OPUS

LOWER MANUHERIKIA VALLEY WATER RESOURCES STUDY

DETAILED CONCEPT STUDY

MANUHERIKIA IRRIGATION CO-OPERATIVE SOCIETY LTD

Lower Manuherikia Valley Water Resources Study

Detailed Concept Study

Manuherikia Irrigation Co-operative Society Ltd

Prepared By

Adrian Mahalingam
Erin Chalk
Helli Tribe
Sheryl Paine
Marq Redeker
Jack McConchie
John Leatherbarrow

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 2010
Reference: 3-50705.00
Status: Final

Contents

List of Figures

List of Tables

1 Executive Summary

Central Otago has a unique and rich history built on the labours of gold field pioneers and long-standing family names that have worked and shaped this harsh landscape through some of the most extreme environmental conditions experienced in New Zealand.

The legacy of this effort has been to turn arid terraces and steep dry hillsides of the Manuherikia Valley into diverse farming units and spectacular lifestyle blocks with a mixture of intensive agriculture through to vineyards and orchards. Some of the land remains under low intensity dry land farming or hobby blocks, some without high expectations of farm gate revenue but with a high intangible value gained from living in this historic landscape.

However, one of the most important features of the Lower Manuherikia Valley, and in fact the wider Central Otago district, is the heavy reliance on irrigation mostly from water available through mining privileges dating back to origins in the 1860's.

Mining privileges were licences issued for water races, dams and similar features under the Mining Act 1926, subsequent amendments, and previous Acts. Among these licenses, only water race licences confer any right to take water. A water race licence stated the location of the taking of water, the amount of water allowed to be taken, the dimensions of the race and the purpose for which water is taken. As miners and landowners developed other land uses, the use of the water changed from mining to irrigation, other rural uses, or industry.

First priority, and in most cases second priority licences were more likely than other licences to provide a reliable supply of water depending on the nature and flows of the water source. People using the system have become accustomed to this system of water allocation and have developed their water and land use patterns in line with this.

With the introduction of the Resource Management Act (RMA) 1991, all current mining privileges and rights granted under the Water and Soil Conservation Act 1967 in substitution of mining privileges that were current immediately prior to the commencement of the Resource Management Act 1991, continued to be authorised until the thirtieth anniversary of the Resource Management Act 1991 on 1 October 2021.

It is this critical deadline upon which the rights to take and use water will come under scrutiny that has underpinned this study of the options for water allocation for the Lower Manuherikia Valley. To ensure long term security of investment, stability of communities and maintenance of environmental values associated with irrigated land holders, the mechanism for determination of consented takes needs in-depth investigation and thorough preparation for an RMA consents process.

The Otago Regional Council (ORC) will, with the water users, investigate and develop methods and strategies for the orderly transition of deemed permits to resource consents, given that the deemed permits will expire on 1 October 2021. The commentary from ORC procedures to this method includes:

"The exercise of deemed permits can constrain opportunities to implement minimum flows established by the Plan to maintain the life-supporting capacity for aquatic ecosystems and natural character of rivers. The Regional Council will assist deemed permit holders with the development of an appropriate management regime to replace deemed permits when they expire. The Council, in partnership with the affected community, will assist with appropriate investigations and monitoring of the effects of deemed permits."

There is no doubt that the irrigated valleys of the Central Otago region face considerable challenges between now and 2021 to ensure that a long-term view is taken, and adequate time and attention is given to gathered data to support applications for water resource allocation, taking into account environmental water quality and minimum environmental flows.

A key advantage in the Otago Region is having an operational water plan that clearly sets out the parameters under which the RMA consenting process will be conducted. These parameters include:

- local water first used for local use
- no area stranded dry
- efficient use of water resources

The need to address potential conflicting demands for water use in a district has focussed the irrigation schemes in the Lower Manuherikia Valley on how to best use their local water for the best community outcome. This includes agricultural use, domestic drinking water for both urban and rural communities, and consideration of environmental flows. This report has provided the basis upon which a community-based decision process can be commenced, and the various features and factors that need to be taken into account investigated in some detail.

This report could equally be used as the basis for further investigation of the Upper Manuherikia Valley water resource dilemma. This point is raised because the solution to the Lower Valley issues can probably not be concluded without close cooperation with the agricultural and other water users of the Upper Manuherikia Valley catchment. One location's solution to the water allocation problem will likely have a direct impact on the other as the water resource volume is directly linked by the Manuherikia River. It could be asserted therefore that the attention given to addressing the Lower Valley issues now needs a similar effort by the Upper Valley to ensure adequate time remains to build a consenting case before 2021.

In this Detailed Concept Study, we present the consenting framework for the irrigation scheme, highlighting the applicable legislation that would need to be addressed as the project progresses. Our prefeasibility study for a mini hydropower station using the existing Manuherikia River consented take and associated existing head-works showed that it had potential and should be considered further in more detail.

Our desktop soil and climate studies highlighted the importance of irrigation in the command area. The data from our soil and climate studies formed the basis for our soil moisture balance which estimated the amount of water available to plants over different months of the year, and hence the irrigation water application depths required. We then used these application depths to build upon the work in our High Level Overview. Our command area is bounded nominally by Lake Dunstan in the west and Tiger Hill in the east. Our High Level Overview reduced the gross command area to an irrigable area of approximately 11,018 ha, accounting for slope limitations, soil suitability, and non-irrigated land area (e.g. access, buildings, etc).

Over several iterations, we looked at a range of options and variables, matching the amount and timing of water required for the various users to the consented amount and timing of water available from Lake Dunstan. Some of the irrigable area that was eventually excluded might be better serviced from water extraction points in the Upper Manuherikia Valley because of elevation and proximity. We have prepared a preliminary estimate of capital costs for the options arising from our later iterations to assist stakeholders in making important decisions moving forward.

Key assumptions have been made about the way in which water will be applied to the land in the future and challenging assumptions have been made about many of the current practices. This is closely aligned to parallel water allocation models being developed in other New Zealand agricultural regions that assume adoption of modern irrigation codes of practice for design and operational practices. The critical factor here will be working closely with the Otago Regional Council in determining what the criticality is of providing a minimum environmental flow in the Manuherikia River to meet its core allocation framework criteria. If the river flow is set at a level that is acceptable to the Regional Council through a consultative process with the community water users, it is likely that this will require a significant modification of the existing border dyke and wild flood irrigation systems commonly used in the area. It is anticipated that a much higher proportion of efficient and effective spray application methods will have to be adopted to meet the local water allocation model.

Although a view has been taken in this report on the likely future mix of agricultural practices, in reality, the type of farming that uses water does not significantly affect the water balance model. It is likely, however, that once a reliable water supply is established for the current and potentially greater irrigated area, land use changes will occur over time, in some cases linked to ownership changes.

Whilst the water extraction point at Dairy Creek provides some elevation advantage being above part of the irrigable land, there is a large proportion of the land that will require the water to be pumped. This obviously has a significant long-term operational cost per hectare for the life of any proposed system. The equitable spread of this cost across the ownership of the scheme will create a value of water that has not previously had high consideration during water management decision making. This scheme will effectively make the efficient and effective management of water a critical factor in the overall agricultural and land ownership decision-making process because of its increased value.

Although this report has considered a number of options for the mechanics of water distribution in the valley to establish some form of capital and operational costing, this report is not a detailed engineering design, and hence any costing are of a rough order. Further decisions will need to be taken by the community through some form of governance mechanism to establish the affordability of whichever option is taken forward.

In common with many irrigated areas of New Zealand, the driver for improved environmental performance and economic stability has indicated a number of improvements or expansion of irrigation systems. The long-term benefits of this infrastructure work will really fall with future generations of water users, both commercial and environmental. The improvement issues being addressed in many cases arise from either deferred maintenance and/or failure to address the underlying drivers over previous generations of land tenure. If the cost of any infrastructure work falls only with the current generation, it is unlikely that these improvements will be realised and hence a higher level view will be necessary. It is acknowledged that parallel to this report, some representation has been made to central Government regarding the need for some form of funding support mechanism.

There are, however, several possible cost offsets, such as the possible provision of secure drinking water supply to Clyde and Alexandra, which if undertaken, would spread the asset costs. Furthermore, there is the potential for cost recovery through mini hydropower generation which could reduce the cost burden to the land owners.

The scope of this report was not intended to be a detailed engineering design or whole of life costing of an irrigation scheme. The intent has been to provide a basis for further investigation of the various options considered and a test of some of the assumptions made around future land use and water demands. The process has included the broad-brush determination of where water will be needed in the Lower Valley and at what depth of application (and thus, annual volumes). Arising from the general conclusions about the feasibility and cost of a scheme to meet the requirements of the combined irrigation schemes, a process of close consultation and surveying of current landholder practices and future intent will need to be conducted to further build on the data available on which development decisions can be made. However, as with many other regions where improved water supply reliability and improved application practices have been achieved, the ownership of land and farming type often changes too. The underlying driver is that 'reliable water supply provides increased options' that are not available for land use and environmental outcome-focused decision-making processes where water is restricted.

Stephen McNally
Manager – Environmental Engineering and Resource Management

2 Report Summary

This feasibility study provides the basis upon which a community-based consultation and decision process surrounding the water resources for Lower Manuherikia Valley can commence, and the various factors that need to be taken into account investigated in some detail.

This study investigates the water resource options available to the Lower Manuherikia Valley in Central Otago, in light of their current water supply sources being under review in the near future. Our Detailed Concept Study covered the following main points:

- We highlight the legislation that will likely influence future decisions by the community surrounding water resource management for the valley.
- We found that mini hydropower generation at the existing Manuherikia scheme intake to offset annual operational costs appears to be technically feasible and has the potential to be economically viable depending on the refinement of some assumed inputs, thus it warrants further investigation.
- We present how we have broadly determined where in the valley and at what application depth irrigation water is required, and therefore estimated the water demands. We then consider several options for the mechanics of water distribution in the valley.

The scope of our study did not include detailed engineering design, thus these options have been developed to a point that capital and operational costing is only of a rough order. Preliminary capital costs for the various options range from $78.6M to $277.7M ($9.4K to $42.6K per hectare), whereas preliminary annual operational and maintenance costs range from $3.1M to $4.7M ($347 to $728 per hectare). These costs have wide ranges, which would be narrowed down through community consultation to determine preferences for the available variables, followed by further engineering design.

The equitable distribution of the costs across the ownership of the scheme will increase the value of water, hence requiring efficient and effective management of water. Furthermore, the long-term commercial and environmental benefits of this scheme will really fall mostly with future generations. If the costs fall only with the current generation, it is unlikely that these improvements will be materialized, and thus, a higher level view by the community will be necessary, with possibly some form of government funding support.

We recommend that the community uses the outcomes of this study to proceed with a process of close consultation that includes surveying of current landholder practices and future intent, establishing landowner buy-in to better refine the actual areas to be irrigated, and working out acceptable risk levels.

3 Acknowledgements

We would like to thank the following parties for their valuable contributions to the production of this report:

- Gary Kelliher, of the Manuheritkia Irrigation Co-operative Society
- Graeme Martin, of the Otago Regional Council
- Mike Cooper and Tony Clough, of Delta Utility Services Ltd
- Peter Morton, of Central Otago District Council
- Mike Kelly, of Galloway Irrigation Society

4 Introduction

The Lower Manuherikia Valley currently relies heavily on irrigation for much of the land area from water available through mining privileges dating back to origins in the 1860s. With the introduction of the Resource Management Act (RMA) 1991, all current mining privileges continued to be authorised until the thirtieth anniversary of the RMA 1991, i.e. 1st October 2021.

It is this critical deadline when the rights to take and use water will come under scrutiny that has underpinned this water resource study for the Lower Manuherikia Valley. To ensure long-term security of investment, stability of communities, and maintenance of environmental values associated with owners of irrigated land, the mechanism for determination of consented takes needs in-depth investigation and thorough preparation for an RMA consents process.

The purpose of the feasibility study is to examine extending the proposed privately-supported Dairy Creek Irrigation Scheme to incorporate the wider objective of community water resources, i.e. a potential Lower Manuherikia Valley Irrigation Scheme. Our work explores the feasibility of combining the various irrigation and water supply schemes in the command area into a single entity and with possibly a single source, i.e. Lake Dunstan.

Partway through our study, a further investigation was commissioned to consider whether it was better to have a separate pipeline network feeding the Dairy Creek area, or to have the Dairy Creek area completely incorporated into a larger Lower Manuherikia Valley pipeline network.

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

- Manuherikia Irrigation Co-operative Society Ltd
- Galloway Irrigation Society
- Otago Regional Council
- Central Otago District Council
- Vincent Community Board

This Detailed Concept Study forms part of this water resource study, and builds upon our previous work in the High Level Overview completed in August 2009. This report is supplemented by the following reports completed as part of the feasibility study:

Report Name	Key Authors
High Level Overview	Stephen McNally, Adrian Mahalingam, Erin Chalk, Helli Tribe, Sheryl Paine, Jack McConchie
Hydrology Study	Helli Tribe, Sheryl Paine, Jack McConchie
Mini Hydropower Pre-feasibility Study	Marq Redeker
Drinking Water Security Review	Jim Graham

5 Background

5.1 Existing Issues

The Manuherikia Irrigation Scheme and part of the Galloway Irrigation Scheme are currently supplied from historic race systems from the Manuherikia River under mining privileges granted for 99 years. These mining privileges expire in 2021, thus there is pressure to identify alternative water sources as a contingency against unsuccessful consenting under the Resource Management Act.

Delta Utility Services (Delta) and Opus International Consultants (Opus) jointly worked on a Design and Build Proposal for the privately-supported Dairy Creek Irrigation Scheme that would use an existing consent to abstract water from Lake Dunstan. Because the proposed scheme would not have fully used the consented allocation, socially-responsible members of the community identified the opportunity to possibly meet the water needs of the entire Lower Manuherikia Valley with the allocation.

The existing consent (Consent No. 2002.725) allows abstraction of water from Lake Dunstan for irrigation and frost fighting with an extraction point identified at Dairy Creek, approximately 1 km 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/s and a maximum of 326,160 m^3/day. It needs to be noted that the daily maximum represents a peak pumping rate of 4.53 m^3/s 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 also be achieved, for example, by pumping at 3.775 m^3 per second continuously for 24 hours a day, if so desired.

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. 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 for this study covered the Lower Manuherikia Valley, which nominally stretches from Lake Dunstan in the west to Tiger Hill in the east. While we start off with this command area, we eventually focused on a smaller area which includes the Manuherikia and Galloway irrigation schemes, as well as the proposed Dairy Creek Irrigation Scheme.

5.2 Water Allocation Framework

The provision of reliable irrigation water to the Lower Manuherikia Valley is important for reasons which include but are not limited to the following:

- As previously mentioned, the water sources supporting the command area are at risk in the near future as water permits expire.
- The current supply to the Manuherikia Irrigation Scheme and part of the Galloway Irrigation Scheme from the Manuherikia River is not sufficiently reliable, because in the dry summer months, rationing is often required.
- As irrigation methods change from less efficient flood irrigation to more efficient irrigation methods like spray and drip irrigation, the supply sources based on private water rights are likely to become less reliable if the traditional irrigation methods have been recharging those private water sources.
- There is land that is currently not being irrigated for various reasons; for example, because of their location above the gravity-fed water races. This potential irrigation scheme provides the opportunity to irrigate these new areas.
- Utilising the Dairy Creek allocation to supply more of the Lower Manuherikia Valley would reduce demand on the Manuherikia River which also supplies irrigated farming operations in the Upper Manuherikia Valley, nominally identified as north-east of Tiger Hill.

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 increase the reliability of supply through the incorporation of additional storage buffers.
- *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.

5.3 Sustainable Development

In preparing this feasibility study, we have been mindful of sustainability issues surrounding the potential irrigation scheme development. Sustainable development, as defined by the Brundtland Commission (World Commission on Environment and Development) in 1987, "meets the needs of the present without compromising the ability of future generations to meet their own needs". For this scheme to truly contribute towards sustainable development of the region, there are four dimensions of wellbeing for present and future generations to consider:

- Environmental
- Social
- Cultural
- Economic

5.3.1 Environmental

In line with Otago Regional Council's mission to improve the efficient allocation of the precious resource of water in the region among its various uses and interests, the potential scheme intrinsically demonstrates an increase in water use efficiency by:

- Moving away from the historical mining privileges to a consented take, thus allowing more efficient, centralised, and holistic allocation of water to users across the region. This promotes the allocation of water to its best use or interest.
- Providing the amount of water that is actually required, thus encouraging the use of efficient application systems such as drip and spray irrigation, moving away from older-style border dyke[1] and wild flood irrigation. Those less water-efficient systems often lead to water running off farms, or soaking straight through the root zone and into the groundwater.
- Using a piped system, which reduces water lost in open water races through evaporation and soakage.
- Providing reliable water on demand would improve water use decision making, enabling farmers to irrigate only when they recognise the need. This is in contrast to a rostered race system where farmers would need to use water when it is available regardless of the weather and soil conditions. This would also have an economic benefit to the system as a whole.

Looking forward, it is important to note that the development of the potential irrigation scheme will involve land disturbance and earthworks that could potentially be detrimental to the environment. Furthermore, moving away from gravity-fed open races to a pumped pipeline system could enlarge the carbon footprint of the region.

[1] Modern border dyke systems are more water-efficient than their traditional counterparts, but still require high instantaneous flow rates that are not compatible with a cost-effective piped system. Therefore, landowners should be encouraged to consider moving away from border dyke systems in general.

However, negative environmental effects can be minimised if it is given sufficient priority. We believe that environmental sustainability needs to be further considered in the detailed design, construction, and operational phases:

- Well thought-out material selection – local and low environmental impact where possible, while also taking other factors into consideration
- Construction material waste minimisation/recycling
- Planning the detailed pipeline route to minimise earthworks
- Appropriately designed and implemented erosion and sediment control
- Pre-construction investigation into local ecology and mitigation measures implemented where needed (e.g. fish passage, preserving/enhancing habitat for native flora and fauna)
- Energy efficient scheme control and management systems to minimise the carbon footprint of the scheme in operation
- Further development of the mini hydropower station if subsequent detailed site investigation affirms that it is economically viable

5.3.2 Social

The economic growth brought about by the availability of irrigation water supply is usually accompanied by community growth and enrichment. 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 a Ministry for the Environment (MfE) report by Ian Brown Consulting and Harris Consulting estimating a population increase of 180 people per cumec attributable to irrigation. While irrigation already occurs in the Lower Manuherikia Valley, albeit in a less reliable form, these changes is still likely to occur (but to a smaller degree) as the reliability of available water supply increases

The demographics would change 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). With the changed demographics, the community would start to have a demand for more family-based social needs, such as schools. While some might be concerned about these changes, they often occur gradually over an extended period (potentially more than a generation), and when managed well by the community, they lead to healthy, sustainable growth for the community.

Looking forward, we propose that social sustainability be considered, for example, by:

- Raising community awareness of the true value of the water resource and the need for a change in the way it is managed, so as to build up community collaboration and support for the scheme;
- Encouraging community participation in decision-making processes;
- Taking into account the visual amenity of the scheme's assets, such as the location and appearance of pump stations;
- Having strategically-located educational boards that explain the purpose and design of the scheme to the community and tourists;
- Prioritising occupational health and safety during construction and operation; and
- Minimising noise levels during construction and pump station operation (through suitable selection of the pump station location and building materials), especially where they are in close proximity to a residential area.

5.3.3 Cultural

With the scheme improving the reliability of water supply for the lower valley, the local community will be able to continue developing the farms in the area, as many have done for several generations. Following on from that, the accompanying local/regional culture is likely to be preserved, and even possibly further enhanced for the benefit of generations to come.

Looking forward, it would be prudent to consider cultural sustainability in the development of the area, for instance, by preserving/enhancing historic buildings or natural sites that may otherwise be affected by the scheme's new assets.

5.3.4 Economic

Individual Farm Owners Level

At the level of individual farm owners, the reliability of irrigation water is a limiting factor in developing farm management practices to meet global market demands which increasingly requires consistent product quality and volume. Without reliable irrigation water supply for crops and pasture in this dry district, there can be short-term loss of productivity and profit, and long-term loss of supply contracts crucial to the viability of their work. Some farmers would have to use conservative dry-land farming systems which probably cannot meet international market demands.

Studies have shown the importance of a reliable irrigation water supply:

- Farms with reliable irrigation water supply have significantly higher farm gate output (revenue), return on capital and cash farm surplus (profit) relative to comparable farms with no reliable irrigation water supply.
- Reliable irrigation water supply enables farms to earn higher and more diverse, and therefore, more resilient profits.
- The access to reliable irrigation water increases the capital value of the land.

The abovementioned studies looked primarily at the potential benefits of introducing irrigation water to previously non-irrigated land. However, these benefits are fully attained only when the irrigation water supply is sufficiently reliable. Therefore, these potential benefits are still very much relevant to the entire command area, including both the currently irrigated and non-irrigated areas.

District/Regional Level

At a district and regional level, the increased agricultural activity, which arises from improved irrigation water supply reliability, will in turn enlarge the regional 'economic pie'. These flow-on effects[2] 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 sales of farming inputs, e.g. fertilizer, following the increase in production
- *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, nutraceuticals or meat processing.

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. The aforementioned MfE report estimated 70 more FTEs would be 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). These reported benefits apply primarily to the introduction of irrigation to non-irrigated areas. However, even in currently irrigated areas in the Lower Manuherikia Valley, these benefits would only be fully attained through sufficiently improving water supply reliability.

[2] Categories used in Opuha Dam Ex Post Study by Harris Consulting, Aug 2006

Because of reliable irrigation water supply, the region would also enjoy higher economic value added, which is an indicator of economic activity. The aforementioned MfE report calculated that value added was higher by $2 - 3 million per cumec of irrigation directly associated to agriculture increase, with 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 potential 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 combined 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 allow more farmers to access the water.

National Level

At a national 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 reliability of irrigation water supply increases farm production and most of this increase is likely to be exported, which would represent an economic benefit for the country.

Considering Economic Sustainability

Looking forward, we believe that economic sustainability can be enhanced by putting careful thought in the design and operation phases, such as:

- Considering the use of local construction materials and labour;
- Considering flexibility in design to ease possible future expansion;
- Having best practice asset management and maintenance systems in place; and
- Managing the system such that pumps are not needed during peak power consumption hours.

5.4 High Level Overview Outcomes

Command Area

In our previous work in the High Level Overview, we started with the entire command area of approximately 15,300 ha covering the Lower Manuherikia Valley in Central Otago, nominally identified as stretching from Lake Dunstan in the west to Tiger Hill in the east. The area encompassed 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.

We applied several considerations to the command area 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 slope limitations of common irrigation systems to operate in these areas, we eliminated some impractical areas.

Of the land that is of acceptable slope, we attempted 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. (In particular, the airport reserve was excluded as low priority for irrigation because commercial growing activities are likely to clash with its use as a local aerodrome.) Irrigation pertaining to urban gardens and other council-operated open spaces are currently supplied from potable supplies and were excluded from our study, albeit subject to on-going review as to the sustainability of this supply mechanism.

Finally, we looked at the soil types and depth to see what, if any, area should be eliminated as simply unsuitable for irrigated farming practices. We incorporated local knowledge along with use of the detailed soil databases available. This process did not significantly reduce the irrigable area.

We divided the remaining area into 8 separate zones for analysis, as presented in Table 5-1 and Figure 5-1.

Table 5-1: Description of zones and irrigable areas as reported in the High Level Overview

Zone	Irrigation Scheme/Potential Area	Irrigable area (ha)
A	Dairy Creek Scheme	3,800
B	Lower Manuherikia Scheme	3,719
C	Galloway Scheme	531
D	Moutere-Disputed Spur Rd Area >300m elevation	1,590
E	Moutere-Disputed Spur Rd Area <300m elevation	131
F	Chatto Creek-Springvale Areas <300m elevation	475
G	Chatto Creek-Springvale Areas >300m elevation	185
H	Galloway Surrounds	587
	TOTAL	11,018

Water Demand

We examined the local climate factors such as rainfall relative to evapotranspiration for this region, which was used as a basis for the soil moisture balance model done in this detailed concept stage.

Our general brief was to look at the likely maximum water demand for the foreseeable future and a figure of 7mm/day was suggested. We used this figure as a starting point, but applied some more analysis to likely options as the study 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. We assumed that the overall command area would in the future have a similar proportion of high and low intensity land use.

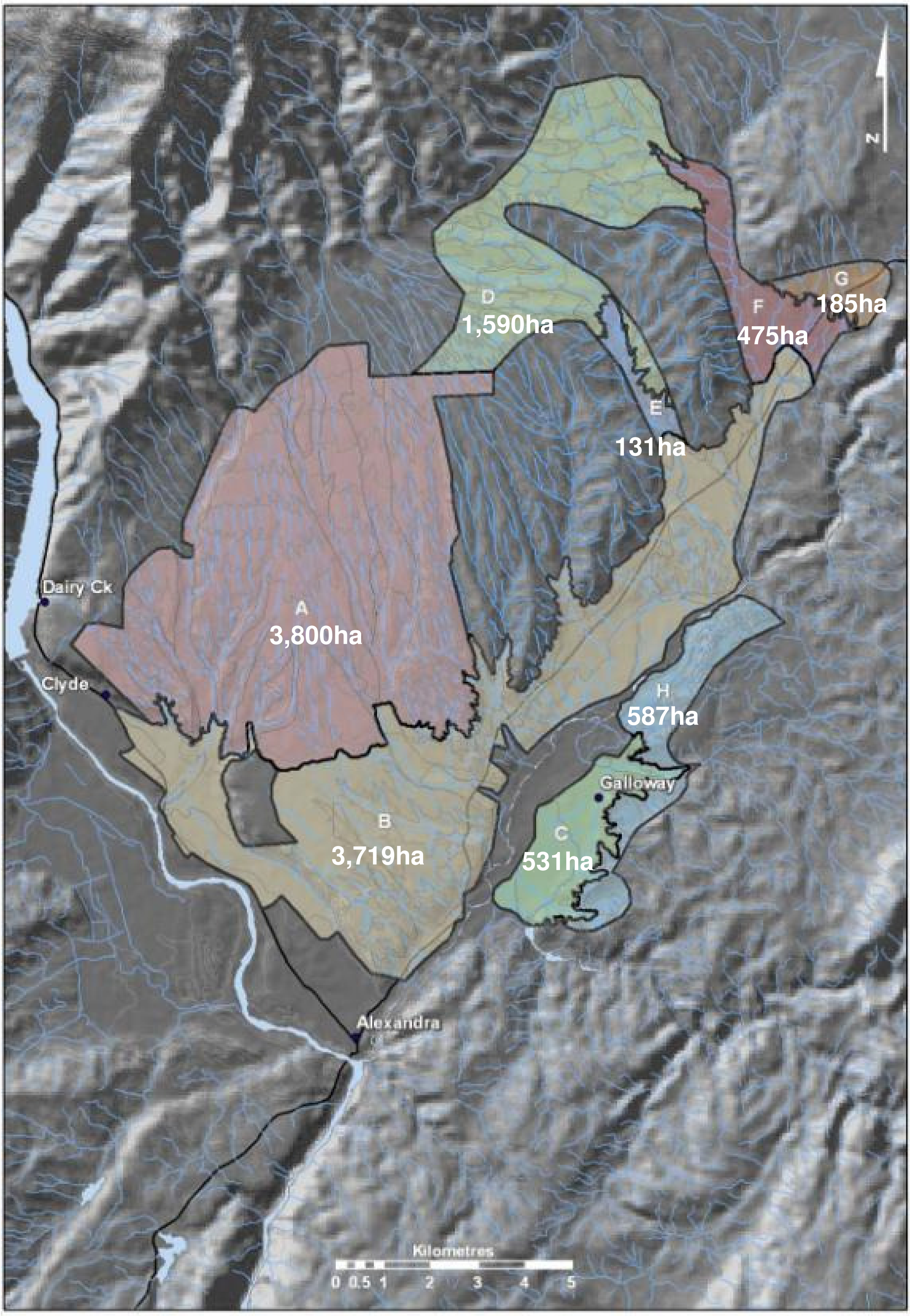

Figure 5-1: Location of zones with irrigable areas labelled

6 Consent Requirements

Although the promoters of the Dairy Creek project hold a consent to take water from Lake Dunstan, they have not yet obtained a consent to use the water and this matter needs addressing. Other consents are likely to be required to construct and operate an irrigation scheme servicing the study area.

An overview of the relevant legislation that will have to be complied with is set out below.

6.1 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 Plan Change 1B (Minimum Flows) and Proposed Plan Change 1C (Water Allocation and Use); and
- Central Otago District Plan (operative 2008) and Proposed Plan Changes 5A to 5W.

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 permits/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. 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. Proposed Plan Changes 5A – 5W amends the plan to include the findings of a Council-initiated Rural Study which addresses rural development issues that impact on landscapes and rural amenity.

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.

6.2 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 section 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.

6.3 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 (Section 14).

The RMA also restricts certain activities within the beds of lakes or rivers. Activities relating to structures, earthworks, planting, reclamation and deposition of substances may not be carried out unless allowed by a rule in a regional plan or a resource consent (Section 13).

The discharge of water to water is prohibited unless specifically allowed by a rule in a regional plan or a resource consent (Section 15).

The use of land is less restricted; however, no person may use land in a manner that contravenes a regional rule or a district rule unless the use is allowed by a resource consent or has established existing use rights.

6.4 Regional Plan – Water for Otago

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

The Regional Plan – Water for Otago has recently been the subject of two plan changes. Plan Change 1B (Minimum Flows) became operative as of 1 March 2010. Plan Change 1C (Water Allocation and Use) is still in the final phase of development. The ORC released its decisions on Plan Change 1C and on all submissions in April 2010. The appeals period on the Plan Change has now closed. The ORC received six notices of appeal. Once these appeals are resolved, the ORC will approve the Plan Change and it will become operative.

As Plan Change 1C is in the final phase of development, significant weight should be given to the relevant provisions. The sections that are under appeal should be given less weight than others as these may be subject to change. The appeals are generally focused on specific sections and will not impact on the overall approach of the Plan or alter the permitted activity thresholds discussed below.

There are a further two plan changes currently in the beginning stages of development –

Proposed Plan Change 3A (Minimum Flow for Taieri River at Tiroiti). This Plan Change will not have any impact on the Manuherikia region.

Proposed Plan Change 2 (Regionally Significant Wetlands). A consultation draft has been released. There are elements of the plan change that may be relevant to the study area.

6.4.1 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/s and 326,160 m^3/day. Various conditions apply to this consent and it expires on 1st April 2038. 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. Permitted activities in relation to water use are limited to:

- an individual's reasonable domestic needs or for an individual's animals for drinking water (12.1.2.1);
- takes from the main stem of the Clutha and Kawarau Rivers, or from Lakes Wanaka, Hawea, Wakatipu, Dunstan and Roxburgh that do not exceed 100L/second nor 1,000,000L/day (12.1.2.2);
- water that is taken from an artificial lake where the water is taken or authorised by the owner of the dam and the artificial lake was created under the Transitional Regional Plan rules prior to February 1998 (12.1.2.3);
- taking surface water for no more than 3 days in a month provided the water is not used for a range of uses including irrigation (12.1.2.4);
- taking water at a volume of no more than 25,000L per day or a rate of more than 0.5L or 1L per second and that is not taken from a wetland above 800m or listed in Schedule 9 (12.1.2.5); and
- taking water for land drainage where the water is not taken from a wetland, does not result in lowering water levels, and does not cause flooding, erosion, or sedimentation damage (12.1.2.6).

As none of the above permitted activity rules will be met, 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; and
- to ensure the efficient use of water resources.

6.4.2 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.

The Regional Plan permits certain small dams in small ephemeral catchments. Dams that do not comply with the permitted activity are a discretionary activity.

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.

6.4.3 Buildings or Structures in Water-bodies

Under the Regional Plan it is a permitted activity to erect or place any structure, other than a defence against water, within 7 m 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 or to excavate or otherwise disturb 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.

6.5 Central Otago District Plan

6.5.1 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 42, 52, 53, 56, and 57.

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

- The area to the east of Lake Dunstan is classified as an Area of Outstanding Landscape Value; and
- A small section of the area is classified as an Area of Significant Natural Value; 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.

6.5.2 Proposed Plan Changes 5A – 5W

These Proposed Plan Changes amend the District Plan to provide for specific landscape elements that have been identified through consultation. The plan changes apply to the Rural Resource Area and are likely to affect some of the activities required to establish a pumped irrigation scheme from Lake Dunstan.

Under the Proposed Plan Change maps, the subject area is classified as ranging from significant sensitivity to limited sensitivity in terms of landscape assessment. New rules are introduced through Proposed Plan Change 5J that deal with areas of extreme or high landscape sensitivity, however these will not impact on the subject area. The landscape units that are relevant include:

- Unit 21 – Lower Manuherikia River;
- Unit 22 – Lake Onslow, Greenland, Manorburn, and Poolburn;
- Unit 6 – Foothills of Pisa, Kakanui, Old Man Ranges, and Mt Buster;
- Unit 16 – Foothills of the Dunstan Range north west of the Manuherikia River;
- Unit 17 – Northern Knobby, Lammerlaw & Lammermoor Ranges;
- Unit 20 – Raggedy, Rough, North Rough, Rock & Pillar Ranges;
- Unit 19 – Sloping plain east of Dunstan Range; and
- Unit 19A – Waikerikeri Valley.

6.5.3 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 (13.7.9). If these standards are not met, then the activity becomes a discretionary activity and resource consent would be required. The standards that must be met cover areas including:

- ground disturbance;
- parking;
- radio frequency radiation;
- stormwater control;
- noise;
- as built plans;
- location and appearance of buildings;
- construction standards; and
- separation distances (13.7.15).

The operation, maintenance, repairs, 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.

The rules in relation to underground or in-ground network utilities will not be affected by Proposed Plan Change 5A-5W. However, Proposed Plan Change 5P requires the Council to have regard to objectives and policies elsewhere in the District Plan when considering an application for an activity to which Section 13 (Utilities) relates.

6.5.4 Earthworks and Vegetation Clearance

Within the Rural Resource Area, some earthworks for tracks, fence-lines and utility service lines are permitted subject to design standards. Other earthworks that are not associated with clean-fill or landfill, construction of irrigation dams, and other farm activities may not exceed 2000 m^2 in area nor 3000m^3 in volume.

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 m 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.

The rules in relation to earthworks and vegetation clearance will not be affected by Proposed Plan Change 5A-5W, except in areas of extreme or high sensitivity.

6.5.5 Buildings or Structures

The Central Otago District Plan provides that the following structures can be established as a permitted activity within 20 metres of the bank of a water-body (4.7.6A(c)):

- 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 m 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 (i.e. buildings are larger than the threshold size), then the activity becomes a discretionary activity and resource consent would be required.

Elsewhere in the Rural Resource Area, buildings and structures must meet standards relating to their visual effects. Proposed Plan Change 5N introduces a colour palette for the external finish of buildings (4.7.6D(a)) and a requirement that buildings may not protrude onto a skyline or above a ridgeline when viewed from a public road or other public place (4.7.6D(b)). Breaches of the standards will be a discretionary activity.

Proposed Plan Change 5K will amend height restrictions for buildings (currently 15 m across the zone) to varying maximum heights depending on the sensitivity of the location depending on the Proposed Landscape Assessment Maps.

6.5.6 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.

Proposed Plan Change 5A-5W increases separation distances in relation to residential activities; however, it will not alter separation distances in relation to irrigation works.

Table 6-1: 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. Permitted or Discretionary Activity.	N/A
Underground Pipes	Permitted Activity if conditions for pipes in, on, under or over bed of river or lake are met. Otherwise Discretionary	Permitted Activity if conditions met. Otherwise Discretionary
Earthworks	Conditions apply for earthworks in bed of river or lake. Permitted or Discretionary Activity.	Permitted Activity provided that within 10m of water body, 20m^3 threshold maintained unless for minor maintenance of a network utility. Otherwise Discretionary (Restricted)
Pump Station	Permitted Activity provided in, on, or under bed of river no more than 2m^2; on riverbank no restrictions. Otherwise Discretionary.	Permitted Activity: Provided no larger than 9m^2 in area and 2m in height. Otherwise Discretionary
Power Generation Facility	Take and discharge water: Discretionary Activity.	Discretionary Activity

6.6 The Historic Places Act

The Historic Places Act applies where there are archaeological sites that pre-date 1900. We are aware that there are a number of pre-1900 mining races and areas that have been mined for gold within the command area. Therefore, any works that will result in physical impact on these features will likely require a process to identify and then manage all major archaeological features prior to any construction work. We recommend that a desk-top archaeological assessment be undertaken initially in order to identify the location and extent of features likely to be affected. If archaeological sites are present and works will impact these, an Archaeological Authority will be required from the Historic Places Trust. This would need to include a full Archaeological Assessment of Effects.

6.7 The Building Act

The Building Act requires that prior to any building work being undertaken, building consent must be applied for and granted. 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 programme.

6.8 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. These provisions may also apply to Marginal Strip Land.

7 Mini-hydropower Generation Option

As part of our Detailed Concept Study, we were asked to consider the feasibility of a mini hydropower station, using an existing water take and use consent. Supplying irrigation water to the lower valley from Lake Dunstan frees up the Manuherikia Scheme water allocation currently abstracted at the Manuherikia Scheme intake from the Manuherikia River. This water could be used possibly in conjunction with the existing Manuherikia head-works infrastructure for hydropower generation. The purpose of such a system would be either:

- A grid-connect/embedded generation system, where the generated power is fed into the local grid and the revenue received from electricity companies is used to offset the operational costs of the irrigation scheme; or
- A self-supply system (where the irrigation scheme's pump stations use the generated power, rather than from the grid) and use the local grid just for transmission.

The hydropower generation opportunity considered here is unique because the mini hydropower station has the advantage of being separate from the potential irrigation scheme. Therefore, generation of power would be independent of the operation of the scheme, i.e. does not occur only when water was being used by the scheme, as is common in other schemes.

The consent held by the Manuherikia Irrigation Co-operative Society allows the abstraction of water to a maximum of 100 heads or 2.83 m^3 per second, and a maximum of 244,512 m^3 per day, from the Manuherikia River near Chatto Creek, about 19.5 km northeast of Alexandra (Figure 7-1), for the purpose of irrigation. Currently, only a maximum of 80 heads is abstracted because of infrastructure limitations. The consent expires on 1st October 2021. The consent to use the abstracted water will need to be varied to allow the water to be used for power generation rather than irrigation, which the existing consent allows. Furthermore, because of the significantly higher flows in the Manuherikia River during winter months, it would be favourable if the consent could also be varied to allow a higher abstraction flow rate to increase power generation during winter months. Because this use is non-consumptive, we do not foresee major hindrances to these consent variations. Instead of varying the consent, it might be best to obtain a whole new suite of consents (i.e. a water permit to take and a discharge permit to return water back to the river), which would require a full assessment of the effects on the river between the take and discharge points.

Figure 7-1: Aerial overview showing current Manuherikia Scheme intake

The accompanying Mini Hydropower Prefeasibility Study report contains full details of the hydrological analysis, power output estimation, turbine technology that is likely to be suitable, and economic feasibility assessment. We found that a proposed mini hydropower station at the site appears to be technically feasible, but recommend that a more detailed assessment be done to confirm this.

Furthermore, our preliminary economic assessment based on the potential annual output and common investment costs indicates that the proposed mini hydropower development may only be viable under certain conditions. Our sensitivity analysis suggested that its economic viability also depends highly on the financial conditions (discount rates and project financing) and specific compensation. It also showed that a short amortization period is unrealistic, especially with embedded generation schemes.

We recommend that the scope of a future expanded feasibility study should include:

- Investigating the possibility of part or all of the generated electricity being used for self-supply (where electricity is consumed by the pump stations, rather than the pump stations using electricity from the grid);
- Making initial contacts with relevant electricity companies and grid operators; and
- Determining the planning framework (resource consent change, consent duration, consent conditions and possibility of an increase of abstraction volume).

8 Climate and Soil Studies

8.1 Desktop Soil Analysis

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

Once the natural annual and seasonal availability of water has been assessed, the hydraulic characteristics of the soil must be quantified. Soil is the product of the interaction, through time, between environmental factors, such as:

- the parent material from which it is derived;
- the position in the landscape where it is situated;
- the climate under which it developed; and
- the biological influences, particularly vegetation, which have modified it.

At any one place, the soil represents the effect of all these factors in combination. Therefore, the soil pattern of a region is a reflection of variation in one or more of these soil-forming factors (Hawke *et al.,* 2000).

Soils can be classified by either their attributes, or their environmental characteristics. Classification enables differences and similarities to be accentuated. The New Zealand Soil Classification (Hewitt, 1998) groups soils on the basis of properties that can be precisely measured and observed. This allows, either directly or by tested inferences, the field assignment of soils to particular classes. These soil classes are analysed to quantify the hydraulic properties and moisture-holding capacity of the soils within the study area. This allows irrigation needs to be “tailored” to specific zones, situations, and anticipated results. Understanding the irrigation requirements of the area is of critical importance to the long-term management of this irrigation scheme for the Lower Manuherikia Valley.

Data from both the New Zealand Fundamental Soil Layer (NZFSL) and the Grow Otago Climate and Soils Maps were analysed, concentrating on the following soil attributes:

- Soil type
- Soil depth
- Soil characteristics (including: potential rooting depth, drainage, permeability, porosity, salinity, and profile readily available water content)

The majority of the soils within the study area are semi-arid (dry for most of the growing season, with moderate to high fertility) with low to very low salinity; and of these most are anthropic (drastically disturbed by human influence). The nature of the soils reflects the climate and land use history of the area. The soils are mainly stony (100–200mm deep), with isolated pockets of shallow to moderately deep soil (200-450mm to 450-900mm). Reflecting these shallow soils, other attributes such as potential rooting depth and profile readily available water content (PRAW) were also found to be respectively shallow and very low. Figure 8-1 shows the extent of the very low PRAW (water that can be readily absorbed by plant roots without resulting in water deficit stress). In general, the soils were also found to have moderate drainage, permeability and porosity qualities.

Given the above analysis, the study area would benefit from a carefully tailored and monitored irrigation regime to ensure efficient use of water. The accompanying Hydrology Study report contains full details and soil descriptions for each zone in the study area.

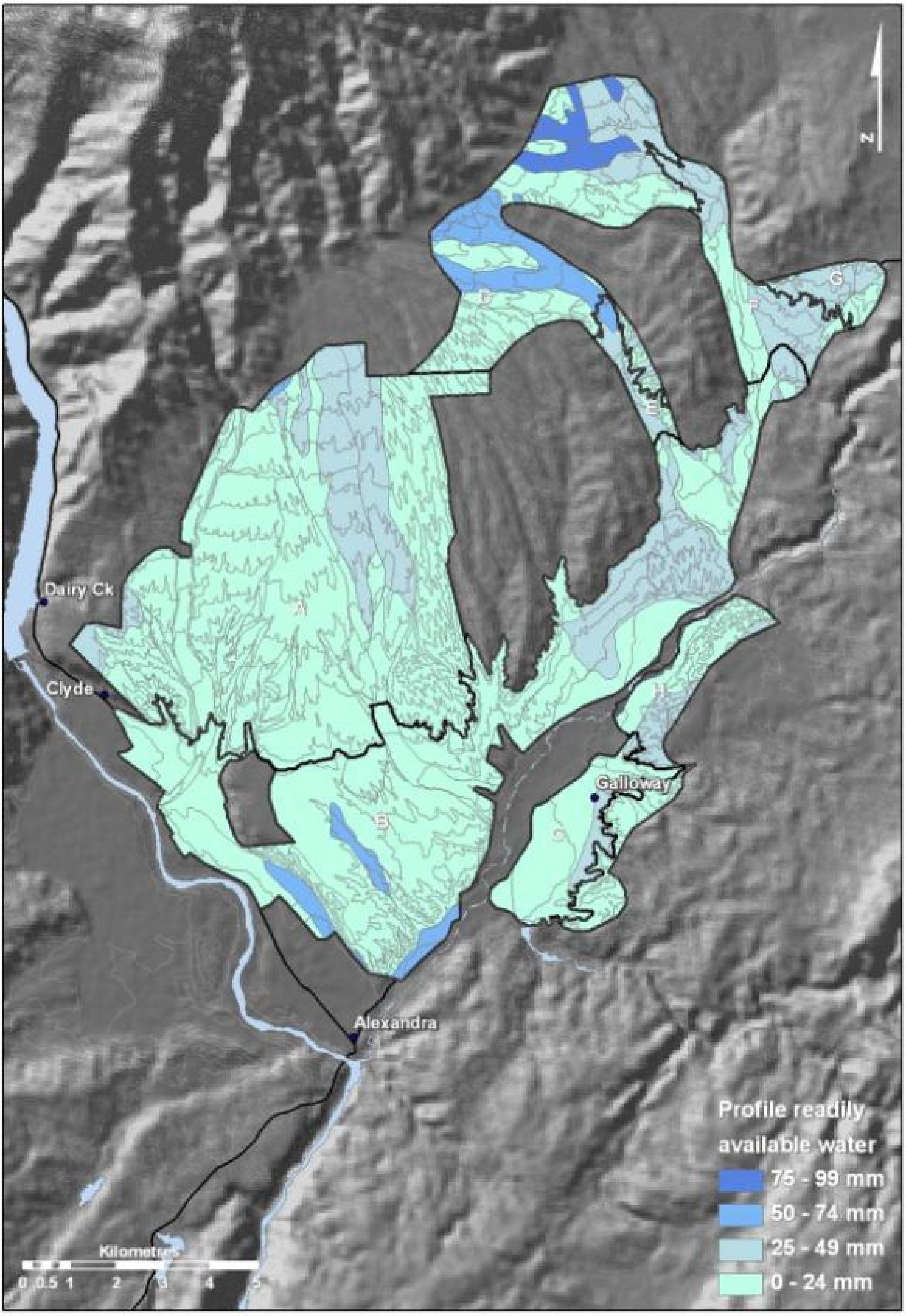

Figure 8-1: Soil profile readily available water across the study area

8.2 Desktop Climate Analysis

A critical element in any environmental system is the availability of water. It determines plant type, plant growth, and agricultural production as well as a range of other environmental attributes. Until the full seasonal pattern of water availability is appreciated, it is difficult to determine what water resources may be present, or needed, for human activities.

Understanding the amount and distribution of 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. Analysis, therefore, involved the quantification of the spatial and temporal variability of the inputs (rainfall) and outputs (evapotranspiration) of moisture. The study determined the one-in-five-year (Q_5) and one-in-ten-year (Q_{10}) minimum growing season (September to April, inclusive) rainfall depths and corresponding effective precipitation to represent drier than average conditions.

Rainfall data from 27 sites, along with pan evaporation and potential evapotranspiration data from 4 sites, were analysed to quantify the inputs and outputs of moisture and the spatial distribution of rainfall across the study area. The highest median annual rainfall totals are found on the Dunstan Mountains because of the elevation. Rainfalls decrease with elevation into the basin near Alexandra. Conversely, evapotranspiration during the growing season is much higher in the basin than in the high country because of higher temperature. The variability apparent in annual rainfall is also present in the monthly patterns.

Effective precipitation was determined by the difference between rainfall and potential evapotranspiration losses. Where potential losses are greater than rainfall, any available soil moisture will be used to make up the shortfall. A deficit occurs when there is not enough moisture in the soil to make up the difference. Unless irrigated, plants will become stressed. None of the zones within the study area showed an annual surplus of effective precipitation for either Q_5 or Q_{10} options. Figure 8-2 shows the results of the Q_5 minimum effective precipitation for the growing season.

These results highlight the need of irrigation over the growing season. The accompanying Hydrology Study report contains full details of this analysis.

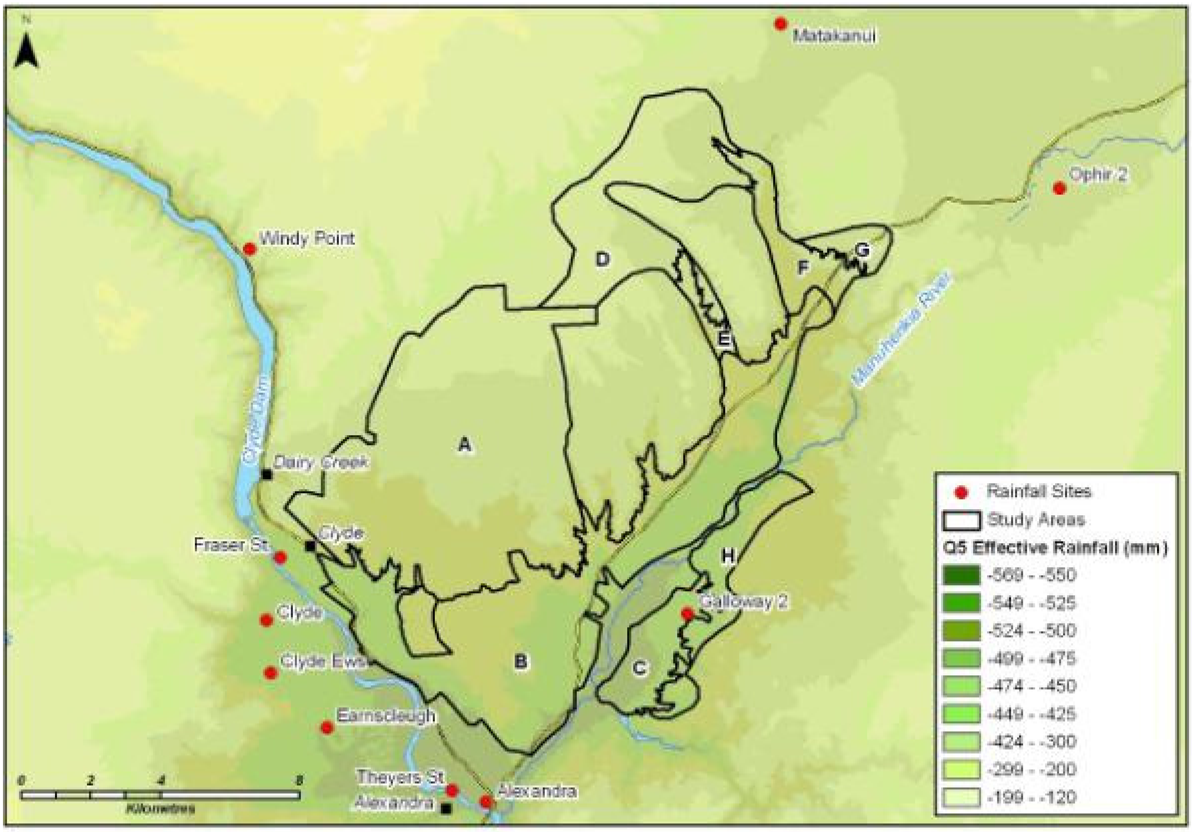

Figure 8-2: One-in-five year minimum growing season effective precipitation (mm)

8.3 The Soil Moisture Balance

A soil moisture balance was used to estimate the availability of water for each month of the year. This is a simple conceptual model of the soil's water budget which accounts for water added, stored and removed from the system. This model can be used to estimate the irrigation required to maintain adequate water within the root zone (Morgan, 1997).

Water enters the system from precipitation and is lost through evapotranspiration and runoff. Potential evapotranspiration is the maximum amount of water lost from the system (assuming an unlimited supply) as a result of solar radiation, wind speed and vapour pressure deficit (McConchie, 2000). However, because of limitations to water availability, this maximum is often not achieved. The actual evapotranspiration is therefore a function of potential evapotranspiration and water availability. It quantifies the actual amount of water lost to the system.

In the water balance, precipitation is initially used to meet the potential evapotranspiration. If precipitation is sufficient, then actual evapotranspiration will equal potential evapotranspiration. Any excess water will recharge the soil water storage, or when that reaches capacity, become surplus runoff. Water is, therefore, stored in the pores of the soil. This moisture is released to the plants and atmosphere when water supply from precipitation is short. However, moisture within the soil may not be sufficient to meet potential evapotranspiration, resulting in a water deficit which places plants under stress. During these times, the soil must be irrigated to prevent lost production or ultimately, death of the plant.

The soil moisture balance for each individual zone was calculated using the available rainfall and evapotranspiration data, and the various storage capacities of the soils (based on the soil profile readily available water data) within each zone. The soil moisture balances quantify the likely monthly water deficit values, highlighting the months from September to April (inclusive, i.e. the growing season) as the period when irrigation will be required.

The accompanying Hydrology Study report contains full details of the analysis and results of the moisture balance for each zone. These results form the basis for the calculation of the required water application depths for each zone in the following section.

9 Refined Inputs for Preliminary Design

9.1 Irrigation Season Length

Our High Level Overview estimated the seasonal and peak daily water requirements based upon a 120-day irrigation season. From client input and based on the 2008/09 Manuherikia River water take data, we recognised that the current irrigation season being practised was closer to a 180- to 240-day season, starting in early September and ending in late April. The current irrigation season length could be attributed to the schemes using a race roster system, which encourages landowners to irrigate earlier than required because it might be too late at their next turn. Therefore, we chose not to simply use those figures, but to investigate the irrigation season length actually required for the valley because it would significantly affect the seasonal irrigation demand.

Table 9-1 presents an extract of the soil moisture balance results showing the monthly water deficit values for the shallowest soils for each zone (which have the highest water deficit values) and the 1-in-5-year minimum growing season effective precipitation.

Table 9-1: Monthly water deficit values from the soil moisture balance

Zone	Jan	Feb[3]	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Zone Totals
A	104	71	48	5	0	0	0	0	17	61	90	106	478
B	106	73	49	6	0	0	0	0	19	63	92	108	489
C	107	74	49	6	0	0	0	0	19	63	92	108	492
D	103	71	47	5	0	0	0	0	17	61	90	105	475
E	105	72	48	6	0	0	0	0	17	62	91	106	483
F	105	72	48	6	0	0	0	0	18	62	91	107	484
G	103	71	47	5	0	0	0	0	17	61	90	105	475
H	106	73	49	6	0	0	0	0	19	63	92	107	488

Note: Please refer to Table 5-1 for a description of each zone.

Based on the results of the soil moisture balance alone, the irrigation season should begin in September and end in April, ramping up in the spring shoulder months, peaking in December and January, and ramping back down in the autumn shoulder months. However, when the soil is too cold (based on common practice, we set a minimum soil temperature of 10°C at 10 cm depth, plant growth is inhibited by the low temperature rather than lack of soil moisture. We looked at the 10 cm depth soil temperature data from the Lauder Electronic Weather Station (EWS), which is low in elevation in the Upper Manuherikia Valley, and thus a conservative

[3] The February water deficit values are lower relative to December and January, although February is often drier than December and January (as confirmed by lower rainfall depths presented in the Hydrology report). However, the lower potential evapotranspiration rates in February cause the water deficit values to be lower.

representative of the command area. Figure 9-1 and Figure 9-2 present the graphs for the 2007 and 2008 data respectively. The data suggests that the soil in the command area would only be warm enough for growth between mid-October and mid-April.

Figure 9-1: Daily average temperature of soil at 10cm depth in 2007

Figure 9-2: Daily average temperature of soil at 10cm depth in 2008

Starting irrigation too early might delay the increase of soil temperatures, whereas starting irrigation too late would delay growth. We estimate that on average, irrigation should be started no earlier than the second week of October, not for growth, but to recharge the soil moisture to field capacity in anticipation of the growing season starting in mid-October. The best time to start irrigating would vary from year to year and is a matter of risk management. Please note that the start date affects the flow rates and storage requirements.

Once the soil moisture is recharged to field capacity, the monthly application depths from the soil moisture balance would be sufficient during the irrigation season to keep the plants from moisture stress so that growth is not inhibited. In calculating the seasonal volume of irrigation water required, we have allowed for irrigation to continue to mid-April to maximise growth before it gets too cold. The resultant irrigation season we have used is for approximately 188 days per year.

9.2 Irrigation Application Depth Profile

To estimate the required net application depth profile, we applied the irrigation season length adjustments to the soil moisture deficit profile, being conservative to use the data for the shallowest soils which have the highest water deficit rates.

The soil moisture deficit profile we have used, and hence the net irrigation application depth profile, is based on the growing season 1-in-5-year minimum rainfall (the level of drought that has 20% probability of occurring each year)[4]. This is an issue of risk management, and can be adjusted in detailed design. If a 1-in-10-year minimum rainfall (the level of drought that has 10% probability of occurring each year) was used as the basis of calculating required application depths, this would demand a higher seasonal volume, and therefore higher flow rates and storage requirements, leading to higher costs. It is important to note that when the growing season rainfall exceeds the 1-in-5-year minimum rainfall, there will be more than sufficient water, and when the growing season rainfall is less than the 1-in-5-year minimum rainfall, there will be insufficient water. Irrigators will need a farm water management plan to decide when best to irrigate, especially during years that are drier than the 1-in-5-year minimum rainfall year.

To estimate the gross application depth profile, we assumed an average efficiency of 80%, taking into account both distribution efficiency (percentage of water reaching the farm gate compared to water leaving the source) and application efficiency (percentage of water retained in the root zone compared to water reaching the farm gate). It is important to note that this accounts for efficiency improvements that are likely to arise from future changes in irrigation methods (from

[4] We note here that this 1-in-5-year minimum rainfall already specifically accounts for the dry climate conditions in the Lower Manuherikia Valley, and requires no further adjustments.

traditional border dyke and flood irrigation to more efficient methods) and in the transmission of water (from unlined, open water races to a piped system).

Table 9-2 presents the required monthly gross application depths, after adjusting for our proposed changes in April and October, as well as application efficiency losses. We have used the average application depths in subsequent calculations.

Table 9-2: Gross application depth profile

	GROSS APPLICATION DEPTHS (mm/month) *(assuming 80% application efficiency)*												
Month	**Jan**	**Feb**	**Mar**	**Apr**	**May**	**Jun**	**Jul**	**Aug**	**Sep**	**Oct**	**Nov**	**Dec**	***Zone Totals***
# Irrigation days	*31*	*28*	*31*	*15*	*0*	*0*	*0*	*0*	*0*	*22*	*30*	*31*	*188*
A	130	89	60	6	0	0	0	0	0	68	113	133	**598**
B	133	91	61	7	0	0	0	0	0	70	115	135	**612**
C	134	93	61	8	0	0	0	0	0	70	115	135	**615**
D	129	89	59	6	0	0	0	0	0	68	113	131	**594**
E	131	90	60	7	0	0	0	0	0	69	114	133	**603**
F	131	90	60	7	0	0	0	0	0	69	114	134	**604**
G	129	89	59	6	0	0	0	0	0	68	113	131	**594**
H	133	91	61	7	0	0	0	0	0	70	115	134	**610**
Average depth for all zones (mm)	**131**	**90**	**60**	**7**	**0**	**0**	**0**	**0**	**0**	**69**	**114**	**133**	
Average daily depth (mm)	**4.2**	**3.2**	**1.9**	**0.4**	**0.0**	**0.0**	**0.0**	**0.0**	**0.0**	**3.1**	**3.8**	**4.3**	

Note: Please refer to Table 5-1 for a description of each zone.

10 Preliminary Storage and Pipeline Design

Having worked out the timing and volume of water available from Lake Dunstan, and the timing and volume of water required by the various users, we developed several preliminary design options for the mechanics of water distribution in the valley. At this stage, these preliminary designs were done for the primary purpose of establishing the feasibility of the scheme in terms of land availability for storage and financial viability.

We made a number of assumptions surrounding several variables including the following:

- the actual area that the landowners want to irrigate (a subset of the total irrigable area);
- the land use intensity relating to agricultural practice (high intensity, e.g. pasture or nutraceuticals, or low intensity, e.g. viticulture or lifestyle blocks);
- rural residential potable water demand all year-round;
- whether water is required for viticulture frost-fighting or alternative measures are used;
- any variations in consent conditions to be sought; and
- whether Central Otago District Council decides to use Lake Dunstan as a raw water source of drinking water for Clyde and Alexandra.

Our Detailed Concept Study involved multiple iterations, but in this report, we have documented only the major iteration stages to keep it as clear and concise as possible.

10.1 Iteration Stage 1

In our earlier iterations, our focus was on working out how much of the irrigable area could actually be irrigated with the water available at the consented abstraction rate. At this early stage, we allocated the entire consented abstraction rate of 4.53m^3/s for irrigation only, hence excluding the following from our calculations:

- *Drinking/potable water for Alexandra and Clyde.* This is because Central Otago District Council (CODC)'s decision on raw water source was still uncertain. If CODC eventually decides to use Lake Dunstan as a source, up to an additional 26,000 m^3/day will need to be pumped from Lake Dunstan. This will affect pump selections and pipe sizes, and in some of these earlier options, may require a variation in consent conditions.
- *Water for frost-fighting.* We assumed that instead of using water, alternative frost-fighting measures would be utilised where required.
- *Rural residential potable water*.

We used the adjusted application depths (as presented in Table 9-2) and the irrigable areas estimated in the High Level Overview to calculate the seasonal volume required (shown in Table 10-1). We did not use any crop factors at this preliminary stage, to allow for the volume required for 100% high-intensity land use to be obtained as a basis for further iterations.

Table 10-1: Required seasonal volumes and peak flow rates

Zone	Irrigable area (ha)	SEASONAL DEMAND (assuming 80% application efficiency) (Mm^3/year)
A	3,800	22.7
B	3,719	22.7
C	531	3.3
D	1,590	9.4
E	131	0.8
F	475	2.9
G	185	1.1
H	587	3.6
All Zones (A through H)	11,018	**66.5**
Current Irrigation Schemes & Areas <300m elevation (excludes D & G)	9,243	**56.0**

Note: Please refer to Table 5-1 for a description of each zone.

Irrigators will decide on daily application rates based on their farm management plans and rainfall on any given day. Thus, there might be some days when they irrigate more and other days when they irrigate less, but their total for the month should roughly match the monthly application rates proposed.

However, to give flexibility to irrigators in allowing for higher application rates on certain days, we sized the pipes to allow for 5 mm/day peak application rates. Table 10-2 presents the daily volumes and peak flow rates calculated by taking the product of the irrigable area and the application depth of 5mm/day. The peak flow rate is the instantaneous flow rate based on pumping for only 20 hours per day (to avoid peak power charge times per day and to provide downtime for the farm irrigation systems during relocation/maintenance).

Table 10-2: Flow Rates used for Sizing pipes

Zone	DEMAND based on 5mm/day and 80% efficiency FOR PIPE SIZING	
	Daily Volume (m^3/day)	Peak Flow Rate (m^3/s)
A	180,000	2.50
B	232,444	3.23
C	33,177	0.46
D	99,383	1.38
E	8,169	0.11
F	29,705	0.41
G	11,550	0.16
H	36,673	0.51
All Zones (A through H)	**504,880**	**7.01**
Current Irrigation Schemes & Areas <300m elevation (excludes D & G)	**416,133**	**5.78**

Note: Please refer to Table 5-1 for a description of each zone.

We considered thirteen options which use a combination of variables surrounding:

- which zones are supplied,
- the use of storage, and
- any change in consent to increase flow rates.

The thirteen options (as compared in Table 10-3) are:

- *Options A1 through A6*, where the entire irrigable area includes all Zones A through H (i.e. approximately 11,000 hectares are irrigated), thus requiring a seasonal volume of approximately 66.5 million m^3 per year;
- *Options B1 through B6*, where the entire irrigable area includes all zones except Zones D and G which are above 300m in elevation (i.e. approximately 9,200 hectares are irrigated), thus requiring a seasonal volume of approximately 56 million m^3 per year; and
- *Option C*, which considers how much area could be irrigated if no storage is used, and no change is made to the existing consented flow rate.

Table 10-3: Combination of storage and consent change requirements for each option

Option	Zones Supplied	Storage use	Consent change	Details
A1	All zones	Yes	No	Zone A supplied directly, other zones share four 10m deep storage dams
A2	All zones	Yes	No	Zone A supplied directly, other zones share a single centralised storage dam
A3	All zones	Yes	No	All zones share five 10m deep storage dams
A4	All zones	Yes	No	All zones share a single centralised storage dam
A5	All zones	No	Yes	Increase consented daily & peak rate to the point that storage is not required, but total seasonal volume is maintained
A6	All zones	Yes	Yes	Increase consented instantaneous rate by $0.5m^3/s$ and daily rate accordingly. Zone A supplied directly, other zones share four 10m deep storage dams
B1	All zones except D&G	Yes	No	Zone A supplied directly, other zones share three 10m deep storage dams
B2	All zones except D&G	Yes	No	Zone A supplied directly, other zones share a single centralised storage dam
B3	All zones except D&G	Yes	No	All zones share four 10m deep storage dams
B4	All zones except D&G	Yes	No	All zones share a single centralised storage dam
B5	All zones except D&G	No	Yes	Increase consented daily & peak rate to the point that storage is not required, but total seasonal volume is maintained
B6	All zones except D&G	Yes	Yes	Increase consented instantaneous rate by $0.5m^3/s$ and daily rate accordingly. Zone A supplied directly, other zones share three 10m deep storage dams
C	As much as possible	No	No	As a basis for comparison, to check how much area can be irrigated with the existing consent and without any storage at all

Note: Where we have indicated "No" for the use of storage, there will still be the use of header tanks and on-farm buffer storage as required.

We found that under Option C, there is sufficient water for only Zone A and part of Zone B. This was deemed to be unacceptable, thus Option C was not considered further. All 12 of the other options seem to give acceptable outcomes. Therefore, we proceeded with the sizing of pipes and storage (where applicable). The increase in consented flow rate required was calculated for each individual option to check the practicality of the sizes.

Table 10-4: Storage and consent change requirements for the different options

Option	Total Storage Volume Required (m^3)	Largest Individual Storage Dam Required (m^3)	Increased Consented Flow Rate Required (m^3/s)
A1	15.9M	7.9M	0
A2	15.2M	15.2M	0
A3	16M	5.5M	0
A4	15.2M	15.2M	0
A5	0	0	4.24
A6	10.7M	5.8M	0.5
B1	6.5M	4.4M	0
B2	6.2M	6.2M	0
B3	6.5M	2.9M	0
B4	6.2M	6.2M	0
B5	0	0	1.44
B6	2.7M	1.1M	0.5

Notes: 1. Volume left in dam not allowed to drop below 15% of gross dam volume.

2. Assumed water lost through evaporation from dams approximately 0.600m per year.

10.2 Iteration Stage 2

At this point of our study, we had a meeting with Gary Kelliher on Tuesday 20th October 2009. Among the various issues discussed was the availability of land for storage. A large central non-irrigable area was considered, but its suitability could not be confirmed without further on-site investigation. Hence, it was not explored further. However, a 6.5 ha area on the airport reserve land was identified as a possible storage site.

Following our meeting, we proposed that in furthering the rest of our Detailed Concept Study, we focus on irrigating a smaller land area. This smaller land area includes only Zones A, B, C and H, and excludes the areas further to the north, i.e. Zones D, E, F and G. This constitutes an area reduction of 2,381 ha from 11,018 ha to 8,637 ha.

We had several reasons for focusing on this smaller land area. Each of these reasons on their own did not necessarily justify excluding the northern areas, but together formed the basis for our recommendation. The first was that if the entire irrigable area up to Tiger Hill was supplied with water from Lake Dunstan, the consented peak flow rate would have to be spread across too large an area, thus requiring large storage dams. From our preliminary calculations, this would require impractically large storage volumes. These entail high costs and large land areas set aside for the storage dams. Changing the consent to allow a higher peak flow rate, while maintaining the annual take volume, is a possible alternative option. However, there might be opposition from other water users.

Secondly, the northern irrigable area has an annular shape with a large non-irrigable area in the middle. In addition, the northern irrigable area is separated from the proposed Dairy Creek Irrigation Scheme area by a large non-irrigable area. The shape and separation mean that long lengths of pipe covering long narrow areas, and large pumping duties to reach some of the higher areas, would be required. This makes supplying those northern areas with water from Lake Dunstan not only difficult, but also less than optimal.

Thirdly, excluding the northern areas does not preclude them from having the opportunity to access water. They could be supplied with water from the Upper Manuherikia Valley for which further study is required. If that were not the case, then pumping water up to these northern areas from Lake Dunstan could be justified, possibly in line with the Otago Regional Council (ORC) objective of “no area stranded dry”.

Fourthly, after taking all other factors into consideration, priority over the water from Lake Dunstan should be given to the areas which are closer to Lake Dunstan; those areas we propose to focus on. We believe that pumping water from Lake Dunstan to the northern areas might be interpreted as being out of line with the ORC objective of “local water used first for local use”.

We then redeveloped the concept design to best suit the reduced command area. We were also asked to further integrate Zone A with the rest of the design. Whereas initially the water requirements of Zone A were left as previously designed, we now applied the same calculations that were used for the other zones. This affected both the storage and pipeline design. We also carried across our assumption from our High Level Overview that 60% of the irrigable area would be used for high-intensity land use (which includes pasture farming) and the other 40% would be used for low-intensity land use (which includes viticulture and lifestyle blocks). In line with the New Zealand Irrigation Code of Practice and Design Standards, we applied a crop factor of 1 and 0.8 to the high-intensity and low-intensity land use areas respectively. This was to account for the different water requirements.

At this stage, we also included the rural residential potable water demand, which was estimated based on the following:

- Approximately 1,000 litres per rural dwelling per day, based on ORC’s advice for potable water use only (excludes curtilage irrigation which is already accounted for)

- Approximately 2,450 rural residential properties in the Lower Manuherikia Valley in the future, based on client input.

The water would be supplied all year round, and would need to be treated on-site prior to domestic use.

After examining several new options, we narrowed them to three:

- *Option N*, where the consented peak flow rate is not increased, but storage is increased as required to irrigate the 8,637 ha;
- *Option O*, where the storage dam is limited to the 6.5 ha land available in the airport reserve area, and the consented peak flow rate is increased (while maintaining the total annual consented volume) as required to irrigate the 8,637 ha; and
- *Option P*, where the consented peak flow rate is not increased and the storage dam is limited to the 6.5 ha land available in the airport reserve area. Only a smaller land area of 8,320 ha could be irrigated with these two constraints of flow rate and storage.

Table 10-5 presents the storage and consent change parameters for the three options. The dam sizing assumes 10m deep dams with 2.5:1 (H:V) batter slopes.

Table 10-5: Storage and consent change requirements for the two options

Option	Irrigated Land Area (ha)	Increase in Consented Peak Flow Rate (m^3/s)	Approximate Storage Volume Required (M m^3)	Approximate Area Required for Storage Dam (m^2)
N	8,637	0	**1.13**	176,000
O	8,637	**0.17**	0.33	65,000
P	**8,320**	0	0.33	65,000

Note: Bolded numbers emphasise changes required for the particular option.

10.3 Iteration Stage 3

After further discussion with Gary Kelliher, it was decided that options N and O were unfavourable because:

- for N, it would be difficult to find land outside of the airport reserve to build a storage dam, and
- for O, it would be difficult to get an increase in the consented peak flow rate.

In addition, Option P involved only a small reduction in the total irrigated land area which was acceptable to the client. With this input from the client, our basis of design changed from maximising the area that can be irrigated, to using as much of the existing consented flow rate as required, while using the limited storage capacity in the airport reserve.

We proceeded to further refine Option P and obtained quotes to estimate the capital costs. As a variation to Option P, we considered Option Q which is similar except that the Dairy Creek Irrigation Scheme is fed directly from Lake Dunstan via a separate, standalone pipeline network. This was the original design of the Dairy Creek Irrigation Scheme Design and Build Brief jointly prepared by the Delta and Opus.

10.4 Iteration Stage 4

After obtaining more local knowledge concerning the progress of the Dairy Creek Irrigation Scheme (Zone A) development, and the current irrigation water allocations in the Manuherikia Irrigation Scheme (Zone B), we decided that not all of the area that we had determined to be irrigable was actually likely to be irrigated. Hence, we decided that it would be prudent to present to the stakeholders options with a further reduced irrigated area.

We therefore further reduced the area to be irrigated to 6,500 ha, which, based on local knowledge, is the more likely scenario. We reduced the Dairy Creek Irrigation Scheme irrigated area by a third (3,800 ha down to 2,533 ha), because some developments are now unlikely to be going ahead. For the Manuherikia Irrigation Scheme, our analysis showed that there are approximately 3,719 ha of irrigable land, but they currently irrigate only 2,200 ha. To adjust this to a reasonable level while allowing for further development, we reduced the Zone B irrigated area to 2,860 ha (still 30% more than the current 2,200 ha).

We also recognised that the major capital costs were in the pipeline network. Thus, we looked at ways to reduce these costs to improve the viability of the scheme. This was done by using a different basis of design – minimising flow rates. Previously, storage was used only to supplement the water take during the peak months. Storage stayed nearly full for most of the rest of the year. The pipelines were sized to take the very large flows that occurred only during the peak months. With these changes, we now designed the scheme to minimise the arterial pipeline flow rates, and therefore the arterial pipeline sizes. This reduces the pipeline cost significantly, but will require more on-farm and/or shared storage. Water will be pumped slowly and constantly for 20 hours per day throughout the permitted 303 days of the year to several shared on-farm storage sites. Water will then be distributed when required to the different users.

Because this new option uses less than the full consented flow rate, we were able to include water for viticulture frost-fighting requirements. We allowed for frost-fighting up to 5 clusters per season of 4 consecutive nights each, up to 9 hours per night, at an application depth of 5 mm per hour.

We used the opportunity to incorporate several other improvement ideas arising from our design iterations. We also refined the application depths to better suit industry standards:

- 5 mm/day for high intensity land use; and
- 2.2 mm/day for low intensity land use (based on viticulture requirements equivalent to 7 litres per plant per day, with plant spacing of 1.5 m in each row and row spacing of 2.2 m)

Table 10-6 presents the change in application depths in December (peak application month), as an indication of the changes made for other months.

Table 10-6: Change in application depths in December

Land use	Assumed proportion of irrigated area	Original average daily application depth in December (mm/day) *(Iterations 1-3)*		Refined average daily application depth in December (mm/day) *(Iteration 4)*	
		Net	Gross (80% efficiency)	Net	Gross (80% efficiency)
Pasture and other high intensity land use	60%	3.5	4.3	5	6.3
Viticulture	20%	2.8	3.4	2.2	2.8
Lifestyle blocks and other low intensity land use	20%	2.8	3.4	2.2	2.8
Overall weighted average[5]		**3.22**	**4.0**	**3.88**	**4.9**

We developed two options based on these changes, R1 and R2. Option R1 had pipeline velocities similar to the previous options. In Option R2, we increased the arterial pipeline velocity range from 1-2 m/s to 2-3 m/s. This option was developed to investigate the indicative effect of increased pipeline velocities, and hence decreased pipe sizes, on the overall life cycle cost of the scheme.

Furthermore, as a variation to Option R1, we considered Option S. This option is similar to Option R1, but like Option Q, has the Dairy Creek Irrigation Scheme being fed via a separate, standalone pipeline network directly from Lake Dunstan, as designed previously by the Delta and Opus. Table 10-7 presents a comparison of the final five options: P, Q, R1, R2 and S.

[5] For comparison, 4.3 mm/day gross average application depth (0.5 L/s/ha) was used for the Tarras Irrigation Scheme design.

Although the five options are not directly comparable because they are based on different assumptions and variables, they enable us to prepare a useful envelope of rough order costs. This will enable the stakeholders to make some decisions that would narrow down the options, and allow future detailed design work to be done. Detailed design work will then allow more accurate costing of the scheme.

Table 10-7: Comparison of Final 5 Options

Variables	Option P	Option Q	Option R1	Option R2	Option S
Basis of Design	Adjust flow rates to accommodate limited storage	Adjust flow rates to accommodate limited storage	Minimise flow rates	Minimise flow rates and pipe sizes	Minimise flow rates
Area To Be Irrigated (ha)	8320	8320	6511	6511	6511
Standalone Dairy Creek	No	Yes	No	No	Yes
Required Storage	Airport Reserve Dam	Airport Reserve Dam	On-farm Shared Storage	On-farm Shared Storage	On-farm Shared Storage
Weighted Average of Peak Gross Application Rate (mm/day)	4.0	4.0	4.9	4.9	4.9
Calculation for High Intensity Land Use Net Application Rate	Crop factor of 1.0	Crop factor of 1.0	Adjusted peak to 5mm/day	Adjusted peak to 5mm/day	Adjusted peak to 5mm/day
Calculation for Low Intensity Land Use Net Application Rate	Crop factor of 0.8	Crop factor of 0.8	Adjusted peak to 2.2mm/day	Adjusted peak to 2.2mm/day	Adjusted peak to 2.2mm/day
Includes Water for Frost-fighting	No	No	Yes	Yes	Yes
Includes Urban Potable Water Needs	No	No	No	No	No
Includes Rural Potable Water Needs	Yes	Yes	Yes	Yes	Yes
Total Seasonal Demand (Mm^3/year)	48	48	57	57	57
Velocity Range in Main Pipelines (m/s)	1-2	1-2	1-2	2-3	1-2

11 Extraction Point

The existing consent is for abstraction from Dairy Creek which flows out of Lake Dunstan. It is approximately 1 km north of the Clyde Dam. However, Dairy Creek is fed from Lake Dunstan via an existing stormwater culvert. The upstream side of the culvert is in Dairy Creek. It is possible for the water level in Lake Dunstan to fall to the point that the culvert does not flow full. Thus, abstraction would require pumping water up the existing stormwater culvert. Preliminary site investigation has shown a possible slump that would affect both construction access, future stability of power supply, pipeline and access road routes.

A variation to the consent may be required to allow abstraction directly from Lake Dunstan. Preliminary site investigation suggests that there might be a suitable location somewhere between the boom anchor and the boat ramp. This needs to be verified thoroughly during future detailed design work. The relocation of the extraction point might also require some negotiations with Contact Energy. While such a route would require an extra culvert across a road, it would avoid the many complications of the existing consented abstraction site. Furthermore, at the proposed location, the pumping station is likely to be blocked from view from the road. It would therefore not detract from the beauty of the local landscape.

12 Pump Stations

Our concept design identified the pumping requirements for the various options. Table 12-1 presents the locations of the pump stations, their application, and pump duties for the five different options. Figure 12-1 presents their locations on a map, represented by stars.

Table 12-1: Pumping duties at full flow for the five options

Pump Station	Location	Application	Pumping Duties for Each Option									
			P		*Q*		*R1*		*R2*		*S*	
			Head	Flow rate	Head	Flow rate	Head	Flow rate	Head	Flow rate	Head	Flow rate
			m	*m³/s*	*m*	*m³/s*	*m*	*m³/s*	*m*	*m³/s*	*m*	*m³/s*
PS 1	Intake point	Drawing from lake	61	4.53	61	2.53	54	2.62	118	2.62	57	1.76
PS 2	Waikerikeri Valley Rd	Booster (on branch)	134	0.83	*N/A*	*N/A*	135	0.34	161	0.34	*N/A*	*N/A*
PS 3	McArthur Rd	Booster (on branch)	172	0.83	*N/A*	*N/A*	181	0.34	225	0.34	*N/A*	*N/A*
PS 4	Golden Rd	Booster (on branch)	75	0.83	*N/A*	*N/A*	73	0.34	74	0.34	*N/A*	*N/A*
PS 5	Chatto Creek-Springvale Rd	Booster (on main line)	51	0.88	51	0.88	72	0.35	177	0.35	71.5	0.35
PS 6	Clyde Alexandra Rd	Booster (on branch)	-	-	-	-	-	-	24	0.09	-	-
PS 7	Manuherikia Rd	Booster (on branch)	-	-	-	-	-	-	17	0.45	-	-

The pump duties were used to estimate operational power requirements and associated costs. These are included in our estimate of annual costs in Section 14.2.

At this stage, we designed each pump station to have multiple main pumps and jockey pumps, rather than one large main pump. This has the disadvantage of requiring a larger pump building. However, this has the advantage of allowing operational flexibility to handle a wide range of required flow rates. Furthermore, we have chosen this setup so that chosen pumps are within manufacturers' normal product ranges and standard auxiliary equipment can be used. This avoids problems in obtaining spare parts for repairs and the need for highly specialised maintenance/repair.

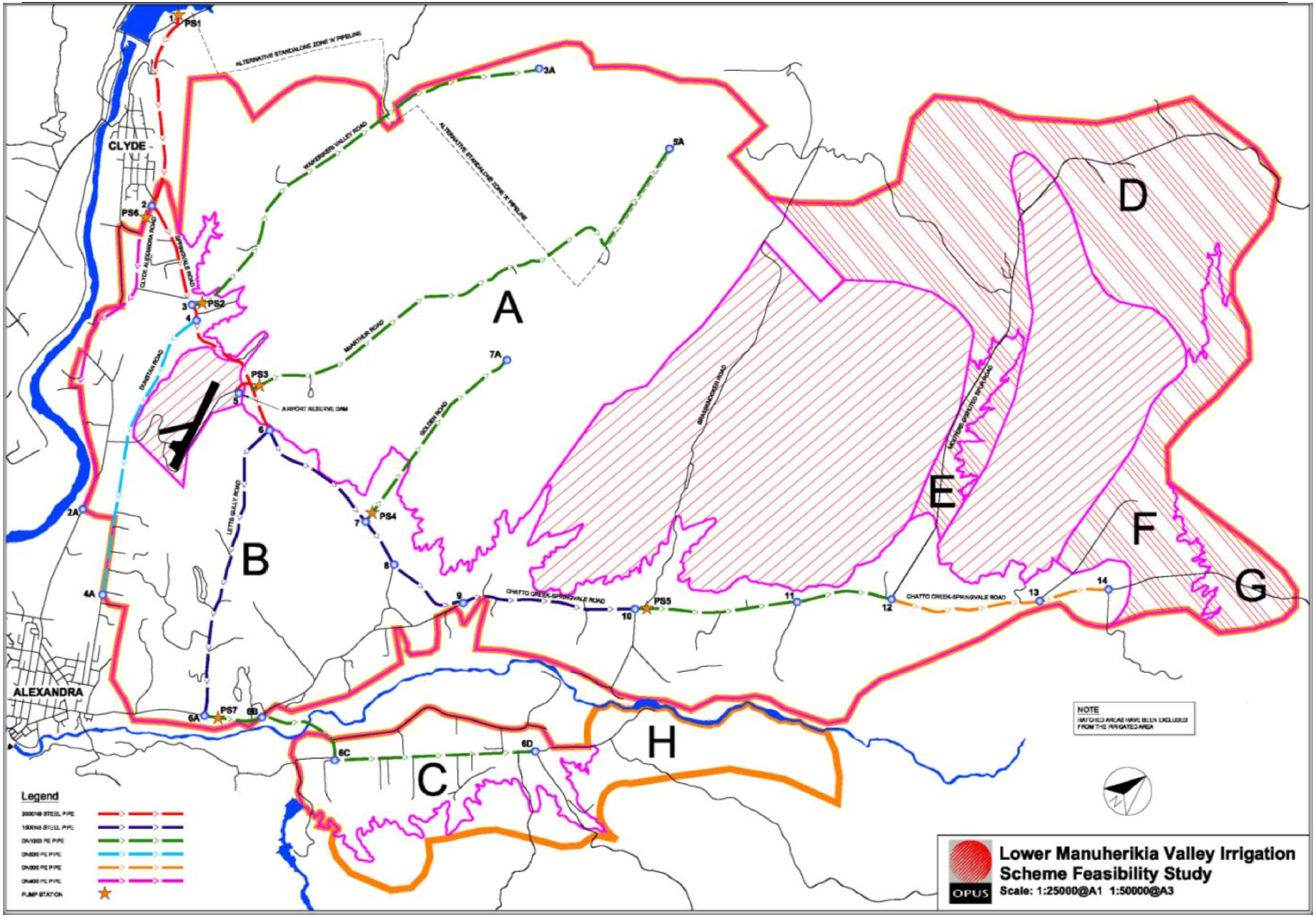

Figure 12-1: Plan showing indicative locations of pump stations (represented by stars) and arterial pipeline route

13 Pipeline Network and Property Off-takes

The pipeline route modelled for our preliminary designs was generally drawn following roads. The pipeline route should be refined during detailed design because there are likely to be alternative routes that are better for various reasons (e.g. more direct, better from a constructability or maintenance point of view, reduce required pumping pressures, etc.).

At this stage, we have not sought information pertaining to the location of the specific farm gates and thus have not designed the pipeline network to that level of detail. Instead, we have designed the arterial pipeline network to supply 20m working pressure to various points within the Lower Manuherikia Valley. With the current design, some properties will receive more pressure, and some less pressure, but this can be adjusted to suit the requirements of the landowners during detailed design[6].

Node identifiers were assigned to several key points of the arterial pipeline route to allow easier identification. These nodes are numbered on the plan in Figure 12-1. The approximate lengths of pipe between nodes were measured, as presented in Table 13-1. We also estimated the lengths of secondary pipelines from the arterial pipeline to the farms or on-farm storage, as presented in Table 13-2. Because of the high level of investigation necessary to obtain accuracy, this is only an approximation that needs to be refined in future detailed design work. The overall pipeline length for the various options varies from 14.7 to 26.3 m/ha[7].

Table 13-1: Approximate length of arterial pipeline network

Pipe section between nodes	Length (m)	Approximate Pipe Outside Diameters (mm)	
		Low Velocity Options (P,Q, R1, S)	*High Velocity Option (R2)*
1 to 3	4,904	1500	1200
3 to 6	2,463	1400	1000-1200
6 to 7	2,021	1000	800
7 to 10	5,039	800	560
10 to 12	3,390	630	450
12 to 14	3,457	315	250
2 to 2A	5,161	280	225
3 to 3A	5,827	630	450
4 to 4A	4,087	315	250
5 to 5A	7,384	630	450
6 to 6A	4,720	800	630
6A to 6D	5,551	710	500
7 to 7A	3,147	630	450
TOTAL	**57,151**		

[6] For comparison, the feasibility study for the Tarras scheme allowed for a farm gate delivery pressure of 2-5m.

[7] For comparison, the feasibility study for the Tarras scheme has an overall pipe length of 5.6m/ha. This could among other things, reflect a difference in the shape of the schemes, and size of properties.

Table 13-2: Approximate length of secondary pipeline network in each zone

Zones	Length (m)
A	1,655
B	42,989
C	14,423
H	6,413
TOTAL	**65,480**

Note: 110mm outside diameter pipe assumed for secondary pipelines at this stage

All property off-takes are likely to require each of the following:

- A flow measurement device;
- A device to transmit the flow information remotely to allow centralized monitoring as part of an efficient water resource use and management system;
- A pressure-reducing valve to protect downstream on-farm pipe networks; and
- An isolation valve to allow maintenance and repairs.

14 Preliminary Cost Estimates

14.1 Capital Costs

Pipeline costs

We modelled the pipeline system based on our preliminary route design in IrriCAD design software, and assigned the minimum required pipe pressure ratings to sections of pipe. We then worked with Delta for supply and install quotations for the required pipes in various materials for comparison and optimisation. Pipe costs include supply and install costs. We have assumed the following:

- For the installation costs, we have assumed that half of the pipe would be installed in roads, and the other half would be installed off-road.
- The cost of pipeline fittings, bends, air valves and access manholes was estimated at 7% of the pipe costs.
- The cost of secondary pipeline turn-outs (including isolating valves, lagging and trace heating for frost protection, pressure-reducing valves, property off-take metering and telemetry, etc) was estimated at 3% of the costs for the main pipelines.

Pump station costs

We used the Hazen-Williams equation to estimate the required pumping duties for the five pumping stations. We checked these values in IrriCAD. We then obtained quotations from suppliers for pumps, motor control centres and valves. We also asked Delta/Aurora Energy for the capital contribution quotation for the electricity infrastructure to support the pumping stations. Some costs were estimated because information was not available.

The costs for the pump stations include:

- Main pumps and valves
- Jockey pumps and valves
- Header pipe and flow meter
- Motor control
- Electrical installation
- Building

Storage Costs

For all options, we estimated the cost of storage based on a unit cost of $\$6/m^3$ of water stored.

For centralised scheme storage in the airport reserve (Options P and Q), we assumed that the storage pond would be lined to reduce leakage, and require earthworks to form all four sides of the pond.

Options R and S use on-farm shared storage dams (that differ in size and cost depending on land use) instead of a centralised scheme storage. The storage costs depend to a large extent on the local topography and soil type at the specific storage sites. We assumed that the storage dam would be lined and require earthworks to form no more than two sides of the dam (requires suitable topography). The breakdown of the storage costs for Options R and S are presented in Table 14-1, with a weighted average storage cost of about $9,650/ha.

Table 14-1: On-farm shared storage for Options R and S

Land use	Total Irrigable area (ha)		Irrigable area served by each storage dam (ha)	Approx. number of storage dams		Approx. storage cost per dam ($mil)	Approx. storage cost per hectare ($)	Total Storage Costs ($mil)	
	R	S		R	S			R	S
High intensity (including pasture)	3907	2387	100	39	24	2.29	**22,938**	**89**	**55**
Low intensity (including lifestyle blocks, but not viticulture)	1302	796	30	43	26	0.33	**10,864**	**14**	**9**
Viticulture	1302	796	100	13	8	2.42	**24,229**	**31**	**19**
								135	**82**

In Appendix A, we present a range of estimates for the cost of storage based on the approximate volume of earthworks and $\$15/m^3$ of earthworks, and the approximate area of polyethylene liner required at $\$15/m^2$ of liner.

Capital Cost Summary

Table 14-2 presents a summary of the rough order capital costs for the various options, presented as a range from most likely costs to expected upper limit capital costs. The most likely costs are those with an average risk allowance (50% probability of being exceeded). The expected upper limit costs are those with a maximum risk allowance (10% probability of being exceeded).

Table 14-2: Summary presenting preliminary range of capital costs for the scheme

No.	Description	Preliminary Range of Capital Costs ($mil)				
		P	Q	R1	R2	S
1	Pump stations	13.3 to 13.9	8.6 to 9.1	10.2 to 10.6	12.4 to 13.2	5.9 to 6.5
2	Pipe work	80.9 to 83.7	48.3 to 50.4	38.3 to 39.6	26.1 to 26.9	22.6 to 23.3
3	Scheme Storage	2.4 to 3.0	2.4 to 3.0	-	-	-
4	Required On-farm Storage	-	-	166.8 to 207.3	166.8 to 207.3	101.9 to 126.7
5	Professional Services Fees[8]	7.6 to 9.5	4.8 to 6.1	16.1 to 20.2	15.3 to 19.2	9.8 to 12.3
6	Original Dairy Creek Irrigation Scheme Costs[9]	-	14.5 to 17.3	-	-	14.5 to 17.3[10]
	Approximate Total Capital Cost ($mil)	**104.2 to 110.1**	**78.6 to 85.9**	**231.6 to 277.7**	**220.6 to 266.6**	**154.7 to 186.1**
	Irrigated Area[11] (ha)	8320	8320	6512	6512	6512
	Approximate Capital Cost per hectare ($'000)	**12.5 to 13.2**	**9.4 to 10.3**	**35.5 to 42.6**	**33.9 to 40.9**	**23.8 to 28.6**

[8] The professional fees category includes professional engineering and planning services which is estimated at 4% of capital cost, as well as construction supervision, estimated at 4% of capital cost.
[9] The original Dairy Creek Irrigation Scheme costs have been extracted without adjustment from the joint Delta-Opus Dairy Creek Irrigation Scheme Design and Build Proposal prepared in 2007.
[10] Although the area for Dairy Creek is reduced for this option, prorating the costs based on area would be an under-estimation (because some costs are fixed regardless of area), thus it has been left as it is, which we recognize is a slight over-estimation.
[11] The irrigated areas for Options Q and S include the Dairy Creek area because the original Dairy Creek Irrigation Scheme costs have been included.

We have included a more detailed cost estimate itemisation for each option in Appendix B. Please note that those spreadsheets exclude the original Dairy Creek Irrigation Scheme costs, which have been included in Table 14-2.

At first glance, our preliminary range of capital costs seem to suggest that Options Q and R1 have the lowest and highest capital costs per hectare of irrigated land respectively. However, we highlight that these five options have different underlying assumptions as previously described. Therefore, comparisons between options are ballpark at best. The primary purpose of these cost estimates is an envelope of rough order capital costs to assist stakeholders to decide on the way forward. The capital cost estimates also suggest that having the Dairy Creek Irrigation Scheme as a separate, standalone pipeline network from the rest of the irrigated area would have a lower cost. We note, however, that the original Dairy Creek Irrigation Scheme costs in 2007 have not been adjusted. Comparing the capital cost estimates for Options R1 and R2 suggests that reducing pipe sizes by increasing pipe velocities would increase capital costs for pump stations, but reduce capital costs for pipe work. This would likely lead to a decrease in the overall capital costs.

14.2 Operational and Maintenance Costs

Our estimate of annual operational and maintenance (O&M) costs is based on:

- A retail power cost of $0.087 per kilowatt-hour, as advised by Aurora Energy (this excludes distribution and transmission line charges which are estimated separately)
- Assumptions of the annual pumping usage for the main pump stations based on annual pumped volumes and expected flow rates.
- Annual allocation into a maintenance fund is estimated based on 1% of pipeline capital cost and 5% of mechanical equipment capital cost. (This cost could be managed differently by the community if desired. The need for long-term maintenance must be recognised.)

Table 14-3: Estimated annual scheme operating and maintenance costs for each option

Category	Description	Estimated Annual Costs ($M/year)				
		Option P	Option Q	Option R1	Option R2	Option S
1	Power Consumption[12]	1.98	0.66	2.20	3.96	0.86
2	Distribution and Transmission Line Charges	0.27	0.27	0.27	0.27	0.27
3	Administration	0.15	0.15	0.15	0.15	0.15
4	Maintenance	1.03	0.66	0.46	0.37	0.26
5	Original Dairy Creek Scheme Annual Costs[13]	-	1.15	-	-	1.87
Approx. Total Annual O&M Costs ($M)		**3.43**	**2.89**	**3.08**	**4.74**	**3.40**
Irrigated area (ha)		8,320	8,320	6,512	6,512	6,512
Approx. Annual O&M Costs per ha ($/ha)		**412**	**347**	**472**	**728**	**523**

As before, our annual cost estimates suggest at first glance that Options Q and R2 have the lowest and highest annual costs per hectare of irrigated land respectively. The options are, however, not directly comparable. These annual cost estimates should be taken as providing a cost envelope that we believe will help stakeholders make informed decisions with regards to this scheme. The annual cost estimates are inconclusive with regards to having the Dairy Creek Irrigation Scheme as a separate, standalone pipeline network. Option Q is cheaper than Option P, but Option S is more expensive than Option R1. Comparing the capital cost estimates for Options R1 and R2 suggests that reducing pipe sizes by increasing pipe velocities would significantly increase pumping requirements, and hence operating costs. This would lead to increased overall annual costs.

14.3 Net Present Value Analysis

To allow meaningful comparison and appraisal of options with different cash flow timings (as it is with this potential project), it is useful to perform a net present value (NPV) analysis. This involves discounting all future cash flows to present value

[12] The annual pumping costs for Option R1 are higher than for Option P. Although Option R1 has a smaller irrigated area, it includes frost-fighting, and therefore has a higher overall flow rate.

[13] The costs for Option Q exclude frost-fighting, and the costs for Option S include frost-fighting. Distribution and transmission line charges and administration costs have been removed to avoid double-counting.

terms, and then summing those present values. This accounts for the time value of money, i.e. that $1 cash received today is worth more than $1 cash in a year's time.

The inputs into the NPV analysis are the cash flows and the discount rate (which is commonly affected by the cost of capital). The cash flows include the following:

- Initial Capital Costs (these have been estimated for the various options)
- Annual Operating and Maintenance Costs (these have been estimated for the various options)
- Debt Financing Costs (these depend on how the scheme is financed and thus not been considered in this analysis)
- Annual Revenue (This has not been investigated but should be similar for all options and thus not been considered in this analysis)

Because revenue has not been included, this NPV analysis is actually a present value analysis of only the initial capital costs, and the annual operating and maintenance costs. Two assumptions were required:

- Project operating life of 25 years (relevant for the annual costs)
- Discount rate of 5%

The net present values would change depending on the expected project operating life, and how the project is financed (which would affect the cost of capital and hence the discount rate). Table 14-4 presents a summary of the scheme costs and net present values. Although these net present values cannot be used to predict the economic viability of the project, they can be used to compare the various options. Looking forward, further detailed design needs to be completed on a single option refined from stakeholders' feedback. Subsequently, more accurate cost estimates will be obtained.

Table 14-4: Summary of Net Present Value of Costs

Option	P	Q	R1	R2	S
Area to be Irrigated (ha)	8,320	8,320	6,512	6,512	6,512
NPV of Costs ($M)	155.4	123.0	297.9	310.4	218.4
NPV of Costs per hectare ($/ha)	18,682	14,778	45,747	47,671	33,532

Note: Lower NPV of costs is better.

The net present values of the costs allow stakeholders to make a rough assessment of how the capital and annual costs would affect the overall lifecycle costs of each option. Because the options have different underlying assumptions, and hence are not directly comparable, these net present values need to be assessed with caution.

However, Options R1 and R2 are directly comparable. We have noted earlier that Option R2, which has reduced pipe sizes compared to Option R1, has lower capital costs but higher annual costs. The net present value analysis indicates that overall, Option R2 would be more expensive.

14.4 Timelines

In the course of obtaining quotations from suppliers, we were advised that the new asset requirements and system upgrading involved in the development of this potential scheme will require RMA and Electricity Act consents, and possibly, significant landowner negotiations. These negotiations might take several years to resolve. In addition, the lead time for transformers 5 MVA and above is approximately 60 weeks. The lead time for pumps is between 16 and 42 weeks, ranging widely depending on the choice of pump supplier.

15 Issues for Future Consideration

15.1 Construction Issues

In our feasibility study, detailed construction issues were largely excluded from our analysis. For example, pipe routes were approximate and not precisely chosen based on detailed contour maps. These issues will need to be considered during the future detailed design process.

15.2 Property Issues (Land Access)

Site-specific property issues relating to land access have not been covered. The process for considering these issues is likely to be extensive, and might require detailed surveys and consultation with the public. This should form part of future detailed design work.

15.3 Asset Management Issues

Once the scheme is designed in detail, constructed and commissioned, proper management of the scheme's assets during its operating life can minimise their total lifecycle cost, and maximise the value that users can draw from them.

Best practice asset management requires scheme-specific skilled consideration and commitment by stakeholders to ensure ongoing implementation. At this preliminary concept stage, we believe that good asset management for this scheme would include having:

- a risk-based framework that balances proactive maintenance strategies and practices against an optimised renewals programme;
- targeted training of operators to have the correct skills;
- occasional investigations to improve operational efficiency;
- scheduled condition assessments as an integral part of the asset management process to pre-empt repairs, and maintain the levels of service required by users; and
- a user-friendly database system that records and analyses maintenance, repair and replacement data to improve long-term asset management.

16 Conclusions and Recommendations

There is a definite need to look at water resource management for the Lower Manuherikia Valley because of water access issues pending in 2021. This study provides the basis upon which a community-based decision process can be commenced. Water resource management of the Lower Manuherikia Valley needs to be considered holistically, and the various features and factors that need to be taken into account investigated in some detail.

We have presented a summary of the consenting framework which is likely to shape the decisions surrounding water resource management in the valley. There is enough water from the existing Dairy Creek abstraction consent to meet the irrigation needs of the Lower Manuherikia Valley. This would free up water in the Manuherikia River for other uses; including a direct benefit to the Upper Manuherikia Valley users. The water can feasibly be distributed through a pressure pipe network to most critical areas below Tiger Hill. Some areas will be better serviced with water sourced from above Tiger Hill. Subject to Central Otago District Council's decision, the potable water needs of Clyde and Alexandra could potentially be served from Lake Dunstan. This might involve sharing some assets, thus spreading the costs and potentially benefiting all parties.

The costing envelopes established are high relative to other schemes in New Zealand and Central Otago. This is because conservative methods have been adopted. Costings are highly dependent on the local topography in relation to the water source at Lake Dunstan. Option Q appears to be the lowest cost option considered. However, our cost estimates need to be refined by additional engineering design, and importantly further input of design criteria from the potential water users. An important criterion is the risk model for supply security. Mini hydropower remains a potential option to offset annual costs to the scheme. It should be investigated further.

Arising from the general conclusions about the feasibility and cost of a scheme to meet the water resource needs of the valley, we recommend that the community proceeds with a process of close consultation. This should include surveying current landholder practices and future intent; establishing landowner buy-in to better refine the actual areas to be irrigated; and resolving acceptable risk levels. The community needs to stay engaged with this process to ensure a suitable outcome is achieved before the deadline of 2021.

17 References

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.

McConchie, J. A. (2000). From floods to forecasts: The hydrology of Wellington, (in) *Dynamic Wellington: A contemporary synthesis and explanation of Wellington* (eds. McConchie, J., Winchester, D., & Willis, R.) Institute of Geography, Victoria University of Wellington, New Zealand. 344p.

Ministry for the Environment (2008) “Proposed National Environmental Standard on Ecological Flows and Water Levels”, Discussion Document

Ministry for the Environment (2008) “Draft Guidelines for the Selection of Methods to Determine Ecological Flows and Water Levels”

Morgan, Y. J. (1997) A methodology for determining irrigation water requirements, Otaki – Te Horo. MSc Thesis, Victoria University of Wellington

Otago Regional Council (2006) “Regional Plan: Water”

Appendix A
Options R &S Storage Cost Comparison

Options R & S Storage Costs (Excluding Inlet/Outlet Structures)						Assume $15/m^3$ earthworks, $15/m^2$ PE liner									Assume $6/m^3$ storage			
						10m deep pond (lined, dammed all four sides)				10m deep pond (lined, dammed on 2 sides)								
Land use	Total Irrigable Area R	Total Irrigable Area S	Irrigable area served by each storage dam (ha)	Approx. number of storage dams R	Approx. number of storage dams S	Approx. cost per dam ($)	Approx. storage cost per hectare ($)	**Total Storage Costs ($mil)** R	**Total Storage Costs ($mil)** S	Approx. cost per dam ($)	Approx. storage cost per hectare ($)	**Total Storage Costs ($mil)** R	**Total Storage Costs ($mil)** S	Approx. cost per dam ($)	Approx. storage cost per hectare ($)	**Total Storage Costs ($mil)** R	**Total Storage Costs ($mil)** S
High intensity (inc. pasture)	3907	2387	100	39	24	4,326,000	**43,260**	**169**	**103**	2,564,700	**25,647**	**100**	**61**	2,293,831	**22,938**	**89**	**55**
Low intensity (inc. lifestyle blocks, but not viticulture)	1302	796	30	43	26	1,714,950	**57,165**	**74**	**45**	934,725	**31,158**	**40**	**25**	325,914	**10,864**	**14**	**9**
Viticulture	1302	796	100	13	8	4,520,250	**45,203**	**59**	**36**	2,634,225	**26,342**	**34**	**21**	2,422,903	**24,229**	**31**	**19**
TOTALS								**301**	**184**			**174**	**107**			**135**	**82**

Appendix B
Preliminary Capital Cost Estimate Schedules

OPTION P

ITEM	DESCRIPTION	UNIT	QUANTITY	Base Rate ($)	Base Cost ($)	Cost with Ave Risk Allowance ($)	Cost with Max Risk Allowance ($)	Spread ($)	Spread^2 ($\$^2$)	Ave Rate	Max Rate
1	**Pump stations**										
1.1	**Power Supply**										
1.1.1	Headworks for new transformer capacity	LS	1	1,024,000	1,024,000	1,228,800	1,536,000	307200	9.44E+10	20%	50%
1.1.2	New assets (35% of total new assets to be provided)	LS	1	1,042,000	1,042,000	1,250,400	1,563,000	312600	9.77E+10	20%	50%
1.2	**Pump station 1**										
1.2.1	Main Pumps	each	4	660,000	2,640,000	2,904,000	3,168,000	264000	6.97E+10	10%	20%
1.2.2	Valves for Main Pumps (set per pump)	each	4	51,438	205,752	246,902	308,628	61725.6	3.81E+09	20%	50%
1.2.3	Jockey Pumps and Valves	each	2	20,000	40,000	48,000	60,000	12000	1.44E+08	20%	50%
1.2.4	Header Pipe and Flow Meter	LS	1	50,000	50,000	60,000	75,000	15000	2.25E+08	20%	50%
1.2.3	Motor Control	LS	1	697,400	697,400	836,880	1,046,100	209220	4.38E+10	20%	50%
1.2.4	Electrical Installation	LS	1	100,000	100,000	120,000	150,000	30000	9.00E+08	20%	50%
1.2.5	Building	LS	1	600,000	600,000	720,000	900,000	180000	3.24E+10	20%	50%
1.2.6	Coarse and fish screening	LS	1	500,000	500,000	600,000	750,000	150000	2.25E+10	20%	50%
1.3	**Pump station 2**										
1.3.1	Main Pumps	each	4	99,100	396,400	436,040	475,680	39640	1.57E+09	10%	20%
1.3.2	Valves for Main Pumps (set per pump)	each	4	19,182	76,728	92,074	115,092	23018.4	5.30E+08	20%	50%
1.2.3	Jockey Pumps and Valves	each	2	20,000	40,000	48,000	60,000	12000	1.44E+08	20%	50%
1.2.4	Header Pipe and Flow Meter	LS	1	40,000	40,000	48,000	60,000	12000	1.44E+08	20%	50%
1.3.3	Motor Control	LS	1	389,950	389,950	467,940	584,925	116985	1.37E+10	20%	50%
1.3.4	Electrical Installation	LS	1	100,000	100,000	120,000	150,000	30000	9.00E+08	20%	50%
1.3.5	Building	LS	1	200,000	200,000	240,000	300,000	60000	3.60E+09	20%	50%
1.4	**Pump station 3**										
1.4.1	Main Pumps	each	4	97,200	388,800	427,680	466,560	38880	1.51E+09	10%	20%
1.4.2	Valves for Main Pumps (set per pump)	each	1	19,182	19,182	23,018	28,773	5754.6	3.31E+07	20%	50%
1.2.3	Jockey Pumps and Valves	each	2	20,000	40,000	48,000	60,000	12000	1.44E+08	20%	50%
1.2.4	Header Pipe and Flow Meter	LS	1	40,000	40,000	48,000	60,000	12000	1.44E+08	20%	50%
1.4.3	Motor Control	LS	1	389,950	389,950	467,940	584,925	116985	1.37E+10	20%	50%
1.4.4	Electrical Installation	LS	1	100,000	100,000	120,000	150,000	30000	9.00E+08	20%	50%
1.4.5	Building	LS	1	200,000	200,000	240,000	300,000	60000	3.60E+09	20%	50%
1.5	**Pump station 4**										
1.5.1	Main Pumps	each	4	79,500	318,000	349,800	381,600	31800	1.01E+09	10%	20%
1.5.2	Valves for Main Pumps (set per pump)	each	1	19,182	19,182	23,018	28,773	5754.6	3.31E+07	20%	50%
1.2.3	Jockey Pumps and Valves	each	2	20,000	40,000	48,000	60,000	12000	1.44E+08	20%	50%
1.2.4	Header Pipe and Flow Meter	LS	1	40,000	40,000	48,000	60,000	12000	1.44E+08	20%	50%
1.5.3	Motor Control	LS	1	335,610	335,610	402,732	503,415	100683	1.01E+10	20%	50%
1.5.4	Electrical Installation	LS	1	100,000	100,000	120,000	150,000	30000	9.00E+08	20%	50%
1.5.5	Building	LS	1	200,000	200,000	240,000	300,000	60000	3.60E+09	20%	50%
1.6	**Pump station 5**										
1.6.1	Main Pumps	each	4	67,200	268,800	295,680	322,560	26880	7.23E+08	10%	20%
1.6.2	Valves for Main Pumps (set per pump)	each	1	19,182	19,182	23,018	28,773	5754.6	3.31E+07	20%	50%
1.2.3	Jockey Pumps and Valves	each	2	20,000	40,000	48,000	60,000	12000	1.44E+08	20%	50%
1.2.4	Header Pipe and Flow Meter	LS	1	40,000	40,000	48,000	60,000	12000	1.44E+08	20%	50%
1.6.3	Motor Control	LS	1	335,610	335,610	402,732	503,415	100683	1.01E+10	20%	50%
1.6.4	Electrical Installation	LS	1	100,000	100,000	120,000	150,000	30000	9.00E+08	20%	50%
1.6.5	Building	LS	1	200,000	200,000	240,000	300,000	60000	3.60E+09	20%	50%
	Total for Pump Stations				**$ 11,376,546.00**	**$ 13,250,655.20**	**$ 15,861,219.00**				
2	**Pipe Work**										
	Costs include supply and installation of new pipe										
2.1	110mm NB PN9 uPVC pipe	m	65,480	30	1,964,400	2,160,840	2,357,280	196,440	3.86E+10	10%	20%
2.2	375mm NB PN9 uPVC pipe	m	2,450	202	493,675	543,043	592,410	49,368	2.44E+09	10%	20%
2.3	DN400 SDR17 (PN10) PE100 pipe	m	2,711	226	612,279	673,507	734,735	61,228	3.75E+09	10%	20%
2.4	DN500 SDR41 (PN4) pipe PE100	m	750	203	152,400	167,640	182,880	15,240	2.32E+08	10%	20%
2.5	DN500 SDR26 (PN6.3) PE100 pipe	m	2,707	247	669,441	736,385	803,329	66,944	4.48E+09	10%	20%
2.6	DN630 SDR26 (PN6.3) PE100 pipe	m	1,300	354	460,044	506,048	552,053	46,004	2.12E+09	10%	20%
2.7	600mm SN5000 0.8Mpa GRP pipe	m	2,787	363	1,011,124	1,112,236	1,213,348	101,112	1.02E+10	10%	20%
2.8	1000mm SN5000 0.4Mpa GRP pipe	m	3,123	847	2,645,181	2,909,699	3,174,217	264,518	7.00E+10	10%	20%
2.9	1000mm SN5000 0.63Mpa GRP pipe	m	7,133	861	6,139,016	6,752,918	7,366,820	613,902	3.77E+11	10%	20%
2.10	1000mm SN5000 0.8Mpa GRP pipe	m	6,435	877	5,646,391	6,211,030	6,775,669	564,639	3.19E+11	10%	20%
2.11	1000mm SN5000 1.0Mpa GRP pipe	m	1,859	896	1,666,315	1,832,946	1,999,578	166,631	2.78E+10	10%	20%
2.12	1000mm SN5000 1.25Mpa GRP pipe	m	1,952	927	1,809,114	1,990,025	2,170,936	180,911	3.27E+10	10%	20%
2.13	1000mm SN5000 1.6Mpa GRP pipe	m	2,672	950	2,538,133	2,791,946	3,045,759	253,813	6.44E+10	10%	20%
2.14	1016mmOD x 9.5WT Spiral Welded Steel pipe	m	2,125	1,078	2,289,688	2,518,656	2,747,625	228,969	5.24E+10	10%	20%
2.15	1500mm SN5000 0.4Mpa GRP pipe	m	9,840	1,431	14,077,104	15,484,814	16,892,525	1,407,710	1.98E+12	10%	20%

2.16	1500mm SN5000 0.63Mpa GRP pipe	m	1,370	1,447	1,982,938	2,181,232	2,379,526	198,294	3.93E+10	10%	20%
2.17	1500mm SN5000 0.8Mpa GRP pipe	m	570	1,476	841,178	925,295	1,009,413	84,118	7.08E+09	10%	20%
2.18	2000mm SN5000 0.4Mpa GRP pipe	m	3,863	2,626	10,143,852	11,158,237	12,172,622	1,014,385	1.03E+12	10%	20%
2.19	2000mm SN5000 0.63Mpa GRP pipe	m	2,827	2,663	7,527,312	8,280,043	9,032,774	752,731	5.67E+11	10%	20%
2.20	2000mm SN5000 0.8Mpa GRP pipe	m	677	2,710	1,834,602	2,018,063	2,201,523	183,460	3.37E+10	10%	20%
2.21	Miscellaneous (fittings, bends, air valves, access manholes etc)	LS	1	3,722,451	3,722,451	4,466,941	5,583,676	1,116,735	1.25E+12	20%	50%
2.22	Secondary pipe turn-outs (isolating valves, lagging and trace heating for frost protection, PRVs, etc)	LS	1	64,825	4,603,799	5,524,559	6,905,699	1,381,140	1.91E+12	20%	50%
	Total for Pipework				**$ 72,830,435.08**	**$ 80,946,103.61**	**$ 89,894,397.16**				
3	**Storage**										
3.1	Earthworks and PE Liner	m^2 storage	325,000	6	1,950,000	2,340,000	2,925,000	585,000	3.42E+11	20%	50%
3.2	Inlet and outlet structures	LS	1	58,500	58,500	70,200	87,750	17,550	3.08E+08	20%	50%
	Total for Storage				**$ 2,008,500.00**	**$ 2,410,200.00**	**$ 3,012,750.00**				
4	**Miscellaneous**										
4.1	Professional services - Construction Supervision	LS	1	$ 3,448,619.24	3,448,619	3,793,481	5,172,929	1,379,448	1.90E+12	10%	50%
4.2	Professional services - Engineering and Planning	LS	1	$ 3,448,619.24	3,448,619	3,793,481	5,172,929	1,379,448	1.90E+12	10%	50%
	Total for Miscellaneous				**$ 6,897,238.49**	**$ 7,586,962.33**	**$ 10,345,857.73**				
					$ 93,112,719.56	**$ 104,193,921.14**	**$ 119,114,223.89**	$ 14,920,302.75	1.24E+13		
								Max Likely Addition	$ 5,993,594.95		
								90th Percentile:	**$ 110,187,516.09**		
	Cost per hectare				**$ 11,191.43**	**$ 12,523.31**	**$ 14,316.61**		**$ 13,243.69**		

Irrigable area
8320
ha

OPTION Q

ITEM	DESCRIPTION	UNIT	QUANTITY	Base Rate ($)	Base Cost ($)	Cost with Ave Risk Allowance ($)	Cost with Max Risk Allowance ($)	Spread ($)	Spread^2 ($^{2})	Ave Rate	Max Rate
1	**Pump stations**										
1.1	**Power Supply**										
1.1.1	Headworks for new transformer capacity	LS	1	1,024,000	1,024,000	1,228,800	1,536,000	307200	9.44E+10	20%	50%
1.1.2	New assets (35% of total new assets to be provided)	LS	1	1,042,000	1,042,000	1,250,400	1,563,000	312600	9.77E+10	20%	50%
1.2	**Pump station 1**										
1.2.1	Main Pumps	each	4	660,000	2,640,000	2,904,000	3,168,000	264000	6.97E+10	10%	20%
1.2.2	Valves for Main Pumps (set per pump)	each	4	51,438	205,752	246,902	308,628	61725.6	3.81E+09	20%	50%
1.2.3	Jockey Pumps and Valves	each	2	20,000	40,000	48,000	60,000	12000	1.44E+08	20%	50%
1.2.4	Header Pipe and Flow Meter	LS	1	50,000	50,000	60,000	75,000	15000	2.25E+08	20%	50%
1.2.3	Motor Control	LS	1	418,440	418,440	502,128	627,660	125532	1.58E+10	20%	50%
1.2.4	Electrical Installation	LS	1	100,000	100,000	120,000	150,000	30000	9.00E+08	20%	50%
1.2.5	Building	LS	1	300,000	300,000	360,000	450,000	90000	8.10E+09	20%	50%
1.2.6	Coarse and fish screening	LS	1	500,000	500,000	600,000	750,000	150000	2.25E+10	20%	50%
1.6	**Pump station 5**										
1.6.1	Main Pumps	each	4	67,200	268,800	295,680	322,560	26880	7.23E+08	10%	20%
1.6.2	Valves for Main Pumps (set per pump)	each	4	19,182	76,728	92,074	115,092	23018.4	5.30E+08	20%	50%
1.2.3	Jockey Pumps and Valves	each	2	20,000	40,000	48,000	60,000	12000	1.44E+08	20%	50%
1.2.4	Header Pipe and Flow Meter	LS	1	40,000	40,000	48,000	60,000	12000	1.44E+08	20%	50%
1.6.3	Motor Control	LS	1	335,610	335,610	402,732	503,415	100683	1.01E+10	20%	50%
1.6.4	Electrical Installation	LS	1	100,000	100,000	120,000	150,000	30000	9.00E+08	20%	50%
1.6.5	Building	LS	1	200,000	200,000	240,000	300,000	60000	3.60E+09	20%	50%
	Total for Pump Stations				**$ 7,381,330.00**	**$ 8,566,716.00**	**$ 10,199,355.00**				
2	**Pipe Work**										
	Costs include supply and installation of new pipe										
2.1	110mm NB PN9 uPVC pipe	m	63,825	30	1,914,750	2,106,225	2,297,700	191,475	3.67E+10	10%	20%
2.2	375mm NB PN9 uPVC pipe	m	2,450	202	493,675	543,043	592,410	49,368	2.44E+09	10%	20%
2.3	DN400 SDR17 (PN10) PE100 pipe	m	2,711	226	612,279	673,507	734,735	61,228	3.75E+09	10%	20%
2.4	DN500 SDR41 (PN4) PE100 pipe	m	750	203	152,400	167,640	182,880	15,240	2.32E+08	10%	20%
2.5	DN500 SDR26 (PN6.3) PE100 pipe	m	2,707	247	669,441	736,385	803,329	66,944	4.48E+09	10%	20%
2.6	DN630 SDR26 (PN6.3) PE100 pipe	m	1,300	354	460,044	506,048	552,053	46,004	2.12E+09	10%	20%
2.7	600mm SN5000 0.8Mpa GRP pipe	m	2,787	363	1,011,124	1,112,236	1,213,348	101,112	1.02E+10	10%	20%
2.8	1000mm SN5000 0.63Mpa GRP pipe	m	4,790	861	4,122,514	4,534,765	4,947,016	412,251	1.70E+11	10%	20%
2.9	1000mm SN5000 0.8Mpa GRP pipe	m	4,721	877	4,142,441	4,556,686	4,970,930	414,244	1.72E+11	10%	20%
2.10	DN1200 SDR41 (PN4) PE100 pipe	m	2,780	1,016	2,823,368	3,105,705	3,388,042	282,337	7.97E+10	10%	20%
2.11	DN1200 SDR26 (PN6.3) PE100 pipe	m	1,370	1,304	1,786,960	1,965,655	2,144,351	178,696	3.19E+10	10%	20%
2.12	1500mm SN5000 0.4Mpa GRP pipe	m	10,043	1,431	14,367,516	15,804,267	17,241,019	1,436,752	2.06E+12	10%	20%
2.13	1500mm SN5000 0.63Mpa GRP pipe	m	3,015	1,447	4,363,911	4,800,302	5,236,693	436,391	1.90E+11	10%	20%
2.14	1500mm SN5000 0.8Mpa GRP pipe	m	677	1,476	999,083	1,098,991	1,198,899	99,908	9.98E+09	10%	20%
2.15	2000mm SN5000 0.4Mpa GRP pipe	m	692	2,626	1,817,123	1,998,835	2,180,547	181,712	3.30E+10	10%	20%
2.16	Miscellaneous (fittings, bends, air valves, access manholes etc)	LS	1	2,781,564	2,781,564	3,337,877	4,172,346	834,469	6.96E+11	20%	50%
2.17	Secondary pipe turn-outs (isolating valves, lagging and trace heating for frost protection, PRVs, etc)	LS	1	63,187	2,807,684	3,369,220	4,211,526	842,305	7.09E+11	20%	50%
	Total for Pipework				**$ 45,325,875.48**	**$ 50,417,387.79**	**$ 56,067,824.86**				
3	**Storage**										
3.1	Earthworks and PE Liner	m^2 storage	325,000	6	1,950,000	2,340,000	2,925,000	585,000	3.42E+11	20%	50%
3.2	Inlet and outlet structures	LS	1	58,500	58,500	70,200	87,750	17,550	3.08E+08	20%	50%
	Total for Storage				**$ 2,008,500.00**	**$ 2,410,200.00**	**$ 3,012,750.00**				
4	**Miscellaneous**										
4.1	Professional services - Construction Supervision	LS	1	$ 2,188,628.22	2,188,628	2,407,491	3,282,942	875,451	7.66E+11	10%	50%
4.2	Professional services - Engineering and Planning	LS	1	$ 2,188,628.22	2,188,628	2,407,491	3,282,942	875,451	7.66E+11	10%	50%
	Total for Miscellaneous				**$ 4,377,256.44**	**$ 4,814,982.08**	**$ 6,565,884.66**				
					$ 59,092,961.91	**$ 66,209,285.87**	**$ 75,845,814.52**	$ 9,636,528.65	6.42E+12		
								Max Likely Addition	$ 4,450,711.43		
								90th Percentile:	**$ 70,659,997.30**		
	Cost per hectare				**$ 12,216.86**	**$ 13,688.09**	**$ 15,680.34**		**$ 14,608.23**		

Irrigable area
4837
ha

OPTION R1

ITEM	DESCRIPTION	UNIT	QUANTITY	Base Rate ($)	Base Cost ($)	Cost with Ave Risk Allowance ($)	Cost with Max Risk Allowance ($)	Spread ($)	Spread^2 ($^{2})	Ave Rate	Max Rate
1	**Pump stations**										
1.1	**Power Supply**										
1.1.1	Headworks for new transformer capacity	LS	1	1,024,000	1,024,000	1,126,400	1,228,800	102400	1.05E+10	10%	20%
1.1.2	New assets (35% of total new assets to be provided)	LS	1	1,042,000	1,042,000	1,146,200	1,250,400	104200	1.09E+10	10%	20%
1.2	**Pump station 1**										
1.2.1	Main Pumps	each	5	155,800	779,000	856,900	934,800	77900	6.07E+09	10%	20%
1.2.2	Valves for Main Pumps (set per pump)	each	5	51,438	257,190	282,909	308,628	25719	6.61E+08	10%	20%
1.2.3	Jockey Pumps and Valves	each	2	20,000	40,000	48,000	60,000	12000	1.44E+08	20%	50%
1.2.4	Header Pipe and Flow Meter	LS	1	50,000	50,000	60,000	75,000	15000	2.25E+08	20%	50%
1.2.5	Motor Control	LS	1	697,400	697,400	767,140	836,880	69740	4.86E+09	10%	20%
1.2.6	Electrical Installation	LS	1	100,000	100,000	120,000	150,000	30000	9.00E+08	20%	50%
1.2.7	Building	LS	1	600,000	600,000	720,000	900,000	180000	3.24E+10	20%	50%
1.2.8	Coarse and fish screening	LS	1	500,000	500,000	600,000	750,000	150000	2.25E+10	20%	50%
1.3	**Pump station 2**										
1.3.1	Main Pumps	each	4	38,951	155,804	171,384	186,965	15580.4	2.43E+08	10%	20%
1.3.2	Valves for Main Pumps (set per pump)	each	4	19,182	76,728	84,401	92,074	7672.8	5.89E+07	10%	20%
1.3.3	Jockey Pumps and Valves	each	2	20,000	40,000	48,000	60,000	12000	1.44E+08	20%	50%
1.3.4	Header Pipe and Flow Meter	each	1	40,000	40,000	48,000	60,000	12000	1.44E+08	20%	50%
1.3.5	Motor Control	LS	1	389,950	389,950	428,945	467,940	38995	1.52E+09	10%	20%
1.3.6	Electrical Installation	LS	1	100,000	100,000	120,000	150,000	30000	9.00E+08	20%	50%
1.3.7	Building	LS	1	200,000	200,000	240,000	300,000	60000	3.60E+09	20%	50%
1.4	**Pump station 3**										
1.4.1	Main Pumps	each	4	46,985	187,940	206,734	225,528	18794	3.53E+08	10%	20%
1.4.2	Valves for Main Pumps (set per pump)	each	4	19,182	76,728	84,401	92,074	7672.8	5.89E+07	10%	20%
1.4.3	Jockey Pumps and Valves	each	2	20,000	40,000	48,000	60,000	12000	1.44E+08	20%	50%
1.4.4	Header Pipe and Flow Meter	each	1	40,000	40,000	48,000	60,000	12000	1.44E+08	20%	50%
1.4.5	Motor Control	LS	1	422,730	422,730	465,003	507,276	42273	1.79E+09	10%	20%
1.4.6	Electrical Installation	LS	1	100,000	100,000	120,000	150,000	30000	9.00E+08	20%	50%
1.4.7	Building	LS	1	200,000	200,000	240,000	300,000	60000	3.60E+09	20%	50%
1.5	**Pump station 4**										
1.5.1	Main Pumps	each	4	36,551	146,204	160,824	175,445	14620.4	2.14E+08	10%	20%
1.5.2	Valves for Main Pumps (set per pump)	each	4	19,182	76,728	84,401	92,074	7672.8	5.89E+07	10%	20%
1.5.3	Jockey Pumps and Valves	each	2	20,000	40,000	48,000	60,000	12000	1.44E+08	20%	50%
1.5.4	Header Pipe and Flow Meter	each	1	40,000	40,000	48,000	60,000	12000	1.44E+08	20%	50%
1.5.5	Motor Control	LS	1	335,610	335,610	369,171	402,732	33561	1.13E+09	10%	20%
1.5.6	Electrical Installation	LS	1	100,000	100,000	120,000	150,000	30000	9.00E+08	20%	50%
1.5.7	Building	LS	1	200,000	200,000	240,000	300,000	60000	3.60E+09	20%	50%
1.6	**Pump station 5**										
1.6.1	Main Pumps	each	4	37,468	149,872	164,859	179,846	14987.2	2.25E+08	10%	20%
1.6.2	Valves for Main Pumps (set per pump)	each	4	19,182	76,728	84,401	92,074	7672.8	5.89E+07	10%	20%
1.6.3	Jockey Pumps and Valves	each	2	20,000	40,000	48,000	60,000	12000	1.44E+08	20%	50%
1.6.4	Header Pipe and Flow Meter	each	1	40,000	40,000	48,000	60,000	12000	1.44E+08	20%	50%
1.6.5	Motor Control	LS	1	335,610	335,610	369,171	402,732	33561	1.13E+09	10%	20%
1.6.6	Electrical Installation	LS	1	100,000	100,000	120,000	150,000	30,000	9.00E+08	20%	50%
1.6.7	Building	LS	1	200,000	200,000	240,000	300,000	60000	3.60E+09	20%	50%
	Total for Pump Stations				**$ 9,040,222.00**	**$ 10,225,244.20**	**$ 11,691,266.40**				
2	**Pipe Work (Arterial and secondary)**										
	Costs include supply and installation of new pipe										
2.1	110mm NB PN9 uPVC pipe	m	65,480	30	1,964,400	2,160,840	2,357,280	196,440	3.86E+10	10%	20%
2.2	DN280 SDR26 (PN6.3) PE100 pipe	m	2,993	80	239,889	263,878	287,867	23,989	5.75E+08	10%	20%
2.3	DN280 SDR21 (PN8) PE100 pipe	m	2,168	89	192,367	211,603	230,840	19,237	3.70E+08	10%	20%
2.4	DN315 SDR41 (PN4) PE100 pipe	m	1,042	95	98,990	108,889	118,788	9,899	9.80E+07	10%	20%
2.5	DN315 SDR26 (PN6.3) PE100 pipe	m	6,120	111	676,505	744,155	811,806	67,650	4.58E+09	10%	20%
2.6	DN315 SDR21 (PN8) PE100 pipe	m	382	128	48,992	53,891	58,790	4,899	2.40E+07	10%	20%
2.7	500mm NB PN20 DI pipe	m	6,749	413	2,788,147	3,066,962	3,345,776	278,815	7.77E+10	10%	20%
2.8	DN630 SDR41 (PN4) PE100 pipe	m	3,123	285	888,931	977,824	1,066,717	88,893	7.90E+09	10%	20%
2.9	DN630 SDR26 (PN6.3) PE100 pipe	m	3,084	354	1,091,366	1,200,503	1,309,639	109,137	1.19E+10	10%	20%
2.10	600mm SN5000 0.8Mpa GRP pipe	m	3,967	363	1,439,228	1,583,150	1,727,073	143,923	2.07E+10	10%	20%
2.11	600mm SN5000 1.0Mpa GRP pipe	m	2,825	382	1,078,303	1,186,133	1,293,963	107,830	1.16E+10	10%	20%
2.12	DN710 SDR26 (PN4) PE100 pipe	m	254	375	95,235	104,758	114,282	9,523	9.07E+07	10%	20%
2.13	DN710 SDR26 (PN6.3) PE100 pipe	m	5,297	460	2,437,203	2,680,923	2,924,643	243,720	5.94E+10	10%	20%
2.14	DN800 SDR41 (PN4) PE100 pipe	m	7,954	473	3,762,560	4,138,816	4,515,072	376,256	1.42E+11	10%	20%

2.15	DN800 SDR26 (PN6.3) PE100 pipe	m	1,805	586	1,057,297	1,163,026	1,268,756	105,730	1.12E+10	10%	20%
2.16	1000mm SN5000 0.4Mpa GRP pipe	m	2,021	847	1,711,787	1,882,966	2,054,144	171,179	2.93E+10	10%	20%
2.17	1500mm SN5000 0.4Mpa GRP pipe	m	3,675	1,431	5,257,455	5,783,201	6,308,946	525,745	2.76E+11	10%	20%
2.18	1500mm SN5000 0.63Mpa GRP pipe	m	3,015	1,447	4,363,911	4,800,302	5,236,693	436,391	1.90E+11	10%	20%
2.19	1500mm SN5000 0.8Mpa GRP pipe	m	677	1,476	999,083	1,098,991	1,198,899	99,908	9.98E+09	10%	20%
2.20	Miscellaneous (fittings, bends, air valves, access manholes etc)	LS	1	2,113,415	2,113,415	2,536,098	3,170,123	634,025	4.02E+11	20%	50%
2.21	Secondary pipe turn-outs (isolating valves, lagging and trace heating for frost protection, PRVs, etc)	LS	1	58,932	2,123,846	2,548,616	3,185,769	637,154	4.06E+11	20%	50%
	Total for Pipework				**$ 34,428,907.10**	**$ 38,295,523.96**	**$ 42,585,866.96**				
3	**Storage**										
3.1	Earthworks and PE Liner	m^2 storage	22,495,245	6	134,971,470	161,965,764	202,457,205	40,491,441	1.64E+15	20%	50%
3.2	Inlet and outlet structures	LS	1	4,049,144	4,049,144	4,858,973	6,073,716	1,214,743	1.48E+12	20%	50%
	Total for Storage				**$ 139,020,613.98**	**$ 166,824,736.78**	**$ 208,530,920.97**				
4	**Miscellaneous**										
4.1	Professional services - Construction Supervision	LS	1	$ 7,299,589.72	7,299,590	8,029,549	10,949,385	2,919,836	8.53E+12	10%	50%
4.2	Professional services - Engineering and Planning	LS	1	$ 7,299,589.72	7,299,590	8,029,549	10,949,385	2,919,836	8.53E+12	10%	50%
	Total for Miscellaneous				**$ 14,599,179.45**	**$ 16,059,097.39**	**$ 21,898,769.17**				
	TOTAL				**$ 197,088,922.53**	**$ 231,404,602.33**	**$ 284,706,823.50**	$ 53,302,221.17	1.66E+15		
								Max Likely Addition	$ 46,282,186.38		
								90th Percentile:	**$ 277,686,788.71**		
	Cost per hectare				**$ 30,265.50**	**$ 35,535.10**	**$ 43,720.34**		**$ 42,642.32**		

Irrigable area
6512
ha

OPTION R2

ITEM	DESCRIPTION	UNIT	QUANTITY	Base Rate ($)	Base Cost ($)	Cost with Ave Risk Allowance ($)	Cost with Max Risk Allowance ($)	Spread ($)	Spread² ($²)	Ave Rate	Max Rate
1	**Pump stations**										
1.1	**Power Supply**										
1.1.1	Headworks for new transformer capacity	LS	1	1,024,000	1,024,000	1,126,400	1,228,800	102400	1.05E+10	10%	20%
1.1.2	New assets (35% of total new assets to be provided)	LS	1	1,042,000	1,042,000	1,146,200	1,250,400	104200	1.09E+10	10%	20%
1.2	**Pump station 1**										
1.2.1	Main Pumps	each	5	200,000	1,000,000	1,100,000	1,500,000	400000	1.60E+11	10%	50%
1.2.2	Valves for Main Pumps (set per pump)	each	5	51,438	257,190	282,909	385,785	102876	1.06E+10	10%	50%
1.2.3	Jockey Pumps and Valves	each	2	20,000	40,000	48,000	60,000	12000	1.44E+08	20%	50%
1.2.4	Header Pipe and Flow Meter	LS	1	50,000	50,000	60,000	75,000	15000	2.25E+08	20%	50%
1.2.5	Motor Control	LS	1	976,360	976,360	1,073,996	1,464,540	390544	1.53E+11	10%	50%
1.2.6	Electrical Installation	LS	1	100,000	100,000	120,000	150,000	30000	9.00E+08	20%	50%
1.2.7	Building	LS	1	600,000	600,000	720,000	900,000	180000	3.24E+10	20%	50%
1.2.8	Coarse and fish screening	LS	1	500,000	500,000	600,000	750,000	150000	2.25E+10	20%	50%
1.3	**Pump station 2**										
1.3.1	Main Pumps	each	4	46,741	186,965	205,661	280,447	74785.92	5.59E+09	10%	50%
1.3.2	Valves for Main Pumps (set per pump)	each	4	19,182	76,728	84,401	115,092	30691.2	9.42E+08	10%	50%
1.3.3	Jockey Pumps and Valves	each	2	20,000	40,000	48,000	60,000	12000	1.44E+08	20%	50%
1.3.4	Header Pipe and Flow Meter	each	1	40,000	40,000	48,000	60,000	12000	1.44E+08	20%	50%
1.3.5	Motor Control	LS	1	467,940	467,940	514,734	701,910	187176	3.50E+10	10%	50%
1.3.6	Electrical Installation	LS	1	100,000	100,000	120,000	150,000	30000	9.00E+08	20%	50%
1.3.7	Building	LS	1	200,000	200,000	240,000	300,000	60000	3.60E+09	20%	50%
1.4	**Pump station 3**										
1.4.1	Main Pumps	each	4	56,382	225,528	248,081	338,292	90211.2	8.14E+09	10%	50%
1.4.2	Valves for Main Pumps (set per pump)	each	4	19,182	76,728	84,401	115,092	30691.2	9.42E+08	10%	50%
1.4.3	Jockey Pumps and Valves	each	2	20,000	40,000	48,000	60,000	12000	1.44E+08	20%	50%
1.4.4	Header Pipe and Flow Meter	each	1	40,000	40,000	48,000	60,000	12000	1.44E+08	20%	50%
1.4.5	Motor Control	LS	1	507,276	507,276	558,004	760,914	202910.4	4.12E+10	10%	50%
1.4.6	Electrical Installation	LS	1	100,000	100,000	120,000	150,000	30000	9.00E+08	20%	50%
1.4.7	Building	LS	1	200,000	200,000	240,000	300,000	60000	3.60E+09	20%	50%
1.5	**Pump station 4**										
1.5.1	Main Pumps	each	4	36,551	146,204	160,824	219,306	58481.6	3.42E+09	10%	50%
1.5.2	Valves for Main Pumps (set per pump)	each	4	19,182	76,728	84,401	115,092	30691.2	9.42E+08	10%	50%
1.5.3	Jockey Pumps and Valves	each	2	20,000	40,000	48,000	60,000	12000	1.44E+08	20%	50%
1.5.4	Header Pipe and Flow Meter	each	1	40,000	40,000	48,000	60,000	12000	1.44E+08	20%	50%
1.5.5	Motor Control	LS	1	335,610	335,610	369,171	503,415	134244	1.80E+10	10%	50%
1.5.6	Electrical Installation	LS	1	100,000	100,000	120,000	150,000	30000	9.00E+08	20%	50%
1.5.7	Building	LS	1	200,000	200,000	240,000	300,000	60000	3.60E+09	20%	50%
1.6	**Pump station 5**										
1.6.1	Main Pumps	each	4	46,985	187,940	206,734	281,910	75176	5.65E+09	10%	50%
1.6.2	Valves for Main Pumps (set per pump)	each	4	19,182	76,728	84,401	115,092	30691.2	9.42E+08	10%	50%
1.6.3	Jockey Pumps and Valves	each	2	20,000	40,000	48,000	60,000	12000	1.44E+08	20%	50%
1.6.4	Header Pipe and Flow Meter	each	1	40,000	40,000	48,000	60,000	12000	1.44E+08	20%	50%
1.6.5	Motor Control	LS	1	422,730	422,730	465,003	634,095	169092	2.86E+10	10%	50%
1.6.6	Electrical Installation	LS	1	100,000	100,000	120,000	150,000	30000	9.00E+08	20%	50%
1.6.7	Building	LS	1	200,000	200,000	240,000	300,000	60000	3.60E+09	20%	50%
1.7	**Pump station 6**										
1.7.1	Main Pumps	each	3	15,000	45,000	49,500	67,500	18000	3.24E+08	10%	50%
1.7.2	Valves for Main Pumps (set per pump)	each	3	5,000	15,000	16,500	22,500	6000	3.60E+07	10%	50%
1.7.3	Jockey Pumps and Valves	each	0	0	0	0	0	0	0.00E+00	20%	50%
1.7.4	Header Pipe and Flow Meter	each	1	20,000	20,000	24,000	30,000	6000	3.60E+07	20%	50%
1.7.5	Motor Control	LS	1	75,000	75,000	82,500	112,500	30000	9.00E+08	10%	50%
1.7.6	Electrical Installation	LS	1	25,000	25,000	30,000	37,500	7500	5.63E+07	20%	50%
1.7.7	Building	LS	1	100,000	100,000	120,000	150,000	30000	9.00E+08	20%	50%
1.8	**Pump station 7**										
1.8.1	Main Pumps	each	4	30,000	120,000	132,000	180,000	48000	2.30E+09	10%	50%
1.8.2	Valves for Main Pumps (set per pump)	each	4	19,182	76,728	84,401	115,092	30691.2	9.42E+08	10%	50%
1.8.3	Jockey Pumps and Valves	each	2	20,000	40,000	48,000	60,000	12000	1.44E+08	20%	50%
1.8.4	Header Pipe and Flow Meter	each	1	40,000	40,000	48,000	60,000	12000	1.44E+08	20%	50%
1.8.5	Motor Control	LS	1	250,000	250,000	275,000	375,000	100000	1.00E+10	10%	50%
1.8.6	Electrical Installation	LS	1	100,000	100,000	120,000	150,000	30000	9.00E+08	20%	50%
1.8.7	Building	LS	1	200,000	200,000	240,000	300,000	60000	3.60E+09	20%	50%
	Total for Pump Stations				**$ 11,003,382.80**	**$ 12,437,221.08**	**$ 15,885,274.20**				

2	**Pipe Work (Arterial and secondary)**										
	Costs include supply and installation of new pipe										
2.1	110mm NB PN9 uPVC pipe	m	65,480	30	1,964,400	2,160,840	2,357,280	196,440	3.86E+10	10%	20%
2.2	200mm NB PN9 uPVC pipe	m	2,225	69	153,859	169,245	184,631	15,386	2.37E+08	10%	20%
2.3	200mm NB PN12 uPVC pipe	m	1,700	80	135,405	148,946	162,486	13,541	1.83E+08	10%	20%
2.7	DN250 SDR41 (PN4) PE100 pipe	m	370	60	22,052	24,257	26,462	2,205	4.86E+06	10%	20%
2.8	DN250 SDR26 (PN6.3) PE100 pipe	m	1,600	71	113,840	125,224	136,608	11,384	1.30E+08	10%	20%
2.9	DN250 SDR21 (PN8) PE100 pipe	m	2,375	77	183,944	202,338	220,733	18,394	3.38E+08	10%	20%
2.10	DN250 SDR17 (PN10) PE100 pipe	m	1,825	87	158,593	174,452	190,311	15,859	2.52E+08	10%	20%
2.11	DN250 SDR13.6 (PN12.5) PE100 pipe	m	700	98	68,548	75,402	82,257	6,855	4.70E+07	10%	20%
2.12	DN250 SDR11 (PN16) PE100 pipe	m	1,000	111	110,525	121,578	132,630	11,053	1.22E+08	10%	20%
2.13	DN280 SDR11 (PN16) PE100 pipe	m	535	131	70,032	77,035	84,038	7,003	4.90E+07	10%	20%
2.14	400mm NB PN20 DI pipe	m	7,398	264	1,955,661	2,151,227	2,346,794	195,566	3.82E+10	10%	20%
2.15	400mm NB PN35 DI pipe	m	4,441	307	1,365,163	1,501,680	1,638,196	136,516	1.86E+10	10%	20%
2.16	DN450 SDR41 (PN4) PE100 pipe	m	2,000	180	360,700	396,770	432,840	36,070	1.30E+09	10%	20%
2.17	DN450 SDR26 (PN6.3) PE100 pipe	m	1,700	217	369,070	405,977	442,884	36,907	1.36E+09	10%	20%
2.18	DN450 SDR21 (PN8) PE100 pipe	m	1,375	242	333,163	366,479	399,795	33,316	1.11E+09	10%	20%
2.19	DN450 SDR17 (PN10) PE100 pipe	m	2,138	271	578,650	636,515	694,380	57,865	3.35E+09	10%	20%
2.20	DN450 SDR13.6 (PN12.5) PE100 pipe	m	2,092	316	660,654	726,719	792,784	66,065	4.36E+09	10%	20%
2.21	DN500 SDR41 (PN4) PE100 pipe	m	1,325	203	269,240	296,164	323,088	26,924	7.25E+08	10%	20%
2.22	DN500 SDR26 (PN6.3) PE100 pipe	m	1,748	247	432,280	475,508	518,736	43,228	1.87E+09	10%	20%
2.23	DN500 SDR21 (PN8) PE100 pipe	m	948	278	263,307	289,638	315,968	26,331	6.93E+08	10%	20%
2.24	DN500 SDR17 (PN10) PE100 pipe	m	873	315	274,559	302,014	329,470	27,456	7.54E+08	10%	20%
2.25	DN500 SDR13.6 (PN12.5) PE100 pipe	m	395	358	141,232	155,355	169,479	14,123	1.99E+08	10%	20%
2.26	DN560 SDR41 (PN4) PE100 pipe	m	2,850	246	699,818	769,799	839,781	69,982	4.90E+09	10%	20%
2.27	DN560 SDR26 (PN6.3) PE100 pipe	m	1,260	299	376,866	414,553	452,239	37,687	1.42E+09	10%	20%
2.28	DN630 SDR26 (PN6.3) PE100 pipe	m	3,942	354	1,394,995	1,534,494	1,673,994	139,499	1.95E+10	10%	20%
2.29	600mm SN5000 0.8Mpa GRP pipe	m	457	363	165,800	182,380	198,960	16,580	2.75E+08	10%	20%
2.30	600mm SN5000 1.0Mpa GRP pipe	m	807	382	308,032	338,835	369,638	30,803	9.49E+08	10%	20%
2.31	700mm SN5000 0.63Mpa GRP pipe	m	1,288	487	627,591	690,350	753,109	62,759	3.94E+09	10%	20%
2.32	700mm SN5000 1.0Mpa GRP pipe	m	717	523	374,962	412,459	449,955	37,496	1.41E+09	10%	20%
2.33	1000mm SN5000 0.63Mpa GRP pipe	m	991	861	852,904	938,195	1,023,485	85,290	7.27E+09	10%	20%
2.34	1000mm SN5000 1.0Mpa GRP pipe	m	1,440	896	1,290,744	1,419,818	1,548,893	129,074	1.67E+10	10%	20%
2.35	1100mm SN5000 0.63Mpa GRP pipe	m	981	978	959,418	1,055,360	1,151,302	95,942	9.20E+09	10%	20%
2.36	1100mm SN5000 1.0Mpa GRP pipe	m	2,269	1,016	2,305,327	2,535,859	2,766,392	230,533	5.31E+10	10%	20%
2.37	1100mm SN5000 1.6Mpa GRP pipe	m	1,386	1,070	1,482,410	1,630,651	1,778,892	148,241	2.20E+10	10%	20%
2.38	Miscellaneous (fittings, bends, air valves, access manholes etc)	m	1	1,457,662	1,457,662	1,749,194	2,186,493	437,299	1.91E+11	20%	50%
2.39	Secondary pipe turn-outs (isolating valves, lagging and trace heating for frost protection, PRVs, etc)	m	1	58,932	1,214,118	1,456,942	1,821,177	364,235	1.33E+11	20%	50%
	Total for Pipework				**$ 23,495,520.84**	**$ 26,112,250.93**	**$ 28,996,159.02**				
3	**Storage**										
3.1	Earthworks and PE Liner	m^2 storage	22,495,245	6	134,971,470	161,965,764	202,457,205	40,491,441	1.64E+15	20%	50%
3.2	Inlet and outlet structures	LS	1	4,049,144	4,049,144	4,858,973	6,073,716	1,214,743	1.48E+12	20%	50%
	Total for Storage				**$ 139,020,613.98**	**$ 166,824,736.78**	**$ 208,530,920.97**				
4	**Miscellaneous**										
4.1	Professional services - Construction Supervision	LS	1	6940781	6,940,781	7,634,859	10,411,171	2,776,312	7.71E+12	10%	50%
4.2	Professional services - Engineering and Planning	LS	1	6940781	6,940,781	7,634,859	10,411,171	2,776,312	7.71E+12	10%	50%
	Total for Miscellaneous				**$ 13,881,561.41**	**$ 15,269,717.55**	**$ 20,822,342.11**				
	TOTAL				**$ 187,401,079.03**	**$ 220,643,926.34**	**$ 274,234,696.31**	$ 53,590,769.97	1.66E+15		
								Max Likely Addition	$ 45,950,033.47		
								90th Percentile:	**$ 266,607,286.82**		
	Cost per hectare				**$ 28,777.81**	**$ 33,882.67**	**$ 42,112.21**		**$ 40,940.92**		

Irrigable area
6512
ha

OPTION S

ITEM	DESCRIPTION	UNIT	QUANTITY	Base Rate ($)	Base Cost ($)	Cost with Ave Risk Allowance ($)	Cost with Max Risk Allowance ($)	Spread ($)	Spread^2 ($\$^2$)	Ave Rate	Max Rate
1	**Pump stations**										
1.1	**Power Supply**										
1.1.1	Headworks for new transformer capacity	LS	1	1,024,000	1,024,000	1,228,800	1,536,000	307200	9.44E+10	20%	50%
1.1.2	New assets (35% of total new assets to be provided)	LS	1	1,042,000	1,042,000	1,250,400	1,563,000	312600	9.77E+10	20%	50%
1.2	**Pump station 1**										
1.2.1	Main Pumps	each	3	155,800	467,400	560,880	701,100	140220	1.97E+10	20%	50%
1.2.2	Valves for Main Pumps (set per pump)	each	3	51,438	154,314	185,177	231,471	46294.2	2.14E+09	20%	50%
1.2.3	Jockey Pumps and Valves	each	2	20,000	40,000	48,000	60,000	12000	1.44E+08	20%	50%
1.2.4	Header Pipe and Flow Meter	LS	1	50,000	50,000	60,000	75,000	15000	2.25E+08	20%	50%
1.2.3	Motor Control	LS	1	418,440	418,440	502,128	627,660	125532	1.58E+10	20%	50%
1.2.4	Electrical Installation	LS	1	100,000	100,000	120,000	150,000	30000	9.00E+08	20%	50%
1.2.5	Building	LS	1	300,000	300,000	360,000	450,000	90000	8.10E+09	20%	50%
1.2.6	Coarse and fish screening	LS	1	500,000	500,000	600,000	750,000	150000	2.25E+10	20%	50%
1.3	**Pump station 5**										
1.3.1	Main Pumps	each	4	37,468	149,872	152,869	164,859	11989.76	1.44E+08	2%	10%
1.3.2	Valves for Main Pumps (set per pump)	each	4	19,182	76,728	78,263	84,401	6138.24	3.77E+07	2%	10%
1.3.3	Jockey Pumps and Valves	each	2	20,000	40,000	48,000	60,000	12000	1.44E+08	20%	50%
1.3.4	Header Pipe and Flow Meter	LS	1	40,000	40,000	48,000	60,000	12000	1.44E+08	20%	50%
1.3.5	Motor Control	LS	1	335,610	335,610	342,322	369,171	26848.8	7.21E+08	2%	10%
1.3.6	Electrical Installation	LS	1	100,000	100,000	120,000	150,000	30000	9.00E+08	20%	50%
1.3.7	Building	LS	1	200,000	200,000	240,000	300,000	60000	3.60E+09	20%	50%
	Total for Pump Stations				**$ 5,038,364.00**	**$ 5,944,839.00**	**$ 7,332,662.00**				
2	**Pipe Work (Arterial and secondary)**										
	Costs include supply and installation of new pipe										
2.1	110mm NB PN9 uPVC pipe	m	63,825	30	1,914,750	1,953,045	2,106,225	153,180	2.35E+10	2%	10%
2.2	DN280 SDR26 (PN6.3) PE100 pipe	m	2,993	80	239,889	244,687	263,878	19,191	3.68E+08	2%	10%
2.3	DN280 SDR21 (PN8) PE100 pipe	m	2,168	89	192,367	196,214	211,603	15,389	2.37E+08	2%	10%
2.4	DN315 SDR41 (PN4) PE100 pipe	m	1,042	95	98,990	100,970	108,889	7,919	6.27E+07	2%	10%
2.5	DN315 SDR26 (PN6.3) PE100 pipe	m	6,120	111	676,505	690,035	744,155	54,120	2.93E+09	2%	10%
2.6	DN315 SDR21 (PN8) PE100 pipe	m	382	128	48,992	49,971	53,891	3,919	1.54E+07	2%	10%
2.8	DN630 SDR26 (PN6.3) PE100 pipe	m	741	354	262,225	267,470	288,448	20,978	4.40E+08	2%	10%
2.9	600mm SN5000 0.8Mpa GRP pipe	m	1,683	363	610,592	622,804	671,652	48,847	2.39E+09	2%	10%
2.10	600mm SN5000 1.0Mpa GRP pipe	m	966	382	368,722	376,097	405,594	29,498	8.70E+08	2%	10%
2.11	DN710 SDR41 (PN4) PE100 pipe	m	254	375	95,235	97,139	104,758	7,619	5.80E+07	2%	10%
2.12	DN710 SDR26 (PN6.3) PE100 pipe	m	5,297	460	2,437,203	2,485,947	2,680,923	194,976	3.80E+10	2%	10%
2.13	DN800 SDR41 (PN4) PE100 pipe	m	9,975	473	4,718,574	4,812,945	5,190,431	377,486	1.42E+11	2%	10%
2.14	DN800 SDR26 (PN6.3) PE100 pipe	m	1,805	586	1,057,297	1,078,443	1,163,026	84,584	7.15E+09	2%	10%
2.15	1000mm SN5000 0.4Mpa GRP pipe	m	3,675	847	3,112,725	3,174,980	3,423,998	249,018	6.20E+10	2%	10%
2.16	1000mm SN5000 0.63Mpa GRP pipe	m	3,015	861	2,594,860	2,646,757	2,854,346	207,589	4.31E+10	2%	10%
2.17	1000mm SN5000 0.8Mpa GRP pipe	m	677	877	594,034	605,914	653,437	47,523	2.26E+09	2%	10%
2.18	Miscellaneous (fittings, bends, air valves, access manholes etc)	LS	1	1,331,607	1,331,607	1,597,928	1,997,411	399,482	1.60E+11	20%	50%
2.19	Secondary pipe turn-outs (isolating valves, lagging and trace heating for frost protection, PRVs, etc)	LS	1	57,443	1,290,787	1,548,944	1,936,181	387,236	1.50E+11	20%	50%
	Total for Pipework				**$ 21,645,352.34**	**$ 22,550,290.34**	**$ 24,858,845.23**				
3	**Storage**										
3.1	Earthworks and PE Liner	m^2 storage	13,741,721	6	82,450,324	98,940,388	123,675,485	24,735,097	6.12E+14	20%	50%
3.2	Inlet and outlet structures	LS	1	2,473,510	2,473,510	2,968,212	3,710,265	742,053	5.51E+11	20%	50%
	Total for Storage				**$ 84,923,833.29**	**$ 101,908,599.95**	**$ 127,385,749.94**				
4	**Miscellaneous**										
4.1	Professional services - Construction Supervision	LS	1	$ 4,464,301.99	4,464,302	4,910,732	6,696,453	1,785,721	3.19E+12	10%	50%
4.2	Professional services - Engineering and Planning	LS	1	$ 4,464,301.99	4,464,302	4,910,732	6,696,453	1,785,721	3.19E+12	10%	50%
	Total for Miscellaneous				**$ 8,928,603.97**	**$ 9,821,464.37**	**$ 13,392,905.96**				
	TOTAL				**$ 120,536,153.61**	**$ 140,225,193.66**	**$ 172,970,163.13**	$ 32,744,969.48	6.20E+14		
								Max Likely Addition	$ 28,585,659.49		
								90th Percentile:	**$ 168,810,853.14**		
	Cost per hectare				**$ 30,300.69**	**$ 35,250.17**	**$ 43,481.69**		**$ 42,436.11**		

Irrigable area
3978
ha

OPUS