Kāpiti Water Supply

Ranked Options - Technical Report

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Prepared for Kapiti Coast District Council by CH2M Beca

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Glossary

Alluvium:	sediment that has been transported and deposited by rivers and streams
Aquitard:	a confining layer of low permeability sediment or rock that restricts the flow of groundwater
Colluvium:	sediment that has been transported by gravity
KCWS Model:	Excel-based surface water yield model developed for this project
Paleo-channel:	old, inactive river or stream channel

Flow Rates

The report uses the units of m^3/day as the preferred unit for water supply, but the units of L/s (sometimes m^3/s) are frequently used in the surface water hydrology and hydrogeology (groundwater) sections. To convert L/s to m^3/day, multiply by 86.4. To convert m^3/s to L/s, multiply by 1000.

Abbreviations

ADD	Average Day Demand
AEE	Assessment of Environmental Effects
ARI	Average Return Interval
ASR	Aquifer Storage and Recovery
BAC	Biological Activated Carbon
CBA	Cost Benefit Analysis
CEA	Cost Effectiveness Analysis
CLS	Cement Lined Steel
DoC	Department of Conservation
DRP	Dissolved Reactive Phosphorus
DWSNZ	Drinking-water Standards for New Zealand
ETS	Emissions Trading Scheme
FRE3	Number of floods greater than three-times the long term median flow
GDP	Gross Domestic Product
GNS	Institute of Geological and Nuclear Sciences
GPI	Genuine Progress Indicator

GWRC	Greater Wellington Regional Council
KCDC	Kāpiti Coast District Council
KWSP	Kāpiti Water Supply Project
LGA	Local Government Act
LTCCP	Long Term Council Community Plan
MAV	Maximum Acceptable Value
MCA	Multi-Criteria Analysis
MCE	Maximum Credible Earthquake
MERA	Monitoring and Evaluation Research Associates Ltd
MfE	Ministry for the Environment
NIMT	North Island Main Trunk Line
NES	National Environmental Standard
NoR	Notice of Requirement
NPS	National Policy Statement
NZSOLD	New Zealand Society of Large Dams
PAC	Powdered Activated Carbon
PACl	Poly-Aluminium Chloride
PDD	Peak Day Demand
PE	Polyethylene
PIC	Potential Impact Classification
PVC	Polyvinyl Chloride
RCC	Roller-Compacted Concrete
RFWP	Regional Freshwater Plan
RMA	Resource Management Act 1991
RPS	Regional Policy Statement
TAG	Technical Advisory Group
TEV	Total Economic Value
TDS	Total Dissolved Solids
WPR	Waikanae-Paraparaumu-Raumati
WTP	Water Treatment Plant
WWTP	Wastewater Treatment Plant

PART A: CONTEXT SETTING

1 Introduction

Providing a reliable water supply for the Waikanae, Paraparaumu and Raumati communities that is sustainable and will meet the expectations of consumers is a fundamental issue for Kāpiti Coast District Council (Council). The existing water supply is under stress in terms of its capacity to meet the peak water demand in summer. The Kāpiti Water Supply Project is seeking to identify the most suitable solution for providing water to meet the communities' needs for the next 50 years. The aim is to find a solution that can be in place by 2015, as there is a risk that within the next five years population growth and high water consumption could result in demand that exceeds the Council's currently consented limit for water abstraction of 23,000 m^3/day.

Council is also addressing other issues relating to water management by implementing the *Water Matters – Sustainable Water Management Strategy* from 2003, including provision of funding and incentives to improve water conservation measures across the district.

This report summarises and evaluates six options (one of which includes sub-options) that have been investigated in Stage 3 of the Kāpiti Water Supply Project. The six options presented in this report were identified following two previous stages of option identification and analysis. A review of 41 options (*Preliminary Status Report*) was tabled with Council on 17 December 2009. Feedback from further consultation and evaluation of options was reflected in the Stage 2 *Option Selection Report,* which recommended a short-list of six options that was adopted unanimously by Council on 11 March 2010.

Sustainable management of natural and physical resources, including water resources, is a key factor in the Council's decision making process. Fourteen principles of sustainable management are detailed in the Long Term Council Community Plan (LTCCP). The Council's *Water Matters* strategy also specifies that as a first preference, water supply be from in-catchment sources. For the Waikanae-Paraparaumu-Raumati (WPR) "catchment" this effectively means that the water source is either from the Waikanae River surface water catchment or from groundwater on the coastal plain.

Through evaluating and ranking the six options, the best attributes of each option have been identified. This provides an opportunity to develop composite options, taking the best components of one option and mixing them with the best components of one or more other options. This is particularly relevant for the WPR community for two key reasons:

- composite options could utilise both water sources in an integrated manner to reduce the impacts of abstraction on the river and aquifer, enhance water quality and improve security of supply.
- composite options may allow a more manageable approach to capital investment for water supply infrastructure (particularly if compared to an option which requires all capital to be expended "up front") which would result in better value for the ratepayer.

1.1 Purpose of Report

The purpose of this report is to:

- present the concept design and findings of technical investigations for each of the six options
- present the results of the extensive consultation that has occurred in this stage of the project

- provide an overview of two Ōtaki River options that have been designed and costed for comparison purposes only
- present the cost estimates in a manner that fully informs decision-makers
- identify and consider composite options
- evaluate and rank the short-listed options
- recommend a preferred solution and the next steps for the project.

A separate *Summary Report* has been prepared as a companion to this technical report.

1.2 Options

Based on Council policy, community feedback and a partnership approach to water management with tāngata whenua, the investigation of in-catchment options is a first priority before looking to out-of-catchment options. Council has set a goal for the Waikanae-Paraparaumu-Raumati (WPR) urban community to live sustainably within its own means, using water supplied from within the WPR catchment in conjunction with Council's water conservation initiatives.

Specifically with regard to the Ōtaki River as a potential source of water, both the Ōtaki Community Board and the tāngata whenua of Ōtaki have given their support for the investigation of in-catchment solutions as a first priority, rather than undertaking further investigations into the Ōtaki River source at this stage. It is clear that the Ōtaki Community Board and the tāngata whenua of Ōtaki do not support the use of the Ōtaki River as a water supply source for the WPR area. However, for the purpose of comparison with the short-listed in-catchment options, this report considers the costs of two Ōtaki River options in Section 14 of the report.

The six in-catchment options can be grouped into dam and groundwater options as follows. In all cases the Waikanae River remains the primary water source for the WPR water supply.

1.2.1 Dam Options

Three different dam sites have been investigated. During low flows in the Waikanae River, water would be released from the dam into the stream, and abstracted at the existing water treatment plant intake. All of the dam options use the same technique of using the river to convey water to the treatment plant. The dam options are:

- Kapakapanui Dam – located on an unnamed tributary of the Waikanae River near to the Kapakapanui Stream. This dam has a smaller contributing catchment area than the other two dam options.
- Lower Maungakotukutuku Dam – located on the Maungakotukutuku Stream in the south-western part of the Waikanae River basin. The dam is well located on a natural gorge allowing an economical dam design.
- Ngātiawa Dam – located on the Ngātiawa River and north of Ngātiawa Road. This catchment has the greatest flows, and hence the dam design in this location must be able to deal with large flood flows.

1.2.2 Groundwater Options

Three further options have been explored which involve using groundwater to varying degrees and in different ways. Only one of the options involves using the bore water for drinking water (Extended Borefield and Storage), and the other two involve innovative uses of the Waikanae Borefield. The three groundwater options are:

- Extended Waikanae Borefield and Storage – two different sub-options have been developed around this option. One sub-option involves blending the existing bore water with stored river water from new storage ponds during periods of low river flow. Two different pond sizes have been considered to provide for different blending proportions. The second sub-option involves expanding the borefield and providing additional treatment of the bore water to avoid the need for storing river water for blending.
- Aquifer Storage and Recovery – this option involves using the aquifer and elements of the existing borefield infrastructure to abstract water from the river during high winter flows, and pump it into the deep Waimea aquifer using new injection wells. The river water is stored underground until abstraction using the existing borefield during drier periods when the river flows are low.
- River Recharge with Groundwater – this option involves taking water from the existing borefield, and discharging it to the Waikanae River immediately downstream from the existing intake. In this way, the groundwater is able to provide the minimum flow in the river, allowing more river water to be abstracted for water supply. The borefield would need to be extended to provide sufficient yield.

1.2.3 Composite Options

The development of variations on the options investigated recognises that the most optimal solution may in fact have components from different, otherwise standalone options. These composite options are also identified and reviewed in this report.

1.3 Community Consultation

During the course of the Kāpiti Water Supply Project there has been a great deal of community consultation. This has occurred in previous stages at the generic level in terms of the values that are important to the community, and in this current stage of the project, in relation to specific options and their potential effects. Running hand-in-hand with the Water Supply Project, Council's water conservation initiatives have also been widely consulted on and form an important component of the overall water management framework.

The results of community consultation in relation to the six short-listed options are provided later in this report, however, understanding the key messages from the wider community are important to set the context.

Overall, the key community messages from Stage 3 consultation remain consistent with the outcomes of the early rounds of consultation in terms of the key values of water quality, security of supply and cost, summarised as follows.

- **Water quality** – The taste of water that is abstracted from the Waikanae River is generally acceptable to the WPR community. When the supplementary borefield supply is used, the taste changes from a 'soft' to a 'hard' water, and the 'saltiness' increases. In addition, the hardness of the bore water has remained a key concern. There is a proportion of the community that is reluctant to support the ongoing use of the borefield for potable water supply. Should the borefield continue to be relied on for water supply, treatment or blending of the bore water to reduce the hardness should be allowed for.
- **Security of supply** – With a growing population, having a reliable supply that can deliver water during a 50 year return period drought is important to the community. The supplementary borefield has been used on a number of summer occasions to ensure that the minimum flow level set by Greater Wellington Regional Council is met. The Waikanae River cannot be relied on to provide the full future demand.

- **Cost** – The water supply option must be affordable and value for money. Stage 3 consultation has shown a strong level of community interest in cost, particularly comparative costs (both construction and operational) between the six short-listed options. There is also some interest in the reasoning for the $23M budget and whether the higher cost options (dams) will be able to fit within that.

In addition, consultation from Stage 3 has provided feedback on the six short-listed options at a more detailed level. Key community messages in this regard include:

- **Process** – All feedback on consultation process has assisted the project team to focus consultation efforts and ensure a coherent and commonsense process to systematically build a case towards a preferred solution. In terms of process, there is overall support for the investigation of in-catchment options as a first priority before looking to out-of-catchment options. Positive feedback has been received regarding the role of the Technical Advisory Group in the option investigation and selection process, particularly in terms of using local knowledge to inform decisions and review the technical investigations.
- **Partnership approach with tāngata whenua** – Council continues to build a partnership approach with tāngata whenua in relation to water management, based around the core values of kaitiakitanga, tino rangatiratanga. tāonga, mauri and whakapapa. The focus on in-catchment options as a first priority is a strong indication that Council is taking into account these core values. At this stage, tāngata whenua have not identified any fatal flaws with any of the six short-listed options and remain committed to supporting a partnership approach to this significant community project. This includes the tāngata whenua of Ōtaki supporting the investigation of in-catchment solutions as a first priority, rather than undertaking further investigations into the Ōtaki River source at this stage. Council is working closely with the Te Āti Awa in the spirit of the Memorandum of Understanding developed for this project, particularly with the Te Āti Awa Water Working Group in the investigation of cultural impacts.
- **Dam options** – The concept of a dam as a water supply solution appears to have general support in the community. However, concern has also been expressed by some residents immediately downstream of the potential dam sites. Those noting support for dam options talk of the benefit of the certainty of a tried and tested concept and of capturing rain water sensibly in the hills. Those noting opposition talk of the risk of dam break and adverse environmental effects, particularly to in-stream ecology and amenity. The Ngātiawa Dam site has potentially more than minor adverse environmental, social and economic effects on directly affected landowners. For that reason, the Ngātiawa Dam is significantly less favoured in comparison to the other two dam sites.
- **Non-dam options** – The non-dam options are generally less-well understood by stakeholders and the wider public than the dam options. Overall, it appears that river recharge with groundwater and aquifer storage and recovery are favoured over extending the borefield, subject to confirming environmental effects generated by discharging groundwater into the Waikanae River and confirming the certainty around the science of injecting river water into the aquifer and recovering it.
- **Water conservation** – The importance of water conservation has been an ongoing theme during the community consultation for this project, with both Council and the community raising a range of methods to achieve lower consumption rates of potable water.

1.4 Design Requirements

The Kāpiti Water Supply Project (KWSP) has a number of design requirements. Some of these requirements were set by Council at the commencement of the project. Over the preceding two stages of the project, and also during this stage, those early requirements have been refined and a number of others have been developed.

This section of the report documents each of the design requirements. It justifies the requirement, describes any underlying assumptions, outlines any further work that needs to be undertaken at the next stage of the project, and shows how the requirement has been (or will be) incorporated into the design of the project.

In addition, each of the six options being considered has specific design requirements and/or assumptions. These option-specific requirements and assumptions are not included in this section, as they are identified and described in relation to the option itself (Part B of this report).

1.4.1 Reliability of Supply

a. Design Requirement

The KWSP must be able to meet the design demand in a drought with a 1 in 50 year return period (i.e. 2% probability of occurring in any one year).

b. Justification and Assumptions

Local authorities in New Zealand normally use a 1 in 50 year target where a drought reliability or security standard is explicitly adopted. For example, the Greater Wellington performance target is expressed in its Annual Report[1] as:

> *Our aim is to manage the bulk water supply system so that water shortages should not occur more than once in 50 years on average: an annual shortage probability of 2%. This standard – agreed with territorial authority customers – is deliberately conservative, given that the consequences of water shortage can be severe.*

Greater Wellington has a sophisticated and robust tool for predicting the yield of the bulk water system (known as the Sustainable Yield Model). In 2008 it revised the annual probability of a water shortage in the system to 3.9%, or once in 26 years on average due to revisions to the model and population growth. Greater Wellington now has a strategy that is aiming to quickly return security of supply to a risk level of 2%, by a series of relatively modest system enhancements, and ensure that level is maintained into the future. It is planning to have this in place by 30 June 2016.

The notable exception to the 1 in 50 year standard in New Zealand is in Auckland. Following the severe 1993/1994 drought in Auckland, the local authority customers of Watercare Services Ltd made it clear that the 1 in 50 year standard was inadequate, and that a greater level of security was needed[2]. Following a review of international practice and also a study of the economic advantages of an increased level of security, a 1 in 200 year (0.5% annual probability of failure) standard was adopted.

There is no doubt that the higher standard of drought reliability in Auckland arose from its population having just experienced a very severe drought and realising that the costs of this (both tangible and intangible) were not acceptable. We would also note that per capita demand is also lower in Auckland than most parts of New Zealand, and accordingly there is less elasticity of demand in times of shortage. In addition, at that time Auckland was heavily dependent on dams for supply, and the other key response was the development of the new source from the Waikato River – with different hydrological characteristics to the dam sources.

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[1] *Water Supply Annual Report: For the year ended 30 June 2009*, Greater Wellington Regional Council

[2] *Future Water Source Project: Options Evaluation Report Phase 1*, Watercare Services Ltd, May 1995

As was stated in the *Preliminary Status Report*, water conservation measures will be in place in Kāpiti for all summers. The consequence in a drought event with a return period of greater than the policy is that more severe measures will need to be imposed. This is likely to involve a complete outdoor watering ban with strict enforcement by patrols, and the imposition of penalties for offenders. If a dam option was to be implemented, once the dam is empty there would be no water available from it or the river until rain restored river flows and started to refill the dam. However, Kāpiti has the alternative of using the borefield in such an extreme situation, and that makes the consequences of an extreme drought event relatively minor. It would require, however, a commitment to maintain a sufficient number of bores within the existing borefield in the event that a dam option was implemented.

The consequences for yield from the groundwater options in a drought event greater than the 1 in 50 year drought will be considered in the next stage of the project with further groundwater modelling.

It is normal practice to have a drought management plan to set out the measures that need to be implemented, and the timing of those measures, during severe droughts. We recommend one is prepared for the selected option to support the resource consent application and to guide the detailed design of the final preferred solution.

Overall, the design requirement has been set on the basis that Council should adopt the standard that is normally used in New Zealand; i.e. a 1 in 50 year drought reliability. Options which have greater headroom in the short term also have the added advantage of providing additional security during any drought events that occur earlier in the 50 year planning horizon.

c. Further Work

Modelling of groundwater and surface water to provide guidance (in the event that a drought of greater than a 1 in 50 year return period occurs), on the optimal emergency water supply sources. This is likely to involve an ongoing commitment to use the existing emergency bores in such situations.

A drought management plan needs to be prepared for the selected water supply solution during detailed design.

d. Incorporation into Design

The design has been undertaken on the basis that the design demand will be able to be supplied in droughts, up to a 1 in 50 year drought reliability, until 2060. To allow for the uncertainties in the demand and drought forecasting (including climate change impacts), there will be a headroom allowance in the design requirement for yield. If a dam option is selected, some of the existing bores should be maintained as a contingency measure in the event of a greater than 50-year drought.

1.4.2 Demand

a. Design Requirements

The design demand for the KWSP has been forecast for the planning horizon year of 2060 on the basis of the following:

- 400 L/person/day peak day consumption (incorporating commercial/industrial demands)
- Unaccounted for water (losses) of 90 L/person/day
- Population growth (and matching increase in demand) at the medium-growth scenario.

The design demand for 2060 is 26,000 m^3/day.

b. Justification and Assumptions

The above design requirements are those documented in the *Preliminary Status Report*, and are consistent with the water consumption standard in Council's *Water Matters* strategy[3], as well as Council's other policy settings in relation to population growth.

The design requirements include a number of assumptions:

- The water conservation measures being taken by Council are successful in depressing the existing level of peak daily demand down to 400 L/person/day
- Commercial/industrial demand is incorporated into per capita demand and therefore not specifically allowed for (e.g. no allowance for new "wet" industry)
- The allowance for losses is a reasonable reflection of reality, and that this figure does not change over the planning horizon
- The design demand is based on population growth in the existing WPR area and does not allow for the connection of additional areas
- No specific allowance for the impact of any climate change on demand over the planning period.

These assumptions are examined in more detail in Section 2.4, and a headroom allowance made in the design requirement for yield to accommodate the uncertainties associated with the forecasting of demand.

c. Further Work

Additional work is underway or planned to improve data on water use and losses from the network. This work includes division of the network into flow monitoring zones and implementation of a water loss reduction strategy. The data gathered will provide more certainty around the assumptions made to forecast future demand.

d. Incorporation into Design

To allow for the uncertainties in the demand forecasting, there will be a headroom allowance made in the design requirement for yield.

1.4.3 Yield

a. Design Requirement

The peak day design yield from the particular water source(s) associated with each water supply option must be:

- 26,000 m^3/day + headroom, or
- 26,000 m^3/day and readily stage-able to accommodate headroom if demand is greater than design requirement.

The working figure for headroom is 6,000 m^3/day. This gives an interim design figure for peak day yield of 32,000 m^3/day, which will be used until the further work on demand and yield is developed.

[3] *Water Matters: Kāpiti Coast District Sustainable Water Management Strategy*, November 2002

b. Justification and Assumptions

For the dam options the yield assumes that the water will be released from the dam to the river, and that approaching 100% of the volume released to the river can be abstracted at the existing water supply intake (i.e. there are no losses to the river bed or to other abstractors). If losses are found to be potentially significant from further study (which is considered unlikely), or there are potential legal risks from other abstractors (which preliminary discussions with Greater Wellington suggest will not be the case), then a pipeline may be required or the size of the dam may need to be increased. This will be reviewed on a cost/benefit basis should investigations identify any risk of released water not being available to Council at the existing intake point at the Water Treatment Plant.

No allowance has been made at this stage for climate change as a preliminary review of the Ministry for the Environment (MfE) guidance document[4], shows that the effects on yield are likely to be small, and much less than year-to-year variability. Because such small effects are not expected to help differentiate between the options, this work will be delayed until detailed design.

c. Further Work

The extent of losses from using the river channel to convey the water to the treatment plant will be confirmed by further study.

The impact of climate change on yield will be investigated for the selected solution during preliminary design (Stage 4 of the KWSP).

A review of the 50 year low flow for the Waikanae River is also planned for the next stage of this project.

d. Incorporation into Design

All the options developed in Stage 3 will provide the design requirement for yield, including headroom.

1.4.4 Treated Water Quality

a. Design Requirement

The treated water quality delivered by the KWSP must meet the following design requirements:

- Compliance with the Drinking-water Standards for New Zealand 2005 (revised 2008)
- Taste, odour and aesthetics (excluding hardness): taste, odour and aesthetic qualities must be acceptable to most consumers
- If groundwater is blended or treated – a target treated water hardness of ≤ 80 mg/L (as $CaCO_3$), sodium of ≤ 200 mg/L and total dissolved solids of ≤ 500 mg/L.

b. Justification and Assumptions

The consultation with the community to date in relation to the KWSP has clearly demonstrated the importance of the quality of the treated water to the community. Taste testing was carried out to explore the taste acceptability of a range of potential finished water quality. This testing indicated that the taste of the water from the borefield is actually reasonable and bore water should not be

[4] *Climate Change Effects and Impacts Assessment: A Guidance Manual for Local Government in New Zealand*, 2nd Edition, MfE

discounted on the basis of taste. In relation to hardness the community's preference would be to have a hardness from any groundwater supply similar to that of the existing river supply (30-50 mg/L as $CaCO_3$).

c. Further Work

The design requirements around hardness, sodium and total dissolved solids need to be confirmed if groundwater is part of the preferred solution. The hardness requirement could be tested with electric kettle trials as the "popping" noise associated with the borefield water is a common complaint.

d. Incorporation into Design

The concept design of the treatment processes for the different options will meet the design requirements for treated water quality.

1.4.5 Design Standards and Design Life

The engineering design standards will be those generally accepted by New Zealand local authorities for water supply and other infrastructure projects, and are expected to primarily be the NZ Building Code, NZ Standards (NZS or AS/NZS), and Water Services Association of Australia (WSAA). If appropriate New Zealand or Australian standards do not exist, then those of the USA or UK will be used.

The design life for buildings and structures will be consistent with the NZ Building Code (i.e. 50 years), while the Importance Level in terms of the structural design standards will be 3 for components not designated as post-disaster and 4 for those with special post-disaster functions.

The specific design standards and design life applying to dams are described in the sections covering the dam options.

2 Water Resources and Water Quality

2.1 Water Management

Water is essential for all life, and the way we manage the water resource is a critical resource management issue. The Resource Management Act (RMA) recognises the "life-supporting" capacity of water as an issue of such critical importance that it is noted in Section 5 of the RMA – the purpose of sustainable management.

Many factors are important in making decisions on water management. These include water allocation, impacts on water quality, the cultural values that Māori place on water, and the social and environmental impacts of water use and conservation.

The Kāpiti Coast district has abundant water resources in the form of river flows and groundwater. The Ōtaki and Waikanae Rivers are both large rivers that are supplied by sizable catchments rising in the Tararua Ranges. Furthermore, there are a number of shallow and deep aquifers along the Kāpiti Coast that are used extensively to support urban and rural activities.

While water resources are abundant, there are many competing demands for water use. These include "environmental flows" through to allocation of water for a range of economic and domestic uses. This project is seeking to identify an additional allocation of water for use in the WPR urban water supply system.

The existing water supply for the WPR communities is sourced from a run-of-river abstraction from the Waikanae River. This is a very sound water source although, like many run-of-river water supply schemes, it cannot cater for peak day demand for the existing population during dry periods when the river flows are low. This is due to both the physical constraints of the river (i.e. lower flows) plus the consented regime, which requires a residual flow of 750 L/s in the river (unless the river naturally falls below this flow). Once the river flow falls below about 1,000 L/s, water for the WPR communities is sourced from the existing Waikanae Borefield.

Greater Wellington Regional Council is the agency responsible for managing water allocation and water quality on the Kāpiti Coast. Ultimately, the aim of the Kāpiti Water Supply Project is to seek a consent to allocate a specified volume of water to the WPR community as a future water supply source. It is therefore important to not only understand the physical availability of water, but also the imperatives of sound water management under the RMA and the approach to consenting water allocation.

For Council the *Water Matters* strategy set the principle that water will be sourced, where possible, from within the catchment that is providing the demand. The option assessment that occurred in Stages 1 and 2 of this project therefore narrowed the options for new water sources down to six in-catchment options. These options essentially involve using the Waikanae River or the Waikanae Aquifer in a range of different ways.

2.2 Water Conservation

Water conservation is a critical platform for Council in delivering an integrated solution to future water supply. While identifying a new source is the focus of this report, Council has a strong program of water conservation in order to achieve the design requirements outlined in Section 1.4 of this report. Water conservation is not further discussed in this report, although there is a great deal of further information that Council is consulting on through its Annual Plan.

This report works on the assumption that further water conservation measures will be successful in reducing demand to Council's target of 490 L/person/day over the next ten years.

2.3 RMA Framework for Water Allocation

Water allocation is governed by the RMA, specifically through the hierarchy of planning instruments established in the Act. This includes the development of National Environmental Standards (regulations issued under sections 43 and 44 of the Act) which require the enforcement of the same standard across the country and Regional Plans which set out the objectives, policies and methods (which include rules) to manage significant resource management issues (including the management of water).

2.3.1 Existing Consents

Council holds four existing resource consents from GWRC which are relevant to the Kāpiti Water Supply Project; these are detailed in the table below. All of the consents are effective from 1 July 2005 and expire on 1 July 2025. Three of these consents are for water allocation from surface water or groundwater.

Table 2-1: Existing Resource Consents held by Council for WPR Water Supply

File Reference	ID	Consent Type	Details
WGN050024	23848	Surface water take	To take water from the Waikanae River at the Waikanae Water Treatment Plant for public water supply purposes. The maximum take is 23,000 m^3/day at a maximum rate of up to 463 L/s when river flows are above 1,400 L/s. Between river flows of 1,400 L/s and 1,100 L/s, the rate of take will be 350 L/s. Once the flows in the river drop below 1,100 L/s, the rate of take will drop proportionally such that a residual flow of 750 L/s is maintained in the river, unless the river naturally falls below 750 L/s.
WGN050024	23850	Discharge to water	To discharge water and sediment from the Waikanae Water Treatment Plant to the Waikanae River when the incoming water is highly turbid at river flows greater than 5,000 L/s; and to discharge the contents of the clarifiers (2,500 m^3), rapid mix tanks (200 m^3), and filters (360 m^3) to the Waikanae River during maintenance activities. The maintenance discharge will occur approximately once every 2 to 5 years. The maximum rate of discharge is 278 L/s and only occurs when flow in the Waikanae River is greater than 2,000 L/s.
WGN050025	23852	Groundwater take	To take and use a combined total of 7,000 m^3/day of groundwater from two bores (PW1 and PW5) for the purposes of a back-up public water supply for the communities of Waikanae, Paraparaumu and Raumati.
WGN050025	25865	Groundwater take	To take and use a combined total of up to 23,000 m^3/day of groundwater from up to eight wells within the Waikanae borefield for the purposes of a supplementary public water supply for the communities of Waikanae, Paraparaumu and Raumati. This borefield includes the wells: K4, Kb4, K5, K6, Kb7, K10, K12, K13 and TW2.

All of the options considered in this report rely on these existing consents for taking water from the Waikanae River, taking groundwater and discharging water and sediment associated with the WTP. However, most of the options involve changing the consented water management regime to use water in different ways.

2.3.2 Central Government Strategy for Water Management

In 2009, the Government announced its new strategy for water management in New Zealand: New Start for Fresh Water*.* A programme of work has been developed that consists of three major components:

- a stakeholder-led collaborative process run by the Land and Water Forum that will develop and recommend shared outcomes, goals and long term strategies for fresh water
- engagement between Ministers and the Iwi Leaders Group to advance discussions on resolving high level freshwater issues
- concurrent scoping of policy options on matters including freshwater allocation, quality and infrastructure (the “officials' work programme”).

The Land and Water Forum is a non-government group, comprising a range of industry groups, environmental and recreational entities, iwi groups and other organisations with an interest in sustainable land and water management. The Land and Water Forum is due to report back to the Ministers of Environment and of Agriculture by the end of July 2010.

The proposed officials' work programme involves a number of priority projects, including the National Policy Statement on Freshwater Management and a National Environmental Standard on ecological flows and water levels.

a. National Policy Statement on Freshwater Management

National Policy Statements are tools available under the RMA to help achieve the purpose of the Act. The proposed National Policy Statement (NPS) for Freshwater Management will identify the management of freshwater resources as a matter of national significance. The proposed NPS will provide objectives and policies to guide councils on how to manage fresh water within their regional and district plans, and through their resource consent decisions.

The proposed NPS will be complemented by National Environmental Standards.

b. Proposed National Environmental Standard on Ecological Flows and Water Levels

The proposed National Environmental Standard (NES) on Ecological Flows and Water Levels is likely to be finalised in the timeframe of this project. The proposed standard aims to promote consistency in the setting of flows and levels required in rivers, lakes, wetlands and groundwater systems to provide for the ecological function of the flora and fauna present within that water body. The proposed standard will include setting interim limits on the alteration to flows and/or water levels that do not have limits imposed through regional plans; and provide a process for selecting the appropriate technical methods for evaluating ecological flows and water levels.

The introduction of the proposed NPS on Freshwater Management and the proposed NES on Ecological Flows and Water Levels may result in a review of the current minimum flows and yields that are specified in the Wellington Regional Freshwater Plan (see next section). This is a significant risk for this project, as all of the supplementary supply options considered in this report are based on the current minimum flow for the Waikanae River of 750 L/s. If the specified minimum flow were to be increased then the supplementary supply would be needed more often and for a longer period of time. Similarly more water may have to be released from the dams to preserve the required minimum flow in the watercourse downstream of the dam.

2.3.3 Wellington Regional Freshwater Plan – Minimum Flows, Safe Yields and Water Allocation

The Wellington Regional Freshwater Plan (RFWP) sets minimum flows, safe yields and water allocation for rivers, streams and aquifers in the region. The design assumptions for this project are based on the current operative RFWP provisions. Greater Wellington Regional Council will shortly undertake a review of its Regional Policy Statement and Plans, including a review of minimum flows, safe yields and water allocation.

a. Rivers and Streams

Policy 6.2.1 of the RFWP sets minimum flows and water allocation limits for some rivers and streams in the Wellington region. This includes a minimum flow for the Waikanae River (refer excerpt of Table 6.1 of the RFWP below), which is based on "habitat methods" though no detail is included in the plan as to what specific methods were used or when. The limits of this policy generally apply to the taking of water, however this policy needs to be considered during the assessment of any application to use, dam or divert water.

The RFWP recognises that under most circumstances flows in the river or stream should not fall below the minimum flow. However, in low flow conditions rivers may occasionally drop below the minimum flows even if no water is abstracted.

Table 2-2: Part of Table 6.1 of the Wellington Regional Freshwater Plan

Table 6.1 Minimum Flows and Water Allocation for Some Rivers in the Wellington Region

Column 1	Column 2	Column 3 Policy 6.2.1(1)	Column 4 Policy 6.2.1(2)	Column 5 Policy 6.2.1(3)	Column 6 Policy 6.2.1(4)		Column 7 Policy 6.2.1(4)	
Part of the **river/ stream** within which allocations in columns 4, 5 6 & 7 apply	The **location of recorders** where flows in columns 3, 5, 6 & 7 are measured	**Minimum Flow** (litres/second)	**Core Allocation** (litres/second)	Flow required for **supplementary allocation** (litres/second)	Flow below which **first stepdown** allocation takes effect (litres/second)	**First stepdown** allocation (litres/second)	Flow below which **second stepdown** allocation takes effect (litres/second)	**Second stepdown** allocation (litres/second)
Waitohu Stream from the headwaters to the boundary of the coastal marine area	At the Kapiti Coast District Council Water Supply Intake	140	57	250	180	40	150	20
Otaki River from the headwaters to the boundary of the coastal marine area	At the Lower Gorge	2550	2120	5175	4375	1820	3975	1400
Mangaone Stream from the headwaters to the boundary of the coastal marine area	At the Ratanui Recorder Site	22	25	80	45	21	30	10
Waikanae River (Option A) from the headwaters to the boundary of the coastal marine area	At the Water Treatment Plant	750	290	2000	900	150	750	120
Waikanae River (Option B) from the headwaters to the boundary of the coastal marine area	At the Water Treatment Plant	750		750				

The RFWP gives two minimum flow and water allocation options for the Waikanae River (Option A and B). When resource consent applications are made for community water supply, the applicant can advise the consent authority on which of the two options it should have regard to when considering the application. In 2004 when Council sought to renew its water permit for the abstraction of water from the Waikanae River for the urban water supply, Council adopted Option B for the application. Under this option, 750 L/s is the minimum flow below which all abstractions should cease and there are no core or stepdown allocations. This means that Council has less security of supply than users of other rivers at times of low flow. In return for the reduction in security of supply, the policy allows the allocation of all the water above minimum flow.

Under option A, the minimum flow (750 L/s) is the flow that the policy aims to achieve under most low flow conditions by allocating a core amount of water from the river (column 4) which is reduced, according to the first and second stepdown allocations (columns 6 and 7), as river flows recede. The minimum flow is not intended as a minimum flow below which all abstractions should cease. Under this option, 290 L/s is the quantity of water that is available to be taken from the river in all but low flow conditions. It is the amount of water which will generally be allocated from a river or stream when the flow is above the flow given in column 6 (when the amount of water is below the flow in column 6, the first stepdown allocation takes effect).

Clause 3 (Column 5) of policy 6.2.1 is designed to provide flexibility when allocating water. Supplementary allocations will allow users to take advantage of the water available at higher flows and will encourage water harvesting and storage of water. A permit to abstract "supplementary" water will include a condition to the effect that the abstraction will cease when the flow in the river drops below the flow shown in column 5 of Table 6.1. Therefore, supplementary allocations differ from the core allocation in that the security of supply is lower. GWRC also retains the discretion to place a maximum limit on the supplementary allocation allowed or to allocate only a proportion of the water available.

b. Aquifers

Policy 6.2.3 sets allocation limits for aquifers in the Wellington Region. The safe yields were amended by Plan Change 3 and the current allocation limits for the Kāpiti Coast are given in Table 2-3 below. These safe yields will guide GWRC when it is issuing consents that allocate water from aquifers. The Waikanae Borefield takes groundwater from the Waimea Aquifer (referred to in the table as the Waikanae Gravel Aquifer) at a depth of around 70-90 metres.

Table 2-3: Table 6.2 from the Wellington RFWP (incorporating Plan Change 3)

Table 6.2 Aquifer Allocation Limits - Kapiti Coast

Groundwater Zone	Aquifer Depth (metres)	Safe Yield (~~m^3/day~~ million cubic metres per year)
Waitohu	2-10	~~8,020~~ 2.9
	20-30	~~4,390~~ 1.6
	50-60	~~5,150~~ 1.9
Otaki	4-11	~~18,250~~ 6.7
	19-35	~~12,470~~ 4.6
Coastal	5-30	~~6,630~~ 2.4
	35-56	~~4,740~~ 1.7
	100-107	~~4,740~~ 1.7
	164-172	~~2,840~~ 1.0
Hautere	10-30	~~7,380~~ 2.7
	40-70	~~5,430~~ 2.0
	90-150	~~5,430~~ 2.0
Waikanae (Sand Aquifer)	0-45	~~14,450~~ 5.3
Waikanae (Gravel Aquifer)	10-17	~~4,200~~ 1.5
	> 40	~~10,700~~ 3.9
Raumati/Paekakariki	0-6	~~5,980~~ 2.2
	> 6	~~7,090~~ 2.6

2.4 Water Demand – Now and Future

This section of the report presents the findings from a review of historical water consumption data for the Waikanae-Paraparaumu-Raumati (WPR) water supply. Following the analysis of the historical data, the future demand for the WPR is forecasted through to 2060 for differing population growth and demand scenarios. These forecasts will inform the Kāpiti Water Supply Project with regards to the appropriate amount of headroom to incorporate in the future supply solution at this stage.

Council collects data from a number of flowmeters and commercial water meters to build a picture of water use in the District. Consequently, as the KWSP progresses, there is an increasing amount of data about water use available. Work is also underway to improve data in order to better understand unaccounted for water, commercial water use and demand patterns for the WPR water supply. The forecasted demands will be reviewed in light of this additional information and be incorporated in the preliminary and detailed design stages for the preferred solution.

2.4.1 Current Overall Daily Demand

The Waikanae Water Treatment Plant (WTP) delivers water to the Riwai and Kakariki reservoirs, which respectively service the Paraparaumu-Raumati and Waikanae supply areas. Daily water consumption (in m^3/day) for the two supply areas is measured by flowmeters at the outlets of these two reservoirs (refer Figure 2-1).

There are some residential properties (approximately 190) between the Waikanae WTP and Riwai Reservoir that are served from the bulk supply main upstream of the reservoir. Consequently these properties are included in the per person consumption figures even though their demand is not included in the total water consumption data.

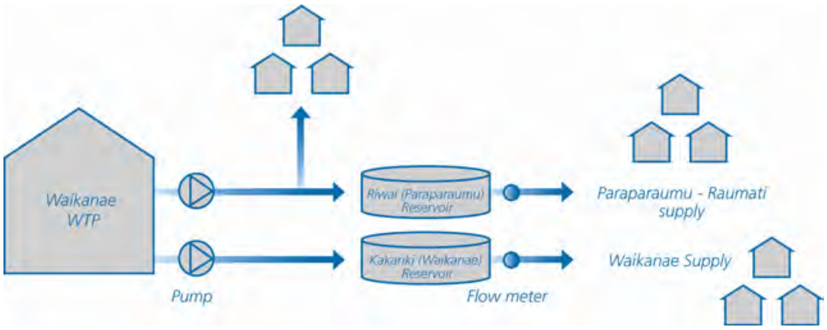


Figure 2-1: Consumption Flow Metering Locations

Daily water consumption data for the period from July 2000 to June 2010 has been supplied by Council and this data is graphed in Figure 2-2. It can be seen from the graph that demand seems to be generally increasing, which would be expected with an increasing population.

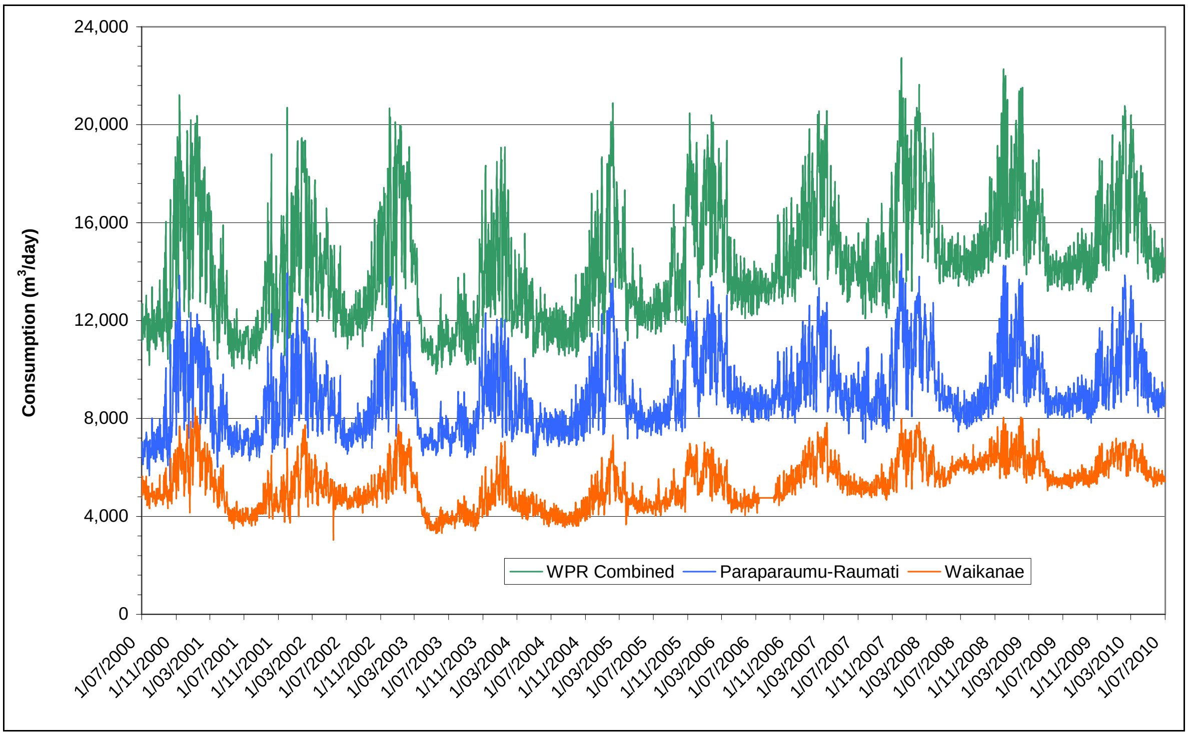


Figure 2-2: Water Consumption for Waikanae, Paraparaumu & Raumati (July 2000-June 2010)

An interesting feature of Figure 2-2 is the steep reduction in water demand in the period February to April 2003. The Kāpiti Coast experienced a drought at this time that had a return period of about 20 years, and the reduction in water demand was the result of strict water restrictions and significant media coverage of the drought. The minimum demand recorded in 2002/03 was 9,828 m^3/day which occurred on 17 May 2003 and was equivalent to approximately 294 L/person/day.

Another noticeable feature of the graph is the low peak demand in 2003/04. This reduced water demand compared to the preceding and following years is likely due to the wet summer experienced in 2003/04.

The average day demand (ADD) and peak day demand (PDD) for each year for the combined WPR supply are given in the following table. The table shows that the peak days often occur at the beginning of the summer (i.e. November or early December) rather than at the typical height of summer (i.e. February). This may be due to increased irrigation in spring/early summer of gardens that are being re-established after the winter. The peak day for the most recent summer was in early February, which is probably reflective of the wetter spring/early summer in 2009/10.

Total water consumption is influenced by changes in population and climatic conditions at the time. The total rainfall and number of sunshine hours and average soil moisture content (measured at the NIWA climate station at the Paraparaumu Aerodrome) for each summer period of November to March is given in the table below to give an indication of whether the summer for a year was particularly wet or dry. The influence of climate on demand is considered further in the following section.

For reporting water use, Council define the summer period as being from 1 November to 31 March. This is based on the Ministry for the Environment's bathing season monitoring period.

Table 2-4: Annual Demand Summary for WPR Water Supply[5]

Year	ADD (m^3/day)	PDD (m^3/day)	Date of PDD	PDD/ ADD	Total Rainfall Nov-Mar (mm)	Total Sunshine Nov-Mar (hrs)	Ave. Soil Moisture Nov-Mar (%)
2000/2001	13,733	21,208	12-Nov-00	1.54	188	1135	3.3
2001/2002	13,585	20,636	2-Dec-01	1.52	539	967	12.2
2002/2003	13,543	20,658	2-Dec-02	1.53	202	1173	4.0
2003/2004	12,808	19,073	4-Jan-04	1.49	628	931	8.9
2004/2005	13,283	20,867	6-Feb-05	1.57	394	1077	8.4
2005/2006	14,661	20,391	7-Nov-05	1.39	290	1112	4.1
2006/2007	14,974	20,549	12-Feb-07	1.37	390	1017	14.3
2007/2008	15,693	22,705	3-Dec-07	1.45	290	1148	10.6
2008/2009	15,800	22,163	1-Dec-08	1.40	363	1089	12.1
2009/2010	15,547	20,753	7-Feb-10	1.33	320	983	13.2

2.4.2 Overall Daily Demand per Person

The daily total consumption figures can be expressed as an overall demand per person, which removes the influence of population growth from the figures. Table 2-5 shows the annual average and peak day demands on a per person basis. This is calculated by dividing the annual average and peak day demands by the estimated population, and therefore the demand includes commercial/industrial use and losses. The estimated population is based on the 2001 and 2006 Census usually resident population figures and the forecasted population since 2006 with medium growth.

[5] Rainfall, sunshine and soil moisture figures calculated from data from NIWA's online climate database.

Table 2-5: Annual Demand Summary for WPR Supply as L/person/day

Year	Population	ADD (L/person/day)	PDD (L/person/day)
2000/2001	31,941[6]	430	664
2001/2002	32,698	415	631
2002/2003	33,455	405	617
2003/2004	34,213	374	557
2004/2005	34,970	380	597
2005/2006	35,727[7]	410	571
2006/2007	36,278	413	566
2007/2008	36,829	426	616
2008/2009	37,381	423	593
2009/2010	37,932	410	547

Council's target peak day demand is 400 L/person/day (incorporating commercial/industrial demands), which is a design requirement for the Kāpiti Water Supply Project. In addition, the design requirements include an allowance of 90 L/person/day for unaccounted for water (losses). The average peak day demand across the years 2003/04 to 2009/10 is 580 L/person/day (including losses). Therefore to meet the design requirements, the peak day demand needs to be reduced by about 90 L/person/day.

The following graphs compare the annual peak day demands with the summer rainfall, sunshine and soil moisture content (from Table 2-4). Typically years with a higher number of sunshine hours in the summer have a higher peak day demand.

[6] 2001 Census usually resident population

[7] 2006 Census usually resident population

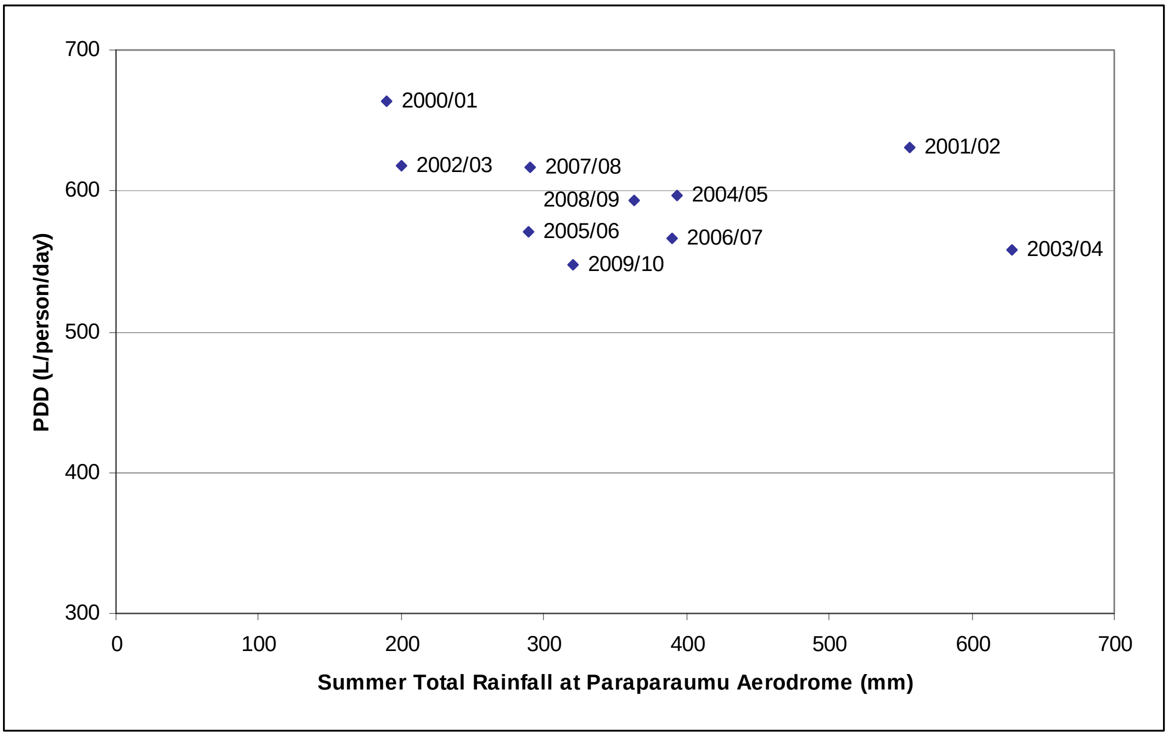


Figure 2-3: Annual Peak Day Demand vs. Summer Rainfall

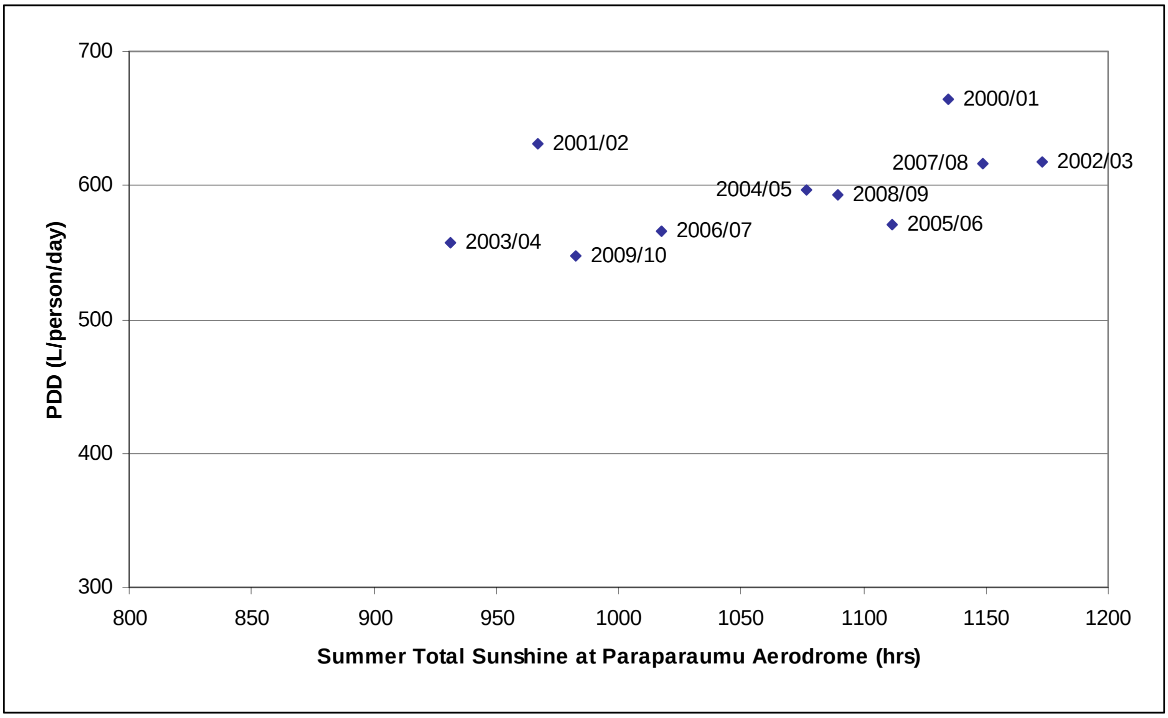


Figure 2-4: Annual Peak Day Demand vs. Summer Sunshine Hours

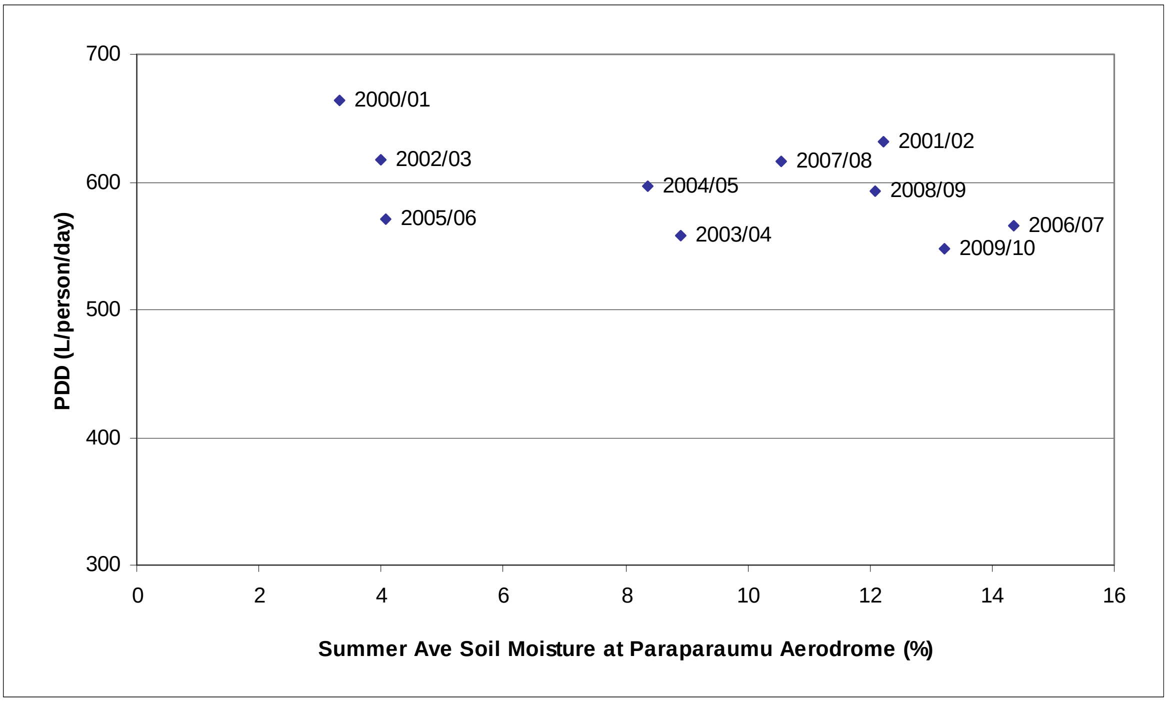


Figure 2-5: Annual Peak Day Demand vs. Summer Average Soil Moisture Content

The following graph shows the annual peak day demands for the two supply areas of Paraparaumu-Raumati and Waikanae, and the combined WPR supply. The peak overall consumption of water per person in Waikanae is approximately 150 L/person/day more than in Paraparaumu-Raumati. The peak demand in Waikanae has been fairly consistent since 2003 and is much lower since 2002/2003. This may be due to water conservation work and a change of behaviour following the drought of 2002/2003. There is an obvious reduction in the peak demand in Waikanae in the past year, which may be related to the low number of sunshine hours for the 2009/10 summer.

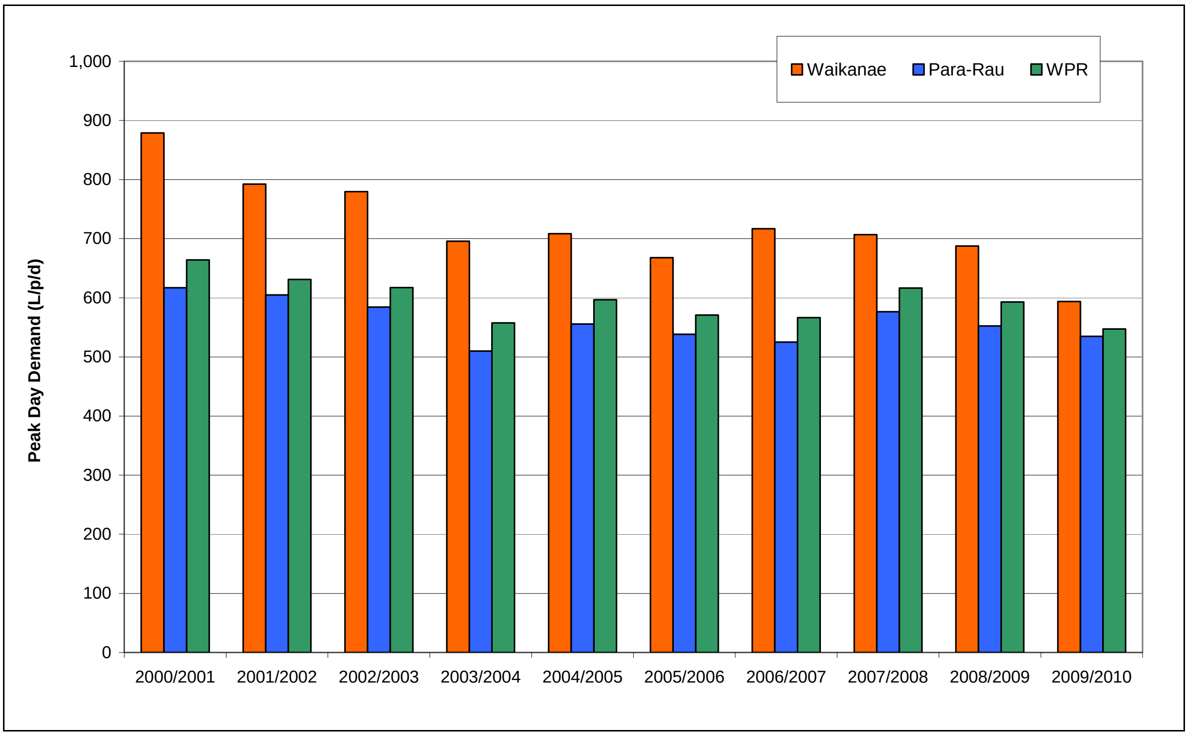


Figure 2-6: WPR Annual Peak Day Demand per Person

2.4.3 Seasonal Variations

The following graph of quarterly peak day demands shows how WPR's water demand is seasonally variable. The year has been split into quarters, where January, February and March form the first quarter (Q1) and so on. As would be expected, the peak day demand is highest in either the fourth or first quarter of a year when temperatures are warmer and there is more water used for garden watering.

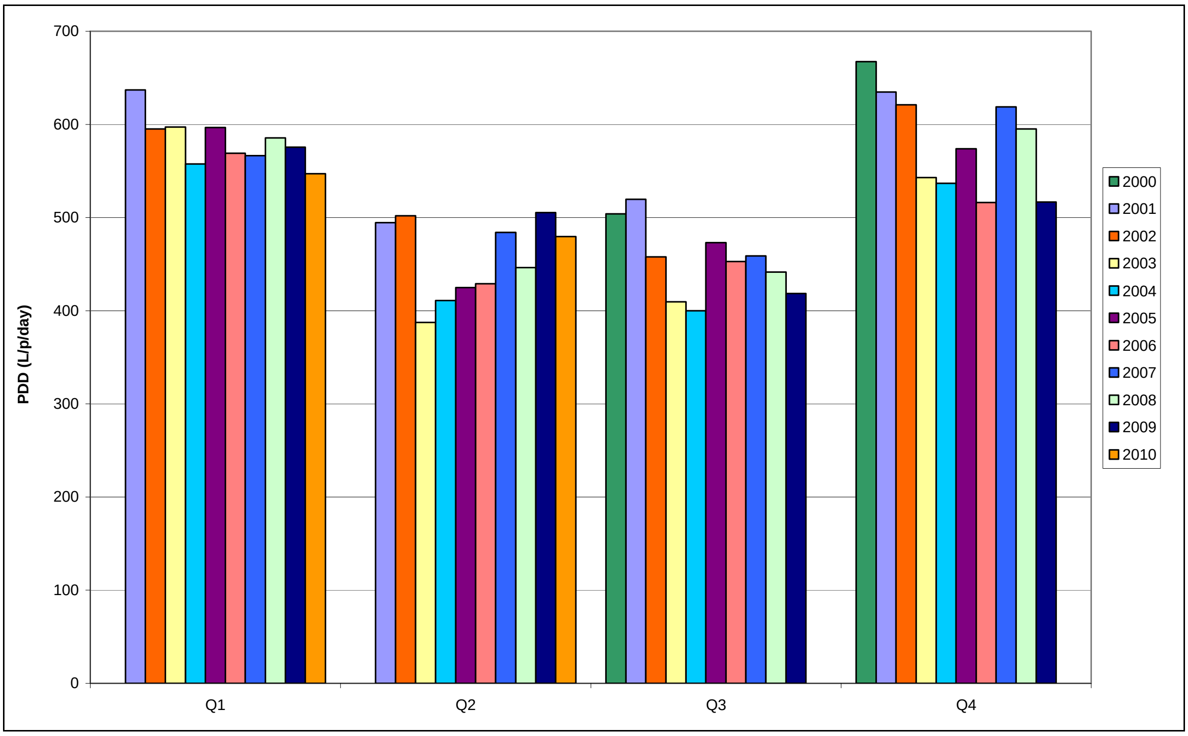


Figure 2-7: WPR Quarterly Peak Day Demand

2.4.4 Forecasting Future Demand

a. Design Requirements

The *Preliminary Status Report* derived the design requirement for the Kāpiti Water Supply Project of peak day demand at 26,000 m^3/day in 2060. This was based on Council's target peak day demand of 400 L/person/day (including commercial/industrial use), medium population growth, and an allowance for unaccounted for water (losses) of 90 L/person/day.

b. Population Projections

Since preparing the *Preliminary Status Report* the population projections for the WPR area and Kāpiti District have been reviewed and revised by Monitoring and Evaluation Research Associates Ltd (MERA) to bring them into line with the population projections used in Council's 2009 LTCCP. The projected WPR population in 2060 under the medium growth scenario is now 2,082 lower than the previous projection.

The revised population projections for the WPR supply area under three growth scenarios are shown in the graph below and key figures are given in Table 2-6 for the medium and high growth scenarios. The projections for Waikanae and Paraparaumu-Raumati through to 2031 come directly from MERA. The population projections for beyond 2031 are based on MERA's population projections for the Kāpiti District as a whole through to 2061 and assume that the proportion of the total Kāpiti District population that lives within the WPR supply area remains constant from 2031 onwards.

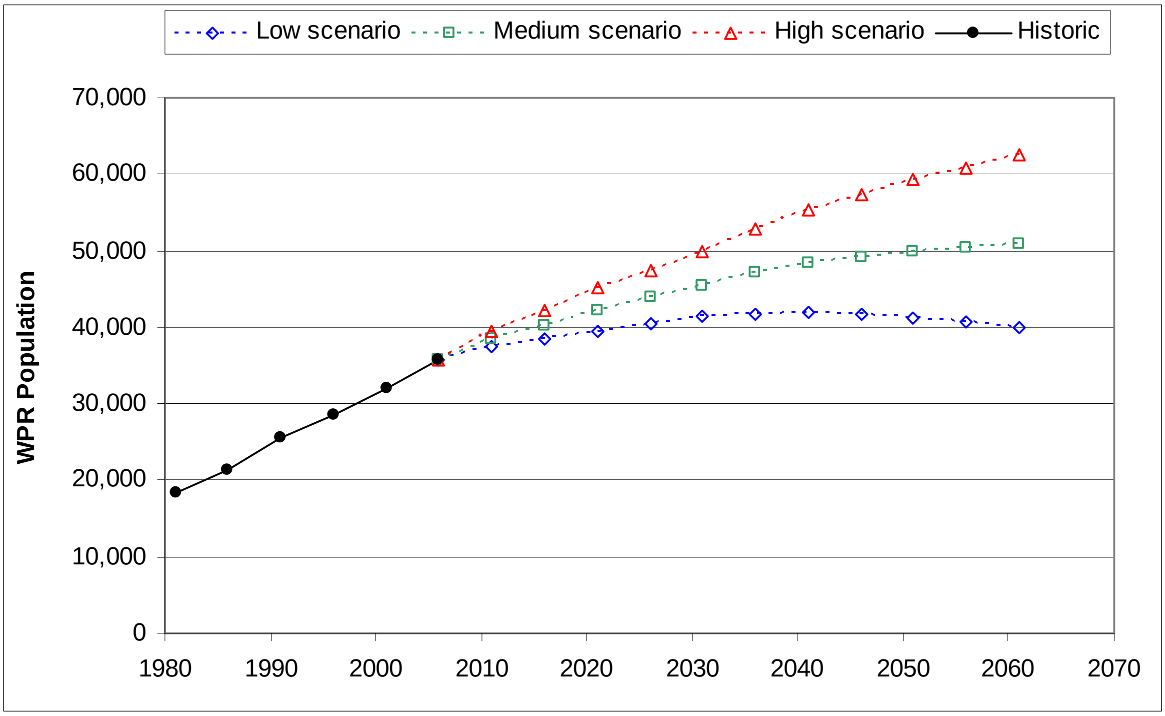


Figure 2-8: WPR Population Projections

The LTCCP 2009 includes a Development Contributions policy based on the medium growth scenario. For this reason and for consistency with Council's other policy settings, the medium growth scenario has been used to arrive at the design requirement of peak demand in 2060. Both the medium and high growth scenarios will be used in this section when considering demands and headroom.

Table 2-6: WPR and Kāpiti District Population Projections

Year	2006	Medium Growth			High Growth		
		2010	2036	2060	2010	2036	2060
Waikanae	10,488	12,074	16,930	18,256	12,294	19,786	23,276
Paraparaumu-Raumati	25,239	25,857	30,121	32,480	26,390	33,062	38,892
WPR Total	35,727	37,932	47,051	50,736	38,684	52,848	62,168
Kāpiti District	46,197	48,698	61,101	65,885	49,651	68,241	80,276

The 2060 projected populations represent an increase of 34% and 61% on the projected 2010 population for the medium and high growth scenarios respectively.

c. Demand Projections

Using the design requirements of peak day consumption of 400 L/person/day (incorporating commercial/industrial demands) and unaccounted for water (losses) of 90 L/person/day together with the medium and high population projections, the forecasted peak day demands in 2060 are 24,860 m^3/day and 30,460 m^3/day. This assumes that the Council's water conservation programme is successful in reducing demand to the Council's target. Figure 2-9 assumes the target is met by 2020.

The average of the observed annual peak day demands from 2003/04 to 2009/10 is 580 L/person/day (including losses). Using this demand (instead of 490 L/person/day) with the medium and high population projections, the forecasted peak day demands in 2060 are 29,430 m^3/day and 36,060 m^3/day (refer Figure 2-9).

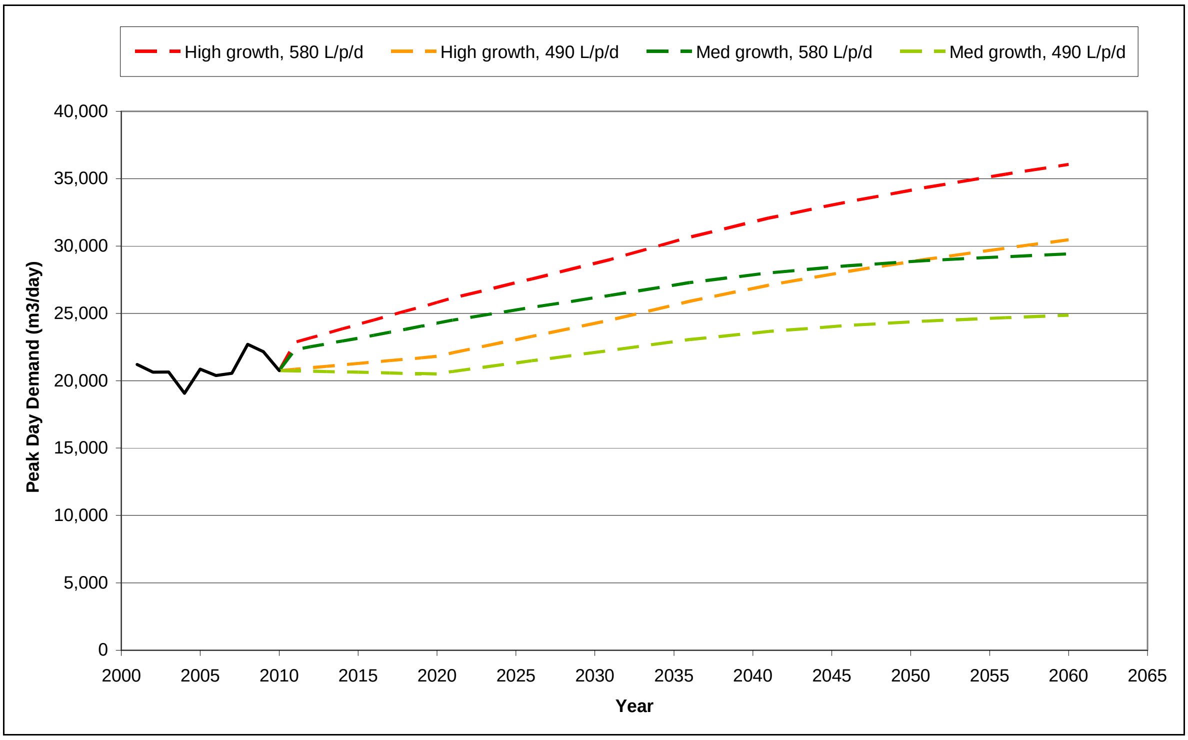


Figure 2-9: Peak Demand Projections

Even though the forecasted population in 2060 is now lower than the population originally used to derive the design peak day demand of 26,000 m^3/day, the resulting difference in demand is small (1,140 m^3/day). For consistency with previous reports (*Preliminary Status Report and Option Selection Report*), this report continues to use 26,000 m^3/day as the design peak day demand. This figure will be reviewed as the project progresses and additional population data becomes available (e.g. Census 2011).

d. Interim Headroom Allowance

There are a number of uncertainties associated with forecasting demand for the next 50 years:

- Future population growth
- Future commercial and industrial growth and demands
- The effectiveness of conservation measures to reduce demand
- The impact of climate change on demand
- Whether the allowance for losses of 90 L/person/day is a reasonable reflection of reality, which doesn't change over the planning horizon.

To accommodate these uncertainties, a headroom allowance will be made in the design requirement for yield. This will be an interim figure until the work currently underway or planned for investigating unaccounted for water and demand patterns is further advanced.

Based on the graph above, it has been decided to adopt an interim peak day yield of 32,000 m^3/day, which provides a working headroom allowance of 6,000 m^3/day on top of the design peak day demand of 26,000 m^3/day. This is expected to cover the possible eventualities of higher population growth, higher demand (either residential or commercial/industrial), greater losses and climate change impacts.

2.5 Water Resources

2.5.1 Waikanae River

The Waikanae River drains the southwestern portion of the Tararua Ranges. The catchment above the water treatment plant predominantly comprises indigenous and exotic forest and pasture. The major tributaries of the Waikanae river are the Ngātiawa River, Rangiora River, Reikorangi Stream and Maungakotukutuku Stream.

Greater Wellington Regional Council (GWRC) monitors the flow in the Waikanae River at a gauging station immediately upstream from the Waikanae WTP. This gauging station (Waikanae at WTP) has been in operation since 1975. The GWRC website[8] provides period of record flow statistics for the Waikanae River, which are repeated in the tables below. A review of the low flow statistics in conjunction with GWRC is planned for the next stage of this project.

Table 2-7: GWRC Waikanae River at WTP Low Flows

Return Period (Year)	Average Annual Probability (%)	Flow (L/s)	
		1 Day	7 Day
Mean annual low flow		950	1,047
5 year low flow	20	715	788
20 year low flow	5	577	635
50 year low flow	2	517	570
100 year low flow	1	481	530

Table 2-8: GWRC Waikanae River at WTP Flood Flows

Return Period (Year)	Average Annual Probability (%)	Flow (L/s)
2 year flood	50	159,000
5 year flood	20	212,000
10 year flood	10	254,000
20 year flood	5	295,000
50 year flood	2	348,000
100 year flood	1	388,000

Daily mean flows from March 1975 to October 2009 have been obtained from GWRC and analysed. The average daily mean flow from this period is 4,770 L/s. The lowest daily mean flow on record is 660 L/s, which occurred in April 2003.

[8] http://www.gw.govt.nz/waikanae-river-at-water-treatment-plant/show/46

2.5.2 Groundwater

Drilling in the Waikanae area has identified a series of sand and gravel aquifers separated by silt, clay and peat aquitards.

A shallow unconfined aquifer extends to a depth of approximately 30 m; a number of existing domestic bores target this aquifer.

Beneath the unconfined aquifer is the 20-30 m thick Parata aquifer. The Parata aquifer is semi-confined with unconfined conditions near the ranges and confined conditions near the coast. The aquifer consists of sand and gravel separated by silt.

An aquitard underlies the Parata aquifer. This unit is 5-10 m thick and comprises mainly sand with a silt component and minor shell fragments; however a high yielding gravel layer (aquifer) of up to 3 m thick has been identified within this unit locally. The existing production well K4 abstracts water from this gravel layer.

The deepest of the sand aquifers (the Waimea aquifer) is encountered at approximately 70 m depth. The production wells (other than K4) of the Waikanae Borefield abstract water from this aquifer. Greywacke basement rock underlies the Waimea aquifer. The thickness of the Waimea aquifer is generally unproven but in three of the existing production wells the bed rock has been encountered at some 90 m depth suggesting an aquifer thickness of 20-30 m. The Waimea aquifer comprises brown and blue gravel with silt and silt-bound gravel layers. This aquifer is considered to be semi-confined.

The general groundwater flow direction is from the foothills (SE) towards the coastline (NW). The horizontal extent of the sand aquifer system varies from about 2,000 m to 5,000 m wide as shown approximately in Figure 2-10 (area enclosed by the thick red line).

The geological and pumping test data available suggests that the aquifers extend to the north and south. Because the soils are alluvial, they will vary from place to place, but further successful well sites are expected to be found. The Waimea aquifer is expected to extend offshore to the west below the seabed.

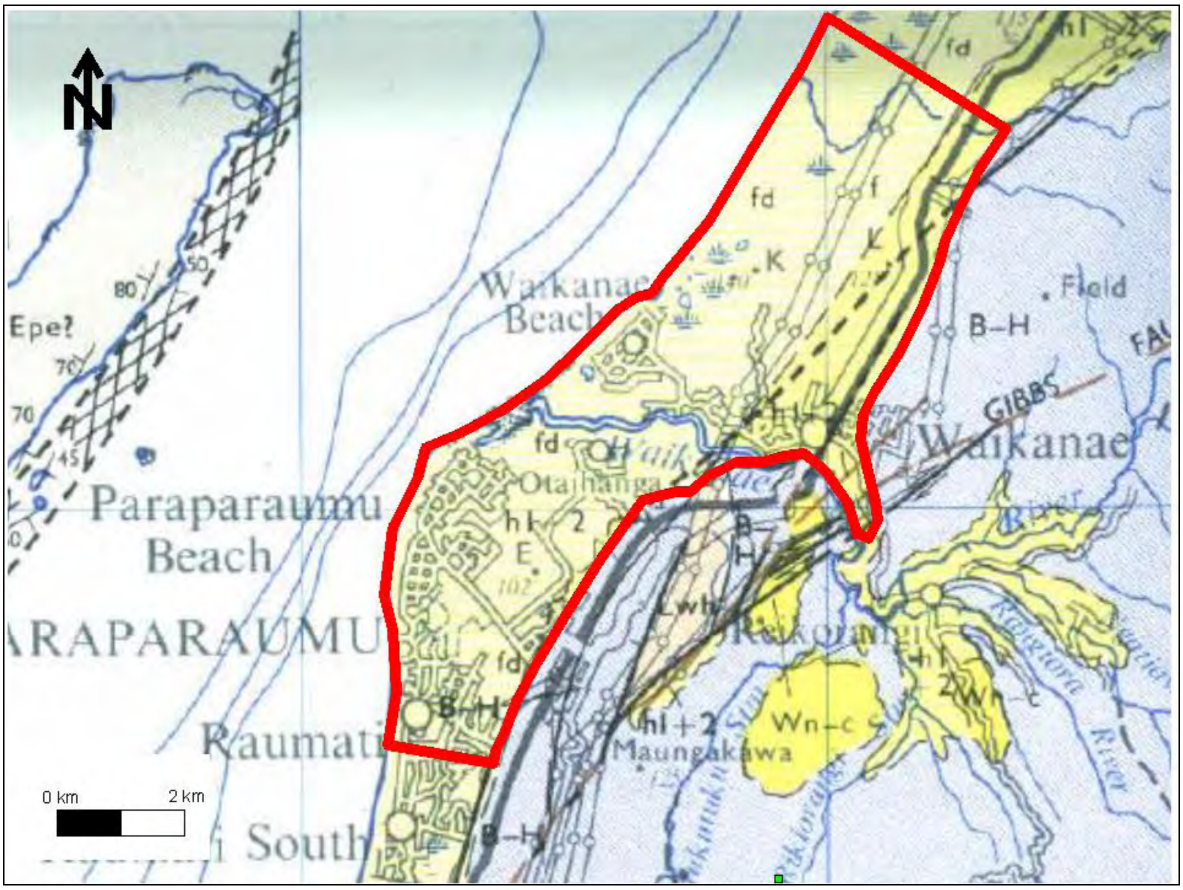
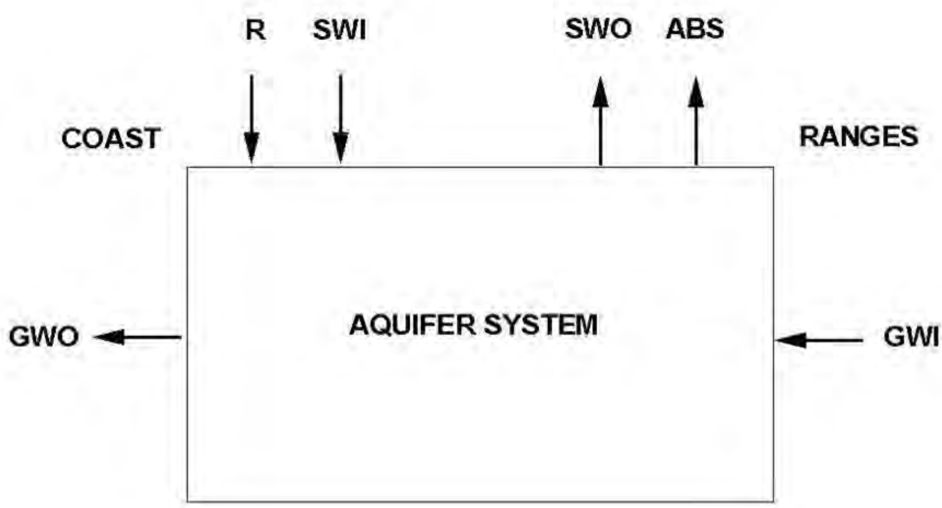


Figure 2-10: Geological map showing extent of the aquifer system

A simplified mass balance diagram is shown in Figure 2-11. This shows where groundwater is coming from and going to.



GWI: Inflow from ranges in east | GWO: Outflow to sea
SWO: Outflow to rivers and streams | SWI: Inflow from Waikanae River
ABS: Abstraction | R: Rainfall recharge

Figure 2-11: Groundwater Mass Balance

The Waikanae Borefield comprises 9 bores in the Waikanae area, although only 6 of the 9 bores are used for production and connected by a pipeline to the Waikanae WTP. These 6 bores are named K6, K5, K4, Kb4, K10 and K13. The other 3 bores are named Kb7, K12 and TW2. The borefield was commissioned in October 2005 and has been used for supplementary supply on a number of occasions of varying duration since then.

2.6 Water Quality

2.6.1 Waikanae River

The Waikanae River water quality is monitored on a monthly basis by Greater Wellington Regional Council, although major ions are not routinely monitored.

Information about the major ion chemistry of the river is available from the results of NIWA's "100 Rivers" program. As part of this program the Waikanae River at SH1 (1 km downstream of the WTP) was sampled on three occasions in 1987 when flow was less than median flow. The raw river water was also sampled at the WTP in June 2003 and December 2005 and analysed for major ions.

The results of analyses of the Waikanae River quality in the vicinity of the WTP from the 100 Rivers study, Council's own sampling and NIWA's investigations for this project (total of 9 samples) are summarised in the following table.

Table 2-9: Summary of Waikane River Water Quality

Parameter	Units	Median	Range
pH		7.4	6.8 - 7.6
Total Dissolved Solids	g/m^3	56	n/a
Conductivity	mS/m	10.2	9.1 - 11.2
Total Hardness	g/m^3 as $CaCO_3$	19.4	18.6 - 22.0
Alkalinity	g/m^3 as $CaCO_3$	19.8	16.0 - 21.0
Bicarbonate	g/m^3	24.0	19.5 - 26.0
Calcium	g/m^3	4.8	4.5 - 5.9
Magnesium	g/m^3	1.8	1.6 - 2.0
Sodium	g/m^3	9.8	8.5 - 12.3
Chloride	g/m^3	14.9	13.3-18.7
Ammoniacal-Nitrogen	g/m^3	<0.01	n/a
Dissolved Reactive Phosphorus	g/m^3	0.0075	0.006 - 0.009
Total Iron	g/m^3	0.03	<0.02 - 0.06
Total Manganese	g/m^3	0.0010	0.0007 - 0.0016

2.6.2 Groundwater

The results of analyses of the groundwater quality from each of the production wells within the Waikanae Borefield are summarised in the following table.

Table 2-10: Groundwater Quality Summary

Parameter	Units	Bore – Median					
		K6	K5	K4	Kb4	K10	K13
pH		7.8	8.1	7.5	7.9	7.8	7.5
Total Dissolved Solids	g/m^3	620	592	320	666	438	1615
Electrical Conductivity	mS/m	112	104	59	123	77	266
Total Hardness	g/m^3 as $CaCO_3$	155	134	31	176	164	450
Alkalinity	g/m^3 as $CaCO_3$	249	238	104	184	217	146
Bicarbonate	g/m^3	301	287	126	223	263	177
Calcium	g/m^3	38	31	4	45	46	100
Magnesium	g/m^3	14	14	5	16	12	50
Sodium	g/m^3	182	174	116	182	95	347
Chloride	g/m^3	209	183	97	280	113	740
Total Iron	g/m^3	0.40	0.06	0.06	0.05	0.18	0.12
Total Manganese	g/m^3	0.09	0.07	0.15	0.03	0.16	0.50

K4 generally has better water quality than the other bores with respect to dissolved solids and hardness, although it does show higher levels of manganese. Bore K4 is screened at a slightly shallower depth than the other bores and is now believed to draw water from a different aquifer (Parata).

Bore K13 has much lower water quality than the other bores, with high levels of ions that contribute to median total dissolved solids (TDS) and hardness concentrations that are more than double the other bores. The concentration of total manganese in the water from bore K13 is also much higher than the other bores.

Age dating of the bore water was undertaken by IGNS on samples collected in September 2005. All of the wells, except K13, had no tritium indicating a mean residence time greater than 100 years.

Radiological testing of the bore water was undertaken in 2005, and although the total alpha concentration of bores K6 and K13 (and potentially Kb4) exceeded 50% of the DWSNZ Maximum Acceptable Value (MAV), the total alpha concentration of the overall water supply (rather than a water source) does not exceed 50% of the MAV, and therefore it was not assigned as a Priority 2 determinand. These results have been discussed with the Ministry of Health Drinking Water Assessor and further clarification is required on this interpretation. It is important to note that the results show that none of the bores exceeded the MAV and thus there are no health concerns associated with this issue.

If the Waikanae Borefield is modified and retained as part of the WPR water supply solution, it is recommended that further radiological testing be undertaken during preliminary design to further investigate the radioactivity of the bore water and confirm its suitability for water supply.

2.7 Water Treatment

Once abstracted from either the Waikanae River or the borefield, water is treated at the Waikanae Water Treatment Plant (WTP). This section provides an overview of the existing process used at the treatment plant to provide treated water to the consumers in the WPR area. This is important, because:

- some of the options being investigated will require treatment of raw water qualities that are different from what the existing treatment process can cope with
- in all cases the plant will require an increase in capacity (to a nominal working figure of 32,000 m^3/day) to meet demand for the next 50 years.

The following figure (Figure 2-12) provides an overview of the existing treatment plant in terms of the treatment process and key elements of the plant.

In summary, the key process steps in the existing WTP are as follows:

- River intake:
  - Weir formed of piles and a concrete beam weir crest, and rock riprap
  - Concrete channel on right bank with screened side wall allowing water to flow into pump station wetwell
- Raw Water Pump Station:
  - Reinforced concrete wetwell and vertical shaft; topped by building housing pump motors and valves
  - Two (duty/standby) vertical turbine pumps
- Borefield Pre-Treatment:
  - Potassium permanganate dosing for manganese removal
  - Aeration tower
- Coagulation / Flocculation:
  - Coagulant dosing (alum or poly-aluminium chloride (PACl))
  - Mechanical flocculators
  - Polyelectrolyte and powdered activated carbon (PAC) dosing
- Clarifier:
  - Single 24.5 m diameter reactor clarifier
- Filters:
  - Four rapid gravity sand/anthracite filters
  - Sequential air scour and water backwash
- Ultraviolet Disinfection:
  - One (duty only) medium pressure UV disinfection reactor
- Clearwater / Chlorine Contact Tank

- Treated Water (High Lift) Pumps:
  - Six vertical turbine pumps
- Sludge / Waste Water / Residuals:
  - One sludge thickener (receiving sludge from clarifier)
  - Two filter backwash holding tanks
  - Grit tank
  - Recovery tank from which sludge and waste water is pumped to Waikanae sewerage system.

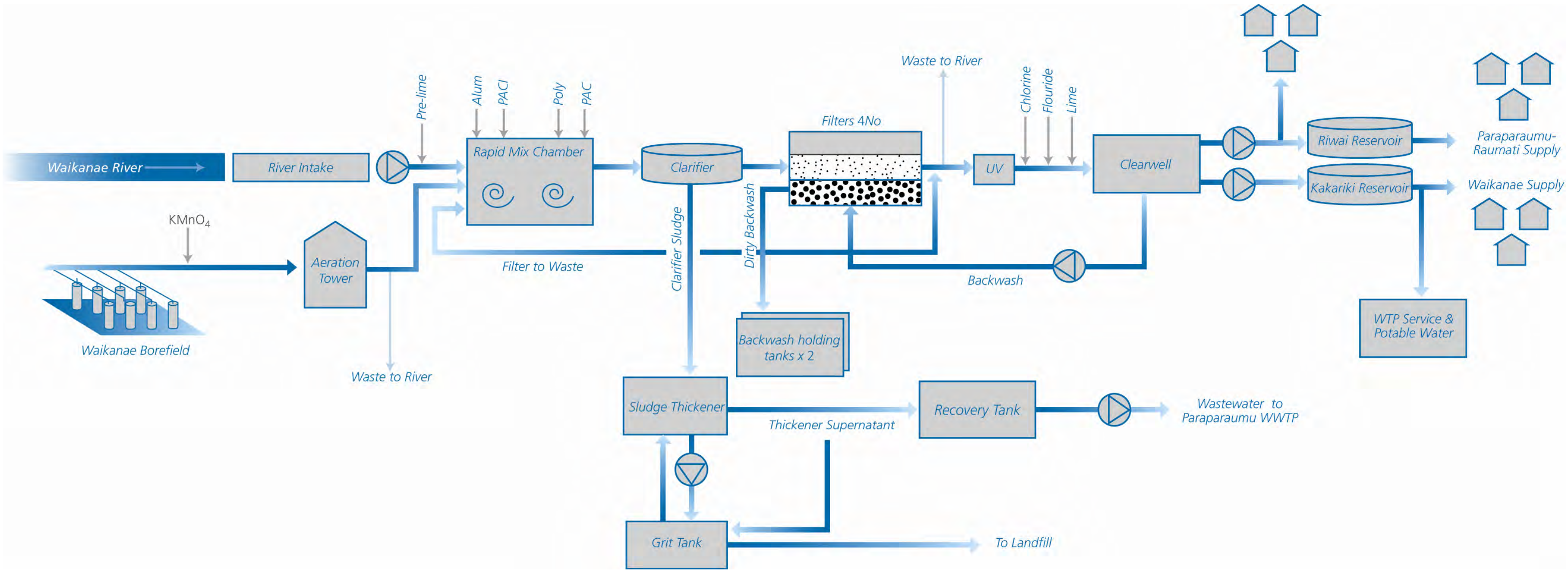


Figure 2-12: Process Flow Diagram for the Waikanae Water Treatment Plant

3 Methodology

3.1 Approach

This section of the report provides the reader with an overview of the multi-disciplinary methodology for the concept design development, and the investigations that have been carried out in order to undertake the design and costing of the options.

In Part B of this report, each of the options is described, and this section follows the same approach. That is, the methodology for each of the following issues/activities is described:

- Concept Design
- Yield
- Treatment
- Environmental Assessment
- Consultation
- Risk Assessment
- Cost Estimates.

3.2 Concept Design

Concept design for the options has been undertaken by CH2M Beca and Damwatch. The concept designs are described in Part B. With regards to the methodology used to produce the designs, the main points to note are that each option has involved a multi-disciplinary design team and the concept designs have been guided by the design requirements which are described in Section 1.4 below.

There have been on-site geotechnical investigations at the Kapakapanui and Maungakotukutuku dam sites to better understand the geology of these sites and thereby allow for more confidence in the proposed concept designs. These investigations have involved site walkovers, surface mapping, test pitting and drilling. A summary of the results of the geotechnical investigations are included with the detail about the relevant option in Part B of this report.

3.3 Yield

Modelling has been undertaken to assess the quantity of water available from both surface water and groundwater.

3.3.1 Surface Water Yield Modelling

Surface water yield modelling of the six options was undertaken using a daily time-step Excel spreadsheet model developed for this project. The model is known as the “KCWS model”. One of the purposes of the modelling was to determine the required storage volumes for the dam and storage pond options. The KCWS model is set up to allow the user to adjust parameters (including storage capacity) to ensure that demand for water can be satisfied with no shortfall.

The key inputs to the model were:

- Flows in the Waikanae River catchment and sub-catchments
- Water supply demand profile
- Abstraction rules for the intake to the Waikanae WTP.

Each of the inputs is considered in the following sections.

a. Flow Data

The Waikanae River is gauged by Greater Wellington Regional Council (GWRC) immediately upstream of the Waikanae WTP intake. There are 35 years (1975-2010) of average daily flow data available. Short gaps in the flow record were filled by reference to flows in neighbouring catchments to provide a complete flow record.

The KCWS model could have been set to run the whole 35 year period of record at one go, but that removes the focus from key periods of drought and/or demand shortfall, as well as significantly adding to the size of the model. Therefore, each run of the model covers a period of four years, starting on 1st July. Four years was chosen as being long enough to allow the development of multi-season droughts and their impacts to be assessed on dam refilling and drawdown.

The next key question is which four year period to use as a basis for modelling that is representative and will allow the critical design requirements to be met. Having reviewed the 35 year record, a key four-year period was identified as being 2002-2006. This period was notable as containing the lowest daily flow and longest flow recession. It also contained some drier than normal winter conditions, which is an important consideration when considering the re-fill of storage reservoirs. Figure 3-1 shows that the lowest average daily flow of 660 L/s occurred in April 2003 following a prolonged drought period. The red line represents the minimum flow level for the Waikanae River of 750 L/s as specified in the Regional Freshwater Plan. Based on GWRC's low flow statistics for the Waikanae River[9] a flow of 660 L/s has an Average Return Interval (ARI) of 10 years.

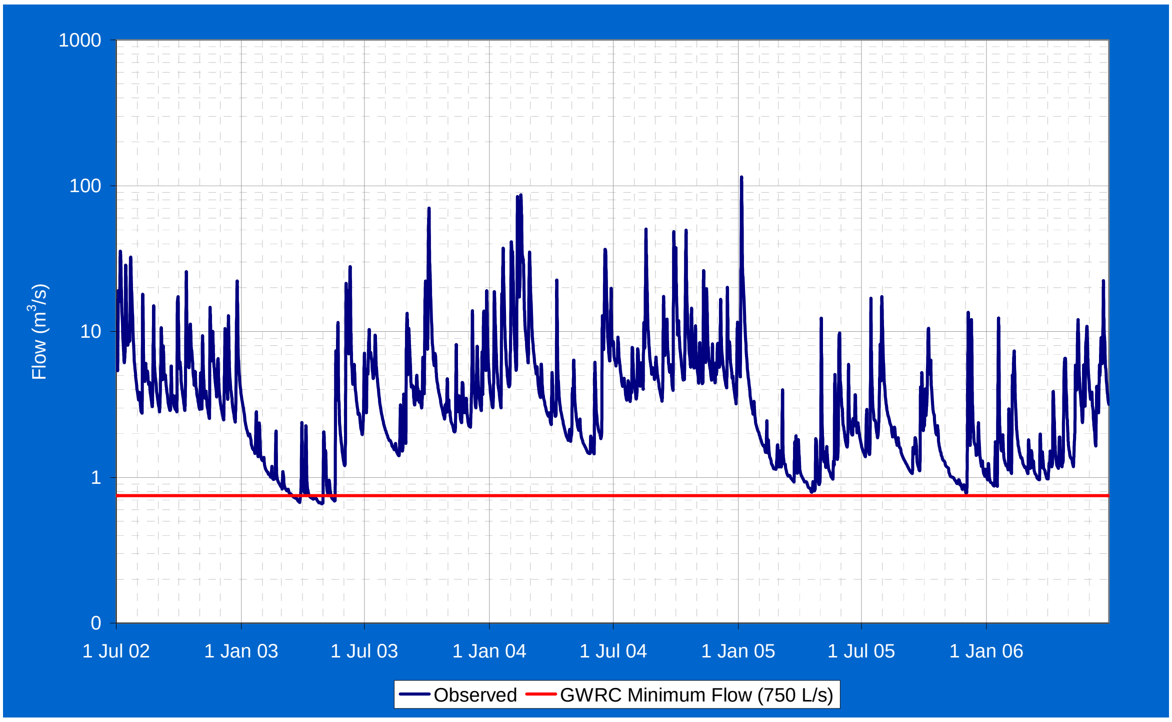


Figure 3-1: Waikanae River flow at WTP (2002-2006)

[9] http://www.gw.govt.nz/waikanae-river-at-water-treatment-plant/show/46

A requirement of the modelling was to assess the performance of options under the 50-year Average Return Interval (ARI) low flow condition. The GWRC website[10] provides period of record flow statistics for the Waikanae River, including estimates for key low flow events. The quoted 50-year 1-day low flow is 517 L/s and the 50-year 7-day low flow is 570 L/s. Taking a precautionary approach GWRC's figures have been used for the yield modelling, though they are lower than low flow statistics calculated previously for Council[11].

The quoted 50-year 1-day low flow of 517 L/s is 143 L/s (22%) less than the observed lowest flows in the 35 year record. In order to model the 50-year low flow, the observed flow recession in early 2003 was extended through until the end of April, as shown in Figure 3-2. This was achieved by removing the two small flood events that occurred around the beginning of April and extrapolating the underlying recession curve through to the end of the month.

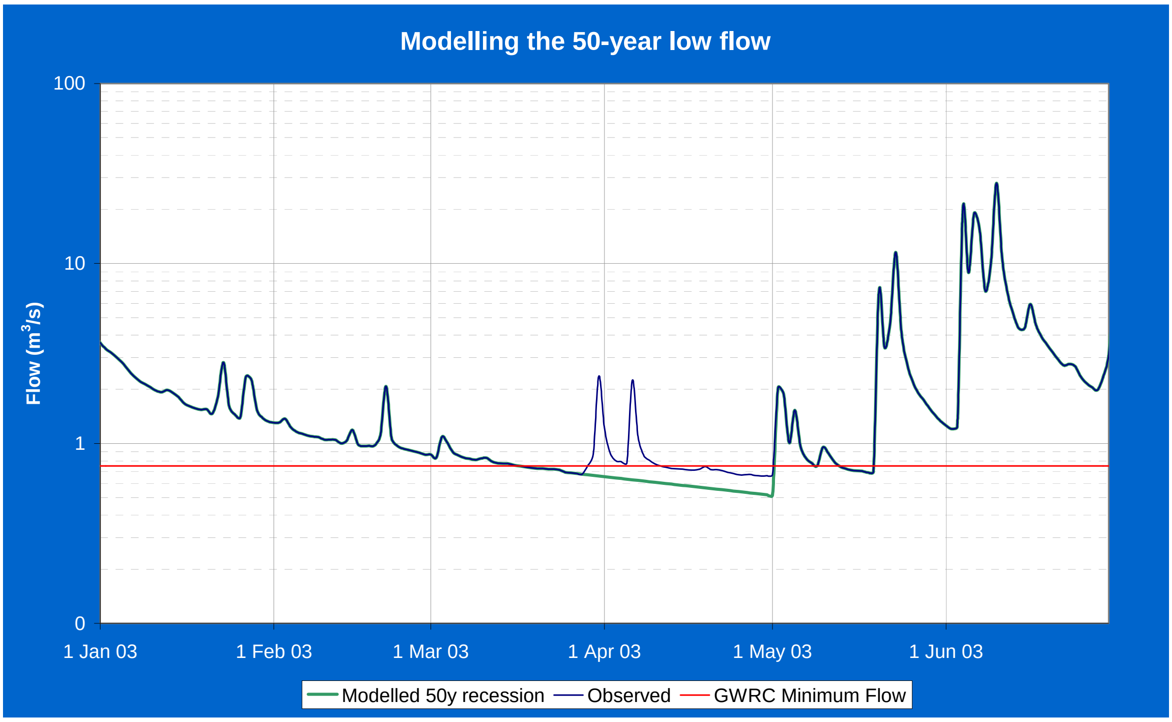


Figure 3-2: Modelled 50 Year Low Flow

This method produces a conservatively shallow recession curve, which gives a lower 50-year, 7-day[12] minimum flow than quoted on the GWRC website. An increase in the flows for a given return period would reduce the duration of the modelled flow recession and thereby decrease the demand shortfall and the live storage capacity required for the dam options.

Though the above recession was used in the modelling, the low flow statistics were discussed with GWRC officers to address concern that the GWRC low flows are too low and the difference between the GWRC 1-day and 7-day values would produce too steep a recession curve. GWRC officers agreed that the difference in 1-day and 7-day values does appear large and have offered to do a more detailed investigation if required, though some of the differences may be accounted for

[10] http://www.gw.govt.nz/waikanae-river-at-water-treatment-plant/show/46

[11] Table 3.7, *Hydrology of the Waikanae River*, Opus International Consultants Ltd for KCDC, 2004

[12] 7-day minimum – The minimum 7-day rolling average flow.

by the adoption of different methods and periods of data used. A review of low flow statistics should be undertaken in the next stage of this project.

b. Water Demand

The water supply demand for WPR was modelled using the observed daily water consumption between 1 July 2007 and 30 June 2008, which is shown as the green line on Figure 3-3. The year 2007/2008 was chosen as the basis for a general year demand profile because:

- Flows in the Waikanae River were less than the required minimum flow residual of 750 L/s at times during the summer period, indicating dry weather. In the 28-day period commencing 12 January 2008, the rainfall total was 4 mm (approximately 5-year return period).
- High water demands were recorded. For example, total recorded consumption was 22,705 m^3/day on 3 December 2007.
- The Waikanae Borefield was in place and therefore water demand would not have been as restricted as it was during the 2002/03 drought when the supplementary supply was not available and a hose ban was imposed.
- The period is relatively recent and therefore better reflects current water use behaviour than the 2000/01 year that has been used for previous analyses.

As the demand in 2007/08 was governed by the specific climatic conditions that occurred at that particular time (rainfall, sunshine hours, soil moisture, etc), a degree of caution must be applied when using this demand profile for other years. In particular, there was a storm on 7-8 January 2008 that resulted in 188.5 mm of rain in 48 hours at the WTP monitoring site; this rainfall event had an estimated return period of more than 25 years. A drop in water demand in the days during and following this storm can be seen from the data. At the next stage of the project, a longer time series of demand will be used for the yield modelling. This may require predictive demand modelling based on climate data.

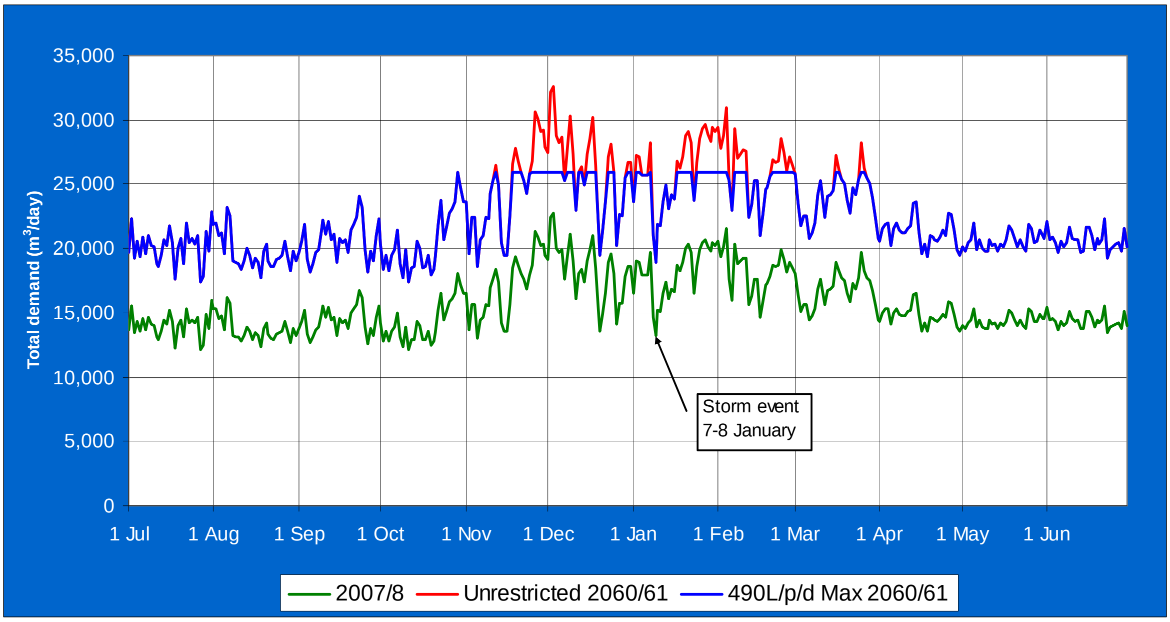


Figure 3-3: Annual Demand Profiles used in Yield Modelling

Future demand was forecast by adjusting the 2007/08 demand to account for population growth through to 2060/61. For modelling the water supply options, two demand scenarios were considered:

- the 2060/61 forecast demand with a demand 'ceiling' of 490 litres per person per day (blue line on Figure 3-3)
- the 2060/61 forecast demand unrestricted (the underlying red line).

The demand profile was copied for each of the four years modelled.

c. Abstraction Rules

The core allocation for the abstraction from the Waikanae River at the WTP has been modelled as 301 L/s (26,000 m^3/d), so as to meet the design requirement for demand when there is enough water in the river.

The minimum flow for the Waikanae River is set at 750 L/s, based on the Regional Freshwater Plan. When modelling the water supply options, the minimum flow has been incorporated within the abstraction rules such that the abstraction must be reduced when river flows drop below 1,051 L/s so as to ensure that the minimum flow is allowed to pass downstream of the WTP. Abstraction must cease altogether when upstream river flows drop below 750 L/s.

The minimum flow of 750 L/s is approximately 75% of the Q95 flow (the flow that is exceeded 95% of the time). Therefore, this factor has been used to set the minimum flow to be released from each of the dams, except when inflows naturally fall below the minimum flow in which case the dam outflow must equal the dam inflow.

d. Modelling dam options

The results of the surface water yield modelling related to each option are provided in Part B of this report. However, as the three dam options were modelled in the same manner a summary of the modelling approach is included here.

To model the inflows to the dam options it was necessary to calculate continuous flow records for each of the sub-catchments as they are not gauged continuously for river flow. In the absence of detailed hydrological investigation at the critical very low flows, the sub-catchment flows were calculated by factoring the observed Waikanae River flows by sub-catchment area and rainfall. Table 3-1 shows the catchment area and rainfall at each of the dam sites and at the Waikanae WTP river gauging station, together with the factor used to calculate the flow into each dam reservoir.

Table 3-1: Sub-Catchment Details for Dam Options

Option	Catchment Area (km^2)	Mean Annual Rainfall (mm)	% of Waikanae River Flow
Kapakapanui	5.9	1294	3.8%
Lower Maungakotukutuku	22.0	1481	16.2%
Ngātiawa	23.0	2213	25.3%
Waikanae at WTP	123.4	1627	-

This is a simple and pragmatic approach. However, it assumes that the relative response of the sub-catchment is the same as the rest of the Waikanae catchment. Differences in catchment parameters such as geology, soils, rainfall patterns and vegetation which will affect local baseflow and runoff have not been taken into account. Further investigation of sub-catchment flows will be undertaken at the next stage of the project if the preferred solution involves a dam.

Account was taken of rainfall and evaporation over the surface area of the dam reservoir. Outflow from the dam comprised of three components, namely the release to satisfy the minimum flow requirement, spill when the dam was full and the additional release made to satisfy any shortfall in meeting demand. The yield model assumes that 100% of the volume released from the dam to the river can be abstracted at the existing water supply intake (i.e. there are no losses to the river bed or to other abstractors). Further study of water losses from the river will be undertaken at the next stage of the project.

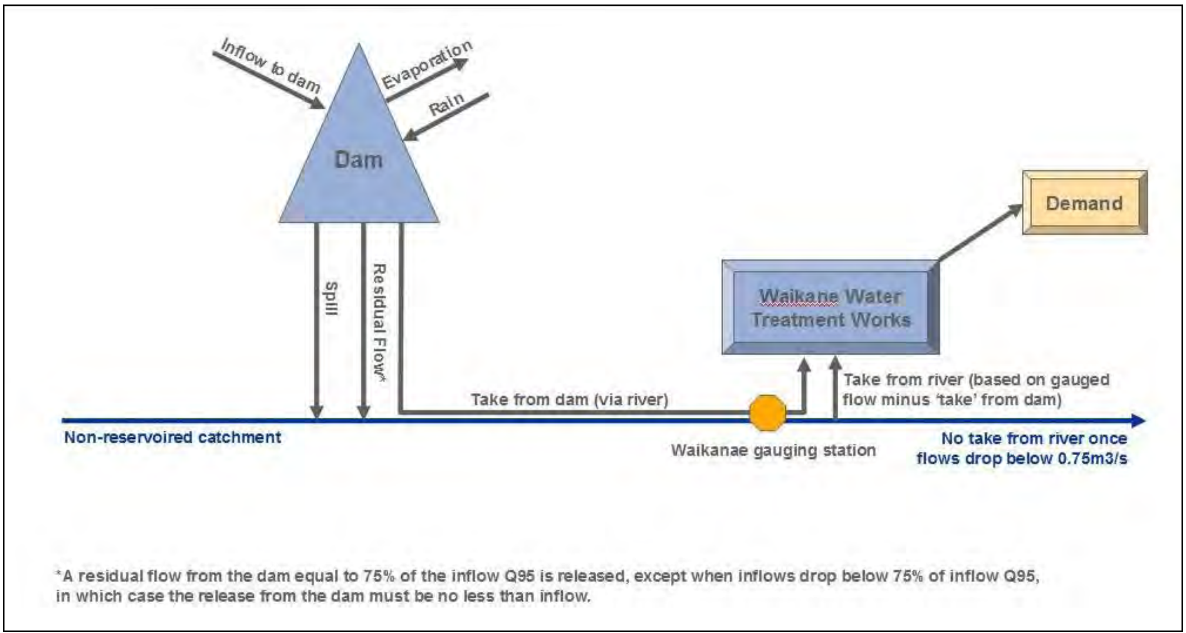


Figure 3-4: Dam Options Modelling Schematic

For each dam option, two storage volumes were chosen for concept design and option assessment. The larger volume was based on GWRC's quoted 50 year low flow in the Waikanae River and the dam being able to fully meet the required yield without shortfall. The smaller volume was based on a less conservative approach that used the lowest observed flow in the Waikanae River from the 35 year flow record (660 L/s), no allowance for headroom and a shortfall of up to 5 days on which demand would have to be met by the existing borefield.

3.3.2 Groundwater Modelling

As part of the investigations of options, three constant rate pumping tests have been undertaken in three of the existing production bores. Hydraulic parameters have been derived from the test results and used to set up and calibrate a 3-dimensional groundwater model with the objective of assessing the sustainable yield from the existing Waikanae borefield and evaluating the feasibility of the groundwater water supply options.

The full report on the aquifer testing and groundwater modelling is included in Appendix E.

a. Pumping Testing

Pumping tests have been undertaken in three selected production wells of the Waikanae Borefield with monitoring of groundwater levels in existing observation bores and wells nearby that are screened in shallower aquifers and the pumped aquifer. Because the wells are in the coastal domain and there is a risk that saline intrusion could occur, it is recommended that each of the production wells be tested individually in the future to better characterise the aquifers, and confirm drawdown, interference effects, hydrogeological boundaries and leakage from shallow aquifers.

Details of the pumping tests are as follows:

- The pumping test of **K6**, screened in the Waimea aquifer, commenced on 31 March 2010. The pumping rate of 58 L/s was maintained for 9 days while groundwater levels were recorded in 19 observation wells spread across the borefield. After 9 days the pump was shut down and recovery was recorded until full recovery had been reached in the pumped well.
- The pumping test of **Kb4**, screened in the Waimea aquifer, commenced on 16 April 2010. The pumping rate of 35 L/s was maintained for 12 days while groundwater levels were recorded in 24 observation wells spread across the borefield. After 12 days the pump was shut down and recovery was recorded until full recovery had been reached in the pumped well.
- The pumping test of **K4**, screened in the gravel lens in the aquitard overlying the Waimea aquifer, commenced on 6 May 2010. The pumping rate of 70 L/s was maintained for 11 days while groundwater levels were recorded in 13 observation wells spread across the borefield. Recovery in the pumping well and the observation wells was recorded until the groundwater level in the pumped well had fully recovered..

The majority of the monitoring bores had been completed with 20 mm diameter PVC piezometers that do not allow for installation of electronic pressure transducers. Therefore frequent monitoring rounds were carried out by Council staff in order to collect manual water level recordings. Water levels in the production wells were recorded with the existing SCADA system.

The results of the pumping tests indicate that some vertical leakage occurs from the shallow unconfined aquifer that overlies the Waimea aquifer when pumping from the Waimea takes place. A summary of the results of the pumping tests is given in Table 3-2.

Table 3-2: Summary of Pumping Test Results

Parameter	Value
Transmissivity, Waimea aquifer, T [m^2/day]	300
Storativity, Waimea aquifer, S [-]	5.0×10^{-4}
Leakage Coefficient, K'/B' [day^{-1}]	2.5×10^{-4}
Specific Yield, shallow aquifer, Sy [-]	0.005

The results indicate that the aquifer is a relatively high yielding aquifer underlying a semi-confined/leaky aquitard. A significant tidal effect is observed in the aquifer during the tests. This is expected as the wells are located close to the coastline. Analysis of the results suggests that 100% of the abstracted volume will be from leakage through the shallower layers (the Parata and shallow unconfined aquifers) after approximately 60 days of constant pumping. This could have implications for secure status of the supply. However, the effective radius at this stage is large and the drawdown effect in the shallow unconfined aquifer relatively small but still measurable (0.03-0.39 m after 9 days pumping of K6 at a constant rate of 58 L/s).

A relatively large drawdown is recorded in the sentinel wells screened in the deeper Waimea aquifer (the aquifer pumped during testing) near the coast. After pumping K6 at a constant rate of 58 L/s for 9 days, a drawdown of 1.1 m was observed in Sentinel # 1.

The results from the pumping tests and the fact that a large number of observation wells have been monitored during the tests allows a detailed calibration of the groundwater model. Observation wells targeting shallow, mid-depth and deep aquifers have been monitored allowing for a reasonable understanding of the aquifer system as a whole.

b. 3-Dimensional Numerical Groundwater Model

The 3-dimensional groundwater modelling was undertaken using the software package Visual Modflow Pro 2009. Visual Modflow is a user interface for the 3D finite difference model, Modflow 2000 and ModPath, developed by the United States Geological Survey.

The model covers an area of 12 km by 13 km. Although the sands and gravels extend further to the South and North than identified in Figure 2-10, the boundaries of the groundwater model have been selected such that they are sufficiently far from the pumping wells that pumping does not result in drawdown at the boundaries. The Waimea aquifer is expected to extend offshore to the west below the seabed.

The head boundary to the east has been assigned from the geological map as the extent of the gravel aquifer. The geological layers have been derived from existing bore logs. The model does not include the underlying greywacke. It is therefore assumed that the greywacke is relatively impermeable compared to the sand and gravel aquifers and that no vertical leakage occurs from the Waimea aquifer to the greywacke (such leakage could perhaps occur through significant fracture zones, should these exist).

Rainfall and river recharge data have been obtained from GWRC and applied to the model as boundary conditions.

GWRC considers a well being pumped at a rate less than 20 m^3/day as a permitted activity. It has therefore conservatively been assumed that each of the unconsented wells in the area is pumped at a constant rate of 0.2 L/s.

The steady state model has been calibrated using long term average groundwater levels from Council's SCADA and records from GWRC as well as hydraulic conductivities for the different geological layers derived from the pumping tests.

To further check the validity of the model, mass balance calculations have been carried out. The results indicate the model is well calibrated.

Following the calibration of the steady state model a transient model has been established and calibrated to fit the drawdown results of the pumping tests. This allows a value of storativity to be obtained for each of the different layers in order to simulate the aquifers' ability to release or receive water when being abstracted from or injected to.

The model has not been calibrated to fit water quality changes over time. However the model can be applied to simulate water quality changes over time e.g. the effects of injecting river water into the Waimea aquifer and the effects from saline intrusion under the different abstraction scenarios.

The validity of the model calibration has been analysed in terms of sensitivity of the hydraulic parameters. The model is most robust in the area where most data is available (in the vicinity of the borefield) but given the relative homogeneity of the aquifer system it is considered that the model allows reasonable predictions in areas further away from the borefield.

The model has been extended to cover the sand and gravel aquifer as far south as Raumati South and as far north as Te Horo. However, only limited geological and hydrogeological data exists for these regions. This means that the reliability of the model at its perimeter is less than it is in the vicinity of the borefield. Overall calibration is good and the predictions of drawdown effects in the different aquifers either when abstracting or injecting water are instructive.

The robustness of the groundwater model will improve as more data from pumping tests becomes available.

c. Modelling Simulations

The calibrated groundwater model has been used to run a series of simulations to evaluate drawdown effects in both the shallow unconfined aquifer and the deep Waimea aquifer resulting from various abstraction and injection scenarios using the Waimea Aquifer. These simulations include existing wells and new wells.

All simulations have been run for 10 years with one abstraction or recharge/abstraction cycle per year. The simulations are run using the average rainfall recharge over the last 10 years. A 50 year drought event has not been modelled at this stage but it is recommended that the model is calibrated against rainfall extremes to simulate climate changes. However, it is anticipated that the effect from a drought on the Waimea aquifer will be minimal given the depth and semi-confined nature of the aquifer.

Wells PW1 and PW2 have not been used for abstraction in simulations because they are close to the coast and pumping from them potentially puts the rest of the aquifer at risk. In all cases pumping from these wells is considered to increase the risk of saline intrusion to the rest of the aquifer system.

While the Waikanae River is known to provide some recharge to the shallow alluvial aquifer system, abstraction from the deeper Waimea aquifer is shown to have a limited effect on the overlying shallow aquifer and is not expected to have a noticeable effect on river flow (i.e. not more than a few percent). By keeping any new wells away from the river, and limiting the amount and extent of the drawdown in the shallow aquifer, these effects can be minimised.

The maximum drawdown results for the Waimea aquifer do not include the drawdown component caused by well losses in the immediate vicinity of the pumped wells. This is expected to be in the order of 10-20 m and will vary as a result of abstraction rate, well construction and development.

3.4 Treatment

3.4.1 Preparation of Concept Designs

In relation to water treatment, an overview of the existing treatment plant is included in Section 2.7. Issues associated with its performance that were taken into consideration when preparing concept designs of the upgrading are detailed in Appendix A. Specific explanation of the treatment requirements of each option and the extent to which either upgrades or renewal is required for the treatment plant is included in Part B. Specifically, we have only allowed for those upgrades that are required as a result of the additional water or a different water source. Upgrading work related to renewals is being dealt with separately by Council.

3.4.2 Approach to Upgrading

In addition to the KWSP project budget, the LTCCP includes a budget for upgrading work at the existing Waikanae WTP, because Council has recognised that the water treatment plant, while performing well, is ageing and is in need of renewals expenditure. How much of this budget may be available for the Water Supply Project is yet to be determined.

In the concept design of the upgrading that is necessary for the various options, work related to asset management (i.e. renewals) has not been included, unless there is an overlap between such work and that needed for the KWSP. Where this occurs, an assessment of what proportion of the costs should be attributable to the KWSP has been made.

A workshop was held with Council operational staff and asset managers on 28 April to discuss the current issues with the operation of the plant and some preliminary concepts for upgrading the process to meet the objectives of both the water supply project and the upgrade project. The workshop opened with Council's operational staff giving their views on treatment technologies and operation philosophies. In summary, these views are:

- While there is a willingness to consider new technologies, any technology must be well proven both from a design and performance point of view, as well as operationally. Proof of good operation needs to be determined from discussions with operational personnel who actually operate the technology.
- Full automation of the plant would only be acceptable if the plant can also be easily made to run in manual mode, to ensure that all operators maintain the skills and ability to run the plant manually in the event of a system failure (e.g. the PLC).

These views are borne from Council's experiences over the years with new and emerging technologies, as well as the fact the Waikanae WTP is the only source of water for WPR and if it failed the community would run out of water.

The upgrading concepts described in Part B (and detailed in Appendix A) are our proposed designs to meet the design objectives outlined below. Based on our experience we consider that the proposed designs are feasible, practical, and are likely to be the best value solution. However, other concepts may well be feasible, suit operational preferences better, and be of similar or better value. This will be considered further at the preliminary design stage.

3.4.3 Raw Water / Future Sources

The final mix of raw water sources to the plant will depend upon the option finally selected. The following assumptions have been made in order to develop the upgrading concepts:

- The Waikanae River will continue to be the primary raw water source
- 4 log removal of protozoa is understood to be required based on Cryptosporidium monitoring of the Waikanae River
- If a dam option is selected, iron and manganese will be controlled at source by use of dam destratification
- If raw water storage in the form of a dam or pond is implemented, there will be increased risk of algal blooms, thereby increasing the risk of algal toxins and taste & odour events occurring. This issue remains a significant risk for the existing plant which needs to be addressed regardless of whether raw water storage is implemented – the inclusion of raw water storage increases the risk
- If groundwater from the existing or extended Waikanae Borefield needs to be treated:
  - The high TDS and hardness, if dilution by river water is inadequate, will be treated by a nanofiltration (NF) plant
  - Following NF the bore water will be dosed with potassium permanganate to precipitate the manganese, and then either be blended with the river water influent at the plant inlet or alternatively bypassed directly to the filters, primarily to remove the precipitated manganese.

3.4.4 Design Objectives

a. Treatment

The criteria for the water quality value developed as part of the MCA process in Stage 2 of the project were:

#	Criteria	Criteria Scale	Explanation
1.1	Public health: risk associated with not meeting the Drinking-water Standards for NZ (DWSNZ)	Almost zero	The risk of the water supply not meeting the requirements of the DWSNZ is almost zero.
		Low	There is a low risk, due the nature of the raw water source, that the water supply may not meet all of the requirements of the DWSNZ all of the time.
1.2	Taste, Odour and Aesthetics (excluding hardness): risks associated with water not being acceptable to most consumers	Almost zero	The risk of taste, odour and aesthetic problems with the water supply is almost zero.
		Low	There is a low risk of the taste, odour and aesthetic quality of the water supply not being acceptable to most consumers.
		Possible	The quality of the water may be such that taste and odour thresholds may be exceeded or the aesthetic quality of the water may not be acceptable to most consumers.
1.3	Hardness: level of hardness in water supply	Matches existing river supply	The hardness of the water supply is similar to the existing river supply (around 30 mg/L - higher value means more likely to get scale deposition).
		Less than 100 mg/L	The hardness of the water supply will be higher than that from the river supply but less than that from the existing Waikanae borefield.
		Greater than 100 mg/L	The hardness of the water supply will be similar to that from the existing Waikanae borefield.

The consultation with the community to date has clearly demonstrated the importance of the quality of the treated water. Given this importance, the treatment objectives should therefore be targeted at meeting the highest criteria in the table above. In summary these are:

- Meeting DWSNZ: The risk of the water supply not meeting the requirements of the DWSNZ is almost zero
- Taste, Odour and Aesthetics (excluding hardness): The risk of taste, odour and aesthetic problems not being acceptable to most consumers is almost zero
- Hardness: The hardness of the water supply is similar to the existing river supply (around 30 - 50 mg/L).

b. Capacity

The predicted 2060 peak day demand including headroom is 32,000 m^3/day. To allow for the transition from the current 23,000 m^3/day consented capacity to the 2060 demand, certain aspects of the upgrading work could be staged if it was economically attractive to do so.

3.4.5 Taste Testing

Given the historic complaints about the taste (and hardness) of water sourced from the Waikanae Borefield, taste testing was proposed to determine whether blending of the bore water with river water, or treating the bore water, will result in a finished water quality that will be more acceptable, in terms of taste, to the general community than the current bore water supply. Water taste testing was held at the Council Chambers on 26 May 2010.

a. Methodology

There were 9 people on the tasting panel who were volunteers from stakeholder groups and people from the water treatment plant's water quality complaints register that were invited to participate in the testing.

The testing involved 5 different samples that provide a range of potential finished water quality:

- A – Raw bore water
- B – Lime softened bore water
- C – Nanofiltered bore water
- D – Raw bore water blended with treated river water
- E – Treated river water (ie, typical WPR water supply)

The samples were prepared by Council's laboratory according to the sample preparation protocol written by CH2M Beca. Nanofiltration of the bore water was carried out by Davey Water Products in Auckland. The treated river water had been through the Waikanae Water Treatment Plant and therefore had been chlorinated and fluoridated. The raw bore water was sourced from bore Kb4 and had not had any treatment, but its sodium content was increased to match that of the combined borefield (excluding K13).

The testers knew that the samples were either river water or bore water or a blend, but did not know the composition or source of specific samples, which were presented in a random order.

For each sample each member of the tasting panel was asked to comment on the appearance and smell of the water, rate the taste of the water 1 to 9 according to the scale provided, and describe or comment on the taste.

The taste rating scale provided to the tasting panel is repeated below. This scale is taken from the Flavour Rating Assessment method, which is taken from *Standard Methods for the Examination of Water and Wastewater*[13]. This method is suitable when the purpose of the test is to estimate acceptability for daily consumption and has been used in consumer surveys to recommend standards around mineral content in drinking water.

1. I would be very happy to accept this water as my everyday drinking water
2. I would be happy to accept this water as my everyday drinking water
3. I am sure I could accept this water as my everyday drinking water
4. I could accept this water as my everyday drinking water
5. Maybe I could accept this water as my everyday drinking water
6. I don't think I could accept this water as my everyday drinking water
7. I could not accept this water as my everyday drinking water

[13] Part 2160C, 19th Edition, 1995, prepared and published jointly by American Public Health Association, American Water Works Association and Water Environment Federation.

8. I could never drink this water

9. I can't stand this water in my mouth and I could never drink it

The water temperature at the testing was 20.6°C. The intensity of taste is greatest for water at body temperature and room temperature.

b. Results

The preferred sample was the raw bore water (A) with a median taste acceptability rating of 3. The lime softened bore water (B), nanofiltered bore water (C) and blend of river & bore water (D) all had a median rating of 4. The treated river water (E) had the lowest median rating with 5. The distribution of taste ratings for each sample is shown in the following graph.

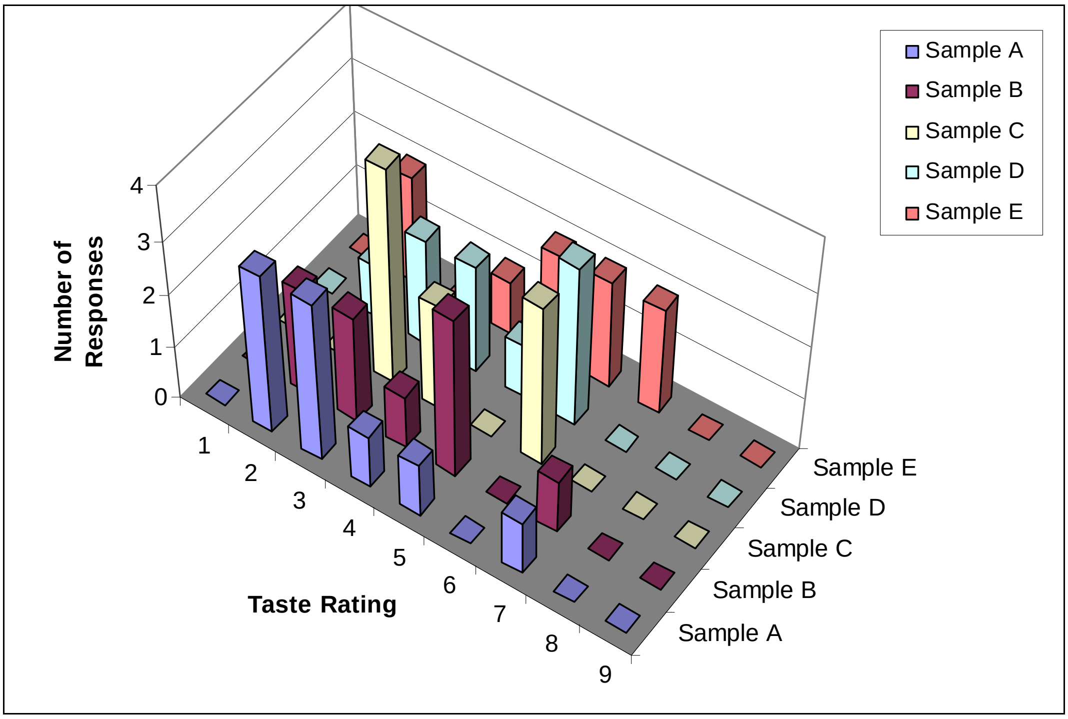


Figure 3-5: Distribution of Taste Acceptability Ratings from Taste Testing

Given the historic complaints about the taste of the bore water, and also feedback during consultation, it was surprising that the raw bore water had the best median taste acceptability rating in this testing and that the treated river water (ie, the typical WPR supply) had the lowest rating.

In the discussion after the testing, a question was raised as to whether the community's impression of the bore water has been tainted by the early operation of the Waikanae Borefield, which included the more mineralised water from Bore K13. Bore K13 has not been used for water supply since about March 2008 and the concept designs for the short-listed options are based on this bore being taken out of service.

The raw bore water had a total dissolved solids concentration of 450 mg/L, sodium concentration of 160 mg/L and hardness of 100 mg/L as $CaCO_3$, which is similar to the combined water quality if all production bores, excluding bore K13, are operated at their maximum capacity.

The pH of the raw bore water was quite high at 9.2, whereas the Drinking-Water Standards for NZ recommend pH should be between 7.0 and 8.5. The high pH of the raw bore water should have caused this water to have a soapy taste and feel, but this was not commented on by the tasting panel. Because of the timing of the pump testing for the hydrogeological investigations the raw bore water was sourced from Bore Kb4 only. This water was diluted with distilled water and had Na_2CO_3 added in order to increase the sodium content to make the raw bore water more like the combined water quality if all production bores, excluding bore K13, are operated at their maximum capacity. The high pH is likely due to the addition of Na_2CO_3.

From the median results it would seem that treatment of the bore water by lime softening and nanofiltration did not improve the taste of the bore water and in fact lowered the taste acceptability. Closer inspection of the results shows that 3 out of 9 tasters preferred the taste of the treated bore water to that of the raw bore water, and for another 3 tasters, who rated the raw bore water highest, they liked the taste of another sample just the same as the raw bore water

The variability of these results demonstrates how each person's opinion on taste is different and subjective.

Samples D and E contained treated river water which had been through the treatment plant and therefore chlorinated. The amount of residual chlorine in sample E was 0.2 ppm, which is the minimum level required in the distribution network, so the amount of chlorine in this sample would have been less than or similar to the typical water supply at the consumer's tap. However, based on the comments it would seem that the low chlorine levels were still detected and the treated river water (sample E) may have been less acceptable because of this.

It is noted that the tasting panel of 9 people is a small sample and the views of the testers may not be representative of the entire WPR water supply community. It is also noted that this testing only looked at the taste of water and did not explore the issues of water hardness and scale formation.

The pH of the raw bore water sample and the chlorine in the river water samples were shortcomings with the testing protocol. The elevated pH in the bore water should have disadvantaged this sample but nevertheless it was the most favoured. The chlorine in the treated water may have adversely affected its ranking, but with the blended/treated samples consistently scoring second, it suggests that the taste of dissolved salts and hardness are not discernable.

The results of the taste testing indicate that the taste of the water from the borefield is actually reasonable and people cannot really differentiate the bore water. This suggests that historical perceptions may be strongly influencing the community's views on the bore water taste.

On the basis of the bore water quality monitoring data and aesthetic guideline values in the Drinking-water Standards for New Zealand, the bore water is reasonable for a drinking water source. Therefore bore water appears to be a feasible option for the future with respect to taste and should not be discounted.

Further testing could be undertaken during the next stages of the project to further explore the taste of the bore water and to investigate people's willingness to pay for hardness removal.

3.5 Environmental Assessment

3.5.1 Two Key Areas

The environmental assessment work to date has involved two key areas of study – in-stream ecology investigations by NIWA and terrestrial ecology investigations by Wildland Consultants. These issues were considered the most significant in terms of evaluating each option and ultimately developing a ranking. There are a number of additional studies required for each option, and these are listed in the recommendations section for the preferred option.

3.5.2 In-stream Ecology

Scientists from NIWA have undertaken investigations within the Waikanae River catchment to enable the assessment of the options with respects to in-stream ecology impacts. The investigations involved:

- Biological surveys in the Waikanae River, the Kapakapanui Dam stream[14] and the Maungakotukutuku Stream
- Laboratory analysis of invertebrate samples collected from the three waterways
- Water quality measurements of the Waikanae River whilst bore water was being discharged to the river as a consequence of the pump testing of the bores
- Hydrological analyses for the options.

These investigations are summarised below and the findings for each option are included in Part B. For further detail refer to NIWA's report in Appendix C.

a. Biological Surveys – Field Methods

Fish and invertebrates were sampled from three waterways in the area in the week of 19-23 April 2010. Two streams were sampled where the proposed dams were to be built – the Kapakapanui Dam stream and the Maungakotukutuku Stream. At each of these streams, samples of freshwater invertebrates were collected at two sites above the proposed dam and at two sites below. Invertebrate samples were also collected from the Waikanae River at sites below the confluence with the Kapakapanui Dam stream and with the Maungakotukutuku Stream, as well as below the water treatment plant.

Fish at all sites were surveyed using a portable electrofishing machine. Electric fishing was done mainly to confirm the presence of fish in the streams, although the single-pass abundance data was used to calculate a first approximation of the relative density of fish per square-metre of streambed. The New Zealand Freshwater Fish Database (NZFFDB) was also accessed for records of fish occurrence in the region.

[14] The name Kapakapanui Dam stream in fact does not refer to the "proper" Kapakapanui Stream, but rather an un-named tributary into the Waikanae River, to the east of the Kapakapanui Stream. For convenience, this un-named tributary has been called the Kapakapanui Dam stream.

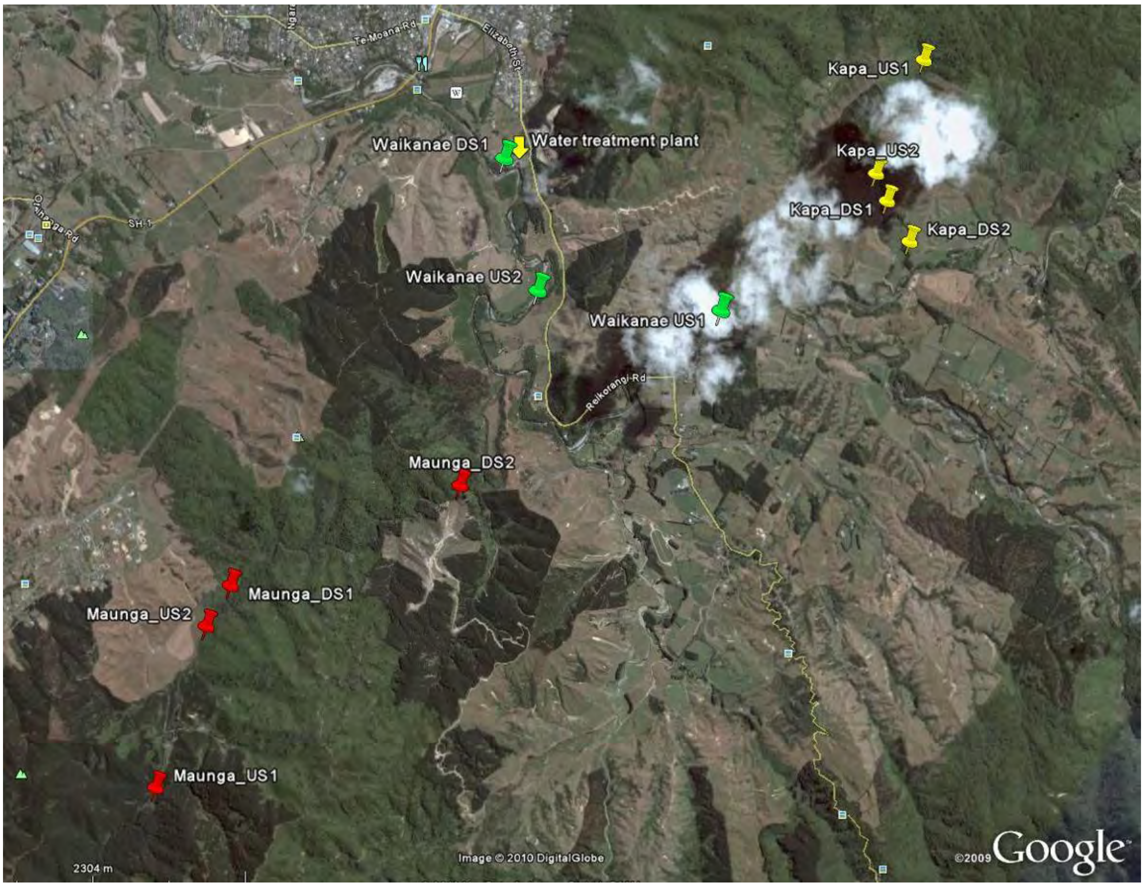


Figure 3-6: Locations of the Biological Survey Sites

b. Laboratory Methods and Analysis

For each invertebrate sample collected, invertebrates were identified to as low a taxonomic resolution as possible and counted. Some of the larger insects (e.g. Trichoptera) could be identified to species, while other insects were either too small to identify to species, or could not be identified due to lack of suitable identification keys.

Invertebrate data from streams in the area was also obtained from the Greater Wellington Regional Council to allow a comparison of the communities in the three waterways surveyed to those of other waterways in the Wellington region. This allows proper assessment of the value and uniqueness of the invertebrate communities.

Biological indices were calculated from the invertebrate data. These indices are useful for assessing both the current condition of the invertebrate community, as well as for monitoring changes to the community over time as a result of any activities in the catchment.

c. Water Quality Measurements

Water quality probes (sondes) were deployed at two sites in the Waikanae River: one above the water treatment plant and one downstream of the WTP, approximately 20 m below the discharge of bore water and 2 m from the true right bank. The sondes were configured to record water temperature, pH, dissolved oxygen and conductivity every 15 minutes, and data was downloaded at regular intervals.

Water samples were also collected during the bore pumping tests from the river upstream of the bore water discharge, and from the river at the lower sonde. Bore water was also collected from the discharge point prior to mixing. All samples were analysed in a laboratory of heavy metals, anions and cations.

A dye test was also conducted to document the flow and dilution dynamics of the proposed bore water discharge into the Waikanae River (Option F). Rhodamine (WT) dye was used to identify the typical dispersion patterns of bore water as it mixed with the river downstream from the discharge. At predetermined distances downstream from the bore water discharge, up to 600 m downstream, water samples were collected just beneath the water surface at four points along each transect. Samples were analysed for subsequent dilution calculations.

Figure 3-7: Dye test in Waikanae River

d. Hydrological Analyses

A river's flow regime is considered one of the most important environmental factors influencing ecological communities. For example, large floods reduce invertebrate densities by washing animals from the streambed. However, numbers can quickly recover because there will always be a source of colonists in sheltered areas at the stream edge, or in smaller side-streams. Moreover, flood events are beneficial to stream ecosystems as they remove excess algal growth and fine sediments that may have deposited in slower flowing areas. Floods also transport recently hatched fish fry from a stream's upper reaches to the ocean. Floods affect stream life in terms of both their magnitude, and their frequency. A useful statistic that combines these parameters is the FRE3 - the number of floods greater than three times the long-term median.

Periods of extended low flow can also influence stream ecosystems, with implications to water chemistry (for example nutrient and oxygen concentrations), stream temperature, and in-stream plant growth. In some instances, extended periods of low flow can result in excessive aquatic plant growth which can alter in-stream habitat conditions to the detriment of fish and invertebrate communities (Suren et al. 2003; Suren and Riis 2010). Potential detrimental effects of extended periods of low flow are ameliorated by "flushing flows" that remove excessive plant growth from streams, and rearrange some of the streambed. These are commonly used below impoundments to ensure the maintenance of healthy ecological conditions.

The different options proposed can be divided into activities having the following hydrological effects. For the dam options, there will be a potential reduction in residual flows below the dam, as well as a potential reduction in flood frequency and/or magnitude. The ASR and Storage Pond options involve extracting additional water from the Waikanae River, which may result in a reduction of some flow related parameters such as frequency or magnitude of flows. For the Storage Pond options water will not be taken to storage when the natural river flow upstream of the WTP is more than about 4,790 L/s (the unmodified mean flow) as turbidity tends to exceed 5 NTU at greater flows and the water becomes too turbid to store. The turbidity requirements for ASR are likely to be more stringent than 5 NTU, so a lower river flow limit is likely. The River Recharge with Groundwater option will, in theory, not change the flow regime of the Waikanae River, as bore water will be used to replenish any additional abstraction of river water, although additional abstraction in the winter/spring for recharging the aquifer will reduce the natural river flows.

Hydrological simulations for the residual flows downstream of the water treatment plant were carried out on the 35 year flow record for the Waikanae at Water Treatment Plant hydrological station together with the water demand profile used in the CH2M Beca surface water yield model (refer Section 3.3.1).

3.5.3 Terrestrial Ecology

Wildland Consultants visited each of the potential dam and storage pond sites and mapped vegetation types onto an aerial photograph of the site. Where it was possible to obtain access to a particular vegetation type, a vascular plant species list was compiled for that area. Likely habitat was searched, to determine if threatened plant species could be identified. Fauna heard and seen was noted for each site. Site visits occurred on 9 April 2010 (Lower Maungakotukutuku), 12 April 2010 (Kapakapanui, Ngātiawa, Storage ponds), and 10 May 2010 (Lower Maungakotukutuku, Kapakapanui, Ngātiawa). One of the reasons for the latter visit, to Lower Maungakotukutuku and Kapakapanui, was to assess the ecological values of the sites proposed for geotechnical drilling.

Field records of vegetation types were then mapped onto digital aerial photography and the total area of potential inundation calculated for each vegetation type at each site. Note that the potential inundation area is not adjusted for topography, thus the areas of potential inundation will be minimum areas.

The findings for each option are included in Part B. For further detail refer to Wildland Consultants' report in Appendix D.

3.6 Consultation

The consultation process and principles are described in detail in Section 12. A summary of key outcomes specific to each option is included in Part B with the description of each option.

The consultation methodology for this project is based on ensuring strong community and stakeholder involvement at all stages of the decision-making process, based around the following 5 project stages:

Stage 1:	Data review and first gaps
Stage 2:	Preliminary options report
Stage 3:	Ranked options report (current project stage)
Stage 4 and 5:	Preferred option development and Assessment of Environmental Effects (planning approval documentation)

The earlier stages of consultation (Stages 1 and 2) focussed on understanding and confirming community values for water supply to inform the development of selection criteria for the short-listing of options. Consultation for this stage has focussed on discussing the short-listed options with iwi, affected landowners, stakeholders and the wider community to inform the selection of a preferred option(s). A range of consultation methods have been used, including public meetings, information days, stakeholder meetings and workshops, water tasting test, community newsletters and newspaper articles.

3.7 Risk Assessment

A number of risk workshops have been undertaken over the course of preparing this report. The ultimate purpose of these workshops has been to develop risk based cost estimates (refer Section 15.3). However, these workshops have also assisted in developing the concept designs and identifying areas where further technical work or investigation is required in subsequent stages of the project.

Initially a concept design review and risk categorisation workshop was held that was attended by the project team, Council officers and two members from the Technical Advisory Group (TAG). At this workshop the design concepts for each option were discussed and risks for each option were identified and assigned to the categories of: water quality, environmental, technical/design, yield and cost. This workshop instigated the project risk register, which will be maintained for the duration of the project. Risks identified during Stage 2 of the project were also reviewed during the preparation of the risk register.

A second risk workshop was attended by the Water Project Steering Group and two members from the TAG. This workshop involved assigning ratings for likelihood and consequence to each of the risks. Together these ratings give each risk a 'risk score', which determines the 'risk priority'.

In preparation for the risk-based cost estimating workshop, each risk was assessed as to whether or not it has cost implications, and a 'cost risk status' assigned.

The third workshop was facilitated by one of CH2M Beca's risk specialists. Each option was assessed individually with the relevant technical professionals and each risk with cost implications was quantified with a best case, most likely and worst case dollar value.

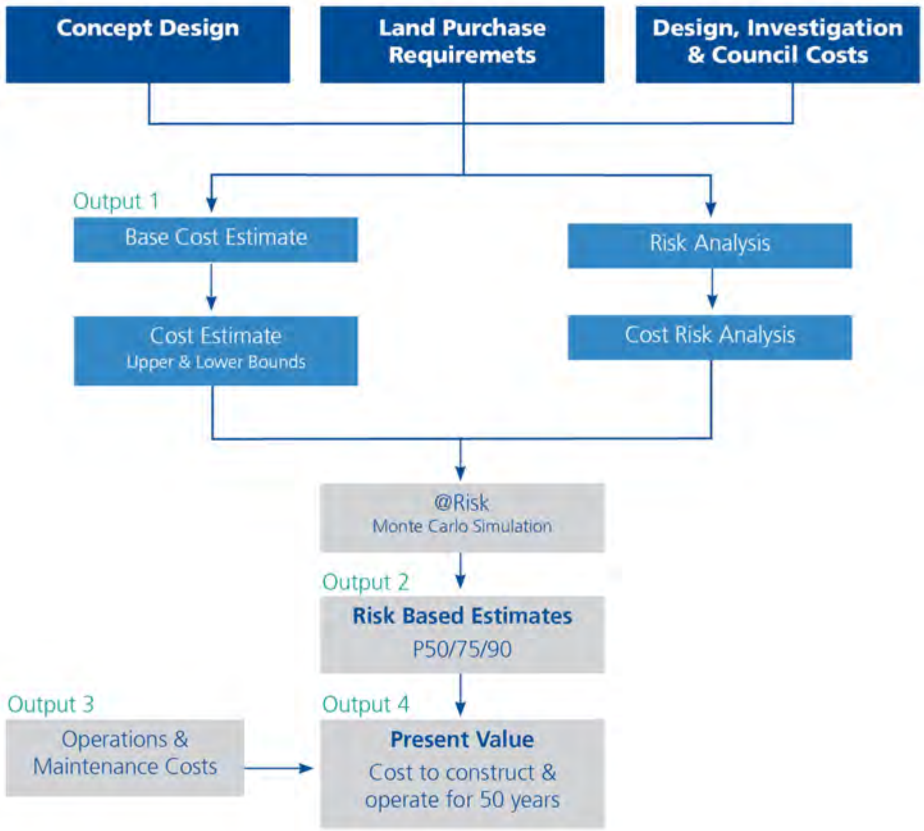


Figure 3-8: Flow Chart of Risk-based Cost Estimating Process

3.8 Cost Estimates

3.8.1 Capital Cost Estimates – Overview

Traditionally capital cost estimates are updated at each phase of a project's development from concept design, culminating in a pre-tender estimate on completion of detailed design (based on a traditional delivery mechanism). The following diagram illustrates the perceived degree of financial risk during the life cycle of a project. In particular, it demonstrates that as the design process advances, cost estimates do tend to move up or down as more information, investigation and design effort occurs. The magnitude of uncertainty therefore decreases, so in practical terms this means that cost estimates move from being ±30% or more, to about ±10% once detailed design is complete. The risk-based estimating process proposed for this project is a more robust approach again, which provides a percentage probability based on costs and risks that the project can be delivered within that dollar figure.

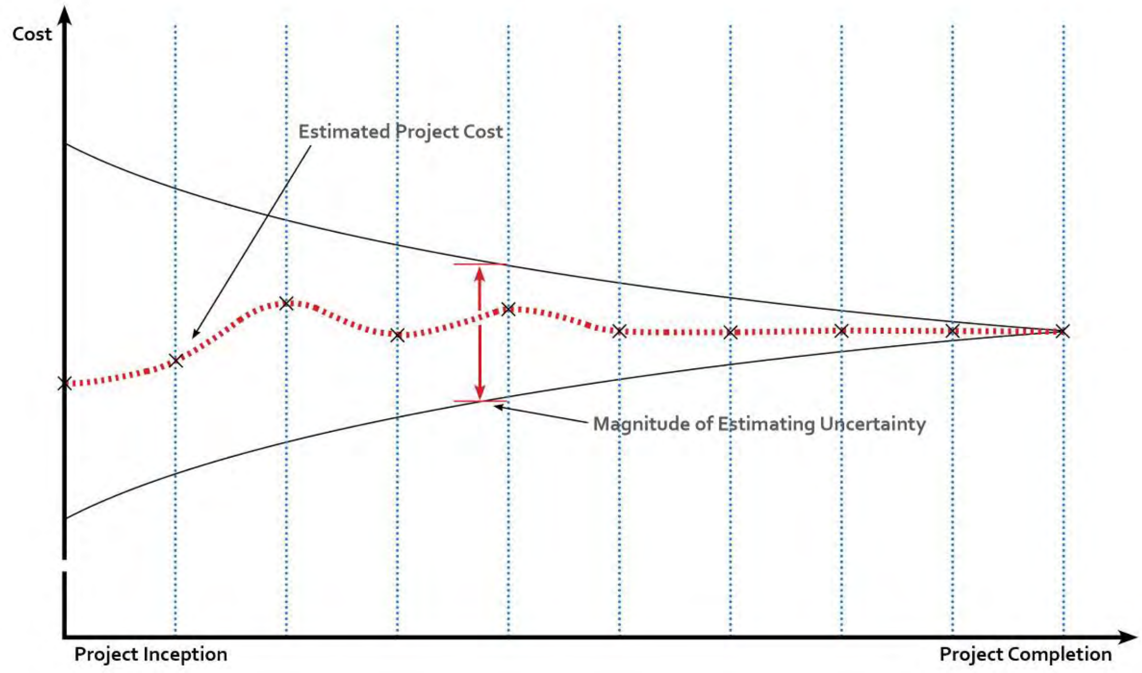


Figure 3-9: Perceived Degree of Financial Risk during the Lifecycle of a Project

The following approach has been taken to cost estimating in this report:

- Production of a *Base Capital Cost Estimate* for the construction cost, plus design and management fees for each option (included in Part B of this report).
- Carry out a quantitative risk analysis on the *Base Capital Cost Estimate* and in addition carry out a qualitative risk assessment on the risks included in the risk schedule that have cost implications. The results of these assessments are manipulated using specialist software (@Risk) to establish a *Risk-based Cost Estimate* (included in Part C of this report).

All capital cost estimates have been prepared based on:

- the information provided in this report
- a cost base date of May 2010
- a traditional project delivery model utilising New Zealand design and construction resources
- all costs are expressed in NZ dollars
- design and management fees based on 12% of the overall capital cost estimate
- land valuations as provided by a registered valuer.

Elemental estimates have been produced for items where enough information is available and allowances have been included for the items not yet defined at this concept stage.

All rates used in these estimates are based on a mixture of the following:

- First principles (rates are built up from the various inputs needed to supply, transport, construct, fix, etc. a specific item)
- Beca/Damwatch databases
- Comparison of similar current and historic projects
- Rawlinson Construction Handbook 2009
- Costs from suppliers.

The base capital cost estimates assume generally no adverse ground conditions and work during normal hours only. They also exclude:

- GST
- Costs for shutting down plant
- Soil investigations
- Relocation of underground services
- Spare equipment
- Staging of the works
- Spare equipment
- Foreign exchange variations
- Capitalised interest
- Escalation
- Risk items

The cost estimates include allowances for preliminary & general, contractor's on-site and off-site overheads plus profit, professional fees, Council's internal project costs and consent fees.

The Base Capital Cost Estimates presented in Part B of this report include a 25% contingency. In Part C of this report, the risk-based cost estimates will be higher than the base estimates, but they will be more sophisticated than simply adding a 25% contingency.

3.8.2 Budget Available

The budget available for the project is set out in the LTCCP, which provides for $23M ($24.8M when inflation adjusted to 2015) for the supplementary water supply. In addition, the LTCCP includes a budget for upgrading work at the existing water treatment plant, because Council has recognised that the water treatment plant, while performing well, is ageing and is in need of renewals expenditure. How much of this budget may be available for the Kāpiti Water Supply Project is yet to be determined.

3.8.3 Land Valuation – Overview

A number of options involve the purchase of significant areas of land. Specifically, these include the three dam sites, plus the storage ponds associated with Option D1. A land valuer (BJ Whitaker) was engaged to prepare these land value estimates and these are included in the overall cost of each option presented in this report. The other options are only expected to involve purchasing small areas of land, if any, and a small, nominal allowance has been made for these at this time.

3.8.4 Operational and Maintenance Costs – Overview

For each option the operational and maintenance (O&M) expenditure has been estimated. The purpose of this is to compare the ongoing cost commitment required from Council for options, in addition to the upfront capital costs. Council has advised that the current annual budget for operating and maintaining the Waikanae Water Treatment Plant and Borefield is $1.23 million.

The following outlines the assumptions made to arrive at the O&M estimates.

a. Assumptions

- Maintenance costs were assumed to be a percentage of the new civil, mechanical and electrical, instrumentation & controls capital costs, which did not include existing plant.

- An allowance was made for the maintenance of existing plant, based on Council's water treatment budget.
- A 10% contingency has been built into the final Operational & Maintenance (O&M) costs.
- Pump power consumption has been based on a pump efficiency of 70% and estimated flows and pumping heads.
- Prices on which this estimate is based are 2010 prices; from this a stream of costs for a 50 year period were derived.
- During times where river water extraction is not allowed, due to the consent constraints, the supplementary water supply will take effect. The use of this supplementary water supply whether it be the borefield or storage is assumed to be for 15 days per year at the start of the 50 year period, ramping up to 45 days per year at the end of the 50 year period. Where possible a linear change from 15 to 45 days per year was used but in some cases this was simplified to an average of 30 days per year.

b. Inclusions

- All major pumping costs.
- Chemical dosing at the Waikanae water treatment plant (WTP) including the nanofiltration plant where applicable.
- Energy consumption at the WTP including specific items such as the raw water pumps, treated water pumps, UV lamps, dosing pumps, backwash pumps and blowers.
- The replacement costs for nanofiltration membranes and UV lamps.
- Various monitoring and reporting allowances for consenting, dam safety and general maintenance.
- General grounds maintenance.
- Labour allowances.

c. Exclusions

- GST has not been included in this estimate.
- Inflation has not been considered e.g. electricity price increases and rising labour costs.
- No allowance has been made for depreciation costs.
- Potential revenue from a mini-hydro scheme as part of a dam option has not been included.

PART B: OPTIONS

4 Option A – Kapakapanui Dam

4.1 Concept Design

The proposed Kapakapanui Dam option is located on an un-named tributary of the Waikanae River in the north of the river catchment, adjacent to the Kapakapanui Stream valley (Figure 4-1). The proposed dam and reservoir would provide storage to augment the existing water supply during periods of low flow in the Waikanae River. Water from the reservoir would be released into the stream to be conveyed by the Waikanae River to the water treatment plant and extracted at the existing intake.

A dam site was identified in the late 1990s where the stream valley narrows downstream of a wider valley section. This site takes advantage of the inherent reduced length of the dam in the narrow section and increased volume of reservoir in the wider section of the valley. In order to reduce the impact on the land owner due to flooding the wider section of the valley, an alternative site 500 m upstream was also investigated as part of this project. The two sites are called the upper and lower sites. The sites are approximately 300 m and 800 m upstream of the confluence with the Waikanae River.

The sites are presently accessed from Mangaone South Road by either of two farm tracks which cross the Waikanae River by way of fords.

Each site is evaluated for two storage volume scenarios referred to as Scenario 1 (1.9M m^3) and Scenario 2 (1.4M m^3). The smaller storage volume scenario requires some use of the existing bores during serious droughts.

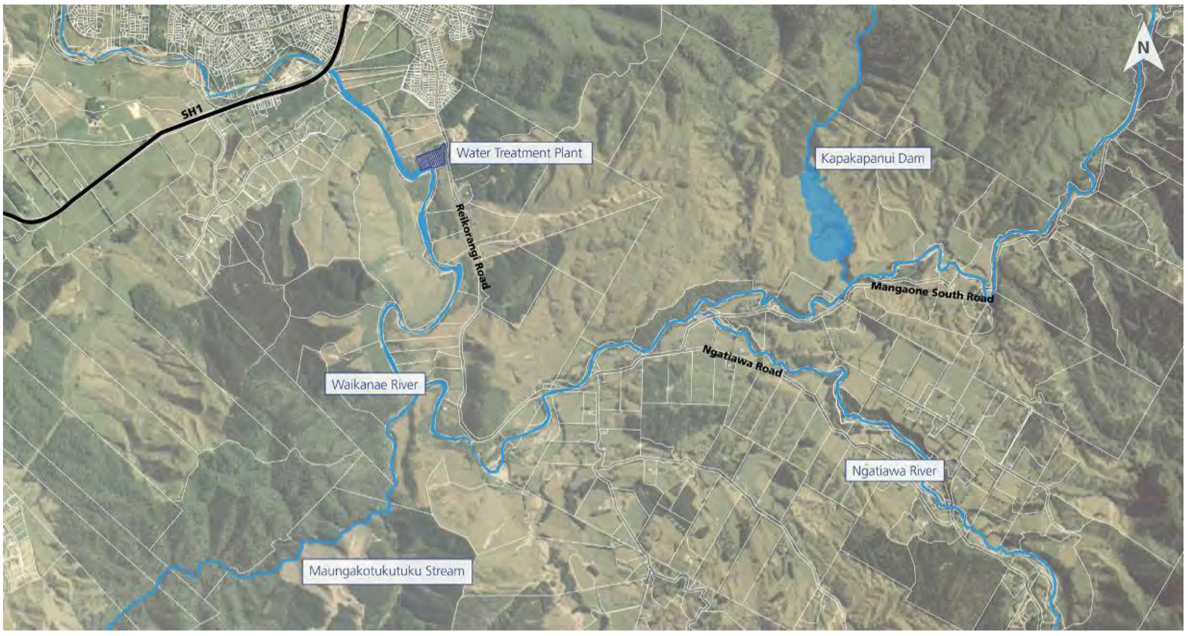


Figure 4-1: Location of Kapakapanui Dam Site

4.1.1 Site Geology

The stream valley has been incised into greywacke basement rock and subsequently been infilled with alluvium. Erosion of the valley has then occurred leaving remnants of these old alluvial terraces on the eastern side of the valley. This has been followed by another period of gravel deposition and erosion resulting in the more recent alluvial deposits in the valley. These cycles of erosion and deposition have resulted in an infilled paleo-channel at the lower site on the western side of the stream (right bank).

The lower site was extensively investigated during earlier studies (MWH, 2000). Further investigations at the lower site have been undertaken as part of this current project. These investigations included surface geological mapping, test pitting and drilling. The geological investigation at the upper site was limited to surface geological mapping and test pitting.

Reservoir slope stability has been assessed as part of the geological inspection. Although there are some areas of the reservoir slopes which display shallow instability occurring in the colluvium overlying bedrock, deep seated instability sufficient to cause dam safety issues is judged unlikely. An area of steep bluffs on the eastern abutment about 250 m upstream of the dam at the lower site will likely require treatment by excavation or buttressing.

a. Lower Site

The lower site is located where the stream has eroded a steep sided gorge about 20 m deep into the greywacke. The geological profile determined from the investigations is shown in Figure 4-2, which shows the infilled paleo-channel.

Deposits of alluvium and colluvium cap the greywacke and form terraces on both sides of the valley as shown in Figure 4-2. These deposits consist of layers of silty lake deposits interspersed with layers of alluvial dirty gravels. Alluvial silty gravels also overlie the greywacke bedrock forming the flat terrace area immediately upstream of the dam (see Figure 4-3).

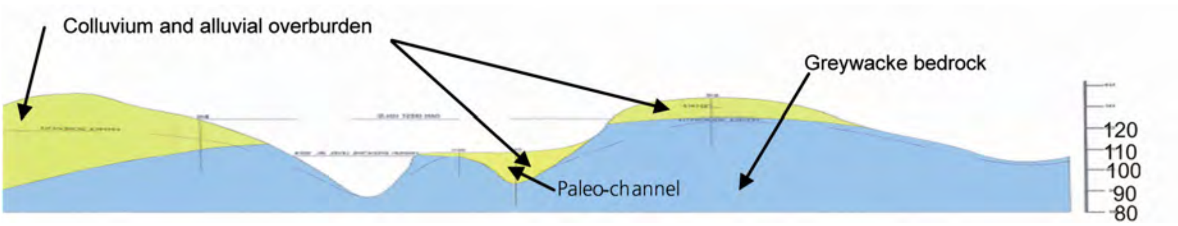


Figure 4-2: Geologic Profile Along the Lower Dam Site Axis Looking Downstream

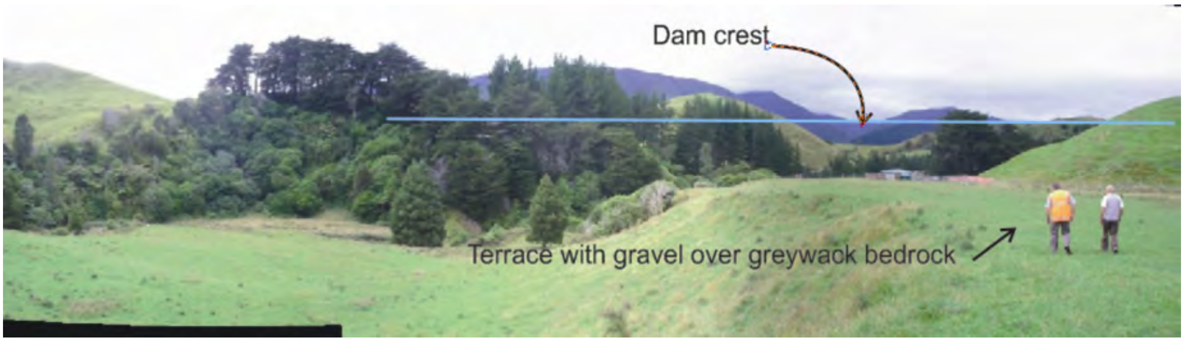


Figure 4-3: Kapakapanui Lower Dam Site Looking Downstream

Both sandstone and argillite lithologies have been identified in the greywacke at the site with the sandstone being dominant. Inspection of drillhole core and rock outcrop shows that the greywacke foundation is generally closely fractured with minor crush zones.

b. Upper Site

A panoramic view of the upper site looking downstream is shown in Figure 4-4. The valley is wider at the upper site with a terrace on the left side of the stream. The geologic profile as determined from the recent investigations is shown in Figure 4-5.

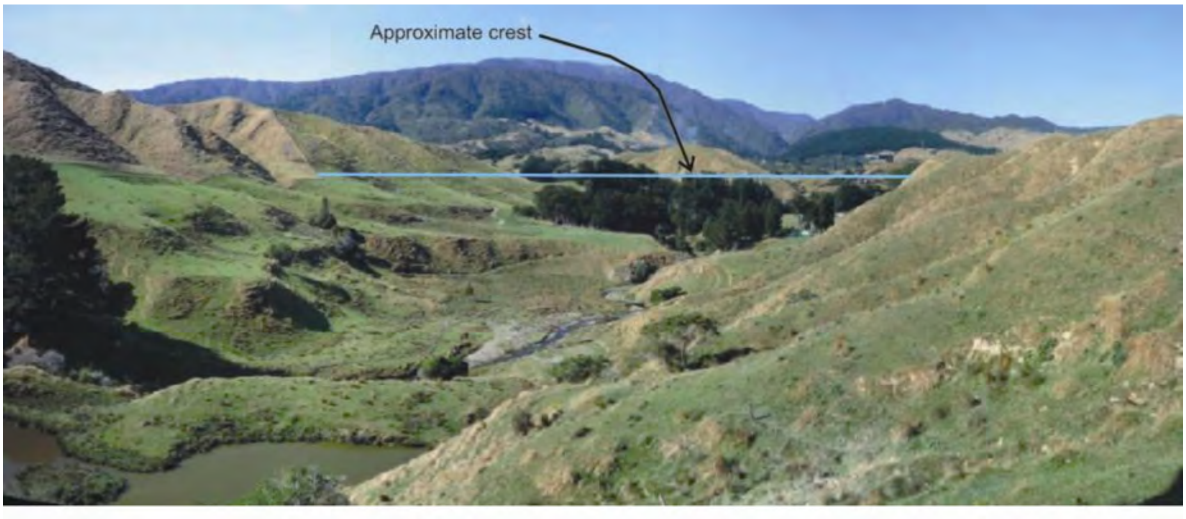


Figure 4-4: Kapakapanui Upper Dam Site Looking Downstream

The depth of overburden at the upper site is not known at this stage of the investigation. It is known to be greater than the depth of the test pits which were mostly about 6 m deep. For the concept design and cost estimate, an overburden depth of 8 m on the west and 12 m on the east terrace has been assumed.

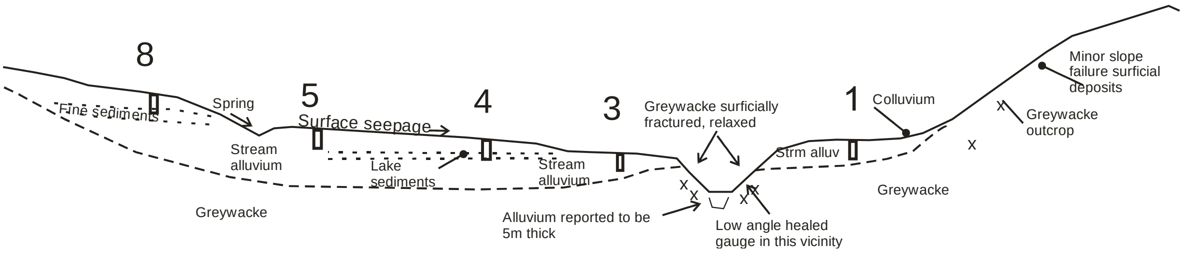


Figure 4-5: Geologic Profile Along the Upper Dam Site Axis Looking Downstream

The units identified in the test pits (numbered in Figure 4-5) were logged as:

- Stream alluvium - generally clayey/silty sandy gravel with few cobbles/boulders
- Lake sediments - silty sand to fine sandy gravel.

4.1.2 Seismicity

The Waikanae River catchment is a zone of high seismicity and is traversed by a number of active faults. Of greatest relevance to the dam site is the system of active faults that include the Ohariu and Gibbs Faults which are shown on Figure 4-6. The nearest fault is the Gibbs Fault, which is located 1 km northwest of the dam site. No evidence has been found of active faulting at the dam sites or in the reservoir.

The Gibbs Fault is probably capable of generating earthquakes in the order of magnitude 7 (GNS, 2003).

Specific studies will be required to determine the earthquake loadings for the dam site.

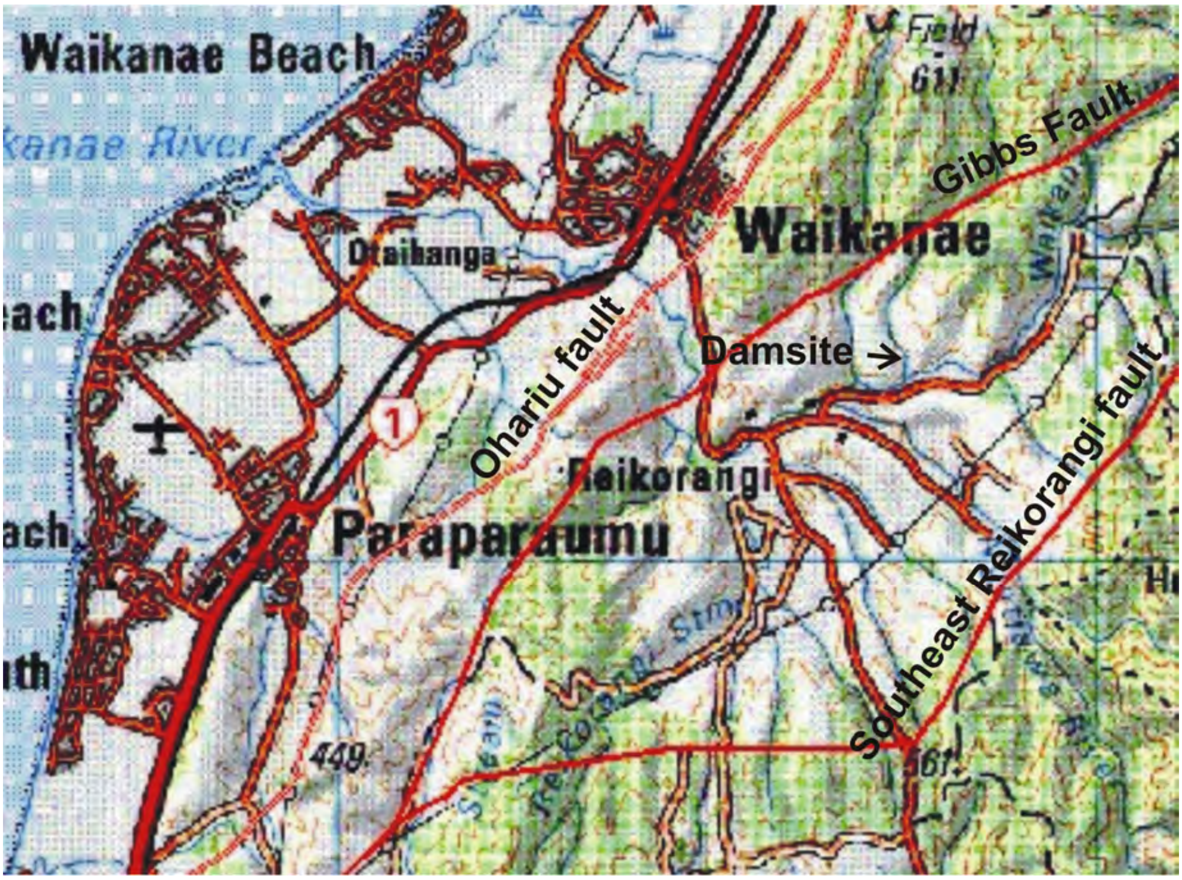


Figure 4-6: Active Faults in the Vicinity of Kapakapanui Dam

Based on the low frequency of large earthquakes and the lack of evidence for flow slides in the reservoir area, the potential for large liquefaction flow slides in the terrace deposits around the reservoir is judged to be low. This will require further evaluation if this option is preferred.

4.1.3 Hydrology

The NIWA Water Resources Explorer website[15] has been used to determine flood magnitudes and sediment entering the dam for the concept design of the dam spillway and diversion works. The data used is summarised in Table 4-1.

Table 4-1: Hydrology Data Used for Kapakapanui Dam Concept Design

Variable	Value from Website (NZ Reach 9003835)	Derived Value
100 year flood	17.7 m^3/s	
5 year flood		10 m^3/s
Mean annual flood	8.2 m^3/s	

[15] http://wrenz.niwa.co.nz/webmodel/

Variable	Value from Website (NZ Reach 9003835)	Derived Value
Mean flow	0.118 m^3/s	
Probable Maximum Flood		35 m^3/s
Sediment	1 kt/year	50 year volume 30,000 m^3

4.1.4 Dam Safety

The design philosophy for Kapakapanui Dam considers safety of the dam structure as a vital component of not only the design, but also of the construction and long-term operation of the water storage scheme.

The design, construction and operation practices must address hazards that have the potential to impact on the safety of the dam and the potential consequences downstream that the dam might influence.

Hazards may be natural hazards such as earthquakes, construction hazards such as poor materials, or operational hazards such as sudden changes in river flow.

The NZSOLD Dam Safety Guidelines (2000) use a classification system for dams based on the damage potential and the consequences (impacts) that would occur if the dams were to release their reservoir contents. Kapakapanui Dam has been assessed as a High Potential Impact Classification (PIC).

Based on the PIC rating, the NZSOLD Dam Safety Guidelines assign an appropriate level of security for the design and operation of the dam. For floods, a High PIC dam must safely pass the "Probable Maximum Flood", a hypothetical extreme flood resulting from the most severe combination of possible meteorological and hydrological conditions. For earthquakes, a High PIC dam must safely retain the reservoir for the Maximum Credible Earthquake (MCE), an extreme earthquake that is capable of generating the largest seismic loading on the structure.

This means that Kapakapanui Dam will be designed to the highest standards, and able to safely withstand any of the known natural hazards that might affect it. Design relating to dam safety depends on management of the design risks (i.e. appropriateness and correctness of the design) and management of the geotechnical risks (i.e. site conditions and available materials). The design must also consider construction management and systems and procedures for managing operational risks. Risks are considered subsequently in Sections 4.6.

4.1.5 Choice of Dam Type

The choice of dam type is greatly influenced by site geometry, foundation conditions and the availability of construction materials in reasonable proximity to the site. The Kapakapanui Dam stream valley contains material sources that are likely to be suitable for the construction of embankment dams and concrete dams.

A potential greywacke aggregate source for concrete has been identified 200 m upstream of the upper dam site on the right bank of the stream. It is a steep, greywacke spur that could readily be trimmed as a quarry operation. Rock mass quality is uncertain with respect to both quarry excavation and suitability for concrete aggregate at the present stage of investigation.

The alluvial materials in the valley are considered to be suitable for an embankment dam. Closer study of the potential material sources would be required to determine which particular type of embankment dam would be most economic.

a. Lower Site

Foundation conditions at the lower site are not favourable for a concrete gravity dam; in particular at the eastern abutment where the lower levels are in rock but the upper levels are against alluvial materials. While treatment would be possible to enable a concrete gravity dam to be built, the work required would be extensive and it would be technically difficult to ensure satisfactory performance under the design earthquake loads.

An embankment dam is therefore favoured. While a central core type dam has not been eliminated, a homogeneous dam with a central chimney drain has been selected for estimating purposes.

b. Upper Site

Concrete gravity dams can withstand overtopping and are commonly designed with the spillway accommodated over the dam body, characteristics not inherent in other types (rockfill and embankment) of dam. With these advantages and assuming that the upper site is underlain by greywacke at a reasonable depth and with no paleo-channels present, a concrete gravity dam was chosen for the upper site. A roller-compacted concrete (RCC) dam construction process has been selected based on the reduced construction cost and duration when compared to conventional mass concrete dam construction.

Roller-compacted concrete has the same ingredients as conventional concrete (cement, water, and aggregates), but RCC is much drier. It can be placed quickly and easily with large-volume earth-moving equipment. For dams the size of Kapakapanui the concrete is generally transported by dump trucks, spread by bulldozers, and compacted by vibratory rollers. Sections are built lift-by-lift in successive horizontal layers (300-600 mm thick) so the downstream slope of the dam resembles a concrete staircase. Once a layer is placed, it can immediately support the earth-moving equipment to place the next layer.

4.1.6 Dam Description

Two reservoir volumes and corresponding dam heights have been assessed for both the lower and upper sites. The proposed concept designs for each of the reservoir volume scenarios are shown in drawings included in Appendix B.

Free overflow spillways have been chosen for reasons of, safety, simplicity of operation and economics and are designed to pass a probable maximum flood in accordance with the High Potential Impact Classification assessed for this site.

The significant characteristics of each scenario for the two dam sites are summarised in Table 4-2.

Table 4-2: Significant Characteristics of Kapakapanui Dam

	Lower Site		Upper Site	
	Scenario 1	Scenario 2	Scenario 1	Scenario 2
Dam Type	Embankment	Embankment	RCC	RCC
Live Storage	1,925,000 m^3	1,425,000 m^3	1,925,000 m^3	1,425,000 m^3
Dead Storage	30,000 m^3	30,000 m^3	30,000 m^3	30,000 m^3
Dam Height	33.4 m	30.6 m	37.6 m	33.1 m
Dam Crest	RL 125.7	RL 122.1	RL 140.0	RL 135.5
Spillway Crest (full supply level)	RL 122.7	RL 119.1	RL 137.0	RL 132.5

	Lower Site		Upper Site	
Spillway Capacity	35 m^3/s	35 m^3/s	35 m^3/s	35 m^3/s
Inundation Area	147,700 m^2	Not calculated	125,000 m^2	105,100 m^2

a. Lower Site

The reservoir inundation plan, the feature plan and sections of the dams for the lower site for Scenario 1 are shown on drawings WS909/20/51, 52 and 53 respectively (Appendix B).

The proposed embankment dam would be founded as shown in Figure 4-7. The dam is founded on rock where this is exposed or under shallow cover. At the left abutment the upper part of the dam is founded against the insitu alluvial materials. To mitigate against leakage through this abutment and to ensure stability, the alluvial slope would be trimmed to a stable angle and a blanket constructed upstream of the dam. In the left abutment above the dam crest the existing slopes would be excavated for dam construction material.

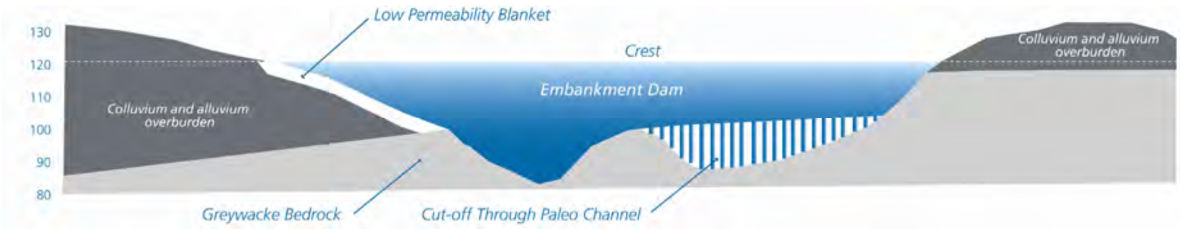


Figure 4-7: Cross-section at Lower Site with the Dam Foundation Looking Downstream

Where the dam crosses the paleo-channel a cut-off is constructed down to rock with a downstream filter that connects back into the main filter drain system.

On the right abutment above dam crest level the slope is excavated for dam construction material and for locating the service spillway with capacity for a 1 in 100 annual exceedance probability flood. The service spillway consists of a concrete rectangular channel that terminates in a flip bucket from which spill flow would discharge into the stream downstream. A free overflow auxiliary spillway located in a saddle 50m upstream of the dam on the west side of the reservoir would discharge infrequently during floods more extreme than 1 in 100 annual exceedance probability.

Outlet works which enable water to be drawn from three levels of the reservoir are accommodated in a free standing intake tower. Delivery from the outlet works is through the diversion pipe. The delivery pipework through the diversion pipe must be constructed after diversion is complete and filling of the reservoir has commenced.

It is anticipated that outlet flows would be controlled remotely from the water treatment plant. This outlet will provide riparian flow immediately downstream during reservoir filling.

b. Upper Site

The reservoir inundation plan and the dam layout for the upper site for Scenario 1 are shown in drawings WS909/20/1, 2 and 4 (Appendix B). This shows the spillway located over the current stream channel. The spillway utilises the stepped downstream face of the dam for the base of the spillway chute that is formed by side walls supported from the downstream face of the dam. A roller bucket energy dissipater is included at the base of the spillway to dissipate energy and reduce erosion downstream when the spillway operates.

The greywacke bedrock is generally closely fractured at the lower site and it is assumed to be similar at the upper site. To reduce seepage through the rock fissures a grout curtain has been included.

Drainage of the downstream area of the dam footprint would be with underdrains placed at the time of preparation of the foundation rock surface. The underdrain for RCC would be a rigid drain utilising no fines concrete or similar. Flows from these drains would be monitored as part of the dam surveillance program.

Outlet works which enable drawing reservoir water from three levels of the reservoir are accommodated in an intake tower which is integral with the upstream face of the RCC dam. The outlet works deliver from the tower through a gallery in the dam body to a control valve discharging into the spillway energy dissipater.

It is anticipated that outlet flows would be controlled remotely from the water treatment plant. This outlet will provide riparian flow immediately downstream during reservoir filling.

4.1.7 Micro-hydro Potential

The dam would remain full most of the time when there is sufficient flow in the Waikanae River to supply the water demand. Stream flow would discharge over the spillway if the outlet works are closed.

There is potential to tap into the water supply outlet works pipe with a micro-hydro penstock. This penstock could feed into a micro-hydro power station immediately downstream of the dam. The amount of flow that could be utilised to generate electricity would be dependent on the generation capacity installed and ability of the plant to utilise low flows.

A mean flow scenario is chosen to illustrate the generation potential. If the micro-hydro plant can utilise 70% of the flow available, which is a normal utilisation for such an installation, the potential energy generation, based on mean flow of 118 L/s and overall efficiency of 80%, would be 188,000 kW.hr per year for Scenario 1 and 174,000 kW.hr per year for Scenario 2.

4.1.8 Construction

The construction contractor would be expected to have relevant track record in dam construction of similar magnitude and complexity to the Kapakapanui dam.

The main construction activities are civil works activities including:

- Progressively clear the construction area of vegetation, strip and stockpile top soil
- Construct access roads and site facilities which includes a permanent bridge over the Waikanae River
- Commence quarry activities and preparation of aggregates for RCC production
- Construct the river diversion
- Construct upstream and downstream cofferdams to protect dam construction activities from the river
- Excavate and prepare dam foundation
- For RCC dam construction form seepage barrier in rock foundations directly beneath dam by drilling and pressure grouting
- Construct dam either using RCC or earth embankment placement methodology depending on alternative adopted
- Selectively clear large trees upstream of the dam site within the reservoir footprint

- Remove downstream cofferdam
- Commence reservoir impoundment by closing the diversion gate, planned with favourable weather forecast
- Commission dam - monitoring reservoir filling and initial dam performance
- Construct concrete plug to seal diversion culvert after commissioning complete and for the earth embankment dam alternative complete outlet works construction
- Clear construction site and complete site rehabilitation works.

The estimated construction period for each site and each scenario is given in the following table.

Table 4-3: Kapakapanui Dam Estimated Construction Periods

Site	Scenario	Live Storage Volume (m^3)	Dam Type	Construction Period
Lower	1	1,925,000	Earth Embankment	22 months
	2	1,440,000		20 months
Upper	1	1,925,000	RCC	18 months
	2	1,440,000		16 months

4.1.9 Commissioning

Under mean flow conditions (118 L/s), and with an allowance for a residual flow downstream of the dam (29 L/s), a reservoir capacity of 1,925,000 m^3 will take some 8 months to fill (this duration will also be somewhat affected by evaporation, infiltration and rainfall, which have not been included). Lake filling will be achieved by closing the diversion culvert bulkhead gates when the dam, spillway and penstock intake structure are complete and functional. Initiation of lake filling will be scheduled with benefit of both favourable short and intermediate range weather forecasts, preferably in autumn to take advantage of higher winter flows to speed filling the reservoir.

During the lake filling period downstream flows will be maintained by discharging through the lowest intake.

Subsequently, after the reservoir has filled the diversion culvert will be permanently plugged with water tight mass concrete infill.

The dam would be instrumented with flow measuring weirs on the outlet to the underdrains. Piezometers would be located under the dam foundation to measure uplift pressure under the dam and for the earth embankment dam alternative, also in the body of the dam. Survey monuments would be located along the crest of the dam to confirm dam deformation behaviour is within expectations. These instruments would be monitored from completion of the dam body through reservoir filling and subsequently over the life of the dam. During the commissioning period, from commencement of reservoir filling through to one month after reservoir full, the frequency of monitoring the weirs and piezometers would be once daily. Thereafter, dependent on satisfactory performance of the dam and foundations, the monitoring frequency would be decreased to weekly and subsequently to bi-monthly. This is expected to be over several months. The dam crest monuments would be surveyed frequently during initial reservoir filling and through the following month. Thereafter, dependent on satisfactory performance of the dam body the frequency of crest monument survey would be decreased to monthly for a period until satisfactory performance is evident. Thereafter a dam deformation survey would be conducted annually.

During reservoir filling the reservoir side slopes would be observed periodically from a boat in the partly filled reservoir in order to check for any signs of slope instability.

4.1.10 Operation and Maintenance

Once operational Kapakapanui dam would require routine maintenance of the facilities including:

- Access roads, including running surface, drainage facilities, berms and verges vegetation control
- Site maintenance including, site drainage facilities, and clearance of debris from the spillway works
- Servicing of the outlet valves and associated automatic controls and actuators
- Routine surveillance which would include bi-monthly inspection and reading of the drainage weir and piezometers; annual inspection and a Comprehensive Safety Review every five years.

4.2 Yield

The following table summarises some of the key results of the yield modelling for the Kapakapanui Dam and the two storage volume scenarios. These results are based on a peak day demand of 32,000 m^3/day, the 2007/08 demand profile, the 2002-2006 Waikanae River flow records adjusted to reach a 50 year low flow, and a core river allocation of 26,000 m^3/day.

Table 4-4: Kapakapanui Dam Yield Modelling Results

Dam Live Storage Volume	1.9M m^3 (Scenario 1)	1.4M m^3 (Scenario 2)
Number of days reservoir used in one year in the modelled 50 year drought	143 days	143 days
Longest period of continuous use of reservoir	59 days	59 days
Maximum daily outflow from dam for water supply	29,400 m^3/day	29,400 m^3/day
Time to fill after the modelled 50 year drought	122 days	109 days
Shortfall - number of days borefield used in the modelled 50 year drought	0 days	12 days
Maximum daily take from borefield	0 m^3/day	19,500 m^3/day

The yield modelling used a flow into the reservoir equal to 3.8% of the flow in the Waikanae River and a minimum residual flow in the stream downstream of the dam of 29 L/s.

The following graph shows how the total demand will be met over the four year modelling period with a minimum river flow of 517 L/s and maximum demand of 32,000 m^3/day. The graph shows that the Waikanae River (turquoise) meets the majority of the demand (up to 26,000 m^3/day). As the river flows reduce or demand increases, then the dam (orange) is used to meet the demand. When neither the river nor dam can meet the demand, then the borefield (purple) is used.

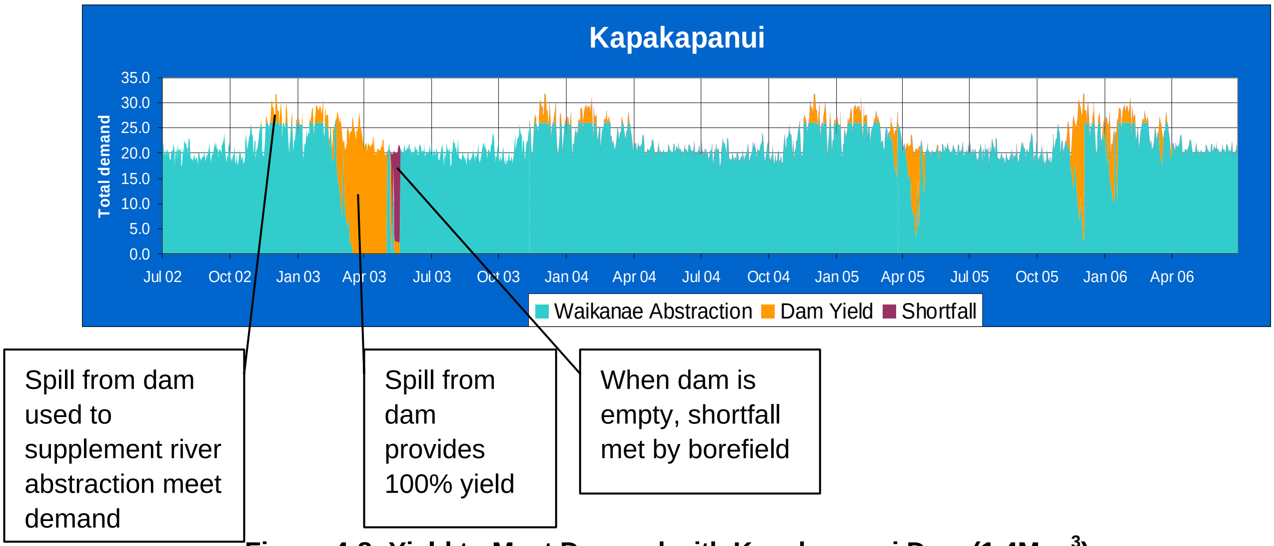


Figure 4-8: Yield to Meet Demand with Kapakapanui Dam (1.4M m^3)

The following graph shows the Kapakapanui Dam with a 1.4M m^3 live storage reservoir emptying and filling over this same period under the same conditions.

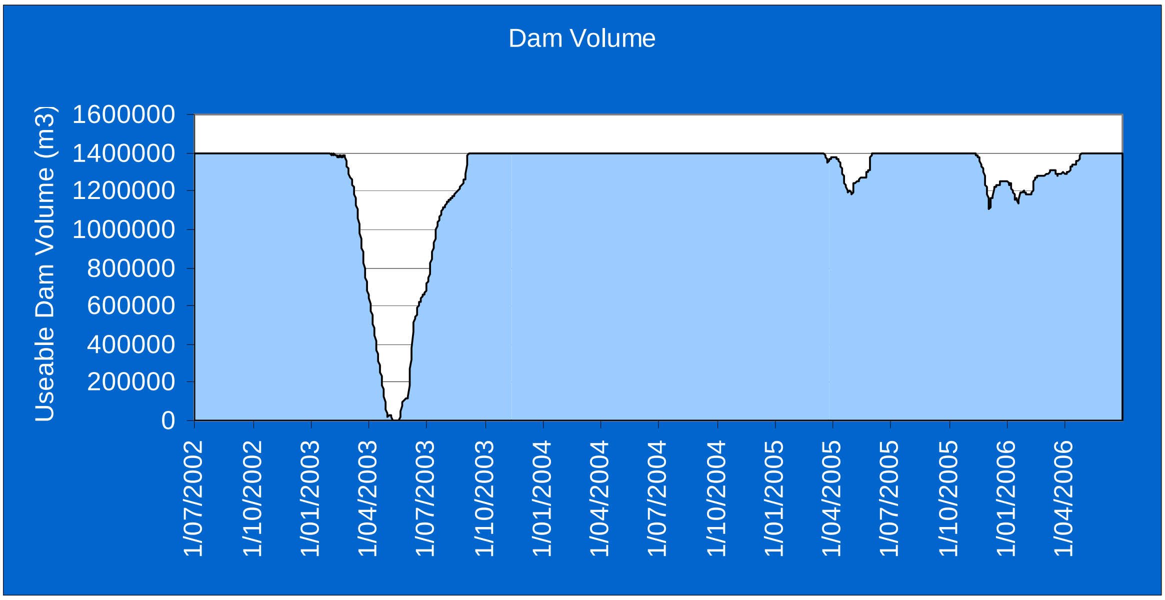


Figure 4-9: Kapakapanui Dam (1.4M m^3) Volume Profile for 50-year Drought

4.3 Treatment

The concept design includes for the following upgrading work at the Waikanae Water Treatment plant (WTP) for all dam options. Scope items that are assessed as being renewals-related rather than project-related are marked with an "R".

- Destratification system in dam reservoir (not within WTP but considered part of treatment)
- River intake screening and air burst system (for screen cleaning)
- Raw water pump station – new pumps and electrical system (R)
- Improved coagulation control/chemical dosing (R)
- Second clarifier (R)
- Convert existing filters to biological activated carbon (BAC) mode (R)

- Add one or two new BAC filters
- Decommission ultraviolet disinfection (R)
- Refurbish existing powdered activated carbon system (R)
- New lime system (R)
- Miscellaneous improvements to chemical storage and handling (R)
- Improvements to clearwater tank (R)
- Consider VSDs on treated water pumps (R)
- Sludge/waste water/residuals improvements (R)
- Building refurbishment (R).

Further details of the proposed upgrading are presented in Appendix A.

A destratification system is proposed for the dam to prevent the reservoir stratifying and anoxic conditions developing at the base of the water column with associated release of iron and manganese. In addition, stratification encourages the growth of cyanobacteria with associated toxin and taste & odour potential.

4.4 Environmental Assessment

4.4.1 In-Stream Ecology

a. Habitat Conditions

The four sites sampled in the Kapakapanui Dam stream differed considerably from each other, with the mid sites closest to the proposed dams (Kapakapanui US2 and DS1) being in open farmland, and the upper and lowermost sites (Kapakapanui US1 and DS2 respectively) being in shaded native forest (Figure 4-10 - Figure 4-13). The streambed at all sites was dominated by boulders, cobbles and coarse gravels. The stream was wider at the upper locations (average width 3.5 m) than the downstream locations (average width 1.75 m).

Figure 4-10: Photograph of the Kapakapanui Upstream Site 1

Figure 4-11: Photograph of the Kapakapanui Upstream Site 2

Figure 4-12: Photograph of the Kapakapanui Downstream Site 1

Figure 4-13: Photograph of the Kapakapanui Downstream Site 2

b. Overview of Evaluations

The biological communities of the Kapakapanui Dam stream were investigated. Four fish species were found in the stream (giant kokopu, koaro, longfin eels and redfin bullies), of which longfin eels and redfin bullies were most numerous. The fish fauna appears typical to that of other rivers within the Waikanae catchment. The invertebrate communities were dominated by four species indicative of streams in good-excellent condition, and typical of streams with low-nutrient water. The community composition changed little along the stream, so loss of a section of stream as a result of creation of the dam will not necessarily lead to a reduction to the invertebrate biodiversity values of this stream. Many of the taxa found here are found in other streams in the region, although this stream supports higher relative abundances of some taxa, such as those indicative of streams in excellent condition.

Refer to Appendix C for further details.

c. Key Issues Encountered

- Dam construction would potentially disrupt movement of native fish to and from the sea. In particular, there is a high risk that eels will encounter the dam when migrating downstream. Survival of, or damage to, eels moving past the dam will be an issue.
- Water quality in the reservoir may be affected as flooded vegetation at the proposed site decomposes. However, much of the area upstream of the proposed dam is grazing land, so this may not be a particularly great issue.
- There will be a total loss of river habitat, displacing both fish and invertebrates from the flooded stream.

d. Mitigation

- Fish passage can be assisted by constructing a bypass pipe/channel such that when water gets close to crest/spill levels, an open pipe through the dam provides safe eel passage down to the streambed.
- A multi-level outlet structure could be included in the dam design to allow the release of both surface oxygenated water, and deeper water to minimise against release of poor quality water. Such a structure has been incorporated in the concept design.

4.4.2 Terrestrial Ecology

The assessment of terrestrial ecology only considered Scenario 1 (1.9M m^3) for the lower Kapakapanui dam site. Refer to Appendix D for further detail.

a. Protected Areas and Areas of Significance

The current access road to the dam site fords the Waikanae River, and the crossing location is within the 0.6 ha Department of Conservation-managed Mangaone River Marginal Strip (R26028). This is a fixed Marginal Strip, under Section 24(3) of the Conservation Act 1987. Upgrading of the access road, or placement of a bridge, to the dam site will need to be undertaken in consultation with the Department of Conservation, or an alternative access route, outside the reserve, will need to be created.

Riparian vegetation in this area is predominantly a mahoe-kamahi canopy with a diverse understorey including rangiora, indigenous tree fuchsia, *Coprosma* and fern species. The width of the riparian margin varies from a few metres to *c*.50 m and will assist with protecting water quality, including sediment and temperature control. Whichever access option is chosen, a small amount of good quality riparian indigenous vegetation will be affected by upgrading of the access route.

b. Vegetation and Habitats

Most of the site that could potentially be inundated comprises habitats with low indigenous ecological values (70% of site), such as pasture and a constructed farm pond. The total inundation area is approximately 14.8 ha (not adjusted for topography), and the vegetation types in this area are summarised in Table 4-5.

Table 4-5: Vegetation Types within Potential Kapakapanui Inundation Area

Ecological Value	Vegetation Type	Hectares	% of Inundation Area
High	Kahikatea/mahoe-kamahi forest	0.88	6.0%
	Kamahi-mahoe forest	0.64	4.3%
High Total		1.52	10.3%
Moderate	Indigenous-exotic forest	0.28	1.9%
	Kahikatea/blackberry scrub	0.19	1.3%
Moderate Total		0.47	3.2%
Low-moderate	Degraded wetlands and seeps	0.93	6.3%
	Introduced conifer forest	0.83	5.7%
	Gravel banks	0.37	2.5%
	Indigenous-exotic shrubland	0.20	1.3%
Low-moderate Total		2.34	15.9%
Low	Pasture	10.27	69.6%
	Farm pond	0.15	1.0%
Low Total		10.42	70.7%
Total Inundation Area		14.76	100.0%
Total Area High and Moderate Value		1.99	13.5%

Low-moderate quality vegetation and habitat types (*c*.16% of site), are largely dominated by exotic species, or are heavily modified through land use or stock browse. A number of macrocarpa and pine shelterbelts and plantations (introduced conifer forest) occur at the site and these tend to have an understorey of mostly indigenous species, including mahoe, tauhinu, karamu, kanono, kawakawa, ongaonga, and a range of indigenous ferns, but also barberry and blackberry.

The indigenous-exotic shrublands are dominated by mahoe, kamahi, ongaonga, remnant mamaku, occasional kotukutuku, barberry, and blackberry, with a range of smaller browse-resistant species or bare earth in the understorey.

Vegetation on gravel substrate was dominated by pasture grasses, fleabane and ragwort. Wetland areas were also dominated by pasture grasses and *Juncus gregiflorus*.

Moderate ecological values (3.2% of the site) were ascribed to forest that was generally dominated by indigenous species such as mahoe, kamahi, tawa, kawakawa, and tree-ferns, but also includes a significant amount of barberry, blackberry, or other exotic and often weedy species. There were also isolated kahikatea along the stream, often with dense blackberry patches at their base.

High ecological value habitats and vegetation types were dominated by indigenous species, with generally intact vegetation tiers, although the understorey was moderately affected by stock browse in places. Only 1.5 ha of high value habitat will be affected by the proposed dam development.

This is mainly riparian vegetation which, in the lower part of the valley, comprises kahikatea trees emergent over 15 m tall mahoe-kamahi forest. In the upper part of the inundation zone, the forest canopy is primarily mahoe-kamahi with occasional emergent pukatea. Both indigenous forest types have a wide range of understorey species.

c. Fauna

The farm is stocked primarily with red deer and sheep, with pheasants common. In pasture areas, New Zealand pipit, paradise shelduck duck, spur-winged plover, pukeko, Australasian harrier, and introduced Australian magpie, goldfinch, and greenfinch were noted. Indigenous species in the forested area included warblers, silvereyes, fantails, and possibly rifleman and the introduced eastern rosella. Goat sign and possum damage was also seen.

d. Possible Ecological Effects

- Clearance of riparian vegetation.
- Vegetation clearance may cause surrounding vegetation to dry out, as a result of removal of buffering vegetation.
- Potential introduction of unwanted species (e.g. weeds).
- Soil compaction.
- Changes to the water table, which could cause previously unaffected vegetation to die or deteriorate through root rot.
- Loss of habitat for indigenous terrestrial fauna.
- Loss of riparian vegetation and potential deterioration of in-stream ecological values, including along the new or realigned access route.

e. Potential Mitigation

- Fence other indigenous forest areas within the property to exclude stock and undertake pest control within these areas.
- Consider legal protection, e.g. covenant, for other indigenous forest areas within the property.
- Check for weeds on construction sites every three months for the first two years, and yearly thereafter, for up to five years, and undertake weed control as required.
- Establish temporary fences or high visibility tape around trees and parts of the sites to be avoided during construction.
- Employ silt-retention devices around the perimeter of the working area.
- Consider establishing an indigenous riparian margin (at least 20 m wide) using suitably eco-sourced plant species, along non-forested sections of the final lake shoreline.

4.5 Consultation

In general, the concept of a dam as a water supply solution appears to have general support in the community. However, concern has also been expressed by some residents immediately downstream of the potential dam sites. Those noting support for dam options talk of the benefit of the certainty of a tried and tested concept and of capturing rain water sensibly in the hills. Those noting opposition talk of the risk of dam break and adverse environmental effects, particularly to in-stream ecology and amenity. This is particularly the case for the Kapakapanui dam site, where concern has been strongly expressed from some local residents downstream in regard to dam break risk and environmental effects of damming the stream.

Key Group	Summary of Consultation Outcomes
Iwi	Council continues to build a partnership approach with tāngata

	whenua and remain committed to supporting a partnership approach to this significant community project. Council is working closely with the Te Āti Awa in the spirit of the Memorandum of Understanding being developed for this project, particularly with the Te Āti Awa Water Working Group in the investigation of cultural impacts. At this stage, tāngata whenua have not identified any fatal flaws with this option in relation to the core values of kaitiakitanga, tino rangatiratanga. tāonga, mauri and whakapapa.
Landowners directly affected	This site has the benefit of a single landowner who is generally supportive of the dam. There are site specific matters to be addressed, including site access and providing for the ongoing operation of farming (deer) activities on site. However, it is anticipated these matters can be satisfactorily addressed through design and mitigation measures.
Other landowners potentially affected	Concern raised from local residents downstream in regard to dam break risk and environmental effects of damming the stream. It is anticipated that some of these residents may not support a consent application for this dam should it be the preferred solution.
Stakeholders GWRC DoC Fish & Game Forest & Bird Department of Conservation Friends of Waikanae River	Key stakeholders have been kept well informed of investigations to date. The six short-listed options were presented to a select group on 8 June 2010 with a focus on environmental effects, including the findings of the investigations of NIWA and Wildland Consultants. Representatives from Fish & Game, Forest & Bird and Friends of Waikanae River attended the presentation. Stakeholders were also presented with a summary of the technical investigations on 1 July 2010. At this stage of the project, initial feedback from stakeholders appears to suggest that there are no apparent fatal flaws with this option, however further detailed investigation will need to be undertaken into the environmental effects if it is preferred, particularly around in-stream ecology and the overall impact on river flow.
Wider Community	The concept of a dam as a water supply solution appears to have general support in the community. Those noting support for dam options talk of the benefit of the certainty of a tried and tested concept and of capturing rain water sensibly in the hills. Those noting opposition talk of the risk of dam break and adverse environmental effects, particularly to in-stream ecology and amenity.

Consultation is discussed further in Section 12 .

4.6 Risk Assessment

4.6.1 Risks Particular to Option

The 'high' and 'very high' risks identified that are particular to the Kapakapanui Dam option include:

- Reservoir takes longer to fill if there is a dry winter/spring
- Uncertainties over depth to bedrock, particularly at upper site where there has been less geological investigation than the lower site
- Effects on water quality from upstream logging or other land uses in catchment

- Public (particularly residents immediately downstream) uncomfortable with technical solutions to engineering risks.

4.6.2 Natural Hazards in Relation to Engineering of Dam

There are different categories of risk, those arising from significant natural hazards of flood, earthquake, and slope instability; and those arising from failure to understand the geotechnical issues, manage the design adequately, construct the project correctly, operate or maintain the dam correctly.

The risks and measures adopted to address the above risks are summarised in Table 4-6.

Table 4-6: Kapakapanui Dam Risks and Mitigation Measures

		Mitigation Measure			
Category	**Risk**	**To* NZSOLD**	**QA System**	**Exper-ienced Designer**	**Exper-ienced Con-tractor**
Natural Hazards	Earthquake	✓	✓	✓	
	Flood	✓	✓	✓	
	Reservoir slope stability		✓	✓	
Technical					
1 Design	Geotechnical	✓	✓	✓	
	Hydrology	✓	✓	✓	
	Structural	✓	✓	✓	
2 Construction	Diversion works	✓	✓	✓	✓
	Foundation preparation	✓	✓	✓	✓
	RCC mix or Embankment fill sourcing**	✓	✓	✓	✓
	RCC placing or Embankment fill placing**	✓	✓	✓	✓
	Conventional concrete	✓	✓	✓	✓
3 Commissioning	Diversion closure	✓	✓	✓	
	Diversion plug	✓	✓	✓	
	Reservoir filling	✓	✓	✓	
	Riparian flow while filling	✓	✓	✓	
	Surveillance	✓	✓	✓	

* Exceeding NZSOLD Dam Safety Guidelines commensurate with assessed Potential Impact Classification

** Dependent on whether upper or lower dam site

Earthquake and flood hazards would be mitigated by appropriate design for:

- The anticipated earthquake shaking determined from proximity to the active Gibbs fault 1 km northwest of the dam site; and
- Capacity to pass flood flows appropriate for during construction and also for Maximum Probable Floods during the life of the dam.

Reservoir slope stability has been assessed as part of the geological inspection for the current level of design. Although there are some areas of the reservoir slopes which display shallow instability occurring in the colluvium overlying bedrock, deep seated instability is judged unlikely.

Detailed design would include use of experienced designers, implementation of a quality assurance program using standards exceeding NZSOLD Guidelines commensurate with the assessed Potential Impact Classification for the dam particularly in respect to:

- Refinement of the geotechnical understanding of the site
- Detailed assessment of the flood risk and associated design of the spillway including the energy dissipater and the diversion works
- Structural assessment of the dam including extent of curtain grouting and underdrains.

Similarly, construction would include use of an experienced contractor and implementation of a quality assurance program particularly for construction of:

- Diversion works
- Foundation preparation
- For the RCC alternatives, Roller Compacted Concrete mix design, reliability and consistency of production, transportation, placement and compaction in both the upstream and downstream dam faces and also in the body of the dam, for the earth embankment alternatives reliable and consistent control of materials and compaction in the embankment
- For conventional concrete measures as for RCC, particularly in the spillway chute walls, energy dissipater, and spillway crest.

Risks during commissioning are particularly important as this process establishes the correct functioning of the dam particularly components that control the seepage and piezometric pressures which contribute to the stability of the dam and the reservoir. Complete closure of the diversion works with a concrete plug is included also. Risks identified in the commissioning plan would identify mitigation measures for:

- Programming of closure of the diversion gate preferably programmed in Autumn so that filling will take advantage of winter rains to hasten filling thus shortening the filling period and the time to commission
- Management of riparian flow downstream utilising the outlet pipe
- Surveillance during commissioning which would include precise deflection survey of dam body, monitoring of piezometers and drains and observation of the reservoir perimeter.

4.7 Cost Estimates

4.7.1 Capital Cost Estimates

The base capital cost estimates for the two sites and two volume scenarios are summarised in the table below.

Table 4-7: Kapakapanui Dam Base Capital Cost Estimates

	Lower Site		Upper Site	
Dam Type	**Earth Embankment**		**RCC**	
Scenario	**1**	**2**	**1**	**2**
Live Storage Volume (m^3)	**1.9M**	**1.4M**	**1.9M**	**1.4M**
Fees, Council Costs & Investigation*	$2.65M	$2.65M	$2.65M	$2.65M
Land Value	$0.37M	$0.37M**	$0.37M**	$0.37M**
Construction Cost	$29.32M	$26.19M	$32.60M	$27.00M
Design and Management***	$4.12M	$3.74M	$4.51M	$3.84M
25% contingency	$8.36M	$7.48M	$9.28M	$7.71M
TOTAL	$44.8M	$40.4M	$49.4M	$41.6M

* This provisional figure is based on the fees to date, plus estimated fees to completion of RMA approvals ($1.7M). In addition, allowance is made for Council internal costs ($650,000), geotechnical investigations carried out during Stage 3 ($120,000), legal fees for Council hearings ($100,000), plus Greater Wellington and Council processing costs ($100,000).

** Not specifically valued, but will be of similar order to Lower Site/Scenario 1.

*** Includes an allowance for Council internal costs during Design and Management phase.

4.7.2 Operation and Maintenance Costs

Operational & maintenance (O&M) costs specific to the dam are related to maintaining the reservoir and its margins, catch and release for upstream fish passage, and those related to dam safety and surveillance. These are estimated at approximately $70,000 per year (excluding contingency).

Overall O&M costs for this option are estimated at $1.36M/year increasing to $1.49M/year in 50 years. There is additional expenditure allowed for in about 25 years of about $2.5M for dam refurbishment work.

5 Option B – Lower Maungakotukutuku Dam

5.1 Concept Design

The proposed Lower Maungakotukutuku Dam is located on the Maungakotukutuku Stream, a tributary of the Waikanae River in the western part of the catchment (Figure 5-1). The proposed dam and reservoir is a means of providing in-catchment storage to augment the existing water supply during periods of low flow in the Waikanae River. Water from the reservoir would be released into the stream to be conveyed by the Waikanae River to the water treatment plant and extracted at the existing intake.

The dam site was identified in the mid 1990s and is located where the valley narrows to a gorge downstream of a wider valley section. This site takes advantage of the inherent reduced length of the dam in the narrow section and the increased volume of reservoir in the wider section of the valley. The dam site is approximately 3 km upstream of the confluence of the Maungakotukutuku Stream with the Waikanae River.

The dam site can be accessed from State Highway 1, Nikau Palm Rd, Maui Pomari Rd and to the end of Mahaki Rd, from where a farm track leads to the Maungakotukutuku Valley upstream of the dam site.

Two storage volume scenarios are considered, which are referred to as Scenario 1 (1.9M m^3) and Scenario 2 (1.4M m^3). The smaller storage volume scenario requires some use of the existing bores during serious droughts.

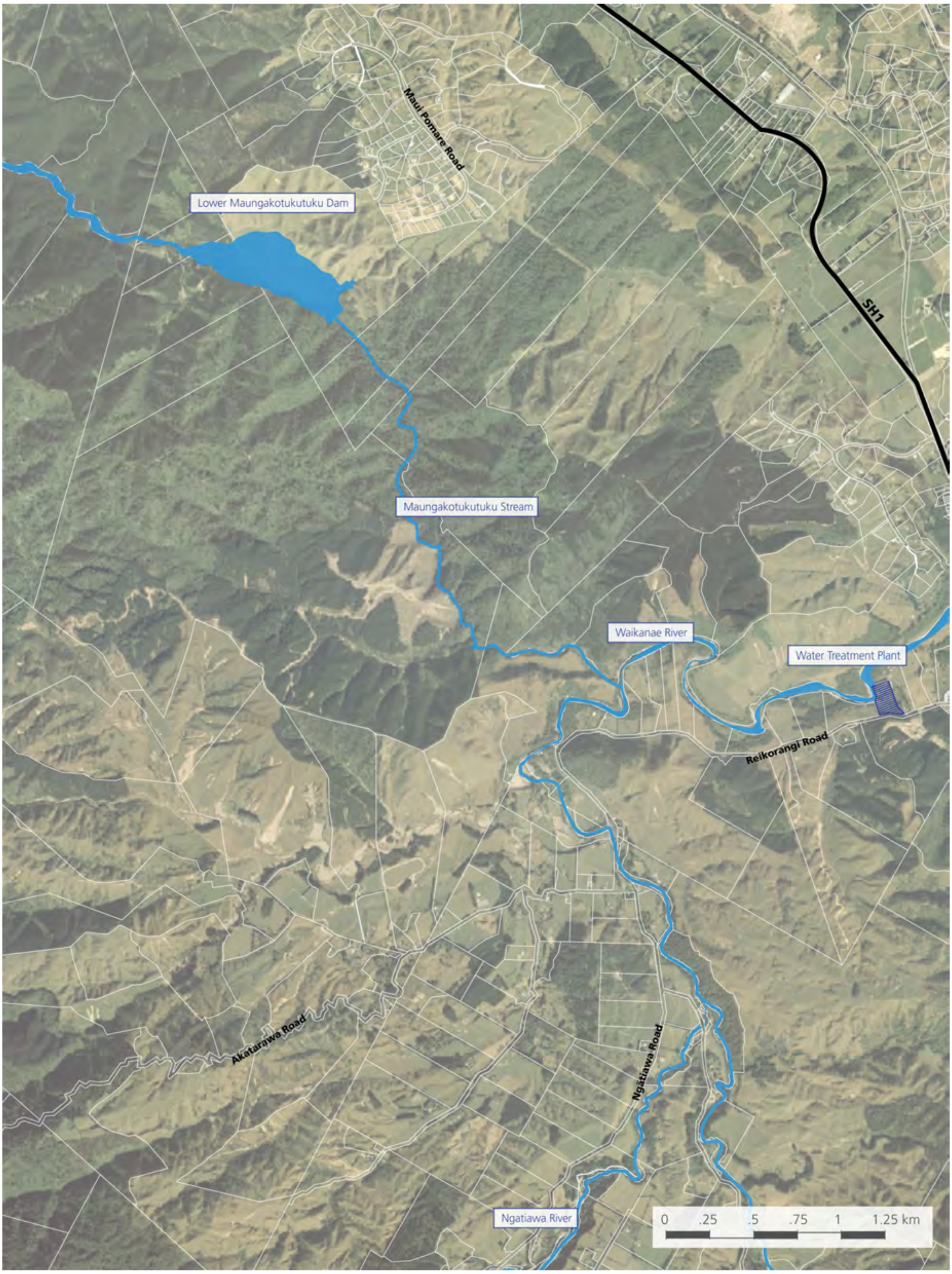


Figure 5-1: Maungakotukutuku Dam Site Location

5.1.1 Site Geology

The geology described in this section is based on walk over and inspection of the dam site and reservoir area and logging of five test pits in the reservoir and saddle areas by an engineering geologist. An investigatory drilling program is underway at the time of writing with the primary purpose to confirm there is no active fault through the valley at the dam site and also to explore dam foundation rock quality – this will be reported separately.

a. Physiography

The site spans a section of gorge immediately downstream from a flat-floored basin. At the dam site the valley is approximately symmetrical with steep slopes extending above the proposed abutment from about RL 170 m. (see Figure 5-2). At the base of the valley there is an inner, slot gorge (>10 m deep) which traverses through the dam site and downstream.

Above the slot gorge, the right bank has a well-developed alluvial terrace at about RL 104 m. An equivalent terrace on the left bank is small and constrained in area.

There are two saddles on the northwest perimeter of the proposed reservoir (see drawings WS909/20/21 and 23 included in Appendix B) which both constrain the top reservoir level and are potential seepage locations.

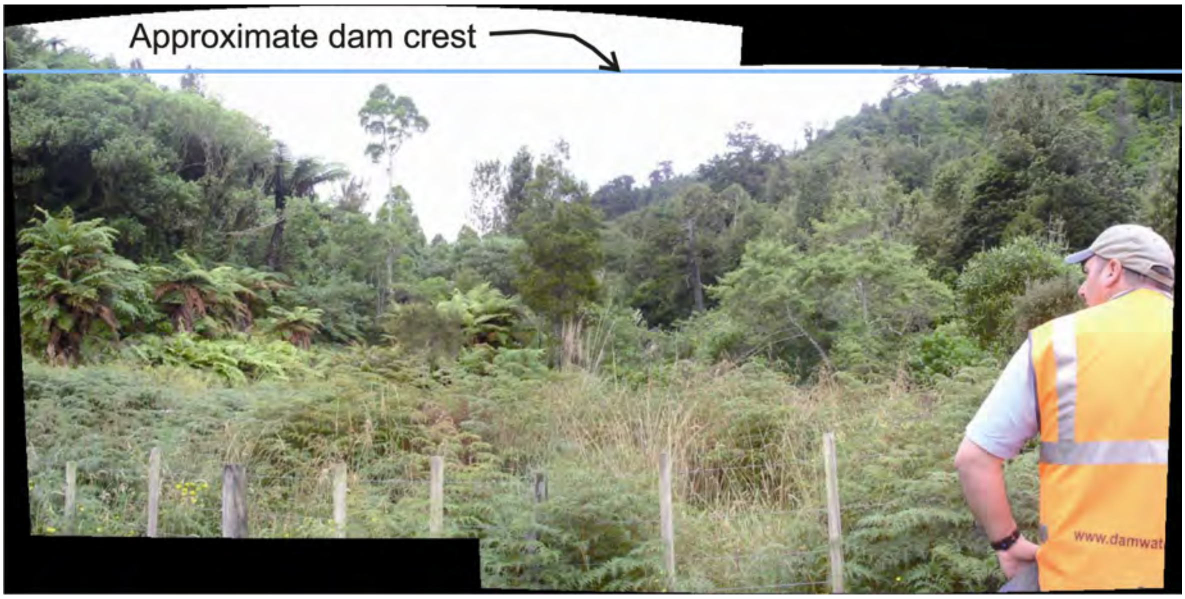


Figure 5-2: Lower Maungakotukutuku Dam Site Looking Downstream

b. General Geology

The basement rock in the area of the dam site and reservoir is greywacke. Although bedrock exposures are limited at the site, those seen show the greywacke to be hard and strong, consistent with the steep terrain. Greywacke exposure in the vicinity of the site is suitable for a dam foundation.

Terraces on both banks at the dam site are the result of previous valley aggradation. Exposures on the right bank show approximately 3 m of relatively fine alluvium. A wedge of alluvium is probably present at the same level on the left bank.

Colluvium mantles steeper slopes in abutment areas (see Figure 5-3). There is a possible small mass movement debris tongue which extends out onto the terrace approximately 600 m upstream from the right abutment. While interpreted as a mass movement deposit the source may be “erosional” rather than a failure in bedrock. This feature would be investigated as part of further design work should this option proceed.

Groundwater profiles are unknown but are expected to be near the bedrock surface.

A traverse of the inner (slot) gorge showed that the stream channel is sinuous and is not controlled by a particular discontinuity i.e. there is no obvious fault present and master joints in the greywacke are random. Most of the gorge walls are very steep to precipitous.

Aerial photographs of the reservoir and dam site area show no sign of major slope failures or mass movement in the steep bedrock slopes of the valley walls.

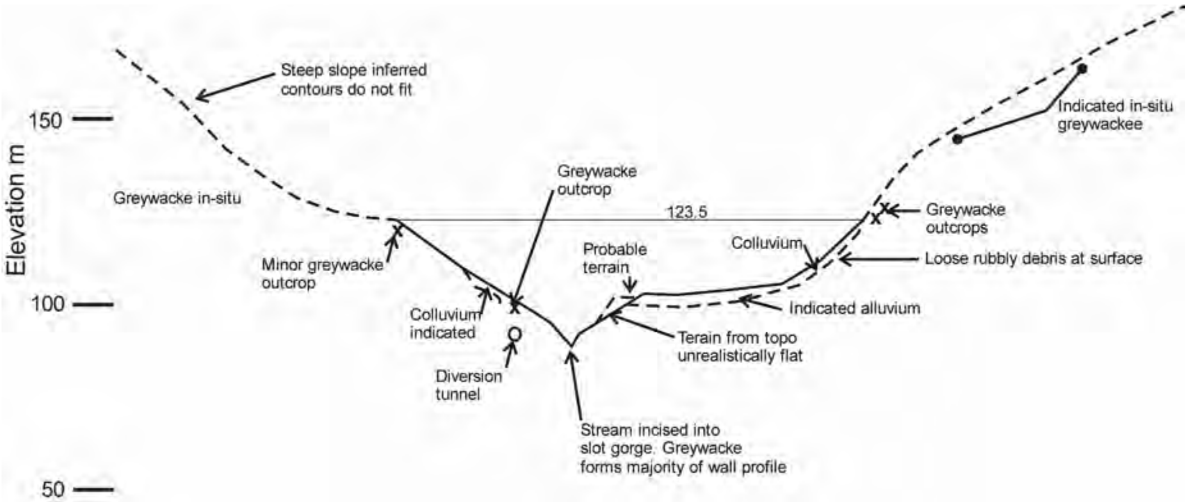


Figure 5-3: Geologic Profile Along Dam Axis Looking Downstream

c. Assessment of Saddles

The two saddles on the northwest perimeter of the reservoir were investigated.

At the southernmost saddle, test pitting identified greywacke bedrock overlain by loess and alluvium judged to have very low permeability. Based on the investigation it is considered that no treatment of this saddle is necessary for reservoir full supply level up to RL 120.5 m as the bedrock rises above the proposed reservoir level.

At the northernmost saddle, surface inspection indicated that a very small saddle dam may be required at this location. The need for and design of a small saddle dam, should it prove necessary, would be included as part of further design work should this option proceed.

5.1.2 Seismicity

Seismic hazards potentially affect dams in three main ways. The first is that an active fault crossing a dam foundation presents potential for fault surface-rupture displacement of the dam itself. The second is that where an active fault crosses a reservoir it presents potential for vertical fault surface-rupture displacement of the reservoir floor to generate a wave that could damage the dam. These are fault displacement hazards. The third is the ground shaking effects of earthquakes on the dam and reservoir slopes.

Seismic hazard assessment therefore requires locating and identifying faults with the potential to affect the dam and determining the characteristics of their activity together with an evaluation of the characteristics of the potential seismic ground shaking effects at the dam.

The faults with the greatest relevance to this dam site are the active Ohariu and Gibbs Faults (see Figure 5-4). A fault hazard assessment in 2004 by the Institute of Geological and Nuclear Sciences (GNS) found no evidence of active faulting passing through the proposed Lower Maungakotukutuku dam site and reservoir. Geological field studies carried out for this report also found no evidence of active faulting passing through the proposed dam site and reservoir. However, the GNS study did map an active fault trace about 170 m downstream of the proposed dam site. The fault trace was mapped for a length of 1.1 km.

While an earlier fault hazard study by GNS in 2003 showed the Gibb Fault as possibly trending up the Maungakotukutuku Valley to the dam site, this was questioned by the 2004 GNS study.

In terms of this report, the most important aspect of the geological studies to date is that there is no evidence to date of active faulting through the dam site or reservoir. In addition the valley slopes in the reservoir area show no signs of major instability and they will have experienced many instances of severe earthquake shaking.

The Gibbs Fault is probably capable of generating earthquakes in the order of magnitude 7 (GNS, 2003).

While the ground shaking hazard has not been evaluated to date for the Lower Maungakotukutuku dam site, experience from other such studies is that dams founded on rock can be designed to withstand ground shaking effects at any location in New Zealand.

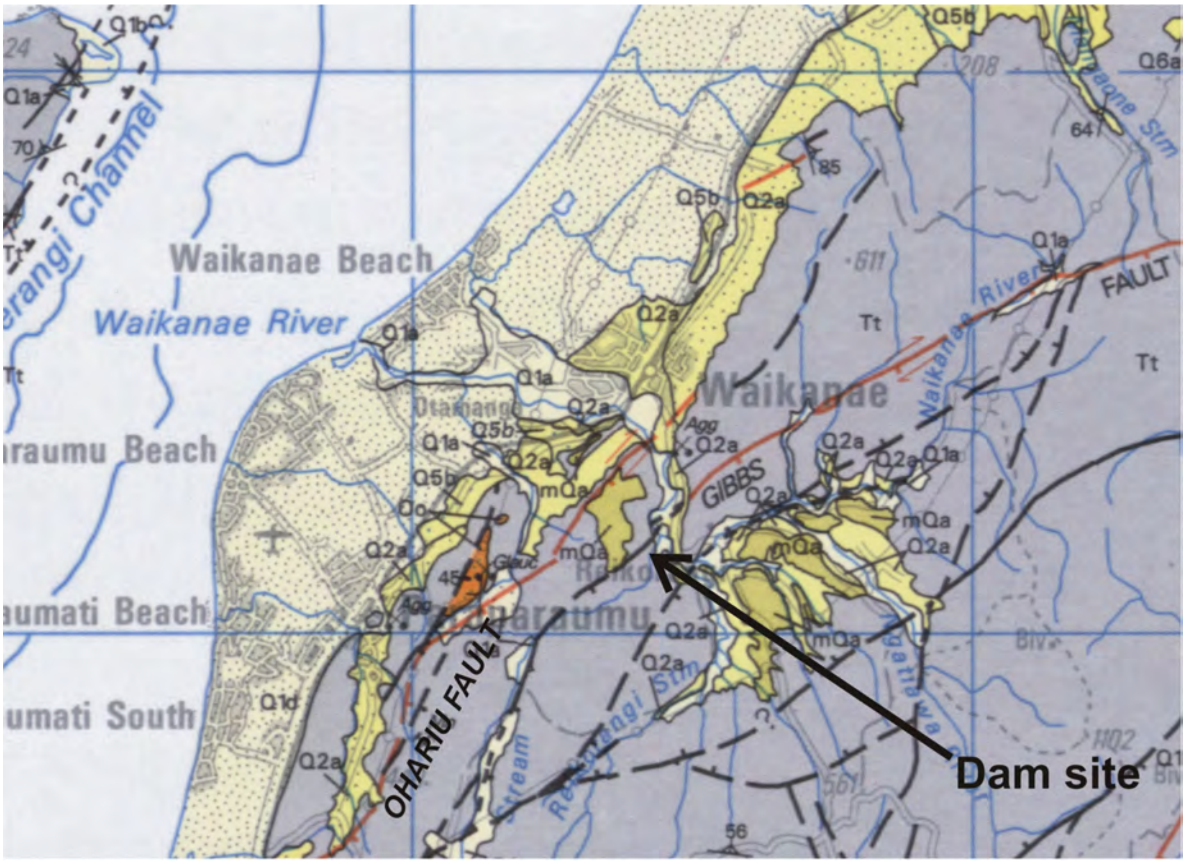


Figure 5-4: Active Faults in the Vicinity of the Lower Maungakotukutuku Dam

5.1.3 Hydrology

The NIWA Water Resources Explorer website[16] has been used to determine flood magnitudes and sediment entering the dam for the concept design of the dam spillway and diversion works. The data used is summarised in Table 5-1.

Table 5-1: Hydrology Data Used for Lower Maungakotukutuku Dam Concept Design

Variable	Value from Website (NZ Reach 9005020)	Derived Value
100 year flood	59 m^3/s	
5 year flood		34 m^3/s
Mean annual flood	26.5 m^3/s	
Mean Flow	0.598 m^3/s	
10,000 year flood		120 m^3/s
Sediment	4.2 kt/year	50 year volume 350,000 m^3

5.1.4 Dam Safety

The design philosophy for the Lower Maungakotukutuku Dam considers safety of the dam structure as a vital component of not only the design, but also of the construction and long-term operation of the water storage scheme.

The design, construction and operation practices must address hazards that have the potential to impact on the safety of the dam and the potential consequences downstream that the dam might influence.

Hazards may be natural hazards such as earthquakes, construction issues such as poor materials, or operational hazards such as sudden changes in river flow.

The NZSOLD Dam Safety Guidelines[17] use a classification system for dams based on the damage potential and the consequences (impacts) that would occur if the dams were to release their reservoir contents. It is standard international practice in dam ownership to provide a means of describing the potential consequences of a dam breaching. The Lower Maungakotukutuku Dam has been assessed as a Medium Potential Impact Classification (PIC) following consideration of public safety and potential economic and environmental impacts.

Based on the PIC rating, an appropriate level of security in the design and operation of the dam has been assigned based on the NZSOLD Dam Safety Guidelines. Having a Medium PIC means that the dam must safely pass the 1:10,000 annual exceedance probability flood. A similar situation applies in regard to earthquake resistance where earthquakes generated by all the active fault sources in the region would be considered in the design of the dam. Similarly, higher standards of design, construction, and operation are demanded where the consequences of dam failure are significant.

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[16] http://wrenz.niwa.co.nz/webmodel

[17] NZSOLD *New Zealand Dam Safety Guidelines*, New Zealand Society of Large Dams, November 2000.

The NZSOLD Dam Safety Guidelines also refer to the risk of landslides in the reservoir potentially affecting downstream safety. International guidelines would be used to assess this risk. The initial assessment of the reservoir and dam site area shows that the slopes are free of areas of major instability.

This means that Lower Maungakotukutuku Dam will be designed to the standards for a Medium PIC dam, and able to safely withstand any of the known natural hazards that might affect it. Design relating to dam safety depends on management of the design risks (i.e. appropriateness and correctness of the design) and management of the geotechnical risks (i.e. site conditions and available materials). The design must also consider construction management and systems and procedures for managing operational risks.

Risks are addressed subsequently in Section 5.6.

5.1.5 Choice of Dam Type

Proximity of greywacke bedrock to found the dam on and locally available potential sources of greywacke rock suitable for concrete aggregate influenced the initial investigation to gravity concrete dam construction. An embankment dam was previously considered for this site[18], however, the colluvium and alluvium available on site has significant amounts of silt and clay fraction which require processing to produce filter and drainage materials or alternatively importation of suitable materials for these components of an embankment dam. Either alternative would be relatively expensive.

A potential greywacke aggregate source for concrete was identified 250 m upstream of the dam access where closely jointed greywacke was found at 2.5 m depth. Rock mass quality is uncertain at the present stage of investigation. Further drilling and seismic survey would be necessary to prove this source should this option proceed.

Concrete gravity dams can withstand overtopping and are commonly designed with the spillway accommodated over the dam body, characteristics not inherent in other types (rockfill and embankment) of dam. The ability of a concrete gravity dam to accommodate an overflow spillway over the dam was influential in the choice of a concrete gravity dam.

A roller-compacted concrete (RCC) dam construction process has been selected based on the reduced construction cost and duration when compared to conventional mass concrete dam construction.

5.1.6 Dam Description

Two reservoir volumes and corresponding dam heights have been assessed. The proposed layouts showing a plan and sections for each of the reservoir volume scenarios are shown on drawings WS909/20/21, 22, 23 and 24, included in Appendix B. The significant characteristics of each scenario are summarised in Table 5-2.

Table 5-2: Significant Characteristics of Lower Maungakotukutuku Dam

	Scenario 1	Scenario 2
Live Storage	1,931,000 m^3	1,431,000 m^3
Dead Storage	350,000 m^3	350,000 m^3

[18] Sinclair Knight Merz, *Preliminary Geotechnical Appraisal of Dam Sites*, 2004

Dam Height	31.5 m	29.5 m
Dam Crest	RL 123.5	RL 121.5
Spillway Crest (full supply level)	RL 120.5	RL 118.5
Spillway Capacity	120 m^3/s	120 m^3/s
Inundation Area	280,200 m^2	235,700 m^2

A free overflow spillway has been chosen for reasons of safety, simplicity of operation and economics. It is designed to pass a 1 in 10,000 annual exceedance probability flood in accordance with the Medium Potential Impact Classification assessed for this dam. The spillway utilises the stepped downstream face of the dam for the base of the spillway chute that is formed by side walls supported from the downstream face of the dam. A roller bucket energy dissipater is included at the base of the spillway to dissipate energy and reduce erosion downstream when the spillway operates.

The RCC dam body is founded on greywacke bedrock. Foundation preparation would involve excavation of alluvium from the flat terrace on the right bank and areas of colluvium on both banks.

The bedrock is generally finely fractured and to reduce seepage through the rock fissures a grout curtain has been included.

Drainage of the downstream area of the dam footprint would be with underdrains placed at the time of preparation of the foundation rock surface. These underdrains would discharge downstream of the dam. Flows from these drains would be monitored as part of the dam surveillance program.

Outlet works which enable drawing reservoir water from three levels of the reservoir are accommodated in an intake tower which is integral with the upstream face of the dam. The outlet works deliver from the tower through a gallery through the dam body to a control valve discharging into the spillway energy dissipater. It is anticipated that outlet flows would be controlled remotely from the water treatment plant. This outlet will provide minimum flows immediately downstream during reservoir filling.

5.1.7 Micro-hydro Potential

The dam would remain full most of the time when there is sufficient flow in the Waikanae River to supply the water demand. Stream flow would discharge over the spillway if the outlet works are closed.

There is potential to tap into the water supply outlet works pipe which passes through the dam body with a micro-hydro penstock. This penstock could feed into a micro-hydro power station immediately downstream of the dam. The amount of flow that could be utilised to generate electricity would be dependant on the generation capacity installed and ability of the plant to utilise low flows.

If, however, the plant can utilise 70% of the flow available, which is a normal utilisation for such an installation, the potential energy generation, based on mean flow of 598 L/s and overall efficiency of 80%, would be 900,000 kW.hr per year for Scenario 1 and 850,000 kW.hr per year for Scenario 2.

The cost of a micro-hydro power station has not been estimated, however, inclusion of a micro-hydro station could be included in later stages of this option should it proceed.

5.1.8 Fish Passage

Provision is allowed in the cost estimates for conveying upward migrating fish past the dam using a “catch and carry” method. This method attracts the upward migrating fish into a trap with a release flow. The trapped fish are then physically carried upstream and transferred to the lake or a tributary upstream. This system is operated over the spring and summer migrating season, with daily checks and transfers.

Downward migration is achieved by screening the normal release conduit so that adult fish migrating downstream cannot enter the release pipe and are attracted to another release pipe designed specifically for transfer of adult migrating fish.

5.1.9 Construction

The construction contractor would be expected to have relevant track record in dam construction of similar magnitude and complexity to the Lower Maungakotukutuku dam.

The main construction activities are civil works activities including:

- Progressively clear the construction area of vegetation, strip and stockpile top soil
- Construct access roads and site facilities
- Commence quarry activities and preparation of aggregates for RCC production
- Construct the river diversion
- Construct upstream and downstream cofferdams to protect dam construction activities from the river
- Excavate and prepare dam foundation
- Construct dam using RCC placement methodology
- Form seepage barrier in rock foundations directly beneath dam by drilling and pressure grouting through a plinth integral with the upstream dam face
- Selectively clear large trees upstream of the dam site within the reservoir footprint
- Remove downstream cofferdam
- Commence reservoir impoundment using closure gate planned with favourable weather forecast
- Commission dam - monitoring reservoir filling and initial dam performance
- Construct concrete plug to seal diversion culvert after commissioning complete
- Clear construction site and complete site rehabilitation works.

The construction period is estimated to be 18-20 months duration for Scenario 1 and 16-18 months duration for Scenario 2.

5.1.10 Commissioning

Under mean flow conditions (598 L/s) and with allowance for a residual flow downstream of the dam (130 L/s), a reservoir with capacity of 1,931,000 m^3 will take some 7 weeks to fill (this duration will also be somewhat affected by evaporation, infiltration and rainfall, which have not been included). Lake filling will be achieved by closing the diversion culvert bulkhead gates when the dam, spillway and penstock intake structure are complete and functional. Initiation of lake filling will be scheduled with benefit of both favourable short and intermediate range weather forecasts preferably in autumn to take advantage of higher winter flows to speed filling the reservoir.

During the lake filling period downstream flows will be maintained by discharging through the lowest intake.

Subsequently, after the reservoir has filled the diversion culvert will be permanently plugged with water tight mass concrete infill.

The dam would be instrumented with flow measuring weirs on the outlet to the underdrains. Piezometers would be located under the dam foundation to measure uplift pressure under the dam. Survey monuments would be located along the crest of the dam to confirm dam deformation behaviour is within expectations. These instruments would be monitored from completion of the dam body through reservoir filling and subsequently over the life of the dam. During the commissioning period, from commencement of reservoir filling through to one month after reservoir full the frequency of monitoring the weirs and piezometers would be once daily. Thereafter, dependant on satisfactory performance of the dam and foundations the monitoring frequency would be decreased to weekly and subsequently to bi-monthly. This is expected to be over several months. The dam crest monuments would be surveyed frequently during initial reservoir filling and through the following month. Thereafter, dependant on satisfactory performance of the dam body the frequency of crest monument survey would be decreased to monthly for a period until satisfactory performance is evident. After that dam deformation survey would be conducted annually.

Monitoring, as described above would consist of reading and recording instrumented values.

During reservoir filling the reservoir side slopes would be observed periodically from a boat in the partly filled reservoir in order to observe any signs of slope instability.

5.1.11 Operation and Maintenance

Once operational Lower Maungakotukutuku dam would require routine maintenance of the facilities including:

- Access roads, including running surface, drainage facilities, berms and verges vegetation control
- Site maintenance including, site drainage facilities, and clearance of debris from the spillway works
- Servicing of the outlet valves and associated automatic controls and actuators
- Routine surveillance which would include bi-monthly inspection and reading of the drainage weir and piezometers; annual inspection and a Comprehensive Safety Review every 5 years.

5.1.12 Summary of Findings from Geotechnical Investigations

The overall findings from the reconnaissance level geological mapping and data from the drilling programme completed in early July 2010 at the Lower Maungakotukutuku Dam site and surrounds is summarised as follows. Further information can be found in Appendix H.

- The dam site is underlain by greywacke bedrock.
  The greywacke bedrock is moderately to highly jointed and sheared. The rock mass however is relatively competent, as demonstrated by the near vertical sides of the inner gorge, which has withstood multiple seismic events over tens of thousands of years.
- The left abutment greywacke has been hydrothermally altered.
  The greywacke beneath the left abutment intercepted by drillhole LM1 has been hydrothermally altered millions of years ago. This accords with observations in the inner river gorge just upstream from the dam site. The extent of this altered greywacke is yet to be defined.
- The permeability of the greywacke rock mass is low.
  Tests within the drillholes indicate the greywacke rock mass has a very low permeability. It is anticipated that foundation treatment, such as grouting, required to control seepage under the dam, would therefore be limited.
- No large scale discontinuities have been identified.
  No faults, or low angle discontinuities of significance have been encountered within the

drillholes. This concurs with the lack of surface displacement displayed at the damsite, inferring an absence of potentially active faults. No sub-horizontal discontinuities or through going faults of recent origin have been encountered, although drilling has yet to fully investigate the dam foundation.

- Overburden on the terraces would need to be stripped.
  Approximately 6m of alluvial and colluvial overburden was intercepted on the right bank terraces with inferred thickening of overburden at the right abutment. Minor alluvium and a wedge of colluvium is present on the left bank. This overburden would be stripped to prepare the dam foundation.
- The site is considered suitable for siting a gravity dam and diversion tunnel.
  The current level of investigation has located no fatal flaws. Further investigation necessary to fill in gaps in the geological information would be required as part of subsequent detailed design.

5.2 Yield

The following table summarises some of the key results of the yield modelling for the Lower Maungakotukutuku Dam. These results are based on a peak day demand of 32,000 m^3/day, the 2007/08 demand profile, the 2002-2006 Waikanae River flow records adjusted to reach a 50 year low flow and a core river allocation of 26,000 m^3/day.

Table 5-3: Lower Maungakotukutuku Dam Yield Modelling Results

Dam Live Storage Volume	1.9M m^3 (Scenario 1)	1.4M m^3 (Scenario 2)
Number of days reservoir used in one year in a 50 year drought	145 days	145 days
Longest period of continuous use of reservoir	59 days	59 days
Maximum daily outflow from dam for water supply	29,500 m^3/day	29,500 m^3/day
Time to fill after a 50 year drought	22 days	21 days
Shortfall - number of days borefield used in a 50 year drought	0 days	7 days
Maximum daily take from borefield in a 50 year drought	0 m^3/day	12,100 m^3/day

The yield modelling used a flow into the reservoir of 16.2% of the flow in the Waikanae River and the minimum residual flow in the stream downstream of the dam is 130 L/s.

The following graph shows how the total demand will be met over the four year modelling period with a minimum river flow of 517 L/s and maximum demand of 32,000 m^3/day.

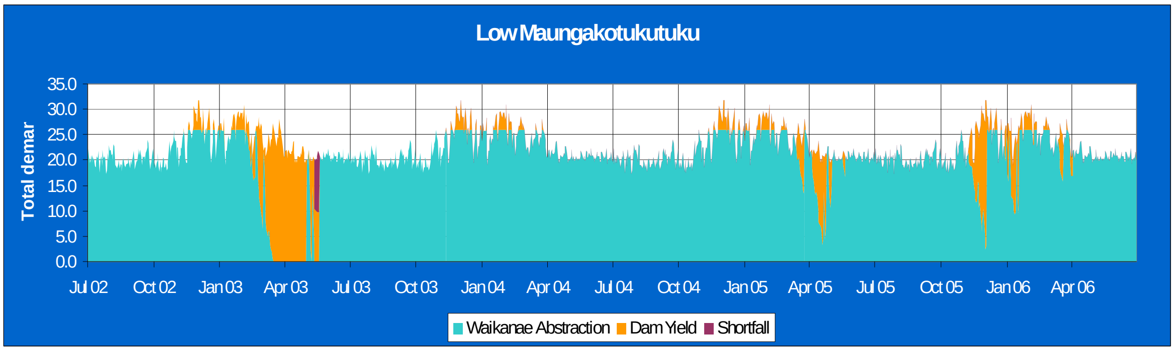

Figure 5-5: Yield to meet demand with Lower Maungakotukutuku Dam (1.4M m^3)

The following graph shows the Lower Maungakotukutuku Dam with a 1.4M m^3 live storage reservoir emptying and filling over this same period under the same conditions.

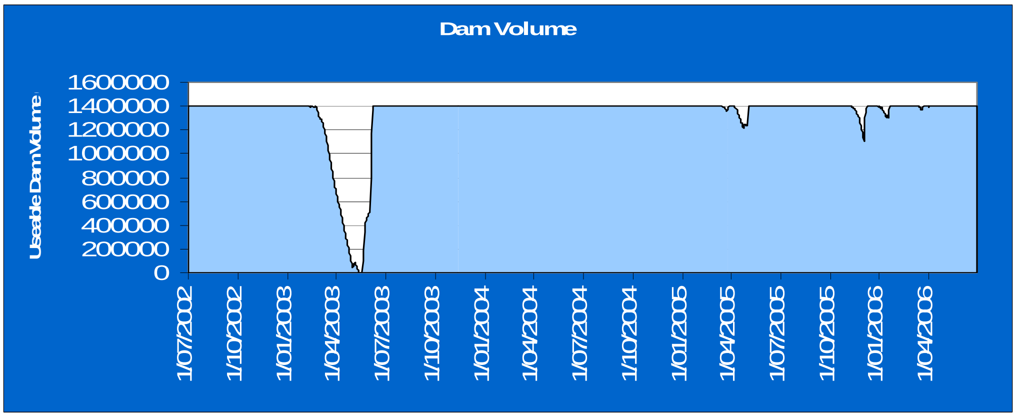

Figure 5-6: Lower Maungakotukutuku Dam (1.4M m^3) Volume Profile for 50-year Drought

5.3 Treatment

The treatment requirements for this option are the same as for the Kapakapanui Dam - refer Section 4.3.

5.4 Environmental Assessment

5.4.1 In-Stream Ecology

a. Habitat conditions

The four sampling sites in the Maungakotukutuku Stream were all fairly similar in that they were all relatively shaded, and had an immediate riparian margin dominated by native vegetation (Figure 5-7 to Figure 5-10). The uppermost site was located in an area dominated by pine plantation, although the immediate riparian vegetation was natural. The other three sites were located in areas dominated by more native bush, although the site immediately above the proposed dam (Maungakotukutuku DS2) was located in an area with regenerating native bush on the true right and pasture on the true left. This stream was deeply incised and flowed through a deep gully for much of its length. The streambed at all sites was dominated by a mixture of small gravels, cobbles and boulders, with areas of bedrock.

b. Overview of evaluations

The biological communities of the Maungakotukutuku Stream were investigated. Six fish species were found, the most common of which were longfin eels and redfin bullies. The fish fauna appears typical to that of other rivers in the area. The invertebrate community was dominated by invertebrates indicative of streams in good-excellent condition, with low nutrient water. Community composition changed little along the stream, so loss of a section of stream as a result of creation of the dam will not necessarily lead to a reduction to the invertebrate biodiversity values of this stream.

Hydrological analysis of data from the Waikanae River shows that there would be very little difference in flow statistics of the residual flows downstream of the take when low flows are augmented with release from the proposed dam.

Refer to NIWA's report in Appendix C for further details.

c. Key Issues Encountered

- Dam construction would potentially disrupt movement of native fish to and from the sea. In particular, there is a high risk that eels will encounter the dam when migrating downstream. Survival of, or damage to, eels moving past the dam will be an issue.
- Water quality in the reservoir may be affected as flooded vegetation at the proposed site decomposes. A decision needs to be made as to whether large trees would be removed prior to reservoir filling, or whether they would be left to decompose. If vegetation is removed, sedimentation may become an issue.
- There will be a total loss of river habitat, displacing fish such redfin bullies and torrent fish and koaro, and invertebrates from the flooded river. Other fish species such as trout, giant kokopu and eels, however, can tolerate lentic (standing water) conditions.

d. Mitigation

- Fish passage can be assisted by constructing a bypass pipe/channel such that when water gets close to crest/spill levels, an open pipe through the dam provides safe passage down to the streambed.
- A multi-level outlet structure could be included in the dam design to allow the release of both surface oxygenated water, and deeper water to minimise against release of poor quality water. Such a structure has been incorporated in the concept design.

Figure 5-7: Photograph of the Maungakotukutuku Upstream Site 1

Figure 5-8: Photograph of the Maungakotukutuku Upstream Site 2

Figure 5-9: Photograph of the Maungakotukutuku Downstream Site 1

Figure 5-10: Photograph of the Maungakotukutuku Downstream Site 2

5.4.2 Terrestrial Ecology

a. Protected areas

About 18 ha of land, in Lot 2 Deposited Plan 360865, has been covenanted by previous landowners under the Reserves Act 1977 to protect ecological values. This area is part of Heritage Site E17 in the District Plan, which is the largest example of indigenous bush/wilderness area on the Coast, and is considered to be of 'Regional Significance'. Approximately 4.41 ha of this covenant would be inundated or affected by construction works, however the effect on the forest could extend beyond this area as waterlogged soils rot roots, and also through edge effects, caused by clearance and related drying out of the interior of the forest margin.

The covenant includes the following provisions:

(a) To protect and enhance the natural character of the Land with particular regard to the indigenous flora and fauna;

(b) To protect the landscape amenity of the Land;

(c) To protect the landscape amenity of the indigenous vegetation, and to preserve the land as a representative sample of the class of natural ecosystem which in the aggregate originally gave the Tararua Ecological District its own recognisable character;

(d) To allow and encourage the natural regeneration of indigenous species;

(e) To preserve freshwater life on and habitat of the land;

(f) To preserve the historical, archaeological and educational values of the land.

Ecological values of this covenant include the primarily indigenous riparian vegetation along the Maungakotukutuku Stream, an extensive area of kohekohe forest on the slopes above the stream and mature (for lowland parts of Tararua Ecological District) podocarp hardwood forest along the lower reaches of the stream within the land parcel.

Refer Appendix D for maps and further details.

b. Vegetation and habitats

Most of the area proposed to be flooded is primarily pasture or exotic plantation forest, with a range of indigenous species in the understorey of the pine plantation. The vegetation types are summarised in Table 5-4.

The riparian margin of the stream comprises primarily indigenous species, including within the plantation forest. The quality of the indigenous riparian vegetation improves along a downstream gradient.

Vegetation at the southern end of the property has been more modified by introduced conifers and stock access. Vegetation along the stream in the northern half of the property progressively improves to become rimu-pukatea/tawa-mahoe canopy at the northern end, especially on the true right side of the stream (i.e. right side when looking downstream). Vegetation on the most downstream section of the true left side appeared to be predominantly kohekohe and mahoe, with mamaku and occasional rewarewa, rimu and matai. A small toetoe-bracken fern wetland is present where the degraded pastoral wetland drains down through the riparian forest to the Maungakotukutuku Stream.

Table 5-4: Vegetation types Within Lower Maungakotukutuku Inundation Area

Ecological Value	Vegetation Type	Hectares	% of Inundation Area
High	Riparian forest	2.67	9.5%
	Mixed hardwood podocarp forest	1.68	6.0%
	Kohekohe forest	0.85	3.0%
	Wetland	0.03	0.1%
High Total		5.23	18.6%
Moderate	Introduced conifer/riparian forest	0.71	2.5%
Moderate Total		0.71	2.5%
Low-moderate	Plantation forest	5.94	21.1%
	Degraded wetland	2.88	10.3%
	Clearing	0.47	1.7%
	Indigenous-exotic shrubland	0.16	0.6%
Low-moderate Total		9.00	33.6%
Low	Pasture	12.69	45.2%
Low total		12.69	45.2%
Total inundation area		27.63	100.0%
Total Area High and Moderate Value		5.94	21.1%

The entire true right face adjacent to the stream, above the strip of riparian vegetation, comprises kohekohe forest or rewarewa/kokekohe forest. Part of this area would also be flooded. The good condition of the kohekohe forest indicates that possums are being controlled to relatively low levels. The canopy is generally completely closed, with the exception of some clearings *c*.100 m upstream of the potential dam site.

Fencing along a section of the southern part of the covenant is in poor repair, with stock grazing the understorey. At the northern end, the fence was in better condition, but stock may still move along the stream and gain access to this area.

In the vicinity of the dam site the vegetation includes a diverse range of species in the canopy, including tawa, rewarewa, pukatea, and kohekohe with stem diameters greater than 30 cm. There is also an impressive old multi-stemmed mahoe with a combined stem diameter greater than one metre and a matai with a diameter at breast height of *c*.1.7 m and *c*.30 m tall. Other canopy species include heketara, pigeonwood, pate, nikau, and mamaku.

Understorey vegetation cover, including that present at the proposed drilling sites, was reasonably dense, reflecting stock exclusion and possum control. Understorey vegetation comprised seedlings and small trees of kohekohe, heketara, rewarewa, kawakawa, mahoe, tawa, and pate. A range of shrub and small tree species was present, including kanono, karamu, *Coprosma rotundifolia*, hangehange, pigeonwood, ramarama, nikau, supplejack vines, silver fern, mamaku, wheki, and kiekie. In most places, a carpet of ferns clothes the ground (Figure 5-11).

Figure 5-11: Dense Understorey Vegetation at Lower Maungakotukutuku Site

No threatened plant species were seen during the brief field surveys. The podocarp-hardwood forest and the kohekohe forest, are not classified as regionally-threatened plant communities in the Wellington Region (Sawyer 2004). Kohekohe forest is under threat from possum browse, but possums are controlled to low levels at this site by the Department of Conservation.

c. Fauna

Tui were abundant, and a black shag was seen to fly into the northern riparian margin, indicating a possible roost or fishing site. Warblers, silvereyes, fantails, and pukeko were common. Kereru, Australasian harrier and paradise shelduck were regularly seen. A range of introduced species use the site, such as eastern rosella, greenfinch, goldfinch, blackbird, and starling. Sheep and cattle graze the paddocks and a goat carcass was seen within the pine forest.

d. Possible ecological effects

- Clearance of vegetation. Indigenous vegetation clearance may be greater than indicated above, as this figure was based solely on potential inundation area and did not include work platform of access or maintenance routes.
- An edge in excess of 700 m long would be created. Vegetation clearance may cause surrounding vegetation to dry out by removal of buffering vegetation. Such edge effects are likely to be more pronounced in taller vegetation.
- Construction and clearance works may cause damage to roots of large trees adjacent to clearance areas, with subsequent deterioration in health.
- Potential introduction of unwanted species (e.g. weeds).
- Soil compaction.

- Changes to the water table, which could cause previously unaffected vegetation to die or deteriorate through root rot.
- Loss of habitat for indigenous terrestrial fauna.
- Loss of riparian vegetation and potential deterioration of in-stream ecological values.
- Soil slumping causing additional loss of vegetation.

e. Potential mitigation

- Replanting edges with suitable eco-sourced plant species to assist with rapid edge reestablishment.
- Check for weeds on construction and works sites every three months for the first two years, and yearly thereafter for up to five years, or until a canopy is re-established, and undertake weed control as required.
- Establish temporary fences or high visibility tape around trees and parts of the site that need to be avoided.
- Employ silt retention devices around the perimeter of the cleared site and construction areas.
- Undertake or fund pest control within remaining area of forest.
- Establish indigenous riparian margin (at least 20 m wide) using suitably eco-sourced plant species, along non-forested portions of the final lake.

5.5 Consultation

In general, the concept of a dam as a water supply solution appears to have general support in the community. However, concern has also been expressed by some residents immediately downstream of the potential dam sites. Those noting support for dam options talk of the benefit of the certainty of a tried and tested concept and of capturing rain water sensibly in the hills. Those noting opposition talk of the risk of dam break and adverse environmental effects, particularly to in-stream ecology and amenity. This dam site is located within a conservation covenanted area, and there are specific issues to be addressed around the inundation of significant vegetation and habitat.

Key Group	Summary of Consultation Outcomes
Iwi	Council continues to build a partnership approach with tāngata whenua and remain committed to supporting a partnership approach to this significant community project. Council is working closely with the Te Āti Awa in the spirit of the Memorandum of Understanding being developed for this project, particularly with the Te Āti Awa Water Working Group in the investigation of cultural impacts. At this stage, tāngata whenua have not identified any fatal flaws with this option in relation to the core values of kaitiakitanga, tino rangatiratanga. tāonga, mauri and whakapapa.
Landowners directly affected	There are two main landowners directly affected by this dam. Both landowners are generally supportive of the dam. There are site specific matters to be addressed, including site access and providing for the ongoing operation of farming and forestry activities on site. It is also likely that an upstream access bridge from the dam site will be inundated and may need to be relocated or replaced. However, it is anticipated these matters can be satisfactorily addressed through design and mitigation measures.
Other landowners potentially affected	Some concern regarding dam break risk from downstream resident and environmental effects of damming stream.

Stakeholders GWRC DoC Fish & Game Forest & Bird Department of Conservation Friends of Waikanae River	Key stakeholders have been kept well informed of investigations to date. The six short-listed options were presented to a select group on 8 June 2010 with a focus on environmental effects, including the findings of the investigations of NIWA and Wildland Consultants. Representatives from Fish & Game, Forest & Bird and Friends of Waikanae River attended the presentation. Stakeholders were also presented with a summary of the technical investigations on 1 July 2010. At this stage of the project, initial feedback from stakeholders appears to suggest that there are no apparent fatal flaws with this option, however further detailed investigation will need to be undertaken into the environmental effects if it is preferred, particularly around conservation values, in-stream ecology and the overall impact on river flow.
Wider Community	The concept of a dam as a water supply solution appears to have general support in the community. Those noting support for dam options talk of the benefit of the certainty of a tried and tested concept and of capturing rain water sensibly in the hills. Those noting opposition talk of the risk of dam break and adverse environmental effects, particularly to in-stream ecology and amenity.

5.6 Risk Assessment

5.6.1 Risks Particular to Option

The ‘high’ and ‘very high’ risks identified that are particular to the Lower Maungakotukutuku Dam option include:

- Algal blooms, particularly when reservoir water level low - shallow depth over paddock area
- Poor water quality during algal blooms in dam and river, and not able to be adequately treated by PAC & BAC at WTP (likelihood considered “rare”, contingency of the addition of ozone treatment)
- Upstream logging & other land use changes (e.g. fertiliser use, pest control etc)
- Dam foundation not as good as what has been assumed for concept design (drilling investigations currently underway to confirm foundations)
- Reservoir takes longer to fill if there is a dry winter/spring or two dry years in a row
- Public (particularly 1 dwelling in floodplain downstream) uncomfortable with technical solutions to engineering risks (dam break and seismic).

5.6.2 Natural Hazards in Relation to Engineering of Dam

There are different categories of risk. They include those arising from significant natural hazards of flood, earthquake, and slope instability; and those arising from failure to understand the geotechnical issues, manage the design adequately, construct the project correctly, operate or maintain the dam correctly.

The risks and measures adopted to address the above risks the same as for the Kapakapanui Dam – refer summary in Table 4-6.

Earthquake and flood hazards would be mitigated by appropriate design. Design to resist the anticipated earthquake shaking determined from proximity to the active Gibbs fault 170 m northwest of the dam site. Capacity to pass flood flows appropriate for during construction and also for extreme floods during the life of the dam.

Reservoir slope stability has been assessed as part of the geological inspection for the current level of design. Although there are some areas of the reservoir slopes which display shallow instability occurring in the colluvium overlying bedrock, deep seated instability is not observed in the reservoir and is judged unlikely.

Detailed design would include use of experienced designers, implementation of a quality assurance program using standards exceeding NZSOLD Guidelines commensurate with the assessed Potential Impact Classification for the dam particularly in respect to:

- Refinement of the geotechnical understanding of the site
- Detailed assessment of the flood risk and associated design of the spillway including the energy dissipater and the diversion works
- Structural assessment of the dam including extent of curtain grouting and underdrains.

Similarly, construction would include use of an experienced contractor and implementation of a quality assurance program with particular emphasis on construction of:

- Diversion works
- Foundation preparation
- Roller Compacted Concrete mix design, reliability and consistency of production, transportation, placement and compaction in both the upstream and downstream dam faces and also in the body of the dam
- For conventional concrete, measures as for RCC, particularly in the spillway chute walls, energy dissipater, and spillway crest.

Risks during commissioning are particularly important as this process establishes the correct functioning of the dam, particularly components that control the seepage and piezometric pressures, which contribute to the stability of the dam and the reservoir. Complete closure of the diversion works with a concrete plug is included also. Risks identified in the commissioning plan would identify mitigation measures for:

- Programming of closure of the diversion gate preferably programmed in Autumn so that filling will take advantage of winter rains thus shortening the filling period and the time to commission
- Management of riparian flow downstream utilising the outlet pipe
- Surveillance during commissioning which would include precise deflection survey of dam body, monitoring of piezometers and drains and observation of the reservoir perimeter.

5.7 Cost Estimates

5.7.1 Capital Cost Estimate

The base capital cost estimates for the two volume scenarios are summarised in the table below. The cost estimate is based on a favourable outcome from the drilling that is being undertaken at the time of writing, particularly that no indication of active faulting is found in the dam foundation and that the foundation rock is suitable for founding a RCC dam.

Table 5-5: Lower Maungakotukutuku Dam Base Capital Cost Estimates

Scenario	1	2
Live Storage Volume (m^3)	1.9M	1.4M
Fees, Council Costs & Investigation*	$2.65M	$2.65M
Land Value	$1.29M**	$1.29M***
Construction Cost	$16.58M	$15.69M
Design and Management****	$2.59M	$2.48M
Contingency (25%)	$4.79M	$4.54M
TOTAL	$27.9M	$26.7M

* This provisional figure is based on the fees to date, plus estimated fees to completion of RMA approvals ($1.7M). In addition, allowance is made for Council internal costs ($650,000), geotechnical investigations carried out during Stage 3 ($120,000), legal fees for Council hearings ($100,000), plus Greater Wellington and Council processing costs ($100,000).

** This figure is based on the cost of buying the area necessary for the dam footprint, associated access, the inundation area of the reservoir and a buffer area around the reservoir. It also includes Emission Trading Scheme (ETS) costs and off-setting of an area of native forest of equivalent conservation value.

*** Scenario 2 not specifically valued, but expected to be of a similar order to Scenario 1

****Includes an allowance for Council internal costs during Design and Management phase.

5.7.2 Operation and Maintenance Costs

Operational & maintenance (O&M) costs specific to the dam are related to maintaining the reservoir and its margins, catch and release for upstream fish passage, and those related to dam safety and surveillance. These are estimated at approximately $70,000 per year (excluding contingency).

Overall O&M costs for this option are estimated at $1.36M/year increasing to $1.49M/year in 50 years. There is additional expenditure allowed for in about 25 years of about $2.5M for dam refurbishment work.

6 Option C – Ngātiawa Dam

6.1 Concept Design

The proposed Ngātiawa Dam is located on the Ngātiawa River, a tributary to the Waikanae River, as shown on Figure 6-1. The proposed dam and reservoir is a means of providing in-catchment storage to augment the existing water supply during periods of low flow in the Waikanae River. Water would be released into the stream to be conveyed via the Waikanae River to the water treatment plant and extracted at the existing intake.

The proposed dam site was identified in the mid 1990s and located where the valley narrows to a gorge downstream of a wider valley section. This site takes advantage of the inherent reduced length of the dam in the narrow section and increased volume of reservoir in the wider section of the valley. The dam site is approximately 3 km upstream of the confluence with the Waikanae River and is accessed from Ngātiawa Road.

Two storage volume scenarios are considered, which are referred to as Scenario 1 (2.0M m^3) and Scenario 2 (1.5M m^3).

Figure 6-1: Ngātiawa Dam Site Location

6.1.1 Site Geology

a. Physiography

The site spans a relatively narrow valley adjoining the road into the Ngātiawa Valley. The valley is relatively symmetrical and there is a deep gorge to the left of centre where the dam site is located (see Figure 6-2).

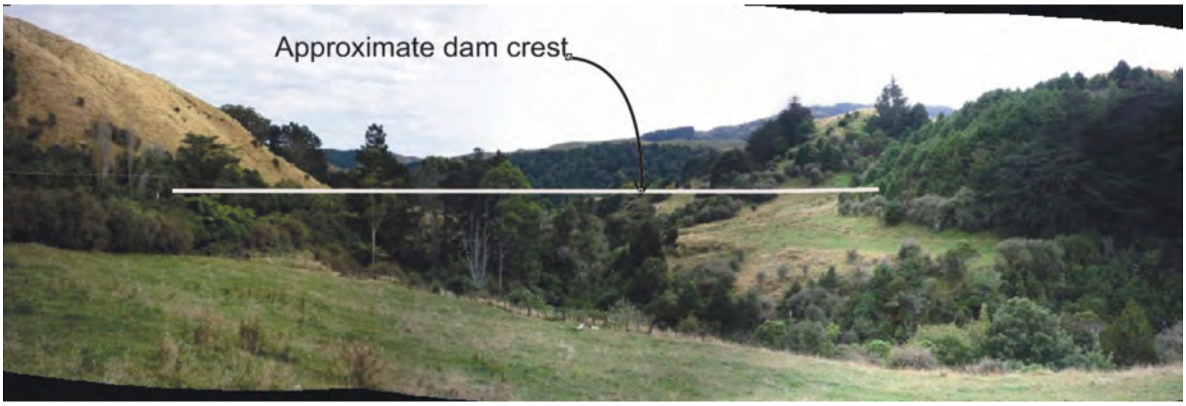

Figure 6-2: Ngātiawa Dam Site Looking Downstream

b. General Geology

The geological investigation at the site was limited to surface geological mapping.

The dam site is underlain by greywacke with minimal overlying materials. Some alluvium may be present on the left abutment bank where there may be the upstream end of a paleochannel.

There are no known discontinuities passing through the site. No mass movement features have been observed in the area. There is an erosion area in colluvial deposits in the road cut batter but this should not be equated to mass movement.

6.1.2 Seismicity

The faults with the greatest relevance to the dam site are the active Ohariu and Gibbs Faults which are located in the vicinity of the dam site. The nearest is the Gibbs Fault, which trends 1.2 km northwest of the dam site and is probably capable of generating earthquakes in the order of magnitude 7 (GNS, 2003).

Fault hazard assessment studies relevant to the dam site area were carried out by the Institute of Geological and Nuclear Sciences (GNS) in 2003[19] and 2004[20]. Both these GNS studies and the geological field studies carried out for this report found no evidence of active faulting passing through the proposed dam site and reservoir.

In terms of this report, the most important aspect of the geological studies to date is that there is no evidence to date of active faulting through the Ngātiawa dam site or reservoir.

[19] Geological and Nuclear Sciences, Van Dissen R,, Heron D, 2003, Earthquake Fault Trace Survey, Kāpiti Coast District

[20] Geological and Nuclear Sciences, Townsend D, Heron D, 2004, Maungakotukutuku Proposed Dam Site, Kāpiti Coast District: Prefeasibility Fault Hazard Assessment

Figure 6-3: Active Faults in the Vicinity of Ngātiawa Dam

6.1.3 Hydrology

The NIWA Water Resources Explorer website[21] has been used to determine flood magnitudes and the amount of sediment entering the dam for the concept design of the dam spillway and diversion works. The data used is summarised in Table 6-1.

Table 6-1: Hydrology Data Used for Ngātiawa Dam Concept Design

Variable	Value from Website (NZ Reach 9004602)	Derived Value
100 year flood	246.8 m^3/s	
5 year flood		136 m^3/s
Mean annual flood	111.6 m^3/s	
Mean Flow	1.09 m^3/s	
10,000 year flood		120 m^3/s
Sediment	7.3 kt/year	50 year volume 610,000 m^3

6.1.4 Dam Safety

The design philosophy for Ngātiawa Dam considers safety of the dam structure as a vital component of not only the design, but also of the construction and long-term operation of the water storage scheme.

The design, construction and operation practices must address hazards that have the potential to impact on the safety of the dam and the potential consequences downstream that the dam might influence.

[21] http://wrenz.niwa.co.nz/webmodel/

Hazards may be natural hazards such as earthquakes, construction issues such as poor materials, or operational hazards such as sudden changes in river flow.

The NZSOLD Dam Safety Guidelines[22] use a classification system for dams based on the damage potential and the consequences (impacts) that would occur if the dams were to release their reservoir contents. It is standard international practice in dam ownership to provide a means of describing the potential consequences of a dam breaching. Ngātiawa Dam has been assessed a High Potential Impact Classification (PIC). Based on the PIC rating, an appropriate level of security in the design and operation of the dam has been assigned based on the NZSOLD Dam Safety Guidelines.

This means that Ngātiawa Dam will be designed to the standards for a high PIC dam, and able to safely withstand any of the known natural hazards that might affect it. Design relating to dam safety depends on management of the design risks (i.e. appropriateness and correctness of the design) and management of the geotechnical risks (i.e. site conditions and available materials). The design must also consider construction management and systems and procedures for managing operational risks. Risks are addressed subsequently in Section 6.6.

6.1.5 Choice of Dam Type

Proximity of greywacke bedrock to found the dam on and locally available potential sources of greywacke rock suitable for concrete aggregate influenced initial investigation to gravity concrete dam construction.

A potential greywacke aggregate source for concrete has been identified 300 m northeast of the right abutment. It is an area on the right bank of the stream above the gorge that could readily be quarried. Rock mass quality is uncertain at the present stage of investigation.

Concrete gravity dams can withstand overtopping and are commonly designed with the spillway accommodated over the dam body, characteristics not inherent in other types (rockfill and embankment) of dam. The ability of a concrete gravity dam to accommodate an overflow spillway over the dam was influential in the choice of a concrete gravity dam.

A Roller Compacted Concrete (RCC) dam construction process has been selected based on the reduced construction cost and duration when compared to conventional mass concrete dam construction.

6.1.6 Dam Description

Two reservoir volumes and corresponding dam heights have been assessed. The proposed layouts showing a plan and sections for each of the reservoir volume scenarios are shown on Drawings WS909/20/31, 32, 33 and 34, included in Appendix B. The significant characteristics of each scenario are summarised in Table 6-2.

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[22] NZSOLD *New Zealand Dam Safety Guidelines*, New Zealand Society of Large Dams, November 2000.

Table 6-2: Significant Characteristics of Ngātiawa Dam

	Scenario 1	Scenario 2
Live Storage	2,031,708 m^3	1,546,962 m^3
Dead Storage	610,000 m^3	610,000 m^3
Dam Height	29.7 m	27.1 m
Dam Crest	RL 114.6	RL 112.0
Spillway Crest (full supply level)	RL 110.6	RL 108.0
Spillway Capacity	500 m^3/s	500 m^3/s
Inundation Area	198,172 m^2	174,744 m^2

A free overflow spillway has been chosen for reasons of safety, simplicity of operation and economics. It is designed to pass a probable Maximum Flood in accordance with the High Potential Impact Classification assessed for this dam.

The spillway utilises the stepped downstream face of the dam for the base of the spillway chute that is formed by side walls supported from the downstream face of the dam. A roller bucket energy dissipater is included at the base of the spillway to dissipate energy and reduce erosion downstream when the spillway operates.

The RCC dam body is founded on greywacke bedrock. Foundation preparation would involve excavation of overburden and weathered greywacke and dental work on any fissures and irregularities exposed in the foundation preparation works

It is anticipated that the bedrock would be generally finely fractured and to reduce seepage through the rock fissures a grout curtain has been included immediately upstream of the dam. The grout curtain would be sealed to the dam body by inclusion of a concrete plinth integral with the body of the dam through which the grout curtain would be constructed.

Drainage of the downstream area of the dam footprint would be with underdrains placed at the time of preparation of the foundation rock surface. These underdrains would discharge downstream of the dam. Flows from these drains would be monitored as part of the dam surveillance program.

Outlet works which enable drawing reservoir water from three levels of the reservoir are accommodated in an intake tower which is integral with the upstream face of the dam. The outlet works deliver from the tower through a gallery through the dam body to a control valve discharging into the spillway energy dissipater. It is anticipated that outlet flows would be controlled remotely from the water treatment plant. This outlet will provide riparian flow immediately downstream during reservoir filling.

6.1.7 Micro-Hydro Potential

The dam would remain full most of the time when there is normal flow in the Waikanae River and sufficient flow to supply the water demand. Stream flow would discharge over the spillway if the outlet works are closed.

There is potential to tap into the water supply outlet works pipe which passes through the dam body with a micro-hydro penstock. This penstock could feed into a micro-hydro power station immediately downstream of the dam. The amount of flow that could be utilised to generate electricity would be dependent on the generation capacity installed and ability of the plant to utilise low flows.

If, however, the plant can utilise 70% of the flow available, which is a normal utilisation for such an installation, the potential energy generation, based on mean flow of 1,090 L/s and overall efficiency of 80%, would be 1,500,000 kW.hr per year for Scenario 1 and 1,400,000 kW.hr per year for Scenario 2.

The cost of a micro-hydro power station has not been estimated, however, inclusion of a micro-hydro station could be included in later stages of this option should it proceed.

6.1.8 Fish Passage

Provision is allowed in the cost estimates for conveying upward migrating fish past the dam using a “catch and carry” method. This method attracts the upward migrating fish into a trap with a release flow. The trapped fish are then physically carried upstream and transferred to the lake or a tributary upstream. This system is operated over the spring and summer migrating season, with daily checks and transfers.

Downward migration is achieved by screening the normal release conduit so that adult fish migrating downstream cannot enter the release pipe and are attracted to another through flow pipe designed specifically for transfer of adult fish migrating downstream and operated only during the migration season.

6.1.9 Construction

The construction period is estimated to be 20-22 months duration for Scenario 1 and 18-20 months duration for Scenario 2.

The construction activities would be the same as for the Lower Maungakotukutuku Dam – refer Section 5.1.9.

6.1.10 Commissioning

Under mean flow conditions (i.e. mean annual inflow 1,090 L/s into reservoir capacity of 2.0M m^3), the reservoir will take 22 days to fill (this duration will also be somewhat affected by evaporation, infiltration and rainfall, which have not been included). Lake filling will be achieved by closing the diversion culvert bulkhead gates when the dam, spillway and penstock intake structure are complete and functional. Initiation of lake filling will be scheduled with benefit of both favourable short and intermediate range weather forecasts preferably in autumn to take advantage of higher winter flows to speed filling the reservoir.

Commissioning activities would be the same as for the Lower Maungakotukutuku Dam – refer Section 5.1.10.

6.1.11 Operation and Maintenance

Operation and maintenance activities would be the same as for the Lower Maungakotukutuku Dam – refer Section 5.1.11.

6.2 Yield

The following table summarises some of the key results of the yield modelling for the Ngātiawa Dam. These results are based on a peak day demand of 32,000 m^3/day, the 2007/08 demand profile, the 2002-2006 Waikanae River flow records adjusted to reach a 50-year low flow, and a core river allocation of 26,000 m^3/day.

Table 6-3: Ngātiawa Dam Yield Modelling Results

Dam Live Storage Volume	2.0M m^3 (Scenario 1)	1.5M m^3 (Scenario 2)
Number of days reservoir used in one year in a 50 year drought	146 days	146 days
Longest period of continuous use of reservoir	59 days	59 days
Maximum daily spill from dam	29,500 m^3/day	29,500 m^3/day
Time to fill after a 50 year drought	19 days	19 days
Shortfall - number of days borefield used in a 50 year drought	0 days	1 day
Maximum daily take from borefield in a 50 year drought	0 m^3/day	6,200 m^3/day

The following graph shows how the total demand will be met over the four year modelling period with a minimum river flow of 517 L/s and maximum demand of 32,000 m^3/day.

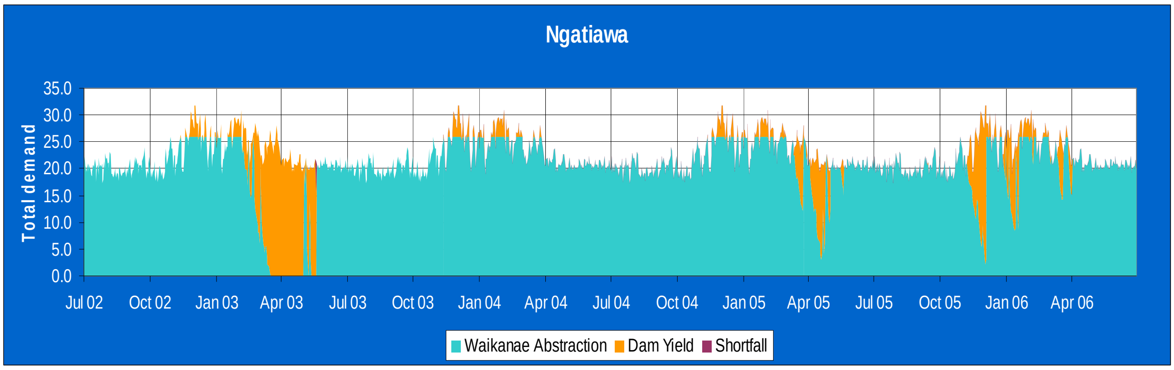

Figure 6-4: Yield to meet demand with Ngātiawa Dam (1.5M m^3)

The following graph shows the Ngātiawa Dam with a 1.5M m^3 live storage reservoir emptying and filling over this same period under the same conditions.

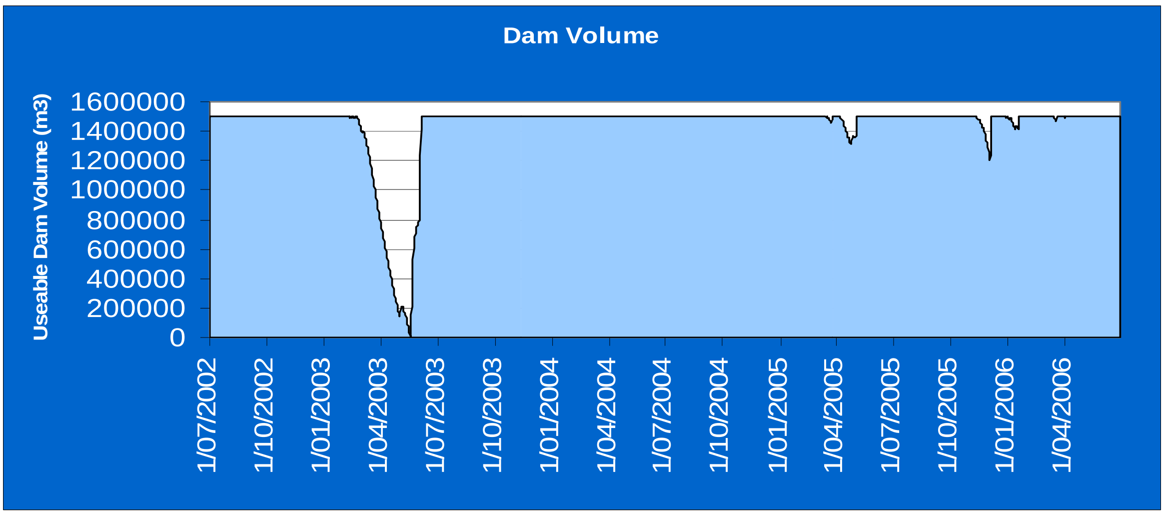

Figure 6-5: Ngātiawa Dam (1.5M m^3) Volume Profile for 50-year Drought

6.3 Treatment

The treatment requirements for this option are the same as for the Kapakapanui Dam - refer section 4.3.

6.4 Environmental Assessment

6.4.1 In-stream Ecology

This assessment was not carried out for this dam. As a result of the order in which investigations were undertaken, it was clear during the early design and costings phases that this dam was likely to be more expensive than Council's budget, and therefore investigations were not undertaken. Should this dam be considered by Council as a viable option, these investigations would need to be completed.

6.4.2 Terrestrial Ecology

a. Protected areas

The Ngātiawa River Marginal Strip (R26039, *c*.1.4 ha) is a Department of Conservation-managed reserve within the proposed dam inundation area. This is a fixed marginal strip, under Section 24(3) of the Conservation Act 1987. Near the bridge to Kents Road, there is a small conservation area: Kents Road Conservation Area (R26030, *c*.0.1 ha), a Stewardship Area under Section 25 of the Conservation Act 1987. Most of the forest in this area is identified in the Kāpiti Coast District Council Heritage Register as Site K080 Ngātiawa Road Bush (8.69 ha), which is of 'District Significance'.

b. Vegetation and habitats

Vegetation in this area is a patchwork mixture of indigenous and introduced vegetation types (Table 6-4; refer also Appendix D). Downstream of the proposed dam site, on the true left side (looking downstream) the canopy appears to be dominated by barberry and tree lucerne. The true right bank and near to the proposed dam location, the canopy principally comprised kamahi-mahoe-kaikomako forest with emergent rewarewa. Upstream of the dam, on the true right side, is a large area of mature tawa canopy with occasional mature emergent kahikatea and rimu. The tawa forest continues along the scarp of the uppermost terrace, on the true right side.

Table 6-4: Vegetation types within potential Ngātiawa Dam inundation area

Ecological Value	Vegetation Type	Hectares	% of Inundation Area
High	(Podocarp)/tawa forest	3.41	17.2%
	(Rewarewa)/mahoe-kamahi-kaikomako forest	2.88	14.5%
	(Kahikatea)/mahoe-kamahi forest	0.84	4.3%
High Total		7.14	36.0%
Moderate-high	Exotic conifers/indigenous forest	2.05	10.3%
	Mahoe-mixed indigenous-exotic forest	0.15	0.8%
Moderate-high Total		2.20	11.1%
Moderate	Indigenous-exotic forest	1.06	5.4%
	Riparian indigenous-exotic scrub	0.79	4.0%
Moderate Total		1.85	9.3%
Low-moderate	Gravel banks	1.66	8.4%
Low-moderate Total		1.66	8.4%
Low	Pasture	4.41	22.2%
Low	Mixed introduced species	1.74	8.8%
Low	Introduced conifer shelterbelts and forest	0.48	2.4%
Low	Introduced conifer and barberry forest	0.34	1.7%
Low Total		6.97	35.2%
Total Inundation Area		19.82	100.0%
Total Area High and Moderate Value		11.19	56.5%

Vegetation on the true left side comprises a mosaic of patches of mahoe-dominant canopy, with a range of indigenous species, with occasional barberry and blackberry. These patches are interspersed with large mature macrocarpa and pine trees with an understorey of indigenous species similar to the mahoe dominant canopy forest.

On the gravel flats near the river, buddleia, barberry, wheki and toetoe were prominent. On less frequently flooded gravel flats the composition becomes more indigenous, in character, with wheki, puka, tutu, and mahoe being more prominent than weedy species. Willow (possibly grey willow) occurs on some of the river banks. Near Kents Road, there are mature sycamore trees, with wildings scattered along the river margins.

More than half of the vegetation and habitat types that could potentially be inundated comprise high or moderate ecological value vegetation, predominantly the tawa forest and mahoe-kamahi forest, and riparian forest.

c. Fauna

Indigenous species were pukeko, paradise shelduck duck, Australasian harrier, warblers, silvereyes, fantails, tui and kereru. Introduced species recorded were Australian magpie, goldfinch, blackbird, and starling.

d. Possible ecological effects

- Clearance of vegetation that includes mature rimu and kahikatea, and tawa forest. Indigenous vegetation clearance may be greater than indicated above, as this figure was based solely on potential inundation area and did not include the work platform or access or maintenance routes.
- Vegetation clearance may cause surrounding vegetation to dry out by removal of buffering vegetation. Such edge effects are more pronounced in taller vegetation.
- Soil slumping, especially on river terraces, causing additional loss of vegetation.
- May cause damage to roots of large trees adjacent to clearance areas, with subsequent deterioration in health.
- Potential introduction of unwanted species (e.g. weeds).
- Soil compaction.
- Changes to the water table, which could cause previously unaffected vegetation to die or deteriorate through root rot.
- Loss of habitat for indigenous terrestrial fauna.
- Loss of riparian vegetation and potential deterioration of in-stream ecological values.

e. Potential mitigation

- It will not be possible to avoid the loss of the relatively large area of mature indigenous forest at the site. This may mean that mitigation, such as pest control, should be undertaken at nearby sites to offset loss of indigenous vegetation.
- Replanting edges with suitable eco-sourced plant species to assist with more rapid edge re-establishment.
- Check for weeds on construction sites every three months for the first two years, and yearly thereafter for up to five years or until a canopy is re-established, and undertake weed control as required.
- Establish temporary fences or high visibility tape around trees and parts of the sites that need to be avoided.
- Employ silt retention devices around the perimeter of the cleared and working sites.
- Establish indigenous riparian margin (at least 20 m wide) using suitably eco-sourced plant species, along non-forested sections of the final lake shoreline.

6.5 Consultation

The concept of a dam as a water supply solution appears to have general support in the community. However, concern has also been expressed by some residents immediately downstream of the potential dam sites. Those noting support for dam options talk of the benefit of the certainty of a tried and tested concept and of capturing rain water sensibly in the hills. Those noting opposition talk of the risk of dam break and adverse environmental effects, particularly to in-stream ecology and amenity. The Ngātiawa Dam site has potentially more than minor adverse environmental, social and economic effects on directly affected landowners. For that reason, the Ngātiawa Dam is significantly less favourable in comparison to the other two dam sites.

Key Group	Summary of Consultation Outcomes
Iwi	Council continues to build a partnership approach with tāngata whenua and remain committed to supporting a partnership approach to this significant community project. Council is working closely with the Te Āti Awa in the spirit of the Memorandum of Understanding being developed for this project, particularly with the Te Āti Awa Water Working Group in the investigation of cultural impacts. At this stage, tāngata whenua have not identified any fatal flaws with this option in relation to the core values of kaitiakitanga, tino rangatiratanga. tāonga, mauri and whakapapa.
Landowners directly affected	There are several landowners directly affected by this option. Unlike the other two dam sites, this option will affect private land with existing houses and well-established lifestyle block amenity. For that reason, the majority of landowners directly affected by this option have expressed concern regarding the adverse social, environmental and economic effects likely to be generated by this option. It is unlikely that design measures alone could satisfactorily mitigate these more than minor adverse effects.
Other landowners potentially affected	Comments from local residents that due to very high river flows and gravel build up the Ngātiawa Dam site may not be suitable for a dam. There does not appear to be the same level of concern from downstream residents regarding dam break, although this will still clearly be a significant issue to address should this be a preferred solution.
Stakeholders GWRC DoC Fish & Game Forest & Bird Department of Conservation Friends of Waikanae River	Key stakeholders have been kept well informed of investigations to date. The six short-listed options were presented to a select group on 8 June 2010 with a focus on environmental effects, including the findings of the investigations of NIWA and Wildland Consultants. Representatives from Fish & Game, Forest & Bird and Friends of Waikanae River attended the presentation. Stakeholders were also presented with a summary of the technical investigations on 1 July 2010. At this stage of the project, initial feedback from stakeholders appears to suggest that there are no apparent fatal flaws with this option, however further detailed investigation will need to be undertaken into the environmental effects if it is preferred, particularly around in-stream ecology and the overall impact on river flow.
Wider Community	The concept of a dam as a water supply solution appears to have general support in the community. However, concern has also been expressed by some residents immediately downstream of the potential dam sites. Those noting support for dam options talk of the benefit of the certainty of a tried and tested concept and of capturing rain water sensibly in the hills. Those noting opposition talk of the risk of dam break and adverse environmental effects, particularly to in-stream ecology and amenity.

6.6 Risk Assessment

6.6.1 Risks Particular to Option

Investigations were stopped on the Ngātiawa Dam option before the formal workshopping of risks. Many of the risks relevant to this site will be common with the other two dam options considered in this report.

6.6.2 Natural Hazards in Relation to Engineering of Dam

There are different categories of risk, those arising from significant natural hazards of flood, earthquake, and slope instability; and those arising from failure to understand the geotechnical issues, manage the design adequately, construct the project correctly, operate or maintain the dam correctly.

Earthquake and flood hazards would be mitigated by appropriate design. Design to resist the anticipated earthquake shaking determined from proximity to the active Gibbs fault 170 m NW of the dam site. Capacity to pass flood flows appropriate for during construction and also for extreme floods during the life of the dam.

Reservoir slope stability has been assessed as part of the geological inspection for the current level of design. Although there are some areas of the reservoir slopes which display shallow instability occurring in the colluvium overlying bedrock, deep seated instability is judged unlikely.

Detailed design would include use of experienced designers, implementation of a quality assurance program using standards exceeding NZSOLD Guidelines commensurate with the assessed Potential Impact Classification for the dam particularly in respect to:

- Refinement of the geotechnical understanding of the site
- Detailed assessment of the flood risk and associated design of the spillway including the energy dissipater and the diversion works
- Structural assessment of the dam including extent of curtain grouting and underdrains.

Similarly, construction would include use of an experienced contractor and implementation of a quality assurance program particular emphasis on construction of:

- Diversion works
- Foundation preparation
- Roller Compacted Concrete mix design, reliability and consistency of production, transportation, placement and compaction in both the upstream and downstream dam faces and also in the body of the dam
- For conventional concrete, measures as for RCC, particularly in the spillway chute walls, energy dissipater, and spillway crest.

Risks during commissioning are particularly important as this process establishes the correct functioning of the dam, particularly components that control the seepage and piezometric pressures, which contribute to the stability of the dam and the reservoir. Complete closure of the diversion works with a concrete plug is included also.

Risks identified in the commissioning plan, prepared in advance would identify mitigation measures for:

- Programming of closure of the diversion gate preferably programmed in Autumn so that filling will take advantage of winter rains to hasten filling thus shortening the filling period and the time to commission
- Management of riparian flow downstream utilising the outlet pipe
- Surveillance during commissioning which would include precise deflection survey of dam body, monitoring of piezometers and drains and observation of the reservoir perimeter.

6.7 Cost Estimates

6.7.1 Base Capital Cost Estimate

The base capital cost estimates for the two volume scenarios are summarised in the table below.

Table 6-5: Ngātiawa Dam Base Capital Cost Estimates

Scenario	1	2
Live Storage Volume (m^3)	2.0M	1.5M
Fees, Council Costs & Investigation*	$2.65M	$2.65M
Land Value	$2.31M**	$2.31M***
Construction Cost	$20.25M	$18.33M
Design and Management****	$3.03M	$2.80M
Contingency (25%)	$5.82M	$5.28M
TOTAL	$34.1M	$31.4M

* This provisional figure is based on the fees to date, plus estimated fees to completion of RMA approvals ($1.7M). In addition, allowance is made for Council internal costs ($650,000), geotechnical investigations carried out during Stage 3 ($120,000), legal fees for Council hearings ($100,000), plus Greater Wellington and Council processing costs ($100,000).

** This is the cost of partial buy of 4 properties and full buy of 2 properties (Section 80 and Lot 2 DP 63227). Partial buy calculated as the dam/reservoir footprint + 10 metre wide perimeter access strip + an obvious severed areas.

*** Scenario 2 not specifically valued, but expected to be of a similar order to Scenario 1.

****Includes an allowance for Council internal costs during Design and Management phase.

6.7.2 Operation and Maintenance Costs

Operational & maintenance (O&M) costs specific to the dam are related to maintaining the reservoir and its margins, catch and release for upstream fish passage, and those related to dam safety and surveillance. These are estimated at approximately $70,000 per year (excluding contingency).

Overall O&M costs for this option are estimated at $1.36M/year increasing to $1.49M/year in 50 years. There is additional expenditure allowed for in about 25 years of about $2.5M for dam refurbishment work.

7 Option D1 – Waikanae Borefield and Storage

7.1 Concept Design

7.1.1 Option Description

The Waikanae Borefield and Storage options utilise the existing Waikanae Borefield infrastructure but with the addition of off-river storage ponds filled with surplus river water during winter/spring. When the water demand cannot be met by the run-of-river abstraction from the Waikanae River (due to consent limits and low river flows) the demand will be met, in part or full, by a blend of stored river water and bore water.

The general concept for this option is illustrated in Figure 7-1.

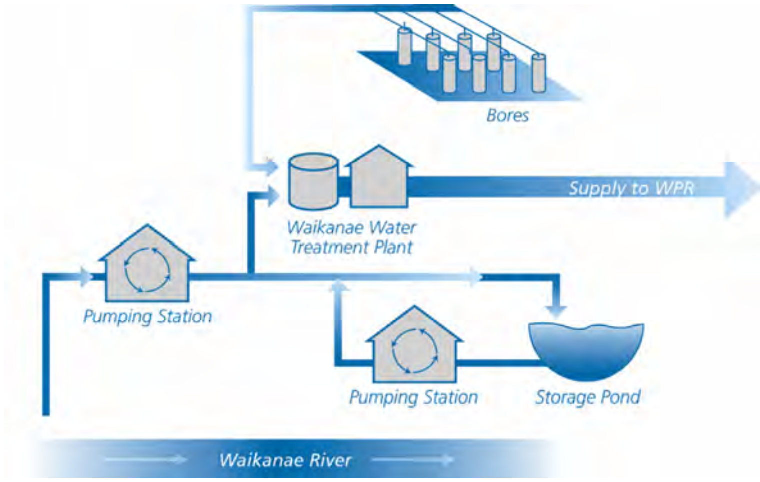

Figure 7-1: Waikanae Borefield and Storage Option Schematic

Two storage pond capacities (Scenario 1 and 2) have been assessed for the Waikanae Borefield and Storage option as follows:

a. Scenario 1 – Two ponds (0.86M m^3) with 50/50 blend

This scenario includes two storage ponds with a total live storage volume of 0.86M m^3. The stored river water from the ponds would be blended with bore water in equal proportions. The two ponds enable the required output from the Waikanae Borefield to be reduced from its current 23,000 m^3/day to 16,000 m^3/day (half of the future peak yield of 32,000 m^3/day). The 50% dilution of the bore water with stored river water will result in a finished water quality that meets the design requirements for treated water quality.

b. Scenario 2 – One pond (0.51M m^3) with 30/70 blend

In this scenario there would be a single storage pond and therefore a greater proportion of bore water is required for supply. The total live storage volume of the pond is 0.51M m^3. The river water from the pond would be mixed with bore water in a blend of 30% stored river water and 70% bore water. With a blended water of these proportions additional treatment of a portion of the bore water will be required to produce finished water that meets the design requirements for treated water quality. The maximum required output from the borefield is 22,400 m^3/day (70% of the future peak yield of 32,000 m^3/day).

7.1.2 Design Approach and Principles – Storage Ponds

a. Location

The preferred storage pond site is located north of the Main Trunk Railway and south of the Waikanae River as shown on Figure 7-2. This site was referred to as Site 4 in the earlier investigations and was the most favourable site following an extensive review of potential sites for storage ponds in 2003.

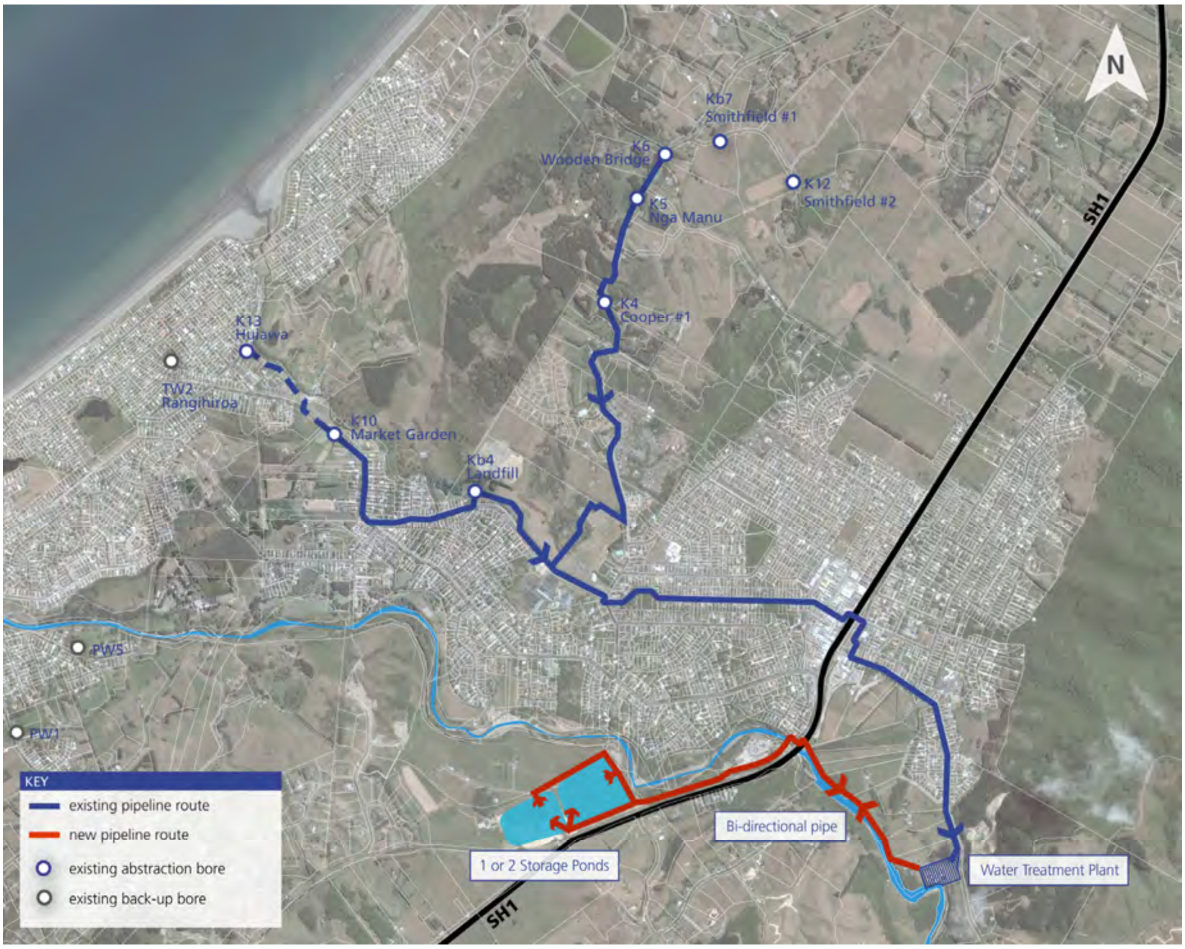

Figure 7-2: Storage Pond Site Location

The site was adopted for this study because the proximity to the Waikanae River for drainage, depth to natural groundwater, favourable geological conditions and relatively short distance from the WTP mean pond development at this site is likely to cost less than elsewhere.

Council owns some 27 hectares of land immediately south (upstream) of the Waikanae WTP. This site was reviewed as a potential site for storage ponds, but the shape of the site and its proximity to both Reikorangi Road and the Waikanae River means that the land area is insufficient.

The Waikanae wastewater ponds located near the coast between Waikanae Beach and Peka Peka were also considered. These ponds are estimated to have a storage volume of around 0.4M m^3, which is less than the required storage volume. This site is also twice as far from the Waikanae WTP as the preferred pond site and there would be substantial works required to prepare these ponds for raw water storage.

The preferred pond site is presently accessed directly off State Highway 1 with an uncontrolled level crossing of the NIMT rail line. This access route is currently being closed off. Therefore the concept design allows for the pond site to be accessed from King Arthur Drive in Otaihanga, which requires a 1 km access track for operation and maintenance.

b. Existing Site Conditions

i. Site Geology

The pond site consists of an upper terrace in the south east area which slopes in a westerly direction. A lower terrace occupying the northern half of the site drains to the Waikanae River. Figure 7-3 shows the upper and lower terrace areas and the two ponds for Scenario 1.

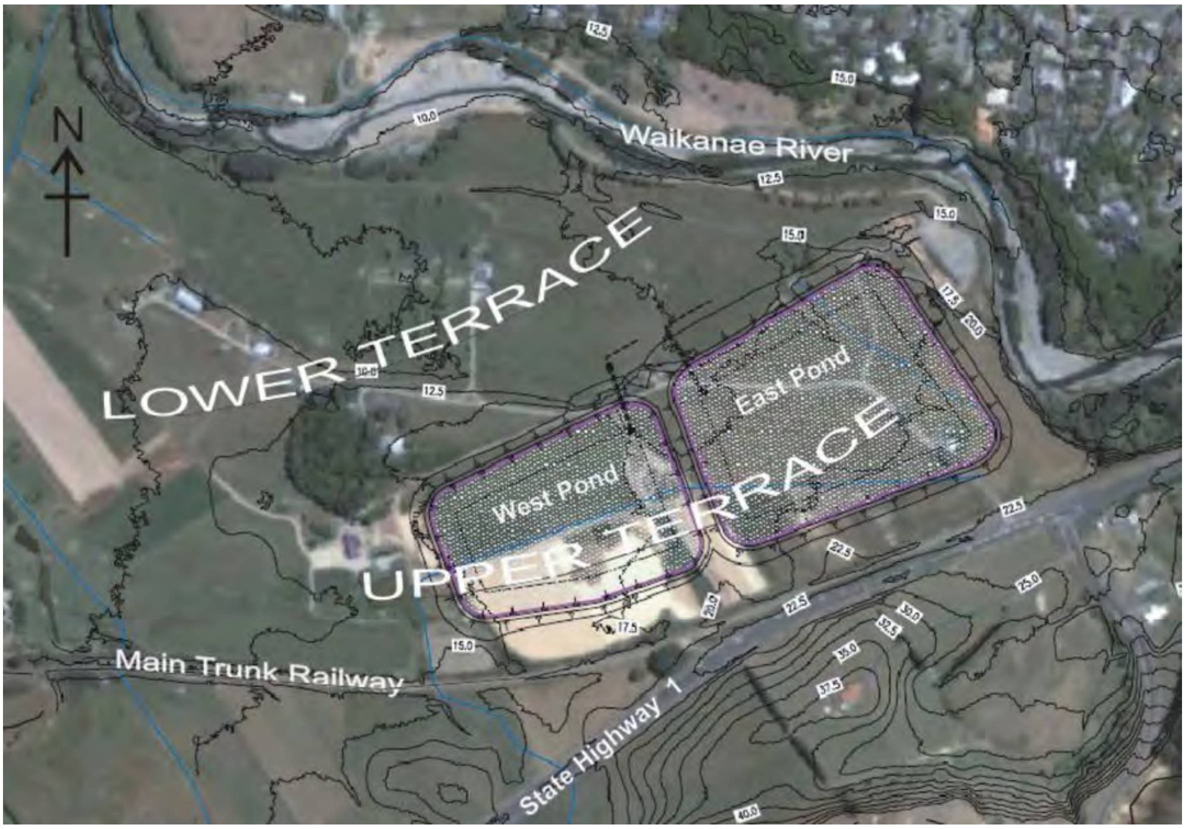

Figure 7-3: Storage Ponds Scenario 1

A geotechnical investigation was conducted by SKM in 2003[23] which included 22 test pits, two exploratory drill holes and the logs of two wells previously drilled at the site.

The investigation showed that the site is characterised by:

- Alluvial deposits, deposited by the Waikanae River located in the eastern higher area of the upper terrace and extending over most of the lower terrace
- Dune sand and silt along with silty clay deposits which extend over the balance of the site

[23] Sinclair Knight Merz, 2004, *Waikanae Storage Pond Development Stage 2 - Feasibility*

- A 1 to 3 m depth of loess covers much of the western area of the upper terrace although the eastern extent of this layer is logged as alluvium in the geotechnical investigation report implying alluvial re-deposition of the loess mantle.

The base of the eastern pond is founded in silt and silty clay which underlies the coarser alluvium. The western pond is founded on sand, silt and silty clay deposits which have variable density. In places these materials are cemented and described as sandstone. Generally the density of these fined grain materials increases with depth.

It is anticipated that the pond embankment foundation preparation would involve stripping of topsoil which varies in thickness from 50 to 500 mm. The embankments would then be founded on loess, silt and silty clay or coarser alluvium depending on the location on the pond perimeter.

The previous geotechnical investigation assessed the potential for liquefaction of the foundation materials as low and current investigations concur with this conclusion, however, potential for liquefaction while low has not been dismissed at the present stage of investigation. Should this option proceed, foundation liquefaction potential would need to be investigated further and if necessary mitigation would be addressed in the detailed design.

ii. Groundwater

Perched water tables were intercepted on several test pits in the proposed reservoir area which caused limited inflow to the pits where they were intersected. The water table recorded for the single borehole in the pond footprint is close to the Waikanae River level north of the borehole. This indicates that the water table is controlled by the Waikanae River.

The ponds have been located so that pond construction including excavation for the material immediately below the pond lining is above the water table. Allowance has been included for pond under-drainage to ensure that the pond liner is not damaged by a high water table under the liner when the pond water level is lowered.

iii. Seismicity

Of greatest relevance to the pond site is the system of active faults that include the Ohariu, and Gibbs Faults which are shown on Figure 7-4. The nearest is the Ohariu Fault, which is 2.5 km south east of the pond site.

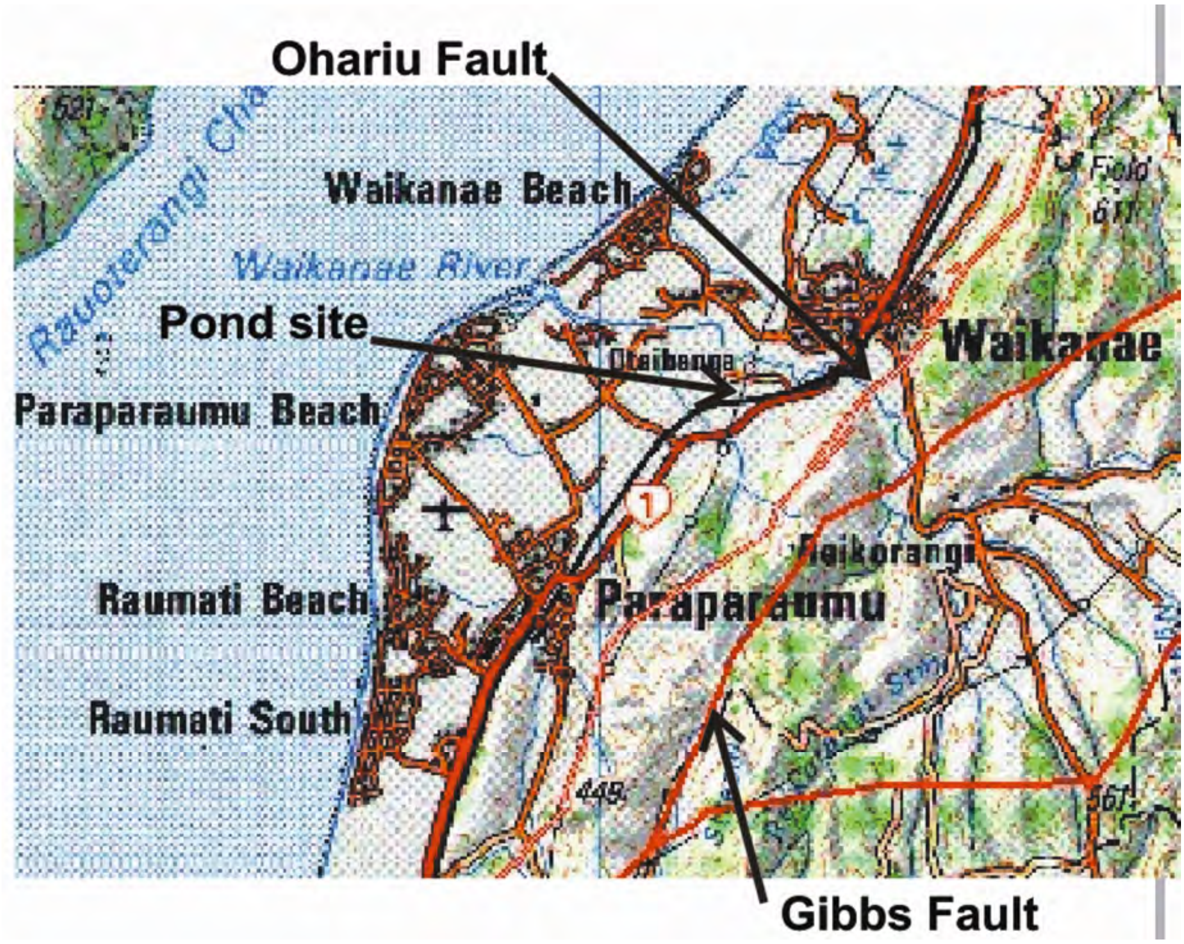

Figure 7-4: Active Faults in the Vicinity of Storage Pond Site[24]

Previous trenching and other detailed studies[25] of the Ohariu Fault in Ohariu Valley, Transmission Gully and Nikau Valley have determined that the fault has a right lateral slip rate of approximately 1-2 mm/yr and an average recurrence interval of surface rupturing earthquakes of 1,500-5,000 years. The Ohariu fault most recently ruptured the ground surface about 1,000 years ago and is capable of generating earthquakes in the order of magnitude 7.5.

c. Design

The ponds are positioned so that the embankment toe is 50 metres from the main trunk railway to the south and also to avoid an area of mature kohekohe trees to the west. A 9 metre maximum water depth has been adopted for the ponds in order to stay within the above constraints and also stay substantially on the upper terrace of the site. The ponds have been located vertically in order to balance excavation from the pond footprint with fill for the embankment assuming 20% of excavated material would be unsuitable for embankment construction. Unsuitable material would be used for landscaping and fill on site or removed from the site.

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[24] Geological and Nuclear Sciences, website, http://data.gns.cri.nz/af/detail.jsp?ID=21455

[25] Geological and Nuclear Sciences, Van Dissen R, Heron D, 2003, *Earthquake Fault Trace Survey Kāpiti Coast District*

The layout plans and sections for each of the scenarios are shown on Drawings WS909/20/41, 42, 43 and 44, included in Appendix B. The significant characteristics of each scenario are summarised in the table below.

Table 7-1: Significant Characteristics of Storage Ponds

Characteristic	Scenario 1		Scenario 2
	East Pond	West Pond	East Pond
Live Storage	860,000 m^3		510,000 m^3
Embankment Height	10 m	10 m	10 m
Embankment Crest	RL 25.3	RL 23	RL 25.3
Full Supply Level	RL 24.3	RL 22	RL 24.3
Spillway Crest	RL 24.7	RL 22.3	RL 24.7
Spillway Capacity	2 m^3/s	2 m^3/s	2 m^3/s

Ideally, the ponds would not be filled with turbid river water as this will result in sediment build up in the ponds and potentially reduce the stored water quality. Therefore, the storage volumes include an additional 5% volume allowance to cover periods of not being able to fill the ponds during high river turbidity.

Earth embankments sourced from the pond footprint have been adopted as this design is considered likely to be the most economic.

Permeability of the materials underlying the pond footprint necessitates a lining to control seepage from the ponds and this lining is to extend up the full height of the pond embankments. Although a low permeability silt liner has been considered previously, a synthetic liner has been adopted for this study in order to provide certainty of the workability of the liner at this stage of the design process. For reasons of longevity and low maintenance the synthetic liner is supported on a silt layer and over laid with stone protection which on the embankment sides must withstand wind generated wave action.

Internal embankment slopes of 1V:3H have been adopted based on experience elsewhere with construction of lined embankment slopes. Embankment outside slopes of 1V:2.5H have been adopted.

Over flow protection is provided with a 10 m crest length grass lined 300 mm lowered section of embankment crest.

The pond liner is protected with gravel and stone protection. The outside of the pond embankment would be top soiled and grassed to control erosion.

Design, construction and operation of the ponds would be in accordance with that adopted for a dam. The ponds would be considered a large dam under the Building Act (2004) as they have an embankment higher than 3 m and retain more than 25,000 m^3.

The storage ponds have been assessed a High Potential Impact Classification (PIC). Based on the PIC rating, an appropriate level of security in the design and operation of the pond has been assigned based on the NZSOLD Dam Safety Guidelines (Nov 2000). Having a High PIC means that the pond must withstand earthquake shaking such that the embankment may sustain damage, but would contain the stored water under a Maximum Credible Earthquake loading (an extreme earthquake that is capable of generating the largest seismic loading on the structure).

d. River intake

The existing river intake will continue to be used to take water out of the Waikanae River at up to 400 L/s. A riser tower with an outlet control valve would be constructed between the river pump station and the rapid mix chamber at the head of the Waikanae Water Treatment Plant (WTP). If there is surplus river water available and the storage ponds need to be topped up, then water will be transferred from the WTP site to the storage ponds via a new pipeline. This pipeline would follow the alignment of the existing 600 mm diameter trunk main that delivers treated water to Paraparaumu. Gravity flow is achievable from the WTP to the storage pond site via this route. Along this route the pipeline must cross the Waikanae River, State Highway 1 and the North Island Main Trunk rail line. Like the existing trunk main, the pipeline will use the existing SH1 bridge for crossing the river and State Highway, and pipe thrusting would be used for the crossing under the rail line.

e. Pond Outlet Structure

The pond outlet structure is designed to allow water draw off at three different pond water depths. Each penstock is fitted with an actuator for remote operation and monitoring.

Because the ponds are at a lower elevation than the WTP site, a pump station is needed to return the stored water to the WTP for treatment. The same pipe used for pond filling will be used for the return of the stored water to the WTP.

A flexible and robust control system will be required for the filling of the ponds and for abstracting water from the ponds and bores in equal proportions.

The ponds will include a scour facility to enable them to be drained down separately for maintenance. The scour pipe(s) will discharge to the Waikanae River via a concrete outlet structure at an appropriate location(s) adjacent to the pond site.

7.1.3 Design Approach and Principles – Borefield

a. Scenario 1: Two Ponds with 50/50 blend

For this option it has been assumed that Bore K13 would be taken out of service because of the low quality of water that is abstracted from this bore and its proximity to the coast. Bore K10 may also be taken out of service because of its proximity to the coast. Without K13 and K10 the Waikanae Borefield can supply up to 16,700 m^3/day. Because only 16,000 m^3/day is required from the borefield, no new bores are required for this option. The existing bore pre-treatment plant would be retained for manganese removal.

b. Scenario 2 – One Pond with 30/70 Blend

For this option it is again assumed that Bore K13 would be decommissioned. Bore K10 may also be decommissioned. 22,400 m^3/day is required to meet 70% of the future yield of 32,000 m^3/day. To make up the difference between what can currently be supplied and what is required, the pumps in bores Kb4 and K5 would be replaced, and two existing wells, Kb7 and K12, would be connected into the Waikanae Borefield via new pipelines. These two wells are already included in the resource consent for the Waikanae Borefield, and the maximum required yield from the borefield is less than the maximum daily abstraction rate currently consented.

To produce a treated water that is acceptable to the community in terms of taste and hardness additional treatment of the bore water will be required. Nanofiltration is considered to be the most appropriate process for treatment of the bore water. This is because of the limited impact of lime softening on reducing the finished water hardness and dissolved salts in the bore water. The nanofiltration plant would treat only a small portion of the bore water (3,400 m^3/day) to reduce the finished water hardness to below the target level of 80 mg/L as $CaCO_3$. This is discussed further in the treatment technical memorandum in Appendix A.

The nanofiltration plant would be located within the Waikanae WTP site. The most economic solution for the brackish reject water from the nanofiltration plant would be to send it to the Paraparaumu Wastewater Treatment Plant via a new dedicated pumping main from the WTP for co-disposal with the wastewater treatment plant effluent into the Mazengarb Drain (i.e. it would not be put through the wastewater treatment process). The environmental effects of the brackish reject water from the nanofiltration process on the Drain need to be investigated.

A new potassium permanganate dosing point would be constructed downstream of the nanofiltration process. The concept design includes pipework modifications that would allow the treated bore water to bypass the rapid mix chamber and clarifier and be diverted directly to the filters.

7.1.4 Pond Construction, Commissioning, Operation and Maintenance

a. Pond Construction

The main construction activities are civil works activities including:

- Progressively clear the construction area of vegetation, strip and stockpile top soil
- Construct access roads and site facilities
- Strip and prepare embankment foundations
- Construct pond embankment in tandem with inlet outlet structures and underdrains
- Prepare inside of pond for placement of synthetic lining
- Progressively place, weld and ballast the synthetic lining including attachment of lining to inlet, outlet structures that penetrate the lining
- Progressively place gravel and stone protection over the lining while removing the ballast
- Commence reservoir filling
- Commission pond - monitoring reservoir filling and initial performance
- Clear construction site and complete site rehabilitation works.

The construction period is estimated to be 24 months for Scenario 1 and 22 months for Scenario 2.

The construction of the two ponds could potentially be staged to match demand, but this has not been considered in detail at this point in time

b. Commissioning

The time to fill the pond(s) depends on the pond volume, the capacity of the supply system and availability of water in the Waikanae River. Based on the anticipated availability of Waikanae River water and the proposed supply system capacity the estimated time to fill the pond is approximately 3 months for Scenario 1 and approximately 2 months for Scenario 2.

The pond(s) would be instrumented with flow measuring weirs on the outlet to the underdrains. Piezometers would be installed through the pond embankments into the foundation to measure piezometric pressures in the embankments and foundation. Survey monuments would be located along the crest of the embankment to confirm embankment deformation behaviour is within expectations. These instruments would be monitored from completion of the embankment through reservoir filling and subsequently over the life of the pond. During the commissioning period, from commencement of reservoir filling through to one month after reservoir full the frequency of monitoring the weirs and piezometers would be once daily. Thereafter, dependent on satisfactory performance of the pond and foundations the monitoring frequency would be decreased to weekly and subsequently to bi-monthly. This is expected to be over several months. The embankment crest survey monuments would be measured frequently during initial reservoir filling and through the following month. Thereafter, dependent on satisfactory performance of the embankment body the frequency of crest monument survey would be decreased to monthly for a period until satisfactory performance is evident. Thereafter dam deformation survey would be conducted annually.

c. Operation and Maintenance

Once operational, the pond would require routine maintenance of the facilities including:

- Access roads, including running surface, drainage facilities, berms and verges vegetation control
- Site maintenance including, site drainage facilities, and clearance of debris from the spillway works
- Servicing of the outlet valves and associated automatic controls and actuators
- Routine surveillance which would include bi-monthly inspection and reading of the drainage weir and piezometers; annual inspection and a Comprehensive Safety Review every 5 years.

7.2 Yield

The following table summarises some of the key results of the yield modelling for the Borefield and Storage scenarios. These results are based on a peak day demand of 32,000 m^3/day, the 2007/08 demand profile, the 2002-2006 Waikanae River flow records adjusted to reach a 50 year low flow, and a core river allocation of 26,000 m^3/day. Note that the yield modelling for Scenario 2 does not include allowance for the additional groundwater required to account for the wastewater produced from the nanofiltration treatment process (about 700 m^3/day).

Table 7-2: Waikanae Borefield and Storage Yield Modelling Results

	Scenario 1	Scenario 2
Storage Volume	**0.86M m^3**	**0.51M m^3**
Number of days storage ponds and borefield used in one year in the modelled 50 year drought	143 days	143 days
Longest period of continuous use of storage ponds and borefield	59 days	59 days
Maximum daily take from storage ponds	14,700 m^3/day	8,800 m^3/day
Maximum daily take from borefield	14,700 m^3/day	20,600 m^3/day
Time to fill ponds after modelled 50 year drought	121 days	79 days
Volume abstracted from aquifer in one year in a 50 year drought	860,000 m^3	1,210,000 m^3

The following graphs shows how the total demand will be met for the two scenarios over the four year modelling period with a minimum river flow of 517 L/s, maximum river abstraction of 26,000 m^3/day and maximum demand of 32,000 m^3/day.

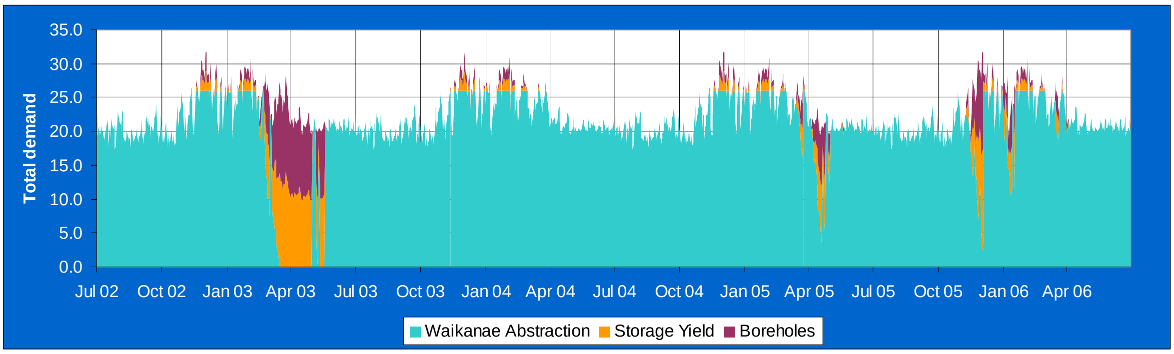

Figure 7-5: Yield to meet demand with Borefield and Storage Ponds Scenario 1

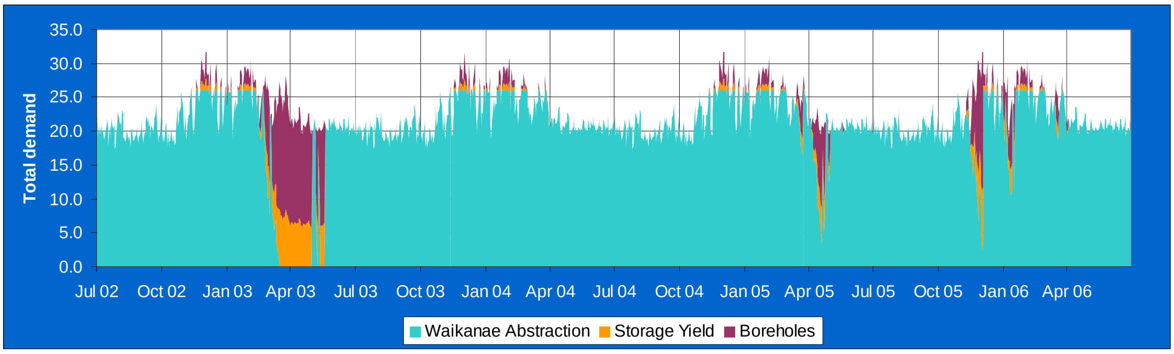

Figure 7-6: Yield to meet demand with Borefield and Storage Ponds Scenario 2

7.3 Treatment

The concept design includes for the following upgrading work at the Waikanae WTP for the Borefield & Storage options. Scope items that are assessed as being renewals-related rather than project-related are marked with an "R".

- Destratification system in storage pond(s) (not within WTP but considered part of treatment)
- River intake screening and air burst system
- Raw water pump station – new pumps and electrical system (R)
- Improved coagulation control/chemical dosing (R)
- Second clarifier (R)
- Nanofiltration plant (Scenario 2 only)
- Convert existing filters to biological activated carbon (BAC) mode (R)
- Add one or two new BAC filters
- Decommission ultraviolet disinfection (R)
- Refurbish existing powdered activated carbon system (R)
- New lime system (R)
- Miscellaneous improvements to chemical storage and handling (R)
- Improvements to clearwater tank (R)
- Consider VSDs on treated water pumps (R)
- Sludge/waste water/residuals improvements (R)
- Nanofiltration reject water pump station and pipeline to Paraparaumu WWTP (Scenario 2 only)
- Building refurbishment (R)

To minimise destratification of the stored water and the resulting water quality issues, the ponds will incorporate a mixing system. There is a risk of algal blooms occurring in the storage ponds, thereby increasing the risk of taste and odour events.

Further details of the proposed upgrading are presented in Appendix A.

7.4 Environmental Assessment

7.4.1 In-Stream Ecology

a. Overview of evaluations

The biological communities of the Waikanae River were investigated. Four native fish species (inanga, longfin eel, redfin bully and torrent fish) and brown trout were found, the most common of which were longfin eels and redfin bullies. The invertebrate communities here were indicative of streams in pristine condition and the ecological condition of the Waikanae River being somewhat better than similar streams in the region. The communities found were very similar to those collected by the Wellington Regional Council, suggesting that both studies consistently described them.

The hydrological effects of flow harvesting for off-river storage may result in a reduction of some flow related parameters such as frequency or magnitude of flows. Analysis of the long-term flow record however showed potential changes to the flow regime were very small, and unlikely to have any demonstrable adverse effects on the fish or invertebrate communities.

b. Key Issues Encountered

- Any modifications made to the inlet structure of the water treatment plant needed to accommodate the greater water demand may result in more fish becoming drawn into it.
- The location and design of the water storage pond needs to be considered to minimise any potential adverse effects on any wetlands, if nearby.

c. Mitigation

- The inlet structure needs to be designed to minimise the number of fish that get drawn into it. This may involve the use of fish screens. This has been allowed for in the concept design.

7.4.2 Terrestrial Ecology

a. Ecological Assessment

Placement of additional bores and pipelines can be micro-sited to avoid areas of significant indigenous vegetation or habitats.

Within the potential storage pond site there is a small, 1.37 ha example of kohekohe-karaka-tawa-titoki forest (Wildland Consultants 2007). This forest is an under-represented habitat type within the Foxton Ecological District, located on an 'Acutely Threatened' land environment. It will also provide occasional habitat for kereru and other indigenous bird species, and management of plant and animal pests is being carried out. The site is very small and vulnerable to wind/edge effects but has a compact shape and good regeneration occurring within it. The site was ranked as being of 'District Significance'.

The ponds have been sited to be clear of this forest area.

No fauna were noted during the visit to the site.

b. Possible ecological effects

Possible effects of storage pond construction include:

- Clearance of vegetation;
- Vegetation clearance may cause surrounding vegetation to dry out by removal of buffer vegetation. Such edge effects are more pronounced in taller vegetation;
- May cause damage to roots of large trees adjacent to clearance areas, with subsequent deterioration in health;
- Potential introduction of unwanted species (e.g. weeds);
- The soil compaction;
- Changes to the water table.
- Changes in hydrology that affect the shallow aquifer and vegetation and habitat dependent on the aquifer.

c. Potential mitigation

- Replanting edges with suitable eco-sourced plant species to assist with rapid edge re-establishment.
- Check for weeds on site every three months for the first two years, and yearly thereafter for up to five years or until a canopy is re-established, and undertake weed control as required.
- Establish temporary fences or high visibility tape around trees and parts of the sites that need to be avoided.
- Employ silt retention devices around the perimeter of the cleared site.
- Undertake or fund pest control within remaining forest area.

7.5 Consultation

Although no fatal flaws have been raised in terms of landowner or stakeholder concerns, there is a general reluctance by many in the community to continue to rely on the borefield for potable water supply due to water quality (taste and hardness). It is anticipated that this option may have difficulty gaining the support of the community without a clear understanding of how the additional treatment will address the issues of taste and hardness.

Key Group	Summary of Consultation Outcomes
Iwi	Council continues to build a partnership approach with tāngata whenua and remain committed to supporting a partnership approach to this significant community project. Council is working closely with the Te Āti Awa in the spirit of the Memorandum of Understanding being developed for this project, particularly with the Te Āti Awa Water Working Group in the investigation of cultural impacts. At this stage, tāngata whenua have not identified any fatal flaws with this option in relation to the core values of kaitiakitanga, tino rangatiratanga, tāonga, mauri and whakapapa.
Landowners directly affected	Identified as Council at this stage, as any new infrastructure and pipes are expected to be located within road reserve and/or on Council-owned land. The landowner of the site identified as an indicative location for the storage pond has been kept informed of investigations, particularly in terms of the significant cost associated with constructing a storage pond.

Other landowners potentially affected	New infrastructure and pipes are expected to be located within road reserve and/or on Council-owned land, however there may be some private property affected.. Some residents of the nearby residential area to the storage pond have raised concerns about possible micro-climatic effects of the pond.
Stakeholders GWRC DoC Fish & Game Forest & Bird Department of Conservation Friends of Waikanae River	Key stakeholders have been kept well informed of investigations to date. The six short-listed options were presented to a select group on 8 June 2010 with a focus on environmental effects, including the findings of the investigations of NIWA and Wildland Consultants. Representatives from Fish & Game, Forest & Bird and Friends of Waikanae River attended the presentation. Stakeholders were also presented with a summary of the technical investigations on 1 July 2010. At this stage of the project, initial feedback from stakeholders appears to suggest that there are no apparent fatal flaws with this option, however further detailed investigation will need to be undertaken into the environmental effects if it is preferred, particularly around water quality, security of supply and borefield impacts.
Wider Community	There is a general reluctance by many in the community to continue to rely on the borefield for potable water supply due to water quality (taste and hardness). Even if blended with river water and/or treated it is anticipated that this option may have difficulty gaining the support of the community.

7.6 Risk Assessment

7.6.1 Risks Particular to Option

The high and very high risks identified that are particular to the Waikanae Borefield and Storage option include:

- Excessive seepage or failure of the large water retaining structure(s)
- Difficulty of road access across private land
- Availability of suitable construction materials for pond(s).

7.6.2 Natural Hazards

Earthquake and flood hazards would be mitigated by appropriate design. This includes particularly, design to resist the anticipated earthquake shaking determined from proximity to the active Ohariu fault 2.5 km south east of the pond site, and drainage and erosion protection to address maximum probable floods in the Waikanae River and extreme rainfall during the life of the pond.

Detailed design would include use of experienced designers, implementation of a quality assurance program using standards exceeding NZSOLD Guidelines commensurate with the assessed PIC for the ponds particularly in respect to:

- Refinement of the geotechnical understanding of the site
- Determination of the appropriate seismic loading
- Detailed assessment of the flood and bank erosion risk from the Waikanae River and also design of the spillway to discharge extreme rainfall or uncontrolled inflow to the pond
- Structural assessment of the pond embankment and design of the underdrains.

Similarly, construction would include use of an experienced contractor and implementation of a quality assurance program particularly for construction of:

- Foundation preparation
- Control of materials for embankment placement and compaction
- Placement, jointing, anchoring and covering of the liner.

Risks during commissioning are particularly important as it is at this time that the correct functioning of the pond particularly the lining (which controls the seepage) and piezometric pressures (which contribute to the stability of the pond embankment) is seen to be functioning correctly.

A commissioning plan would identify mitigation measures for monitoring during commissioning which would include precise deflection survey of embankment body, monitoring of piezometers and drains and observation of the reservoir perimeter.

7.7 Cost Estimates

7.7.1 Base Capital Cost Estimates

The base capital cost estimates for the two volume scenarios are summarised in the table below.

Table 7-3: Borefield and Storage Base Capital Cost Estimates

Scenario	1	2
Live Storage Volume (m^3)	0.86M	0.51M
Fees, Council Costs & Investigation*	$2.65M	$2.65M
Land Value	$4.88M	$3.00M
Construction Cost	$34.34M	$25.86M
Design and Management**	$4.72M	$3.70M
Contingency (25%)	$9.76M	$7.39M
TOTAL	$56.4M	$42.6M

* This provisional figure is based on the fees to date, plus estimated fees to completion of RMA approvals ($1.7M). In addition, allowance is made for Council internal costs ($650,000), geotechnical investigations carried out during Stage 3 ($120,000), legal fees for Council hearings ($100,000), plus Greater Wellington and Council processing costs ($100,000).

** Includes an allowance for Council internal costs during Design and Management phase.

7.7.2 Operation and Maintenance Costs

Overall O&M costs for Scenario 1 of this option are estimated at $1.33M/year increasing to $1.47M/year in 50 years; and for Scenario 2 the estimates are $1.42M/year increasing to $1.57M/year in 50 years.

8 Option D2 – Waikanae Borefield and Treatment

8.1 Concept Design

8.1.1 Option Description

This option involves extending the existing Waikanae Borefield to provide water for the WPR supply at times when the run-of-river abstraction from the Waikanae River is limited. Simply put, this option is the same as the current set-up but the capacity of the groundwater supply is extended to cater for growth in demand and there would be additional treatment of the bore water.

The current bore water supply is unacceptable to the community due to water hardness and taste issues. To address these issues, a portion of the bore water would be treated in a nanofiltration plant.

The current Waikanae Borefield was designed to supply up to 23,000 m^3/day. Therefore, the borefield would need to be extended in order to meet the future peak day demand of 32,000 m^3/day. The new bores can be staged over the next fifty years to match demand. The resource consent for groundwater abstraction would need to be modified (or a new consent sought) to increase the maximum daily groundwater take from 23,000 m^3/day to 32,000 m^3/day.

During the investigation phase, the detailed groundwater model identified potential concerns relating to saline intrusion in the aquifers. In order to avoid this, the design was refined to include recharge of the aquifer (refer Figure 8-1).

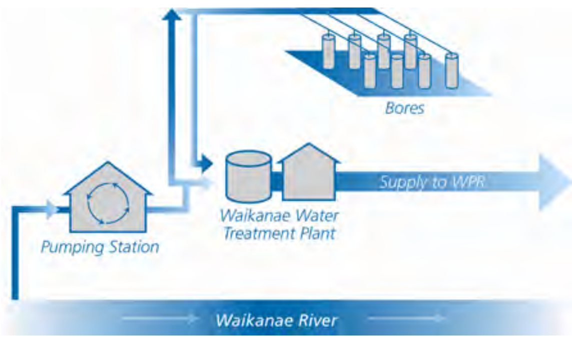

Figure 8-1: Waikanae Borefield and Treatment Option Schematic

8.1.2 Design Approach and Principles

There are six existing production bores within the Waikanae Borefield, which supply up to 23,000 m^3/day of groundwater. The water pumped from bore K13 is highly mineralised with high concentrations of sodium, chloride, calcium and magnesium. Because of its low water quality it has been assumed that this particular bore would be taken out of service. Bore K10 is close to the coastline, which increases the saline intrusion risk, so this bore would also be taken out of service. Without bores K13 and K10 the Waikanae Borefield can only supply up to 16,700 m^3/day.

The concept design allows for the connection of bores Kb7 and K12 into the pipeline from the Waikanae Borefield. The current resource consent for groundwater abstraction already includes these two bores. Bores Kb7 and K12 were developed as production bores but were not connected to the borefield pipeline because of low yield (1,500 m^3/day total) and so these bores are not equipped with pumps or wellheads. The concept design includes:

- Supply and installation of pumps for bores K7 and K12
- Wellheads, power supply and controls for bores K7 and K12
- New pipeline from bores K7 and K12 to existing pipeline at bore K6.

The pumps in bores K5 and Kb4 would be replaced to increase the yield from these bores.

The concept design also includes four new bores to provide an additional 13,800 m^3/day of groundwater to meet the peak demand and allow for the quantity of reject water produced by the nanofiltration plant. These bores are provisionally located north east of the existing borefield on the eastern side of Stage Highway 1 (refer drawings in Appendix B). The locations for these new bores were chosen based on the following criteria:

- at least 3000 metres from the coastline to minimise the risk of saline intrusion
- spacing of 500 m between wells to reduce interference effects
- wells being in a line perpendicular to the groundwater flow direction to minimise interference effects between production wells
- the alluvial aquifer widens to the north of the WTP and narrows towards the south.

The bores have been located adjacent to roads to minimise disruption to private landowners. The exact number of bores and the location of the bores would be selected based on investigation bores, in situ tests and consultation with potentially affected landowners. There are opportunities to optimise the bore layout based on the results of investigation bores, which would provide savings in pipework costs. At this stage a conservative approach has been taken.

The new bores and wellheads will be similar in design to the existing bores within the Waikanae Borefield. The wellhead of one of these bores is shown in the photo below. If necessary, the wellhead can be constructed within a below ground chamber. Each new bore would have two monitoring bores – one shallow and one deep.

A new pipeline would be constructed from the new bores to the Waikanae WTP site. A portion of the new pipeline would need to cross State Highway 1 and the North Island Main Trunk rail line. It is assumed this would be completed by pipe thrusting.

The pipeline from the new abstraction bores is assumed to be PVC to match the existing borefield pipeline. At the preliminary design stage a value engineering exercise would be undertaken to assess the most appropriate pipe material.

Figure 8-2: Existing Bore K4 Wellhead

To mitigate risks around saline intrusion, allowance has been made for a new pump station at the Water Treatment Plant site to transfer river water to the Waikanae Borefield (via the existing 450mm diameter pipeline) for recharging the aquifer. Three of the existing bores would be modified to enable them to be used for recharge as well as abstraction. The groundwater modelling has shown that the saline instrusion risk can be managed if up to 10,000 m^3/day is injected into the aquifer for up to 5 months. The amount of water injected to the aquifer would be less than for an Aquifer Storage and Recovery scheme.

The nanofiltration plant would treat only about half of the bore water (13,000 m^3/day permeate) to meet the design requirements for treated water quality. There may be potential water quality benefits from recharging the aquifer with river water, which have not been taken into account at this stage.

The nanofiltration plant would be located within the Waikanae WTP site. The most economic solution for the brackish reject water from the nanofiltration plant would be to send it to the Paraparaumu Wastewater Treatment Plant via a new pipeline from the WTP for co-discharge with the WWTP effluent to the Mazengarb Drain (i.e. the reject water would not be put through the WWTP process). A provisional volume for reject water is 3,300 m^3/day.

A new potassium permanganate dosing point would be constructed downstream of the nanofiltration process. The concept design includes pipework modifications that would allow the treated bore water to bypass the rapid mix chamber and clarifier and be diverted directly to the filters.

The existing (and extended) borefield is sized to provide the peak yield over a 24 hour period. Therefore, if there is a problem with the borefield or water treatment plant, the water supply is more reliant on storage in reticulation network than, for example, the existing river abstraction. The river abstraction is sized and consented for up to 400 L/s and so the current maximum daily take of 23,000 m^3/day could be achieved within 16 hours.

8.1.3 Construction Programme

The following table gives an indicative programme for the construction of the full extended borefield and treatment scheme:

Table 8-1: Extended Borefield Indicative Construction Programme

		Month											
Activity	**Duration**	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**	**11**	**12**
Mobilisation & set-up	1 month												
Injection pump station, and drill and develop new production bores	6 months												
New abstraction pipeline	4 months												
Extend borefield to Kb7 & K12	2 months												
Upgrade WTP (including nanofiltration plant)	6 months												
Commissioning	2 months												

The construction of the full extended borefield scheme could potentially be staged to match demand as per the programme in the table below (assuming that injection is required from the start).

Table 8-2: Extended Borefield Staging Programme

Year	Activity	Yield
2014	Construct wellheads at Kb7 and K12 and connecting pipeline to K6 Replace pumps in bores K5 and Kb4 Construct injection pump station and modify wellheads for injection Construct 2 bores north of Waikanae and connecting pipeline Construct nanofiltration plant and WTP upgrade works	28,500 m^3/day less nanofiltration reject water
2024	Construct 1 more bore north of Waikanae and connecting pipework	32,000 m^3/day less nanofiltration reject water
2042	Construct 1 more bore north of Waikanae and connecting pipework	35,400 m^3/day less nanofiltration reject water

8.2 Yield

The following table summarises some of the key results of the yield modelling for the Borefield and Treatment option. These results are based on a peak day demand of 32,000 m^3/day, the 2007/08 demand profile, the 2002-2006 Waikanae River flow records adjusted to a 50 year low flow, and a core river allocation of 26,000 m^3/day. Note that the yield modelling does not include allowance for the additional groundwater required to account for the wastewater produced from the nanofiltration treatment process (about 3,300 m^3/day).

Table 8-3: Extended Borefield Yield Modelling Results

Number of days bores used in one year in the modelled 50 year drought	143 days
Longest period of continuous use of bores	59 days
Maximum daily take from bores	29,400 m^3/day
Volume abstracted from aquifer in one year in the modelled 50 year drought	1,721,000 m^3

The following graph shows how the total demand will be met over the four year modelling period with a minimum river flow of 517 L/s , maximum river abstraction of 26,000 m^3/day and maximum demand of 32,000 m^3/day. The supplementary use of the borefield is shown by the purple areas.

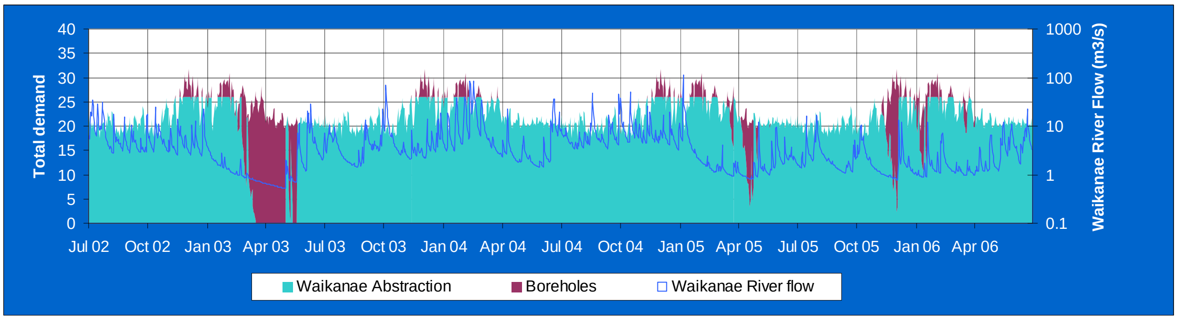

Figure 8-3: Yield to meet demand with Extended Borefield

Refer section 10.2 for the results of the groundwater modelling for extending the borefield.

8.3 Treatment

The concept design includes for the following upgrading work at the Waikanae WTP for the Waikanae Borefield & Treatment option. Scope items that are assessed as being renewals-related rather than project-related are marked with an "R".

- Raw water pump station – new pumps and electrical system (R)
- Improved coagulation control/chemical dosing (R)
- Nanofiltration plant (nominal production capacity of 13,000 m^3/day)
- Refurbish existing filters (R)
- Install standby ultraviolet disinfection (R)
- Install new powdered activated carbon system (R)
- New lime system (R)
- Miscellaneous improvements to chemical storage and handling (R)
- Improvements to clearwater tank (R)
- Consider VSDs on treated water pumps (R)
- Sludge/waste water/residuals improvements (R)
- Nanofiltration reject water pump station and pipeline to Paraparaumu WWTP
- Building refurbishment (R).

Further details of the proposed upgrading are presented in Appendix A.

8.4 Environmental Assessment

8.4.1 In-Stream Ecology

The in-stream ecological effects of this option on the Waikanae River should be no different to the current water supply scheme. During the periods of aquifer injection in winter and spring river flows would be reduced, but the potential changes to the flow regime are likely to be small and unlikely to have any demonstrable adverse effects on the fish or invertebrate communities.

Extending the borefield and increasing the amount of groundwater extracted from the aquifer is not expected to adversely affect flows in the Waikanae River.

The impacts of brackish water discharge (nanofiltration plant reject) when co-discharged with the WWTP effluent into the Mazengarb Drain has not been considered to date. It will need to be investigated in detail if this option is carried forward (including whether there are adverse effects on the bank erosion that has been an historical problem along the drain).

8.4.2 Terrestrial Ecology

Few, if any, adverse terrestrial ecology effects are expected with this option. The groundwater modelling has shown limited impacts on the shallow aquifer, allaying concerns over the potential for adverse effects on wetlands and indigenous wet forest dependent on the aquifer.

8.5 Consultation

Although no fatal flaws have been raised in terms of landowner or stakeholder concerns, there is a general reluctance by many in the community to continue to rely on the borefield for potable water supply due to water quality (taste and hardness). It is anticipated that this option may have difficulty gaining the support of the community without a clear understanding of how the additional treatment will address the issues of taste and hardness.

Key Group	Summary of Consultation Outcomes
Iwi	Council continues to build a partnership approach with tāngata whenua and remain committed to supporting a partnership approach to this significant community project. Council is working closely with the Te Āti Awa in the spirit of the Memorandum of Understanding being developed for this project, particularly with the Te Āti Awa Water Working Group in the investigation of cultural impacts. At this stage, tāngata whenua have not identified any fatal flaws with this option in relation to the core values of kaitiakitanga, tino rangatiratanga. tāonga, mauri and whakapapa.
Landowners directly affected	Identified as Council at this stage, as any new infrastructure and pipes are expected to be located within road reserve and/or on Council-owned land.
Other landowners potentially affected	New infrastructure and pipes are expected to be located within road reserve and/or on Council-owned land, however there may be some private property affected.
Stakeholders GWRC DoC	Key stakeholders have been kept well informed of investigations to date. The six short-listed options were presented to a select group on 8 June 2010 with a focus on environmental effects, including the findings of the investigations of NIWA and Wildland

Fish & Game Forest & Bird Department of Conservation Friends of Waikanae River	Consultants. Representatives from Fish & Game, Forest & Bird and Friends of Waikanae River attended the presentation. Stakeholders were also presented with a summary of the technical investigations on 1 July 2010. At this stage of the project, initial feedback from stakeholders appears to suggest that there are no apparent fatal flaws with this option, however further detailed investigation will need to be undertaken into the environmental effects if it is preferred, particularly around water quality, security of supply and borefield impacts.
Wider Community	There is a general reluctance by many in the community to continue to rely on the borefield for potable water supply due to water quality (taste and hardness). Even if blended with river water and/or treated it is anticipated that this option may have difficulty gaining the support of the community.

8.6 Risk Assessment

The 'high' and 'very high' risks identified that are particular to the Borefield and Treatment option include:

- Insufficient sustainable yield from aquifer (now addressed through groundwater modelling)
- In-stream and other consenting risks associated with discharge of the nanofiltration reject.

8.7 Cost Estimates

8.7.1 Base Capital Cost Estimate

A breakdown of the base capital cost estimate for this option is given in the table below.

Table 8-4: Borefield and Treatment Capital Cost Estimate

	Cost
Fees & Investigation*	$2.65M
Land Value	$0.07M
Construction Cost	$22.01M
Design and Management***	$3.24M
Contingency (25%)	$6.31M
TOTAL	$34.3M

* This provisional figure is based on the fees to date, plus estimated fees to completion of RMA approvals ($1.7M). In addition, allowance is made for Council internal costs ($650,000), geotechnical investigations carried out during Stage 3 ($120,000), legal fees for Council hearings ($100,000), plus Greater Wellington and Council processing costs ($100,000).

** This option requires disposal of brackish reject water via the wastewater treatment plant discharge to the Mazengarb Drain. This will require additional consultant, design and investigations (including ecology) and potentially some additional attenuation pond storage if this option is pursued. It is considered that these costs are included in the contingency.

*** Includes an allowance for Council internal costs during Design and Management phase.

8.7.2 Operation and Maintenance Costs

Overall O&M costs for this option are estimated at $1.71M/year increasing to $1.89M/year in 50 years.

9 Option E – Aquifer Storage and Recovery

9.1 Concept Design

The Aquifer Storage and Recovery (ASR) option involves injecting surplus water from the Waikanae River into the deep Waikanae aquifer (Waimea Aquifer), or possibly the overlying thin gravel aquifer that overlies the Waimea Aquifer (that K4 is screened in), for storage. Council currently abstracts water from the Waimea aquifer via the Waikanae Borefield for supplementary water supply for the WPR community.

9.1.1 Option Description

New recharge bores would be constructed up-gradient of the existing Waikanae Borefield bores for injecting water into the aquifer. The injected river water would displace the naturally occurring groundwater and the aquifer would act like a storage reservoir for the river water. During times of low flow in the Waikanae River, when the abstraction from the river must be reduced to maintain minimum residual river flows, the stored river water would be abstracted from the aquifer via the existing bores and conveyed to the Waikanae Water Treatment Plant (WTP). The abstracted water would be treated in the existing treatment plant before being put into supply.

ASR is successfully used in the USA, Europe and Australia for irrigation and drinking water supplies. The water used in these schemes for injection to the aquifer is surface water, stormwater or treated wastewater.

The following schematics illustrate the concept of ASR. In effect, the aquifer is used as an underground storage reservoir.

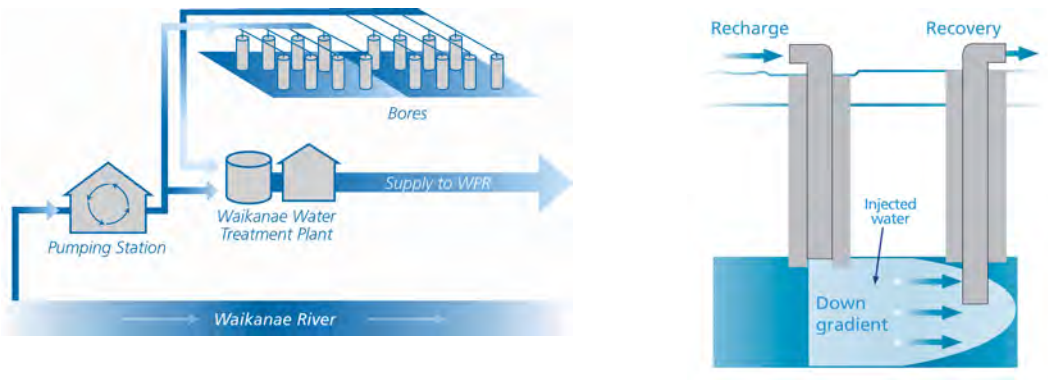

Figure 9-1: Aquifer Storage and Recovery Schematics

ASR offers the potential benefits of improving the quality of water abstracted from the aquifer for water supply and enhancing the sustainability of the aquifer.

It is assumed that, other than the existing treatment process at the Waikanae WTP, there will be no additional treatment of the abstracted water. This is based on the assumption that the abstracted water will be mostly river water that has not been in contact with the deep gravels for long enough to change in chemical composition. The appropriateness of this assumption can only be confirmed through further hydrogeological modelling work and with a full scale trial injection bore.

9.1.2 Design Approach and Principles

Even with the existing groundwater monitoring regime, the pumping tests and the groundwater model, there is still relatively limited knowledge about the aquifer. Therefore, a conservative approach has been adopted and the concept design for ASR is based around separate wells for recharge and recovery. Following further investigations, this approach could be re-visited if it looks feasible to use the existing bores for both recharge and recovery.

A key consideration with the ASR concept design is to try to utilise the existing Waikanae Borefield infrastructure as much as possible. The proposed new injection bores are located upgradient of the existing Waikanae Borefield so the existing bores can continue to be used for abstraction. The locations of the injection bores as shown in the figure below (refer Fig. 1a in Appendix B) are indicative only. It is desirable to site the injection bores west of the state highway to ensure that the bores tap into the aquifer which becomes thinner moving eastward towards the foothills of the Tararuas. While the preferred location for any new bores is on Council land or road reserve, there are very few existing roads in the area indicated for recharge bores. The exact location of these bores will need to take into consideration the development plans for this area which is part of the Waikanae North Development Zone.

At this early stage of the design, five injection bores have been allowed for. In the cost estimate, allowance has been made for two failed recharge bores, and a shallow and a deep monitoring well for each injection bore.

The existing river intake pumps are the original pumps that were installed in the mid 1970s and are therefore well past their original design life and in need of replacement. Nevertheless, the existing river intake structure will continue to be used to take water out of the Waikanae River at a rate of up to 400 L/s. A flow splitting chamber and pump station would be constructed between the river pump station and the rapid mix chamber at the head of the Waikanae Water Treatment Plant (WTP). If there is surplus river water available and the aquifer can be, or needs to be, replenished, then the new pump station will provide the energy required to transfer the water from the WTP site to the recharge bores (via the existing 450 mm diameter pipeline from the Waikanae Borefield) and inject it into the aquifer. The concept design for the new pump station is for 3 pumps delivering up to 200 L/s in a duty/duty/standby configuration.

To avoid clogging the injection bores and aquifer with fine silt or clay particles there would need to be limits on the quality of water for reinjection, for example turbidity may need to be less than 1 NTU. A 50 µm self cleaning strainer has been allowed for to reduce the risks of particulates being injected. Further pre-treatment of the water for injection (e.g. pH adjustment) may be required. This would be determined from injection trials.

The current Waikanae Borefield was designed to supply 23,000 m^3/day. Therefore, the borefield would need to be modified in order to provide enough water to meet the required yield of 32,000 m^3/day. The concept design allows for replacement pumps and modifications to the existing bores to increase the flow delivered from each bore. The power supply for each bore will also need to be upgraded. Bores Kb7 and K12, which were developed as production bores but not connected to the WTP because of low yield, would also be connected up to the network. One additional bore provisionally located between Bores K4 and Kb4, near the cemetery, is also included. The wellheads for the new bore and bores Kb7 and K12 would be similar to the existing production bores.

It is assumed that Bores K13 and K10 would be taken out of service because they are in a line parallel to the direction of groundwater flow and downstream of Bore Kb4 which leads to interference effects, and they are closer to the coastline which increases the risk of saline intrusion.

The existing pipeline from the Waikanae Borefield was designed to deliver up to 347 L/s to the Waikanae WTP. However, for a future yield of up to 32,000 m^3/day, at least 370 L/s must be conveyed. The resulting pipe velocities and head loss associated with putting this increased flow through the existing pipeline are unacceptably high. To maintain reasonable pipe velocities and minimise friction losses, a second pipeline will be laid adjacent to the existing. This pipeline must cross State Highway 1 and the North Island Main Trunk rail line en route to the WTP. For costing purposes it has been assumed these crossings would be constructed by pipe thrusting.

The buried pipelines to the recharge bores and from the abstraction bores are assumed to be PVC to match existing the borefield pipeline. At the preliminary design stage a value engineering exercise would be undertaken to assess the most appropriate pipe material, and also assess whether the second pipeline is in fact a cost-effective solution.

In summary, the concept design includes:

- A flow splitting chamber and pump station at the WTP site
- 5 recharge bores and feed pipeline connected to existing Waikanae Borefield pipeline
- Install pumps and wellheads at bores Kb7 and K12, and connect to existing abstraction bores with pipeline
- Development of one new abstraction bore including pump, pipework, monitoring wells and power supply
- Modifications to 4 existing bores – replace pumps, pipe modifications and power upgrade
- Duplicate pipeline from Waikanae Borefield to the WTP site
- Works at the WTP (as set out in Section 9.3).

9.1.3 Construction Program

The following table gives an indicative programme for the construction of the full ASR scheme. For the programme it is assumed that one recharge bore would constructed in the short-term to trial injection and abstraction before proceeding to detailed design; this bore would then be incorporated in the final scheme.

Table 9-1: ASR Indicative Construction Programme

		Month												
Activity	**Duration**	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**	**11**	**12**	**13**
Mobilisation & set-up	1 month													
Recharge pump station and pipework at WTP	2 months													
Drill, develop and test 4No. recharge bores	6 months													
Recharge pipeline	2 months													
Works to abstraction bores	3 months													
Duplicate abstraction pipeline	4 months													
Upgrade WTP	6 months													

Activity	Duration	Month												
		1	2	3	4	5	6	7	8	9	10	11	12	13
Commissioning	3 months													

The construction of the full ASR scheme could be staged to match demand, but this has not been considered in detail at this point in time.

9.1.4 Engineering Issues

Further investigations are needed to be more confident of the feasibility of ASR with the Waimea aquifer. These investigations would commence with the development of a single recharge bore that would be trialled and monitored. A key outcome from these investigations would be the appropriate maximum recharge rate, which would then dictate the number of recharge bores required.

The water quality of the abstracted water is unknown at this stage. Further modelling and trial work is needed to better understand if and how the quality of the injected water changes.

The existing borefield, and concept design for the ASR abstraction, is sized to provide the peak yield over a 24 hour period. Therefore, if there is a problem with the borefield or water treatment plant, the water supply is more reliant on storage in reticulation network than, for example, the existing river abstraction. The river abstraction is sized and consented for up to 400 L/s and so the current maximum daily take of 23,000 m^3/day could be achieved within 16 hours.

The groundwater modelling has subsequently shown that the concept ASR scheme described above has saline intrusion risks. To overcome this issue additional recharge and abstraction bores are likely to be needed to the north to reduce the stress on the existing borefield area. The borefield layout and pumping rates would need to be revised, and the cost estimates updated, if this option proceeds to the next stage.

9.2 Yield

With aquifer storage and recovery (ASR) the WTP has first call on water to meet the demand within the normal abstraction rules. However, if the demand is less than the maximum allowable take, then the surplus water may be pumped into the aquifer.

When demand exceeds the allowable take from the river, the shortfall would be met with water abstracted from the aquifer.

The following table summarises some of the key results of the yield modelling for the ASR option. These results are based on a peak day demand of 32,000 m^3/day, the 2007/08 demand profile, the 2002-2006 Waikanae River flow records and a core river allocation of 26,000 m^3/day.

Table 9-2: ASR Yield Modelling Results

Number of days aquifer used for supply in one year in the modelled 50 year drought	143 days
Volume abstracted from aquifer for supply in one year in the modelled 50 year drought	1,721,000 m^3
Longest period of continuous abstraction from aquifer	59 days
Maximum daily take from aquifer	29,400 m^3/day

The following graph shows how the total demand will be met over the four year modelling period with a minimum river flow of 517 L/s , maximum river abstraction of 26,000 m^3/day and maximum demand of 32,000 m^3/day.

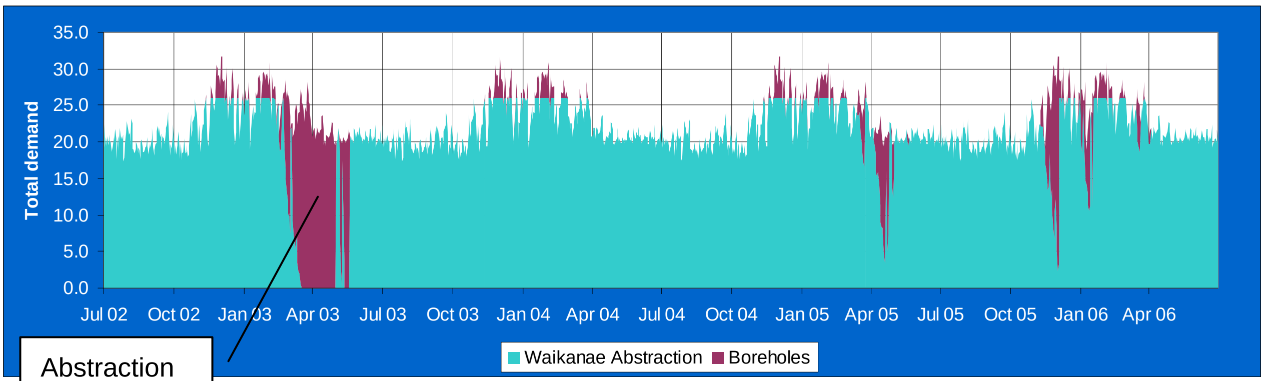

Figure 9-2: Yield to meet demand with ASR Scheme

The following graph shows the river flow available for recharging the aquifer based on the 2002-2006 river flow records and a core river allocation of 26,000 m^3/day. Note, not all of this water would necessarily be used for recharging the aquifer. Recharge of the aquifer would also temporarily cease during times of high river turbidity.

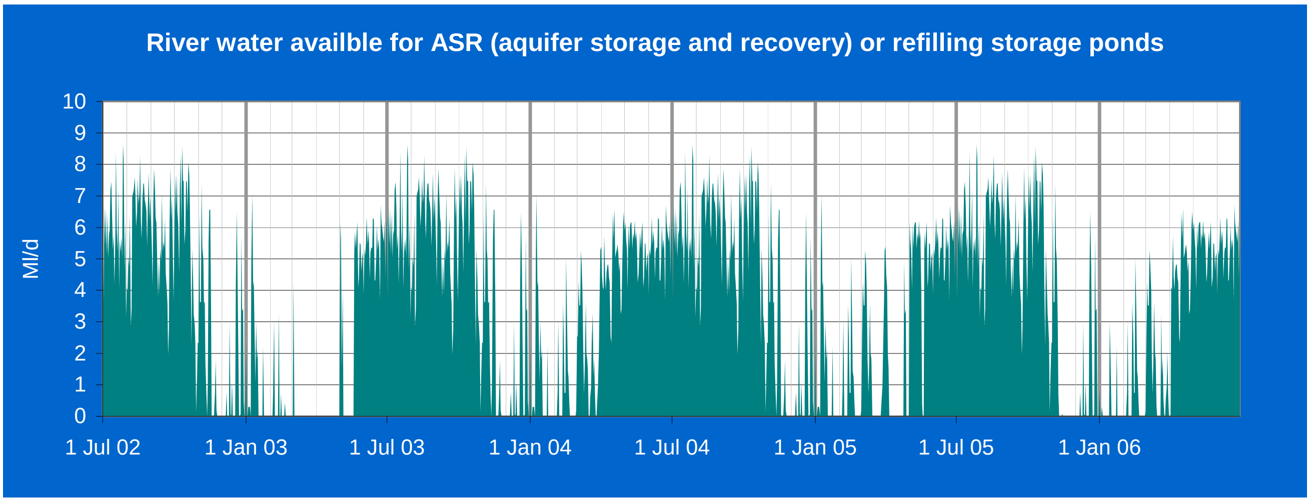

Figure 9-3: River Water Available for Recharging the Aquifer for ASR

In addition to the above work on yield from the Waikanae River that is available for injection and the required yield from the borefield, the ASR scheme has been simulated in the groundwater model. Refer Section 5.3 of Appendix E.

The ASR simulation includes a period of five months where the Waimea aquifer is recharged from three injection wells at a total rate of 10,000 m^3/day (120 L/s). Following the injection period abstraction from the borefield is carried out at a rate of 32,000 m^3/day for 60 days.

The pumping results in drawdown within the shallow, unconfined aquifer of up to 1.2 m and up to 16 m in the Waimea aquifer.

As noted above, with the proposed concept design the drawdown in the abstraction wells could potentially result in draw-in of the freshwater-saltwater interface (saline intrusion) over time. The borefield layout and pumping rates for this option would need to be revised to reduce drawdown in the aquifers to mitigate this risk if this option were to proceed.

9.3 Treatment

The concept design includes for the following upgrading work at the Waikanae WTP for the ASR option. Scope items that are assessed as being renewals-related rather than project-related are marked with an "R".

- Raw water pump station – new pumps and electrical system (R)
- Improved coagulation control/chemical dosing (R)
- Separate coagulation/flocculation of borefield train to allow for direct filtration of borefield water
- Refurbish existing filters (R)
- Add one or two new filters
- Install standby ultraviolet disinfection (R)
- New powdered activated carbon system (R)
- New lime system (R)
- Miscellaneous improvements to chemical storage and handling (R)
- Improvements to clearwater tank (R)
- Consider VSDs on treated water pumps (R)
- Sludge/waste water/residuals improvements (R)

- Building refurbishment (R).

Further details of the proposed upgrading are presented in Appendix A.

9.4 Environmental Assessment

9.4.1 In-Stream Ecology

The key in-stream ecological issue relates to the impacts of flow harvesting. Flow harvesting for storage in the aquifer may result in a reduction of some flow related parameters such as frequency or magnitude of flows. Potential changes to the flow regime are likely to be small and unlikely to have any demonstrable adverse effects on the fish or invertebrate communities.

9.4.2 Terrestrial Ecology

Few, if any, adverse terrestrial ecology effects are expected with this option. The pumping tests and modelling indicates limited impacts on the shallow unconfined aquifer that overlies when abstracting for supply. During periods of injection there may be an increase in the water table of the overlying shallower aquifer. This could result in the reappearance of local springs, and possibly increased water levels in wetlands and wetland forest in the area. These changes could potentially be beneficial to wetlands, provided that the changes occur over several years, rather than abruptly, to allow vegetation to adjust to the altered water table.

9.5 Consultation

Although no fatal flaws have been raised in terms of landowner or stakeholder concerns, this option may not find the favour of the community due to being unfamiliar with it and there being a level of uncertainty around the aquifer dynamics and therefore security of supply and water quality.

Key Group	Summary of Consultation Outcomes
Iwi	Council continues to build a partnership approach with tāngata whenua and remain committed to supporting a partnership approach to this significant community project. Council is working closely with the Te Āti Awa in the spirit of the Memorandum of Understanding being developed for this project, particularly with the Te Āti Awa Water Working Group in the investigation of cultural impacts. At this stage, tāngata whenua have not identified any fatal flaws with this option in relation to the core values of kaitiakitanga, tino rangatiratanga. tāonga, mauri and whakapapa.
Landowners directly affected	Identified as Council at this stage, as any new infrastructure and pipes are expected to be located within road reserve and/or Council-owned land.
Other landowners potentially affected	New infrastructure and pipes are expected to be located within road reserve and/or on Council-owned land, however there may be some private property affected.
Stakeholders GWRC DoC Fish & Game Forest & Bird Department of Conservation	Key stakeholders have been kept well informed of investigations to date. The six short-listed options were presented to a select group on 8 June 2010 with a focus on environmental effects, including the findings of the investigations of NIWA and Wildland Consultants. Representatives from Fish & Game, Forest & Bird and Friends of Waikanae River attended the presentation. Stakeholders were also presented with a summary of the technical investigations on 1 July 2010.

Friends of Waikanae River	At this stage of the project, initial feedback from stakeholders appears to suggest that there are no apparent fatal flaws with this option, however further detailed investigation will need to be undertaken into the environmental effects if it is preferred, particularly around water quality, security of supply and the hydrogeology of the aquifer.
Wider Community	Although viewed as innovative, this option may not find favour with the community due to unfamiliarity with, and there being a level of uncertainty around, the aquifer dynamics and therefore security of supply and water quality.

9.6 Risk Assessment

The 'high' and 'very' high risks identified that are particular to the ASR option include:

- Quality of the river water recovered from the aquifer, primarily related to taste and hardness
- Possible production of springs during injection periods
- ASR is essentially an untried technique in New Zealand
- Possible need to pre-treat river water prior to injection.

9.7 Cost Estimates

9.7.1 Base Capital Cost Estimates

A breakdown of the base capital cost estimates for this option is given in the table below.

Table 9-3: Aquifer Storage and Recovery Capital Cost Estimate

	Cost
Fees, Council Costs & Investigation*	$2.65M
Land Value	$0.07M
Construction Cost	$15.38M
Design and Management**	$2.45M
Contingency (25%)	$4.46M
TOTAL	$25.0M

* This provisional figure is based on the fees to date, plus estimated fees to completion of RMA approvals ($1.7M). In addition, allowance is made for Council internal costs ($650,000), geotechnical investigations carried out during Stage 3 ($120,000), legal fees for Council hearings ($100,000), plus Greater Wellington and Council processing costs ($100,000).

** Includes an allowance for Council internal costs during Design and Management phase.

9.7.2 Operation and Maintenance Costs

Overall O&M costs for this option are estimated at $1.38M/year increasing to $1.54M/year in 50 years.

10 Option F – River Recharge with Groundwater

10.1 Concept Design

The River Recharge with Groundwater option involves abstracting groundwater from the Waikanae Borefield and discharging this to the Waikanae River, immediately downstream of the WTP intake to provide the residual flow needs of the river. The groundwater discharge would bolster river flows downstream of the WTP and thus enable more water to be taken from the river at the WTP intake. Groundwater would only be discharged to the river when the natural river flow was at a level such that demand could not be met without going below the minimum residual river flow.

10.1.1 Option Description

When the river flow is low and the amount of water that can be taken from the river is limited, every additional litre abstracted from the river would be offset by a litre of groundwater discharged downstream. There will be no treatment of the groundwater prior to discharge to the river.

The current Waikanae Borefield was designed to supply 23,000 m^3/day. Therefore, the borefield would need to be extended in order to offset the future peak yield of 32,000 m^3/day. Similarly, the resource consent for abstraction from the river would need to be modified (or a new consent sought) to increase the maximum daily groundwater take from 23,000 m^3/day to 32,000 m^3/day.

As with the Borefield and Treatment option, the design of this option was refined to include recharge of the aquifer to mitigate the risk of saline intrusion.

The following schematic illustrates the concept of river recharge with groundwater (including aquifer injection):

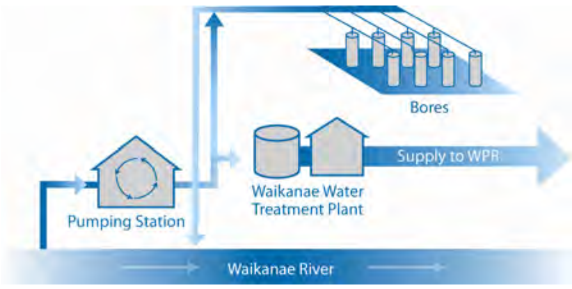

Figure 10-1: River Recharge with Groundwater Schematic

The following figure further illustrates the concept of river recharge with groundwater and shows the worst-case design scenario of a 50 year low flow in the Waikanae River (517 L/s) and the 2060 peak day demand including headroom (32,000 m^3/day or 370 L/s). Under this scenario the flow downstream of the groundwater discharge would comprise 72% groundwater and 28% river water. At the minimum residual river flow of 750 L/s with a peak abstraction of 370 L/s (32,000 m^3/day), the flow downstream of the groundwater discharge would comprise 49% groundwater and 51% river water.

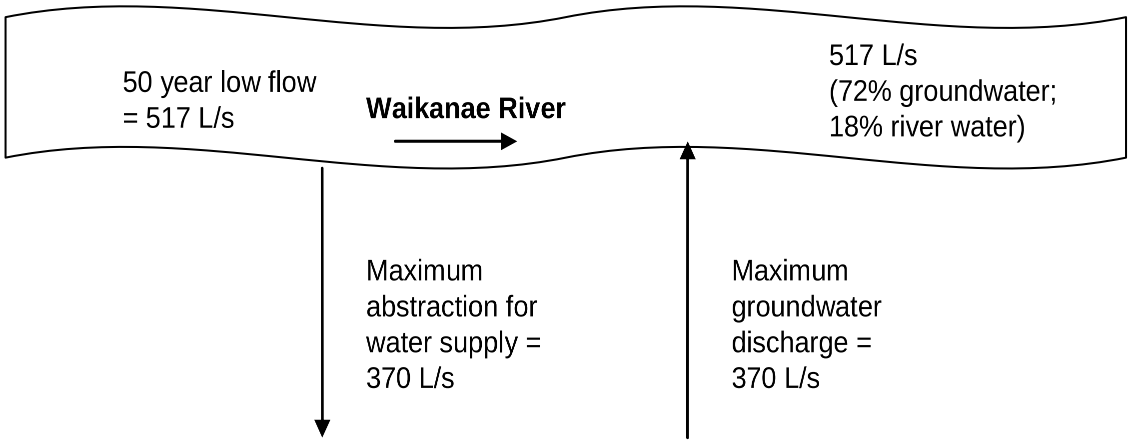

Figure 10-2: River Recharge with Groundwater in 50 Year Drought with Maximum Yield

10.1.2 Design Approach and Principles

a. Extended Borefield

The concept design for the extension of the borefield is the same as required for the Borefield and Treatment option (refer Section 8.1). However only 3 new bores (instead of 4) are required for this option because it does not include nanofiltration treatment and so there is not a quantity of reject water to allow for. The three new bores would provide an additional 10,400 m^3/day of groundwater.

The concept design includes:

- Supply and installation of pumps for bores K7 and K12
- Wellheads, power supply and controls for bores K7 and K12
- New pipeline from bores K7 and K12 to existing pipeline at bore K6
- Decommission bores K13 and K10
- Replacement pumps in bores Kb4 and K5
- Three new bores northeast of existing borefield
- New pipeline from the new bores to the Waikanae WTP site.

As for the Borefield and Treatment option, to mitigate risks around saline intrusion, allowance has been made for a new pump station at the Water Treatment Plant site to transfer river water to the Waikanae Borefield (via the existing 450 mm diameter pipeline) for recharging the aquifer. Three of the existing bores would be modified to enable them to be used for recharge as well as abstraction. The groundwater modelling has shown that the saline instrusion may be avoided if up to 10,000 m^3/day is injected into the aquifer for up to 5 months.

There are opportunities to optimise the borefield layout to reduce pipework costs and facilitate staging, but a conservative approach has been taken at this stage.

b. River Discharge

The Waikanae WTP is currently configured to enable groundwater arriving at the plant to be diverted to the stormwater system and discharged to the Waikanae River if it is not needed for supply. This facility is used for maintaining the bore pumps and routine sampling of the bore water quality. The existing river outfall is located on the right bank of the river, approximately 70 m downstream of the WTP river intake. To minimise the length of river in between the abstraction and recharge points, allowance has been made for a new discharge outfall pipe that would be positioned within the rock protection on the downstream face of the Waikanae WTP weir (refer Figure 10-3). This means that the discharge is located as close as possible to Waikanae WTP intake, whilst remaining downstream of the intake to avoid groundwater being put into supply.

Figure 10-3: Existing Weir in Waikanae River at WTP

The concept design for the discharge structure is designed to distribute the groundwater across the full width of the river to encourage mixing and dilution of the groundwater. This design would be reviewed at the next stage of the project as there may be some advantages to reducing the width of the discharge plume (e.g. limiting region of potential algal growth associated with elevated phosphorus in the groundwater). The existing fish ladder at the WTP weir would be reinstated following construction of the discharge pipe.

The aeration tower at the WTP could continue to be used to increase the dissolved oxygen concentration in the groundwater before discharge to the river, but a new purpose-built aerator may be required.

10.1.3 Construction Programme

The following table gives an indicative programme for the construction of the full river recharge with groundwater scheme:

Table 10-1: River Recharge with Groundwater Indicative Construction Programme

		Month											
Activity	Duration	1	2	3	4	5	6	7	8	9	10	11	12
Mobilisation & set-up	1 mnth												
River discharge structure and injection pump station	2 mnths												
Drill, develop and test new production bores.	5 mnths												

Activity	Duration	Month											
		1	2	3	4	5	6	7	8	9	10	11	12
Modify injection wells													
New abstraction pipeline	4 mnths												
Extend borefield to Kb7 & K12	2 mnths												
Upgrade WTP	6 mnths												
Commissioning and Demobilisation	2 mnths												

The construction of the full river recharge scheme could potentially be staged to match demand as per the programme in the table below (assuming injection is required from the start). We consider that there may be opportunity to optimise the staging further, and this will be investigated if this option is carried forward.

Table 10-2: River Recharge with Groundwater Staging Programme

Year	Activity	Yield
2014	Construct new river discharge outfall Construct wellheads at Kb7 and K12 and connecting pipeline to K6 Replace pumps in bores K5 and Kb4 Construct injection pump station and modify wellheads for injection Construct 1 bore north of Waikanae and connecting pipeline WTP upgrade works	25,100 m^3/day
2024	Construct 1 more bore north of Waikanae and connecting pipework	28,500 m^3/day
2042	Construct 1more bore north of Waikanae and connecting pipework	32,000 m^3/day

10.1.4 Engineering Issues

Investigation bores and pumping tests will be required at the new bore locations to determine their suitability and yield.

The existing Waikanae River gauging station immediately upstream of the WTP is owned and operated by GWRC. The water level in the river is continuously measured and this is converted to a flow based on the river's rating curve which is derived from surveys of the cross-section profile of the river. When the river profile is re-surveyed, the rating curve relating water level to flow is updated. The rate of groundwater abstraction (and therefore discharge to river) would be determined based on the upstream river flow and the required river take to meet demand. Therefore this option will require accurate river flow measurements that can be linked into the control system for the groundwater abstraction pumps. Further investigation is needed to determine the suitability of GWRC's gauging station for this purpose.

Further engineering work is needed to check the ability of the existing river intake and pump station to abstract sufficient water at low river levels.

Because water is currently not taken from the river at low flows and low flows are relatively infrequent, the river water quality at these flows is not well understood.

10.2 Yield

The following table summarises some of the key results of the yield modelling for the River Recharge with Groundwater Scheme. These results are based on a peak day demand of 32,000 m^3/day, the 2007/08 demand profile, the 2002-2006 Waikanae River flow records and a core river allocation of 26,000 m^3/day.

Table 10-3: River Recharge with Groundwater Yield Modelling Results

Number of days groundwater discharged to river in one year in the modelled 50 year drought	143 days
Volume abstracted from aquifer for river recharge in one year in the modelled 50 year drought	1,720,800 m^3
Longest period of continuous discharge to river	59 days
Maximum daily discharge to river	29,400 m^3/day

The following graph shows the discharge of groundwater to the Waikanae River over the four year modelling period with a minimum river flow of 517 L/s and maximum demand of 32,000 m^3/day.

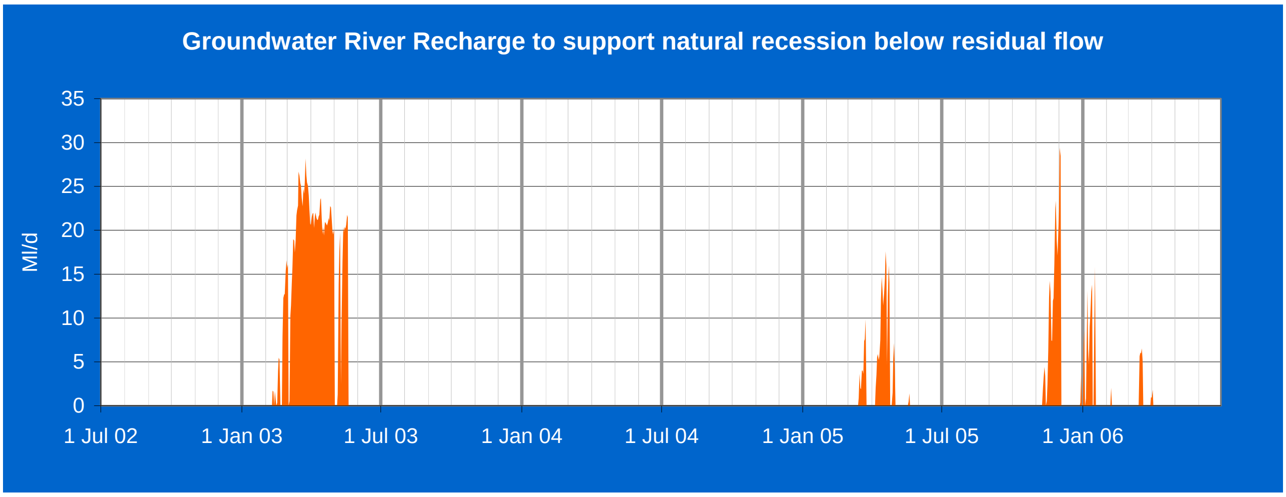

Figure 10-4: Discharge to River for River Recharge with Groundwater Scheme

In addition to the above work on yield from the Waikanae River and the required yield from the borefield, the extended borefield for the River Recharge with Groundwater scheme has been simulated in the groundwater model. Refer Section 5.5 of Appendix E.

The groundwater modelling showed that without injection of river water to the aquifer there was a risk of saline intrusion and so additional modelling was undertaken with the preferred scenario involving injection to three of the existing bores (K4, K5 and K6).

The simulation uses three existing bores for injection of 10,000 m^3/day for 150 days and the existing bores plus three new wells to abstract a total of 32,000 m^3/day for 90 days per year. This injection and abstraction scenario results in aquifer drawdowns of up to 6 m in the Waimea Aquifer and up to 1.6 m in the shallow aquifer.

The results indicate that drawdown should not increase over time, that is, the aquifer system recovers fully after 90 days of pumping before the borefield is operated again.

The results show that injecting water into the Waimea aquifer through the three existing wells reduces the risk of saline intrusion in comparison to the previous simulations in that the extent of drawdown in the seaward direction is reduced and the maximum drawdown in both the shallow aquifer and the deep aquifer is reduced (from 2.2 m to 1.6 m in the shallow aquifer) after 90 days of pumping.

Injection into the Waimea aquifer increases the head equipotential in the Waimea aquifer but because of the semi-confining nature of the overlying layer the effect of injection will be small on the shallow aquifer. It is noted that the water table is already free flowing in the area around K12 and K7 and it is therefore not recommended to use these wells as injection wells.

Minor settlement in the vicinity of the well heads may occur as a result of the pumping over the long term, however whether this occurs and the extent of the settlement that might occur is dependent on the existence and distribution of compressible soils within the drawdown cone. The risk of settlement is considered to be minor, and the amount of settlement caused is likely to be small.

MfE[26] recommends that the consequences of a sea level rise of at least 0.45 m be considered as part of expected climatic changes to 2060 – 2069. A sea level rise would result in a small shift of the coastline and saltwater/freshwater interface inland over time, and hence an increased risk of saline intrusion to the existing wells near the coast. However even with an increase of 0.45 m, modelling suggests that the minimum head equipotential would remain above mean sea level.

10.3 Treatment

The concept design includes for the following upgrading work at the Waikanae WTP for the river recharge option. Scope items that are assessed as being renewals-related rather than project-related are marked with an “R”.

- River intake screening and airburst system
- Raw water pump station – new pumps and electrical system (R)
- Improved coagulation control/chemical dosing (R)
- Second clarifier (R)
- Convert existing filters to biological activated carbon (BAC) mode (R)
- Add one or two new BAC filters
- Decommission ultraviolet disinfection (R)
- Refurbish existing powdered activated carbon system (R)
- New lime system (R)
- Miscellaneous improvements to chemical storage and handling (R)
- Improvements to clearwater tank (R)
- Consider VSDs on treated water pumps (R)
- Sludge/waste water/residuals improvements (R)
- Building refurbishment (R).

Further details of the proposed upgrading are presented in Appendix A.

[26] MfE, March 2009: *Preparing for Coastal Change: A guide for Local Government in New Zealand*

10.4 Environmental Assessment

10.4.1 In-Stream Ecology

a. Overview of Evaluations

Augmenting flows below the water treatment plant with bore water would allow extraction of more river water than present. The main issue for this option includes changes to the water chemistry of the Waikanae River from the bore discharge, and potential effects of these changes on the river's ecology. Data sondes (recording water temperature, pH, dissolved oxygen and conductivity) were deployed at two sites: one above the water treatment plant, and one below the discharge of bore water. Water samples were collected during bore water discharge tests from upstream and below the outflow of the bore. A dye test (using Rhodamine WT) was also conducted to document the flow and dilution dynamics of the bore water discharge.

b. Key Issues Encountered

- The dye plume became more diluted as it moved downstream, and complete mixing was observed after 100 m. Dye concentration here was only 1% of that at the discharge point.
- Modelling showed that bore water augmentation to the Waikanae River would increase conductivity, alkalinity, dissolved calcium and hardness, pH, ammonium-N and dissolved reactive phosphorus (DRP). Concentrations of the latter approximately doubled within the mixing zone.
- It is unlikely that the groundwater recharge option will have any adverse ecological effects on fish and invertebrates. This contention was able to be tested to a limited extent by the invertebrate sampling conducted in the Waikanae River on April 21, mid way through the second bore test. No difference was found in any of the calculated biotic metrics at sites within the bore plume or at the upstream sites. This suggests that even within the plume, and before complete mixing has occurred, invertebrate communities were not responding in a demonstrable way to the discharge of bore water - at least in the short term (days to weeks). Also, no major differences in the fish communities at sites above and below the bore discharge point were found.
- Increased DRP concentrations, when combined with stable low flows may result in undesirable periphyton growth in the mixing zone. Nutrient diffusing assays would enable determination of whether the algal communities in the river are nutrient limited (and in particular phosphorus limited).

Further detail is given in NIWA's report in Appendix C.

The taking of water from the river during winter and spring for injection to the aquifer will reduce river flows, but the potential changes to the flow regime are likely to be small and unlikely to have any demonstrable adverse effects on the fish or invertebrate communities.

c. Mitigation

- The mixing zone covers only a relatively small proportion of the channel, and so it is unlikely that high algal blooms would occur in the remainder of the river outside the mixing zone. Localised increases in algal biomass are not considered to be a major issue.
- Modification of the existing bore outlet structure to allow for discharge of bore water across the entire channel will maximise dilution, and further minimise the size of the mixing zone, and area of possible undesirable algal growth. As described above, a new discharge structure is included in the concept design.

10.4.2 Terrestrial Ecology

Topping up the additional water-take from the river with water sourced from the deep-aquifer is unlikely to have adverse effects on terrestrial ecology in the short-term. The groundwater modelling has shown that extended use of the aquifer will cause limited drawdown in the shallow aquifer, which allays concerns over potential adverse effects on wetlands and indigenous wet forest dependent on the aquifer.

10.5 Consultation

There are no apparent fatal flaws with this option, however further detailed investigation will need to be undertaken into the environmental effects if it is preferred, particularly around the environmental effects of discharging groundwater into the Waikanae River. It appears that should the environmental effects assessment show that the adverse effects on the Waikanae River are no more than minor, this option may find the favour of the community, particularly in terms of cost and as a smart way to use existing infrastructure.

Key Group	Summary of Consultation Outcomes
Iwi	Council continues to build a partnership approach with tāngata whenua and remain committed to supporting a partnership approach to this significant community project. Council is working closely with the Te Āti Awa in the spirit of the Memorandum of Understanding being developed for this project, particularly with the Te Āti Awa Water Working Group in the investigation of cultural impacts. At this stage, tāngata whenua have not identified any fatal flaws with this option in relation to the core values of kaitiakitanga, tino rangatiratanga, tāonga, mauri and whakapapa.
Landowners directly affected	Identified as Council at this stage, as any new infrastructure and pipes are expected to be located within road reserve and/or Council-owned land.
Other landowners potentially affected	None identified at this stage.
Stakeholders GWRC DoC Fish & Game Forest & Bird Department of Conservation Friends of Waikanae River	Key stakeholders have been kept well informed of investigations to date. The six short-listed options were presented to a select group on 8 June 2010 with a focus on environmental effects, including the findings of the investigations of NIWA and Wildland Consultants. Representatives from Fish & Game, Forest & Bird and Friends of Waikanae River attended the presentation. Stakeholders were also presented with a summary of the technical investigations on 1 July 2010. At this stage of the project, initial feedback from stakeholders appears to suggest that there are no apparent fatal flaws with this option, however further detailed investigation will need to be undertaken into the environmental effects if it is preferred, particularly around the environmental effects of discharging groundwater into the Waikanae River.
Wider Community	There has been no significant concern expressed regarding this option. It appears that should the environmental effects assessment show that the adverse effects on the Waikanae River are no more than minor, this option may find the favour of the community, particularly in terms of cost and a smart way to use existing infrastructure.

10.6 Risk Assessment

The high and very high risks identified that are particular to the River Recharge with Groundwater option include:

- Water quality from new bores may be inferior to that from existing bores, and limits may be required on what percentage can be mixed with the river water
- Sustainable yield of aquifer (largely addressed through groundwater modelling).

Other risks to the River Recharge option which arise from implementation, environmental and economic issues are addressed elsewhere.

10.7 Cost Estimates

10.7.1 Base Capital Cost Estimates

A breakdown of the base capital cost estimate for this option is given in the table below.

Table 10-4: River Recharge with Groundwater Capital Cost Estimate

	Cost
Fees & Investigation*	$2.65M
Land Value	$0.05M
Construction Cost	$13.41M
Design and Management**	$2.21M
Contingency (25%)	$3.91M
TOTAL	$22.2M

* This provisional figure is based on the fees to date, plus estimated fees to completion of RMA approvals ($1.7M). In addition, allowance is made for Council internal costs ($650,000), geotechnical investigations carried out during Stage 3 ($120,000), legal fees for Council hearings ($100,000), plus Greater Wellington and Council processing costs ($100,000).

** Includes an allowance for Council internal costs during Design and Management phase.

10.7.2 Operation and Maintenance Costs

Overall O&M costs for this option are estimated at $1.37M/year increasing to $1.52M/year in 50 years.

11 Statutory Context

A preliminary assessment of the relevant planning provisions has been undertaken for the short-listed options. This section summarises the relevant statutory considerations and recommends an approach for securing planning approvals. The detailed preliminary assessment of each option is available in Appendix F.

11.1 Relevant Statutory and Planning Documents

The short-listed options have been assessed against the following planning documents prepared under the Resource Management Act 1991 (RMA):

- Operative Wellington Regional Policy Statement (1995) and Proposed Wellington Regional Policy Statement (2009)
- Wellington Freshwater Regional Plan (1998)
- Wellington Regional Soil Plan (1999)
- Wellington Regional Discharges to Land Plan (1999)
- Kāpiti Coast District Plan (1999).

In addition, some of the options may also require approvals under the following legislation:

- Conservation Act (1987)
- Reserves Act (1977)
- Historic Places Act (1991).

The relevant provisions of these documents are discussed below.

11.1.1 Kāpiti Coast District Plan Review

The Kāpiti Coast District Plan review has commenced and will be ongoing during the timeframe of this project. The last District Plan took 4 years from notification to becoming operative. Based on the current programme, the draft district plan is expected to be notified by the end of 2011. The Review will cover a range of topics, to be confirmed through the current scoping exercise. Topics of potential relevance to the water project are likely to include: ecological sites (hill country), sites of importance to tangata whenua, archaeological sites, and earthworks.

11.1.2 Regional Plan Reviews

Within the timeframe of the water project, the GWRC intend to commence a comprehensive review of regional plans. If the review results in changes to regional rules being notified prior to lodgement of any resource consents for the Project, the recent amendments to the RMA mean that rules in a proposed plan only have legal effect once a decision on submissions relating to the rule is made and publically notified[27]. The exception to this is rules relating to water, air or soil (for soil conservation) and the other matters listed in section 86B(2) of the RMA. Ongoing discussions with GWRC officers will identify the timeframes and any impact of the regional plan reviews.

[27] Section 86B (When rules in proposed plan have legal effect) of the RMA.

11.2 Designation of Land for the Project

Kāpiti Coast District Council is a Requiring Authority and Network Utility Operator under section 166 of the RMA. Therefore, Council has the option to designate land for the project following the statutory process set out in sections 168 and 169 of the RMA. The designation process (and associated Outline Plan process) will not completely exempt Council from restrictions on land use contained in section 9 of the RMA, or restrictions on air, water and the coastal marine area. Also, any designation will not apply to the beds of rivers.

At this stage, it is recommended that Council consider using the designation provisions for the following:

- Land associated with the Kapakapanui, Lower Maungakotukutuku and Ngātiawa Dams, and the Waikanae Storage Ponds, should these options be taken forward for further evaluation.
- Designation for bores and pipes that are not located within the road reserve, particularly where the pipes cross open space zones.

The assessment below does not consider any subdivision or boundary adjustment that may be required as a result of acquiring land for the project. This assessment will need to be undertaken once these requirements are better defined.

11.3 Regional and District Policy

The Regional Policy Statement, Regional Plans and District Plan contain objectives and policies to guide the sustainable management of natural and physical resources on the Kāpiti Coast. This includes the management of water and development of water supply to provide for well-being of the community.

11.3.1 Regional Policy Statement

At the broadest level, the following provisions of the Regional Policy Statement (RPS) are relevant to a new water supply via a dam, off-line storage pond or groundwater option. The assessment of any resource consents required from the GWRC will consider whether the proposal is consistent with the objectives and policies set out in the RPS and Regional Plans.

Table 11-1: Proposed Regional Policy Statement

Issue	Objective	Policy	Relevance
Regionally significant infrastructure	Objective 10: The social, economic, cultural and environmental, benefits of regionally significant infrastructure are recognised and protected.	Policy 6: Recognising the benefits from regionally significant infrastructure and renewable energy – regional and district plans	The new water supply will be of regional significance by providing water supply to communities within the region.
The quantity and quality of fresh water	Objective 12: The quantity and quality of fresh water to (a) meet the range of uses and values for which water is required; (b) safeguard the life supporting capacity of water bodies; and (c) meet the reasonably	Policy 11 and 39: Maintaining and enhancing aquatic ecosystem health in water bodies – regional plans and consideration	Assessment of preferred option to consider impacts on aquatic ecosystems.
		Policy 12: Allocating water – regional plans	The regional plan contains rules for the allocation of water in the region.

	foreseeable needs of future generations.	Policy 14 and Policy 40: Minimising the effects of earthworks and vegetation disturbance – district and regional plans and consideration	The regional plan contains rules for earthworks and vegetation disturbance.
The health of the region's rivers, lakes and wetlands	Objective 13: The region's rivers, lakes and wetlands support healthy functioning ecosystems.	Policy 16 and 42: Protecting aquatic ecological function of water bodies – regional plans and consideration	Assessment of preferred option on aquatic ecosystems.
		Policy 17: Protecting significant values of rivers and lakes – regional plans	Assessment of preferred option to consider impacts on the values of rivers.
Efficient use of water	Objective 14: Water is used efficiently and is not wasted.	Policy 18: Using water efficiently – regional plans and consideration	End use of water.
		Policy 19: Prioritising water abstraction for the health needs of people – regional plans	Water abstraction for all of the options.
		Policy 43: Managing water takes to ensure efficient use – consideration	The effects of taking water on other users. Note that WPR community water supply is the only current consented water take from the Waikanae River and the Waikanae River is currently identified as fully allocated.
		Policy 65: Promoting efficient use and conservation of resources – non-regulatory	Water conservation measures as part of the suite of measures.
Protection and enhancement of ecological values	Objective 16: Indigenous ecosystems and habitats with significant biodiversity values are maintained and restored to a healthy functioning state.	Policy 23: Protecting indigenous ecosystems and habitats with significant indigenous biodiversity values – district and regional plans	Avoiding, remedying or mitigating effects on significant indigenous biodiversity values.
		Policy 46: Managing effects on indigenous ecosystems and habitats with significant indigenous biodiversity values – consideration	Impacts of preferred option on indigenous ecosystems and biodiversity.

In addition to the above objectives and policies, the RPS also contains provisions relating to resource management with tangata whenua. These are relevant to all options and have also guided the discussions with iwi regarding in-catchment and out-of-catchment water supply options. Many of these policies are given effect through detailed objectives, policies and rules in the regional plans.

11.3.2 District Policy

There are a number of District policy documents that are relevant to the development of a new water supply. These include:

- The Sustainable Water Management Strategy
- The Long Term Council Community Plan (including the sustainable development principles in this document)
- Development Management Strategy

These documents summarise Council policy position in relation to both growth of the District, water supply and water conservation. The strategy developed by this policy was discussed in the Stage 1 *Preliminary Status Report* and the Stage 2 *Option Selection Report*. Many of the strategies established by these documents are given effect through detailed objectives, policies and rules in the District Plan.

11.4 Resource Consent Requirements

11.4.1 Regional Consents

The construction and operation of all of the short-listed options will require resource consents from the GWRC. These approvals are required in accordance with sections 9-15 of the RMA.

a. Relevant Regional Notations

The regional plans identify a number of values for the watercourses associated with the short-listed options as set out in Table 11-2.

Table 11-2: Values identified in the Regional Plans

Regional Plan Value	Kapakap-anui Dam	Lower Maungako-tukutuku Dam	Ngātiawa Dam	Waikanae River (at the WTP)
Water Bodies with a High Degree of Natural Character (Appendix 2)	x	x	x	x
Water Bodies with Nationally Threatened Indigenous Fish (Appendix 3)	✓	✓	✓	✓
Water Bodies with Important Trout Habitat (Appendix 4)	x	✓	x	✓
Water bodies with Water Quality to be Managed for Water Supply Purposes (Appendix 6)	x	✓	✓	✓

✓: Value identified in the Regional Plans

x : Value not identified in the Regional Plans

b. Summary of Regional Consents

The following table summarises the regional consents that may be required for each of the options.

Table 11-3: Summary of Regional Consents for the Short-listed Options

Activity	Option					
	Kapakapanui Dam	Lower Maungakotukutuku Dam	Ngātiawa Dam	Waikanae Borefield & Storage or Treatment	Aquifer Storage and Recovery	River Recharge with Groundwater
Activities at the WTP						
Discharges from the WTP	D	D	D	D	D	D
Taking additional water from the Waikanae River (above consented take)	D	D	D	D	D	D
New discharge structure downstream from the existing intake at the WTP	NA	NA	NA	NA	NA	D
Activities involving watercourses and earthworks						
Damming and diverting a watercourse	D	D	D	NA	NA	NA
Structures (a dam) in the bed of a river	D	D	D	NA	NA	NA
Constructing a bridge over the Waikanae River for access from Mangaone South Road	D	NA	NA	NA	NA	NA
Constructing an off-line storage pond	NA	NA	NA	D	NA	NA
Activities involving earthworks and vegetation clearance						
Earthworks for site preparation, access, and dam construction.	RD	RD	RD	P	P	P
Vegetation removal for site preparation and dam/access constriction.	RD	RD	RD	P	P	P
Activities involving groundwater						
New abstraction bore/s	NA	NA	NA	D	D	D
Taking groundwater	NA	NA	NA	D	D	D
Earthworks for pipe construction	NA	NA	NA	P/RD	P/RD	P/RD
Discharging freshwater to ground (aquifer injection)	NA	NA	NA	D	D	D
Discharge groundwater to the Waikanae River	NA	NA	NA	NA	NA	D
Overall consent status	**D**	**D**	**D**	**D**	**D**	**D**

D = Discretionary activity

RD = Restricted discretionary activity

P = Permitted activity

NA = Not Applicable

The assessment indicates that the three dam options will require resource consents from GWRC for damming and diverting watercourses and structures within the bed of a river. These will be assessed as a discretionary activity. These options will involve taking water from the Waikanae River at the WTP. Taking additional water above that consented[28] will require an additional consent from GWRC and will be assessed as a discretionary activity.

The Waikanae Borefield and Storage option requires resource consents for earthworks and vegetation clearance. Taking water from the Waikanae River for this option will use the existing resource consent for taking surface water[28] and taking groundwater[29]. However, the storage pond options will need to increase river take from 23,000 m^3/day to 26,000 m^3/day and similarly the Borefield & Treatment option will need to increase groundwater take.

The River Recharge with Groundwater option will require resource consents for the construction of new bores, taking groundwater, constructing a new discharge structure in the Waikanae River near the WTP and discharging the groundwater to the Waikanae River. These will be assessed as a discretionary activity. The Freshwater Regional Plan does provide for the discharge of water (in this case groundwater) to water as a permitted activity provided it meets a number of standards. The discharge of groundwater to the Waikanae River is unlikely to meet the requirement relating to temperature of the water throughout the year and therefore resource consent is required. Taking additional water above that currently consented will require an additional consent from GWRC and will be assessed as a discretionary activity.

The Aquifer Storage and Recovery option will require resource consents for new abstraction bores and to discharge surface water from the Waikanae River into the aquifer. These will be assessed as a discretionary activity. These consents will also be required for the Borefield and Treatment and River Recharge with Groundwater options for injection of river water to the aquifer to mitigate saline intrusion risks. The diversion of groundwater (from injecting freshwater into the aquifer and displacing groundwater) should meet the permitted activity standards in the Freshwater Regional Plan and can therefore be considered a permitted activity. Taking additional water above that currently consented will require an additional consent from GWRC and will be assessed as a discretionary activity.

11.4.2 District Consent Requirements

As set out previously, if Council seek a notice of requirement to designate land for any of the options, the rules in the District Plan are not relevant. However, the rules of the District Plan are relevant to any activities which will not be within the designation (e.g. pipes) and the District Plan rules are also a matter that Council needs to consider when assessing the Notice for a Requirement. There are also a number of District Plan notations (e.g. Ecological Areas) which are relevant to both a Notice of Requirement or resource consents due to the potential effects on these values.

a. Relevant District Plan Notations

The following table summarises the relevant notations for each of the dam and storage pond options.

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[28] consent WGN050024

[29] consent WGN050025

Table 11-4: Summary of District Plan Notations for Dams and Storage Pond

District Plan Notation	Option			
	Kapakapanui Dam	Lower Maungakotukutuku Dam	Ngātiawa Dam	Waikanae Borefield and Storage
Zoning:	Rural	Rural	Rural / Open Space	Rural and a small portion of River Corridor
Historic building:	None	None	None	None
Heritage trees:	None	None	None	None
Heritage Wahi Tapu:	None	None	None	None
Hazards – Faultline:	Near Gibbs fault and Ohariu Fault	On Gibbs Fault. Within well defined fault zone. Within an uncertain poorly constrained fault zone.	Near Gibbs fault and Ohariu Fault	None
Hazards – Flooding:	None	None	None	None
Ecological Sites:	Ecological site E17 - Tararua Ranges.	Ecological site E17 - Tararua Ranges.	Ecological site K080 – Ngātiawa Bush.	None
Outstanding Landscapes:	None	Near an Outstanding Landscape, but not within one.	None	Pond encroaches on an Outstanding Landscape associated with the Waikanae River
Designation:	None	None	None	Pond encroaches on Designation 403 D1133 Waikanae River walkway from State Highway 1 to the sea

The following table summarises the relevant notations for each of the options which involve groundwater including pipelines to transport water to or from groundwater sources. The proposed routes for pipelines are yet to be confirmed and therefore only a broad planning assessment of the routes has been undertaken. However, the route identification process will be guided to some extent by the planning constraints that have been identified. It may be possible at the next stage of the project to refine a route to avoid effects on significant values (for example ecological areas).

Table 11-5: Summary of District Plan Notations for Groundwater Options

District Plan Notation	Option			
	Waikanae Borefield and Storage (Pipework to WTP)	**Waikanae Borefield and Treatment**	**Aquifer Storage and Recovery (for pipes and other structures)**	**River Recharge with Groundwater (for pipes and other structures)**
Zoning:	Rural/River Corridor/	Residential/Rural	Rural/Residential/ Open Space/ Waikanae Development Zone	Residential/Rural
Hazards – Faultline:	Nil	Nil	Ohariu Fault line Well Defined Fault line	Nil
Ecological Sites:	Nil	Nil	K070 Russell Reserve Bush	Nil
Designations that the pipe crosses:	0301 Railway Purposes (Rail line) 0101 State Highway Purposes (SH1) D1135 – Roading (all local roads)	D1135 – Roading (all local roads) D0102 Western Ring Route	D0102 Western Ring Route 0301 Railway Purposes (Rail line) 0101 State Highway Purposes (SH1) D1135 – Roading (all local roads)	0301 Railway Purposes (Rail line) 0101 State Highway Purposes (SH1) D1135 – Roading (all local roads) D0102 Western Ring Route

Where the pipe routes cross designations, the process set out in section 176 of the RMA applies and requires that Council obtain the written approval of the relevant requiring authority for the designation to confirm that pipe will prevent or hinder that public work.

b. Summary of District Consents Required for the Project

Based on the above planning notations, the following table summarises the district consents that may be required for each of the options (should the designation process not be used).

Table 11-6: Summary of District Consents for the Short-listed Options

Activity	Options					
	Kapakapanui Dam	Lower Maungakotukutuku Dam	Ngātiawa Dam	Borefield and Storage or Treatment	Aquifer Storage and Recovery	River Recharge with Groundwater
Earthworks which do not meet the permitted activity standards.	D	D	D	D	N/C – due to open space zone	NA
Dam/Pond structure which exceed the height limits and separation distance to watercourses of the zone.	D	D	D	D	NA	NA
Pipes within roads	NA	NA	NA	P	P	P
Upgrading of existing pipes and other infrastructure associated with borefield	NA	NA	NA	P	P	P
Pipeline within rural zoned land (underground)	NA	NA	NA	P	P	P
The disturbance, removal, damage or destruction of naturally occurring indigenous vegetation (not in an ecological area)	D	D	NC – due to Open Space Zone	NA	N/C – Due to Open Space	NA
Construction noise – provided it complies with the standards in the District Plan.	P	P	P	P	P	P
Earthworks for pipeline in residential land (underground)	NA	NA	NA	D	D	D
The disturbance, removal, damage or destruction of naturally occurring indigenous vegetation within an ecological area	D	D	D	D	D	NA
Overall status	**D**	**D**	**NC**	**D**	**N/C**	**D**

NC = Non-complying
D = Discretionary activity
RD = Restricted discretionary activity
P = Permitted activity
NA = Not Applicable

For the above assessment, the biggest impact on the planning assessment results from the presence of Open Space. For the Ngātiawa Dam, this area of open space is located within the dam impound area and therefore there is no possibility of designing to avoid this. For the Aquifer Storage and Recovery Option, the preliminary pipeline route crosses an area of Open Space. There is scope to refine the route to potentially avoid or minimise the impact on open space areas.

11.5 Other Statutory Approvals

11.5.1 Reserves Act 1977 and Conservation Act 1987

There are a number of reserves, covenants and other limitations on areas of land within the project sites. The relevant considerations are summarised in the table below.

Kapakapanui Dam

The Waikanae River crossing is within the DoC managed Mangaone River Marginal Strip (Section 24(3) of the Conservation Act).

No other areas subject to the Conservation Act are within the dam impound area.

The approval approach/options for the marginal strips will need to be investigated with the Department of Conservation in further detail if the Kapakapanui Dam is a preferred option.

Lower Maungakotukutuku Dam

An 18 ha area of land within Lot 2 DP 360865 has been covenanted under the Reserves Act and is administered by the Department of Conservation.

No other areas subject to the Reserves Act are within the dam impound area.

The approval approach/options for the covenanted area will need to be investigated with the Department of Conservation in further detail if the Lower Maungakotukutuku Dam is a preferred option.

Ngātiawa Dam

Ngātiawa River Marginal Strip, DoC managed (Section 24(3) of the Conservation Act).

No other areas subject to the Conservation Act are within the dam impound area.

The approval approach/options for the marginal strips will need to be investigated with the Department of Conservation in further detail if the Ngātiawa Dam is a preferred option.

Groundwater Options

Placement of additional bores and pipelines can be micro-sited to avoid areas of significant indigenous vegetation or habitats.

11.5.2 Historic Places Act 1991

The options under investigation do not impact on any specific sites identified under the District Plan as requiring protection for heritage value. The following approaches should be considered for Historic Places Act approvals:

- A general authority under section 12 of the Historic Places Act should be sought for an entire pipeline route (where proposed). This application could be made at the same time as the NoRs and resource consents, or, as the application does not require notification, later in the RMA statutory process once the nature and extent of submission are known.
- A section 11 authority to be sought for specific known sites at the appropriate time.

11.6 Statutory Process

The options available for the statutory process are:

- Separate statutory processes with KCDC and GWRC
- A joint statutory process, including joint notification and hearing
- Call-in
- Direct referral to the Environment Court.

The project is unlikely to meet the criteria for a Call-in set out in section 141(2) of the RMA, being essentially of local rather than national significance. At this stage, Call-in is not considered to offer any time or process advantages for this project.

The preferred option is a joint statutory process (involving the KCDC and GWRC) as provided under section 102 of the RMA. This will enable all aspects of the project (regional consents and district land use consents/NoR) to be considered as a whole, and avoid unnecessary duplication of work and resources. Given the scale of the Project, it is likely that some approvals for the project (depending on how activities/consents are packaged) will be publically notified.

Direct referral to the Environment Court may assist where a particular option has strong opposition from a few groups/individuals. Until a preferred option is selected it is too early to determine whether there are any advantages to direct referral.

12 Consultation

12.1 Consultation Principles and Commitments for the Project

Council is committed to maintaining a high level of community input and consultation as achieved in the earlier stages of this project. Consultation with iwi, stakeholders, the community and potentially affected parties forms a crucial part of the project. In developing the consultation methodology for the various stages of the project, Council has been guided by the Council's 'Consultation Policy' (December 2003) which sets out the Council's commitment to consultation with the people of the Kāpiti Coast, sections 82-90 of the Local Government Act (LGA) 2002 which outline the consultation requirements for local authorities, and the requirements of the Resource Management Act (RMA) 1991. Of primary importance is the recognition that consultation is a two way process between project proponents and people with an interest in a project. Consultation facilitates understanding between parties, and provides a forum for sharing ideas and concerns. Effective consultation on the project should improve decisions.

The following bullet points outline a number of principles that help define the meaning of good consultation. These have been adopted for this project.

- Early - consult as soon as possible when the details of a proposal are less 'set in concrete' and you have more flexibility to make changes to address issues raised by interested and affected persons.
- Transparent - be open about what you want to achieve, what scope you may have to change certain aspects of your proposal, and why there might be elements that you may not be able to change.
- Open minded - keep your views open to the responses people make and the benefits that might arise from consultation.
- Two-way process - consultation is intended as an exchange of information and requires both you and those consulted to put forward their points of view and to listen to and consider other perspectives.
- Not a means to an end - while consultation is not an open-ended, never-ending process, it should not be seen merely as an item on a list of things to do that should be crossed off as soon as possible.
- Ongoing - it may be that consultation - or at least ongoing communication - will continue after your application has been lodged or even after a decision has been made.
- Agreement not necessary - consultation does not mean that all parties have to agree to a proposal, although it is expected that all parties will make a genuine effort. While agreement may not be reached on all issues, points of difference will become clearer or more specific.

For this project the Council has committed to:

- Adhere to the principles and requirements for consultation under the RMA, LGA, Council's 'Consultation Policy' and the principles defining good consultation set out above
- Identify potentially affected or interested parties and stakeholders and invite them to participate in the consultation process
- Recognise stakeholder and community knowledge and resources in the identification of matters to be considered in the project
- Involve stakeholders in the identification of issues and options involved within the area. Provide various opportunities for stakeholders to provide feedback

- Receive, consider and respond to the feedback received by stakeholders with transparency and outline how such information has contributed to the decision making process
- Provide the identified stakeholders with timely information regarding the project and the proposed consultation process.

12.2 Consultation Objectives

The consultation objectives for this stage of the project are as follows:

- To build on the consultation undertaken during the previous stages of the project
- To consult iwi, affected parties and relevant stakeholders on the short-listed options to inform the selection of a preferred option
- To identify potential effects and mitigation options for each option based on discussions with affected parties and key stakeholders
- To inform the wider community on project progress
- To provide confidence to Council that the preferred option arising from this stage will have support from the Waikanae/Paraparaumu/Raumati (WPR) communities.

12.3 Consultation Activities

The consultation activities for this project are based on strong community and stakeholder involvement at all stages of the decision-making process, based around the following 5 project stages:

Stage 1:	Data review and first gaps
Stage 2:	Preliminary options report
Stage 3:	Ranked options report (current project stage)
Stage 4 and 5:	Preferred option development and Assessment of Environmental Effects (planning approval documentation)

The earlier stages of consultation (Stages 1-2) focussed on understanding and confirming community values for water supply to inform the development of selection criteria for the short-listing of options.

In December 2009 a series of meetings were held to introduce the water supply project and seek feedback on community values to inform the selection of options. Meetings were held at Paekākāriki, Raumati, Ōtaki, Waikanae and Paraparaumu. Those invited to attend the meetings included identified interest groups and individuals/organisations that made submissions to the LTCCP on water related issues. These meetings were also open to the public. A meeting was held at Whakarongotai Marae mid December to discuss iwi values and consultation process with Ati Awa ki Whakarongotai and similarly with Ngā Hapū o Ōtaki.

The discussions and feedback at the December meetings assisted in the identification of key values for consideration when selecting a water supply options. In addition to obtaining input via consultation the values were also informed by the following:

- The sustainable management framework set out in the Resource Management Act and supported in the regional and district planning documents, including the Council's *Water Matters* document
- The Sustainability Principles in the LTCCP. The LTCCP was developed after consultation with all communities on the Coast

- The issues that were identified in previous water supply investigations for the Kāpiti Coast. Some of those investigations involved discussions with communities.

Consultation during January to early March focussed on better understanding and ranking the values identified to inform selection criteria for option assessment. Further community meetings, public questionnaire and feedback and a Water Forum with key stakeholders assisted in ranking the values. Water Quality was identified as the value of most importance to the community, followed closely by technical performance (security of supply) and cost (an affordable and value for money solution). Other values identified as important for selection criteria included environmental effects, ability to act (consent/implement) and social/ cultural effects.

On 11 March 2010, Council short-listed the six options that are the subject of this report, based on consultation feedback and Council policy for water management. Consultation for this stage has focussed on discussing the short-listed options with iwi, affected landowners, stakeholders and the wider community to inform the selection of a preferred option(s). The consultation for this stage of the project has involved the following activities:

Activity	Description
Partnership approach with iwi in water management issues	Council has a strong commitment to a partnership approach with iwi in water management issues. Two key consultation activities for this stage of the process have been to: Confirm iwi support for the investigation of in-catchment solutions as a first priority. This includes confirming the position of Ngāti Raukawa in regards to supporting the investigation of in-catchment options and not investigating the out-of-catchment option of the Ōtaki River source at this stage. Work in partnership with Te Āti Awa to investigate the merits of the short-listed in-catchment options in accordance with the specific Water Project Memorandum of Understanding that is being developed in relation to matters relating to water
Sustainable Home & Garden Show	The Sustainable Home & Garden Show took place over the weekend of 27-28 March 2010. The six short-listed options together with Council's water conservation initiatives were presented in a display tent. The Water Supply Project was a prominent display that was well attended by the public.
Directly Affected Landowner Consultation	All directly affected landowners have been identified and consulted as part of this stage of the project. In particular, the landowners of the three potential dam sites have been well consulted to investigate issues and impacts. The landowner of the three potential 'non-dam' options is identified as Council at this stage, as any new infrastructure and pipes are expected to be located within road reserve and/or Council-owned land. The exception to this is the storage pond site and the landowner of that site has been contacted to confirm progress with that option.
Ōtaki Community Board Decision	The Ōtaki Community Board made a decision on 11 May 2010 to confirm the Ōtaki community's opposition to the Ōtaki River as a source of water supply for this project.
Public Information Days	Public Information Days were held on 20 and 22 May 2010 to present and discuss the six short-listed options, the consultation process to date and Council's water conservation initiatives. Both events were well attended, with approximately 70 people attending the event on the 20th and 20 people attending the event on the 22nd. In particular, the events were

	well attended by locals living in proximity to the potential dam sites.
Water Taste Test	A Water Taste Test was held on 26 May 2010. An invited group of 9 people tasted a variety of water samples to investigate any taste differences between bore and river water and degrees of water treatment.
Regular Newspaper Articles & Information	The Water Supply Project has been a regular feature in the *Kapiti Observer* and *Kapiti News*, helping to ensure the community is well informed of the project as it progresses. Articles have included the Sustainable Home & Garden Show, dye testing (front page), geotechnical investigations (front page), taste testing (front page), articles reporting the information days and regular updates in the Mayoral column.
Key Stakeholder Consultation GWRC DoC Fish & Game Forest & Bird Department of Conservation Friends of Waikanae River	A number of key stakeholders have been consulted on the six short-listed options. In particular: ■ Greater Wellington Regional Council Presentation 6 May 2010: A preliminary presentation has been given to GWRC to familiarise the resource consents team with the six short-listed options. ■ Environmental/ River Care Groups Presentation 8 June 2010: The six short-listed options were presented to a select group with a focus on environmental effects, including the findings of the investigations of NIWA and Wildland Consultants. Representatives from Fish & Game, Forest & Bird and Friends of the Waikanae River attended the presentation. ■ Key stakeholder presentation 1 July 2010: summarising the technical investigations of the short-listed options.

12.4 Key Consultation Outcomes and Response

There have been a number of important consultation outcomes that will help inform the selection of a preferred solution and also guide consultation efforts in the next stage of this project.

12.4.1 In-catchment confirmed as a first priority

In terms of process, there is overall support for the investigation of in-catchment solutions as a first priority. This support has not only come from the out-of-catchment Ōtaki community and Ngāti Raukawa. Te Āti Awa and a large proportion of community members attending the Sustainable Home & Garden Show and Public Information Days support the in-catchment policy set in Council's *Water Matters* document, particularly in terms of living sustainably within the means of the in-catchment water supply. There is strong community support for Council's Water Conservation Initiatives, and feedback that water conservation is a key part of the water supply project has been a consistent theme throughout the consultation for this project.

There was a small proportion of the community that expressed a strong preference for the Ōtaki River option. However, it appeared that some of those people were generally supportive of the investigation process of considering in-catchment options before looking to out-of-catchment options. All feedback on consultation process has assisted the project team to focus consultation efforts and ensure a coherent and commonsense process to systematically build a case towards a preferred solution.

Recommended action:

Record the general support for the process of investigating in-catchment solutions as a first priority, being consistent with the *Water Matters* policy. Also record the support of others for the Ōtaki River option and their concern regarding the dismissal of that option at this stage of the investigation.

12.4.2 Partnership approach with tāngata whenua

Council continues to build a partnership approach with tāngata whenua to water management, based around the core values of kaitiakitanga, tino rangatiratanga. tāonga, mauri and whakapapa. The focus on in-catchment solutions as a first priority is a strong indication that Council is taking into account these core values. At this stage, tāngata whenua have not identified any fatal flaws with any of the six short-listed options and remain committed to supporting a partnership approach to this significant community project. This includes the tāngata whenua of Ōtaki supporting the investigation of in-catchment solutions as a first priority, rather than undertaking further investigations into the Ōtaki River source at this stage.

With a focus on the in-catchment solutions, Council is working closely with the Te Āti Awa Water Working Group. A Memorandum of Partnership exists between Te Āti Awa and the Kāpiti Coast District Council which sets out the general principles of partnership under the umbrella of Te Whakaminenga o Kāpiti Working under this framework, a specific Water Project Memorandum of Understanding is being developed in relation to specific matters relating to water with the following goal:

> *That Kāpiti Coast District Council and Te Āti Awa will work together in the spirit of partnership to explore practical, innovative, culturally appropriate management of water, including the supply of potable water to all communities within the Waikanae, Paraparaumu and Raumati catchment area*

Recommended action:

Continue to build a partnership approach between Council and tāngata whenua to water management. Continue to work together closely in investigating cultural impacts as part of Stages 4-5 (Preferred option development and Assessment of Environmental Effects).

12.4.3 Directly affected landowners of dam sites

The issues of directly affected landowners of the dam sites are well understood. In short, the landowners of the Kapakapanui and Maungakotukutuku dam sites are generally supportive of establishing a dam on their property, whereas there are multiple landowners for the Ngātiawa dam site and the majority of those are not supportive. The reasons for a lack of support from these landowners is well justified, and relate to adverse environmental, social and economic effects of inundating their land. Overall, this is a significant disadvantage of the Ngātiawa dam site compared to the other two sites. There are site specific issues to work through with the Kapakapanui and Maungakotukutuku dam sites, particularly site and public access and the ongoing provision for surrounding farming and forestry activity.

Recommended action:

Promptly inform landowners of Council's decision on a preferred option(s). Landowners that are no longer directly affected by the project should be thanked for their support with the investigations to date – all landowners have been very accommodating of the investigations. Any landowners who remain directly affected by the project should continue to be closely consulted with.

12.4.4 Downstream residents of dam sites

During the Public Information Days and in recent correspondence with Council, a number of downstream residents to the dam sites have expressed concerns regarding the risk of dam break and potential adverse environmental effects of damming tributaries to the Waikanae River. Most concern was expressed by residents below the Kapakapanui dam site; followed by those below the Maungakotukutuku dam site.

Recommended action:

Promptly inform downstream residents of Council's decision on a preferred option(s). Should a dam option be preferred, any downstream residents should be directly consulted with. As a first step, the investigations for Stage 3 regarding assessment of dam design specifications, land stability and faultline assessment, and assessment of property effects in the unlikely event of dam break should be presented to downstream residents as a basis for progressing discussion.

12.4.5 Unfamiliarity with non-dam options

Overall, it appeared that many were unfamiliar with the concepts of the non-dam options and familiar with the concept of a dam. That uncertainty with the non-dam options is potentially directing those people towards favouring a dam, in the absence of fully understanding the non-dam options. Several people commented that if they could more fully understand the concept and environmental effects of the non-dam options, they might consider those viable solutions. In particular, the river recharge with groundwater was seen as attractive as it used existing infrastructure and was less costly, provided the environmental effects on the Waikanae River were no more than minor.

Recommended action:

Should a non-dam option(s) be the preferred solution, attention must be given to clearly presenting the working design concept to the community, with a particular focus on removing any uncertainty around security/reliability of supply and environmental effects. A clear explanation of why dam options have not been preferred will also be required.

12.4.6 Greater Wellington Regional Council

A preliminary presentation has been given to GWRC to familiarise the resource consents team with the options being evaluated. While the initial feedback appears to suggest that there are no apparent fatal flaws with any of the short-listed options in conceptual terms, further evaluation will be required of the technical work undertaken to date (i.e. of this report and its appendices). As the consenting authority, GWRC has requested to be kept well informed as the investigation of any preferred option(s) continue, particularly in terms of environmental effects assessment.

Recommended action:

Keep GWRC well informed as the investigation of any preferred option(s) continue, particularly in terms of environmental effects assessment.

12.4.7 Key Stakeholders

Key stakeholders have been kept well informed of investigations to date. In particular, the Department of Conservation has been heavily involved in the geotechnical investigations for the Maungakotukutuku dam site due to the works being located within a conservation covenanted area.

The six short-listed options were presented to a select group on 8 June 2010 with a focus on environmental effects, including the findings of the investigations of NIWA and Wildland

Consultants. Representatives from Fish & Game, Forest & Bird and Friends of Waikanae River attended the presentation. A further stakeholder meeting was held on 1 July 2010 to present and discuss the short-listed options and technical investigations.

At this stage of the project, initial feedback from stakeholders appears to suggest that there are no apparent fatal flaws with any of the short-listed options in conceptual terms, however further detailed investigation will need to be undertaken into the environmental effects of the preferred option(s), particularly around any discharges to, or takes or damming of the Waikanae River and its tributaries. The technical investigations undertaken by NIWA and presented to key stakeholders have provided an early indication that the environmental effects of any of the short-listed options will be no more than minor in terms of water quality and associated ecological effects, and environmental effects can be sufficiently mitigated through design and sound environmental management.

Recommended action:

Keep stakeholders well informed as the investigation of any preferred option(s) continue, particularly in terms of environmental effects assessment.

12.5 Summary – Key Messages from Consultation

The previous stages of consultation focused on understanding and confirming community values for water supply to inform the development of selection criteria for the short-listing of options. Consultation for this stage has focussed on discussing the short-listed options with iwi, affected landowners, stakeholders and the wider community to inform the selection of a preferred option(s). Key messages from this stage of consultation are summarised as follows:

- **Process** – All feedback on consultation process has assisted the project team to focus consultation efforts and ensure a coherent and commonsense process to systematically build a case towards a preferred option(s). In terms of process, there is overall support for the investigation of in-catchment solutions as a first priority before looking to out-of-catchment solutions. Positive feedback has been received regarding the role of the Technical Advisory Group in the option investigation and selection process, particularly in terms of using local knowledge to inform decisions and review the technical investigations.
- **Partnership approach with tāngata whenua** – Council continues to build a partnership approach with tāngata whenua in relation to water management, based around the core values of kaitiakitanga, tino rangatiratanga. tāonga, mauri and whakapapa. The focus on in-catchment options as a first priority is a strong indication that Council is taking into account these core values. At this stage, tāngata whenua have not identified any fatal flaws with any of the six short-listed options and remain committed to supporting a partnership approach to this significant community project. This includes the tāngata whenua of Ōtaki supporting the investigation of in-catchment solutions as a first priority, rather than undertaking further investigations into the Ōtaki River source at this stage. Council is working closely with the Te Āti Awa in the spirit of the Memorandum of Understanding developed for this project, particularly with the Te Āti Awa Water Working Group in the investigation of cultural impacts.
- **Dam options** – The concept of a dam as a water supply solution appears to have general support in the community. However, concern has also been expressed by some residents immediately downstream of the potential dam sites. Those noting support for dam options talk of the benefit of the certainty of a tried and tested concept and of capturing rain water sensibly in the hills. Those noting opposition talk of the risk of dam break and adverse environmental effects, particularly to in-stream ecology and amenity. The Ngātiawa Dam site has potentially more than minor adverse environmental, social and economic effects on directly affected

landowners. For that reason, the Ngātiawa Dam is significantly less favourable in comparison to the other two dam sites.

- **Non-dam options** – the non-dam options are generally less-well understood by stakeholders and the wider public than the dam options. Overall, it appears that River Recharge with Groundwater and Aquifer Storage and Recovery are favoured over the other borefield options, subject to confirming environmental effects generated by discharging groundwater into the Waikanae River and confirming the certainty around the science of injecting river water into the aquifer and recovering it.
- **Water Conservation** – the conservation target of 400 litres/ person/ day (peak day demand) forms a fundamental design assumption for the water supply project. The importance of water conservation has been an ongoing theme during the community consultation for this project, both Council and the community raising a range of methods to achieve lower consumption rates of potable water.

13 Composite Options

13.1 Purpose and Principles

In addition to the six options considered in the preceding sections of the report, there are a number of further options that have been considered arising from composites of those six options. The purpose in investigating composite options is to test whether, by combining or staging one or more of the six options, better value for money can be delivered for the ratepayer. Better value for money could be achieved, for example, by reducing any short term impacts of debt on Council's balance sheet by pushing capital expenditure further into the future (i.e. by staging); or by combining aspects of two or more options in such a way that the design requirements are still met but the capital costs are reduced.

With this overall purpose in mind, a series of principles for composites are defined as follows:

- Must be in-catchment solutions
- Must be able to meet design solutions for at least a 10 year period (i.e. for staged solutions, should be able to achieve all design requirements for 10 years based on medium growth and water conservation targets being met until further works are required)
- Optimise the ability to stage development and/or delay the inclusion of headroom
- Improve used as part of the overall water management regime
- Not add undue operational management complexity
- Likely to be equal to, or lower in cost, than the six options
- If possible, provide greater benefits than the six options in relation to one or more of the following: security of supply (diversification of water sources), taste and hardness of water, environmental impacts, potential future changes in consenting regime, and utilisation of existing borefield infrastructure.

In all cases that involve options that seek to delay capital expenditure, more specific yield modelling is required to determine how long the composite would be able to delay such expenditure while still meeting the design requirements.

A number of composite options have been developed over the course of Stage 3. Ultimately only two composites were found to have merit, and both related to river recharge. As Stage 3 has progressed, the River recharge with groundwater concept design was refined to address saline intrusion. The preferred means of managing saline intrusion risk was to inject river water into the existing wells – meaning the composite uses some of the best aspects of ASR, but without the riskier components of that option. The second composite with River Recharge considered possible blending of the abstracted groundwater with river water. This option can be further explored as part of the preliminary design of River Recharge, should that option be identified as Council's preferred solution. Use of blending (in addition to the underground storage proposed as a result of river water injection) may assist in the consenting process with ecological impacts and also may improve drinking water quality during very low flows in the river (e.g. if/when algal blooms occur in the river).

13.2 Composite Options Developed

A large number of ideas for composite options have been raised over the last few months by Council staff, by the TAG and by the CH2M Beca team. The following are those believed to be worth considering further:

13.2.1 Composite G1: Smaller Dam and Borefield

This composite nominally involves constructing a smaller dam at Lower Maungakotukutuku (the preferred dam site from the evaluation of the three dam options). The desired capacity has not yet been determined but is likely to be nominally 1M m^3. The dam would be sized based on the continued use of the existing borefield based on its determined sustainable yield, with bores K13 and K10 decommissioned. Groundwater from the borefield would be used in more serious droughts and blended with river water to met water quality objectives in relation to taste and hardness.

Based on the estimated $1.3M difference in cost between the 1.5M m^3 dam and the 2M m^3 dam, it is likely there would be in the order of a $2M to $2.5M difference between a 2M m^3 dam and a 1M m^3 dam.

The advantages of this composite are:

- Saving in capital costs over the full sized dam
- Utilises the existing borefield assets.

The disadvantages of this composite are:

- Significant sacrifice in dam capacity compared with relatively small saving in capital costs compared with the full sized dam
- Depth of impounded water over large paddock area would be less, increasing risks of algal blooms.

13.2.2 Composite G2: River Recharge with Groundwater & Blending of Groundwater

This composite involves Solution F (River Recharge with Groundwater), but rather than use all of the groundwater for recharging the river, a portion (say nominally 50%) would be used for supply. The reduced abstraction from the river would be blended with the groundwater within the treatment plant.

The advantages of this composite are:

- It could assist in reducing any residual consenting risks of Solution F because a smaller proportion of the river low would be groundwater
- It may improve drinking water quality during very low river flows.

The disadvantages of this composite are:

- It relies on community accepting blended groundwater.

13.2.3 Composite G3: ASR and River Recharge

One of the objectives for ASR is replacing the mineralised groundwater that is naturally present with river water, and thereby overcoming concerns over the taste and hardness of the groundwater. The actual extent to which this will occur is not known until at least the trial injection well is developed, and even then it won't be known with certainty until the full ASR scheme is constructed. This composite is a way of mitigating the risks of the water quality objective not been fully realised. The water abstracted from the ASR system would be used recharge the river rather than be used in the treatment plant and sent to supply.

Our current understanding of the potential for in-stream effects from the river recharge option has only identified a risk associated with dissolved reactive phosphorus (DRP) in the groundwater. The extent to which this could be mitigated with ASR needs to be considered further if this composite is carried forward.

Overall we believe that this composite is only worth considering further if the groundwater modelling work on Solution F (River Recharge with Groundwater) finds that extending the borefield is not a sustainable option, and that ASR then becomes the preferred solution.

The advantages of this composite are:

- It could be used to mitigate the risks of the water quality objective for ASR in relation to taste and hardness not been fully realised
- Potentially could reduce effects of DRP in the native groundwater on the river.

The disadvantages of this composite are:

- No cost savings over the ASR option.

13.2.4 Composite G4: Peak Lopper

This composite has been suggested by the TAG as a means to delay capital expenditure. While it is not a true composite of the six solutions, it is an extreme case of solutions involving storage. Essentially, it involves using a storage pond of approximately 20,000 m^3 to reduce the peak daily demand by about 2,000 m^3/day. Storage would be of raw water abstracted from the river, although refilling of the pond with river water could only occur when river flows are not particularly low and so the community would still need a supplementary supply during periods of low river flows. It could be located on land already owned by Council on the right bank of the river upstream of the WTP.

With peak daily yield predicted to increase by about 200 m^3/day per year, this option could delay the implementation of the long term solution by about five years.

Because the cost of building a small storage pond of 20,000 m^3 volume would be much greater per cubic metre than the preferred dam option, this composite does not make economic sense to combine with a dam option. Therefore it only makes economic sense to combine with a borefield option. Because its cost is likely to be of the same order as increasing the borefield capacity to provide an additional 2,000 m^3/day, it is considered unrealistic.

The advantages of this composite are:

- Could delay the need for implementation of the long term solution by five years.

The disadvantages of this composite are:

- Doesn’t satisfy a willingness by the Council and the community to implement a long term solution now
- Adds operational complexity for limited gain
- Higher potential for algal blooms in such a small storage pond
- Once the long term solution is implemented the pond would become a “white elephant” unless it was decommissioned and filled in, and the area restored to farmland.

13.2.5 Composite G5: Staging of Dam

The preferred dam site from the evaluation of the three dam options (Lower Maungakotukutuku) could be constructed as a smaller capacity dam (say 1 M m^3) initially and then raised in the future if time shows that the predicted headroom is actually required. As for Composite G1 (Smaller Dam and Borefield) the marginal cost of constructing additional storage capacity now is relatively small

($2M to 2.5M for the Lower Maungakotukutuku dam). The future additional costs associated with a second stage would include: design, retendering, contractor mobilisation and demobilisation, and increased difficulty of quarrying aggregate for the dam raising once the reservoir impoundment is created. These costs, plus the costs of the dam raising, are likely to be five to ten times the marginal cost of constructing additional storage capacity now.

Assuming the dam raising could be delayed for 25 years, in present value terms staging may still represent a reasonable economic approach. Nevertheless there are risks around the future consenting of the dam raising that need to be considered.

The advantages of this composite are:

- Saving in capital costs over the single stage dam, and allows for future matching of increased demand if it actually eventuates.

The disadvantages of this composite are:

- Significant sacrifice in dam capacity compared with relatively small saving in capital costs compared with the full sized single stage dam
- Future consenting risks if need to raise dam
- Depth of impounded water over large paddock area would be less, increasing risks of algal blooms.

13.3 Composite Short-listing

For many of the composite options described above the disadvantages outweigh the advantages. Table 13-1 summarises those composites we consider are worthy of short-listing, and the key reasons why we haven't short-listed the remaining composites.

Table 13-1: Composite Short-listing

Composite	Short-list?	Reason
G1: Smaller Dam and Borefield	✕	Small saving in capital costs and increased algal bloom risk.
G2: River Recharge with Groundwater & Blending of Groundwater	✓	
G3: ASR and River Recharge	✓	
G4: Peak Lopper	✕	Doesn't assist in providing a long term solution.
G5: Staging of Dam	✕	Relatively small saving in capital costs and future consenting risks.

14 Review of Ōtaki River Options

In addition to the options covered above, two options that involve using water from the Ōtaki River were reviewed from a design perspective and then cost estimates were prepared on the same basis as the short-listed in-catchment options. While the Ōtaki River options were not considered appropriate by Council due to district policy and local community concerns, this work was undertaken in order to ensure that Council has sufficient information in front of it to make the best decision possible. The Ōtaki River options have not been investigated in terms of environmental or other effects/risks, and there has been no specific consultation in relation to these options as part of Stage 3. Both the Ōtaki Community Board and the tāngata whenua of Ōtaki have given their support for the investigation of in-catchment solutions as a first priority, rather than undertaking further investigations into the Ōtaki River source at this stage. These options were costed purely to inform Council.

14.1 Yield

14.1.1 Flow Records

Greater Wellington Regional Council (GWRC) monitors the flow in the Ōtaki River at the Pukehinau gauging station, which is located just downstream of the vehicle suspension bridge at the start of the gorge and has been in operation since 1980. The catchment area for this gauging station is 306 km^2 (for comparison, the catchment area above the Waikanae at WTP gauging station is 125 km^2)[30].

The GWRC website provides low flow statistics for the Ōtaki River, which are repeated in the table below.

Table 14-1: GWRC Ōtaki River at Pukehinau Low Flows[31]

Return Period (Year)	Average Annual Probability (%)	Flow (L/s)	
		1 Day	7 Day
Mean annual low flow		4,790	5,310
5 year low flow	20	4,040	4,340
20 year low flow	5	3,340	3,500
50 year low flow	2	2,990	3,090
100 year low flow	1	2,760	2,830

Daily mean flow data for the period July 1980 to October 2009 was obtained from GWRC and analysed during Stage 2 of the Kāpiti Water Supply Project. The average daily mean flow from this period is 30,590 L/s. The minimum daily mean flow recorded is 3,190 L/s (30 April 2003), which has a return period of about 30 years based on the 1-day low flow return periods in the table above. The daily mean flow recorded in the Waikanae River at this time was 660 L/s, which is the lowest on record for the Water Treatment Plant gauging station.

[30] GWRC (2005) *Hydrological Monitoring Technical Report*

[31] <http://www.gw.govt.nz/otaki-river-at-pukehinau/show/58>

14.1.2 Regional Freshwater Plan

The minimum flow and water allocation limits for the Ōtaki River that are given by Policy 6.2.1 of the RFWP for are shown in the following graph (Figure 14-1). The minimum flow for the Ōtaki River at the Lower Gorge is 2,550 L/s, which is based on "habitat methods". The core allocation (2,120 L/s) is the quantity of water that is available to be taken from the river in all but low flow conditions. When the Ōtaki River flow is below 4,375 L/s the allocation is reduced to 1,820 L/s and when the river flow is below 3,975 L/s the allocation is reduced further to 1,400 L/s. If the river flow continues to fall below these flows, then the Council will consider issuing a Water Shortage Direction. Until such time as a Water Shortage Direction is issued, the amount of water identified by the stepdown allocation is available for use, unless otherwise restricted by a resource consent.

Although not required by the RWFP, a resource consent to abstract water from the Ōtaki River may include further step-down allocation limits to preserve the minimum flow specified in the RFWP (red dashed line in Figure 14-1).

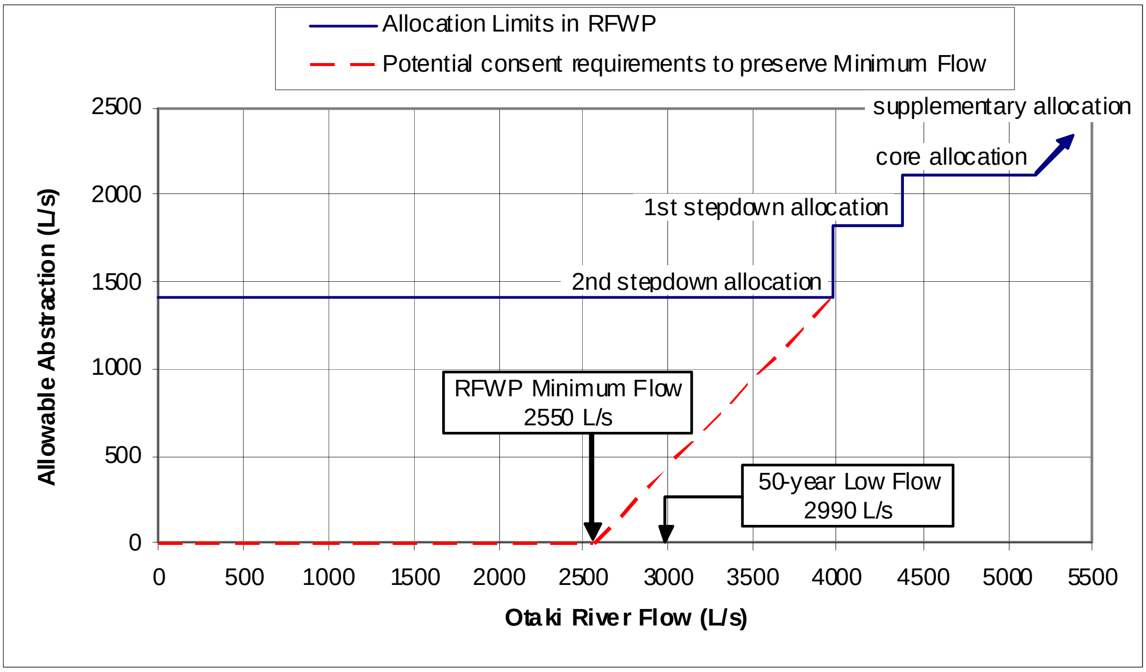


Figure 14-1: RFWP Core and Stepdown Allocations for the Ōtaki River

14.1.3 Existing Allocations

Information provided by GWRC indicates that 68.1 L/s (maximum instantaneous take) is currently allocated from the Ōtaki River. The information provided does not include the Hautere/Te Horo Rural Water Supply Scheme which draws from two shallow bores (9 m deep) adjacent to the Ōtaki River. Kāpiti Coast District Council has a resource consent (WGN010125) to take up 1,382 m^3/day (16 L/s) for this water supply scheme[32]. These shallow bores are effectively drawing from the Ōtaki River and so this take should be allowed for within the existing allocation volumes (even though GWRC did not). Therefore, up to 84 L/s is currently allocated from the Ōtaki River.

[32] <http://www.kapiticoast.govt.nz/Your-Council/A---Z-Council-Services-and-Facilities/Water-Services/Water-Supplies-and-Treatment-/> The Hatuere/Te Horo is a restricted flow water supply that services around 700 people. This supply is at capacity and it is Council's policy that there are no further connections to this supply.

14.1.4 Water Available

The core allocation in the RFWP for the Ōtaki River is 2,120 L/s, however abstraction must not exceed 1,400 L/s when river flows drop below 3,975 L/s, which has a return period of about 5 years. Accounting for 84 L/s already allocated, leaves a potential resource of up to 1,316 L/s at low flows.

However, a resource consent to abstract water from the Ōtaki River may include further step-down allocation limits to preserve the minimum flow specified in the RFWP. With a 50-year low flow of 2,990 L/s, a minimum flow of 2,550 L/s and existing allocations of up to 84 L/s, this means that up to 356 L/s (30,700 m^3/day) is potentially available for abstraction from the Ōtaki River in a 50 year drought.

In this case the full WPR peak day design yield (32,000 m^3/day or 370 L/s) may not be met. This assumes that the peak day demand coincides with the 50-year low river flow. Note that the RFWP states that the minimum flow for the Ōtaki River is not intended as a minimum flow below which all abstractions should cease. Also, the design yield includes a headroom allowance so the actual required yield may be less than 370 L/s. As such, the WPR peak day yield could potentially be met in a 50 year drought but this is dependent on the conditions of consent and the actual required yield.

It is noted that the existing Ōtaki Water Supply (consented for 11,233 m^3/day) has more than adequate capacity to meet the forecasted 2060 Ōtaki urban demand for water (4,900-9,000 m^3/day).

14.2 Options

Two options were reviewed and costed:

- Ōtaki Wellfield and Pipeline
- Ōtaki River Transfer.

14.2.1 Ōtaki Wellfield and Pipeline

This option involves the transfer of water from the Ōtaki River via a pipeline to the Waikanae WTP for treatment and distribution. Water would be abstracted from a shallow aquifer adjacent to the Ōtaki River. The aquifer has a good hydraulic connection with the Ōtaki River, making the abstraction from the wellfield effectively a run of river water take.

This option has previously been considered in the report *"Kapiti District Water Supply Project – Preliminary Design Report"* prepared by Woodward-Clyde (1998) and advanced to the consenting stage in 2001. The option was abandoned when the consent application was declined. Many of the details presented in this preliminary design report, including the proposed preferred pipe route, have been carried over to this cost estimate.

A new wellfield would be constructed on the southern bank of the Ōtaki River downstream of State Highway 1 (SH1), at the northern end of Lethbridge Road. The wellfield would have a capacity of 32,000 m^3/day but it is anticipated that it would only operate during peak demand during the summer months. A total of six wells, five duty and one standby, would be constructed.

Electricity to the wellfield would be supplied by new overhead lines running along the existing access track on the southern side of the Ōtaki River from the existing electrical supply along SH1. A transformer onsite would provide electricity to the control shed and pumps.

The borehole pumps have been sized to transfer the borewater approximately 16.55 km to the Waikanae WTP. The proposed pipe route is:

- East along Lethbridge Road to Te Waka Rd
- Underneath Te Waka Rd, running along the eastern side of the road until SH1
- South alongside SH1, crossing underneath it twice to avoid residential and retail areas
- Underneath the North Island Main Trunk Railway and SH1 for a third time at Waikanae
- Through the verges of residential roads to the Waikanae WTP on Reikorangi Road.

Refer to Figure 14-2 for more detail on the pipe route.

The majority of the pipe route would be located in the verge of SH1. It is estimated that less than 10% of the proposed pipeline route would pass through private property.

Cement lined steel (CLS) pipe has been provisionally selected as it is a recognised well-performing pipe material for pressure pipelines. It has a lower supply cost when compared with polyethylene (PE) pipe. Ductile iron may prove to be more economic, but this is very dependent on prevailing market conditions and has not been priced at this time.

The pipeline would connect directly into the rapid mix tank at the Waikanae WTP.

Figure 14-2: Ōtaki Wellfield and Pipeline – Pipeline Route

14.2.2 Option 2: Ōtaki River Gorge Transfer

This option involves the transfer of water from the Ōtaki River (downstream of the gorge) to the headwaters of the Waikanae River. There have been no investigations for this option, however it is assumed water could be abstracted from a shallow aquifer adjacent to the Ōtaki River similar to Option 1 or to the Hautere/Te Horo water supply scheme. If the shallow aquifer has a good hydraulic connection with the Ōtaki River, the abstraction from the wellfield would effectively be a run of river water take. The water discharged in the upper Waikanae River would flow downstream to be abstracted at the existing intake adjacent to the Waikanae WTP for treatment and distribution.

A new wellfield would be constructed on the southern bank of the Ōtaki River upstream of SH1, at Totaranui Road (off Ōtaki Gorge Road near Te Horo). The wellfield would consist of five (four duty and one standby) wells with a total capacity of 32,000 m^3/day. It is anticipated that the wellfield would only be required to operate during peak demand in the summer months.

An electrical supply would be brought underground from Electra's nearby zone substation to two 1 MVA transformers located at the wellfield. Electra has provided a conservative rough order cost estimate for this work ($4 million).

The borehole pumps have been sized to transfer the borewater 10.5 km to the headwaters of the Waikanae River. The proposed pipe route is:

- South along Hautere Cross Road to Mangaone North Road
- East along Mangaone Road to the Mangaone walkway
- Following the Mangaone Walkway through the hills east of Hemi Matenga Memorial Park
- Discharge into the upper Waikanae River downstream of the confluence with two unnamed tributaries, at a location approximately halfway between the ends of Mangaone North and Mangaone South Roads.

The pipe route climbs approximately 230 m to a peak along the Mangaone Walkway before descending approximately 70 m to the Waikanae River. Some of the pipe route is across private land and the implications of this has not been costed. Refer to Figure 14-3 for more detail on the pipe route.

As for Option 1, cement lined steel (CLS) pipe has been provisionally selected as it is a recognised well-performing pipe material for pressure pipelines, particularly under high head. It has a lower supply cost when compared with PE. Ductile iron may prove to be more economic, but this is very dependent on prevailing market conditions and has not been priced at this time.

Two discharge structures would be constructed in the upper Waikanae River. The structures would include pressure sustaining valves to prevent negative pressures developing on the section of pipeline downstream of the summit. The need for negative pressure mitigation, and whether a more economic design is feasible, should be considered in preliminary design.

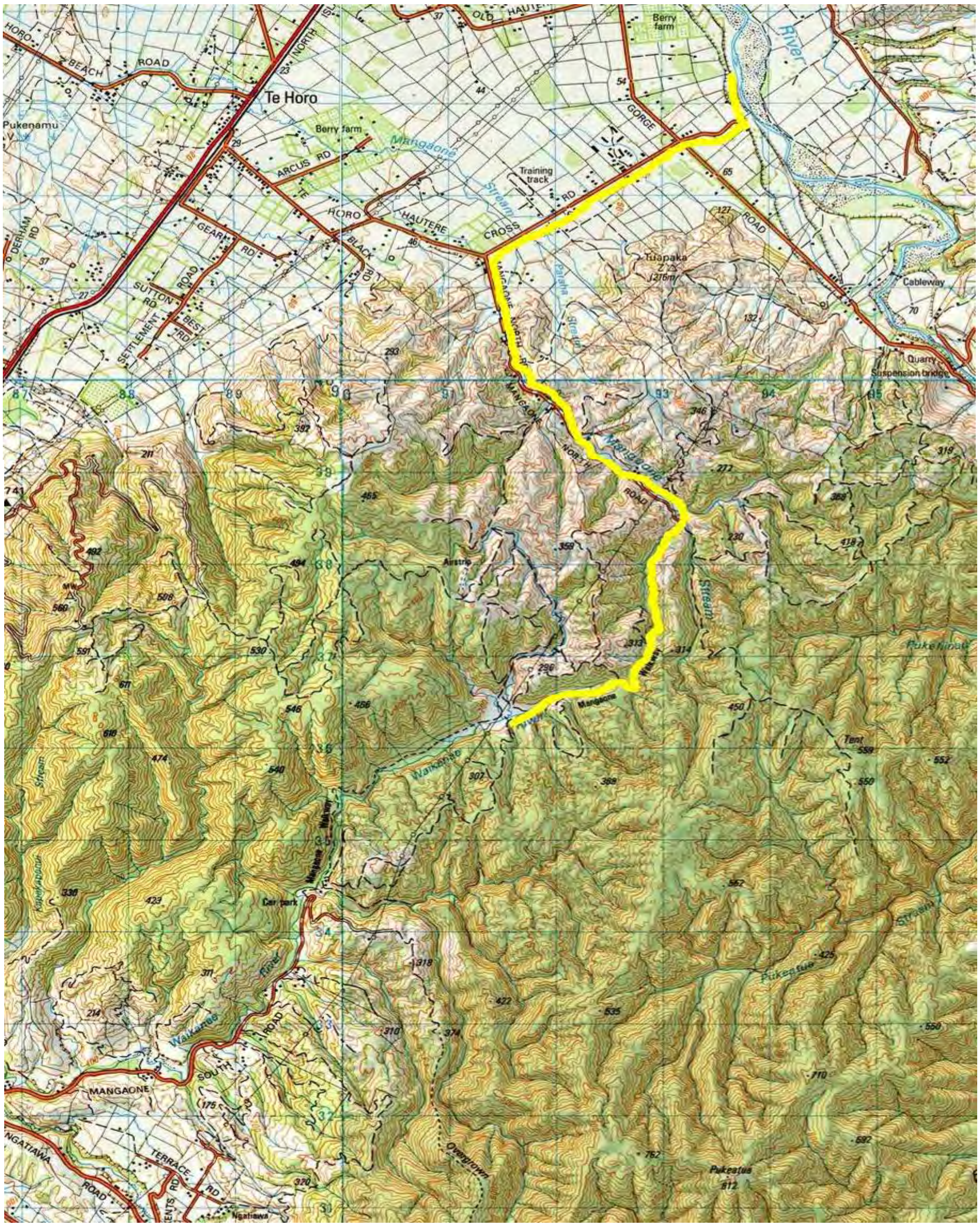


Figure 14-3: Ōtaki River Transfer – Pipeline Route

14.3 Capital Cost Estimates

The two Ōtaki River options have been costed based on a level of design similar to the short-listed in-catchment options. The estimates are in the order of ±25% accuracy.

The costs estimates for both options include the following:

- 350 mm diameter, 12 m deep wells (including well development and testing)
- Stainless steel multistage borehole pumps, seated inside the well casing
- VSDs for the borehole pumps
- Bore headworks including in-line check valve, pressure gauge, actuators, air valve, flow meter and isolating valve

- Hydropneumatic tanks at each wellhead to mitigate water hammer effects
- Earth bunding and fencing around each well and also perimeter fencing around wellfield
- Control shed to house instruments
- Power supply to wells and control shed (including transformers and new connections to network)
- Supply and installation of 500 mm diameter CLS pipeline
- Air valves located at all high points in the pipeline and at minimum 1 km spacing
- Isolation and scour valves along pipeline route
- Thrusting under roads and stream crossings where necessary
- Works to the existing Waikanae Water Treatment Plant.

GST has been specifically excluded from the cost estimate.

The cost estimates include allowances for preliminary & general, contractor's on-site and off-site overheads plus profit, professional fees and consent fees. The costs of consenting risks associated with the Ōtaki River are not included.

As the pipe route for the Wellfield and Pipeline option requires a significant length of pipe to be installed adjacent to SH1, allowance has been made for traffic management to meet NZTA requirements during construction.

Table 14-2: Base Capital Cost Estimates for Ōtaki River Options

	Wellfield and Pipeline	River Transfer
Fees, Council Costs & Investigation[33]	$2,650,000	$2,650,000
Land Value[34]	Not estimated	Not estimated
Construction Cost	$24,590,000	$20,900,000
Design and Management[35]	$3,550,000	$3,110,000
25% Contingency	$7,040,000	$6,000,000
TOTAL	$37,830,000	$32,700,000

Comparison with Historic Cost Estimates

The last reported cost estimate for the Ōtaki Wellfield and Pipeline project before the resource consent application was declined, is from January 2000 (*Otaki Pipeline - Supplement to the Preliminary Design Report*, Woodward Clyde). The preliminary budget cost estimate at this time was $10,219,100.

The 2000 cost estimate was at the low end of a range of five estimates listed in the report *Supplement to the Preliminary Design Report* ($10,219,100 to $12,187,900).

[33] This provisional figure is based on the fees to date, plus estimated fees to completion of RMA approvals ($1.7M). In addition, we have allowed for Council internal costs ($650,000), geotechnical investigations carried out during Stage 3 ($120,000), legal fees for Council hearings ($100,000), plus Greater Wellington and KCDC processing costs ($100,000).

[34] Land required adjacent to river for shallow wells has not been valued.

[35] Includes and allowance for Council internal costs during Design and Management phase.

To escalate the 2000 estimate to today's cost terms, a factor of 1.5 has been applied. This is based on the latest NZTA cost adjustment factors for construction and the Capital Goods Price Index for "other construction".

The 2000 cost estimate did not include a contingency allowance, or design and management costs, or fees and investigation costs, or Council internal costs. Therefore, the escalated 2000 estimate should be compared to the Construction Cost line item of $24,590,000 from the current estimate.

The current estimate includes costs for upgrading works at the existing Waikanae WTP. It appears from the summary schedule of work that the 2000 estimate may not have included power supply from the electricity network to the wellfield site, which has been included in the current estimate. Therefore, to allow for a fairer comparison, these two items have been added to the historic estimate. This leaves a difference of some $4,020,000 to $6,980,000 between the historic construction estimate and the current construction estimate.

Table 14-3 shows a comparison between the historic and current estimates as base capital cost estimates.

Table 14-3: Comparison of Historic and Current Cost Estimates for Wellfield and Pipeline

	Historic Estimate (Woodward Clyde, 2000)		Current Estimate (Beca, 2010)
	Lower Range	Upper Range	
2000 Construction Cost	$10,220,000	$12,190,000	n/a
2010 Construction Cost	$15,330,000	$18,290,000	$24,590,000
Works at Waikanae WTP	$ 1,060,000	$ 1,060,000	Included above
Power supply	$ 1,220,000	$ 1,220,000	Included above
Subtotal – Construction	$17,610,000	$20,570,000	$24,590,000
Fees, Council Costs and Investigation	$ 2,650,000	$ 2,650,000	$ 2,650,000
Land Value	-	-	-
Design and Management[36] (12%)	$ 2,710,000	$ 3,070,000	$3,550,000
Contingency (25%)	$ 5,080,000	$ 5,910,000	$7,040,000
TOTAL	$28,050,000	$32,200,00	$37,830,000

The January 2000 cost estimate was updated from an estimate prepared in October 1997. It is worth noting that the 1997 estimates showed a 33% difference in the highest and lowest construction cost estimates provided by three contractors and a 65% difference in the highest and lowest 500 mm diameter pipe supply cost estimates provided by six suppliers. The lowest cost contractor and two lowest cost pipe suppliers were consulted for preparation of the 2000 updated estimate.

Therefore, at least some of the difference between the current and historic estimates is likely to be caused by standard Beca practice in cost estimating of using more midpoint rates/costs instead of the low end of the range as used in the historic estimates by Woodward Clyde.

[36] This figure also includes an allowance for Council internal costs

Unfortunately, without a detailed breakdown of the cost estimates prepared by Woodward Clyde it is difficult to determine where the exact cost differences lie, and properly explain the differences.

The objective of this stage of the project is to compare the options on the basis of cost (as well as their other attributes). Because the cost estimates for all the options have been prepared from concept designs developed to a similar level of detail, and by the same cost engineers, it is important to appreciate that there is a common basis for a fair comparison. If the Beca cost estimates for the Ōtaki Wellfield and Pipeline option are in fact too conservative, then this conservatism will be shared by the other options, but a fair comparison is still possible.

PART C: EVALUATION AND RANKED OPTIONS

15 Option Assessment and Analysis

15.1 Option Short-listing

Once concept designs were completed on all eight options, sufficient investigations undertaken to fully understand the range of issues and base capital cost estimates prepared, an interim report called the *Option Short-listing Report* was submitted to Council.

The base capital cost estimates for a number of options (Kapakapanui Dam, Ngātiawa Dam and Waikanae Borefield and Storage) indicated that they were substantially over the capital budget allocated by Council (refer summary of base capital cost estimates in Table 15-1). In addition, Solution C: Ngātiawa Dam had reasonably significant ecological and social impacts associated with it.

Table 15-1: Summary of Base Capital Cost Estimates

Option	Capital Cost Estimate (incl. 25% contingency)
A: Kapakapanui Dam*	$44.8 M
B: Lower Maungakotukutuku Dam**	$27.9 M
C: Ngātiawa Dam**	$34.1 M
D1: Waikanae Borefield and Storage – Scenario 1	$56.4 M
D1: Waikanae Borefield and Storage – Scenario 2	$42.6 M
D2: Waikanae Borefield and Treatment	$34.3 M
E: Aquifer Storage and Recovery	$25.0 M
F: River Recharge with Groundwater	$22.2 M
Ōtaki Wellfield and Pipeline	$37.8M
Ōtaki River Transfer	$32.7M

* Lower Site, Scenario 1

** Scenario 1

On the basis of the work undertaken up to that point, the following recommendations were made to Council in mid June 2010:

- That the following options be put on hold, and not considered further:
  - Kapakapanui Dam
  - Ngātiawa Dam
  - Waikanae Borefield and Storage Pond options.
- That Council recognise that each of these options, while being put on hold for capital cost (and other reasons for Ngātiawa), also have a number of other pros and cons, and these may well need to be re-evaluated in the event that no clear preferred option emerges from the final ranked options report.
- That Council communicate with those landowners or other parties directly affected by these options so they are aware that these options are being placed on hold.

- That Council continue to investigate the remaining four options, and note that a detailed technical report and executive summary will be received by Council in July 2010 with the ranked list of options, as well as consideration of relevant composite options.

Overall, the options recommended for placing on hold also have a number of high level consenting, design and construction risks, so there is a high degree of confidence that holding further investigations of these options is the right decision at this stage. In particular, this will provide some certainty to those landowners and affected parties that have concerns.

The above recommendations were adopted by Council on 24 June 2010.

Table 15-1 shows that, on the basis of capital costs, the two Ōtaki River source options rank lower than the Lower Maungakotukutuku Dam, Aquifer Storage & Recovery and River Recharge with Groundwater options. Therefore, simply on cost grounds, there are three in-catchment options that would be preferred for the WPR supplementary supply over the options using the Ōtaki River as a source. In addition there are significant consenting hurdles to be overcome with any Ōtaki River option, and some uncertainty about how the minimum flow setting in the RFWP would be dealt with in a resource consenting process.

The following assessment and analysis of the options therefore only includes:

- B: Lower Maungakotukutuku Dam
- D2: Borefield and Treatment
- E: Aquifer Storage and Recovery
- F: River Recharge with Groundwater.

Note the following analysis of the Lower Maungakotukutuku Dam is based on a live storage capacity of 1.9M m^3, which allows for the required headroom.

15.2 Risk Assessment

Various risks have been identified in the three risk workshops held during the course of the project to date. These risks are categorised into the following:

- design requirements,
- general risks (including cultural),
- water quality,
- environmental,
- technical/design,
- costs; and
- yield.

The risks for the four short-listed options that were assessed as having implications that were able to be costed have been addressed in the risk-based costing, which is reported in Section 15.3 following. In undertaking the risk-based costing we incorporated the most recent groundwater modelling information around saline intrusion and how it can be mitigated, as well as the additional geotechnical information from the drilling investigations relating to the Lower Maungakotukutuku Dam.

There are a number of risks in the Risk Register that were assessed as being too difficult to cost and/or being risks that are potential fatal flaws. For the four short-listed options, those non-cost risks which are "live", and have either a "high" or "very high" risk priority, are presented in the following table. The table includes the status of the risk in the light of the completion of the design and investigations in Stage 3, and what further work will be undertaken in Stages 4 & 5 to understand and/or mitigate the risk should the particular option be preferred.

Table 15-2: Assessment of Non-Cost Risks

Risk	Current Status	Further Work
Design Requirements		
Reliability of supply – non-acceptance by Councillors of the 1 in 50 year return period drought standard	From presentations to Councillors during the course of Stage 3, this has not been raised as an issue.	None if Council accepts Stage 3 report on 19 August.
Reliability of supply – possibility of a review of the minimum flow on the Waikanae River through the Regional Freshwater Plan.	At meeting with key stakeholders on 1 July, GW advised that minimum flow settings are being reviewed.	Further discussion with GW is required. The minimum flow could be altered through the Regional Freshwater plan – which not only takes time, but also has many rights of appeal etc. The minimum flow regime could be altered either to benefit or adversely affect KCDC. The only further work at this stage is to liaise closely with GW.
Demand & yield – headroom allowance for uncertainties in demand forecasting is not adequate	Unchanged	Further work being done on demand and losses, due for reporting in September This work will confirm whether headroom allowance is adequate.
Demand & yield – losses from existing water supply network greater than assumed and too difficult and/or costly to reduce	Unchanged	Further work being done on demand and losses, due for reporting in September This work will confirm extent of losses and difficulty of reducing.
Treated water quality – for Borefield & Treatment option (the only short-listed option which involves supply of groundwater), the hardness and salinity targets are not acceptable to most consumers	Taste testing in May showed little ability to differentiate between river and bore water – likelihood of taste risk probably reduced to “rare”. Hardness may still be an issue, however	Investigate hardness target further.
Cultural		
Cultural – iwi identify fatal flaws with the project process or the water supply options under investigation	Risk is being managed through ensuring that the project process provides for a partnership approach to water management. With a focus on in-catchment solutions, Council is working closely with Te Āti Awa Water Working Group to understand and mitigate cultural risks. At this stage iwi	Continue to ensure that the project process provides for a partnership approach, including working towards a Water Project Memorandum of Understanding between Te Āti Awa and KCDC. Te Āti Awa to undertake a Cultural Impact Assessment.

Risk	Current Status	Further Work
	have not identified any fatal flaws with the process or the water supply solutions under investigation.	
B: Lower Maungakotukutuku Dam		
General - active fault line through dam foundation	Drilling investigations have shown no evidence of active faulting. Likelihood reduced to “rare”.	Further physical investigations proposed.
Water quality – algal blooms in dam reservoir particularly when water level is low	Unchanged. Risk mitigated by destratification in reservoir and improvements to treatment process.	Consider ways of improving flow through reservoir to induce more turnover of shallow area.
Water quality – logging and other land use impacts (e.g. fertiliser/ pesticide use) in upstream catchment	Unchanged	Consider how the Council’s duties under Health (Drinking Water) Amendment Act 2007 and the National Environmental Standard for Sources of Human Drinking Water could be used to mitigate this risk.
Environmental – potential impacts on the one dwelling in floodplain downstream of dam	Risk will be mitigated through detailed design and construction to meet regulatory requirements.	Further consultation with affected landowner. Dam break analysis and seismic hazard assessment.
Technical/design – seepage from reservoir results in loss of water that is higher than acceptable	Risk will be mitigated by grouting of dam foundations.	Further physical investigations (drilling and seismic refraction survey).
Technical/design – potential seismic impacts (including public perception)	Risk will be mitigated through detailed design and construction to meet regulatory requirements.	Seismic hazard assessment.
Yield – time to fill reservoir takes longer than assumed because of dry winter/spring or have two dry years in a row	Unchanged	Further work on surface water hydrology of catchment.
Yield – uncertainties as to whether there will be legal entitlement to abstract water released from dam at WTP intake	This would be closed off during the resource consent phase. Given excellent knowledge of the hydrology and other abstraction consents, this risk is considered low.	Continue to liaise with GW on water rights issues. Confirm legal position.
Yield – loss of released water to groundwater	Unchanged	Potential for loss of portion of released flow to be further investigated.
D2: Borefield & Treatment		
None		

Risk	Current Status	Further Work
E: Aquifer Storage & Recovery		
Water quality – quality of water recovered from aquifer not acceptable, and it needs to be treated for hardness and/or salt content to make it acceptable	Unchanged.	Trial injection well to confirm performance of aquifer and quality of recovered water.
Environmental – public is opposed to groundwater because of history of borefield and/or perceptions of drinking water from under the ground	Unchanged	Communications with media and public planned for August to explain and promote preferred option.
Environmental – possible creation of new springs and/or raising of water table to near the ground surface during periods of injection	This risk is now also applicable to F: River Recharge with Groundwater, as injection is now proposed to mitigate saline intrusion risk. Groundwater modelling work has shown a small effect on the shallow aquifer during injection. Likelihood reduced to "unlikely".	Further pumping tests and modelling.
Environmental – uncertainties associated with a new technology for New Zealand	Refer following risk.	
Technical/design – design and/or operation fails to work as intended	Mitigated by use international ASR specialist to provide peer review.	Ongoing involvement of ASR specialist.
F: River Recharge with Groundwater		
Environmental – possible creation of new springs and/or raising of water table to near the ground surface during periods of injection	Refer ASR above	Refer ASR above

A fourth risk workshop will be held early in Stages 4 & 5 to reassess the risks of the preferred option, review the proposed mitigation measures and further work, and update the Register. The further work associated with the preferred option will then be undertaken to assist in better understanding the risks, to allow mitigation measures to be refined and the risks appropriately managed. Once the further work has been completed, a fifth workshop will be held to reassess the risks in the light of the findings of the further work and close out any risks that are no longer of concern.

The key message in relation to risk, and specifically the risk-based cost estimates, is that as the project moves through consenting, and on towards detailed design and construction, the aim will be to actively manage all risks, and avoid or reduce them wherever possible. A number of risks that have been, or that will be, identified may arise, and reducing their impact on the project budget will a particular focus for the project team.

15.3 Risk-Based Cost Estimates

15.3.1 Approach

Risk-based cost estimates have been developed in accordance with the requirements of NZTA's Cost Estimation Standard SM014 to Option Estimate standard. This is commonly applied as a standard by local government around New Zealand. For risk-based estimates, this standard is also the one accepted by Treasury.

A risk register of project cost risks has been prepared and quantitatively analysed based on a correlated triangulation method where the best case and worst case inputs are deemed the 10th percentile and 90th percentile scenarios.

The following SM014 terms are used in this report:

Base Estimate: The total sum of the elements that make up an estimate but not a contingency

Expected Estimate: The Base Estimate plus an allowance for contingency based on the 50th percentile output from the risk analysis

Funding Risk: An additional provision for known/unknown risk between the Expected and 90th Percentile Estimate

15.3.2 Estimate Development and Assumptions

The cost estimates were developed from first principles, using quantified resources to develop the cost of identified components of the project.

The key assumptions are as follows:

1. Base date of estimate is July 2010;
2. No escalation is allowed for;
3. The estimate has been developed as an Option Estimate (OE);
4. There is no property acquisition constraint on programme;
5. There are no funding or cash flow payment constraints and the construction cash flow is neutral to the Contractor;
6. The delivery model is Design, Tender and Construct with only one Head Contract for physical works;
7. Project property costs include all acquisition and associated costs; and are net of residual value.
8. The estimate includes current professional fees and council costs through to, and including, lodgement, hearing and decision on the Resource Consent. A favourable outcome is assumed, although worst case estimates on fees allow for dealing with appeals to the Environment Court.

15.3.3 Risk Analysis Process

The objective of project cost reliability is to:

- Provide the basis for funding applications for the project, whether that is funding for professional fees, land and property or construction works

- Provide Council with a level of assurance that the proposed project estimate is justifiable and is considered sufficiently robust and takes into account project uncertainty.

Beca carried out the following actions, as part of a "risk-based" project cost estimate.

For each risk identified as having a possible affect in the estimate, a level of discrete contingency has been included in the estimate until such times as the risk has either been mitigated and no longer represents an issue to the project, or that an accurate expenditure is known against each risk issue.

The project estimate has been assessed in line with the principles of NZTA's SM014 Cost Estimation Manual requirements with values for Base, Expected (50%ile) and 90%ile Estimates being clearly indicated along with the base date to which the rates used in the estimate relate.

15.3.4 Derivation of Estimates

The method of cost estimation for this project allows for the cost to be built from base principles upwards, i.e. quantities have been measured from the latest scheme drawings allowing a work schedule to be produced which can then be rated to provide a total project cost, without contingency. The estimate has been assessed using a traditional contract tendering procedure.

The rates used in the production of this estimate have been derived from a combination of:

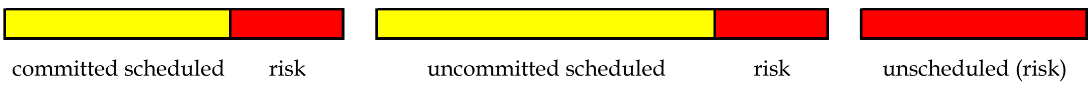
- Historical cost information
- Beca's cost database of similar projects (NZ)
- Engineering judgement and best practice estimating principles

Excluded from the estimate:

- GST
- Loss of land resale value
- Finance costs

The make-up of the cost estimate can be defined in a series of 3 elements:

- Committed scheduled work items
- Uncommitted scheduled work items
- Unscheduled items – items of risk identified through the above process



For ease of reference, specific examples for the above can be defined as:

Committed scheduled work items are those items measured from specimen drawings and rated using any of the methods identified above. The main risk associated with these items is that of design development, or confirmation. This design development is covered under the risk schedule in terms of a best case and worst case input against the quantity and rate for each work element in the estimate.

Uncommitted scheduled work items are those items included in the measured schedule but which are uncertain in their scope of works. Examples for this type of item are service relocations and protection and cut and under-cut to waste. These items have also been included in the risk schedule in terms of the best case and worst case inputs against the quantity and rate for each work element in the estimate, and will be confirmed as the detailed design is produced.

Unscheduled work items (risk) are those identified items having a possibility of occurrence. As the project moves through the design period these types of risk will either:

- be confirmed and incorporated within the scheduled work items
- mitigated through proactive management
- remain as risks to the project which will need to be managed to reduce the likelihood and consequence impact.

15.3.5 Risk Analysis Output

The risk analysis output should provide a meaningful and sensible estimate range against set criteria. For this project we have used statistical distribution and probability, which is considered to be the most appropriate form at the time, for both scheduled and unscheduled work items. The unscheduled items have also being assigned a probability of occurrence. This method of risk analysis is widely held to give the most representative results for a project estimate. By assigning probability against unscheduled work items the analysis will mimic possible “real-life” scenarios. As the model incorporates 1,000 iterations, it is, in effect assessing 1,000 possible “real-life” scenarios for the project and providing a probability distribution that reflects those possibilities. The risk analysis was produced with Palisades Decision Tools @Risk software using the triangulation method of simulation.

The risk analysis model includes for risk on the base estimate quantities and rates, those identified residual cost risks from the risk assessment and further risks that were identified during the estimating process. We have also assumed that the Best Case and Worst Case inputs are 10% and 90% values and therefore the output could be less or greater than these values.

With regard to quantity and price risk, we have chosen to use this method due to the stage of the project and the detail available at the time of producing this estimate. It is expected during the design development generic risks on quantity, will be replaced by specified risk items.

Items that require correlation, such as valves and pipe fittings, earthworks and pavement and P&G/Margins/Fees schedule items have been correlated and assigned a correlation value of 0.80. This means that all corresponding input cells will occur in the same “ratio”.

The graphical output from @Risk shows the most sensitive inputs (based on stepwise regression) calculated for the project during the @Risk analysis. These inputs are the most sensitive due to their possible range of outcomes in terms of financial effect on the project cost estimate.

15.3.6 Summary of Estimates

This section summarises the process used and the results of the estimate and associated quantitative risk analysis. Care has been taken to retain the underlying assumptions, project physical work scope and level of overall design for each option. This enables a fair comparison over the intervening period of each option.

The estimated out turn costs of each of the four options are presented in Table 15-3 below:

Table 15-3: Summary of Cost Estimates

Option	Base Estimate	Expected Estimate – 50th Percentile (P50)	90th Percentile (P90)
B: Lower Maungakotukutuku Dam	$23.1M	$28.6M	$33.2M
D2: Borefield and Treatment	$28.0M	$34.1M	$37.3M
E: Aquifer Storage & Recovery	$20.6M	$24.8M	$26.9M
F: River Recharge with Groundwater	$18.3M	$21.9M	$23.8M

15.3.7 Market Volatility and Programme Effects

The estimates provided at this stage allow comparison of the options as a "snapshot" of the estimated project cost as at July 2010. There are other additional costs which will require review in order to build up a "total" cost. These exclusions are:

- Allowance for further market volatility causing input cost escalation during the approval, design and delivery phases
- Project financing during construction. This will depend on the overall project delivery method and hence programme. It is noted that some consideration of this occurs in the production of the present value estimates presented elsewhere.
- The cost effects of any change in legislation or regulation (e.g. the introduction of a carbon tax, change in GST, etc)
- The cost effects of the statutory consent process, in particular the consent conditions over and above the allowance for reasonable mitigation that has been included in the estimate.
- The effects of further volatility in foreign exchange rates
- The effects of any major change in project physical work scope

It is expected that the Council will have a preferred rationale for handling escalation. The cost estimates do not attempt to predict the degree of future market movement and provides no allowance for this. Foreign exchange rate movement is similarly treated.

A detailed project cashflow has not been developed at this stage (refer to economic analysis in next section and preliminary cash flows for each option in Appendix G). This task and the concurrent estimate of finance costs is yet to be undertaken.

Although the statutory consent process is yet to be complete, there have been a number of environmental investigations carried out, as well as consultation with key stakeholders – including consenting authorities. On this preliminary basis, the estimates include an allowance for mitigation of adverse effects for each option, noting that some options have greater adverse effects than others. Other cost effects are included in the risk analysis process.

15.4 Quantitative Economic Analysis

15.4.1 Quantitative Analysis Methodology

a. Cost Effectiveness Analysis

Cost effectiveness analysis (CEA) attempts to estimate the costs associated with various options and rank them on the basis of least cost to provide a predetermined level of service provision. In this project CEA is used to estimate the costs to Kāpiti District rate payers of the least cost option to provide for the long term (50 years) supply of drinking water for the district.

As the benefits are the same for each option (i.e. provision of a specified quantity of potable water) a full cost benefit analysis (CBA) is not required.

b. Discounted Cash Flows

As the costs of the different options vary over time there needs to be a way of comparing them on an equal basis as people generally prefer to delay expenditure for as long as possible. Discounting future costs is a way of taking into account individuals' time preference for money as a dollar today is worth more than a dollar in the future.

In this study the standard Treasury discount rate for infrastructure projects of 8% real is used to discount future cash flows. The cash flows are then summed to a present value (PV), which is a single figure where the lowest value indicates the most cost effective option.

As the discount rate has the impact of inflation removed, the cash flows must also be estimated in real terms and thus all the costs in the project are in 2010 prices.

A sensitivity analysis using discount rates of 4% and 6% is also provided.

c. Costs

The costs of each option are divided into capital costs and operating and maintenance costs (O&M).

Capital costs are the upfront costs of an option and include investigation and consenting, land purchase, construction (includes design/management fees and Council's internal costs) and risk register costs (i.e. costs contingent on materialisation of known risks).

O&M costs are the ongoing costs of running the option and include power, labour, materials, chemicals and repairs and maintenance (new and existing) costs. Depreciation is not included; rather any plant or equipment that needs to be replaced during the project life is entered directly into the cash flows. The assumption is made that by the end of the 50 year project life all investment expenditure will have zero terminal value.

d. Analysis of Risk and Uncertainty

As the future is not known with certainty and there are different risks associated with each option, there needs to be a way of summarising this for decision makers. For example, an option with high upfront costs and low ongoing costs is likely to have different risks and uncertainty associated with it compared with a project with low up front costs and high ongoing costs.

Quantitative Risk Analysis (QuRA™)[37] is the tool used to quantify risks and uncertainty in the present value analysis. The steps in undertaking QuRA are as follows:

1. Identify the key variables within an option using sensitivity analysis.
2. Assess which of these key variables have the most risk or uncertainty. Usually, there will be three to five key risky variables that have a major influence on the PV of an option.
3. Estimate the low, most likely and high values for each variable. The low and high values are defined as the number where there is a 5% chance of a lower or higher value respectively.

[37] QuRA™ is a tool developed by Nimmo-Bell to consistently apply risk analysis to risky projects.

4. Choose a probability distribution that best represents the variable. A versatile and much used distribution is the Triangular, which only requires estimates of the low, most likely and high values to define it. A key attribute of the triangular distribution is that the most likely value can be skewed to one or other end of the distribution, a feature common when estimating future uncertainties. For example, a variable may have a long tail to the right which means that the most likely value will be skewed to the left.

5. Check to see if there is correlation between the risky variables once the distributions are chosen. Preferably the variables should be independent. If there is correlation, the best way to deal with this is to combine the variables into a new higher level variable with one distribution.

6. Simulate the risk using @Risk, an add-on to Excel. Values are drawn from each distribution, usually over 5,000 iterations according to the probability of each variable.

The key risky variables for all options are construction, risk register and O&M costs. The low, most likely and high values for the construction and risk register costs were generated from a risk analysis that simulated risks for many line items under construction and risk register. The low and high values for O&M were set at plus/minus 5% of 100% of O&M costs. Appendix G shows the risky variables as a table under each option's cashflow.

e. Results

The results of the analysis are presented as the present value (PV) of each option at the expected value (P50) derived from QuRA™ along with the probability distribution of the PV. This presentation allows the analyst to show the cost for any level of probability, e.g. P75 (a 75% likelihood the cost will be less than this value) or P90 (a 90% likelihood the cost will be less than this value).

The results are also expressed in terms of the Levelised Cost. This is the PV of total cost divided by the PV of additional water demand over the life of the project and expressed as $PV/m^3. Future water demand is discounted in the same way that future cost is discounted on the basis that a litre of water today is worth more than a litre of water in the future. The same discount rate is used for both costs and water demand.

15.4.2 Options and Results

The following options have been short-listed for economic analysis:

- B: Lower Maungakotukutuku Dam
- D2: Borefield & Treatment
- E: Aquifer Storage & Recovery
- F: River Recharge with Groundwater.

The capital costs and O&M costs for each option are summarised in the table below.

Table 15-4: Capital and O&M Costs

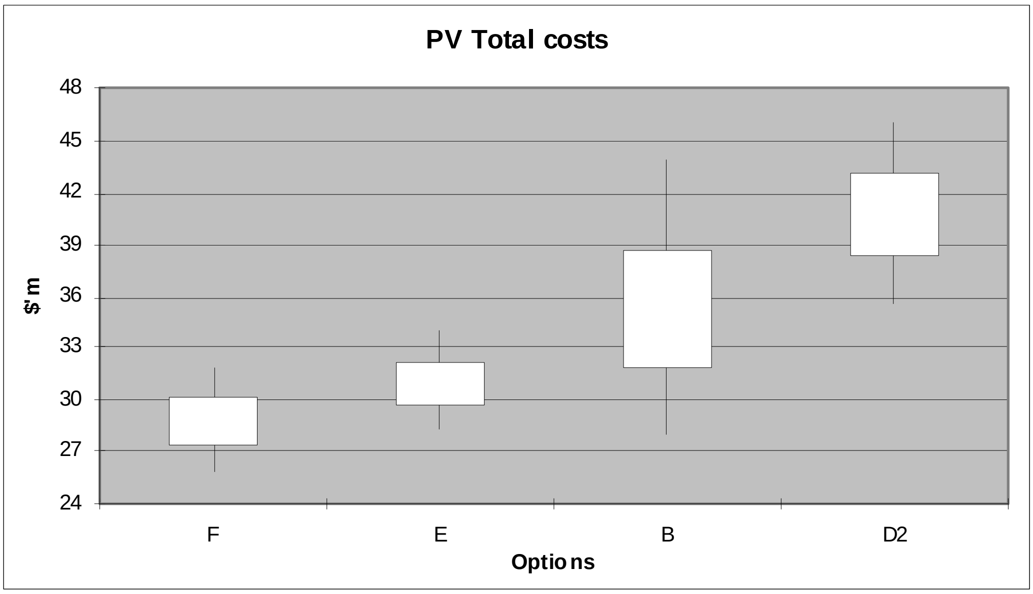
Option	P50	P90	O&M Costs over 50 years
B: Lower Maungakotukutuku Dam	$28.6M	$33.2M	$1.36M/year – $1.49M/year
D2: Borefield and Treatment	$34.1M	$37.3M	$1.71M/year – $1.89M/year
E: Aquifer Storage & Recovery	$24.8M	$26.9M	$1.38M/year – $1.54M/year
F: River Recharge with Groundwater	$21.9M	$23.8M	$1.37M/year – $1.52M/year

The cash flows for each option are set out in Appendix G with the results of the analysis summarised in Table 15-5 and Figure 15-1 below.

Table 15-5: Cost Effectiveness Analysis

Summary: Present value (NZ$'000)				
Options	B	D2	E	F
P50				
Capital Expenditure				
Investigation and consenting	2,369	2,136	2,135	2,083
Land purchase	1,557	82	101	73
Construction costs	16,278	21,068	15,138	13,391
Risk register	2,940	2,474	1,476	1,207
Total capital expenditure	23,144	25,760	18,849	16,754
Total O&M	12,143	15,058	12,207	12,054
P50: PV Total Costs @ 8%	35,253	40,794	31,042	28,801
Risk Analysis				
P75: PV Total Costs @ 8%	37,056	42,056	31,695	29,502
P90: PV Total Costs @ 8%	38,702	43,159	32,247	30,127
Sensitivity to discount rate				
P50: PV Total Costs @ 4%	51,302	60,826	46,902	44,169
P50: PV Total Costs @ 6%	41,489	48,629	37,205	34,742
O&M as % of total costs	34%	37%	39%	42%
PV additional water demand ('000 m3)	54,807	54,807	54,807	54,807
P50 PV levelised cost ($/m3)	0.64	0.74	0.57	0.53

Note: There is a slight discrepancy between P50 PV Total Costs at 8% compared with the total capital expenditure and O&M breakdown arising from the simulation convergence process, however this does not affect the outcomes of the analysis.



Options:
F River Recharge with Groundwater
E Aquifer Storage & Recovery
B Lower Maungakotukutuku Dam
D2 Borefield & Treatment

Figure 15-1: Summary of Risk Results (Box and Whisker Plot)[38]

Based on the analysis the ranking of the options on a cost effectiveness basis is as follows (see Table 15-6):

Table 15-6: Economic Analysis Ranking of Options

Rank	Option	Total Cost (P50 PV $M)	Levelised Cost (PV $/m^3)
1	F: River Recharge with Groundwater	28.8	0.53
2	E: Aquifer Storage and Recovery	31.0	0.57
3	B: Lower Maungakotukutuku Dam	35.3	0.64
4	D2: Borefield & Treatment	40.8	0.74

Option F: River Recharge with Groundwater has the lowest total cost with a PV at an 8% discount rate of $28.8 million and therefore is the most cost effective option. This option has the lowest cost for both capital and O&M costs at $16.8 million and $12.1 million respectively. O&M is high relative to total costs at 42% - the highest percentage among all options.

[38] Note: the box shows the range at the 10% and 90% level of probability and the whiskers the maximum and minimum values

When risk is considered, Option F also has the second least volatility (narrower P10-P90 confidence interval) as shown in Figure 15-1. This is reinforced by the coefficient of variation[39] (CV) with Option F CV at 3.5% slightly higher than Option E having the lowest CV at 3.0%.

In addition, Option F remains the most cost effective option at 6% and 4% discount rates.

With slightly overlapping confidence intervals, the P50 of the options were tested as to whether the difference is statistically significant. The statistical test used was the Student's t-test on equality of the means (i.e. P50) for any two options with overlapping confidence intervals at 95% confidence level. The t-test results show that no two P50 values are the same as all t-statistics are lower than the critical value. This implies that the differences in the P50 values are statistically significant.

Based on the quantitative economic analysis, Option F:- River Recharge with Groundwater is clearly preferred having the lowest cost and relatively low risk of all the options.

15.5 Non-Market Values (Qualitative Economic Analysis)

15.5.1 Introduction

The objective of this section of the report is to identify the scope and size of non-market values (i.e. costs and benefits) associated with water supply security and quality. Water supply options are categorised on similarity of impacts; being dams, groundwater and river recharge with groundwater (Option F). This report complements the economic analysis of the market values of the short-listed options for the Kāpiti Water Supply Project.

Non-market values are important and need to be considered alongside market values in decision-making. The Total Economic Value (TEV), both market and non-market, of a natural resource is grounded on the utility of the natural resource. The range of utility derived results in a spectrum of values grouped as active use and passive use values (see Figure 15-2).

Active use values are classified as direct use, indirect use and option value[40]. Direct use values are consumptive and production related (e.g. agriculture, fisheries, water supply), and are mostly captured in market values (i.e. Gross Domestic Product (GDP)).

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[39] Coefficient of variation shows the standard error as a percentage of the mean (P50). A higher number results in a wider confidence interval. The CVs for Options B and D2 are 7.3% and 4.4%, respectively.

[40] Studies cited later in the report have slightly different classification of value. One will classify option value under passive use. Another will classify recreation and cultural value as direct use value.

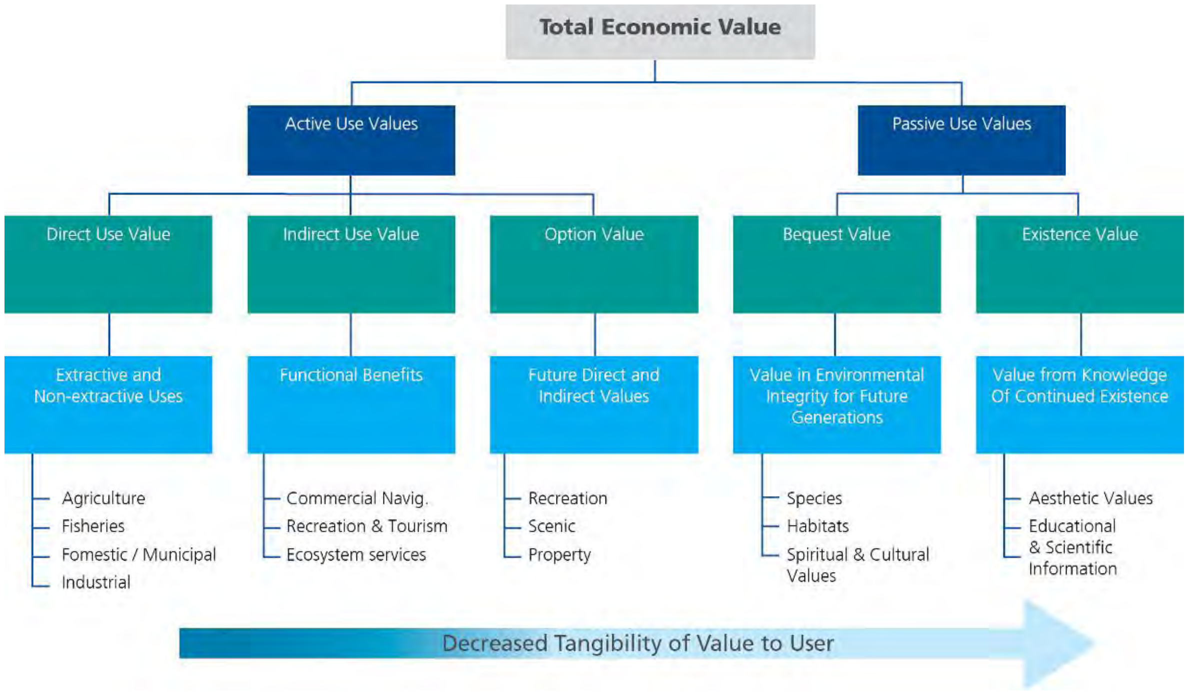

Figure 15-2: Total Economic Value (Source EVRI 2009)

Indirect use values are functional benefits that support or protect direct use (market-based) activities (e.g. recreation, water retention, nutrient recycling).

Option value relates to the benefit of preserving the natural resource for a potential future direct and indirect use (e.g. forest biodiversity as future source of medicines).

Passive use values are classified as bequest value (preservation for future generations) and existence/intrinsic value (e.g. aesthetic, habitat, biodiversity).

It is important to note that the way in which economists categorise these values is to recognise the spectrum of total economic value. Traditionally, only the direct active use values are estimated in cost benefit analysis (CBA) and cost effectiveness analysis (CEA) because there are market prices that can be applied to quantity changes to estimated changes in value.

Most of the values in Figure 15-2 must be valued indirectly through non-market valuation techniques. Attempting to estimate a dollar amount for these values for the Kāpiti Water Project is beyond the scope of this study. Instead the focus is on a qualitative analysis of the main non-market values (costs and benefits) that may be relevant to the project.

15.5.2 Valuing Natural Capital

Natural capital encompasses ecosystems, biodiversity[41] and natural resources. It provides benefits that sustain societies. The foundation of valuing these ecosystem services is scientific information that assesses the impact of biodiversity loss and changes in ecosystem services.

The practical use of economic valuation is assessing incremental change arising from an investment option and not at valuing an entire ecosystem (TEEB, 2009). The purpose of economic

[41] Biological diversity (biodiversity) is the variety of all living things (plants, animals, fungi and microorganisms) and the ecosystems where they live (A strategy for New Zealand's biodiversity, www.biodiversity.govt.nz)

valuation in these decisions is to provide information on the impact of the change and not to value the entire site. For example, in the groundwater river recharge option, economic valuation would estimate the impact on the river's biota and water quality and not attempt to value all the goods and services provided by the river.

The value of ecosystem services is context specific and not uniform universally. This means that economic values are not intrinsic to the ecosystem but linked to the utility and welfare it provides. This utility is influenced by the number of beneficiaries and the socio-economic context. For example, the service 'water regulation' (regulation of hydrological flows such as provisioning of water for agricultural, industrial and transportation use) is an essential component for some locations but only an incidental service in others. As a result, applying values from one primary study site to an investment site (which is the subject of a decision) can only be done if suitable adjustments are made that take into account both the differences in the sites and the populations affected (TEEB, 2009).

Implementation of an investment option does not necessarily result in the loss of ecosystem service(s). Ecosystems have built-in resilience in the face of changing environmental conditions and disturbances. While there is uncertainty on threshold levels, the critical point at which the eco-system is significantly changed, a precautionary approach is recommended (TEEB, 2009).

A change to Gross Domestic Product (GDP) is a typical way to assess how well a nation's being is changing. GDP, which can also be estimated at the regional level (GRP), focuses on market values and does not distinguish between desirable welfare-enhancing activities against undesirable welfare-reducing activities (Costanza et al., 2004). For example, expenditure on prisons adds to GDP, while the benefits of reducing the jail population are not counted.

In order to better reflect over-all well being alternative more holistic measures have been devised. For example, the Genuine Progress Indicator (GPI) measures net human welfare that covers both positive and negative contributors to human welfare. This includes both market and non-market values. For example, non-market services of parents (i.e. unpaid work) caring for children does not increase GDP but if the parent decides to work and pay for child care, GDP increases. GPI attempts to include unpaid services, such as child care.

GPI measures that could be considered for water supply options include:

- Changes in water quality (taste and hardness)
- Loss of wetlands
- Loss of farmland
- Loss of native bush
- Gains from lakes behind dams.

GPI is one method of measuring total well-being. Another measure is Gross National Happiness (GNH), which is used in Bhutan (Adams, 2010). As yet the concepts of GPI or GNH have not found their way into official statistics in New Zealand or any other developed country, but their introduction may not be that far off. For example, Environment Waikato has commissioned research to estimate GPI for the Waikato region. While this study does not go as far as estimating GPI for Kāpiti the methodology described could be used as building blocks in the development of a GPI for the region.

15.5.3 Non-market Values

a. Indigenous Biodiversity

There have been a number of attempts to place dollar values on New Zealand's indigenous biodiversity.

The annual value of land-based indigenous biodiversity in New Zealand as whole ecosystems (i.e. not as value at the margin) was estimated at $46 billion in 1994 (Patterson and Cole, 1999). This was broken down into direct use, indirect use and passive use values. Direct uses, valued at $9 billion per annum, included food, raw materials and timber from land use. Indirect uses accounted for the largest value at $30 billion per annum and included ecosystem services such as climate regulation, erosion control, soil formation, nutrient retention, waste treatment, pollination and biological control. Passive use values, estimated at $7 billion per annum, included option value (option for future use), existence/intrinsic value (preserving biodiversity for its own sake) and bequest value (preserving for future generations).

In 2007, a Greater Wellington survey showed households are willing to pay additional rates per year for biodiversity enhancement (i.e. planting scheme) on private and public land. The average amounts were $174 per household per year for planting schemes on public lands and $166 per household per year on planting schemes on private lands (Kaval, et al., 2007).

Nimmo-Bell (2009) has developed a database of non-market values covering four key sites and 16 attributes including 13 biodiversity values: South Island high country (plants, insects and fish), Beech forest (increased or decreased bird and insect abundance, wasp stings), Coastal marine (shellfish, coastal vegetation, recreational fishing and children's ability to paddle) and a North Island urban lake (charophytes, birds, fish and mussels). The primary purpose of this database is for Biosecurity New Zealand to use it to estimate the economic value of biosecurity response activities affecting indigenous biodiversity. The database will also be useful for other decision making involving changes to indigenous biodiversity by organisations such as DoC and regional councils.

While Maori and other peoples place an intrinsic value on indigenous biodiversity attempting to estimate dollar signs for these can be highly sensitive. For Maori, such values are an integral part of their belief system being based on the principle of guardianship (kaitiakitanga).

b. Ecosystem Services

Ecosystem services can make up a significant component of TEV. Below are two case studies that illustrate this significance.

Case study 1

The direct and indirect use value of ecosystem services from the Manawatu-Wanganui region has been estimated at $6 billion (2006 dollars) by using a rapid assessment methodology (i.e. benefit transfer). Market-based direct use values such as food and raw material production were based on regional GDP figures. Non-market direct use (e.g. recreation, water regulation), and indirect use (e.g. erosion control, nutrient cycling), values were derived from a global meta analysis by Costanza et al. in 1997 thereby making the assumption that the region's ecosystems services are comparable with the rest of the world (van den Belt et al., 2009).

The ecosystem service value for the Manawatu-Wanganui region is still considered conservative as it does not include some direct and indirect use values for some ecosystem types. More important, it does not account for passive values due to lack of primary valuation studies (van den Belt et al., 2009). Such passive values can be significant as is shown in the next case study.

Case study 2

A contingent valuation study of the Whangamarino Wetland in an unpublished Master's thesis quoted by Schuyt and Brander (2004) showed passive use values exceeded use values. As an annual benefit, the passive use (preservation) value of the Whangamarino Wetland was assessed as 2.7 times greater than the use value (recreation, flood control and fishing). The high passive value might have been influenced by the ecological significance of this wetland.

The Whangamarino Wetland presents a case study of the ecosystem services provided by flood control on the Lower Waikato River (DOC, 2007). Its ability to store water during peak flows results in reduced public works on flood gates (estimated at millions of dollars) and less damage to surrounding farmland (avoided flooding of 7,300 hectares estimated at $5.2 million). Other ecosystem services provided by the wetland include:

- Raising of water tables for irrigation during dry periods
- Carbon sequestration (0.5 tonnes per year from peat bogs)
- Gamebird hunting (tens of thousands of gamebirds each year)
- Recreational fishing (eels)
- Attraction for overseas tourism (bird watching)
- Habitat for diverse native wetland birds and other threatened/uncommon wetland birds (hosts 20% of New Zealand's breeding population of native wetland birds).
- Diverse freshwater fish fauna (threatened black mudfish)
- 239 wetland plant species (60% indigenous; a number are rare).

c. Drinking Water Quality

A study has shown that improving drinking water quality beyond mandated minimum standards can provide benefits that exceed the costs. Such benefits need to include non-market values such as health and quality of life (Silverman, 2007). A survey before and after a water treatment upgrade in a city in Ohio, United States, revealed:

- enhanced public satisfaction with a high-profile public interest issue around improved water quality
- potential health benefits to the community through risk reduction in exposure to toxic substances
- while water bills increased, this is more than offset by savings from lower use of bottled water and home water treatment systems.

There is anecdotal evidence of a heightened public satisfaction issue with bore water in Kāpiti. When the existing supplementary bore water is used during low flows in the Waikanae River, there are increased levels of complaints from the community regarding taste, quality and hardness. While no direct survey has been carried out, it can be assumed that the community would be willing to pay to for a more secure and consistent water supply free of taste, quality and hardness issues. Whether the amount would be sufficient to reduce the difference between supply options is unknown. The extent of the willingness to pay is a key question that can be estimated by conducting non-market valuation surveys.

d. Lessons for Kāpiti

It is expected that the aquifer storage, groundwater and river recharge options will be unlikely to have adverse impacts of fish or invertebrate communities in the district. The dam options while having some impact are also not expected to have adverse impacts on fish or invertebrates that cannot be readily mitigated within the dam designs (NIWA 2010).

However a dam will have impacts on native bush by the creation of a lake. The literature indicates that the direct and indirect use value of a lake is potentially greater than the native bush displaced. For the Manawatu-Wanganui region the former is estimated at $18,750 per hectare while the latter is estimated at $1,083 per hectare in 2006 dollars (van den Belt, 2009). The largest contributors (89%) to the lake value are water regulation (regulation of hydrological flows) and water supply (storage and retention of water, which is counted under direct active use). After adjusting for factors such as ecosystem functioning (i.e. artificial lakes do not provide the same functions as natural lakes) and scarcity (less native bush), the magnitude of the difference may still make the lake more valuable than the native bush that is lost. Furthermore, even if public access to the lake is prohibited the passive values of the lake (such as the value of the lake for its own sake) may exceed that of the bush displaced.

While a benefit transfer study is not being undertaken here, one of the key issues would be whether Kāpiti people share the same views of the environment as the global average (sourced from a global meta-analysis of Costanza et al., 1997) as used for the Manawatu-Wanganui region. This would normally be elicited by surveying, however, for the purpose of this study, this is not possible. Therefore, the following issues have been identified from the case studies:

- Dams – loss of native bush and creation of a lake
- Aquifer storage, groundwater and river recharge – minimal ecological impacts and water 'taste'/quality issues.

15.5.4 Conclusions

The water supply options considered appear to have minimal impacts on non-market values in the affected area. While there are non-market costs associated with the options, there are also non-market benefits. These costs and benefits need to be anchored on the ecological assessment of the changes and stakeholder perceptions of these changes, as non-market values are essentially grounded on human well-being.

For the dam options, non-market costs relate to the loss of native bush. However, non-market benefits are created through higher standards of water quality in the context of a high profile public interest issue. The creation of a lake is also a significant non-market benefit. Even adjusting for ecosystem functioning and scarcity factors, the dam option non-market benefits could potentially outweigh the non-market costs.

The main non-market cost for the groundwater options is lower public satisfaction with water 'taste'/quality, but on the other hand its ecological impact is minimal.

The non-market costs for the groundwater river recharge options are expected to be minimal. Non-market benefits relate to higher standards of water quality.

16 Final Evaluation of Options

16.1 Advantages and Disadvantages

A summary of the key advantages and disadvantages of the four short-listed options is presented in Table 16-1; categorised into cost, engineering, water quality, yield/security, environmental impacts, and social impacts/community acceptance.

Table 16-1: Summary of Key Advantages and Disadvantages of Options

Category	Advantages	Disadvantages
Option B: Lower Maungakotukutuku		
Cost	Could provide opportunity for micro-hydro generation to offset some O&M costs	Second most expensive in both capital and PV.
Engineering	Site confirmed as providing suitable foundation for the dam.	
Water Quality	Taste and hardness matches existing river supply	Potential for algal bloom, particularly in shallower areas, could add to management complexity.
Yield/Security	Greater level of certainty compared with groundwater options.	
Environmental Impacts	Creation of lake habitat which will favour trout, giant kokopu and eels. No threatened plant species identified. Adverse environmental effects are considered to be minor, and able to be sufficiently managed.	Displacement of redfin bullies, torrent fish and koaro, as well as river invertebrates. Fish passage for native fish disrupted (can be mitigated). Loss of 5.23 ha of high value ecological forest. Loss of indigenous terrestrial fauna habitat. Potential edge effects to remaining forest (mitigated by planting). Dam site is located within a conservation covenanted area.
Social Impacts/ Community Acceptance	Two main landowners are both generally supportive. Concept of a dam as a water supply solution appears to have general support in the community. Potential recreation opportunities with reservoir.	Some general community concern regarding dam break risk and environmental effects of damming stream.
Option D2: Borefield & Treatment		
Cost	PV can be reduced by staging.	Highest capital cost and PV.
Engineering	Borefield extension and nanofiltration treatment can be staged to meet demand growth.	Uncertainty about additional bores
Water Quality	Improvement on taste and hardness of existing borefield supply.	Taste and hardness greater than existing river supply (but less than existing borefield).
Yield/Security	Increased flexibility from having two	Risks of unknown geology to the

Category	Advantages	Disadvantages
	separate raw water sources.	northeast of the existing borefield for new bores. Requirement for additional water to account for losses through treatment process.
Environmental Impacts	New bores and pipelines can be sited to avoid ecologically significant areas. Limited drawdown effects on the shallow aquifer.	Requires disposal of up to about 3,300 m^3/day of brackish water. Impacts of this uncertain and not investigated.
Social Impacts/ Community Acceptance		General reluctance by many to continue to rely on the borefield for potable water supply due to history of water quality issues. Disruption during construction to urban areas (including parks etc).
Option E: Aquifer Storage and Recovery		
Cost	Second lowest cost in terms of capital and NPV. PV can be reduced by staging.	
Engineering	Borefield extension can be staged to meet demand growth.	Need trial well to demonstrate feasibility. River water may require pH correction prior to reinjection.
Water Quality	Likely improvement on taste and hardness of existing borefield supply.	Taste and hardness greater than existing river supply (but expected to be less than existing borefield supply).
Yield/Security	Some additional flexibility from having additional underground storage. Can be designed to minimise risk of saline intrusion.	Risks around unknown geology to the east of the existing borefield for new injection bores.
Environmental Impacts	Limited drawdown effects on the shallow aquifer, and may be enhanced during injection periods.	
Social Impacts/ Community Acceptance	New infrastructure located within road reserve/ Council-owned land. Overall a minor impact on landowners and minor social impact from construction and ongoing operation.	Reluctance by many to continue to rely on the borefield. May not find favour due to lack of understanding of concept of ASR – need for clear explanation. Disruption during construction to urban areas (including parks etc).
Option F: River Recharge with Groundwater		
Cost	Lowest capital cost and PV. PV can possibly be reduced further via staging review	
Engineering	Borefield extension can be staged to meet demand growth.	
Water Quality	Uses river water, so will match existing	

Category	Advantages	Disadvantages
	water supply taste.	
Yield/Security	Increased flexibility from using two separate raw water sources, albeit only one water source used for drinking purposes.	Risks around unknown geology to the northeast of the existing borefield.
Environmental Impacts	Limited drawdown effect on the shallow aquifer. Very minor adverse in-stream ecological effects. Potentially reduced further by injection of river water into aquifer.	Possible adverse effects from nutrients (mainly phosphorus) in groundwater recharge to river. This needs to be investigated further. Use of injection will possibly reduce this concern further.
Social Impacts/ Community Acceptance	Use of existing infrastructure. No significant concerns expressed regarding this option. If no adverse effects on the Waikanae River are confirmed, this option may find favour in the community.	Disruption during construction to urban areas (including parks etc). Time taken for rehabilitation to occur.

If we consider the advantages and disadvantages summarised in Table 16-1, and compare the dam option against the groundwater options, the following is clear:

- The dam option is more expensive in capital cost than all but one of the groundwater options
- The dam option provides more certainty around yield than the groundwater options
- Only the dam option and River Recharge with Groundwater will match the taste and hardness of the existing river supply
- The environmental effects associated with the dam are greater than those for the groundwater options, but the effects are considered able to be sufficiently managed
- The dam option has general support in the community, but only one of the groundwater options (River Recharge with Groundwater) is likely to have general community acceptance. The other two groundwater options may find it difficult to gain general community acceptance, and for ASR education around the underlying concept of the option is likely to be required.

16.2 Multi-Criteria Analysis

In the Stage 2 report (*Option Selection Report*, dated 4 March 2010) a multi-criteria analysis (MCA) methodology was used to reduce down from 31 options to allow a short-list to be carried forward into Stage 3. The MCA methodology is recognised as a useful tool for decision makers where there are a complex range of variables that have to be considered and balanced. The MCA was built up from extensive community and stakeholder consultation, to arrive at “values”, “criteria”, and how much weight should be assigned to those criteria. Finally, scoring of each criterion against each of the options was undertaken by a multidisciplinary workshop of technical specialists.

To further assist in the decision-making process we have repeated the MCA process on the four short-listed options now being considered, except that a workshop has not been used to assign the scores. The same values and criteria have been used, but the scoring is now able to be better informed by the extensive investigations, concept design and costing work that has been undertaken in Stage 3.

The following pages present the results of the re-analysed MCA on the four short-listed options.

Option B – Lower Maungakotukutuku Dam

Value		Criteria		Rating	Comments
1	Quality of Water Supplied to Consumer	1	Public health	Almost zero risk	
		2	Taste, Odour and Aesthetics	Low risks	Some risk of algal blooms in dam reservoir even though reservoir destratification system will be included.
		3	Hardness	Matches existing river supply	
2	Social	1	Impact during construction	Medium impact	
		2	Impact for ongoing operation	Low impact	
		3	Social impact of catastrophic failure	Medium impact	Dam will be designed and constructed to safely withstand any of the known natural hazards that might affect it.
		4	Other social benefits (e.g. recreation)	Yes	Recreation use possible due to close proximity to existing reserve. Level of access would need to consider public health risks to water source.
3	Cultural	1	In catchment solutions	Water source is in-catchment	
		2	Water conservation	Not supportive	Large volume of stored water may give impression of limitless water being available
		3	Identity	No identified risk of compromising this value	
4	Environmental	1	Impact on in-stream ecology	Medium impact	Effects able to be mitigated.
		2	Impact on vegetation/ terrestrial ecology	Medium impact	Effects able to be mitigated, for example off-seting covenanted land.
		3	Impact on groundwater	Low impact	
		4	Impact on natural and/or urban landscape	Medium impact	Tararua Ranges ecological area.
		5	Impact on future use of land	High impact	Inundated area is currently productive land.
5	Performance	1	Ability to make best use of existing infrastructure	Medium	Not using Waikanae Borefield except in extreme droughts.
		2	Ability to be staged over time	Low	Can be staged but not cost-effective.
		3	Ability to expand	Low	
		4	Security of supply over time	High	Can use existing borefield in extreme droughts.
6	Implementation	1	Difficulty in obtaining resource consents	Medium	
		2	Difficulty in acquiring land and/or access	Low	
		3	Level of uncertainty in water resource and design/technology	Low	
7	Economic	1	Cost to construct	>$20 million	Excluding investigations, fees and Council costs
		2	Operational cost	Of about the same order as current river water supply	Hydro power not accounted for
		3	Impact on opportunity cost of other potential water users	Low impact	

Option D2 – Borefield and Treatment

Value		Criteria		Rating	Comments
1	Quality of Water Supplied to Consumer	1	Public health	Almost zero risk	
		2	Taste, Odour and Aesthetics	Low risks	Salt content will not match existing river source.
		3	Hardness	Less than 100 mg/L	Nanofiltration treatment to reduce hardness.
2	Social	1	Impact during construction	Low impact	Works mostly within road reserves
		2	Impact for ongoing operation	Low impact	Modelling has shown limited effects on shallow aquifer.
		3	Social impact of catastrophic failure	Low impact	
		4	Other social benefits (e.g. recreation)	No	
3	Cultural	1	In catchment solutions	Water source is in-catchment	
		2	Water conservation	Supportive	
		3	Identity	No identified risk of compromising this value	
4	Environmental	1	Impact on in-stream ecology	Medium impact	Effects of brackish water discharge on Mazengarb Drain.
		2	Impact on vegetation/ terrestrial ecology	Low impact	Because modelling has shown limited effects on the shallow aquifer, no adverse effects on wetlands to the north have been assumed.
		3	Impact on groundwater	Medium impact	Potential risk of saline intrusion mitigated by injection
		4	Impact on natural and/or urban landscape	Low impact	
		5	Impact on future use of land	Low impact	
5	Performance	1	Ability to make best use of existing infrastructure	High	
		2	Ability to be staged over time	High	
		3	Ability to expand	High	Not modelled but aquifer is likely to extend north and south.
		4	Security of supply over time	Medium	Need to inject water to aquifer to avoid saline intrusion
6	Implementation	1	Difficulty in obtaining resource consents	Medium	
		2	Difficulty in acquiring land and/or access	Low	
		3	Level of uncertainty in water resource and design/technology	Low	
7	Economic	1	Cost to construct	>$20 million	Excluding investigations, fees and Council costs
		2	Operational cost	Higher than current river water supply	
		3	Impact on opportunity cost of other potential water users	Medium impact	Unlikely to be other potential water users.

Option E – Aquifer Storage & Recovery

Value		Criteria		Rating	Comments
1	Quality of Water Supplied to Consumer	1	Public health	Almost zero risk	
		2	Taste, Odour and Aesthetics	Low risks	Low rating needs to be confirmed by trial reinjection well to determine the extent of mixing and whether quality (especially hardness) of river water changes in aquifer.
		3	Hardness	Less than 100 mg/L	Assumes mixing of river and groundwater in aquifer.
2	Social	1	Impact during construction	Low impact	
		2	Impact for ongoing operation	Low impact	
		3	Social impact of catastrophic failure	Low impact	
		4	Other social benefits (e.g. recreation)	No	
3	Cultural	1	In catchment solutions	Water source is in-catchment	
		2	Water conservation	Supportive	
		3	Identity	No identified risk of compromising this value	
4	Environmental	1	Impact on in-stream ecology	Low impact	
		2	Impact on vegetation/ terrestrial ecology	Low impact	Wetlands may be enhanced by higher aquifer levels during reinjection periods.
		3	Impact on groundwater	Medium impact	Further work may show this rating could be reduced to Low.
		4	Impact on natural and/or urban landscape	Low impact	
		5	Impact on future use of land	Low impact	
5	Performance	1	Ability to make best use of existing infrastructure	High	
		2	Ability to be staged over time	High	
		3	Ability to expand	High	Not modelled but aquifer is likely to extend north and south.
		4	Security of supply over time	High	Climate change impacts not modelled, but ability to store winter/spring river flows gives this option additional security.
6	Implementation	1	Difficulty in obtaining resource consents	Medium	Taking water from the Waikanae River and discharging water to ground
		2	Difficulty in acquiring land and/or access	Low	
		3	Level of uncertainty in water resource and design/technology	High	Trial injection well required to test feasibility.
7	Economic	1	Cost to construct	>$20 million	Excluding investigations, fees and Council costs
		2	Operational cost	Of about the same order as current river water supply	
		3	Impact on opportunity cost of other potential water users	Low impact	Because taking water at high flows and storing in aquifer.

Option F – River Recharge with Groundwater

Value		Criteria		Rating	Comments
1	Quality of Water Supplied to Consumer	1	Public health	Almost zero risk	
		2	Taste, Odour and Aesthetics	Low risks	Low risk of taste & odour from algae blooms in river during extreme low flows (can be further mitigated by future addition of ozone).
		3	Hardness	Matches existing river supply	
2	Social	1	Impact during construction	Low impact	
		2	Impact for ongoing operation	Low impact	
		3	Social impact of catastrophic failure	Low impact	
		4	Other social benefits (e.g. recreation)	No	
3	Cultural	1	In catchment solutions	Water source is in-catchment	
		2	Water conservation	Supportive	
		3	Identity	No identified risk of compromising this value	
4	Environmental	1	Impact on in-stream ecology	Medium impact	Further investigation of effects of nutrients required. Possibly a “Low” rating is more appropriate.
		2	Impact on vegetation/ terrestrial ecology	Low impact	
		3	Impact on groundwater	Medium impact	Potential risk of saline intrusion mitigated by injection
		4	Impact on natural and/or urban landscape	Low impact	
		5	Impact on future use of land	Low impact	
5	Performance	1	Ability to make best use of existing infrastructure	High	
		2	Ability to be staged over time	High	
		3	Ability to expand	High	Not modelled but aquifer is likely to extend north and south.
		4	Security of supply over time	Medium	Need to inject water to avoid saline intrusion
6	Implementation	1	Difficulty in obtaining resource consents	Medium	Consents needed for taking groundwater, discharging to river, and taking river water.
		2	Difficulty in acquiring land and/or access	Low	
		3	Level of uncertainty in water resource and design/technology	Low	
7	Economic	1	Cost to construct	$10-20 million	Excluding investigations, fees and Council costs
		2	Operational cost	Of about the same order as current river water supply	
		3	Impact on opportunity cost of other potential water users	Medium impact	Unlikely to be other potential water users.

When the final weightings used in the Option Selection Report are applied to the scoring of the four shortlisted options as tabulated above, the MCA model ranks the options as follows (with the total score shown in brackets):

- First – F: River Recharge with Groundwater (7.28)
- Second – E: Aquifer Storage & Recovery (6.98)
- Third – B: Lower Maungakotukutuku Dam (6.46)
- Fourth – D2: Borefield & Treatment (6.09).

The ranking of first for the River Recharge with Groundwater option is understandable considering the weight given to water quality (25%), and economic (15%) as it is a clear advantages on these values.

The ranking of second for ASR reflects its strong environmental and performance scoring compared with the other options, particularly its advantages in relation to reducing the risks of saline intrusion.

The Lower Maungakotukutuku Dam's ranking of third, when compared with the fourth ranked Borefield & Treatment option, mainly reflects:

- lower hardness
- lower operational costs.

It should be noted that the ranking scores derived from the MCA calculations are used in this project to inform the decision-making process, rather than the highest score automatically indicating the most preferred option. A range of factors must be considered along-side the MCA results, including community and stakeholder feedback, Council policy and budget, and the relative pros and cons of each option. This is particularly the case when MCA scores are close between the options, as is this case.

16.3 Composites

In section 13.3 the following composite options were shortlisted:

- G2: River Recharge with Groundwater & Blending of Groundwater
- G3: ASR and River Recharge.

Both of these shortlisted composites involve variations on the groundwater options. Essentially G2 could assist in the consenting of Option F: River Recharge with Groundwater, and is a concept that should be carried forward if Option F is selected as the preferred solution.

G3 is a variation on ASR that overcomes potential issues with the quality of the water that is recovered from the aquifer, and again is a concept that should be carried forward if Option E is selected as the preferred solution.

16.4 Discussion and Preferred Options

There are two characteristics of ASR that were important in its genesis and in its being brought forward into Stage 3. Firstly were the early concerns about the sustainability of the Waimea aquifer. Although the results of the pumping tests and modelling have shown the aquifer is high yielding, modelling of sustained abstraction at 32,000 m^3/day has raised concerns about the risks of saline intrusion and the design of the borefield has been modified to allow for injection.

The second characteristic of ASR was the idea of being able to recover softer river water from the aquifer and overcome the need for expensive treatment for hardness. While a trial injection well may well confirm that this is feasible, the composite option G3: ASR and River Recharge, provides a way round this issue without the associated risks.

We therefore consider that Option F: River Recharge with Groundwater, but with injection wells (similar to composite G3) represents the optimal solution for groundwater.

Our analysis of the advantages/disadvantages, the MCA, and the discussion above, draws us to the conclusion that the two preferred options (in order) are:

- F: River Recharge with Groundwater (with the injection well concept of ASR and used for river recharge rather than water supply)
- B: Lower Maungakotukutuku Dam.

17 Ranked Options and Recommendations

17.1 Ranked Options

Our assessment of the ranking of the four short-listed options, including consideration of key issues of yield and security of supply, water quality and their capital and PV costs, as well as the full range of advantages and disadvantages presented earlier in this report, is presented below. It is noted that in respect of the groundwater options, staging is a key benefit of these options compared with the dam option. Further improvement to the PV is expected in the event a groundwater option is chosen.

Table 17-1: Ranked Options

Rank	Option
1	River Recharge with Groundwater (RRwGW)
2	Lower Maungakotukutuku Dam
3	Aquifer Storage & Recovery (ASR)
4	Borefield and Treatment

17.2 Recommendations – Preferred Solution

Given the extensive process to evaluate options undertaken to date, the recommendations in this report build on each other. While there are four in-catchment options under consideration, the report also provides a comparable cost estimate for two Ōtaki River options. It is therefore important that our recommendations reflect the extensive process.

17.2.1 In-Catchment Solutions

The first key conclusion is that in-catchment solutions are available to resolve Council's long term water supply requirements for the WPR area. However, while all four options provide for the yield, security and water quality specified in the design requirements, they are not all equal. For instance, there is a significant spread of overall cost, and the risk profiles of each option also differ markedly.

On the basis of the ranked options list, two options are identified as being less optimal. That is, Aquifer Storage and Recovery and Borefield and Treatment. Each of these is considered below:

Aquifer Storage and Recovery is without doubt an innovative solution. It essentially involves storing water in the aquifer in winter and spring for use during summer. The key concerns are that this is not a technology that has been used in New Zealand before to the best of our knowledge, although it is relatively common internationally (particularly in Australia and USA). There are a number of risks associated with being a NZ first and early adopters of technology. One key uncertainty is the as yet unproven ability to recover soft river water from the aquifer for drinking. This option may also encounter perception problems with the community in terms of drinking bore water, although that is not a primary concern that has influenced our recommendation. In addition, it is more expensive than the River Recharge option.

However, while ASR is not recommended for further consideration, the benefits of this approach have been included in part in the refined concept for River Recharge with Groundwater. The River Recharge option now requires the injection of soft river water into the aquifer to manage saline intrusion risk. While this refined approach does involve underground storage and recovery of water, the key differences between this and ASR are that the need to fully recover the river water for drinking disappears – and with it, a significant number of risks and uncertainties. Of course, in the event river water is recovered, because it is being used to recharge the minimum flow of the river, it will further lessen the already minor ecological effects on the Waikanae River downstream from the current intake. Overall, the principle of river water injection to the aquifer can be applied to River Recharge option to get a better end result.

Borefield and Treatment is a relatively simple option to dismiss. At over $37M, it is simply too expensive. Furthermore, it is the one option that involves continuing to drink bore water, albeit that there would be enhanced treatment. Based on our extensive community consultation carried out over the past nine months, this option may have difficulty gaining the support of the public.

Recommendation 1: Eliminate two options

That Council eliminate the Aquifer Storage and Recovery and Borefield and Treatment options from further consideration due to:

- **In the case of ASR, risk and uncertainty in relation to the ability to recover sufficient river water from the aquifer for drinking and the relative untested nature of the approach in New Zealand**
- **In the case of the Borefield and Treatment option, cost that is over Council's allocated budget.**

17.2.2 Preferred Solution

This leaves two potential options:

- Lower Maungakotukutuku
- River Recharge with Groundwater (modified to include injection)

In developing our final recommendation on the preferred solution, we have considered key issues such as:

- Engineering and design issues
- Water quality
- Yield and security
- Environmental impacts
- Social impacts and likely community acceptance
- Risk
- Cost

Overall, this analysis leads us to conclude that River Recharge with Groundwater provides the most sustainable, consentable, and cost effective solution. This option is preferred due to:

- This option being the lowest cost option;
- Providing the greatest benefit in terms of staging and future flexibility; and
- Has the least environmental impacts and best mix of benefits of all the shortlisted options; and
- Will provide a water quality to consumers that they are already satisfied with (that is, soft Waikanae River water).

Before this option is recommended, it is important to note the next steps that are seen as being critical to this recommendation. The next steps include:

- Preparing an Assessment of Environmental Effects / Resource Consents, and liaising with Greater Wellington Regional Council to discuss a range of issues in advance of any eventual application by KCDC.
- Stakeholder consultation
- Implementing a specific monitoring program in the short term to gather further data on the interface between the freshwater aquifers and salt water to enable better management of saline intrusion risks. This will include drilling (or using existing) a series of deep and shallow wells near the coast to monitor conductivity (saline intrusion);
- Further pumping tests of existing wells
- Limited further 3D groundwater modelling to confirm (or further refine) the design and to support AEE
- Drill and test new wells required as part of the extension of the borefield to confirm feasibility and yield
- Work out staging more definitively to optimise the benefits of managing cashflow over the 50 year period.

Recommendation 2: Preferred Solution

That Council proceed with River Recharge with Groundwater as the preferred solution and undertake the following steps to confirm the feasibility of this option:

- **Establish a monitoring program to establish the existing salt and freshwater boundary in the aquifer, and to monitor for signs of saline intrusion**
- **Drill test wells for the three new bores that need to be added to the overall scheme**
- **Further pumping tests to existing wells**
- **Optimise the approach to staging**
- **Complete the investigations and stakeholder consultation.**

It is noted that not all of the above are likely to be required in order to complete the AEE, but should be required to satisfy Council before proceeding with construction of this option.

During these further investigations, there remains a possibility or risk that further knowledge gained from testing and modeling outlined above causes the River Recharge option to become unfeasible or unconsentable. While this is considered unlikely, if investigations fail to confirm feasibility, then Council should proceed with the Lower Maungakotukutuku dam option as the next preferred solution.

17.2.3 Future Proofing

During the course of preparing our recommendations, it became clear that Council has a further opportunity to consider water supply planning over a much longer-term period than this project has to date been examining. That is, while the recommendation to proceed with River Recharge will provide up to 50 years of supply, the future WPR community will need to identify additional supply for the 50 years beyond that.

Given that investigations carried out over the course of this project into all options have been extensive, and the two most cost-effective solutions have been identified, we consider it unlikely the relative merits of other options will change in future (without significant changes in circumstances e.g. changes to minimum flow regimes, technology, etc).

It is highly likely that a future Council will be faced with an equally challenging task of identifying and securing access to a new water source for the WPR area (or indeed the wider community as it exists at that time) for that 50-100 year period. By that time, unless options for providing water in 50-100 years time are protected now, they would have been lost or foreclosed. Given that the two best and most cost effective options have been identified through this extensive process, if the next preferred option – being the Lower Maungakotukutuku dam – is not protected in some form, inevitably any other future WPR supply option will be more difficult and expensive. Therefore, it is our recommendation that Council consider the merits of future-proofing the WPR water supply for 50-100 years. The estimated short term cost is between $1.3M and $2M. However, this figure would need to be confirmed through negotiations with landowners and other stakeholders. Specifically, there would be a series of short term costs associated with securing the site, and removal of the covenant. Then, longer term costs associated with construction of the dam would be incurred well into the future – in approxaimtely 50 years time if design assumptions are correct.

Recommendation 3: Future-Proofing WPR Water Supply

That Council future-proof the WPR water supply for the long term (e.g. 50-100 years) by:

- **Securing an option to buy land in the short term for the Lower Maungakotukutuku Dam site**
- **Resolving the covenant on the site (i.e. through mitigation and discussion with DoC)**
- **If successful with above, exercise option to buy and purchase land ($1.3-2M)**
- **Signal the long-term intention to develop a dam on the site (i.e. in the District Plan).**

17.2.4 Ōtaki River

Given that the preferred solution and also the future-proofing are lower cost than either of the Ōtaki River supply options, combined with the possible inability of the Ōtaki to supply the yield required, it is clear that there would be an unwarranted cost premium for using Ōtaki water. Furthermore, the option of sourcing water for the WPR area from the Ōtaki River remains unpopular with many in the Ōtaki community, and would likely be difficult to consent.

Recommendation 4: Ōtaki

That Council reject all options to supply WPR from the Ōtaki River source, due to:

- **Base capital costs for the two favoured Ōtaki River options being higher than for other acceptable in-catchment solutions**
- **Concerns regarding the ability to secure the required volume of water under the minimum flow regime**
- **Community and tangata whenua opposition to abstracting Ōtaki River water for the WPR supply.**

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