2004.

Building (Dam Safety) Regulations 2008.

Conservation Act 1987.

Reserves Act 1977.


OPUS