HARRISON GRIERSON

ecoEng LIMITED

Golder Associates

AKAROA WASTEWATER TREATMENT AND DISPOSAL

WASTEWATER OPTIONS & RISK ANALYSIS REPORT

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EXECUTIVE SUMMARY

Christchurch City Council (CCC) commissioned Harrison Grierson and sub-consultants Golder Associates and ecoEng to undertake an issues and risks analysis for harbour discharge and land irrigation options for Akaroa and Takamatua. Akaroa is located 75km southeast of Christchurch and is a popular holiday destination in the region. Akaroa Harbour hosts a number of recreational activities including water skiing, swimming and boating etc.

The existing Akaroa wastewater treatment plant (Akaroa WwTP) is located south of the township at Red House Bay, and consists of trickling filtration and UV disinfection. The treated effluent is discharged into the harbour via a 100m open-ended outfall pipe.

The existing wastewater treatment plant resource consent requires that the Christchurch City Council identifies a preferred option for the long term management of wastewater at Akaroa. In addition, Iwi have for a long time expressed concerns over the existing treatment plant site, which has significant historical and cultural importance. Two relocation options, Akaroa North and Akaroa South were previously identified (MWH, Oct 2008). The current study (this report) evaluated the issues and risks associated with building a new treatment plant, harbour outfall discharge and irrigation fields at these potential sites.

Outline of Study

The dispersion modelling study by Golder Associates (Appendix Two) examined the issues, effects and risks associated with harbour discharge. It was found that near-shore outfalls are less suitable because of near shore effects, lower dispersion and poorer community acceptance. A mid-harbour outfall at the existing site has the best attributes in terms of lowest risks to the receiving environment and economic utility of the harbour.

The irrigation assessment by ecoEng (Appendix Three) examined the issues, effects and risks associated with effluent irrigation at the new sites, Akaroa North and Akaroa South. Two irrigation options were considered, "All Dry Weather Flow (DWF) to Irrigation" and "Hybrid Disposal". "All Dry Weather Flow to Irrigation" is based on the irrigation of treated dry weather flow to land while treated wet weather flow is stored and may bypass to a harbour discharge when the storage lagoon becomes full. "Hybrid Disposal" is based on irrigation of dry weather flow to land during the summer months (October to March) only and discharge to the harbour during the winter months and wet weather events. The scenario of "All Flow to Irrigation" was also considered but was found to be unfeasible and impractical because of very large irrigation area required.

The conclusion of the irrigation assessment is that Akaroa South has sufficient irrigable area for All Dry Weather Flow irrigation and for Hybrid Disposal if areas of steeper slope and higher elevation are also used. Akaroa North is not feasible due to lack of available and suitable areas.

Therefore, a total of six wastewater options were further evaluated:

1. Treatment Plant Upgrade at Existing Site with Mid-Harbour Outfall
2. Treatment Plant Upgrade at Existing Site with All Year Round Irrigation at South Akaroa (Dry Weather Flow only)
3. Treatment Plant Upgrade at Existing Site with Hybrid Irrigation Disposal at South Akaroa
4. Relocate the Treatment Plant to Akaroa South with Mid-Harbour Outfall Disposal
5. Relocate the Treatment Plant and establish All Year Round Irrigation at Akaroa South (Dry Weather Flow only)
6. Relocate to the Treatment Plant to Akaroa South with Hybrid Disposal (Irrigation in Summer and Mid-Harbour Disposal in Winter and Wet Weather)

The upgrade requirements, issues and risks of conveyance, wastewater treatment plant and effluent discharge/irrigation for the above options were assessed.

Options Comparison

Table A1: Akaroa Wastewater Options –Cost Estimate Summary

	Remain at Existing Site			Relocate to Akaroa South		
	Harbour Outfall	**All DWF Irrigation**	**Hybrid Disposal**	**Harbour Outfall**	**All DWF Irrigation**	**Hybrid Disposal**
CapEx ($M)	11.9	23.2	21.0	23.8	29.1	27.8
OpEx ($/yr)	347,000	532,200	467,500	404,500	587,600	536,700
NPV ($M)	**18.7**	**34.1**	**30.5**	**32.0**	**41.2**	**38.8**

Notes*: Refer to Section 6 and 7.1 for details and assumptions of these cost estimates.*

Upgrading the existing treatment plant with new mid-harbour outfall is considered as the "Baseline option" as it represents the option with the minimum upgrade requirement. This option has the lowest capital and operating costs. However, this option is likely to be a subject of serious cultural and social concern due to the site location and the community's perception to harbour discharge.

Relocating the treatment plant would incur additional cost between $12 to $20M. Both the "All DWF to irrigation" options and hybrid disposal options are possible in Akaroa South but with a higher cost as more new infrastructure is required.

A risk assessment was performed to assessed the risks and issues associated with the options. Table A2 below presents a summary of the risk analysis, and the full details on the analysis is appended in Appendix Six.

Table A2: Akaroa Wastewater Options Study – Risk Evaluation Summary Table

		Remain at Existing Site			Relocate to Akaroa South		
	Risks	***Harbour Outfall***	***All DWF Irrigation***	***Hybrid Disposal***	***Harbour Outfall***	***All DWF Irrigation***	***Hybrid Disposal***
Social	Visual Impact	Low	Medium	Medium	Medium	Medium	Medium
	Odour Impact	Low	Low	Low	Low	Low	Low
	Noise Impact	Low	Low	Low	Low	Low	Low
	Community non-acceptance towards site location	High	High	High	Medium	Medium	Medium
	Community non-acceptance towards effluent disposal	High	Medium	Medium	High	Medium	Medium
Cultural	Effect on Mauri	High	Low	Medium	High	Low	Low
	Cultural non-acceptance towards site location	Very High	Very High	Very High	Medium	Medium	Medium
	Cultural non-acceptance towards effluent disposal	Very High	Very High	High	Very High	High	High
Enviro	Adverse Effects on Harbour	Medium	Low	Low	Medium	Low	Low
	Adverse Effects on Recreation Water Users	Medium	Low	Low	Low	Low	Low
Feasibility	Consenting Process	High	High	High	High	High	High
	Land Availability	Low	High	High	Medium	High	High
	Restriction on Irrigation due to stability/ watertable	Low	High	Medium	Low	High	Medium
	Option Not Affordable	Medium	High	High	High	High	High

Conclusions

Upgrading the existing treatment plant and replacing the outfall pipe with a mid-harbour outfall is considered to be the "baseline" option in this report. This option is the most economic in terms of capital works and operating costs. However, the social and cultural factors such as historical significance of the site which the treatment plant is located, acceptability of harbour discharge and cultural issues need to be taken into consideration.

Relocating the treatment plant to Akaroa South and adopting a land-based effluent treatment and disposal scheme ("All DWF to irrigation" or hybrid disposal) is likely to be more culturally acceptable. Nevertheless, the costs for these two options are significantly higher and the availability of effluent irrigation area is subjected to successful negotiation between the Christchurch City Council and the respective landowners.

Further Studies

The following further studies are recommended:

- Detailed geotechnical investigation will be required for consenting purposes. This will include detailed soils characterisation and stability analysis.
- Further assessment to evaluate the optimum land use management options of irrigable areas.
- More detailed nutrient budgeting and assessment of landuse options for the preferred irrigable areas.
- Hydrogeological modelling – This examines the irrigation water flow path in the soil and the fate and potential effects on the waterbody. This is expected to be required as part of consenting requirement.
- Landowner consultation.
- Preliminary engineering – Once the Christchurch City Council and the Akaroa Wastewater Working Party select the preferred option, preliminary engineering on the conveyance, treatment plant, outfall pipe and irrigation field are to be undertaken. This will also include flow monitoring and geotechnical investigation.

GLOSSARY OF TERMS

Aerobic Tank / Zone / Cell — A tank that is mechanically aerated and is the 'zone' of the treatment plant in which most biological oxidation occurs.

Alkalinity — A measurement of the ability of the wastewater to buffer acid addition.

Ammonia — Reduced nitrogen formed by the hydrolysis of naturally occurring urea and organic nitrogen in the wastewater.

Anaerobic Tank / Zone / Cell — Describing the condition where no molecular oxygen (O_2) and nitrate (NO_2^-) is present .

Anoxic Tank / Zone / Cell — Describing the condition where no molecular oxygen (O_2) is present but inorganic oxygen is available in the form of nitrate (NO_3^-).

Annual Average Flow (AAF) — Annual average flow refers to the average incoming wastewater flow. This includes measurements of both dry and wet weather period which inflow and infiltration enters to the treatment plant.

Average Dry Weather Flow (ADWF) — Average dry weather flow refers to the average incoming wastewater flow under dry period (i.e. no or negligible inflow and infiltration)

This is often derived from multiplying the population figures by the flow per capita generation rate or by actual wastewater flow measurements.

Biochemical Oxygen Demand (BOD) — A measurement of the amount of oxygen required to break down organic matter in wastewater. The amount of oxygen required to achieve this is proportional to the amount of biodegradable material present. Therefore BOD is also a measurement of the amount of organic matter in the wastewater.

Biochemical Oxygen Demand is sometimes expressed as BOD_5 - the suffix 5 referring to the five-day incubation period adopted in the standard test procedure for determining Biochemical Oxygen Demand of wastewater.

The concentration of BOD is measured in gm^{-3} or the numerically equal mg/L.

Chemical Oxygen Demand (COD) — A measurement of the amount of oxygen required to chemically oxidise organic matter in wastewater using dichromate in an acid solution. The amount of oxygen required to achieve this is proportional to the amount of biodegradable material present and is generally a more consistent (repeatable) and higher value than BOD measurements. Therefore COD is also a measurement of the amount of organic matter in the wastewater.

Clarifier — This unit separates the treated effluent from the mixed liquor via gravity sedimentation. The sludge settles inside the clarifier and is returned to reactor as RAS (returned activated sludge).

Coliforms Types of bacteria used as indicators of the presence of pathogens (harmful bacteria), usually in water in this context. Bacteria may be of human or animal origin.

Denitrification The biological process where nitrate – nitrogen (NO3-) is converted to atmospheric nitrogen (N2) under anoxic conditions in the presence of organic carbon.

Dissolved Inorganic Nitrogen (DIN) This comprise ammoniacal nitrogen, nitrate and nitrite nitrogen.

Dissolved Reactive Phosphorus (DRP) This is a measurement of soluble species of phosphorus in wastewater/effluent.

Endogenous Respiration Oxygen requirement for organism maintenance.

Influent Raw wastewater.

Maximum Daily Flow (MDF) Maximum daily flow refers to the maximum daily incoming wastewater flow. The figures used in this report were obtained from the MWH 2007 feasibility report.

Mechanical Aerator Machine submerged in the Mixed Liquor of the Aeration Tank. Entrains oxygen and imparts a mixing motion to the contents of the basin.

Micro-organism Refers broadly to bacteria and protozoa within the mixed liquor.

Mixed Liquor The contents of the treatment plant reactor tanks. Comprises wastewater and biomass.

Mixed Liquor Suspended Solids (MLSS) The mixture of degraded, partly degraded and non-degradable solids together with a mass of biological organisms in suspension within the Aeration Basin. The concentration of MLSS within Mixed Liquor is measured as gm-3 or the numerically equal mg/L.

Nitrification Autotrophic process in which ammonia (Amm-N) is converted to nitrate (NO3--N).

Nutrients Nitrogen and phosphorus present in wastewater in one form or another, such as Total Kjeldahl Nitrogen (TKN), Ammoniacal Nitrogen (NH4N), Nitrate-Nitrogen (NO3-N), Dissolved Reactive Phosphorus (DRP) and Total Phosphorus (TP).

Oxidation Process in which organic and inorganic matter is broken down into smaller constituents and ultimately to carbon dioxide, cell matter or nitrate.

Peak Wet Weather Flow (PWWF) Peak Wet Weather Flow refers to the maximum value of instantaneous wastewater flow. This is often derived from multiplying the average dry weather flow (ADWF) by a peaking factor as observed from historical data.

Sludge — The mix of influent solids and alive and dead biomass that has been produced in the treatment reactors. The term sludge is especially used to describe the MLSS that has been pumped from the biological reactors and is considered a waste product to be process and disposed of.

Sludge age — Also known as sludge retention time (SRT) or mean cell residence time (MCRT). SRT is defined as the total quantity of biomass in the system divided by the amount of sludge wasted per day.

Total Suspended Solids (TSS) — The solid material suspended in the wastewater. This material is maintained in suspension by water movement (turbulence) and/or electrical charge on particles. Therefore when the wastewater is allowed to remain quiescent, some of the suspended solids will settle (settleable matter) while some will remain suspended (causing turbidity).

Total Solids (TS) — Suspended solids plus dissolved solids. The concentration of SS and TS is measured in gm-3 or the numerically equal mg/L.

Treated Effluent — Treated wastewater exiting the wastewater treatment plant.

Waste Activated Sludge (WAS) — Activated sludge that is wasted from the system to maintain a relatively constant concentration.

Units

g/c/d	Pollutant per capita generation rate, gram per capita per day
g/m^3	Concentration unit, gram per cubic metre
kg/d	Mass flow unit, Kilogram per day
L/s	Flow unit, litre per second
L/c/d	Flow per capita generation rate, litre per capita per day
MLD	Flow unit, mega litre per day
mg/L	Concentration unit, milligram per litre

1.0 INTRODUCTION

Christchurch City Council (CCC) commissioned Harrison Grierson in conjunction with ecoEng Ltd and Golder Associates Ltd to undertake a wastewater options study and risk analysis for Akaroa and Takamatua townships.

Akaroa and Takamatua are located 75km southeast of Christchurch and are a popular holiday destination in the region. Given the significance of the natural environment in the area, CCC is undertaking a long term wastewater servicing planning in the area.

An Akaroa Wastewater Working Party (WP), involving key stakeholder groups within the harbour area, was established to recommend to the Christchurch City Council a preferred option for long term wastewater disposal at Akaroa.

Previous investigations (MWH, Oct 2008) examined a number of treatment plant relocation options and shortlisted three sites, 1) the existing site, 2) an Akaroa North site and 3) an Akaroa South site. This report is a follow-on study examining the issues, risks and costs associated with the different options.

Along with land irrigation, the option of harbour discharge has been included in this study. Hence, in addition to the irrigation field studies, outfall dispersion modelling was also undertaken to establish the final effluent quality requirement.

Based on the findings of the irrigation study and outfall dispersion modelling, a number of wastewater options are proposed in this report. A detailed comparison of issues and risks associated with the options has been made.

1.1 Methodology and Report Structure

Section 2 provides a description of the three sites.

Section 3 presents a discussion of existing wastewater infrastructure and the future flows and loads from Akaroa and Takamatua.

A summary of the outfall dispersion modelling and risk assessment on the harbour discharge options (Golder, Oct 2009) is presented in **Section 4**. The dispersion modelling provides a qualitative assessment of the risks and issues associated with discharge into the harbour as well as a robust review of the environmental, social and cultural impacts of the various harbour discharge regimes. From this assessment, a number of outfall options or discharge regimes were shortlisted for further consideration in this study.

A summary of the irrigation area assessment based on a combination of field work and desktop study (ecoEng, Jan 2010) is presented in **Section 5**. This study evaluated the availability and suitability of potential irrigation sites, and examined issues and risks associated with a range of irrigation options. From this assessment, a number of irrigation options were shortlisted for further consideration in this study.

As a result of the above assessments, suitable effluent quality was identified for harbour discharge and land irrigation options. Accordingly, suitable conveyance and treatment plant upgrades were conceptualised. **Section 6** presents a discussion of the wastewater options (conveyance, treatment and effluent discharge/ irrigation) considered in this study.

Section 7 compares the risks, issues and costs associated with all the options.

Section 8 presents the conclusion and recommendations.

2.0 RELOCATION OF WASTEWATER TREATMENT PLANT

It is understood that the site on which the treatment plant is located, has significant historical, cultural and spiritual significance to iwi. As a result, options for relocating the treatment plant were studied in the previous investigation. Two potential sites were identified and shortlisted from the previous study (MWH, Oct 2008).

This section presents the options considered in this study for location of treatment plant and effluent disposal alternatives.

2.1 Treatment Plant

The existing Akaroa wastewater treatment plant is located at Red House Bay, which is approximately 2km south of the township. Figure 2.1 below shows the approximate location of the existing treatment plant and the proposed sites (Akaroa North and Akaroa South)

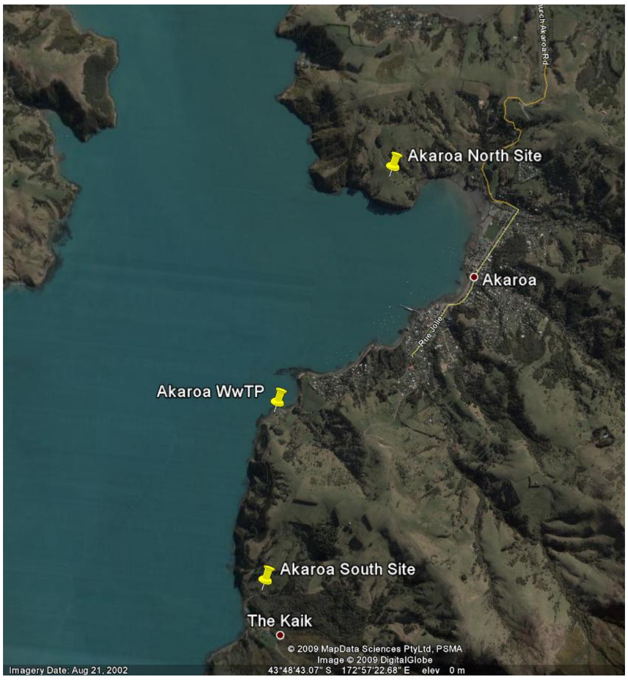


Figure 2.1: Location of potential sites for wastewater treatment in Akaroa (source of picture: Google Earth).

Two alternative sites have been assessed in this report from a perspective of land irrigation and harbour discharge of treated effluent.

The Akaroa North site is approximately 1.5km northwest of the township with an elevation of approximately 120m.

The Akaroa South site is approximately 4km south of the township with an elevation ranging from 100 to 340m.

2.2 Treated Effluent Disposal

The following disposal options have been investigated:

1. Harbour Discharge;
2. Land Irrigation; and
3. Hybrid consisting of dry weather flow to land and wet weather to harbour.

3.0 BASIS OF STUDY

This section presents a discussion of the existing wastewater treatment plant and disposal assets and future wastewater flow and loads.

3.1 Existing Wastewater Conveyance and Treatment

Currently, the wastewater conveyance network in Akaroa consists of three pump stations (Recreation Reserve, Fire Station and the Glen). The Glen pump station is the terminal pump station which conveys all wastewater to the existing Akaroa wastewater treatment plant (Akaroa WwTP), at Red House Bay.

Untreated wastewater enters the inlet screen before being split between two Imhoff tanks. The Imhoff tanks is a primary treatment process in which suspended solids are settled while the settled wastewater flows into a trickling filter for further treatment.

Settled wastewater combines with trickling filter effluent recycle flow, is then dispersed on the rock media in the trickling filter. Secondary biological treatment is achieved by the biofilm attached to the rock media. The filtered effluent then flows into a secondary clarifier, where organic solids (humus) are settled.

The settled sludge from the secondary clarifier is pumped to the Imhoff tank for co-settling with primary solids and digestion. The waste sludge is removed offsite for further processing and disposal.

Clarified effluent flows into the Ultraviolet (UV) channel for disinfection prior to gravity discharge through a 100m long outfall. The effluent is only pumped when there is high flow and/or high water level in the harbour.

3.2 Existing Effluent Discharge

The current WWTP discharges treated wastewater via a single port outfall that is approximately 100 m from the shoreline in about 5.9 m of water. Red House Bay is relatively shallow within 50-80 m of the shoreline, and then rapidly deepens within increasing distance from the shore. Red House Bay is north-west facing, and the edge of the bay is defined by rocky outcrops that are visible at low tide. The northern rocky outcrop is commonly known as Green Point.

Due to the relative proximity of the current outfall to the shoreline, and the localised water current circulation present in the bay, dispersion and dilutions in the order of 50x are predicted (KML, 2005). The location of the outfall results in plume impingement on the shoreline of Red House Bay (MWH, 2005).

Based on NZWERF (2002) guidelines, an harbour outfall exhibiting generally less than 50 fold dilution at 100m is indicative of poor dilution. This is characterised by a conspicuous and persistent plume in the receiving environment. A dilution of between 50-250 fold dilution at 100m is indicative of moderated dilution, while excellent dilution occurs from an outfall exhibiting in excess of 250 fold dilution.

3.3 Future Wastewater Flow and Loads

Harrison Grierson in conjunction with Christchurch City Council (CCC), have developed the design basis for this study. Table 3.3 presents the design basis for this project.

Table 3.3: Akaroa Wastewater Options Risk Analysis – Design Basis Summary

Parameters	Values	
Design Horizon	2041	
Off-Peak Period ADWF (m^3/day)	382	
Peak Summer Period ADWF (m^3/day)	1625	
Maximum Daily Flow (m^3/day)	1795	
Peak Hourly Flow (L/s)	94	
Influent Pollutant Loads (kg/day)	**Off-Peak Period**	**Peak Summer Period**
BOD5	122	520
TSS	122	520
TN	26	111
AmmN	17	73
TP	4.2	18

Refer to Appendix One for more details on how the design numbers were derived.

4.0 INVESTIGATION OF HARBOUR DISCHARGE

All options associated with harbour outfall were investigated by Golder Associates (Oct 2009). A full report is presented in Appendix Two. A methodology of this investigation is described in the paragraphs below.

Two options of outfall type were studied: (i) Near-shore outfall (similar to existing) and (ii) Mid-harbour outfall. A long ocean outfall was not considered in this report, which has been studied previously, but it was too costly to consider further.

Section 4.1 presents a description of the harbour hydraulic conditions for both outfall types from each of the three treatment plant sites.

Section 4.2 presents the broad risk factors considered in the risk assessment and also gives a rating to each of the options, before undertaking the technical modelling works. The intention of the rating is to identify suitable options on a purely evaluative basis prior to detailed assessment based on modelling. Such an approach facilitates a comparison of the results from a qualitative assessment to that from post modelling.

Following the above, the receiving environment criteria is presented in Section 4.3.

Sections 4.4 to 4.8 presents the findings of the modelling exercise.

Section 4.9 presents the effluent quality targets to achieve the environmental criteria.

Section 4.10 summarises the risk assessment based on environmental and social impact.

4.1 Outfall Options

4.1.1 Existing Site

Two outfall options were considered for the existing site:

- Near-Shore Outfall – a new outfall approximately 600m long from the shoreline in 8m of water. The outfall will extend approximately 400m past the headlands of Red House Bay and as a consequence it will be exposed to the diurnal tidal currents.
- Mid-Harbour Outfall – a new outfall located between Red House Bay and Wainui Bay. This possible outfall would be in approximately 9.8 m of water, and would extend approximately 1.6 km from the Red House Bay shoreline.

4.1.2 Akaroa North

If the treatment plant is relocated to the Akaroa North site, an outfall pipe will originate from the western shore of Childrens' Bay, and follow the headland into the Akaroa Harbour. Two outfall options were considered:

- Near-Shore Outfall – Due to the proximity of the water skiing lanes in Childrens Bay and the proximity of French Bay (Akaroa) a 1.5 km outfall is anticipated for this option. The outfall will be approximately 200 - 300m from the shoreline and in 8.8 m of water.
- Mid-Harbour Outfall - The mid-harbour outfall, considered in this study, is assumed to be located between French Bay and Tikao Bay. The outfall would be in approximately 8.2 m of water, and in the middle of the Akaroa Harbour. Similar to the near shore outfall, the outfall will most likely originate from the western shore of Childrens Bay. A 2.5 km outfall will be required.

4.1.3 Akaroa South

Similarly, two outfall options were considered for the South Akaroa Site:

- Near-Shore Outfall – A near shore outfall, approximately 600 m in length will be required. In the vicinity of The Kaik, the water is relatively deep. The proposed near shore outfall, whilst only 600 m from the shoreline, resides in approximately 9.4 m of water (at Chart Datum).
- Mid-Harbour Outfall - The mid-harbour outfall will be located 1.5 km west of Te Ahiteraiti (south of The Kaik). The outfall would be in approximately 12.8 m of water, and in the middle of the Akaroa Harbour. Similar to the near shore outfall, the outfall will most likely originate from north of the Kaik and Onuku Marae. A 1.9 km outfall will be required.

4.2 Broad Risk Factors

The following broad risk factors were considered in the risk assessment (NZWERF 2002):

- Human health and safety
- Ecology
- Community value
- Cultural
- Economic utility
- Aesthetics

4.2.1 Human Health and Safety

The risks for human health and safety is particularly relevant to the outfall options, since many of the options have the potential to impinge on areas with contact recreational values. The concern is associated with the potential contact with pathogens in the treated wastewater and/or physical hazards that may be caused by poor water clarity and /or slime build-up on substrates.

Limited specific information on contact recreation in Akaroa Harbour was identified however the following observations are made:

- The majority of swimming and bathing is expected to occur from the shore and therefore closest to near-shore outfalls.
- Water ski access lanes are located in Childrens Bay and at the Glen.
- Childrens Bay is likely to be popular for contact recreation as it is close to Akaroa Township and has a beach.
- The Akaroa Recreation Ground boat ramp is located in Childrens Bay.
- Childrens Bay is classified as a Class Coastal CR (contact recreation) Water Quality Area (ECan 2005).
- Swimming and bathing occurs in other areas of Akaroa Harbour from private and commercial (i.e. swimming with the dolphins) vessels.
- French Bay and Glen Bay are Mooring Areas (ECan 2005).

4.2.2 Ecology

The following is a summary of key species, communities and ecosystems that may be adversely affected by the discharge of wastewater.

Of particular relevance are aquatic sediments and the sensitivity of benthic communities as they are a good indicator of wastewater impacts. NIWA (2004) noted the following in relation to aquatic sediments in Akaroa Harbour:

- Sediment characteristics were quite similar throughout the harbour (north of Lucas Bay).
- Mud generally comprised the majority of sediment.
- Sediment organic content was generally low to moderate.
- Total nitrogen in sediment decreased towards to harbour mouth.
- Metal content of sediment showed little pattern.

NIWA (2004) noted the following in relation to benthic communities in Akaroa Harbour:

- Species occurrences were similar throughout the harbour (north of Lucas Bay).
- Mean faunal densities increased steadily to seaward.
- Several common benthic species tended to be less abundant inshore.
- The distribution of fauna or community pattern was most strongly correlated with the combination of three factors: water depth (most), sediment organic content and zinc content.
- Total faunal diversity in Akaroa Harbour was similar to that reported for other locations around Banks Peninsula.
- Benthos densities in Akaroa Harbour varied widely but were largely consistent with benthos densities elsewhere around Banks Peninsula.
- Lyttelton Harbour and Akaroa Harbour share many common species.
- Faunistically, inner harbour stations were very similar to each other, but dissimilar to the outer harbour stations.

Particular areas of high sediment or benthic community quality were not identified within Akaroa Harbour.

In relation to hard bottom benthos, (NIWA 2004) noted that:

- Patterns of intertidal biota distributions appear largely controlled by exposure to wave action.
- The intertidal biota in Akaroa Harbour comprised species that are widely distributed around Banks Peninsula and elsewhere along the east coast of the South Island.

Limited specific information on plankton ecology of Akaroa Harbour was identified (NIWA 2003) however ECan (2005) notes the following:

- Based on dissolved inorganic nitrogen (DIN) concentrations there is a slightly greater likelihood of enhanced phytoplankton growth at the heads of the harbour.
- The seasonal pattern in dissolved nutrient concentrations reflects the uptake of these nutrients by the phytoplankton in the spring and the release of nutrients back into the water column in mid-late autumn.

Ten species of phytoplankton formed blooms (cell concentrations >10,000 L-1) in Akaroa Harbour on one or more occasions between mid 1999 and November 2002 (Fenwick and Image, 2002). As nutrients were not monitored over this period the relationship between nutrient concentrations and phytoplankton has not been investigated (ECan 2005).

Treated wastewater is currently discharged into Akaroa Harbour at Wainui and Duvauchelle in addition to the existing Akaroa WwTP discharge. Stormwater in the region generally enters small streams which flow into the harbour or directly into the sea via stormwater outlets. Stormwater flow can result in inputs of contaminants such as sediment, nutrients, metal and pathogens. In wet weather, fertiliser and animal wastes run off from the surrounding hillside into streams which then flow into the harbour contributing to the nutrient load to the harbour water. Marine farming (in particular salmon farming) activities are located along the western side of the harbour near the mouth and are another potential source of nutrients in the harbour (ECan 2005).

Fish species observed in the area include wrasse, butterfish, red and blue cod, blue moki, triplefin, leatherjacket, carpet shark and whitebait (AHMPS, 1996). Many other oceanic and both feeding fish may enter the harbour on occasions.

A marine discharge via an outfall has the potential to affect fish spawning areas, increase sedimentation and fish flesh tainting.

There is no evidence of any commercial flatfish species having significant spawning grounds in the vicinity of the possible outfall locations. The fish resources in the area of the possible outfall locations have not been quantified and the possible effects of an outfall on the fish resource are difficult to predict without better baseline information of the fish resource and the species present.

Based on the performance of the existing outfall, possible sedimentation effects are less than minor and not differentiable from regions elsewhere in the harbour. Fish flesh tainting can affect the palatability of aquatic food. An analysis of the potential for fish flesh tainting for the Christchurch outfall concluded that the low concentration of compounds known to cause fish flesh tainting in the mean dilution factor of the treated wastewater in the near field, demonstrated that the concentrations of these compounds fell below those known to cause tainting (NIWA, 2004).

It is possible that the increased nutrient supply in a harbour discharge could be beneficial for plankton and this ultimately as food for fish, but this effect, if it occurred, would likely manifest itself within the harbour rather than in the vicinity of the outfall.

Hectors Dolphins are common in Akaroa Harbour. They can be found in the inner harbour during summer (DoC website). Hectors Dolphin densities are reported as being quite variable in Canterbury coastal waters but high densities have been reported in Akaroa Harbour (NIWA 2003). The entire harbour is a Marine Mammal Sanctuary for Hectors Dolphins.

Hector Dolphins feed mostly on school-fish around 10-35cm in length, most likely found within the harbour (PBAL, 2001). Research indicates that the predominant prey species of Hector dolphin includes red cod, stargazer, ahuru and Sole species, mid-water spray, yellow-eyed mullet, hake, squid and small barracouta.

A search of literature did not elicit any evidence indicating that the current discharge of treated wastewater into the Akaroa Harbour is adversely affecting the health of Hectors Dolphins. In a recent presentation to the Working Party, Dr Liz Slooten (University of Otago) indicated that information on the concentration of bioaccumulating, non-biodegrading and carcinogenic compounds; and certain bacteria in the treated wastewater and sediments may assist in determining the risk of adverse impacts on Hectors Dolphins from the discharge of treated wastewater. However, there appears to be no documented evidence that current discharge of treated effluent is a primary cause of historical decline in Hector Dolphin numbers.

Although not proximate to any of the outfall options considered, it is noted that the Dan Rogers Marine Reserve is proposed for the eastern side of the harbour entrance.

4.2.3 Community Value

Community value has been taken to include cultural or social risk factors. The key consideration for Akaroa Harbour is understood to relate to shellfish gathering. Limited specific information on shellfish gathering in Akaroa Harbour was identified however the following is noted:

- The majority of the harbour is classified as Class Coastal SG (shellfish gathering) Water Quality Area (ECan 2005).
- Green-lipped mussels (Perna canaliculis) are reported to form a dense covering over rock surfaces and dominate the sublittoral fringe on rocky shores (NIWA 2003).
- The area to the south of the The Kaik, around Te Ahiteraiti is highly regarded by the Onuku Runanga for its kai moana and is proximate to the Onuku Marae.
- Onuku Runanga do not currently collect kai moana from Red House Bay (or Takapuneke) due to the current discharge of treated wastewater into the bay.

- The entire harbour is a Taiapure (Taiapure are local fisheries in coastal waters which recognise the special significance of the area to local iwi or hapu, either as a source of seafood, or for spiritual or cultural reasons. Taiapure give Maori greater say in the management of their traditionally important area. A major difference between mataitai and taiapure is that taiapure allow commercial fishing (DoC website)).

Mäori are offended by the discharge of human wastes to natural waters (sea or rivers) and also under certain circumstances to land. Historically, in Mäori settlements, "kuparu" (human wastes) were disposed of to land and kaumatua decided how many years needed to pass before Papatuanuku had transformed the wastes into non-human form. Onuku Runanga have expressed cultural concerns regarding the disposal of wastewater to the harbour.

It is expected that further information on community value risk factors will be obtained through consultation as part of options assessment process.

4.2.4 Economic Utility

The key current economic uses of the harbour that may be adversely affected by the discharge of treated wastewater are expected to be commercial fishing, marine farms and tourism. Limited specific information on economic uses of Akaroa Harbour was identified however the following observations are made:

- Marine Farms are located on the western (opposite) side of the harbour from the outfall locations assessed.
- The Akaroa Harbour ecology directly supports a range of tourism activities such as dolphin watching, swimming with dolphins, kayaking and general sightseeing tours. Tourism activities that use the marine environment of Akaroa Harbour include:
  - Wildlife cruises and tours
  - Kayak hire and tours
  - Fishing charters
  - Swimming with Hector Dolphins
  - Water skiing
  - Yacht tours, charters and boat hire
  - Walking Trails
  - Jet-boat tours

Specific details of the location and intensity of these tourism activities is not known. Wildlife cruises and tours are expected to predominantly occur south of the Akaroa township except in adverse weather.

Currently, there is no issue of tourists being aware of, or being affected by the existing harbour discharge. If the options of harbour discharge in conjunction with land irrigation are selected, this would result in smaller discharge quantity and with better water quality. In addition, if mid-harbour outfalls are used instead of near-shore outfalls will lead to better dispersion and much reduced near-shore effects. Therefore, the harbour discharge options are unlikely to cause any negative impact on tourism.

4.2.5 Aesthetics

Aesthetic risk factors overlap to a degree with matters addressed under community value and economic utility such as proximity to reserves and recreational areas, and tourist activity.

Treated wastewater that is of similar colour and clarity to the receiving water is expected to pose a lower risk of potential adverse impact on aesthetics.

The risk of adverse impacts on visual clarity is reduced due to the naturally turbid waters within Akaroa Harbour.

4.2.6 Summary of Broad Risk Factors

Based on the information summarised above, the risk factors relevant to the discharge of treated wastewater into Akaroa Harbour for each of the outfall locations assessed have been summarised in Table 4.2.6. The risk has been ranked from one to six, with one being the highest risk and six being the lowest risk.

Table 4.2.6: Summary of Broad Risk Factors and Ratings for Harbour Outfall Discharge (Golder, Oct 2009)

Outfall Location	Human Health & Safety	Ecology	Community Value	Economic Utility	Aesthetics	Comments
Akaroa North – near-shore	1	1=	1	2	1	High recreational activity, Close proximity to Akaroa
Akaroa North – mid-harbour	4	2=	4	4	2	Close proximity to Akaroa
Current WWTP – near-shore	3	1=	3	5	3=	Lower cost, but higher potential impact.
Current WWTP – mid-harbour	5	2=	5	3	5	Higher cost, but lower potential impact
Akaroa South – near-shore	2	1=	2	6	3=	High cultural value, close proximity to Marae.
Akaroa South – mid-harbour	6	2=	6	1	6	Higher cost, but lower potential impact

As shown in the table above, a new mid-harbour outfall at the existing site offers the most favourable attributes among all the harbour discharge options.

4.3 Receiving Environment Criteria

A number of guidelines were referred to when considering the appropriate receiving environment criteria. In particular Bolton-Ritchie (2007) studies, ANZECC (2000) and ECan (2005) were considered.

Table 4.3 provides a summary of relevant water quality guidance values when considering what values are applicable in assessing the effects of any discharge to Akaroa Harbour.

Table 4.3: Summary of Receiving Environment Criteria (Golder, Oct 2009)

	Bolton-Ritchie (2007) 80%ile values	**ECan (2005a) 1**	**ANZECC (2000)2**	**USEPA (2006), USEPA (1989) 3**	**MfE (2003)**
Temp (°C)		25 (±3)			
Nutrients					
TN	0.21		0.12		
NOx	0.023		0.005		
TP	0.039		0.025		
DRP	0.017		0.01		
Oxygen					
DO (% sat.)		>80	90-110		
BOD5 sol.		2			
Toxicants					
Ammonia	0.910		0.910	14 (pH 7.0) – 1.4 (pH 8.0)4	
Copper (mg/m3)		5	1.3	3.1	
Lead (mg/m3)		5 (sol.)	4.4	8.1	
zinc (mg/m3)		50 (sol.)	15	81	
Bacteria					
Enterococci		35/100 mL (median), 277/100 mL (single sample)	35/100 mL (primary), 230/100 mL (secondary)		140/100mL
Faecal coliforms		14/100 mL (median), 43/100 mL (90%ile)	150/100 mL (primary), 1,000/100 mL (secondary)		14/100 mL (median), 43/100 mL (90%ile)

Note: *All units in g/m^3 unless otherwise stated. 1 Class Coastal SG and CK waters. 2 South-east Australia marine water for nutrients and oxygen; 95% level of protection for marine ecosystems for toxicants; and recreational water quality guidelines for bacteria. 3 Chronic value for toxicants. 4 Based on a water temperature of 15°C and salinity of 10 ppt.*

4.3.1 Receiving Environment Quality

In assessing the implications of any discharge, a number of factors need to be considered. These include:

- Assessing the effects within the immediate mixing zone to ensure that there are no acute effects arising from the discharge.
- Sedimentation effects arising from the discharge (in situations where solids concentration is elevated).
- Toxicity effects arising from chronic exposure to the wastewater discharge (generally for wastewater these effects are predominantly due to unionised ammonia).
- Chronic effects arising from elevated concentrations of oxygen demanding substances in the discharge.
- The effects of nutrients in the discharge including on shoreline ecology and on plankton in the harbour.
- Public health effects including contact recreation and shellfish gathering.

For the purposes of this initial assessment, the following guidance values in Table 4.3.1 were adopted to establish the benchmark in the harbour water (i.e. at the edge of the mixing zone).

4.3.2 Receiving Environment

The following may have an influence on what wastewater treatment standards will be required:

- The entire harbour is a Taiapure (Taiapure are local fisheries in coastal waters which recognise the special significance of the area to local iwi or hapu, either as a source of seafood, or for spiritual or cultural reasons. Taiapure give Maori greater say in the management of their traditionally important areas. A major difference between mataitai and taiapure is that taiapure allow commercial fishing. – DoC website).
- The Dan Rogers Marine Reserve is proposed for the eastern side of harbour entrance.
- Majority of harbour is Class Coastal SG (shellfish gathering) Water Quality Area (ECan 2005a).
- The near shore area of Children's Bay is Class Coastal CR (contact recreation) Water Quality Area (ECan 2005a).
- The entire harbour is a Marine Mammal Sanctuary (Hectors Dolphins) and dolphins are found in the inner harbour during summer (DoC website).
- Marine farms located along the western shore of Akaroa Harbour between Wainui and Timutimu Head.

Table 4.3.1: Receiving Environment Criteria for Akaroa Harbour Outfall Options (Golder, Oct 2009)

BOD5	TN	Amm-N	NOx	TP	DRP	Cu	Pb	Zn	Enterococci	Faecal coliforms
2	0.21	1.4	0.023	0.039	0.017	1.3	4.4	15	140 cfu/100 mL	14 cfu/100 mL

Note: *All units in g/m^3 unless otherwise stated.*

4.4 Outfall Modelling

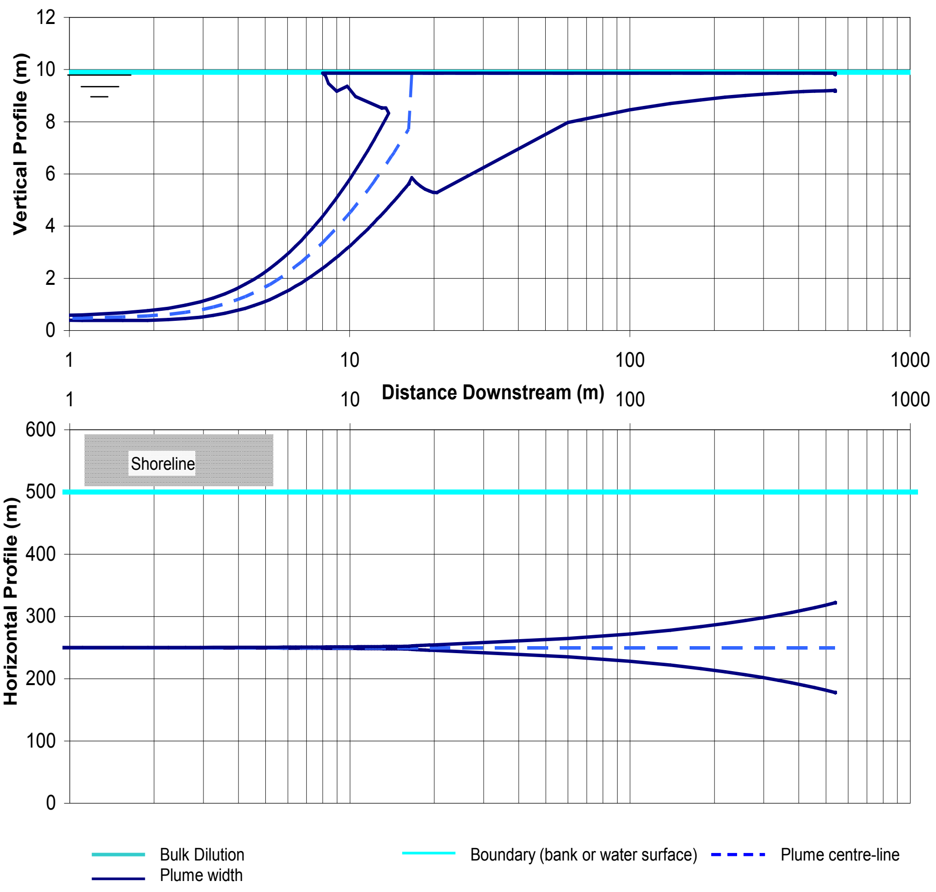
A dilution and dispersion modelling was conducted using CORMIX software package. CORMIX is a United States Environmental Protection Agency (USEPA) supported mixing zone model and decision support system that is often used to assess the impact on the mixing zones environment from continuous point source discharges into water bodies (Doneker & Jirka, 1996).

This modelling assessment provides a summary of the likely minimum dilution expected from each of the six outfalls evaluated in this study (two from each of three sites). The evaluations are based on an extreme rate of discharge from the wastewater treatment plant, and tidal conditions. These predicted rates of dilution form the basis of the risk assessment and the determination of the likely performance requirements of possible upgrades to the current wastewater treatment plant or design of a new wastewater treatment plant.

The discharge of the treated wastewater from the diffuser exhibits the following shape and profile.

The discharge is hydrodynamically "stable", that is, momentum of the discharge is weak compared to the relative effect of the discharge buoyancy. The discharge is effectively clean water that is lighter than the saline harbour water, and as a consequence it tends to rise to the surface.

The discharge of treated wastewater from the outfall progressively passes through a number of phases. Further description is provided in Golder Report under Appendix One.



4.5 Mixing Zones

Each of the discharge options considered was modelled using CORMIX. Outfall modelling needs to consider typical (long-term) and worst case (short-term) discharge flows.

The table below provides discharge dilution information during peak daily flows which encompass average daily flows (so is relatively conservative in terms of daily flow using average or 90%ile discharge quality concentrations).

Table4.5: Modelled minimum dilution at edge of mixing zones at outfall options (Golder, Oct 2009)

WWTP Location	Outfall Location	Reasonable Mixing Zone (m)	Minimum Dilution
Akaroa North	Near Shore	100	215
	Mid-Harbour	250	275
Existing	Near Shore	100	251
	Mid-Harbour	250	340
Akaroa South	Near Shore	100	526
	Mid-Harbour	250	871

Based on the current effluent quality, modelled site specific dilution and the receiving environment goals set out in Table 4.3.1, the following parameters are unlikely to meet the receiving water numerical guidelines beyond a zone of immediate mixing.

- Dissolved inorganic nitrogen (DIN) at the existing and Akaroa North near shore outfalls;
- Dissolved Reactive Phosphorus (DRP) and Total Phosphorus at Akaroa North near shore and existing site mid-harbour outfalls.

For full details of how the above conclusions were drawn, refer to Table 7 of Appendix Two.

The above assessment suggests that if the above mentioned locations are considered, the treatment plant will have to produce lower concentrations of dissolved inorganic nitrogen and phosphorus in the final effluent compared to the existing effluent quality.

Further details on the following items are presented in Appendix Two.

- Effects within the immediate mixing zone to ensure that there are no acute effects arising from the discharge;
- Sedimentation effects arising from the discharge (in situations where solids concentration is elevated);
- Chronic effects arising from the discharge including toxicity arising from ammonia and contaminants;
- Chronic effects arising from the discharge relating to elevated concentrations of oxygen demanding substances;
- The effects of nutrients in the discharge including on shoreline ecology and on plankton in the harbour;
- Public health effects including contact recreation and shellfish gathering; and
- The effects of contaminants in the discharge on Hectors Dolphins.

4.6 Options For Improved Dispersion

The location of an outfall (being either near-shore or mid-harbour) has a direct correlation to the probability and hence risk of unacceptable algal growth on the shoreline and the potential bacterial (or viral) contamination of shellfish or recreational users.

In general the mid-harbour outfalls are in deep water some distance from the shoreline, and hence less likely to contribute to algal growths, contamination of shellfish or come in contact with shore-based recreational users of the Akaroa Harbour.

Due to the relative low discharge rate, a single riser harbour outfall comprising a single port would be suitable. A duckbill valve is proposed on the outfall port, which prevents ingress of sea water and reduces the accumulation of sand or shellfish growths which can potentially reduce the hydraulic capacity of the outfall.

A frame structure (or similar) would be required over the diffuser riser, to prevent fishing nets and anchors entangling the outlet port, causing damage to the diffuser, outfall pipe and/or the fishing nets. A typical example of such a structure is presented in the report under Appendix Two.

4.7 Discharging On Outgoing Tides

Discharging on the outgoing tides will require the WWTP to store at least 75 % of the maximum daily discharge of treated wastewater. It is assumed that the discharge will occur on the first three hours of the outgoing tide, with two discharges per day. Consequently, a storage tank providing at least 1,220m^3 (Peak summer ADWF 1,625m^3/day x 0.75 day) of active storage would be needed. This is equivalent to a tank 6m in height and 18m in diameter.

Whilst the storage tank will be capable of storing some wet weather inflows into the plant, it is neither practical nor feasible to retain all the wet weather discharges. During extreme wet events excess treated effluent will be discharged to the harbour, possibly during periods of the incoming tide. Coinciding with periods of extreme wet weather events, the harbour is highly loaded with silt and sediments from the streams that feed into the harbour, and the harbour is not actively used by residents or visitors. As a consequence, the environmental and social risk of the wet weather discharge is reduced.

A comparative assessment of the option of continuously discharging treated wastewater to the harbour and discharging on the outgoing tide identified the following attributes:

- The mass of nutrient or contaminant load into the harbour is identical.
- The effective residence time that the nutrients/ contaminants remain in the harbour are near identical.
- Discharging on the outgoing tide reduces the risk of exposure to the treated wastewater, as the discharge is on average only 6 hours per day.
- The discharge on the outgoing tide reduces the possibility of plume attachment to the harbour bottom or shoreline to areas down current of the respective outfall(s).
- To overcome the increase in rate of discharge of a outgoing tidal option, a multiport port diffuser would be required. Consequently, the size of the reasonable mixing zone would need to increase to reflect the spacing between the diffusers. This would be expected to increase reasonable mixing zone by 40-50m.
- A multiport diffuser would incur a marginal increase in cost to construct and install.

The hydraulic residence time in the harbour is in the order of 7.6 days. Discharging on the outgoing tide is unlikely to result in a noticeable change in the retention of nutrients and possible contaminants in the harbour.

The advantage of this discharge option is that the extent and direction of the possible discharge plume can be restricted to a zone in the direction of the outgoing current from the respective outfall.

The earlier dispersion and dilution studies are directly applicable to this discharge option, with the exception that the zone of reasonable mixing will be slightly larger to reflect the size of a multi-port diffuser.

4.8 Hybrid Land Irrigation/Harbour Discharge

Hybrid options were considered for the scenario in which a portion of treated effluent is discharged into the harbour when the treated effluent irrigation becomes difficult, e.g. wet weather and winter months.

Under hybrid options, it is expected that land irrigation will predominantly occur during summer. However during winter, or during prolonged periods of wet weather, the land irrigation blocks may be unable to assimilate additional treated wastewater. At this point the excess treated effluent will be discharged to the harbour.

The land irrigation system will consist of an effluent storage pond which provides hydraulic buffering of treated effluent and is likely to result in a harbour discharge less than the CORMIX assessed discharge of 1,795 m^3/day (being the maximum daily inflow into the WWTP in 2041). As a consequence the earlier CORMIX dispersions studies could be applied to these discharge scenarios.

The primary advantage of this discharge option is that frequency of discharge is restricted to periods in which the recreation values in the Akaroa Harbour are low, due to inclement weather.

4.9 Required Wastewater Quality

Treated wastewater quality standards for harbour discharge have been based predominantly on the preliminary risk assessment by outfall dispersion modelling.

Also, the proposed standards are similar to those specified on other marine wastewater discharge permits in Canterbury, as shown in the report under Appendix One.

Table 4.9 on the following page presents the recommended effluent quality for harbour discharge in Akaroa.

Table 4.9: Comparison of Current and Proposed Final Effluent Quality for Akaroa WwTP (Harbour Discharge)

Parameters	**Current Discharge Standards at Akaroa WwTP (Median)**	**Proposed Final Effluent Quality for Akaroa WwTP for Harbour Discharge**		
		From Investigation/ Modelling	***Proposed Discharge Standards (Median)***	***Likely final effluent quality (Median)***
BOD5 (mg/L)	< 30	< 500	< 30	< 20
TSS (mg/L)	< 30	-	< 30	< 20
TN (mgN/L)	-	< 40	< 30	< 10
AmmN (mgN/L)	-	< 350	-	< 2
DIN(mgN/L)	-	< 8	< 6	< 6
TP (mgP/L)	-	< 10	< 8	< 8
DRP (mgP/L)	-	< 5	< 4	< 4
Faecal Coliform (/100mL)	< 1000	< 3000	< 1000	<1000
Enterococci (/100mL)	-	< 19000	< 1000	<1000

Currently, there are no nutrient discharge limits for the Akaroa WwTP; particularly dissolved inorganic nitrogen (DIN) would be a key parameter that would dictate the design and operation of the WwTP for a harbour discharge.

For detail discussion of the various standards, refer to Appendix Two.

4.10 Risk Assessment and Findings

The Leopold Matrix was employed to qualitatively assess the environmental and social issues, impacts and risks associated with various harbour outfall discharge options. An in-depth discussion on the application of the matrix and the results is presented in Appendix Two.

Table 4.10 presents the findings of the risk assessment. Risk scores with least negative values imply lower risks.

From the assessment above, a mid-harbour outfall, offshore from the Red House Bay and discharging during outgoing tide would cause the least environmental, social and cultural effects. However, the benefit of an outgoing tidal discharge is barely distinguishable from a conventional (continuous) discharge or the hybrid discharge option and the additional benefit associated with it is unlikely to warrant the additional costs. Therefore, mid-harbour continuous discharge and hybrid discharge options were evaluated further in this report.

Table4.10: Comparison of Various Outfall Options and Discharge Regimes (Golder, Oct 2009)

	Leopold Matrix Risk Score	Rank
Comparison of Location of WwTP and Outfall Discharge		
Current WWTP – near-shore outfall	-17.8	4
Current WWTP – mid-harbour outfall	-10.6	1
Akaroa North – near-shore outfall	-24.5	6
Akaroa North – mid-harbour outfall	-13.5	3
Akaroa South – near-shore outfall	-21.4	5
Akaroa South – mid-harbour outfall	-11.5	2
Comparison of Discharge Regimes at existing location		
Continuous Discharge – near-shore outfall	-21.7	6
Continuous Discharge – mid-harbour outfall	-11.9	3
Outgoing Tidal Discharge – near-shore outfall	-20.2	5
Outgoing Tidal Discharge – mid-harbour outfall	-11.2	1
Hybrid Discharge – near-shore outfall	-18.9	4
Hybrid Discharge – mid-harbour outfall	-11.4	2

4.11 Conclusions of Harbour Outfall Dispersion Modelling

Based on the above assessments, the following top four options are discussed below.

If only harbour discharge is considered in isolation (i.e. no land irrigation), the following options in terms of location appear favourable:

1. Current WwTP – mid harbour outfall
2. Akaroa South – mid harbour outfall

However, based on discharge regimes, the following options are favourable:

1. Tidal discharge – mid harbour outfall
2. Hybrid discharge – mid harbour outfall

The tidal discharge option scores 0.2 higher than the hybrid discharge option and 0.5 higher than the continuous discharge option. However, the additional benefit for a tidal discharge is marginal and is unlikely to warrant the additional cost associated with the storage tank and outfall pipe.

Therefore, the near-shore and tidal discharge outfall options are less favourable and are not considered further in this study.

5.0 LAND BASED EFFLUENT IRRIGATION INVESTIGATION

EcoEng Limited has undertaken an assessment of irrigation of treated effluent in Akaroa. A full copy of the report is presented in Appendix Three.

The investigation has followed a logical methodology and the findings are presented in the following order:

Section 5.1 lists the technical and non-technical factors that are taken into consideration while designing a land irrigation system for treated effluent.

Section 5.2 describes the desktop study carried out by ecoEng on the nominated sites.

Section 5.3 describes the field study carried out by ecoEng and Geotech Consulting Limited.

Section 5.4 presents a discussion on the soil-water modelling, which estimates the required irrigation field areas and storage volume.

Based on the above assessments, Section 5.5 recommends the quality of treated effluent required for land irrigation on the nominated sites.

Section 5.6 discusses and compares options for land use.

Section 5.7 provides a discussion on issues and risks for land irrigation at the nominated sites in Akaroa.

5.1 Technical and Non-Technical Issues

Whilst irrigating treated effluent to land has been around for many years in New Zealand with examples including Rotorua, Taupo and Otautau, there are a number of factors to be taken into consideration for establishing an effluent irrigation scheme in Akaroa:

- Technical Issues:
  - Suitable soils characteristics
  - Suitable topography and hydrological conditions
  - Suitable climate
  - Efficient system design
  - Effective site preparation
  - Good management and appropriate monitoring
- Cultural and Consent Issues:
  - Ecologically sustainable
  - Landowner and community acceptance
  - Tangata Whenua acceptance
  - Consentable and compliance with relevant acts (RMA, Public Health Act and Building Act)
  - Maintainable and serviceable using local capacity
- Affordability and Economically Sustainable

Effluent irrigation provides two resources, water and nutrients. Reclaiming treated effluent as a water resource for irrigation is an alternative to develop new water supply source, especially for area such as Akaroa where the limitation of the water supply restricts development. Nutrients in effluent such as nitrogen and phosphorus are essential components for plant growth and would improve yield and decrease fertiliser usage if the sites are managed and operated properly.

Typical effluent irrigation in New Zealand is used in exotic forests, pastures, native bush and golf courses.

5.1.1 Irrigation Technology

There are a range of irrigation methods, from flood irrigation system, large centre pivot sprinkler system, mini, micro and pop-up sprinklers system and subsurface and surface dripper irrigation system. Sprinkler irrigation and dripper irrigation are selected for assessing potential effluent irrigation in Akaroa. Table 5.1.1 presents a comparison of two irrigation systems.

Table 5.1.1: Comparison of Dripper and Sprinkler Irrigation (ecoEng, Jan 2010)

	Advantages	Issues
Subsurface Drip Irrigation	More even subsurface moisture distribution – if well designed. Higher irrigation efficiency. Normally higher yields. Highest level of health protection – no aerosol and odour risks. Almost all crops can be grown	High cost (about twice the sprinkler option Can interfere with cultivation, replanting and harvesting. Root penetration may be a problem.
Sprinkler Irrigation	Normally capital lower cost compared to drip irrigation. Medium irrigation efficiency	Lower level of health protection. Crops may suffer leaf damage. Can interfere with cultivation.

The type of irrigation technology and layout will depend on a number of factors including:

- Land Use,
- Topography,
- Ecological and public health risks to mitigate,
- Local management capacity, and
- Capital and operating costs.

5.2 Irrigation Desktop Study

A desktop study of the Akaroa North and Akaroa South sites was carried out. The study identifies possible sites and areas where the irrigation of the treated effluent could be technically performed with minimum social, cultural and environmental impacts and risks, as well as maximum benefit.

Criteria used for the selection of possible sites include:

- Land owners' willingness to allow access for site and soil assessment and in-boundary preference for the location of the irrigation field(s),
- Geotechnical stability,
- Suitable soil profiles,
- Slopes less than 15 degrees with up to 20 degrees under certain circumstances,
- Avoid low-lying wet areas,
- Less than 250m above sea level,
- Larger land parcels preferred,
- Suitable site for large storage facility,
- Setback from surface water 20m, and
- 50m from water supply bores.

Figure 5.2a and 5.2b present the results of the desktop study in which the green shades correspond to areas where the slopes are less than 15 degrees and the orange shades correspond to areas where the slopes are between 15 and 20 degrees. The figures relating to area (ha) of the green shades.

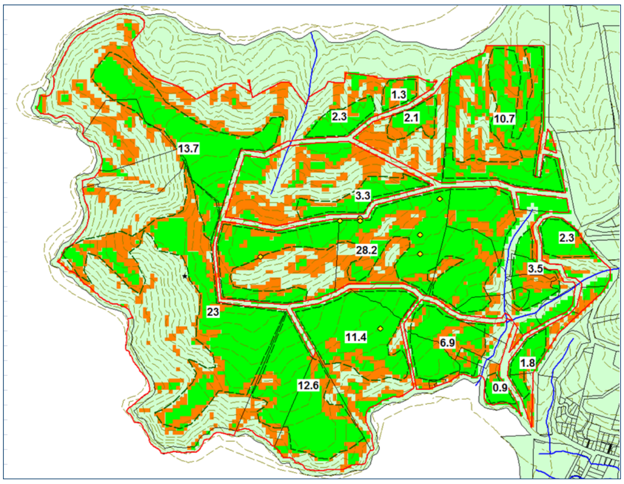


Figure 5.2a: Potential Irrigation Area in Akaroa North (ecoEng)

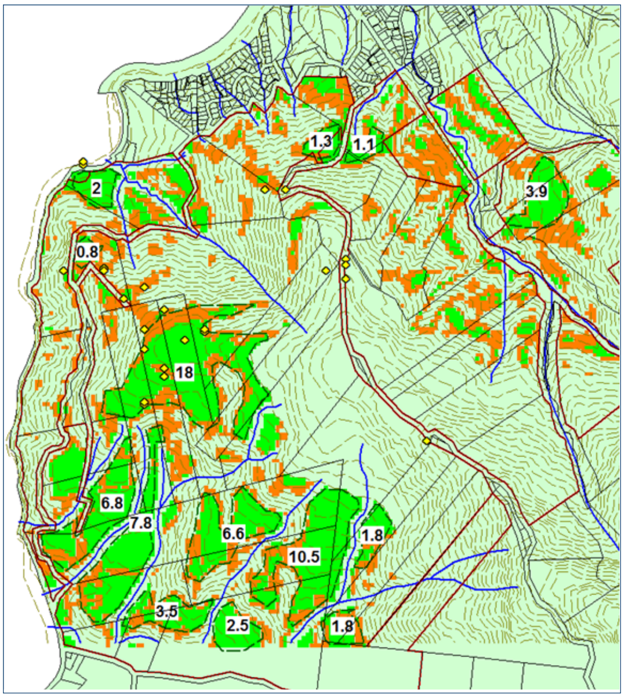


Figure 5.2b: Potential Irrigation Area in Akaroa South (ecoEng)

As illustrated in Figures 5.2a and b, the potential irrigable areas at the South Akaroa site are more disperse and also have higher elevation than those at the North Akaroa Site.

This study assisted in determining the preferred areas to carry out actual field assessment work. Site and soils investigations were carried out in early August 2009 and assessment of geotechnical mass stability was carried out in early October 2009.

5.3 Fieldwork and site assessment

Following the desktop study, potential irrigation areas were identified and site investigation was undertaken accordingly.

5.3.1 Site Access Approval

A necessary pre-requisite to site assessment was obtaining land owner approval to access the land areas identified in the desktop studies as potentially suitable. Land access approval was organised by Christchurch City Council. Figure 5.3.1a and 5.3.1b illustrate those properties for which access was approved or denied.

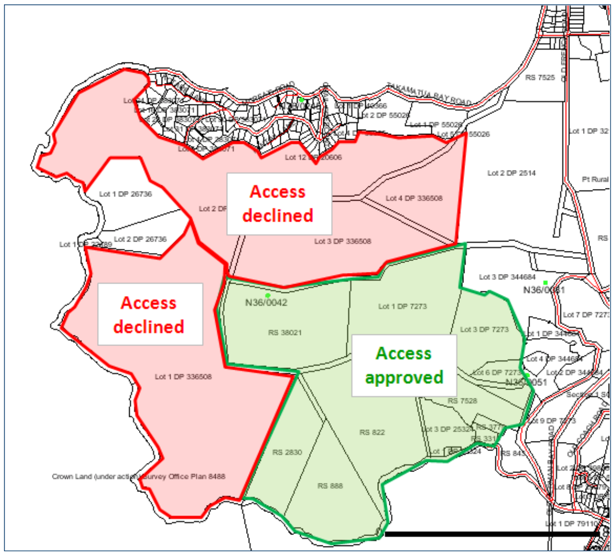


Figure 5.3.1a: Akaroa North Site Access (ecoEng, Jan 2010)

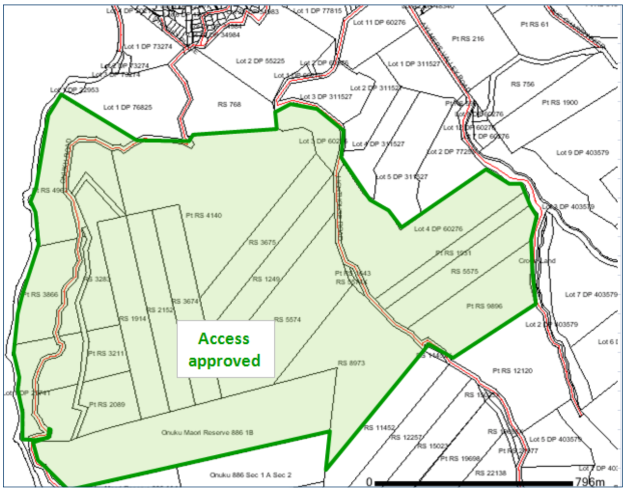


Figure 5.3.1b: Akaroa South Site Access (ecoEng, Jan 2010)

As shown, two out of the three sites in Akaroa North were denied access. Therefore, fieldwork was restricted to the southern end in Akaroa North, while the entire site in Akaroa South was available.

5.3.2 Site and Soils Assessment

Approval was obtained to carry out site and soils assessment on three separate properties. Two of these properties are in Akaroa North and the third site is in Akaroa South. Only the results for Akaroa South are included as the soil from the available site in Akaroa North was found to be geotechnical unsuitable.

A number of tests were carried out to understand soil characteristics and their suitability for effluent irrigation.

Observations

Soil Stability - Many of the fine silty soils on the Banks Peninsula show slaking tendency and some are also dispersive. There was evidence, particularly on the Akaroa South site of surface instability and tunnel gully erosion. The Emersion test was done on four subsoil samples and three showed slaking tendency. The fourth sample was stable.

Soil Bulk Density - Soil bulk density ranged from 1.07 to 1.47 g/cm^3 for the Northern site and 1.07 to 1.34 g/cm^3 for the Akaroa South site.

Soil Hydraulic Test

Talsma-Hallam constant head test was employed to determine the saturated hydraulic conductivity (Ksat) and long term acceptance rate (LTAR). Double ring infiltrometer was used to gain a measure of surface infiltration. These tests provide an understanding of the soil draining characteristics. As presented in Table 5.3.2a, the soils in the area is slow draining.

Table 5.3.2a: Results of Soil Hydraulic Tests (ecoEng, Jan 2010)

Site	Test Depth mm	Ksat mm/h	LTAR mm/day	Class	Ring Infiltrometer mm/hr
Akaroa South, H1	220 - 420	10.6	15.22	Low	8.7
Akaroa South, R2	170 - 410	6.0	14.09	Very slow	30.6

Notes:

- *Ksat refers to saturated hydraulic conductivity.*
- *LTAR refers to Long Term Acceptance Rate, which is used for soils water modeling.*
- *Results from the Akaroa North site are not reported as the site above directly above Childrens Bay was assessed to be unsuitable due to geotechnical instability as discussed in Section 5.3.3.*

Chemical Characteristics

Two soil pits were dug in the Akaroa South site to collect soil profile samples. The samples were analysed for chemical characteristics and the tests were undertaken at the Bromley Wastewater Treatment Plant.

The purposes of these tests was to gain an indicative picture of nutrient and chemical status of the root zone soils at this site. The results are presented in Table 5 of Appendix Three.

The analysis identified that the soil has low to medium CEC value (Cation Exchange Capacity – a measure of soil ability to attract, retain and exchange cation) and low sodium concentration. Low to medium CEC value implies low to medium soil capacity to store plant nutrients, with irrigating treated wastewater will increase the organic contents of the soils, which normally leads to higher CEC. Low sodium concentration implies low dispersive qualities of the soil.

A more detailed analysis will be required at the subsequent stage to assist with irrigation management and nutrient budgeting to mitigate risks to soil structure and effects on the environment.

5.3.3 Geotechnical Stability

Geotech Consulting Ltd carried out a preliminary assessment of the sites in Akaroa North and Akaroa South in October 2009.

In their report (Appendix Four), they advised that a significant proportion of the Akaroa North site is a large ancient landslide, and the area encompassed by this landslide includes the proposed irrigation areas, site for the treatment plant and storage reservoir. The report further emphasises the potential increased risk of slope instability as a consequence of effectively doubling the rainfall by irrigation on this south facing ancient deep seated landslide.

The southern slope of the Akaroa North site (above Childrens Bay) has a significant and highly visible large ancient landslide, and some areas within it are actively growing despite modest rainfall since 1995. Geotech Consulting Ltd have advised against the inclusion of the area directly above Childrens Bay (The majority of the area shaded green in Figure 5.2a).

There is clear evidence of active land mass movement on the property (Lot 1 DP336508) to the west of the selected Akaroa North site, (refer to Figure 5.3.3).

Figure 5.3.3: Active mass earth movement: Lot 1 DP336508 (ecoEng, Jan 2010)

While the report indicated that the north facing slopes above Takamatua are suitable from a geotechnical perspective, the option of using this area has since been excluded from further consideration as the land is not available for this purpose. (Refer Figure 5.3.1a).

The report suggested that amongst the two sites, Akaroa South is the most suitable for land irrigation from a geotechnical perspective. In particular the higher west-facing subarea (27 hectare area). Geotech Consulting Ltd noted that "*the land is currently rural and stable and that the site could be consented on the basis that it will be operated initially on a relatively low load basis during which the water table and stability would be carefully monitored over the initial years of operation to determine if loadings can be progressively increased. If piezometers are installed in the best likely irrigation locations as soon as possible, and baseline readings taken of the normal seasonal water table fluctuations through the 2010 winter and during the consenting process, then reliable field information could be obtained on real water table impacts which can be used in slope stability analysis.*"

Therefore, the irrigation report focused the investigation and assessment on the Akaroa South area as the potential sites.

5.3.4 Available Land Areas for Irrigation

Figure 5.3.4 illustrates the potential areas for irrigation, a new wastewater treatment plant and storage reservoir areas proposed for the Akaroa South site. The total area potentially suitable for irrigation is about 32ha. All original criteria referred to in Section 5.2 have been met apart from slope and elevation. The maximum elevation permitted has extended to about 340m (cf original 250m) and the maximum slope used in selection of the irrigable area is 20° (cf original 15°).

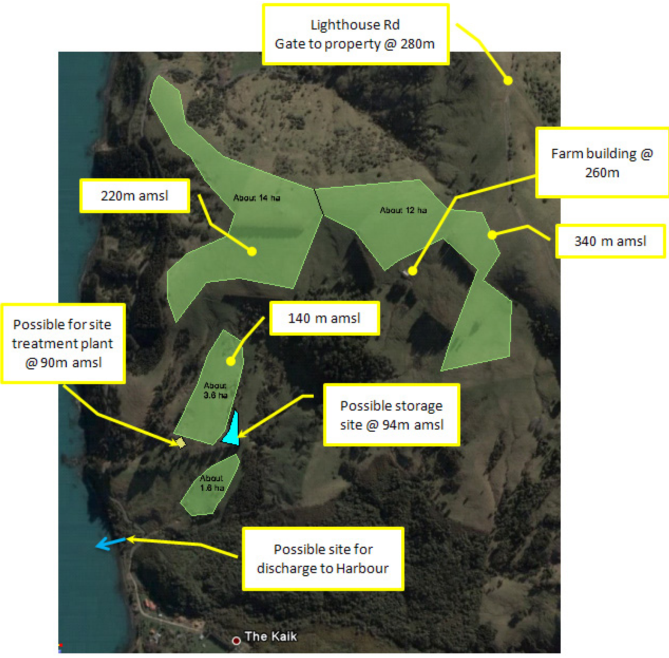


Figure 5.3.4: Irrigable Areas in Akaroa South (ecoEng, Jan 2010)

5.4 Soil Water Modelling

A daily soil water spreadsheet model was used to model soil moisture content and nutrients for the selected sites. This model allows the setting of site specific soil-water-plant rules and calculates the land area required and balancing storage required for the given wastewater volumes conveyed to the site.

The monthly wastewater volumes (projected to 2041) used in the model are given in Table 5.4a.

Table 5.4a: Monthly ADWF used for Soil-Water Modelling (ecoEng, Jan 2010)

Months	Monthly ADWF m3/day
January	1675
February	1117
March	1024
April	744
May	385
June	382
July	382
August	382
September	382
October	558
November	775
December	1055

The model was used to determine the optimum required irrigation area for different pre-irrigation storage volume. Irrigation for each day, over the 49 years of daily rainfall (RF) and evapotranspiration (ET) data, were used.

A number of input data were used to develop this soil-water balance model, including the following assumptions:

- Historical rainfall and evapotranspiration data from nearby weather stations over 49 and 40 years respectively.
- Soil Properties:
  - Bulk density: 1.3g/cm^3
  - Porosity: 40%
- Soil Characteristics:
  - Rooting depth: 600mm
  - Crop factor: 0.9 to 1.1 (season dependent)
- Soil Water Characteristics:
  - Field capacity: 28%
  - Permanent wilting point: 15%
  - Total available water: 101.4mm
  - Percentage saturation 92%[1]
  - Saturation level 287mm
  - LTAR 7mm/day
- Maximum Total Nitrogen Loading: < 210kg/ha/year
- Maximum Total Phosphorus Loading: < 42kg/ha/year

Irrigation Options

Since the soil in the area is slow draining and the hydraulic capacity will be greatly reduced during wet weather events, the required irrigation area or storage volume would be very large and uneconomic. Hence, the treated effluent during wet weather events would need to be stored and in the rare occasions when the storage becomes full, the excess treated effluent will need to be disposed into the harbour.

1 Recommended in NZ Land Treatment Collective 2000

Four irrigation options were considered to estimate the irrigation area requirements and balancing storage volume:

1. Option 1 – All treated Dry Weather Flow (DWF) to land irrigation, with wet weather flow balanced in a storage lagoon
2. Option 2 – Treated DWF during May to September discharges to the Akaroa Harbour with remaining DWF to irrigation
3. Option 3 – Treated DWF during May to August discharges to the Akaroa Harbour with remaining DWF to irrigation
4. Option 4 – Treated flow during April to September discharges to the Akaroa Harbour with DWF to irrigation in summer months.

The estimated area and storage requirements are presented in Table 5.4b.

Table 5.4b: Estimated Irrigation Area and Storage Volume from the Soil-Water Modelling (ecoEng, Jan 2010)

Options	Land Area (Ha)	Storage Volume m3	Ave. OF(1) days/yr	TN Loading kg/ha/yr	TP Loading kg/ha/yr
Option 1 (All DWF to Irrigation All Year)	26	8000	10	207	41
Option 2 (DWF to Irrigation Oct –Apr)	20.5	5200	10	205	41
Option 3 (DWF to Irrigation Sep–Apr)	21.5	5200	10	206	41
Option 4 (DWF to Irrigation Oct-Mar)	18.5	4520	10	203	41

Note: *"Ave. OF" is average overflow days per year. Constructed wetland will be required for Option 1.*

As presented in Table 5.4b, the required irrigation area ranges between 18 to 26 hectares and the storage volume ranges between 4500 and 8000m^3.

The Akaroa South site appears to have sufficient irrigable area to cater for all four irrigation options in the above table. Further assessment was made to evaluate the location options for storage reservoir, irrigable areas and wastewater treatment plant. The irrigation report recommended that the overflow from the treated effluent storage reservoir during storm events and winter months be discharged into the harbour via a series of constructed wetlands and drop structures. Figure 5.4 presents the location options considered for the Akaroa South site.

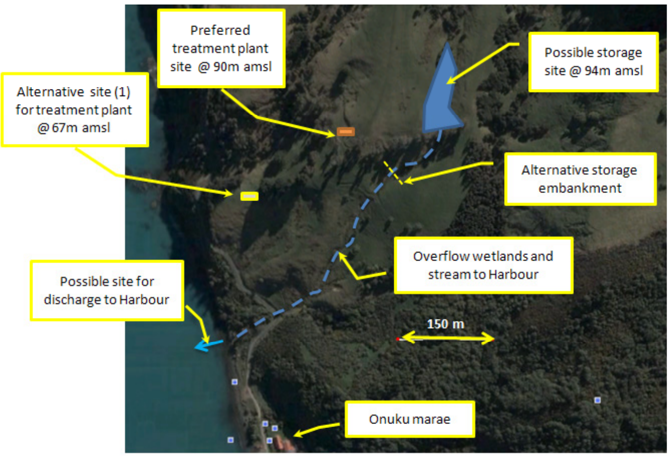


Figure 5.4: Akaroa South Storage Reservoir, Treatment Plant and Irrigation Area Location Options (ecoEng, Jan 2010)

5.5 Treated Effluent Quality for Irrigation

This section presents the required treated effluent quality for irrigation. Two irrigation options were considered, All ADWF to Irrigation and Hybrid Option.

All DWF to Irrigation

The following table (Table 5.5a) presents a comparison of the current discharge standards and the proposed future discharge standards for all Dry Weather Flow (DWF) irrigation.

Table 5.5a: Comparison of Current and Proposed Final Effluent Quality for Akaroa WwTP (Effluent Irrigation)

Parameters	Current Discharge Standards at Akaroa WwTP (Median)	Proposed Final Effluent Quality for Akaroa WwTP for Irrigation		
		From Irrigation Investigation	*Proposed Discharge Standards (Median)*	*Likely final effluent quality (Median)*
BOD5 (mg/L)	< 30	< 20	< 20	< 18
TSS (mg/L)	< 30	< 20	< 20	< 18
TN (mgN/L)	-	< 22	< 22	< 20
AmmN (mgN/L)	-	-	-	< 5
TP (mgP/L)	-	< 4	< 4	< 4
Faecal Coliform (/100mL)	< 1000	< 1000	< 1000	< 1000

The proposed discharge standards for BOD5 and TSS are lower than those in current discharge permit because of reducing the risk of biological build-up and clogging in the irrigation pipework. This risk could be further minimised by placing fine filters at the irrigation site.

There are no nitrogen and phosphorus limits in the current discharge permit; the proposed total nitrogen and total phosphorus discharge standards have been determined based on restricting the nitrogen and phosphorus loading on the irrigation area to 210kgTN/ha/year and 42kgTP/ha/year respectively.

The wet weather flow will be temporarily stored, the treated effluent will be discharged to the harbour under prolonged wet weather conditions.

Hybrid Disposal (Irrigation and Harbour Discharge)

A hybrid effluent disposal option, involving irrigation during summer months and harbour outfall discharge via constructed wetlands during winter months and wet weather events, was also considered.

Under this effluent disposal scenario, the proposed discharge standard presented in Table 5.5a will apply during summer months (October to March) and the proposed discharge standards for Harbour discharge will apply during winter months (April to September), refer to Table 5.5b (the figures are re-produced from Table 4.9).

- Recreational area / sites e.g. golf course or reserve
- Agricultural use – cut and carry

Different landuse options are presented in the irrigation assessment report (ecoEng, Jan 2010). It should be noted that these land use options have not been assessed in details as limited information was available.

Table 5.5b: Proposed Final Effluent Quality for Harbour Discharge

	Proposed Final Effluent Quality for Akaroa WwTP for Harbour Discharge		
Parameters	***From Dispersion Modelling***	***Proposed Discharge Standards (Median)***	***Likely Final Effluent Quality (Median)***
BOD5 (mg/L)	< 500	< 30	< 20
TSS (mg/L)	-	< 30	< 20
TN (mgN/L)	< 40	< 30	< 10
AmmN (mgN/L)	< 350	-	< 2
DIN(mgN/L)	< 8	< 6	< 6
TP (mgP/L)	< 10	< 8	< 8
DRP (mgP/L)	< 5	< 4	< 4
Faecal Coliform (/100mL)	< 3000	< 1000	<1000
Enterococci (/100mL)	< 19000	< 1000	<1000

5.6 Land Use Options

Land use of the irrigable areas has significant impacts on the selection of irrigation technology, cost and layout. A number of land use options may be applicable for Akaroa irrigation scheme. They include:

- Tree production:
  - Short-term coppice for biofuels
  - Medium term coppice firewood
  - Long term timber crops
  - Specialist nursery

5.7 Issues and Risks for Irrigation System

The following risks and issues need to be taken into consideration for the effluent irrigation at Akaroa.

Land Owner Acceptance

The landowners of the sites investigated agreed to the site assessment stage. There has been no agreement with land owners to the use of their land for irrigation of the wastewater. Further discussion and negotiation will be required.

Should land owners refuse to co-operate this would present a major obstacle to progressing this option. To mitigate this risk, a sound communication and consultation process is required and best practicable design is essential.

Cultural and Social Issues

Discussions and consultation with the Rununga on the issue of proposed site location, overflow and harbour discharge is in progress.

In the event that this option does not achieve Iwi and/or general community acceptance, this option may not succeed. To mitigate this risk, a sound communication and consultation process with the Iwi and general community is required and best practicable design is essential.

Construction Risks

The main construction activities at the irrigation sites will be installation of pipelines, pump and control headworks and the large storage ponds. As the site is not in built-up areas, impacts from dust and noise are unlikely to be significant. Risks to the environment during construction will be mostly as a consequence of the earthworks to construct the storage ponds, and overflow wetlands. The key risk will be sediment laden stormwater runoff to adjacent streams. Mitigation measures during construction to minimise sediment runoff during construction is recommended.

Operational Risks

The following table summarises the key operational risks and recommended mitigation measures.

Table 5.7: Irrigation Operational Risks Summary (ecoEng, Jan 2010)

Risk	Mitigation measures
Soil saturation leading to runoff and contamination to surface water and ultimately to the Akaroa Harbour	Automated on-demand irrigation is recommended: soil moisture sensors in the irrigation field will determine whether or not irrigation will occur. If the soil moisture is too high the wastewater will be retained in the storage pond.
Slope Instability	Further geotechnical investigation, monitoring and groundwater modelling are required to determine the risk of slope instability. Staged development with site monitoring is recommended.
Overflow from the storage pond	Should it be decided to implement staged development, overflow frequency to the harbour will be higher in the initial years. As the irrigation is extended in accordance to the results from the scheme monitoring, less overflow to the harbour can be anticipated. It is recommended that the overflows from the storage reservoir be discharged via a series of constructed wetlands and drop structures providing additional storage and treatment before being released to the Harbour.
Nutrient build-up in the receiving soils.	Nutrient loading (nitrogen (N) and phosphorus(P)) has been modelled. N loading is within acceptable rates while P loading is considered high. Land use management is recommended to achieve maximum nutrient uptake. Riparian planting adjacent to nearby surface water bodies is recommended. Soil nutrient monitoring is recommended.

Table 5.7: Irrigation Operational Risks Summary (ecoEng, Jan 2010)

Risk	Mitigation measures
Heavy metal build-up in the receiving soils	Heavy metal concentration tends to be an issue when industrial wastewater enters the wastewater stream. Wastewater from Akaroa (and Takamatua) is all domestic. Furthermore most heavy metals are concentrated in the treatment plant biosolids, which will not be applied to the proposed irrigation sites.
Release of pharmaceuticals into the environment	This study has investigated the risk to the receiving environment of pharmaceuticals in the treated wastewater. The research reviewed indicates that at the application rates proposed, the majority of pharmaceuticals in domestic wastewater will breakdown rapidly in the topsoil profile.
Odour for the storage ponds	The wastewater being stored in the ponds is aerated secondary effluent which present a low odour risk . The ponds will also be sited several hundred metres away from permanent residences.
Mosquito and insect breeding and swarms in the ponds	The pond edges will be at batters of 3(horizontal) to 1 vertical and lined with a plastic liner. Therefore the ponds will be an unsuitable habitat for mosquito and insect breeding.
Aerosols from irrigation sites	Where aerosols are a potential risk subsurface irrigation, rather than over head sprinkler irrigation is recommended.
Contamination of groundwater wells and springs	Safe and conservative setback distances between water supply bores and springs are recommended.

Consentability and Ecosystem Effects

Application of wastewater onto and into land will require a Resource Consent to discharge under Section 15 of the Resource Management Act (RMA)

The relevant Canterbury Regional Council rules that apply Section 15 are the Transitional Regional Plan (TRP), the proposed Natural Resources Regional Plan (NRRP) and the notified Variation 14 (of Rule WQL8) of the NRRP, Environment Canterbury.

These rules identify a number of potential risks. These include:

- Risk to groundwater and surface water
- Risks to community water supplies
- Risks to public health
- Effects on air quality
- Effects on cultural and historical values
- Surface ponding, flooding and slope stability

The site selection and preliminary design of the irrigation system will take these and other factors into consideration.

5.8 Conclusions of Effluent Irrigation Investigation

Based on the above assessment, the findings are as follows:

- Within the criteria specified, the site assessment identified approximately 32 hectares of irrigable land area within the Akaroa South site. To achieve this, it has been necessary to extend elevation and slope criteria to 350m and 20° respectively.
- It appears that the irrigable area is sufficient for all irrigation options considered including all year round DWF irrigation.
- However, it is recommended that for purposes of consenting, the land irrigation of the treated wastewater be initially operated on a relatively low load basis during which the water table and

stability would be carefully monitored over the first years of operation to determine if loadings can be progressively increased.

- Therefore, two irrigation options for the Akaroa South site are carried forward:
  - All year round DWF irrigation with operating as a hybrid disposal option in the initial years
  - Hybrid irrigation option with irrigation in summer months and harbour discharge during winter months and prolonged wet weather periods.
- Field instruments will be installed to monitor parameters such as water table fluctuation, soil moisture etc of the selected irrigable areas.
- There are a number of possible sites for both the treatment plant and the storage reservoir. A more detailed site assessment is recommended to optimise and finalise the sites.
- At this stage, the unknown issues are whether this site presents any significant cultural concern for the Rununga and access to this land will be subjected to successful negotiations between the Christchurch City Council (CCC) and the respective landowners.
- The recommendations from the irrigation report are:
  - Additional geotechnical monitoring that were recommended by Geotech Consulting Limited (in progress).
  - Further discussion and negotiations with the landowners of the South Akaroa site is recommended to gain formal agreement on terms of future access and management of the irrigable land area and sites for the storage reservoir, treatment plant and overflow channel.
  - Further detailed evaluation of optimum land use management options.
  - Further detailed nutrient budgeting and assessment of land use options for the preferred irrigation sites.

From the above assessment, a number of wastewater treatment and effluent disposal options were conceived for further evaluation in this study (Section 6.0):

1. Upgrade existing treatment plant with all DWF irrigation in Akaroa South.
2. Upgrade existing treatment plant with hybrid disposal option (land irrigation during summer and harbour discharge in winter) in Akaroa South
3. New wastewater treatment plant with all DWF irrigation in Akaroa South
4. New wastewater treatment plant with hybrid disposal option in Akaroa South

6.0 WASTEWATER INFRASTRUCTURE UPGRADES

6.1 Wastewater Plant Options

From the outfall and irrigation assessments presented in Section 4.0 and 5.0, a number of wastewater options were considered to be not feasible due to insufficient irrigable areas or poor acceptance by the community. Table 6.1 is a summary of the wastewater options considered in this study.

Table 6.1: Akaroa Wastewater Options Summary

Options	Existing Site	Relocate to Akaroa North	Relocate to Akaroa South
Near-shore outfall	Not considered due to poor acceptance by the community and potential environmental effects		
Mid-harbour outfall only	√	Not Feasible	√
Irrigation Only (including wet weather)	Not considered because of insufficient irrigable areas.		
All DWF to Irrigation	√ (Irrigation in Akaroa South)	Not Feasible	√
Hybrid Option (Summer to Irrigation, Winter to Mid-Harbour Outfall)	√ (Irrigation in Akaroa South)	Not Feasible	√

Notes: *From the geotechnical assessment, relocation to Akaroa North is not feasible.*

Hence, a total of six wastewater options were considered:

- Remain at Existing Site:
    1. Upgrading existing treatment plant and a mid-harbour discharge
    2. Upgrading existing treatment plant and a all DWF irrigation system at Akaroa South
    3. Upgrading existing treatment plant with a hybrid disposal option (mid-harbour outfall and irrigation at Akaroa South)
- Relocate to Akaroa South:
    4. Upgrade conveyance network, new treatment plant and mid-harbour discharge of treated effluent in the Akaroa South Site
    5. Upgrade conveyance network, new treatment plant and all DWF irrigation in the Akaroa South site
    6. Upgrade conveyance network, new treatment plant and hybrid disposal in the Akaroa South site

This section presents an assessment of conveyance and treatment plant upgrades in Akaroa for the scenarios of existing site and new treatment plant site.

6.2 Treated Effluent Quality

Based on the outfall and irrigation assessments presented in Section 4.0 and 5.0, Table 6.2 summarises the required treated effluent quality for the following effluent discharge options:

- Harbour Outfall Discharge;
- All ADWF to Land Irrigation; and
- Hybrid Option (Summer ADWF to Irrigation and Winter to Harbour).

Table 6.2: Proposed Treated Effluent Quality (Median Values) in Akaroa

	Harbour Outfall	All ADWF to Irrigation	Hybrid Option	
			Summer (Oct to Mar)	*Winter (Apr to Sept)*
BOD5 (mg/L)	< 30	< 20	< 20	< 30
TSS (mg/L)	< 30	< 20	< 20	< 30
TN (mgN/L)	< 30	< 22	< 22	< 30
DIN(mgN/L)	< 6	-	-	< 6
TP (mgP/L)	< 8	< 4	< 4	< 8
DRP (mgP/L)	< 4	-	-	< 4
Faecal Coliform (/100mL)	< 1000	< 1000	< 1000	< 1000
Enterococci (/100mL)	< 1000	-	-	< 1000

6.3 Upgrades At Existing Site

6.3.1 Conveyance Upgrades

A review of the existing conveyance network in Akaroa was undertaken as part of the previous evaluation (MWH, Oct 2008). No additional evaluation has been carried out as part of this study.

A new wastewater collection system will be built in Takamatua and the wastewater will be pumped from a central pumping station to the Akaroa reticulation network via a 2.6km rising main. It is assumed that the rising main will directly connect to the Reserve Road Pumping Station and some minor upgrades and operational changes of the main pump stations at Akaroa may be required.

The engineering details including inflow & infiltration (I&I) study will be examined as part of the detailed reticulation network design.

6.3.2 Treatment Plant Upgrades

The existing treatment process is based on a trickling filtration process followed by UV disinfection, and the treated effluent is discharged into the harbour.

A total of five treatment plant upgrade options were considered:

- Plant Expansion by Increasing Trickling Filter Capacity
- Solids Contact Process with Biological Nutrient Removal
- Modified Ludzack-Ettinger Activated Sludge Process
- Sequencing Batch Reactor (SBR)
- Membrane Bioreactor (MBR)

Below is a brief description of the plant upgrade options.

Option 1 Plant Expansion by Increasing Trickling Filter Capacity

Process Description

A new trickling filter with plastic media will be installed downstream of the existing trickling filter, which will increase the plant's hydraulic and organic capacity.

Under this option, the effluent from the Imhoff tanks will be treated by existing trickling filter, which becomes a high rate filter, for organic removal. The new trickling filter will receive the effluent from the first trickling filter and converts ammonia into nitrate. The trickling filter effluent will flow into the existing clarifier for sedimentation. Liquid alum will be dosed at the clarifier inlet to form phosphorus precipitates for phosphorus removal.

The clarified effluent will be dosed with methanol and pumped to three new denitrifying sandfilters for denitrification. The filtered effluent will be disinfected by the UV before outfall disposal.

The waste sludge and backwash will be stored in the Imhoff tanks and the humus tank. A new sludge thickener will be installed to thicken the waste sludge before the thickened sludge is taken offsite for further processing and disposal.

Plant Operation During Construction

The existing process will continue to operate while new plant components are being built.

After the new treatment process units are built, the new plant configuration will be commissioned.

Option Evaluation

The option has the advantage of maintaining the existing process configuration but it will be unreliable in maintaining consistent removal of nitrogen as required. Methanol dosing will increase the operating costs and further complicate health and safety issues. In addition, the additional process units are unlikely to be accommodated at the existing site.

Option 2 Solids Contact Process with Biological Nutrient Removal

Process Description

Under this option, a biological nutrient removal (BNR) activated sludge process will be installed downstream of the existing trickling filter to increase plant capacity and achieve nutrient removal.

The existing trickling filter will be operated as a high rate trickling filter to achieve organic removal. The trickling filter effluent will flow into an activated sludge basin which consists of a modified Ludzack-Ettinger (MLE) configuration for biological nitrogen removal. The reactor tanks will contain media to increase the biofilm surface area thus resulting in a compact reactor. Liquid alum will be dosed into the reactor basin to form phosphorus precipitates.

The mixed liquor from the reactor basin will flow to the secondary clarifier for solids/liquid separation. Clarified effluent will pass through cloth media filters for tertiary solids removal during wet weather events. The filtered effluent will be disinfected by an UV unit.

The excess sludge will be stored in the Imhoff tank. A new sludge thickener will be installed to thicken the waste sludge before being taken offsite for further processing and disposal.

Plant Operation During Construction

The trickling filter process will continue to operate while the activated sludge reactor basin is being constructed. The ancillary building (blower room) and chemical storage and dosing system will also be built.

After the new treatment process units are built, the new treatment configuration can be commissioned.

Option Evaluation

This option has advantages including efficient utilisation of existing assets while achieving higher effluent quality. It also has lower operating cost compared to other activated sludge processes. The drawback of this option is that supplementary carbon dosing into the activated sludge reactor will be required but this can be mitigated by bypassing a portion of the screened wastewater to the reactor basin.

Option 3 Modified Ludzack-Ettinger Activated Sludge Process

Process Description

Under this option, the existing trickling filter tank will be demolished and two new activated sludge reactor basins will be built.

The screened wastewater will flow into one of the Imhoff tanks for primary clarification before being split equally to the two new activated sludge reactor tanks. The reactor tanks will be in a modified Ludzack-Ettinger (MLE) configuration, consisting of anoxic cells followed by aerobic cells. Blowers will be used to provide air for the aerobic process. Liquid alum will be dosed in the aerobic cells for forming phosphorus precipitates.

Recycle pumps will be installed to return the nitrate-rich mixed liquor from the aerobic cells to the anoxic cells. The secondary clarifier will separate the final effluent from the mixed liquor through sedimentation. Clarified effluent will pass through cloth media filters for tertiary solids removal during wet weather events. The filtered effluent will be disinfected by an UV unit.

The waste sludge will be stored in the Imhoff Tanks. A new sludge thickener will be installed to thicken the waste sludge before being taken offsite for further processing and disposal.

Plant Operation During Construction

One of the new bioreactors will be built while wastewater is continued to be treated by the existing process. After the first bioreactor tank is commissioned to receive and treat the wastewater, the existing humus tank and trickling filter will be demolished and the second bioreactor tank will be built.

The ancillary building (blower room) and chemical storage and dosing system will also be built.

Option Evaluation

The advantage of this option is consistent effluent quality and reliable operation. However, this option makes little use of the existing assets resulting in higher capital costs and it has a higher operating cost than the solids contact option (Option 2) because of higher aeration requirements.

Option 4 Sequencing Batch Reactor (SBR)

Process Description

Under this option, the existing trickling filter, clarifier and humus tank will be demolished and two new sequencing batch reactor basins will be built. SBR is a variant of the activated sludge technology in which the reactor basins will undergo fill, aerate, mix, settle and decant phases.

The screened wastewater will be split equally to the two reactor tanks. Each reactor tank will have two compartments, pre-anoxic and main reactor cell. Recycle pumps will be installed to return the nitrate-rich mixed liquor from the main reactor compartments to the pre-anoxic compartments. Decanters will be installed in the SBR basin to decant the clarified effluent. A new decant tank will be built to buffer the decant flows. The SBR effluent will then be pumped to the cloth media filters for tertiary solids removal and will be disinfected by an UV unit. Liquid alum is dosed into the SBR basins to form phosphorus precipitates.

The Imhoff tanks will be used as sludge storage tanks. A sludge thickener will be installed to thicken the waste sludge and the thickened waste sludge is taken offsite for further processing and disposal.

Plant Operation During Construction

One of the new SBR basins will be built while wastewater is continued to be treated by the existing process. After the first SBR tank is constructed and it will be commissioned to receive and treat the wastewater, the existing tanks will be demolished and the second reactor tank will be built.

The ancillary building (blower room) and chemical storage and dosing system will also be built.

Option Evaluation

SBR plants are more tolerant towards variable loads than other processes. Due to the flexibility in cycle durations, higher hydraulic loads can be accommodated. However, this option, like Option 3, has little use of the existing assets in this option and it is likely to be more expensive in terms of capital and operating costs.

Option 5 Membrane Reactor (MBR)

Process Description

Under this option, two new membrane bioreactor basins will be built east of the existing trickling filter. MBR is a variant of the activated sludge technology in which the activated sludge is separated by membrane filtration units instead of secondary clarifiers. The bioreactor tanks in the MBR processes are usually smaller because it operates at a higher mixed liquor suspended solids (8 to 10g/L) which could be detrimental to sludge settling in the secondary clarifiers for other activated sludge processes.

Similar to Option 3, the screened wastewater will flow into one of the Imhoff tanks for primary sedimentation and the clarified wastewater will be split equally to the two reactor tanks. Each reactor tank will consist of an anoxic cell followed by an aerobic cell, like an MLE configuration in Option 3. Recycle pumps will be installed to return the nitrate-rich mixed liquor from the aerobic cells to the pre-anoxic cells. The mixed liquor will be separated by the membrane filtration modules. As the membrane modules act as physical barrier for solids and pathogens, additional tertiary solids removal process and UV disinfection is not required. The existing clarifier will be converted as a storm flow storage tank.

Liquid alum will be dosed into the aerobic cells to form phosphorus precipitates.

The Imhoff Tanks will be used for storing waste sludge. A thickener will be installed to thicken the waste sludge and the thickened waste sludge will be taken offsite for further processing and disposal.

Plant Operation During Construction

One of the new MBR basins will be built while wastewater is continued to be treated by the existing process. After the first tank is constructed and it will be commissioned to receive and treat the wastewater, the existing plant will be decommissioned and the second bioreactor tank will be built.

The ancillary building (blower room) and chemical storage and dosing system will also be built.

Option Evaluation

MBR processes often deliver higher effluent quality as it does not rely on sludge settling characteristics to produce clear effluent. However, there is low reuse of the existing assets in this option and it is likely to be more expensive in terms of capital and operating costs. Moreover, as the membrane modules can operate with a fixed range of throughput, it is likely that a larger flow balancing tank may be required.

Process Options Comparison

Table 6.3.2a summarises the issues of various plant upgrade options considered for the existing site.

Table 6.3.2a: Upgrade Options Evaluation Summary – Existing Site

	Option 1 TF Expansion	**Option 2 Solids Contact**	**Option 3 Activated Sludge**	**Option 4 SBR**	**Option 5 MBR**
Robust Process		√	√	√	√
Reuse existing asset	√	√			
Capital Cost	Lower	Lower			
Operating Cost		Lower			
Fit in the existing site	No	√	√	√	√ (Excluding storm tanks)
Recommended		**Y**			

As presented in Table 6.3.2a, the option of Solids Contact Process with BNR allowance not only meets the treatment objectives, but also allows reuse of existing assets, resulting lower capital and operating costs than other options. Hence, this option is the preferred option.

Concept Design of the Treatment Plant Upgrade

Table 6.3.2b presents a summary of the proposed treatment plant upgrades.

Table 6.3.2b: Summary of Plant Upgrades at Existing Site

Parameters	Existing Set-Up	Proposed Upgrade	
		Upgrades	***Reasons***
Inlet Screen	60L/s	94L/s	Capacity increase
Primary Treatment	Two Imhoff Tanks	-	No upgrade is required.
Biological Treatment	BOD5 removal by Trickling Filter	Maintain the trickling filter and build a new AS reactor with submerged media	New AS reactor will achieve biological nitrogen removal.
Chemical Dosing	None	Liquid alum and acetic acid dosing system will be installed.	Liquid alum is used for chemical phosphorus removal. Acetic acid is used for supplementary carbon source for denitrification.
Clarifier	A 12m diameter clarifier	-	No upgrade is required.
Tertiary Treatment	UV Disinfection, 60L/s	Cloth media filter will be installed upstream of UV unit. Upgrade of UV Unit	Filter will provide extra protection of UV unit in terms of solids interference. Higher disinfection performance is required.
Sludge Processing	Storage in Imhoff Tank.	Imhoff Tank will continue to store and consolidate primary sludge and secondary sludge.	Additional sludge storage volume for flow increase and change of process configuration.
Other Upgrade Works		New blower room	Supply air to the activated sludge basin

Below is a discussion of the proposed upgrades:

- Inlet Screen – The existing inlet screen is rated for 60L/s (MWH, Feb 2008) and is lower than the projected peak hourly flow in 2041 (94L/s). A new step screen will be installed to replace the existing unit.
- Imhoff Tanks and Trickling Filter – These units are the existing treatment process and they will be used to reduce the amount of organic loads to the biological process.
- Bioreactor Basin – The basin will be constructed east of the existing clarifier and trickling filter. This basin will be arranged in two parallel process trains, consisting of anoxic and aerobic reactor cells. The basin size is approximately 14m by 7m with submerged media. This process is designed to achieve nitrification (converting ammonia into nitrate) and denitrification (converting nitrate into nitrogen gas). As the denitrification requires readily degradable organic, this will be met by a portion of screened wastewater bypassing the humus tank and trickling filter and acetic acid addition as a supplementary carbon source.
- Blower Room – A new blower room will be constructed adjacent to the new reactor basin. Blowers will be installed to provide air supply to the aerobic biological process.
- Chemical Storage and Dosing – Liquid alum (47%w/w) will be stored on site and added into the activated sludge basin for chemical phosphorus removal. An acetic acid storage tank will also be built.
- Clarifier – The existing clarifier is found to have sufficient capacity to handle the projected flows in 2041. Thus, no upgrade is required.
- Tertiary Cloth Media Filter – A new tertiary cloth media filter will be installed downstream of the clarifier. This unit will be used to remove solids spikes in the clarified effluent, typically experienced during storm events, to avoid adverse effects of the downstream UV unit.
- UV unit – An upgrade to the UV unit will be required to achieve higher order of disinfection.
- Sludge consolidation in Imhoff Tanks – The tanks are used for consolidating the primary and trickling filter sludge at present. The tanks will be used for consolidating the primary sludge and a portion of the secondary waste sludge in the future.
- Sludge Thickening – A thickener (12m^3/h) will be installed to thicken the sludge to 4 to 5%DS and will be stored in a 30m^3 PE tank.
- Sludge Disposal – Thickened sludge will be transported offsite for further processing and disposal similar to the existing set-up.

6.3.3 Effluent Discharge and Disposal

All Year Round Harbour Outfall Discharge

The existing outfall pipe will be demolished and replaced with a new mid-harbour outfall pipe 1600m long into the harbour. This reduces any potential effects in the near shore recreational activities including shellfish gathering.

All Year Round DWF Irrigation Option

Under this option, the existing outfall pipe will be de-commissioned. The treated effluent will be pumped to the new irrigation field of approximately 26ha in Akaroa South. The effluent will be stored in a storage reservoir (a lagoon) at the irrigation field before being irrigated. During extreme wet weather where the fields are saturated and the storage lagoon is full, the treated effluent from the treatment plant will be discharged to the harbour via a new mid-harbour outfall pipe taking the overflow from the storage pond to the harbour via a series of constructed wetlands and drop structures.

However, it is proposed to lower the irrigation volume in the initial years to monitor the effects on the water table and stability before gradually increasing the loading to allow all year round DWF irrigation. Therefore, the effluent disposal in the initial years will be similar to a hybrid effluent disposal option.

Hybrid Disposal Option

This option is similar to the DWF irrigation option except the existing outfall pipe will be replaced with a new mid-harbour outfall pipe. A smaller storage lagoon (~4500m^3) and irrigation area (~19ha) will be developed at the Akaroa South site. During summer months, the treated effluent will be pumped from the treatment plant to the storage lagoon at the irrigation field.

During winter months and extreme wet weather, the treated effluent will be directly discharged into the harbour via the new mid-harbour outfall pipe at the treatment plant.

6.4 Upgrades for Akaroa South Options

This subsection discusses the upgrade requirements for Akaroa South.

6.4.1 Conveyance Upgrades

Below is the assessment on the information presented in the previous reports (MWH, Oct 2008).

This new site is located about 2km south of the existing treatment plant. The conveyance to transfer the wastewater from the township to the new site requires a long distance pipeline and high pumping head due to terrain.

Modifications will be made to the Glen pumping station and a new rising main will be built to convey the wastewater along the Onuku Road to the new treatment site in the south. Intermediate pumping stations would be required to overcome the pressure head.

The wastewater collection and conveyance from Takamatua to the Akaroa reticulation network for this option will be similar to the option of remaining at the existing site (Refer to Section 6.3.1).

Details of the pump station and rising mains will need to be examined in the engineering stage.

6.4.2 Treatment Plant Upgrades

The following treatment processes were considered for the scenario of relocating the treatment plant to a new site (Akaroa South):

- Modified Ludzack Ettinger Activated Sludge Process
- Sequencing Batch Reactor Process
- Membrane Bioreactor Process

Below is a brief description of the options. The existing treatment plant will continue to be operated while the new treatment plant is being constructed.

Option 1 Modified Ludzack-Ettinger Activated Sludge Process

Under this option, a treatment plant based on MLE activated sludge process will be constructed in Akaroa South.

The wastewater will be pumped to the inlet works at the new site, which consists of an automatic step screen followed by grit removal unit. The preliminary treatment prevents accumulation of large and heavy solids in the downstream reactor basins.

The screened wastewater will be equally split between two activated sludge basins. The basins are configured based on a MLE process, which consists of anoxic cells followed by aerobic cells. The nitrate-rich mixed liquor in aerobic cells is returned to the anoxic cells for denitrification. Liquid alum will be dosed in the aerobic cells to form phosphorus precipitates.

Two secondary clarifiers will be built for secondary clarification. Clarified effluent will pass through the cloth media disc filters prior to UV disinfection.

Since the wastewater flow is expected to increase over 3 folds during peak summer, the biomass inventory could be built up through restricted wasting and incremental increase in loads.

The excess sludge from the biological process will be stored in WAS tanks before it is thickened to 4 to 5%DS. The thickened sludge will be transported to Bromley WwTP for further processing and disposal.

Option 2 Sequencing Batch Reactor (SBR) Process

Under this option, a treatment plant based on the SBR process will be constructed.

The wastewater will be pumped to the inlet works at the new site, which consists of an automatic step screen followed by grit removal unit. The preliminary treatment prevents accumulation of large and heavy solids in the downstream reactor basins.

The screened wastewater will be equally split between two SBR basins. The basins consist of pre-anoxic zones followed by main reactor zones. Decanters will be installed in the SBR basin to decant the clarified effluent. A new decant tank will be built to buffer the decant flow. The SBR effluent will then be pumped to the cloth media filters for tertiary solids removal and will be disinfected by an UV unit.

Liquid alum will be dosed in the aerobic cells to form phosphorus precipitates.

Since the wastewater flow is expected to increase over 3 folds during peak summer, the biomass inventory could be built up through no wasting and incremental increase in loads.

The excess sludge from the biological process will be stored in WAS tanks before it is thickened to 4 to 5%DS. The thickened sludge will be transported to Bromley WwTP for further processing and disposal.

Option 3 Membrane Bioreactor

Under this option, a treatment plant based on the MBR process will be constructed.

The wastewater will be pumped to the inlet works at the new site, which consists of an automatic step screen followed by grit removal unit. The preliminary treatment prevents accumulation of large and heavy solids in the downstream reactor basins.

The screened wastewater will be equally distributed between two bioreactor trains. The bioreactor tanks in the MBR processes are usually smaller because it operates at a higher mixed liquor suspended solids (8 to 10g/L) which could be detrimental to sludge settling in the secondary clarifiers for other activated sludge processes. Each reactor tank will consist of an anoxic cell followed by an aerobic cell, like an MLE configuration. Recycle pumps will be installed to return the nitrate-rich mixed liquor from the aerobic cells to the pre-anoxic cells. The mixed liquor will be separated by the membrane filtration modules. As the membrane modules act as physical barrier for solids and pathogens, additional tertiary solids removal process and UV disinfection is not required.

Liquid alum is dosed in the aerobic cells to form phosphorus precipitates.

Since the wastewater flow is expected to increase over 3 folds during peak summer, the biomass inventory could be built up through no wasting and incremental increase in loads.

The excess sludge from the biological process will be stored in WAS tanks before it is thickened to 4 to 5%DS. The thickened sludge will be transported to Bromley WwTP for further processing and disposal.

Process Options Comparison

All three treatment options considered would deliver similar treated effluent quality, with lower suspended solids from the MBR process. However, the MBR option would require the membrane system to be over-sized to treat the wastewater flow during summer peaks and wet weather periods. In addition, the MBR option has slightly higher operating costs attributed to the scouring aeration, cleaning chemicals and membrane replacement.

SBR process is commonly used in places where there are significant variations in flow as the cycle length in the SBR basins can be adjusted to suit the incoming wastewater flow. However, the range of hydraulic throughput and the tight nitrogen removal requirement would require a storage basin for untreated diluted wastewater, which could be an odour source. Therefore, this option is less preferred.

The activated sludge process with clarifiers is the preferred option as the capital and operating costs are expected to be slightly lower than the other two options.

Table 6.4.2a summarises the comparison of the three treatment options.

Table 6.4.2a: Upgrade Options Evaluation Summary – New Site

	Option 1 Activated Sludge	**Option 2 SBR**	**Option 3 MBR**
Robust Process	√	√	√
Capital Cost	Slightly lower		
Operating Cost	Slightly lower		Higher
Peak Flow Management	Clarifiers	Storm Flow Lagoon	Over-size MBR & Storm Flow Lagoon
Recommended	**Y**		

Concept Design of the Treatment Plant Upgrade

Table 6.4.2b presents a summary of the proposed treatment plant upgrades.

Table 6.4.2b: Summary of Plant Upgrades in Akaroa South

Parameters	**Proposed New Treatment Plant**	
	Upgrades	***Reasons***
Inlet Screen	94L/s	Capable to handle peak hourly flow
Primary Treatment	-	No primary treatment required
Biological Treatment	Two reactor basins in parallel	To provide biological treatment
Chemical Dosing	Liquid alum and acetic acid dosing system will be installed.	Liquid alum is used for chemical phosphorus removal. Acetic acid is used for supplementary carbon source for denitrification.
Clarifier	Two clarifiers	To separate mixed liquor in offpeak and peak period
Tertiary Treatment	Cloth-Media Filter	Filter will provide extra protection of UV unit in terms of solids interference.
	UV Unit	UV Disinfection
Sludge Processing	Two WAS Tanks	Temporary storage of waste sludge
	Sludge Thickener	Thicken WAS to 4 to 5%DS
	One TWAS Tank	Storage of TWAS before transport
Other Upgrade Works	New electrical, control and blower room	

Below is a discussion of the proposed upgrades:

- Inlet Works – A new inlet screen and grit removal system will be installed.
- Activated Sludge Basin – The basin will be constructed to include two parallel process trains, consisting of anoxic and aerobic reactor cells. The reactor size is 27m by 18m. This process is designed to achieve nitrification (converting ammonia into nitrate) and denitrification (converting nitrate into nitrogen gas). The degradable organic required for denitrification will be met by influent organic in the screened wastewater and occasionally acetic acid.
- Blower Room – A new blower room will be constructed adjacent to the new reactor basin. Blowers will be installed to provide air supply to the aerobic biological process.
- Chemical Storage and Dosing – Liquid alum (47%w/w) will be stored on site and added into the activated sludge basin for chemical phosphorus removal. An acetic acid storage tank will also be installed.
- Clarifiers – Two clarifiers (10m diameter) will be constructed to provide sufficient capacity to handle the projected flows in 2041.
- Tertiary Cloth Media Filter – A tertiary cloth media filter will be installed downstream of the clarifier. This unit will be used to remove solids spikes in the clarified effluent, typically experienced during storm events, to avoid adverse effects of the downstream UV unit.
- UV unit – A UV unit will be installed downstream of the tertiary filter to provide disinfection.
- Sludge consolidation in WAS Tanks – The tanks will be used for consolidating the waste sludge.
- Sludge Thickening – A thickener (16m^3/h) will be installed to thicken the sludge to 4 to 5%DS and will be stored in a 30m^3 PE tank.
- Sludge Disposal – Thickened sludge will be transported offsite for further processing and disposal similar to the existing set-up.

6.4.3 Effluent Discharge and Disposal

Three effluent disposal options were considered, mid-harbour outfall option, All DWF to Irrigation and hybrid disposal option.

All Year Round Harbour Disposal

Under the mid-harbour outfall option, an outfall pipe will be built which extends 1,900m from the shoreline. The outfall pipe will be connected to the outlet of the treatment plant.

All DWF to Irrigation

Under this scenario, a new irrigation field of 26ha and a storage lagoon volume of 8000m^3 will be built.

The irrigation assessment indicated that there is sufficient irrigable area in South Akaroa provided that areas with steeper slope (20°) and higher elevation are included. Further discussions with prospective landowners are recommended to confirm the availability of the irrigation areas.

The treated wet weather flow will be stored in the lagoon under this option. When the lagoon becomes full under extreme circumstances, the treated wastewater will overflow into an overflow channel consisting of a series of constructed wetlands and drop structures before being discharged into the Harbour via a mid-harbour outfall.

It has been recommended by the irrigation report (ecoEng, 2010) that a lower irrigation volume will be applied in the initial years, particularly during winter months to observe any effects on the water table and stability by allowing some of the effluent to discharge to the harbour via the overflow channel. Therefore, this scheme will be similar to the hybrid disposal option in the initial years.

Hybrid Disposal (Irrigation in Summer Months Only)

For hybrid disposal option of irrigation and harbour outfall, an irrigation area of 18.5ha and 4500m^3 storage volume will be required for effluent irrigation during summer months (October to March). The wet weather flow and winter flow are discharged into the harbour via an overflow channel consisting of a series of constructed wetland and drop structure followed by a new mid-harbour outfall.

7.0 OPTION COMPARISON

The investigation of harbour discharge (Section 4.0) concluded that the mid-harbour outfall options are more favourable than the near-shore outfall options due to higher dispersion and dilution, lower near-shore effects and higher acceptance by the community.

The irrigation assessment (Section 5.0) examined the feasibility of effluent irrigation in Akaroa North and Akaroa South. It was found that effluent irrigation in Akaroa North is not feasible as the potential sites are either unsuitable or not available. Treated effluent disposal in Akaroa South would be necessary to include steeper slope (<20°) and higher elevation (<350m). From the site assessment, the Akaroa South site has sufficient irrigable areas for both "All DWF to Irrigation" option and Hybrid Disposal Options. It has been recommended that allowing harbour discharge in winter months in the initial years in the "All DWF to Irrigation" option, this is to reduce the effluent loading on the irrigation area. Any potential effect on the water table and stability will be monitored and the irrigation volume loading is expected to be progressively increased.

This section presents a comparison of issues, risks and costs associated with wastewater conveyance, treatment and effluent disposal requirements for the following options:

1. Treatment Plant Upgrade at Existing Site with Mid-Harbour Outfall
2. Treatment Plant Upgrade at Existing Site with All Year Round Irrigation in South Akaroa (Dry Weather Flow Only)
3. Treatment Plant Upgrade at Existing Site with Hybrid Disposal in South Akaroa (Irrigation in Summer and Mid-Harbour Disposal in Winter and Wet Weather)
4. Treatment Plant Upgrade at Akaroa South with Mid-Harbour Outfall
5. Treatment Plant Upgrade at Akaroa South with All Year Round Irrigation (Dry Weather Flow Only)
6. Treatment Plant Upgrade at Akaroa South with Hybrid Disposal (Irrigation in Summer and Mid-Harbour Disposal in Winter and Wet Weather)

7.1 Preliminary Cost Estimates

The section presents the indicative capital and operating cost estimates for various service scenarios.

Capital Cost Estimates

The capital cost estimates for the wastewater options are presented in Table 7.1a, which is on the following page.

Table 7.1a: Akaroa Wastewater Options – Capital Cost Estimates ($M)

	Remain at Existing Site			Relocate to Akaroa South		
	Harbour Outfall	***All DWF Irrigation***	***Hybrid Disposal***	***Harbour Outfall***	***All DWF Irrigation***	***Hybrid Disposal***
Takamatua Reticulation	5.5	5.5	5.5	5.5	5.5	5.5
Akaroa Conveyance Upgrade	0.0	0.0	0.0	6.7	6.7	6.7
Treatment Plant Upgrade	4.4	4.4	4.4	9.1	9.1	9.1
Harbour Disposal	2.0	2.5	2.0	2.5	2.5	2.5
Irrigation Disposal	0.0	10.8	9.1	0.0	5.3	4.0
Total ($M)	***11.9***	***23.2***	***21.0***	***23.8***	***29.1***	***27.8***

Notes:

- *Akaroa Conveyance Cost for Relocation options include wastewater collection and conveyance from the Kaik area.*
- *Consenting and Land purchase costs are not included.*
- *The accuracy of the cost estimates presented above is +-15%*
- *The above items (other than land purchase) include Preliminary & General (10%), Design and Construction Monitoring (16%) and Contingency Sum (20%).*

As presented in Table 7.1a, the option of upgrading the existing treatment plant to allow mid-harbour outfall discharge is the most economic because existing infrastructure is utilised and only minimum new infrastructure is required. The cost is between $11 to 13M compared with the costs for other options which range between $20 to $30M.

Hence, it can be concluded that the baseline option (upgrading the existing treatment plant with a mid-harbour outfall) will cost approximately $12M, while relocating the treatment plant and irrigation to Akaroa South would cost additional $12 to 18M. Nonetheless, the additional cost of providing effluent irrigation for the upgraded existing site is in the order of $9 to 12M.

The following assumptions were used when estimating the capital cost estimates:

- Akaroa Conveyance – the estimates are based on the quantities from the previous investigation (MWH, Oct 2008) and include only the terminal pump stations and rising mains as upgrades for sewer pipes upstream of the pumping station are expected to be similar between the options.
- Conveyance for Takamatua – the cost includes providing a pressure sewer collection network, a main pump station and a conveyance pipeline. The budgetary cost for these assets is around $5.5M (inclusive of 20% contingency); the rates are from recent comparable projects.

- Conveyance for Akaroa South Relocation – this also includes a sewer collection network for the Kaik area and the indicative cost is around $860,000.
- Wastewater Treatment – the rates used for the plant equipment are based on recent projects in New Zealand.
- Land Purchase – The cost of land purchase has not been included.
- Harbour Disposal – the estimates are based on rates from recent comparable projects.
- Irrigation Disposal - the estimates are based on rates from recent project experiences and include irrigation equipment and storage lagoon.

Operating Cost Estimates

The estimated operating costs are presented in Table 7.1b below.

Table 7.1c: Akaroa Wastewater Options – Operating Cost Estimates

	Remain at Existing Site			Relocate to Akaroa South		
	Harbour Outfall	***All DWF Irrigation***	***Hybrid Disposal***	***Harbour Outfall***	***All DWF Irrigation***	**Hybrid Disposal**
Conveyance	17,000	17,000	17,000	63,000	63,000	63,000
WW Treatment	330,000	331,200	320,500	341,500	358,600	352,700
Effluent Disposal (Irrigation)	0	184,000	130,000	0	166,000	121,000
Total ($/yr)	***347,000***	***532,200***	***467,500***	***404,500***	***587,600***	***536,700***

The following assumptions were made when estimating the operating costs:

- Only the terminal pump station power cost is included in the "conveyance" items as limited information is known about the existing conveyance network and the power and maintenance costs upstream of the terminal pump station are similar between the options;
- Wastewater treatment plant operating costs are based on experiences from similar projects;
- Irrigation operating costs are based on experiences from similar projects.

Net Present Values

The net present values (NPV) estimate the total project cost for various options. The estimates have been estimated based on the following assumptions:

- Annual inflation of 3% pa
- Annual Discount Rate of 6% pa
- 31 Years Duration (2010 to 2041)

Table 7.1c presents the net present values for the Akaroa wastewater options.

Table 7.1b: Akaroa Wastewater Options – Net Present Values Estimates

	Remain at Existing Site			Relocate to Akaroa South		
	Harbour Outfall	***All DWF Irrigation***	***Hybrid Disposal***	***Harbour Outfall***	***All DWF Irrigation***	***Hybrid Disposal***
CapEx ($M)	11.9	23.2	21.0	23.8	29.1	27.8
OpEx ($/yr)	347,000	532,200	467,500	404,500	587,600	536,700
NPV ($M)	***18.7***	***34.1***	***30.5***	***32.0***	***41.2***	***38.8***

As presented in Table 7.1c, the option of upgrading the existing treatment plant with harbour outfall disposal has the lowest net present value due to lower capital and operating costs. The total project cost of implementing effluent irrigation in South Akaroa is between $12 to $20M higher.

7.2 Issues and Risks

7.2.1 Treatment Plant Location Options

Existing Location

The existing treatment plant site has the advantages of allowing maximum reuse of existing infrastructure and it has low visual impact due to screening by vegetation, but the available area for plant expansion is limited.

However, the site has significant historical and cultural importance, which is a factor to be considered in the final decision regarding plant relocation.

Relocate to Akaroa South

The Akaroa South site is located in the southern face of the Kaik and north of the Onuku Marae. Due to difficult rolling terrain, a number of pump stations will be required to convey the wastewater from the Glen pumping station at southern end of Akaroa township to the new treatment plant.

The site has medium visual impact from the harbour and the Onuku Road, hence plantation screening will be required. Given that the site is located far away from the township, it is expected to have minimal noise and odour impact on the residents, however best design practice must still be followed to minimise any possible impacts on the Onuku Marae. If this site is selected for relocating the treatment plant, odour dispersion modelling is recommended to assess the potential impact on the marae.

In addition, it is important to note that the near-shore area close to the Onuku Marae is used for kai moana. With a proposed mid-harbour outfall length of 1.5km, the potential effects on shore-based activities is likely to be minimal. A more detailed assessment will be carried out as part of the Assessment of Environmental Effects (AEE) study.

Relocating the wastewater treatment plant provides an opportunity for the Kaik area to connect into a public wastewater reticulation system. From the information provided, it is envisaged that up to 50 houses might be connected.

The new mid-harbour outfall pipe at Akaroa South is expected to have no more than minor effect on the shellfish (kai) gathering activities along the foreshore. This could be confirmed by further public health risk assessment.

Relocate to Akaroa North

Relocating to Akaroa North is not feasible due to lack of available land.

7.2.2 Effluent Disposal Options

Harbour Outfall Options

Currently the treated effluent is disposed via a near shore outfall pipe into the Akaroa Harbour. If the plant remains at the existing site, this will be replaced by a mid-harbour outfall.

However, there are considerable cultural concerns expressed by the local iwi groups for disposing effluent (human waste) into the harbour.

All Year Round Irrigation

Effluent contact with land is more culturally acceptable, however all year round irrigation including wet weather flow is not feasible in Akaroa as the general soil is very slow draining and rolling landscape in the area would result in increase of surface runoff and soil erosion. Therefore, options of irrigation all dry weather flow with storage lagoon were considered.

An integral part of all irrigation proposals will be that excess treated effluent overflow from the storage reservoir will pass through a series of constructed wetland cells prior to discharge into the harbour.

All Dry Weather Irrigation Option at Akaroa South

Under this irrigation option, the treated dry weather flow will be irrigated to land during summer with wet weather flow will be stored in storage lagoon. Under infrequent circumstances, the lagoon will overflow to the harbour when it is full. It is proposed that the overflow channel will comprise a series of constructed wetlands and drop structures before the effluent is discharged via a new mid-harbour outfall.

From the irrigation assessment, the South Akaroa site has sufficient irrigable area to irrigate all dry weather flow if areas with steeper slope (<20°) and higher elevation (<350m) are included.

In addition, it has been recommended that additional geotechnical monitoring to be carried out to monitor the water-table and stability issues of the prospective irrigation areas while reducing the loading on the irrigation fields by operating similar to the hybrid disposal options during the initial years.

Land availability for effluent irrigation is subject to negotiation between the Christchurch City Council (CCC) and the landowners.

Hybrid Disposal Options

The hybrid disposal options allow irrigation only during the summer and harbour discharge via a wetland treatment system during winter months and wet weather periods when the irrigation fields have less capacity and the recreation values in the Akaroa Harbour are lower, due to weather.

The Akaroa South site is expected to have sufficient area for the hybrid disposal option and the land availability subject to negotiation between CCC and the landowners.

7.3 Risks and Issues Table

A risks and issues table is presented in Appendix Six. The risks are evaluated based on "Likelihood" and "Consequence". The matrix is explained are below.

Likelihood Level	**Consequence Level**				
	Severe	***Major***	***Moderate***	***Minor***	**Negligible**
Almost Certain	***Very High***	***Very High***	High	High	Medium
Likely	***Very High***	High	High	Medium	Medium
Possible	High	High	High	Medium	Low
Unlikely	High	Medium	Medium	Low	Low
Rare	High	Medium	Medium	Low	Low

A summary of the risk analysis table is presented below (Table 7.3)

Table 7.3: Risk Evaluation Summary Table

		Remain at Existing Site			Relocate to Akaroa South		
Risks		***Harbour Outfall***	***All DWF Irrigation***	***Hybrid Disposal***	***Harbour Outfall***	***All DWF Irrigation***	***Hybrid Disposal***
Social	Visual Impact	Low	Medium	Medium	Medium	Medium	Medium
	Odour Impact	Low	Low	Low	Low	Low	Low
	Noise Impact	Low	Low	Low	Low	Low	Low
	Community non-acceptance towards site location	High	High	High	Medium	Medium	Medium
	Community non-acceptance towards effluent disposal	High	Medium	Medium	High	Medium	Medium
Cultural	Effect on Mauri	High	Low	Medium	High	Low	Low
	Cultural non-acceptance towards site location	Very High	Very High	Very High	Medium	Medium	Medium
	Cultural non-acceptance towards effluent disposal	Very High	Very High	High	Very High	High	High
Enviro	Adverse Effects on Harbour	Medium	Low	Low	Medium	Low	Low
	Adverse Effects on Recreation Water Users	Medium	Low	Low	Low	Low	Low
Feasibility	Consenting Process	High	High	High	High	High	High
	Land Availability	Low	High	High	Medium	High	High
	Restriction on Irrigation due to stability/ watertable	Low	High	Medium	Low	High	Medium
	Option Not Affordable	Medium	High	High	High	High	High

As presented in the risk analysis table in Appendix Six, the Hybrid Disposal Option at Akaroa South is expected to have the least high risk issues, however this option is more expensive and subjected to negotiations between the Christchurch City Council and the respective landowners.

The option of upgrading the existing treatment plant with mid-harbour outfall is considered as the "baseline" option in this study. Although it is the least expensive, its feasibility is dependent on acceptance by the community and iwi on the treatment plant location and effluent discharge route.

8.0 CONCLUSIONS

This study has examined and evaluated the issues and risks for a number of wastewater options to service Akaroa in future.

Akaroa Wastewater Treatment Plant is currently located at Red House Bay and the site has significant cultural and historical value to the community. Options of treatment plant relocation to Akaroa North and Akaroa South were shortlisted from previous investigations and have been further analysed in this study with respect to issues and risks associated with harbour outfall discharge and land irrigation.

The harbour outfall discharge assessment examined the near-shore outfall options, mid-harbour outfall options, tidal discharge options and hybrid discharge options. The mid-harbour outfall options and hybrid discharge options were preferred and they have been considered further in this study.

The effluent irrigation assessment reviewed the issues and risks associated with effluent irrigation in Akaroa North and Akaroa South. It was found that effluent irrigation in Akaroa North is not feasible due to lack of suitable and available irrigable land. Therefore, the irrigation assessment focused on the Akaroa South area only.

The "All DWF to Irrigation" options and the hybrid disposal options were examined and was found that about 26 and 18 hectares net irrigation area will be required respectively. The Akaroa South site is expected to have sufficient irrigable area

A total of six options were examined in detail, including conveyance, wastewater treatment and effluent disposal. They include:

1. Treatment Plant Upgrade at Existing Site with Mid-Harbour Outfall
2. Treatment Plant Upgrade at Existing Site with All DWF Irrigation at Akaroa South
3. Treatment Plant Upgrade at Existing Site with Hybrid Disposal (Mid-Harbour Outfall in winter by the treatment plant and pump to Akaroa South for irrigation in summer)
4. New Treatment Plant at Akaroa South with Mid-Harbour Outfall
5. New Treatment Plant at Akaroa South with all DWF irrigation
6. New Treatment Plant at Akaroa South with Hybrid Disposal (Irrigation in Summer and Mid-Harbour Disposal in Winter and Wet Weather)

The option of upgrading the existing treatment plant with a mid-harbour outfall discharge is considered as the "Baseline" option, but the associated social and cultural issues, especially the cultural and historical significance of the treatment site are important factors to be taken into consideration.

If the treatment plant is relocated to Akaroa South, the "All DWF to Irrigation" and hybrid disposal options both offer better attributes compared with the harbour discharge only option. However, the options have significantly higher capital and operating costs compared to the baseline option. It should be noted that the availability of potential irrigation areas are subjected to successful negotiation between CCC and the landowners. In addition, the irrigation assessment recommended that the "all DWF to irrigation" options will be operated as hybrid disposal options in the initial years to reduce the loading on the soil resulting lower risk of instability.

Table 8.0 presents a summary of costs, issues and risks identified for the wastewater options.

Table 8.0: Evaluation Summary of Wastewater Treatment and Disposal Options for Akaroa

WwTP Location Option	Effluent Disposal Options	Technical Issues (Feasibility)	Environmental Issues	Cultural & Social Issues	CapEx ($M)	Op Ex ($/y)	NPV ($M)	Major Risk Factors
Existing Site	Mid-Harbour Outfall	Limited area for plant expansion	Concern about harbour discharge	Significant cultural site, Harbour discharge not preferred	$12M	347,000	$19M	Cultural issues on the site location and harbour discharge
	All DWF Irrigation at Akaroa South	Limited area for plant expansion Difficult terrain for pumping effluent to Akaroa South for irrigation Potential run-off and slope stability issues	Low environmental risk from harbour discharge	Significant cultural site, Visual impact of the irrigation site, require screening	$23M	532,000	$34M	Cultural issues on the site location Slope stability issue at the irrigation field (reduction in available irrigable area)
	Hybrid Disposal (Irrigation in Summer/ Harbour Discharge in Winter)	Limited area for plant expansion Difficult terrain for pumping effluent to Akaroa South for irrigation	Lower environmental risk from harbour discharge	Significant cultural site, Visual impact of the irrigation site, require screening	$21M	468,000	$30M	Cultural issues on the site location
Akaroa South	Mid-Harbour Outfall	Difficult terrain for pumping for treatment	Concern about harbour discharge	Important cultural site, Harbour discharge not preferred	$24M	404,000	$32M	Cultural Issues on the site location and harbour discharge
	All DWF Irrigation	Difficult terrain for pumping for treatment Potential run-off and slope stability issues	Low environmental risk from harbour discharge	Important cultural site, Screening for WwTP & irrigation site	$29M	588,000	$41M	Potential cultural issues on the site location Slope stability issue at the irrigation field (reduction in available irrigable area)
	Hybrid Disposal (Irrigation in Summer/ Harbour Discharge in Winter)	Difficult terrain for pumping	Lower risk from harbour discharge	Important cultural site, Screening for WwTP & irrigation site	$27M	537,000	$39M	Cultural Issues on the site location

8.1 Further Studies

It is recommended that the following investigations and actions to be undertaken:

- Detailed geotechnical investigation will be required for consenting purposes. This will include detailed soils characterisation and stability analysis.
- Further assessment to evaluate the optimum land use management options of irrigable areas.
- More detailed nutrient budgeting and assessment of landuse options for the preferred irrigable areas.
- Hydrogeological modelling – This examines the irrigation water flow path in the soil and the fate and potential effects on the waterbody. This is expected to be required as part of consenting requirement.
- Landowner consultation.
- Preliminary engineering – Once CCC and the WP select the preferred option, preliminary engineering on the wastewater collection. Conveyance, treatment plant, outfall pipe and irrigation field are to be undertaken. This will also include flow monitoring and geotechnical investigation.

9.0 REFERENCES

1. EcoEng. Irrigation of Domestic Wastewater – Akaroa Options. 18 February 2010.
2. Geotech Consulting Ltd. Preliminary Geotechnical Appraisal of Potential Slope Stability Issues in relation to the proposed Wastewater Irrigation of Areas near Akaroa. 15 February 2010.
3. Golder Associate. Akaroa Wastewater Options Risk Analysis. 8 October 2009.
4. MWH. Akaroa Water Management Strategy. Part 6 - Wastewater Treatment Options. February 2008.
5. MWH. Akaroa Wastewater Selected Options 2008. October 2008.

10.0 LIMITATIONS

General

This report is for the use by Christchurch City Council only, and should not be used or relied upon by any other person or entity or for any other project.

This report has been prepared for the particular project described to us and its extent is limited to the scope of work agreed between the client and Harrison Grierson Consultants Limited. No responsibility is accepted by Harrison Grierson Consultants Limited or its directors, servants, agents, staff or employees for the accuracy of information provided by third parties and/or the use of any part of this report in any other context or for any other purposes.

Estimates

Should this report contain estimates for future works or services, physical or consulting, those estimates can only be considered current and will only reflect the extent to which the detail of the project is known to the consultant (feasibility, concept, preliminary, detailed, tender etc) at the time given.

The client is solely responsible for obtaining updated estimates from the consultant as the detail of the project evolves and/or as time elapses.

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APPENDIX ONE:

AKAROA WASTEWATER OPTIONS RISK ANALYSIS INFLUENT FLOWS AND LOADS

TECHNICAL MEMORANDUM

HARRISON GRIERSON CONSULTANTS LIMITED

To	**Simon Collin, Mike Bourke (Christchurch City Council)**
cc	**Andrew Dakers (Ecoeng), Mark Ellis (Golder Associates), Shane Dixon (Harrison Grierson)**
From	**Ian Ho and Ash Deshpande (Harrison Grierson)**
Date	**6th August 2009**
Re	**Akaroa Wastewater Options Risk Analysis – Influent Flows and Loads**
HG Ref.	**2150-128694-01**

This technical memorandum presents influent flow and loads to be considered in the design and risk assessment of Akaroa wastewater treatment and disposal options. Presented below is a detail derivation of the design flows and associated assumptions.

1.0 SUMMARY OF DESIGN BASIS

The following table (Table 1) presents a summary of design flows and loads to be considered for the Akaroa Wastewater Treatment Plant. For further details, please refer to the following sections.

Table 1: Akaroa Wastewater Options Risk Analysis – Design Basis Summary

Parameters	Values	
Design Horizon	2041	
Off-Peak Period ADWF (m^3/day)	382	
Peak Summer Period ADWF (m^3/day)	1625	
Maximum Daily Flow (m^3/day)	1795	
Peak Hourly Flow (L/s)	94	
Influent Pollutant Loads (kg/day)	**Off-Peak Period**	**Peak Summer Period**
BOD_5	122	520
TSS	122	520
TN	26	111
AmmN	17	73
TP	4.2	18

2.0 INFORMATION PROVIDED

The following information has been provided by Christchurch City Council (CCC) to date:

- Projection figures of permanent dwellings and holiday homes in Akaroa;
- Projection figures of permanent population in Akaroa;
- Suggested occupancy ratio during peak summer period;
- Projection figures of permanent dwellings and holiday homes and permanent population for Takamatua;

- Projection figures of commercial development;
- Water meter readings from existing commercial properties;
- Recent wastewater flow measurements (June 06 to Jun 09) from Akaroa WwTP.

3.0 POPULATION ESTIMATES

Table 2 below presents projected population growth in Akaroa up to the design horizon, 2041.

Table 2: Akaroa Population Projection Summary

	Households		Population		Commercial Properties
	Permanent	Holiday	Permanent	Peak Summer[2]	
2009	309	582	591	2919	136
2011	311	594	591	2967	142
2016	315	623	589	3080	156
2021	316	653	582	3194	173
2026	318	682	573	3301	188
2031	320	702	574	3382	200
2036	321	722	574	3462	210
2041	322	742	574	3542	221

Notes

1. The figures for permanent and holiday households, permanent population and non-residential developments are provided by CCC (email dated 23.07.09)
2. The peak summer population includes the permanent population and the holiday home population (number of holiday homes x 4 persons/house)

Table 3 below presents projected population growth in Takamatua up to the design horizon, 2041.

Table 3: Takamatua Population Projection Summary

	Households		Population	
	Permanent	Holiday	Permanent	Peak Summer[2]
2009	101	121	196	680
2011	102	124	198	694
2016	105	131	200	724
2021	107	137	201	749
2026	109	142	201	769
2031	111	146	204	788
2036	113	150	206	806
2041	115	155	209	829

Notes

1. The figures of permanent and holiday households and permanent population are provided by CCC (email dated 29.07.09)
2. The peak summer population includes the permanent population and the holiday home population (number of holiday homes x 4 persons/house)

4.0 WASTEWATER FLOW PROJECTION

Based on the recent influent flow data provided by CCC, the daily wastewater flow in Akaroa ranges between 50 and 2500m^3/day. It is understood that the flowmeter is faulty and the readings likely to be inaccurate. CCC is working with the flowmeter supplier to re-calibrate the flowmeter.

However, for the purposes of this study, it has been decided to disregard the flow measurements and consider typical New Zealand per capita wastewater generation rates.

The following assumptions have been made for estimating the design wastewater flows:

- The domestic wastewater flow will be based on a per capita generation rate of 200L/day. This applies to both off-peak (average) and peak summer conditions;
- The wastewater flow from commercial properties is assumed to be 90% of the water consumption;
- Commercial wastewater flow during off-peak periods is approximately 30% of the peak period;
- Peak period lasts for approximately 2 weeks;
- Takamatua will be connected to Akaroa wastewater system in 2011.

Tables 4 and 6 present the future design wastewater flows from Akaroa and Takamatua during off-peak and peak periods.

Table 4: Akaroa WwTP – Average Daily Wastewater Flow (Off-peak Period)

	Domestic		Commercial		Total WW Flow (m^3/d)
	Population[1]	Flow (m^3/d)	Accounts	Flow (m^3/d)[2]	
2011	789	158	142	145	303
2016	789	158	156	160	317
2021	783	157	173	176	333
2026	774	155	188	192	347
2031	778	156	200	204	360
2036	780	156	210	214	370
2041	783	157	221	225	382

Notes:
1. Akaroa plus Takamatua
2. 30% of peak period flow shown in Table 5

Table 5: Akaroa WwTP – Peak Summer Daily Wastewater Flow (Peak Summer Period)

	Domestic		Commercial		Total WW Flow (m^3/d)
	Population[1]	Flow (m^3/d)	Accounts	Flow (m^3/d)	
2011	3661	732	142	482	1214
2016	3804	761	156	532	1293
2021	3943	789	173	588	1376
2026	4070	814	188	640	1454
2031	4170	834	200	680	1514
2036	4268	854	210	714	1568
2041	4371	874	221	751	1625

Notes:
1. Akaroa plus Takamatua

The off-peak wastewater flow is expected to increase to 382m^3/day in 2041. Similarly, the peak summer wastewater flow is expected to increase to 1625m^3/day in the same period.

5.0 MAXIMUM DAILY FLOW AND PEAK HOURLY FLOW

Table 6 below presents the maximum daily flows and peak hourly flows.

The maximum daily flows have been derived based on 4.7 times the average daily flows in off-peak period. The peak hourly flows are based on 5 times the peak summer flows.

Table 6: Wastewater Flow Summary to Akaroa WwTP

Years	Off-peak Daily Flow (m^3/d)	Peak Summer Daily Flow (m^3/d)	Maximum Daily Flow (m^3/d)	Peak Hourly Flow (L/s)
2009	257	1046	1208	61
2011	303	1214	1424	70
2016	317	1293	1492	75
2021	333	1376	1565	80
2026	347	1454	1630	84
2031	360	1514	1690	88
2036	370	1568	1740	91
2041	382	1625	1795	94

6.0 INFLUENT CHARACTERISTICS

Table 6 below presents the influent characteristics and projected mass loads to the Akaroa WwTP.

In deriving the mass loads the following per capita rates have been assumed for domestic wastewater.

- BOD – 70 g/c/d ; TSS – 70 g/c/d ; TN – 15 g/c/d; Total Phosphorus – 2.5 g/c/d; (as per AS/NZS – 1546:3 (2000))
- Ammonia Nitrogen – 10 g/c/d (Lyttelton Harbour Wastewater Project);
- Wastewater from commercial properties are assumed to be similar in concentration as the domestic wastewater.

Table 6: Influent Characteristics (Akaroa and Takamatua)

Parameters	Influent Concentration	Projected Influent Pollutant Loads (kg/d)			
		Off-peak Period		Peak Summer Period	
		2009	2041	2009	2041
BOD_5	320 mg/L	82	122	335	520
TSS	320 mg/L	82	122	335	520
TN	68 mg/L	17	26	71	111
AmmN	45 mg/L	12	17	47	73
TP	11 mg/L	2.8	4.2	12	18

7.0 DESIGN EFFLUENT QUALITY

The final effluent quality will be driven by the effluent disposal route. Two disposal options (Harbour Discharge and Land Irrigation) will be assessed in this study. Further assessments and modelling will establish the required effluent quality.

Should you have any queries, please do not hesitate to contact the under-signed.

Ian Ho	Ash Deshpande
Process Engineer	Lead Process Engineer / Associate

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APPENDIX TWO:

AKAROA WASTEWATER OPTIONS RISK ANALYSIS

(GOLDER ASSOCIATES)

APPENDIX THREE:

IRRIGATION OF DOMESTIC WASTEWATER AKAROA OPTIONS

(ECOENG)

Ecological water and wastewater engineering

Irrigation of domestic wastewater

Akaroa Options

Draft Engineering Report

For Harrison and Grierson

by

Andrew Dakers

18 January 2010

DOCUMENT CONTROL SHEET

Client	Harrison and Grierson	Job #	090801Ak	
Project Title	Land Application of Wastewater			
Document Title	Irrigation of domestic wastewater: Akaroa Options Akaroa Options			
Document Ref.	091130AkD03			
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Contents

1.0 BACKGROUND

The application of treated wastewater to land is receiving increasing attention in NZ and other countries. With a growing focus of sustainability in all aspects of human endeavour, wastewater is seen as no longer a waste to be discharged but rather a resource to be better managed. This is not a new concept in NZ (Refer to section 1.2). One of the first guidelines for land application of wastewater was published in 1976 by the then NZ Department of Scientific and Industrial Research (DSIR. 1976). This early publication identified *a resurgence of interest in land as a means of effluent disposal, as a further treatment to remove constituents not removed by prior treatments, as a source of irrigation water, and as a means of recharging aquifers.* While most these principles still apply more 40 years later, there are additional drivers for land application of wastewater. In the context of management of Akaroa's wastewater stream these include some critical cultural risks and the sustaining both the healthy ecology of the Akaroa Harbour and vitality to local and regional economic activities.

To achieve successful land application of wastewater the DSIR Guidelines list the flowing key considerations:

- *Suitable soils.*
- *Suitable topography and hydrological conditions.*
- *Suitable climate.*
- *Efficient system design.*
- *Effective site preparation.*
- *Good management.*

In the case of the Akaroa project we would add to this list the following:

- Landowner and community acceptance.
- Tangata Whenua acceptance.
- Consentable (RMA, Public Health Act, Building Act).
- Economically and ecologically sustainable.
- Technically feasible.
- Land stability and other geotechnical risks
- Maintainable and serviceable using local capacity.
- Appropriate monitoring.

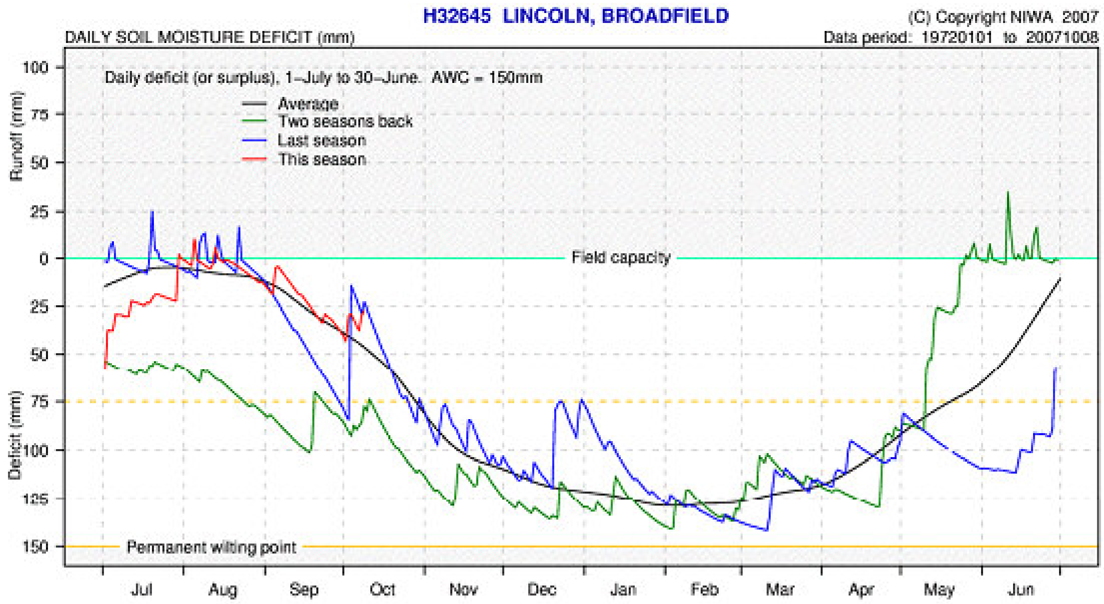
A more recent guideline published by Forest Research (NZ Land Treatment Collective. 2000) endorses the above criteria for successful land application of wastewater.

Domestic wastewater contains both water and dissolved and suspended constituents. The water component is a resource and its value will depend not only on its end use but also on the cost to supply it as a safe product. The dissolved and suspended components are both resources (e.g nutrients) and risks (e.g. pathogens, heavy metals, pharmaceuticals). The resource value of the wastewater nutrients will also depend on the actual end use and the cost per unit to supply the nutrients safely and conveniently.

The drivers for the increasing interest in reclaiming and realising the resource value of wastewater is the growth of human populations with increasing expectations in terms of living standards, and placing greater demands on limited non-renewable water and nutrient resources. In the context of Canterbury, there is increasing pressure on the limited water resources, and while a 2002 Lincoln Environmental report for Ministry of Agriculture and Fisheries, Canterbury Regional Council, Ministry for the Environment, suggested that *the region has enough water to meet foreseeable, reasonable water demands,* the report also noted that *water is not always in the right place at the right time,* and *large areas of Canterbury do not have ready access to a reliable water source.* (Morgan, 2002).

There are periods of significant soil moisture deficit within the Canterbury region. The closest climate station that provides this deficit data, is the Lincoln Broadfields site. Ecan's most recent publication on the state of the region's water resource (Martin and Williams, 2007), published daily soil moisture deficit data for the Lincoln Broadfields site. This is presented in Figure 1.

Figure 1. Water Deficit



Where water supply is expensive and in short supply, recovery of the water component in a wastewater stream can be an economic option. In Akaroa the limitations of the water supply is already restricting development (Sleeman, 2009).

Nutrients are another resource in wastewater. The eminent and well known (in the wastewater industry) Professor Emeritus of Civil Engineering, (University California, Davis), George Tchobanoglous, recently toured NZ (including Christchurch) and he referred to "peak phosphorous" and the high cost and scarcity of phosphorous presents globally to food security. At the moment many cities are pumping millions of cubic meters of wastewater with their increasingly valuable nutrients out to sea to be deposited in sea floor sediment and rendering these nutrients impracticable to recover. Furthermore there is increasing interest and research in phosphorus recovery from wastewater streams.

In their recent text on *Water Reuse*, Metcalf an Eddy (2007), not only list many case studied throughout the world where wastewater is being managed as a recyclable resource, but they provide full scientific and engineering details of technologies and the potential risks to public health and ecological systems.

2.0 WASTEWATER IRRIGATION IN NZ

2.1 OVERVIEW

The intent of this section of the report is to review existing effluent irrigated land treatment schemes in New Zealand.

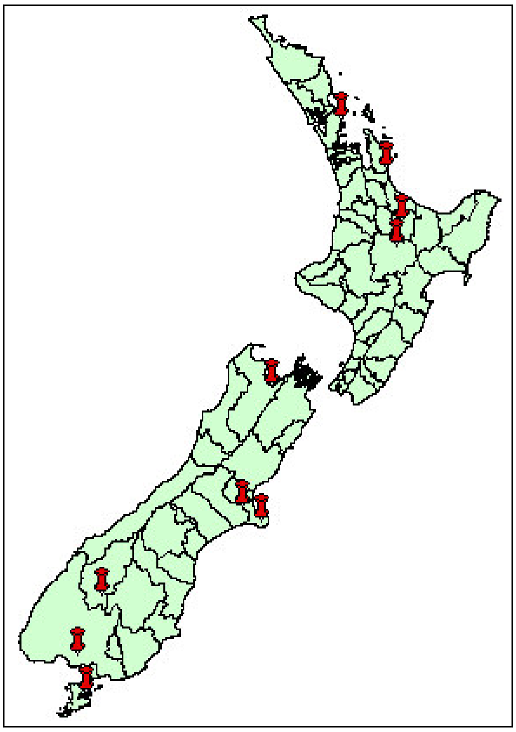
The systems reviewed have a maximum consented discharge of 20m^3 per day or greater and the effluent used in irrigation must be domestic and/or municipal wastewater.

2.2 LOCATION OF THE SCHEMES

Domestic and/or municipal effluent irrigated land treatment schemes that are currently employed in New Zealand are found in many regions all across the country. In the North Island, these systems can be found in the Auckland, Waikato, and Bay of Plenty Regions. The South Island has these systems in use in the Canterbury, Otago, Southland, Nelson, and Marlborough Regions. Figure 2 displays the effluent irrigated land treatment schemes currently in use for all of New Zealand.

There are a total of 12 effluent irrigated land treatment schemes reviewed, including one in the Chatham Islands. Many of the schemes were commissioned recently (in the past decade), with the most recent being in 2008; however, there were a few systems in operation from as early as 1958. In most cases the consent periods of these schemes were between 15-35 years.

Figure 2. Location of domestic wastewater irrigation sites in NZ



2.3 IRRIGATION, SOIL, AND WASTEWATER CHARACTERISTICS

Wastewater Characteristics

The total amount of discharge from the land treatment schemes ranged from an average daily dry weather flow of 460 m^3/day in Otautau to an average daily dry weather flow of 19000 m^3/day in Rotorua. The maximum consented discharge for the schemes ranged from 30 m^3/day in Tikao Bay to 15000 m^3/day in Taupo. In total, there were just over 330 ha of land being irrigated by domestic and/or municipal effluent with schemes ranging from 0.75 ha in Tikao Bay to 193 ha in Rotorua.

Soil Characteristics

The topography in most of the effluent irrigated land treatment schemes consisted of mainly level to moderately sloping land. There were areas within the schemes that were steep; however, most of the irrigation occurred on flatter ground due to high levels of surface runoff in steeper regions. The soils were typically well drained to moderately well drained and ranged distinctly from sandy-loam and silt loam to glacial till and volcanic soils.

Irrigation Techniques

Many of the effluent irrigated land treatment schemes were applying the treated wastewater using drip or subsurface drip irrigation and sprinkler-type systems. The daily application rates for these systems varied between 2 L/m^2 to a maximum of 15 L/m^2,(Note that L/m^2 per day is the same as mm/day). Storage was provided in the form of storage ponds for most of the effluent irrigated land treatment schemes, and on average they provided 1-2.5 days storage.

2.4 LAND USE AND FINANCIAL IMPLICATIONS

Land Use

For the majority of the schemes the main land cover consisted of exotic forests (including pine and Podocarp forests), followed by pasture (including harvested crops), and permanent non-harvested vegetation including golf courses and native bush. Table 1 depicts the percentage in which the land use and cover are dominated by exotic forests, pasture, or non-harvested vegetation by number of schemes and by a per hectare basis.

Table 1 Land Use and Cover (by number of schemes) versus Land Use and Cover (per hectare)

	Land use and cover	
	By number of schemes	By area
Non harvested vegetation	20%	4%
Pasture	40%	18%
Exotic forest	40%	78%

In Table 1 it can be noted that while there are the same amount of domestic and/or municipal effluent irrigated land treatment schemes in New Zealand that are planted with exotic forests as those that have pasture land, the area of land that these exotic forests occupy are by far the vast majority.

Costs and Returns

The bulk of the effluent irrigated land treatment schemes that were involved in this comparative study are council owned. The capital costs for these schemes ranged from $50,000 to $21,000,000 (Rotorua) and the operating costs ranged from $77,500 to $230,000 per year. Since the majority of these schemes were commissioned recently, none of the effluent irrigated land treatment schemes have reported any financial return. However, there is financial potential for all of the harvested crops involved in this study including exotic forests and pastures. Non-harvested crops such as golf courses could have some financial relief by using effluent as irrigation due to a decrease in fertilizer use.

2.5 PROBLEMS AND IMPACTS

There were very few problems experienced with these effluent irrigated land treatment schemes. The environmental impacts were found to be low and property values were not adversely affected. Many of the schemes reported an increase in the nutrient status of soils which resulted in stimulated growth in forests and improved quality of fairways in the golf courses.

In some cases, the nutrient loading from the irrigated effluent was greater than what was anticipated. The total nitrogen content of the irrigated soil was found to be higher than in the non-irrigated soil and there were also increases in carbon (C), nitrate nitrogen (NO_3-N), chlorine (Cl), sodium (Na), and calcium (Ca) noted in many irrigated soils. There were a few minor problems with the blocking of sprinkler heads and with ponding when a pump stopped which caused the effluent to backflow. However, these problems can be easily fixed with implementing mitigation measures such as wastewater treatment to decrease nutrient loadings and manage the form of applied N, vegetation management, irrigation management, and possible wetland modifications.

2.6 IRRIGATION OPTIONS

There are a number of different irrigation methods such as, flood irrigation systems, large centre pivot sprinkler systems, mini, micro and pop-up sprinklers systems and subsurface and surface dripper irrigation systems. The two that are likely to be recommended for detailed assessment are sprinkler irrigation (including pop-up if appropriate to the land use) and dripper line irrigation (surface and subsurface) systems. These types of system are better suited for rolling topography and lower application rates (as will be required for the soils on these sites). Table 2 is an adaption of Metcalf and Eddy's (2007) comparison of the attributes of these two options.

Table 2. Comparison of drip and sprinkler irrigation

Subsurface and drip irrigation	• High cost (about twice the sprinkler option. • More even subsurface moisture distribution – if well designed. • Higher irrigation efficiency. • Normally higher yields. • Highest level of health protection – no aerosol and odour risks. • Almost all crops can be grown. • Can interfere with cultivation, replanting and harvesting. • Root penetration may be a problem.
Sprinkler irrigation	• Normally capital lower cost compared to drip irrigation. • Medium irrigation efficiency. • Lower level of health protection. • Crops may suffer leaf damage. • Can interfere with cultivation. • Can be affected by wind causing distorted distribution patterns of the wastewater and aerosol drift.

The type of irrigation technology and layout chosen will depend on the following factors;

- Landuse.
- Topography.
- Ecological and public health risks to mitigate.
- Local management capacity.
- Capital and operating costs and availability of technologies.
- Climate and microclimate

Figure 3. Photos of two irrigation technologies

Subsurface irrigation dripperlines being installed on a golf course

Sprinkler irrigation system using movable pods: design for low application rates for wastewater.

3.0 SITE SELECTION

3.1 SITE SELECTION CRITERIA

In order to carry out this study it was necessary to identify possible sites within selected properties where the irrigation of the treated wastewater could be technically performed with the minimum social, cultural and environmental impact and risk, as well as maximum benefit.

The criteria used for the selection of possible sites included:

1. Land owner willing to allow access for site and soil assessment and in-boundary preference for the location of the irrigation field(s);
2. Geotechnical stability;
3. Suitable soil profiles;
4. Slopes less than 15 degrees with up to 20 degrees under certain circumstances;
5. Avoid low-lying wet areas;
6. Less than 250m above sea level;
7. Larger land parcels preferred;
8. Setback from surface water 20m;
9. 50m from water supply bores.
10. Suitable site for large storage facility.

An initial desk top study of the northern and southern sites was carried out. The criteria used for this study included criteria 4-9 as listed above. In Figures 4 and 5 the green areas indicate less than 15 degrees slopes while the orange shaded zones are 15 to 20 degrees. The figures are the areas of the green in ha.

Figure 4. Results of desktop study: Northern Site.

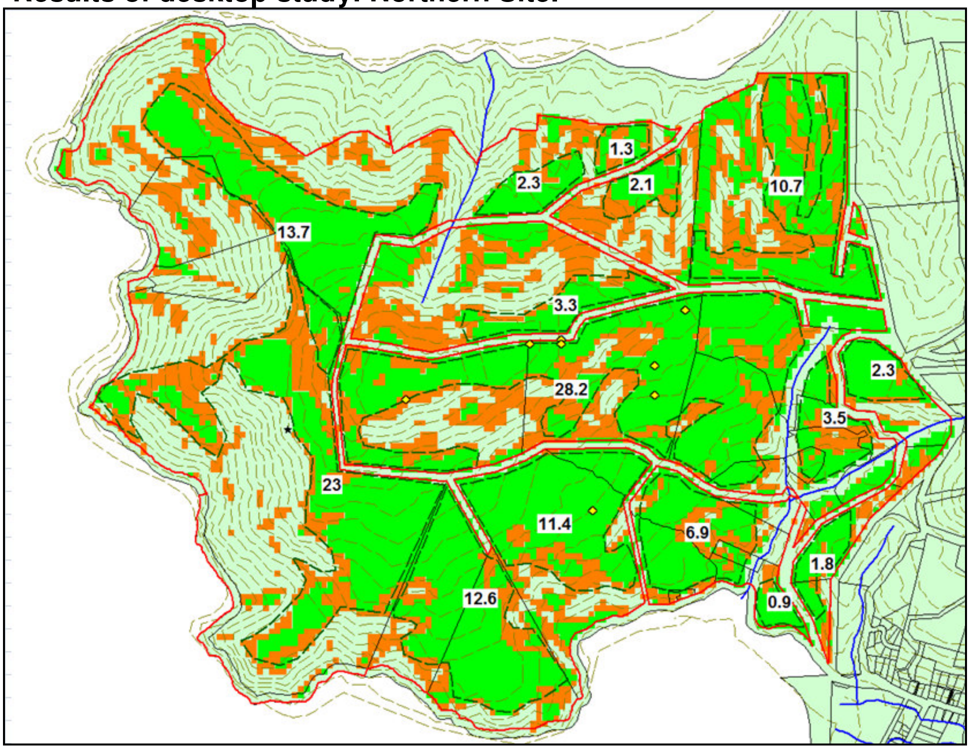
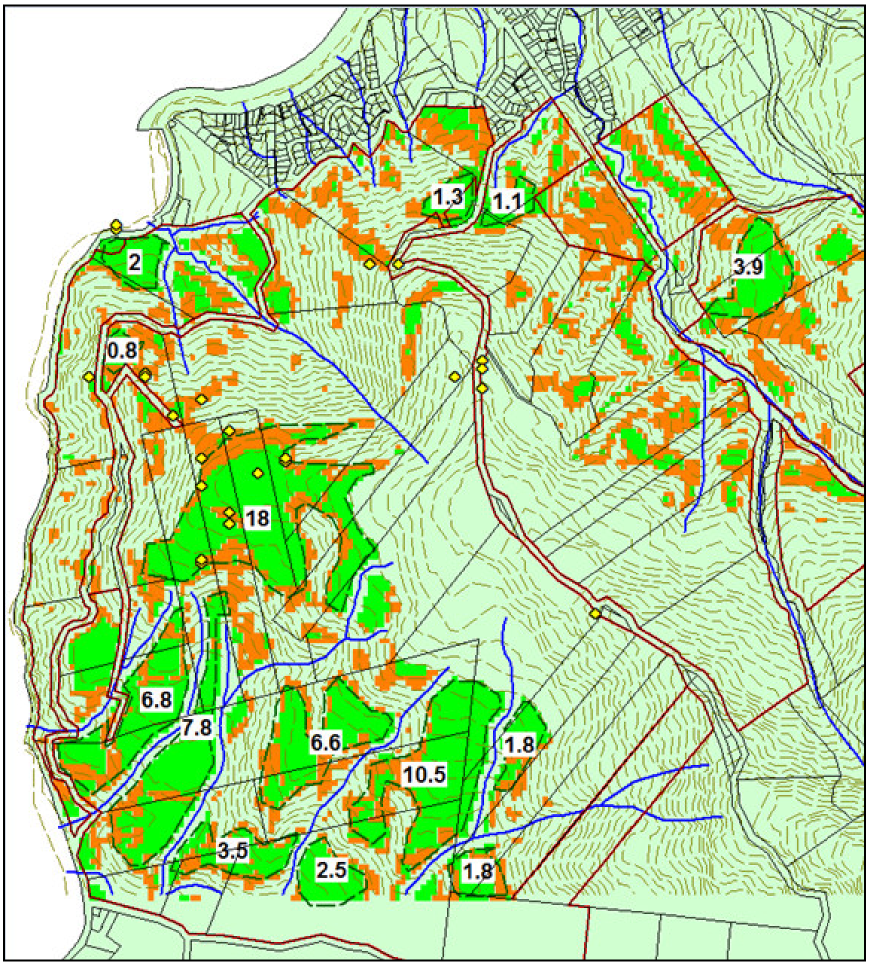


Figure 5. Results of desktop study: Southern Site.



Approval was obtained through Christchurch City Council to carry out site and soils assessment on three separate properties. Two of these properties were to the north of Akaroa (Northern Site while the third was to the south (Southern Site).

Note that the purpose of the desk-top study was to assist with deciding best areas to carry out the field assessment work. Site and soil investigations were carried out on the early August 2009. Assessment of geotechical mass stability was carried out in early October 09.

3.2 LAND ACCESS APPROVAL

A necessary pre-requisite to site assessment was obtaining land owner approval to access the land areas identified in the desk studies as potentially suitable. Land access approval was organised by the Christchurch City Council. Figures 6 and 7 illustrate those properties for which access was approved and denied.

Figure 6. Northern site access

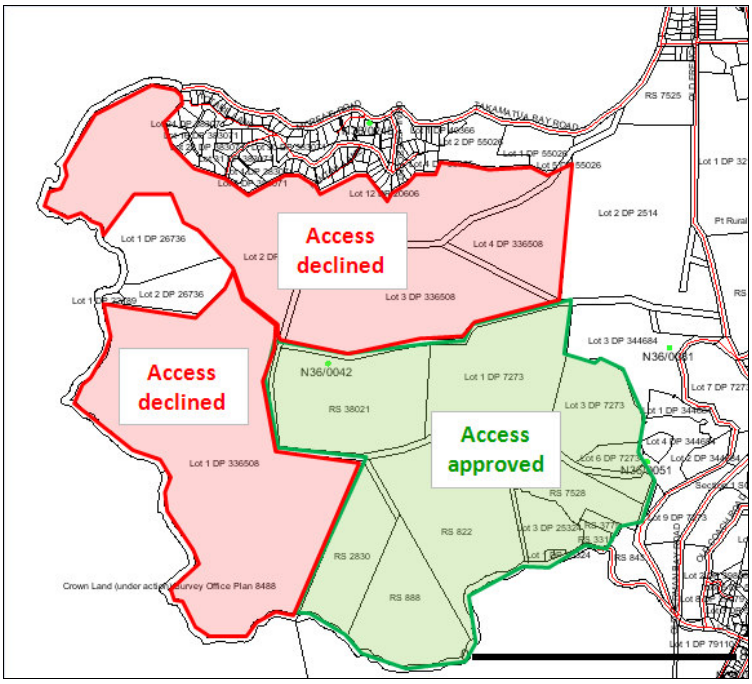
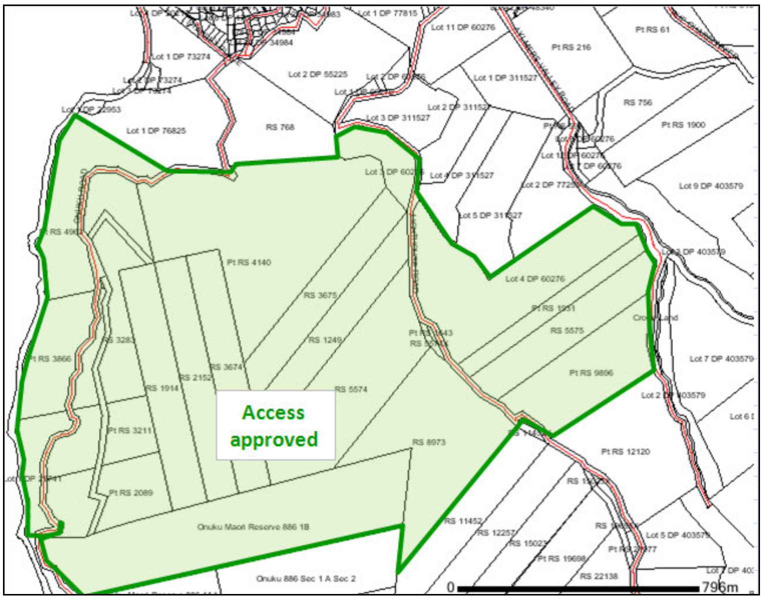


Figure 7. Southern site access



3.3 LAND STABILITY GEOTECHNICAL ASSESSMENT

On the 6 Oct Mark Yetton (geotechnical engineer with Geotech Consulting Ltd) carried out a preliminary assessment of the Northern site and Southern sites.

Geotech Consulting Ltd submitted a report (*Preliminary geotechnical appraisal of potential slope stability issues in relation to the proposed wastewater irrigation of areas of land near Akaroa. 1 Dec*ember 2009*)* which should be read in conjunction with this report. It is clear that this report will be significant in terms of the option selection process. The report advises that a significant proportion of the northern site is a large ancient landside, and the area encompassed by this landslide includes the proposed irrigation areas, site for the treatment plant and storage reservoir. The report further emphasises the potential increased risk of slope instability as a consequence of effectively doubling the rainfall on this south facing ancient deep seated landslide.

The report notes that Childrens Bay *has a significant and highly visible large ancient landslide, and some areas within it are actively growing despite modest rainfall since 1995.* The report advises against the inclusion of the area directly above Childrens Bay (The majority of the area shaded green in Figure 6)

There is clear evidence active land mass movement on the property (Lot 1 DP336508) to the west of the selected Northern site, (refer to Figure 8).

Figure 8. Active mass earth movement: Lot 1 DP336508

While the report found that the north facing slopes above Takamatua....*are the most suitable at the northern site* this area has been excluded as an option due to the land owner denying access (Refer Section 3.2).

The report advises that the best location from a geotechnical perspective for the application wastewater by irrigation *appears to be the southern site, and in particular the higher west facing sub - area (27 hectare area).* Geotech Consulting Ltd note that the land is stable and that the site *could be consented on the basis that it will be operated initially on a relatively low load basis during which the water table and stability would be carefully monitored over the first years of operation to determine if loadings can be progressively increased.*
If piezometers are installed in the best likely irrigation locations as soon as possible, and baseline readings taken of the normal seasonal water table fluctuations through the 2010 winter and during the consenting process, then reliable field information could be obtained on real water table impacts... which can be used in slope stability analysis.

In view of the option of the northern site being excluded due to denial of access to land above Takamatua by the land owner and the recommendation by Geotech Consulting Ltd that the land above Childrens Bay is geotechnically unsuitable, this remainder of the report focuses on the Southern site.

3.4 SOILS ASSESSMENT

The soils in the potential areas suitable for application land are predominantly yellow-grey to yellow brown earth soils classified as Pawson[1] - mostly silt loam. These soils are derived from sub-moderately argillised loess from schist and greywacke. These soils are liable to slope instability (sheet and slump erosion) on the steeper slopes. (See Figure 9).

Figure 9. Soil profile and slumping

Northern Site showing soil profile	Southern Site show slumping and erosion on slopes
	

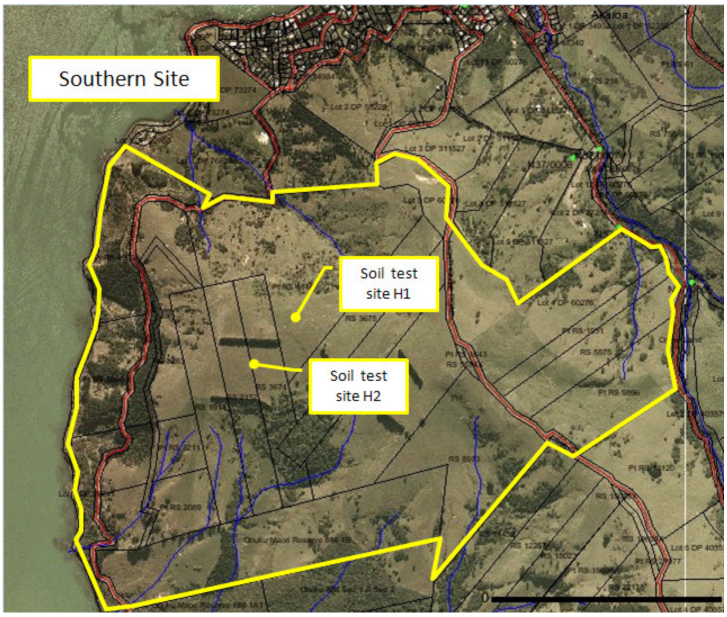
[1] Soil Map NZDSIR 1965: General survey of the soils of the South Island of New Zealand. Map 9.

Tow representative soil profiles (Figures 10) were studied in detail by soil scientist Dr Asoka Senarath to assess the suitability. Genetic soil horizons were identified in each soil profile. Their morphology and physical characteristics were studied up to a depth of one meter or more where possible. Soil samples were collected from each soil horizon for chemical analysis. In addition to the 4 major soil pits assessed, exposed embankments and smaller pits were observed.

Soil drainage characteristic were assessed in the field by using a constant head permeability test (using the Talsma-Hallam test) and the double ring infiltration test.

Chemical soil properties which are important to this study are being carried out by the Christchurch City Council laboratory and the Wastewater Treatment Plant.

Figure 10. Southern Site



Soil site H1 This is a deep, well drained soil having a 200 mm thick silt loam topsoil underlain by silty clay loam and silty loam sub surface soil (> 1 m). The topsoil properties are similar to that of profile R1.

The presence of strong brown mottling below 900 mm (BW3 horizon) is an indication of fluctuating water table at this level. However, a minimum of 700 mm (BW1+BW2 horizons) of soil depth with suitable soil textural and hydraulic conductivity properties is available for effluent purification process. The physical properties of the soil profile, particularly texture, structure and moisture regime is highly desirable for movement of water into and through the soil allowing considerable time for the process of effluent purification. The sub-surface characteristics of the disposal area are among the most important factors governing the performance of effluent treatment processes.

The presence of many grass roots indicates that there is good aeration in this horizon and hence good biological activity. This will help decomposition of organic material and nitrates present in wastewater.

The absence of colored mottling or gleying indicates that there is no influence of fluctuating water table in this zone.

There are no hard layers or pans which would prevent downward water movement, present in this soil. This soil has the best morphological and physical properties suitable for wastewater irrigation, compared to the other two soils.

Another soil profile was investigated at the same site and found to be the same as H1.

Soil profile description

Profile No.	H1
Drainage	Well drained
Ap	0-200 mm
	Dark brown (7.5YR 3/2); silt loam; friable; slightly sticky; slightly plastic; strongly developed fine to medium nuts plus granular structure; abundant fine grass roots; few earthworms; clear diffuse boundary.
Bw1	200-800 mm
	Brown (7.5YR 4/3); silty clay loam; friable; slightly sticky; slightly plastic; moderately developed fine to medium nutty; many fine and medium grass roots; clear smooth boundary.

BW2 800-900 mm

Light olive brown (2.5Y 5/4); silt loam; friable; slightly sticky slightly plastic; weakly developed medium nutty; very few fine grass roots; clear smooth boundary.

BW3 900-1100+ mm

Light olive brown (2.5Y 5/3); strong brown (7.5YR 4/6) mottles; silt loam; friable; slightly sticky slightly plastic; weakly developed medium nutty.

Soil site H2

The soils at the site were not significantly different to H1.

Soil drainage characteristics

The Talsma-Hallam constant head test for saturated hydraulic conductivity (Refer, AS/NZS 1547:2000) was used to determine the subsoil long terms acceptance rate (LTAR). The LTAR was used for the soil moisture modelling. (Refer to Section 1.5).

The double ring infiltrometer was used to gain a measure of surface infiltration.

The above hydraulic conductivity tests were done 2 days after several days of wet weather and the subsoils would have been near field capacity, although no saturated.

The results of the in-field hydraulic tests are given in Table 3 .

Table 3. Results of soil hydraulic tests

Site	Test Depth mm	K_{sat} mm/hr	LTAR (1) mm/day	Class	Ring Infiltrometer mm/hr
H1	220 - 420	10.6	15.22	Low	8.7
H2	170 - 410	6.0	14.09	Very slow	30.6

1. LTAR mm/day = 401.4k - 48.9/(.294+log k) where k_{sat} is cm/sec (Laak 1986)	
Talsma-Hallam Equipment 	Double Ring Infiltrometer 

Soil Stability

Many of the fine silty soils on the Banks Peninsula show slaking tendency and some are also dispersive. There was evidence, particularly on the Southern Site of surface instability and tunnel gully erosion. The Emerson test was done on 4 subsoil samples and three showed slaking tendency. The forth sample was stable. Slope stability was assess by Geotech Consulting Ltd. (Refer to separate report by Geotech Consulting, *Preliminary geotechnical appraisal of potential slope stability issues in relation to the proposed wastewater irrigation of areas of land near Akaroa. 1 Dec*ember 2009)

Soil bulk density (Table 5)

Soil bulk density ranged from 1.07 to 1.47 g/cm^3 for the Northern site and 1.07 to 1.34 g/cm^3 for the Southern Site.

Chemical Characteristics

For the southern site two soil pits were dug (Figure 10) and soil profile samples were taken and analysed for chemical characteristics, by the laboratory at the Christchurch City Council Wastewater Treatment Plant (Bromley) .

The profile samples are listed in Table 4

Table 4. Soil profile location

Soil Pit (Refer Fig. 10)	Profile label	Sample depth
Soil pit H1	H18/1	0 – 200 mm
	H18/2	500 – 800 mm
	H 18/3	800 – 900 mm
	H18/4	900 – 1100 mm
Soil pit H2	H24/1	0 – 250 mm
	H24/2	250 – 400 mm
	H24/3	400 mm – 600 mm
	H24/4	600 – 800 mm
	H24/5	800 + mm

The results of the soil chemical analyses are given in Table 5.

Table 5 Soil chemical characteristics

Sample	N%	C%	C/N	Cation (meq/100ml)					Base Sat	P Retention	Bulk Dens	pH
				Ca	K	Na	Mg	CEC	%	%	BD g/cm3	
H18/1	0.38	3.64	9.6	6.5	0.50	0.20	1.61	24.00	36.79	30	1.11	5.7
H18/2	0.13	1.19	9.2	5.6	0.38	0.18	1.78	16.00	49.56	28	1.07	6.0
H18/3	0.073	0.63	8.7	5.4	0.39	0.22	1.26	13.00	55.81	28	1.07	6.1
H18/4	0.019	0.28	14.8	5.7	0.11	0.28	2.45	12.00	71.35	25	1.34	6.3
H24/1	0.41	4.40	10.7	6.0	0.47	0.17	2.02	23.00	37.43	34	-	5.6
H24/2	0.14	1.53	10.9	1.7	0.27	0.09	1.03	15.00	20.87	37	-	5.5
H24/3	0.088	0.98	11.1	1.5	0.22	0.11	1.00	13.00	21.90	32	-	5.7
H24/4	0.043	0.54	12.6	1.5	0.11	0.19	1.38	13.00	24.21	29	-	6.0
H24/5	0.018	0.28	15.6	1.5	0.07	0.30	1.79	12.00	30.27	28	-	7.4

<u>Interpretation of the soils data</u>

The purpose of these tests was to gain an indicative picture of the nutrient and chemical status of the root zone soils at this site. Should this site be chosen for irrigation of the treated wastewater it is recommended that more detailed analyses of the soil chemical characteristics be carried to assist with irrigation management and nutrient budgeting to mitigate risk to soil structure and less-than-minor detrimental impacts on neighbouring ecosystems from nutrient export.

A summary interpretation of the results in Table 5 follows:

CEC - medium to low

Ca - medium to low

Mg - medium

Na - low

K - medium ton low

Base Exchange - medium to low

TN - variable – TS high, subsoil low

C/N - low

P retention - low.

Other comments:

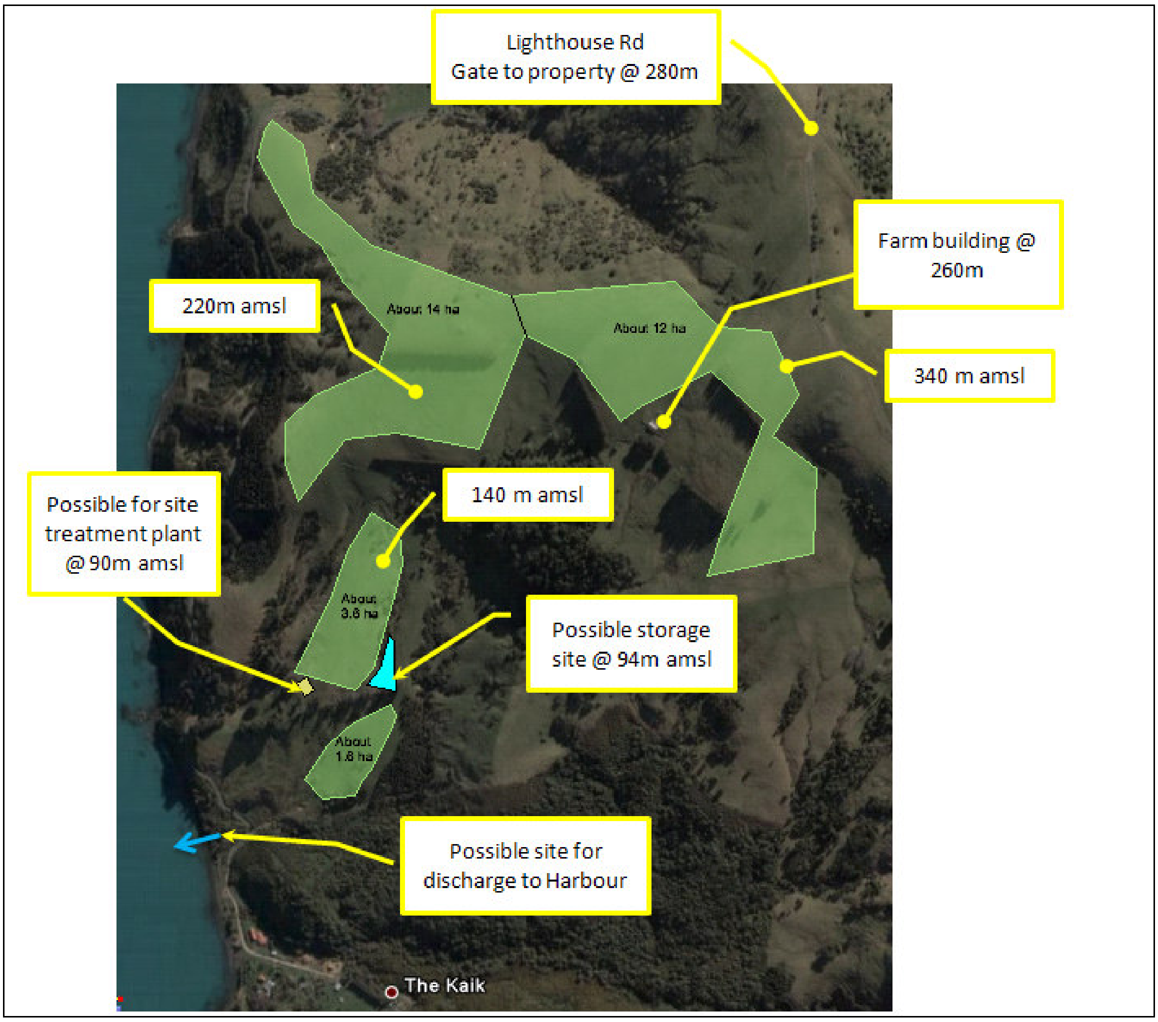
Low to medium CEC implies low to medium soil capacity to store plant nutrients. Irrigating with wastewater will increase organic content of the soils, which normally leads to higher CEC.

Low sodium implies low dispersive qualities

3.5 IRRIGABLE LAND AREAS

Figure 13 illustrates the irrigable areas for the southern site. The total available irrigable area is about 32 ha. All original criteria referred to in Section 3.1 have been met apart from slope and elevation. The maximum elevation permitted has extended to about 340m (cf original 250m) and the max slope used in selection of the irrigable area is 20 degrees (cf original 15 degrees) .

Figure 11. Irrigable areas for the southern site



3.6 SUMMARY OF KEY OUTCOMES

- Mass earth instability and land owner refusal to permit access has excluded that Northern site as an option for land application of the treated wastewater.
- The southern site can provide adequate irrigable area provided criteria for maximum permissible slope is 20 degrees and maximum elevation is 350m.

The above factors will be taken into consideration in the soil water modelling, Section 4.0

4.0 SOIL WATER MODELLING

A daily soil water model has been used to model soil moisture content and nutrients for the selected sites. This model allows the setting of site specific soil-water-plant rules and calculates the land area required and balancing storage required for the given wastewater volumes delivered to the site.

The monthly wastewater volumes (projected to 2041) inputted to the model are given in Table 6.

Table 6. Average Daily dry-weather flow for each month (2041)

Monthly ADWF	m^3/day
January	1675
February	1117
March	1024
April	744
May	385
June	382
July	382
August	382
September	382
October	558
November	775
December	1055

The model was used to determine the optimum required irrigation area for different pre-irrigation storage volumes. Irrigation for each day, over the 49 yrs of daily rainfall (RF) and evapotranspiration (ET) data, was permitted provided soil moisture content in the root zone (600mm depth) was less than the 92% saturation level [2].

The input data for this model included:

- Forty nine years of daily rainfall from Onawe Duvauchelle Bay weather station;
- Forty years of potential evapotranspiration derived from Priestley-Taylor data from Christchurch Airport weather station (the nearest climate station with sufficient ET data)
- Soil properties:
    - Bulk density 1.3 gm/cm^3
    - Porosity 40%
- Soil plant characteristics:
    - Rooting depth 600mm
    - Crop factor 0.9 to 1.1 (depending on season)
- Soil water characteristics:
    - Field capacity 28%
    - Permanent wilting point 15%
    - Total available water 101.4 mm
    - Percent saturation 92%
    - Saturation level 287 mm
    - LTAR 7mm/day

[2] Recommended in, NZ Land Treatment Collective. 2000

- Maximum nutrient loading:
  - Total nitrogen 210kg/ha/yr
  - Total phosphorus 42 kg/ha/yr
- Irrigated wastewater characteristics;

Biochemical oxygen demand, BOD_5	<20 gm/m^3
Suspended solids (SS)	<20 gm/m^3
Total nitrogen (TN)	<20 gm/m^3
Total phosphorus (TP)	<4 gm/m^3
Faecal coliform	< 1000 FCU/100ml

Land area requirements and balancing storage were calculated for the following 4 options (Refer to Table 7):

Option 1. All treated ADWF to land irrigation (year 2041).
Option 2. Treated ADWF during May to September will discharge to the Harbour with remaining ADWF to irrigation (year 2041).
Option 3. Treated ADWF during May to August to the Harbour with remaining ADWF to irrigation (year 2041).
Option 4. Treated ADWF during April to September to the Harbour with remaining ADWF to irrigation (year 2041).

Table 7 identifies deficit months (i.e, months where the total evapotranspiration for that month exceeds the total rainfall) for:

- Mean RF and PET (Priestley-Taylor ET).
- Wet year: 80 Percentile RF and 20 percentile PET.
- Dry year: 20 Percentile RF and 80 percentile PET.

Table 7. Deficit Months and Harbour Discharge Options

Deficit	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC
Mean	68.6	42.4	3.5	-51.6	-80.1	-96.0	-120.8	-100.6	-22.2	6.0	41.8	55.7
Wet year	37.2	10.3	-29.2	-89.5	-112.2	-133.3	-163.0	-173.7	-57.3	-17.7	12.0	17.6
Dry year	111.5	79.2	38.0	0.0	-40.8	-56.6	-63.5	-37.7	5.3	45.4	75.8	102.6
Option 1	DWF Land Irrigation											
Option 2	DWF Land Irrigation				Harbour Discharge					DWF Land Irrigation		
Option 3	DWF Land Irrigation				Harbour Discharge				DWF Land Irrigation			
Option 4	DWF Land Irrigation			Harbour Discharge						DWF Land Irrigation		

The four options in Table 6 for for four different irrigation operation rules:

- Option 1: irrigation (when soil moisture status permits) all year;
- Option 2: discharge all wastewater to the harbour from May to September (incl) with managed irrigation for the remaining months;
- Option 3: discharge to all wastewater to the harbour from May to August (incl) with managed irrigation for the remaining months;
- Option 2: discharge to all wastewater to the harbour from April to September (incl) with managed irrigation for the remaining months;

5.0 REQUIRED IRRIGATION AREAS AND STORAGE REQUIREMENTS

The results of the modelling are given in Table 8.

Table 8. Land area and Storage requirements (Based on ADWFs for 2041)

	Land Area (Ha)	Storage m3	Ave. OF(1) days/yr	TN kg/ha/yr	TP kg/ha/yr
Option 1	26	8000	10	207	41
Option 2	20.5	5200	10	205	41
Option 3	21.5	5200	10	206	41
Option 4	18.5	4520	10	203	41

1. OF is overflow days. This the average expected number of overflows per year from the storage reservoir. Overflow will be to a constructed wetland.

Note: The overflow days (OF) in Table 8 will result when the storage is full and irrigation is not permitted due to soil moisture levels being too high. The value of no more than 10/yr on average, was arbitrarily selected. If this was considered too frequent then it could be reduced by increasing storage volume. It should also be noted that the water balance was

The average daily irrigation rates (IR) for each month (mm/day) are given in Table 9 for each option.

Table 9. Irrigation rates, IR.

	Option 1		Option 2		Option 3		Option 4	
Month	m^3/day	IR mm/day	m^3/day	IR mm/day	m^3/day	IR mm/day	m^3/day	IR mm/day
January	1675	6.4	1675	8.2	1675	7.8	1675	9.1
February	1117	4.3	1117	5.4	1117	5.2	1117	6.0
March	1024	3.9	1024	5.0	1024	4.8	1024	5.5
April	744	2.9	744	3.6	744	3.5	0	0.0
May	385	1.5	0	0.0	0	0.0	0	0.0
June	382	1.5	0	0.0	0	0.0	0	0.0
July	382	1.5	0	0.0	0	0.0	0	0.0
August	382	1.5	0	0.0	0	0.0	0	0.0
September	382	1.5	0	0.0	382	1.8	0	0.0
October	558	2.1	558	2.7	558	2.6	558	3.0
November	775	3.0	775	3.8	775	3.6	775	4.2
December	1055	4.1	1055	5.1	1055	4.9	1055	5.7

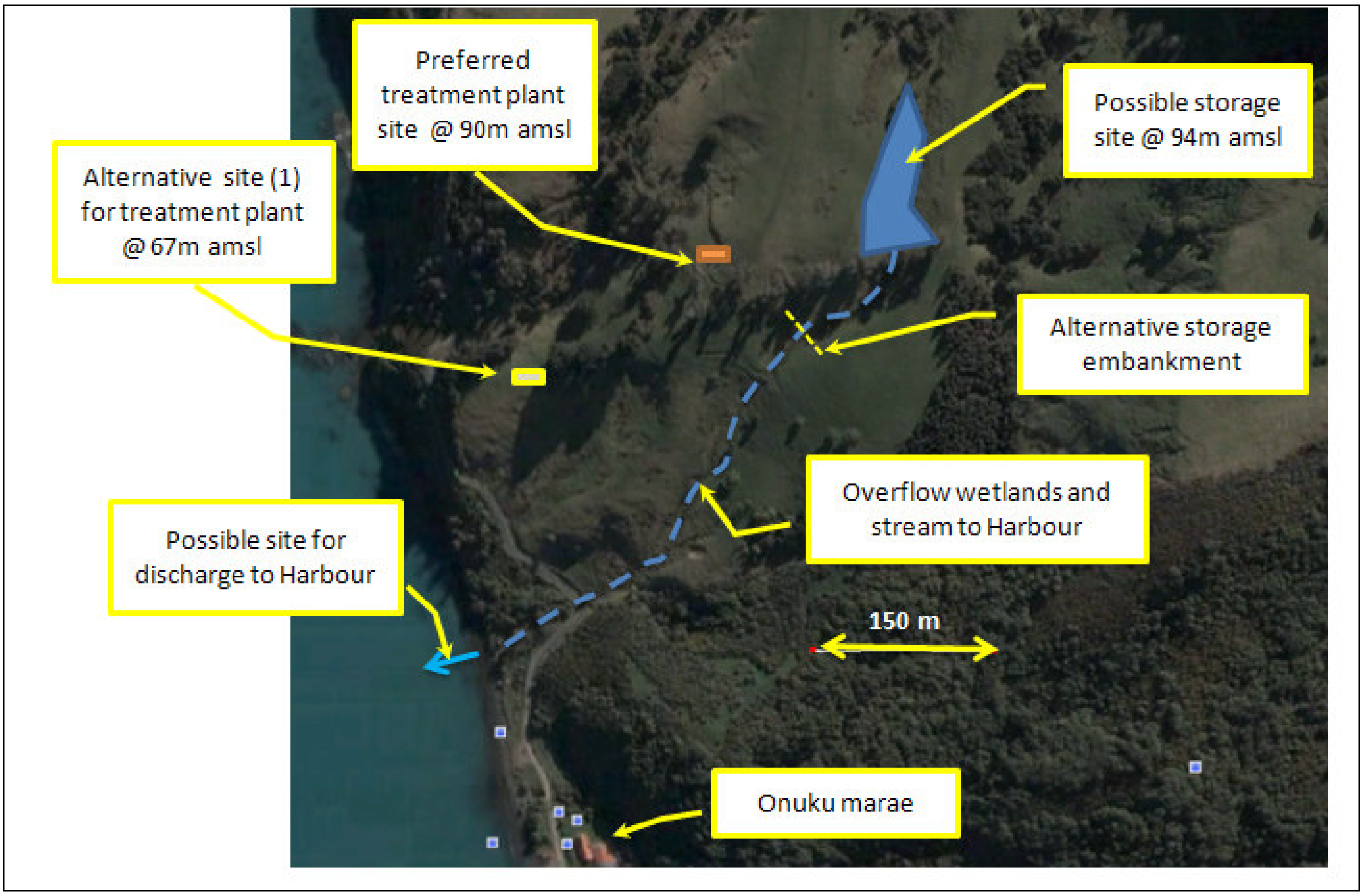
The total depth applied compared to the average annual rainfall will impact on normal groundwater levels and pore water pressure profiles. This could have implications with respect the slope stability. The average annual rainfall (Onawe data) is 782mm. The annual depth of wastewater added based on the modelling ranges from 917mm (Option 1) to 874mm (Option 4).

One of the key consideration in assessing the sites was to ensure that there was a suitable site for both the treatment unit and storage site.

Possible sites for both the storage reservoir and the treatment facilities are illustrated in Figure 12. There are a number of possible options for the siting of these facilities, however further detailed site work will need to be carried out to optimise the site selection.

Reservoir overflow will be discussed in Section 9, where it is recommended that designed channel with a series of constructed wetlands and drop structures be incorporated into an existing channel as illustrated in Figure 12. If this options is adopted it will be necessary (and relatively easy) to divert catchment flow above the storage to the neighbouring gulley.

Figure 12. Site options for treatment unit and storage



5.1 KEY OUTCOMES

- An irrigable area of about 32 ha is available within the southern site.
- Storage volume required ranges from 4.5ML to 8 ML.
- Southern site is more stable in terms of slope stability and has deeper soils.
- There a options for technically suitable sites for the location of the treatment plant and the storage reservoir within the southern site.

6.0 LANDUSE OPTIONS

Three land use options may be applicable for Akaroa . These include:

- Tree production (for biofuel and/or timber production);
- Agriculture: cut and carry;
- Horticulture;
- Recreation site e.g. golf course, reserve.

The site may in fact be a combination of two or more of the above.

6.1 Tree crops

The land use options using trees included:

- Short-term coppice for biofuels;
- Medium-term coppice for firewood;
- Long-term timber crops;
- Specialist nursery;
- Conventional cut and carry agriculture.

6.1.1 Short-term coppice for biofuels

This option requires almost flat land to enable regular harvesting at an economic level and robust soil structure to avoid soil compaction which is detrimental to root growth and water percolation. The loess soils of the Peninsula are unfortunately already susceptible to compaction. Basket willow (Salix Viminalis varieties) have proved to be the most amenable to short term coppice harvesting. While being able to evapotranspire large volumes of water from the soil during summer months, these deciduous trees lose their leaves over the winter period and consequently evapotranspiration reduces to almost nil.

Once the willow coppice has been harvested, there are different ways of using it as a bio fuel. These are outlined below:

- Electricity: Burned in small chip-fuelled stations, where biomass from the willow can be used for commercial generation of electricity for rural based industries. Surpluses can be feed into the national grid.
- Heating: Briquettes can be manufactured from willow biomass and are a competitive option when comparing with briquettes from other sources. The energy value of the briquettes is about 19.5MJ kg^{-1}. These briquettes can be sold to be used in boilers for heating of residential homes, or burned in specially designed fire boxes. These could also be used for heating larger commercial or industrial buildings as well.
- Bio ethanol: The manufacture of ethanol from the willow biomass is another option available. Techtrol Ltd., in Canada has developed a process called enzymatic hydrolysis, which can convert the biomass to ethanol. This ethanol could then be used as a high octane enhancer in petrol to replace the lead used in conventional fuels. However it is more efficient to use the biomass directly as an energy source (i.e. in a boiler) than to convert it to ethanol.

Maximizing opportunities for evapotranspiration is critical to minimize on-site storage requirements and costs. For this reason the option of growing salix on a larger scale is not recommended. Running small plot trials to gain a better understanding of the economic feasibility of this option, may subsequently be considered appropriate.

6.1.2 Medium term coppice firewood.

Tree species that are considered as suitable for medium term coppice firewood include, for example, eucalyptus, acacia and casurina. These species are quick growing with minimum silvicultural requirements. Volume growth of these species is good, usually in excess of that expected for Pinus radiata and wood density adequate for good firewood. Economic return from the crop is within the medium term. Evergreen species are recommended to ensure evapotranspiration all year round (obviously peaking in the summer). The product can be processed on site and sold locally reducing transportation costs and providing local employment and services. Nutrients are removed from the site as a consequence of harvesting reducing nutrient accumulation in the soils. If the trees are planted in succession to generate regular harvest, differing tree heights will contribute to wind turbulence increasing evapotranspiration. Shorter tree height and quicker rotation lengths relative to a timber crop, will reduce exposure to wind throw. This option is almost carbon neutral.

There are some negative attributes for this option. Regular vehicular access is required, limiting the slope of land suitable and generating the most land compaction potential. Regular harvesting is necessary and once harvesting starts this can be visually obtrusive. If processing is done on site security can be an issue. More regular vehicle access increases the risk of damage to the irrigation works. Potential for brushweed control problems as suppression from canopy closure is minimised. Finally the crop may become redundant if the burning of firewood is legislated against.

6.1.3 Longer Term Timber Crops

For longer term timber crops the easiest and cheapest species to establish would be Pinus radiata for which good information and a ready market exist. Eucalyptus obliqua would also be suitable and potentially more valuable however the final market is more fickle.

The harvest rotation for this option is longer than the firewood option so less vehicle access is required but heavier vehicles are likely to be used resulting in only minor gains in reducing soil compaction. Longer rotation reduces the frequency of harvesting operations relative to firewood engendering less public opposition. There is less weed control problems as the canopy closure shades out light. This option is almost carbon neutral.

There are negative attributes for this option. Produce is likely to be sold into the Christchurch market increasing transport costs (compared to the firewood option) and impacting on the roading network. Longer rotation also increases the risk of loss to windthrow. Damage to the irrigation works is almost inevitable at harvest. Wilding seedling spread could occur into the native areas and ungrazed land outside the project area.

6.1.4 Specialist Nursery

A land use option investigated was the establishment of an irrigated nursery specializing in native plants for the local market. This option was discussed with the DOC native plant nursery based in Motukara. It was pointed out that:

- There are several small native nurseries in the region.
- Continuity of supply and demand is a limitation;
- The nursery will need to hire fulltime staff (2 x $45000/yr);
- It was agreed that water is limiting and nursery plants would benefit from irrigation;
- Demand comes from special conservation projects (DOC Motukarara currently meeting .

6.1.5 Establishment riparian zones

In order to mitigate any risk of runoff from the irrigated fields to either coastal or waterways it is recommended riparian zones be established. The plants used should be a variety of evergreens to maximise all year round to evapotranspiration, as well as providing buffer zones that will be designed to increases local biodiversity, and where appropriate, ecological corridors. In addition these riparian zones could be designed to provide recreational potential in the form of walkways or cycle ways if public access is permitted. Once the site is established and canopy closure has taken place very little input is required (limited almost to an occasional sweep for weed species needing control).

6.1.6 Recreational area

It is possible that the irrigated site, or part of, could be designed and managed as a recreational park involving such activities as native plantings and walkways, mountain biking, ecological park, golf course and other recreational activities that would fit with the local and Banks Peninsula tourism and holiday image. Concerns about health risks would and could be addressed by sound engineering design technology selection and system management.

6.1.7 Economics

The decision to invest in the establishment of a waste water application system will involve the designated application area(s) to be committed to the land uses considered the most appropriate. Although it may be demonstrated that these are high value land uses, there may be a time when future alternatives are far more attractive. Therefore there is the potential that at some point the proposed land use could be performing at a financial return below that of alternatives. This lack of ability to change land use would therefore mean that the current system would bear the opportunity cost; which would be the difference between the potential land use return and the actual land use return.

The harvest incomes are initially based on non-irrigated situations as a conservative estimate. The literature on irrigated forestry is rare and claims of increased production vary wildly from 50% increase in growth to 400%. In the case of native revegetation and riparian planting the addition of the nutrient enriched wastewater will enhance growth reducing the time until canopy closure. As no harvest is taking place increased volume is of no consequence.

In the case of the firewood project where a target piece size is desired, the additional growth will result in reduced rotation times rather than more tonnes per hectare. It is anticipated that for Akaroa conditions, 5 years would be the minimum time to get any decent firewood yield. In the case of the timber, crop rotation length needs to stay at 30 years to reach a desired timber stiffness. The extra growth would manifest as larger piece sizes and greater volumes. Tonnages of up to 1000 tonne per hectare have been recorded from higher rainfall areas. This is expected to represent a maximum.

6.1.8 Agricultural landuse options

This study has assumed that land irrigated with treated human wastewater is not able to be directly grazed by livestock because of the potential risk for cross contamination and disease transfer. Therefore land use options considered are cropping and “cut and carry” feed systems. Cropping systems could be for cereal crops or small seeds. Cut and carry systems refer to the practice of growing pasture (including lucerne) or crop species that are then mechanically harvested and transferred to livestock in a conserved form (hay, silage , baylage). Clearly this option of landuse is only viable for the areas where slope will permit easy access and management of the crop. For the steeper slopes cropping with the cut and carry option will not be viable.

Land growing stock feed crop is the most responsive to the proposed activity for a number of reasons. The most significant is that the land use is able to utilise the water applied throughout the full growing season. Arable crops mature in late January and early February and at this point they do not require soil moisture and therefore will not utilise the moisture applied.

If the subsoil dripper system is chosen the deep rooting plants such as lucence, maize and cereals should be considered to access and utilise the moisture and nutrients applied in the waste water.

Current agricultural land use in this area is medium intensive sheep and beef grazing.

In terms of the more traditional agricultural land use, the most significant benefit will be the irrigation effect of the addition of water to land which historically experiences periods during the growing season when there is a soil moisture deficit. This means that plant growth is either severely reduced or, under prolonged soil moisture deficit conditions, may stop all together and end in plant death

As seen in Table 6 the number of water deficit months will vary between 8 months (for a dry year) and 4 months (for a wet year)

During these deficit month soil moisture will constraining plant production. Therefore the soils will be highly responsive to the application of irrigation during the deficit months.

The net benefit to irrigation can be considered as the difference between average production without irrigation and that which can be achieved under conditions where soil moisture is not constraining. This has been calculated by multiplying the proportion of time when pasture growth is constrained by soil moisture deficits by the difference between irrigated and dry land monthly pasture growth rate for each month in the area[3]. This calculation shows that average pasture production in the area would be increased by approximately 2,100 kg Dry Matter /ha /year. Under dryland conditions an annual average pasture production of 7,000 to 8,000 kg Dry Matter /ha could be expected.

The value of this grass production as supplementary feed varies according to supply and demand conditions in each year. However with the increasing dairy industry in the region relying on a substantial amount of purchased supplementary feed the market is expected to remain strong in most years. It would be reasonable to assume a range in values between $0.20 and $0.30 / kg Dry Matter standing in the paddock.

The extra benefit achieved by the increase in dry matter by the application of wastewater as irrigation would be in the order of $420 to $630 / ha / annum. This would effectively double the net returns from the land above those currently achieved. The current land use of dryland livestock production is returning a Gross Margin (direct costs – direct expenditure) of approximately $660 / ha [4]under a sheep system. It is assumed that there is no extra cost to the irrigation as application costs are attributed to the waste water disposal not the irrigation effect. The waste water contains concentrations of nutrients that are beneficial to the soils in the area and contribute to increased pasture production. These are total nitrogen (TN) and total phosphate (TP). As an example at an average irrigation rate of 3 L/m^2 over the year, the expected annual application will be about 12045 m^3 per hectare. If these concentrations of TP and TN were, for example, 20 g/m^3 and 4 g/m^3 respectively, then the nutrient loading rate and dollar value (per hectare) would indicate an effective application range as shown in Table 10.

Table 10. Value of nutrients as fertiliser substitute

Nutrient	kg/ha.yr	$/kg	Fertiliser value
Total nitrogen, TN	220	2.2	$ 540
Total phosphorus TP	44	3.1	$ 300
		TOTAL	**$ 840**

.It can be concluded that the most significant benefits are:

- The irrigation effect on soils that are naturally limited by soil moisture deficits in the summer months and the significant nutrient value of the wastewater. The extra feed grown under irrigation would have a value of between $420 to $630 / ha / annum; effectively doubling the net returns from the land above those currently achieved.

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[3] Lincoln University (2006): Technical Farm Budget Manual –Pasture growth rates at Lincoln.
[4] Lincoln University (2008): Financial Budget Manual –Sheep Gross Margins.

- Using the current values of the nutrients applied as artificial fertiliser[5] the benefit of the nutrients is in the order of $840 per ha per annum

7.0 RISKS ASSESSMENT AND MANAGEMENT

The risk assessment for this option focused on the irrigation component.

7.1 PLANNING AND DESIGN

Land owner acceptance

There has been no formal agreement with land owners to the use of their land for irrigation of the wastewater. Clearly further discussion and negotiation will be required.

Should land owners refuse to co-operate this would present a major obstacle to progressing this option. To mitigate this risk a sound communication and consultation process is required and best practicable design is essential.

7.2 CULTURAL AND SOCIAL ISSUES

Discussions and consultation with the Rununga on the issue of the proposed siting, overflow and Harbour discharge is in progress.

In the event that this option does not achieve Iwi and/or general community acceptance this will present a major obstacle to its adoption. To mitigate this risk a sound communication and consultation process with the Iwi and general community is required and best practicable design is essential.

7.3 CONSTRUCTION RISKS

The main construction activities at the irrigation sites will be installation of pipelines, pump and control headworks, the large storage reservoir and overflow channel. As the sites are not in built-up areas, impacts from dust and noise are unlikely to be significant. Risks to the environment during construction will be mostly as a consequence the earthworks necessary to construct the storage ponds, and overflow wetlands. The key risk will be sediment laden stormwater runoff to adjacent streams. Mitigation measures during construction to minimise sediment runoff during construction will be necessary.

[5] Ravensdown Fertiliser Price List (effective 1 September 2008)

7.4 OPERATIONAL RISKS

The following Table 11 summarizes the key operational risks and recommended mitigation measures.
‘

Table 11 Operational risks summary

Risk	Mitigation measures
Soil saturation leading to runoff and contamination to surface water and ultimately to the Akaroa Harbour	Automated on-demand irrigation is recommended: soil moisture sensors in the irrigation field will determine whether or not irrigation will occur. If the soil moisture is too high the wastewater will be retained in the storage pond. Staged development with site monitoring is recommended.
Slope instability	Further geotechnical investigations, monitoring and groundwater modelling are required to determine the risk of slope instability. . Staged development with site monitoring is recommended.
Overflow from the storage pond.	Should it be decided to implement staged development, overflow frequency to the harbour will be higher in the initial years. As the irrigation is extended in accordance the results from the scheme monitoring, less overflow to the Harbour can be anticipated. It is recommended that the overflow from the storage reservoir will be to a series constructed wetlands and drop structures providing additional storage and treatment before being released to the Harbour.
Nutrient build-up in the receiving soils.	Nutrient loading (nitrogen (N) and phosphorus(P)) has been modelled. N loading is within acceptable rates while P loading is considered high. Land use management is recommended to achieve maximum nutrient uptake. Riparian planting adjacent to nearby surface water bodies is recommended. Soil nutrient monitoring is recommended.
Heavy metal build-up in the receiving soils	Heavy metal concentration tends to be an issue when industrial wastewater enters the wastewater stream. Wastewater from Akaroa (and Takamatua) is all non-industrial. Furthermore most heavy metals are concentrated in the treatment plant biosolids, which will not be applied to the proposed irrigation sites.
Release of pharmaceuticals into the environment	This study has investigated the risk to the receiving environment of pharmaceuticals in the treated wastewater. The research reviewed indicates that at the application rates , the majority of pharmaceuticals in domestic wastewater will breakdown rapidly in the topsoil profile.
Odour for the storage ponds	The wastewater being stored in the ponds is aerated secondary effluent which present a low odour risk . The ponds will also be sited several hundred metres away from permanent residences.
Mosquito and insect breeding and swarms in the ponds	The pond edges will be at batters of 3(horizontal) to 1 vertical. Therefore the ponds will be an unsuitable habitat for mosquito and insect breeding.
Aerosols from irrigation sites	Where aerosols are a potential risk subsurface irrigation, rather than over head sprinkler irrigation is recommended.
Contamination of groundwater wells and springs	Safe and conservative setback distances between water supply bores and springs are recommended.

8.0 CONSENTABILITY AND ECOSYSTEM EFFECTS

Application of wastewater onto and into land will require a Resource Consent to discharge under Section 15 of the Resource Management Act (RMA).

The relevant Canterbury Regional Council rules that apply to Section 15 are the Transitional Regional Plan (TRP), the proposed Natural Resources Regional Plan (NRRP) and the notified Variation 14 (of Rule WQL8) of the NRRP, Environment Canterbury.
These rules identify a number potential risks. These include:

- Risk to groundwater and surface water;
- Risks to community water supplies;
- Risks to public health;
- Effects on air quality;
- Effects on cultural and historical values;
- Surface ponding, flooding and slope stability.

The site selection and design of the irrigation system will take these and other factors into consideration.

The key consentability issues for all options will be impact of the wastewater irrigation on slope stability, groundwater and Iwi concerns. As stated earlier further work is underway to assess slope stability, which will also be linked to groundwater and pore water pressure profiles.

Consultation with Iwi to identify their concerns is currently in progress.

9.0 PRELIMINARY CONCLUSIONS AND RECOMMENDATIONS

In this first stage of work, the assessment of the sites has progressed to the point where certain conclusions can confidently be made. Final conclusions and recommendations will be made following feedback from CCC, Working Party and Rununga.

The preliminary conclusions and recommendations are:

1. Within the criteria specified, site assessment identified 32 ha of irrigable land area within the Southern site. To achieve this it has been necessary to extend elevation and slope criteria to 350m amsl and 20 degrees respectively.
2. It is recommended that for purposes of consenting the land irrigation of the treated wastewater be initially operated on a relatively low load basis during which the water table and stability would be carefully monitored over the first years of operation to determine if loadings can be progressively increased.
3. Subject to land owner agreement, it is recommended that the first stage of development of the irrigation area should be a smaller area of land (say 18 to 20 ha) as recommended by Geotech Consulting based on the results from the initial groundwater and slope stability monitoring. The operating rule is likely to be similar to that suggested for option 4 (Section 4)..
4. There a number of possible sites for both the treatment plant and the storage reservoir. At the final design stage further, more detailed site assessment is recommended to determine optimum sites.

5. At this stage the unknown issues are whether this site presents significant cultural concerns for the Rununga and access to this land will be subject to successful negotiations between CCC and the respective land owners.

10.0 ADDITIONAL WORK

The following additional work is recommended:

- Additional geotechnical monitoring has been recommended by Geotech consulting and this is now underway.
- Further discussion and negotiations with the land owner of the southern site is recommended to gain firmer agreement on terms of future access and management of the irrigable land area and sites for the storage reservoir, treatment plant and over flow channel.
- More detailed evaluation of optimum land use management options,
- More detailed nutrient budgeting and assessment of land use options for the preferred irrigation sites.

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APPENDIX FOUR:

PRELIMINARY GEOTECHNICAL APPRAISAL REPORT

(GEOTECH CONSULTING LTD)

GEOTECH
consulting ltd

Preliminary geotechnical appraisal of potential slope stability issues in relation to the proposed wastewater irrigation of areas of land near Akaroa.

January 15, 2010

Prepared for Christchurch City Council

Prepared by Dr Mark Yetton

Geotech Consulting Ltd.

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Preliminary geotechnical appraisal of potential slope stability issues in relation to the proposed wastewater irrigation of areas of land near Akaroa.

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Report

1) Background and brief.

Following a site meeting and a subsequent draft report from Ecoeng Ltd entitled "Irrigation of domestic wastewater, Akaroa Options, draft engineering report" (dated 15 October 2009) Geotech Consulting Ltd has been engaged to undertake a geotechnical appraisal of two general areas of land identified in that report for possible irrigation with treated wastewater. Slope stability is the main focus of this appraisal because of the risk that irrigation with wastewater could renew or trigger slope instability in parts of the irrigated area.

There will be other issues that affect the final selection of the irrigation areas such as visibility, proximity to houses, elevation etc but we left such issues to those with appropriate expertise to properly evaluate.

2) Work undertaken.

We have undertaken detailed engineering geological mapping of the south facing Childrens Bay portion of the northern disposal area, and wider scale reconnaissance appraisal of the slopes that face to the north and west above Takamatua. We have mapped in detail the central portion of the southern disposal area, and carried out preliminary reconnaissance of the areas surrounding this. We have reviewed the available records for annual rainfall for the area and compared the typical fluctuations with respect to the mean as a way of assessing the potential impact of irrigation on slope stability.

3) Northern disposal area, including Childrens Bay.

Figure 1 is plan of the potential northern irrigation area. We have defined the approximate extent of land we consider sufficiently stable to consider for wastewater irrigation (subject to adoption of appropriate loadings). We have rated the areas from 1 to 3, with areas ranked 1 currently the most stable and thus the least likely to be affected adversely by irrigation. The definition of geotechnically suitable areas has not been restricted here by their elevation, which is obviously an important

GEOTECH

General plan of the possible northern Akaroa wastewater irrigation area showing sub-areas of land considered sufficiently stable for irrigation at rates yet to be determined.

Drawn: Mark Yetton

Date: 11 November 2009

Client: CCC

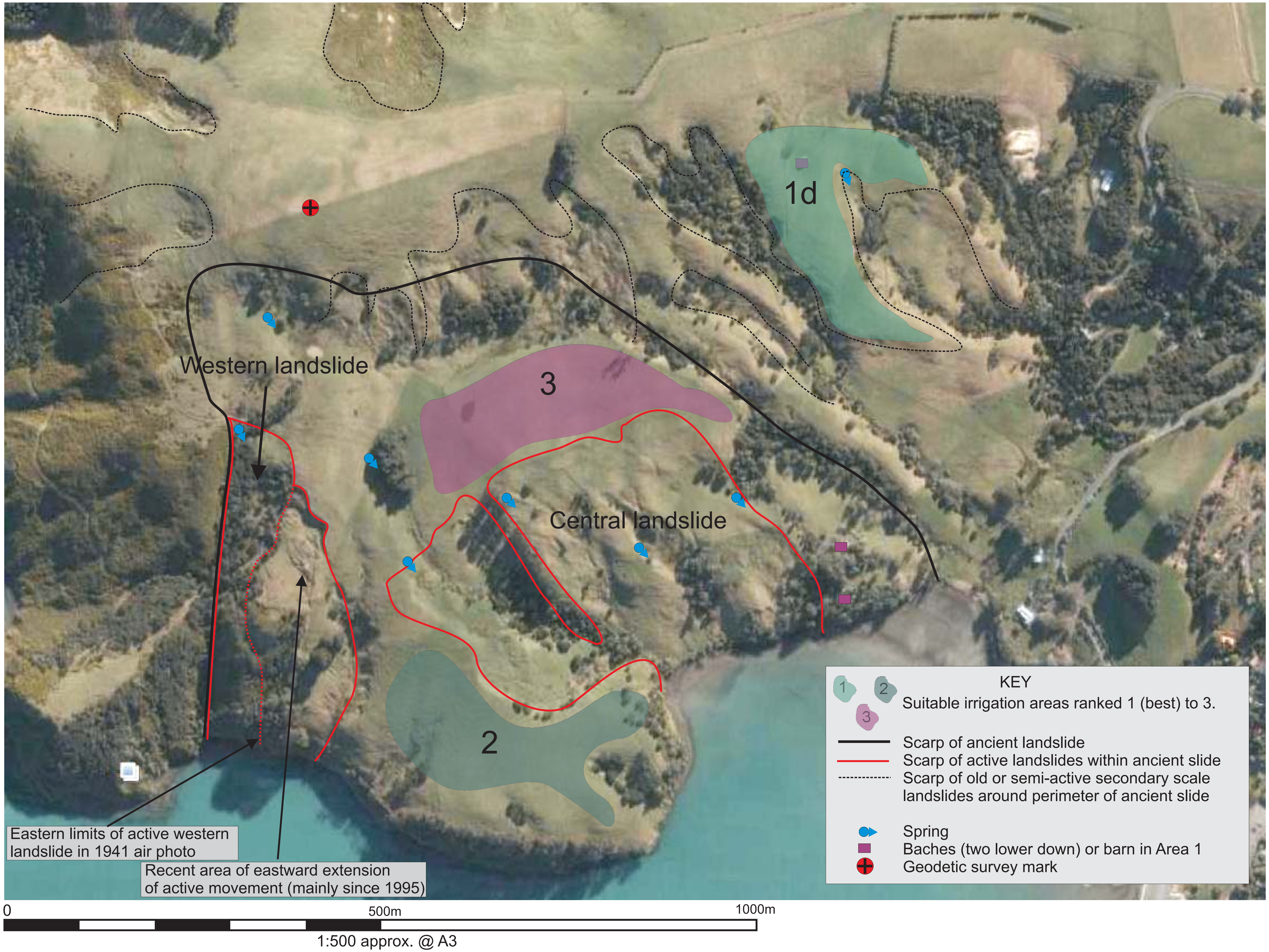
Figure 1/1821

secondary factor when reticulation and pumping costs have to be considered. It may be appropriate for others to reduce the areas shown here using some form of elevation criteria or ranking to better target the preferred areas.

It is clear that the largest areas of suitable land are located on the north facing slopes above the holiday settlement of Takamatua. Generally north facing slopes are more stable than south facing slopes because of the improved evaporation, particularly during low winter sun conditions. The combined area of land considered geotechnically suitable on the north facing slopes is in the order of 25 hectares.

The south facing slopes above Childrens Bay are more problematic. We show in Figure 2 an enlargement of the Childrens Bay area showing in detail the patterns of slope instability. The great majority of the south facing slope area is dominated by an ancient deep seated landslide. This feature has formed in the underlying volcanic bedrock and we estimate the ancient slide plane is in the order of 50m deep. We do not know the age of the original movement but suspect it may be more than 10,000 years old, and could even be in the order of 100,000 years old. In the last few years we have identified and mapped approximately 8 of these features within the perimeter of Akaroa Harbour. We do not know if such large ancient features continue to move periodically, for example in the extreme wet cycles that appear to occur in the area at approximately 30 year intervals. However, generally within each ancient landslide there are at least some sub-areas of active or semi-active movement. Figure 3 is an annotated oblique photograph from Lighthouse Road that shows the subsided ancient landslide that dominates the Childrens Bay site and which was proposed in the draft report as a possible location of the wastewater storage facility.

In Figure 2 we show in red those areas of slope that are currently active (moving most winters) or semi-active (i.e. moving by slope creep in the wetter winters, typically in the order of every 5 – 10 years). There is a feature we refer to as the western landslide, at the western margin of the ancient landslide, which has defied typical patterns of movement and continued to steadily grow in extent and area since 1995 when it was first inspected. Unfortunately we did not accurately mark the 1995 limits but we can show in Figure 2 the degree to which the western landslide has grown since the first available aerial photographs in the area in 1941. Photograph 1 was taken in the head scarp area of the active western landslide in 2004. The photograph shows the extent of deep vertical ground cracking and extension implying deep seated movement in this head area. There are many linear scarps within and defining the western landslide perimeter and this pattern, along with the deep



GEOTECH

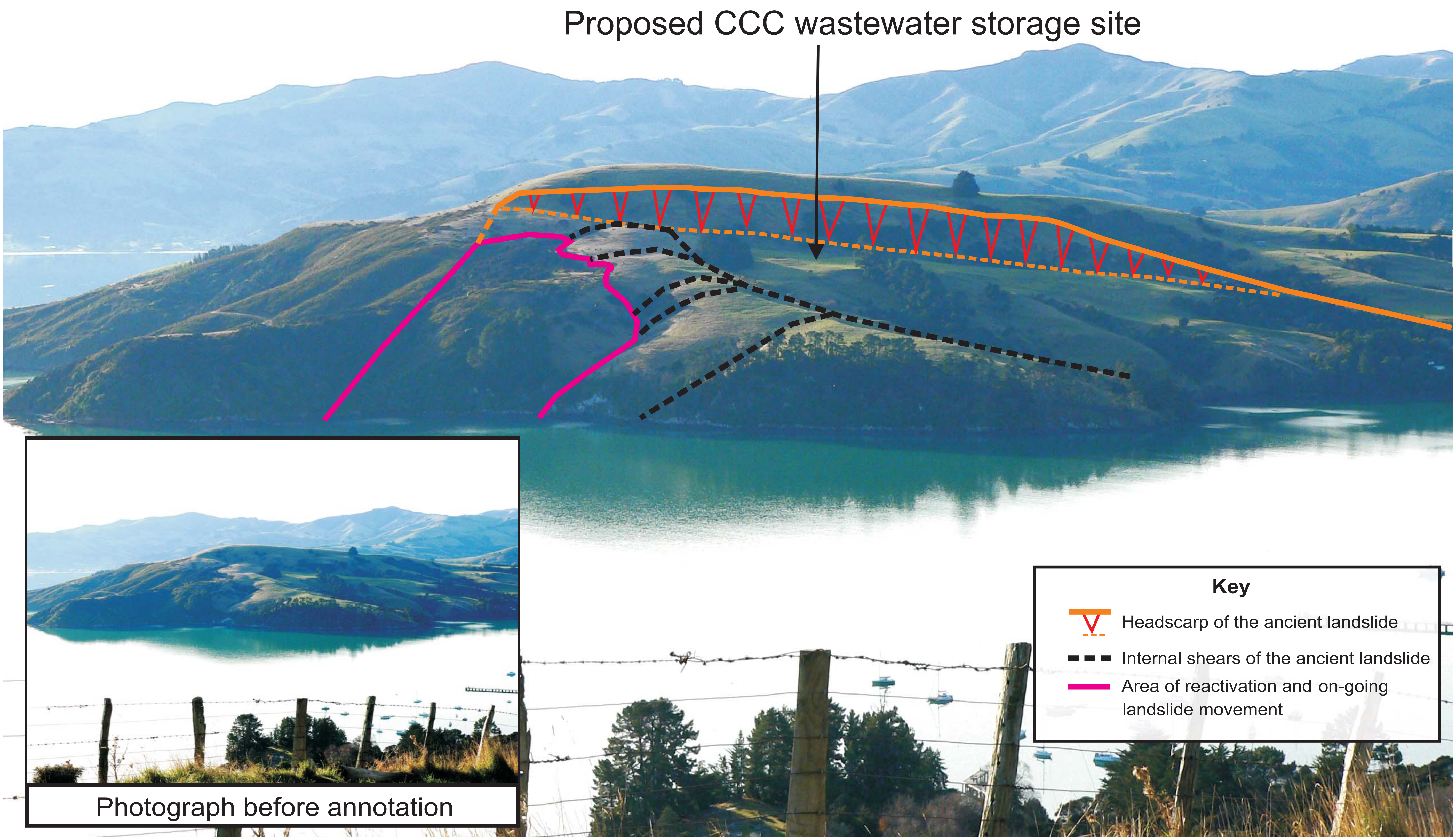
Detailed engineering geological plan of the Childrens Bay sub-area of the northern irrigation area showing the details of slope instability (both ancient and active).

Drawn: Mark Yetton

Date: 11 November 2009

Client: CCC

Figure 2/1821



Oblique view of the Childrens Bay area of the northern irrigation area showing the extent of the ancient landslide and the smaller area of recent reactivation and on-going deformation marked in magenta at the left.

Drawn: MDY

Date: Nov 2009

Fig: 3/1821

cracking, suggest that once again deep seated bedrock movement is occurring (bedrock commonly having linear weakness patterns) rather than superficial loess soil movement.

Photograph 1: The head scarp of the western landslide at the margins of the ancient landslide feature that dominates the south facing slopes above Childrens Bay (photograph summer 2004).

There is also a central active and semi-active landslide area at Childrens Bay, the eastern limits of which come close to two holiday houses. We show in Figures 1 and 2 two areas within the ancient landslide that could conceivably be considered for irrigation of wastewater but we recommend extreme caution, particularly in the central area ranked 3. The danger in this area is that irrigation may inadvertently remobilise the slope to the east on which the two holiday houses are located.

The coastal area ranked 2 appears to be a semi-intact bedrock block of the ancient landslide and has high steep basalt cliffs at the southern coastal area. While irrigation is unlikely to remobilise the intact block as a whole it could widen the extent of the adjacent western and central landslides.

Further north east, and off the ancient landslide, is an area ranked 1 (with a red barn near the top) that appears to be the intact remnant of an old alluvial surface (i.e. a bench or terrace). The instability each side of this area is relatively old or semi-active, as opposed to continually active, so that there is an approximately 3 hectare area that could be considered for irrigation. However, because the slopes are south facing they will remain more sensitive to irrigation loadings than the north facing slopes above Takamatua.

4) Southern irrigation area

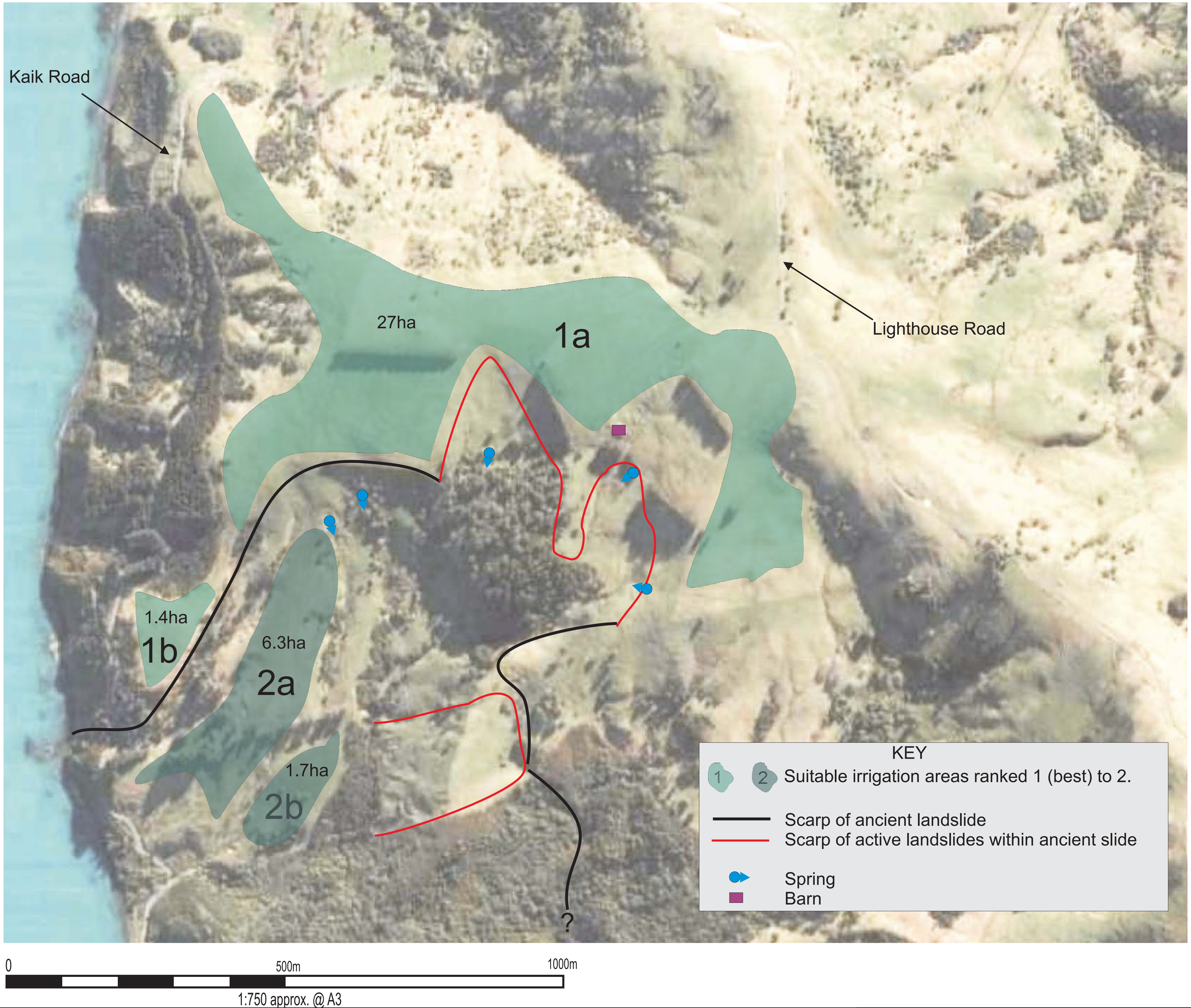
Figure 4 shows the southern irrigation area. It is clear from our initial reconnaissance that there is considerably more land available at the southern site for irrigation in a relatively compact format in comparison to the northern area. In particular sub- area 1A is a 27 hectare area of generally moderate slopes that face west (west is also a relatively sunny aspect). We have mapped the area as extending virtually up to Lighthouse Road, where elevation may once again be a potential issue, but we leave elevation to others to introduce in further screening criteria if and when appropriate.

There is another ancient landslide (scarp marked black in Figure 4), that has failed many thousands, or hundreds of thousands of years ago, leaving an evacuated central and southern area of shaded south facing slope that includes fringing areas of active and semi-active movement (red in Figure 4). One of these areas (the southernmost) was previously considered as a site for the wastewater storage facility but in view of the landslide movement we recommend that the wastewater storage facility be located elsewhere.

We show two smaller areas ranked 2 (totalling 8 hectares) within the evacuated middle of the ancient landslide. There will still be landslide debris at depth below these areas, and the slopes are slightly more shaded and south facing than the higher 27 hectare area, so more care (and lower loading rates) would be appropriate.

5) Proposed irrigation loadings compared to rainfall and suggested approach to selection of irrigation loading rates

The Ecoeng Ltd report of October 2009 notes on page 26 that the annual depth of wastewater that is proposed to be added to the soil (based on modelling) ranges from 874mm to 917mm. This compares to an average annual rainfall in Akaroa of approximately 1000mm. Thus the proposed loadings approximately double the annual rainfall. We show below in Figure 5 a moving mean comparison of annual fluctuations in the percentage about the mean of annual rainfall at three locations, including Akaroa. The moving mean is a three year total which we have found best shows the cyclic variations in cumulative rainfall that is the key requirement in the initiation of widespread



GEOTECH	Engineering geological plan showing the southern irrigation area in relation to slope stability and approximate sub-areas considered suitable for irrigation with wastewater.	Drawn: Mark Yetton	Client: CCC
		Date: 11 November 2009	Figure 4/1821

slope instability. Landslides can and do occur most winters, but a series of wet winters that steadily build groundwater levels is the pre-requisite to widespread movement on a range of scales. Figure 5 shows that there have been two cycles of successive wet years in the last approximately one hundred years in the Akaroa area. The first was during the Second World War (peak approximately 1944) while the second was the late 1970's. Aerial photographs taken before and after these periods suggest approximately 75% of fresh landslides (i.e. those landslides 100 years or younger) occurred in one or other of these two periods. The variation from the average that initiated the widespread landsliding of vulnerable slopes during the two periods was only 140%.

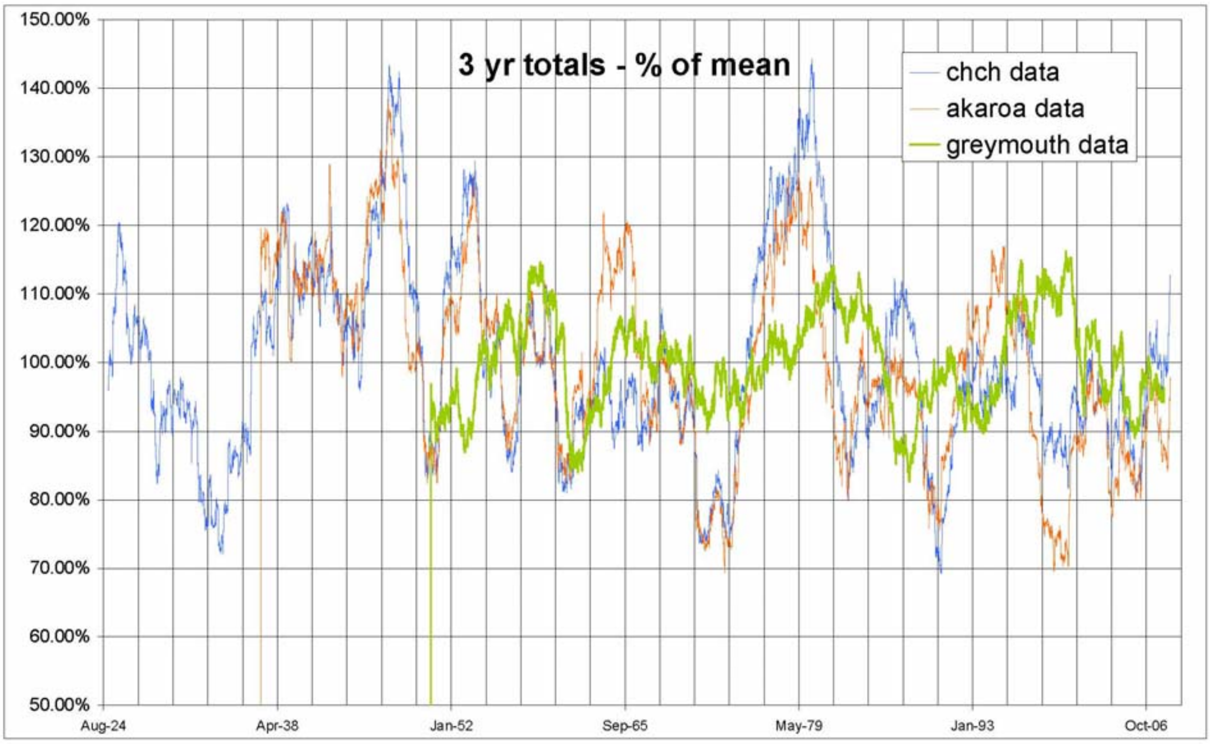


Figure 5: Analysis of Akaroa (red), Christchurch (blue) and Greymouth (green) rainfall data using a three year moving mean and plotting the moving mean as a percentage of the average rainfall.

Figure 5 shows that the irrigation loadings as currently proposed (in the order of 200 %) must be very carefully considered and assessed. However, a simplistic comparison between the proposed loadings and the annual rainfall totals in Figure 5 is complicated by the proposed component of summer irrigation. In general infiltration to reach groundwater does not occur over the mid to late summer period because of the high evaporation and evapo-transpiration rates. A better comparison would be obtained by excluding proposed loadings for the months January to mid-March (i.e. mid to late summer, subsequently referred to here as peak summer) in any comparison with the data in Figure 5.

In our opinion the best approach is to calculate the loadings by excluding the peak summer irrigation component and then restricting the remaining annual loading over the non-peak summer period to no more than 250mm (i.e. approximately 125% of the average rainfall). Achieving this will require a greater total irrigation area than is currently proposed and it may mean that not all wastewater can be irrigated.

With careful monitoring of both groundwater level increases and slope stability it may be possible over time to increase the loadings above this suggested initial level, but in the current absence of field trial data and other comparable irrigation operations in the district, it would be best to keep the available consented area as large as possible in case increased loadings in the future are not feasible.

6) Conclusions and recommendations

1) Because Childrens Bay has such a significant and highly visible large ancient landslide, and some areas within it are actively growing despite modest rainfall since 1995, we do not recommend initial inclusion of the areas ranked as 2 and 3 (Figures 1 &2). Many years of practical experience in wastewater irrigation within more stable local areas need first to be gained to help better assess the potential stability impacts. Similarly the area of south facing slope ranked 1c may be better suited to a second stage of development.

2) The north facing slopes above Takamatua (subareas 1A- 1C, Figure 1) are the most suitable at the northern site.

3) The best location from a geotechnical perspective for the trial application of wastewater for irrigation appears to be the southern site, and in particular the higher west facing sub- area 1A (27 hectare area).

4) Because the land is rural and currently stable, we suspect the site could be consented on the basis that it will be operated initially on a relatively low load basis during which the water table and stability would be carefully monitored over the first years of operation to determine if loadings can be progressively increased. If piezometers are installed in the best likely irrigation locations as soon as possible, and baseline readings taken of the normal

seasonal water table fluctuations through the 2010 winter and during the consenting process, then reliable field information could be obtained on real water table impacts once the irrigation commences which can be used in slope stability analysis. Real groundwater data of this type would be much more reliable than attempting to model the impact of the irrigation on the water table prior to the consent, and having to rely on and defend that type of theoretical model at a consent hearing.

7) Further work

We recommend the following additional geotechnical and stability related work:

- Drilling and installation of piezometers in the most promising and likely areas for future use is a high priority once ground conditions dry sufficient to allow drill rig access (January – February 2010 is probably the ideal period). Initial water level measurements will be required regardless of any final decision with respect to the merits of real time water level monitoring outlined in 6.4 above, as opposed to theoretical computer modelling of the impact of infiltration on existing groundwater levels.
- Refinement of existing sub-areas and extension of the area mapped at the southern site to include some of the adjacent land further to the south.
- A detailed geotechnical report will be required for the consent hearings detailing soil types, depths, rock types, slope angles and geomorphology once the likely initial areas for irrigation have been targeted and investigated by drilling. Some laboratory testing of soil strengths from drilling samples is also recommended. This information is necessary for consenting but will not affect the classification as suitable of the areas chosen here.
- Preliminary stability analysis will then be possible to indicate the general order of the current factor of safety of the slope areas prior to any irrigation commencing.
- The establishment of a baseline geodetic survey network is also recommended so that future resurveys can be done during irrigation operation to detect and monitor any subtle slope creep (at rates of mm/year, a common precursor to major movement) should slope movement begin to occur as wastewater loads are applied and/or progressively increased.

Standard Limitations

This report has been prepared for the benefit of, and under specific instruction from Christchurch City Council as our client with respect to the brief. The reliance by other parties on the information or opinions contained in the report shall be at such parties' sole risk.

Opinions and judgements made in this report are based on our understanding and interpretation of current regulatory standards and should not be construed as legal opinions. Where opinions or judgements are to be relied on they should be independently verified with appropriate legal advice.

Technical recommendations and opinions in this report are based on a discrete number of natural exposures, geomorphic observations and walkover inspections in partly forested terrain with limited (or no) vehicle access. The nature and continuity of subsoil conditions and geomorphic processes away from the data locations are inferred and it must be appreciated that actual conditions could vary from the assumed model.

During excavation and construction, an Engineer or Engineering Geologist competent to judge whether the exposed sub-soils are compatible with the inferred conditions on which the report has been based should examine the site. It is possible that the nature of the exposed sub-soils may require further investigation, and the subsequent modification of design work. For this reason it is important that Geotech Consulting Ltd be contacted if there is any variation in subsoil conditions from those described in this report as it may alter our recommendations.

SIGNED:

(Dr Mark Yetton for Geotech Consulting Ltd), January 15, 2010

APPENDIX FIVE:

AKAROA WASTEWATER OPTIONS COST SUMMARY TABLE

Project: **Akaroa Wastewater** | Job #: 2150-128694-01
Date: Rev 19.01.10
Sheet: **Capital and Operating Cost Summary** | Prepared by: ICH / LCA
Checked by: AMD /TBH

Filepath: N:\2150\128694_01\400 Tech\[calc05v3-Akaroa Wastewater Management Total Cost.xls]Summary Sheet

Treatment Plant at Existing Site

	Harbour Outfall Only	DWF Irrigation	Hybrid Disposal
Capital Cost Estimates			
Takamatua Conveyance	5,507,000	5,507,000	5,507,000
Akaroa Conveyance Upgrade	Not Required	Not Required	Not Required
Land Purchase (Excluded)	0	0	0
Treatment Plant Upgrade	4,403,000	4,403,000	4,403,000
Harbour Outfall Upgrade	1,953,000	2,499,000	1,953,000
Irrigation Upgrade incl rising main	0	10,805,000	9,130,000
Total Capital Cost Est ($)	***$ 11,863,000***	***$ 23,214,000***	***$ 20,993,000***
Operating Cost Estimates			
Conveyance to WwTP	17,000	17,000	17,000
Wastewater Treatment	330,000	331,200	320,500
Effluent Disposal (Land)		184,000	130,000
Total Operating Cost ($/y)	**347,000**	**532,200**	**467,500**
Net Present Value			
Net Present Value ($M)	**$ 18.7**	**$ 34.1**	**$ 30.5**
(3% inflation, 6% discount)			

Treatment Plant at Akaroa South

	Harbour Outfall Only	DWF Irrigation	Hybrid Disposal
Capital Cost Estimates			
Takamatua Conveyance	5,507,000	5,507,000	5,507,000
Akaroa Conveyance to new WwTP	6,702,000	6,702,000	6,702,000
Land Purchase (Excluded)	0	0	0
New Treatment Plant	9,061,000	9,061,000	9,061,000
Harbour Outfall Upgrade	2,499,000	2,499,000	2,499,000
Irrigation Upgrade	0	5,338,000	4,037,000
Total Capital Cost Est ($)	***$ 23,769,000***	***$ 29,107,000***	***$ 27,806,000***
Operating Cost Estimates			
Conveyance	63000	63000	63000
Wastewater Treatment	341500	358600	352700
Effluent Disposal (Land)	0	166000	121000
Total Operating Cost ($/y)	**404,500**	**587,600**	**536,700**
Net Present Value			
Net Present Value ($M)	**$ 32.0**	**$ 41.2**	**$ 38.8**
(3% inflation, 6% discount)			

APPENDIX SIX:

AKAROA WASTEWATER OPTIONS RISK ANALYSIS TABLE

AKAROA WASTEWATER OPTIONS AND RISK ANALYSIS

<u>**Risk Matrix**</u>	**Severe**	**Major**	**Moderate**	**Minor**	**Neligible**
Very Likely	Very High	Very High	High	High	Medium
Likely	Very High	High	High	Medium	Medium
Possible	High	High	High	Medium	Low
Unlikely	High	Medium	Medium	Low	Low
Rare	High	Medium	Medium	Low	Low

RISKS		**WASTEWATER OPTIONS FOR AKAROA**																		**Comments**
		Existing Site - Harbour Disposal			**Existing Site - All DWF Irrigation**			**Existing Site - Hybrid Disposal**			**Akaroa South - Harbour**			**karoa South -All DWF Irrigatio**			**Akaroa South - Hybrid Disposal**			
		Likelihood	Consequence	Risk	Likelihood	Consequence	Risk	Likelihood	Consequence	Risk	Likelihood	Consequence	Risk	Likelihood	Consequence	Risk	Likelihood	Consequence	Risk	
SOCIAL	Visual Impact	Unlikely	Minor	Low	Possible	Minor	Medium	Possible	Minor	Medium	Possible	Minor	Medium	Possible	Minor	Medium	Possible	Minor	Medium	Higher visual impact anticipated for the South Akaroa site
	Odour Impact	Unlikely	Minor	Low	Unlikely	Minor	Low	Unlikely	Minor	Low	Unlikely	Minor	Low	Unlikely	Minor	Low	Unlikely	Minor	Low	Sufficient setback and odour control equipment will greatly reduce this risk.
	Noise Impact	Unlikely	Minor	Low	Unlikely	Minor	Low	Unlikely	Minor	Low	Unlikely	Minor	Low	Unlikely	Minor	Low	Unlikely	Minor	Low	Good design practice will minimise this risk.
	Community non-acceptance towards site location	Possible	Major	*High*	Likely	Major	*High*	Likely	Major	*High*	Rare	Major	Medium	Rare	Major	Medium	Rare	Major	Medium	Existing WwTP site holds very important cultural value.
	Community non-acceptance towards effluent disposal	Likely	Major	*High*	Unlikely	Major	Medium	Unlikely	Major	Medium	Likely	Major	*High*	Unlikely	Major	Medium	Unlikely	Major	Medium	Community prefers land discharge over harbour discharge
CULTURAL	Effect on Mauri	Possible	Moderate	*High*	Rare	Minor	Low	Unlikely	Moderate	Medium	Possible	Moderate	*High*	Rare	Minor	Low	Unlikely	Minor	Low	Subject to further consultation
	Cultural non-acceptance towards site location	Very Likely	Major	***Very High***	Very Likely	Major	***Very High***	Very Likely	Major	***Very High***	Unlikely	Major	Medium	Unlikely	Major	Medium	Unlikely	Major	Medium	High cultural values in existing / south akaroa sites
	Cultural non-acceptance towards effluent disposal	Very Likely	Major	***Very High***	Very Likely	Major	***Very High***	Possible	Major	*High*	Very Likely	Major	***Very High***	Possible	Major	*High*	Possible	Major	*High*	Harbour discharge is a contentious issue.
ENVIRONMENT	Adverse Effects on Harbour	Unlikely	Moderate	Medium	Unlikely	Minor	Low	Unlikely	Minor	Low	Unlikely	Moderate	Medium	Unlikely	Minor	Low	Unlikely	Minor	Low	Higher risks associated with all year round discharge due to greater effluent volume
	Adverse Effects on Recreation Water Users	Unlikely	Moderate	Medium	Rare	Minor	Low	Unlikely	Minor	Low	Unlikely	Minor	Low	Rare	Minor	Low	Unlikely	Minor	Low	DWF irrigation and hybrid options only discharge to the harbour when there are less recreational water users
FEASIBILITY	Consenting Process	Likely	Moderate	*High*	Possible	Moderate	*High*	Possible	Moderate	*High*	Likely	Moderate	*High*	Possible	Moderate	*High*	Possible	Moderate	*High*	Cultural issues around existing site/Akaroa south. Harbour discharge is not preferred by the
	Land Availability	Rare	Minor	Low	Possible	Severe	*High*	Possible	Severe	*High*	Unlikely	Moderate	Medium	Possible	Severe	*High*	Possible	Severe	*High*	Under investigation
	Restriction on Irrigation due to stability/ watertable	Rare	Neligible	Low	Possible	Severe	*High*	Unlikely	Moderate	Medium	Rare	Neligible	Low	Possible	Severe	*High*	Unlikely	Moderate	Medium	Restriction in irrigation area will significantly affect the All DWF irrigation options as the flow to be bypassed will be increased.
	Option Not Affordable	Unlikely	Major	Medium	Possible	Major	*High*	Possible	Major	*High*	Possible	Major	*High*	Likely	Major	*High*	Likely	Major	*High*	Options with Relocation/Irrigation are over $20M. Options with Relocation/Harbour is ~ $15M