CASTALIA

Economic Cost Benefit Evaluation – Whakamana Te Waituna Contaminant Intervention Project

Report for Living Water, a partnership between Fonterra and the Department of Conservation

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Definitions

The Lagoon	The Waituna Lagoon
LWP	Living Water Programme
DOC	Department of Conservation
CBA	Cost Benefit Analysis
N	Nitrogen
NPV	Net Present Value
BCR	Benefit-Cost Ratio
COS	Cash Operating Surplus
ICOLL	Intermittently Closed and Open Coastal Lake or Lagoon
PV	Present Value
ha	Hectare
SDR	Social Discount Rate
PCE	Parliamentary Commissioner for the Environment
SRTP	Social Rate of Time Preference
SOC	Social Opportunity Cost

Executive summary

The Waituna Lagoon (The Lagoon) is a coastal wetland that lies at the bottom of the Waituna catchment in Southland and forms part of the Awarua Wetlands. It is one of New Zealand's last remaining natural coastal lagoons and is renowned for its cultural and scientific value. The Waituna catchment has experienced substantial land-use intensification over the last century. Land development to increase agricultural productivity has increased flows of nutrients and fine sediment into the lagoon. Climate change is expected to increase these stresses on the lagoon's ecosystem.

The Living Water Programme (LWP) is a 10-year partnership between the Department of Conservation (DOC) and Fonterra to enable farming and freshwater to thrive together.[1] The programme is working with iwi and several local organisations as part of the Whakamana Te Waituna Partnership to improve the health and resilience of the Waituna Lagoon.

Whakamana Te Waituna is a coordinated catchment management effort that aims to maintain and enhance the Waituna Lagoon ecosystem. One of the goals of Whakamana Te Waituna is to increase the resilience of the lagoon by reducing the sediment and nutrient losses that reach the Waituna Lagoon.[2]

Living Water hired Castalia to evaluate the economic impacts of the Whakamana Te Waituna Contaminant Intervention Project (the Project) in the Waituna catchment to help with understanding the costs and benefits of freshwater stewardship.

We evaluate the impact of the Whakamana Te Waituna Contaminant Intervention Project by analysing different scenarios that change the risk of the Waituna Lagoon shifting to an algal dominated regime

We evaluate two alternative Whakamana Te Waituna Scenarios against three counterfactual scenarios that account for uncertainties about the future status of the Lagoon under business as usual.

We defined the '**catchment-level interventions scenario'** as the most favourable scenario presented in a report commissioned by the Whakamana Te Waituna partnership and written by the environmental science advisory firm, Aqualinc. This scenario is dominated by strategic interventions at the catchment scale, and included only minor on-farm changes. We assume that the catchment-level interventions scenario achieves a 50 percent nitrogen load reduction.

The '**farm-level interventions Scenario'** includes adjustments to the interventions outlined in the Aqualinc report that were decided upon in consultation with local stakeholders. This scenario has a greater focus on on-farm interventions, and includes fewer catchment-level interventions. Unlike the catchment-level interventions scenario, the farm-level interventions scenario interventions are not expected to reduce N load by 50 percent. Therefore, the lagoon will be at higher risk of a regime shift to an algal-dominated state.

We also modelled a third scenario, called the 'no-land purchase scenario' which was identical to the farm-level interventions scenario but without additional land purchase around the

1 Living Water website. Living Water Partnership. Available online at: https://www.livingwater.net.nz

2 Bright, J., Legg, J., Irving, C., Ingle, A., & Parshotam, A. (2021). *Whakamana Te Waituna: Containment Load Reduction Plan.* Aqualinc Research Limited, Prepared for Whakamana Te Waituna Trust. RD18020/1

Waituna Lagoon. The interventions modelled in these three scenarios are shown in Table 0.1, below.

Table 0.1: Interventions modelled in the three scenarios analysed.

Scenario name	Level of on-farm mitigations[3]	Drainage network modifications	Retirement of farmed areas near the lagoon
Catchment-level interventions	Low	Two constructed wetlands (one mid-catchment and one in lower Waituna Creek) with a total area of 200 ha, bank re-shaping, and sediment filters	Retirement of 1,937 ha of land adjacent to the Waituna Lagoon
Farm-level interventions	Medium	One constructed wetland in the mid-catchment with a total area of 150 ha, bank re-shaping, and sediment filters	Retirement of 1,937 ha of land adjacent to the Waituna Lagoon
No-land purchase	Medium	One constructed wetland in the mid-catchment with a total area of 150 ha, bank re-shaping, and sediment filters	Retirement of 451 ha of land adjacent to the Waituna Lagoon[4]

The counterfactual scenarios estimate a state of the world in which Whakamana Te Waituna does not go ahead. To account for the uncertainty about the impacts of this on the Waituna Lagoon, we compare the costs and benefits against three potential counterfactual scenarios:

- **Stable –** The risk of the Lagoon shifting from a macrophyte dominated state to an algal dominated state remains equal over time
- **Moderate deterioration –** The probability of a regime shift to an algal dominated state increases moderately over time
- **High deterioration –** The impacts of nutrient inflows are compounded by the impacts of climate change. The probability of a regime shift to an algal dominated state increases rapidly over time.

The Net Present Value (NPV) of the Whakamana Te Waituna Contaminant Intervention Project is negative in all scenarios evaluated

Table 0.2 below shows the estimated NPV of the Whakamana Te Waituna Contaminant Intervention Project in both the catchment-level interventions scenario and the farm-level interventions scenario against the three counterfactual scenarios.

[3] The level of on-farm mitigations are taken from the Aqualinc report and the specific changes are detailed in Tables 4.2 and 4.5, below.

[4] Whakamana Te Waituna has already purchased 451 hectares of dairy and beef farmland adjacent to the Waituna lagoon to restore, over time, to its natural state.

Table 0.2: Estimated NPV of the Whakamana Te Waituna Contaminant Intervention Project in each scenario

Scenario	Stable	Moderate	High
Catchment-level interventions scenario	-$1,407,000	-$1,073,000	-$718,000
Farm-level interventions scenario	-$10,825,000	-$10,424,000	-$10,068,000

The NPV should be compared to the benefits that sit outside the CBA

We have not estimated some important benefits in dollar terms, and these benefits have not been included in the numerical CBA. The following benefits were not quantified, because their assessment was outside the scope of the current report:

- Cultural values, including historic and traditional association and mauri
- Ecological and scientific significance

The NPV should **not** be interpreted as a definitive estimate of the value of the Whakamana Te Waituna Contaminant Intervention Project because it needs to be compared against benefits that sit outside the CBA. Given that the net present value of each of the scenarios tested is negative, the question for decision-makers is:

Is the net present cost of undertaking the Whakamana Te Waituna Contaminant Intervention Project justified by the combined benefits of:

- ***Protecting cultural values including historical and traditional association and preserving and enhancing the mauri of the area***
- ***Preserving the ecological and scientific significance of the Waituna Lagoon?***

Figure 0.1 and Figure 0.2 illustrate the NPV, quantified economic costs, and quantified economic benefits of the farm-level interventions scenario and the catchment-level interventions scenario respectively.

Figure 0.1: NPV of farm-level interventions scenario

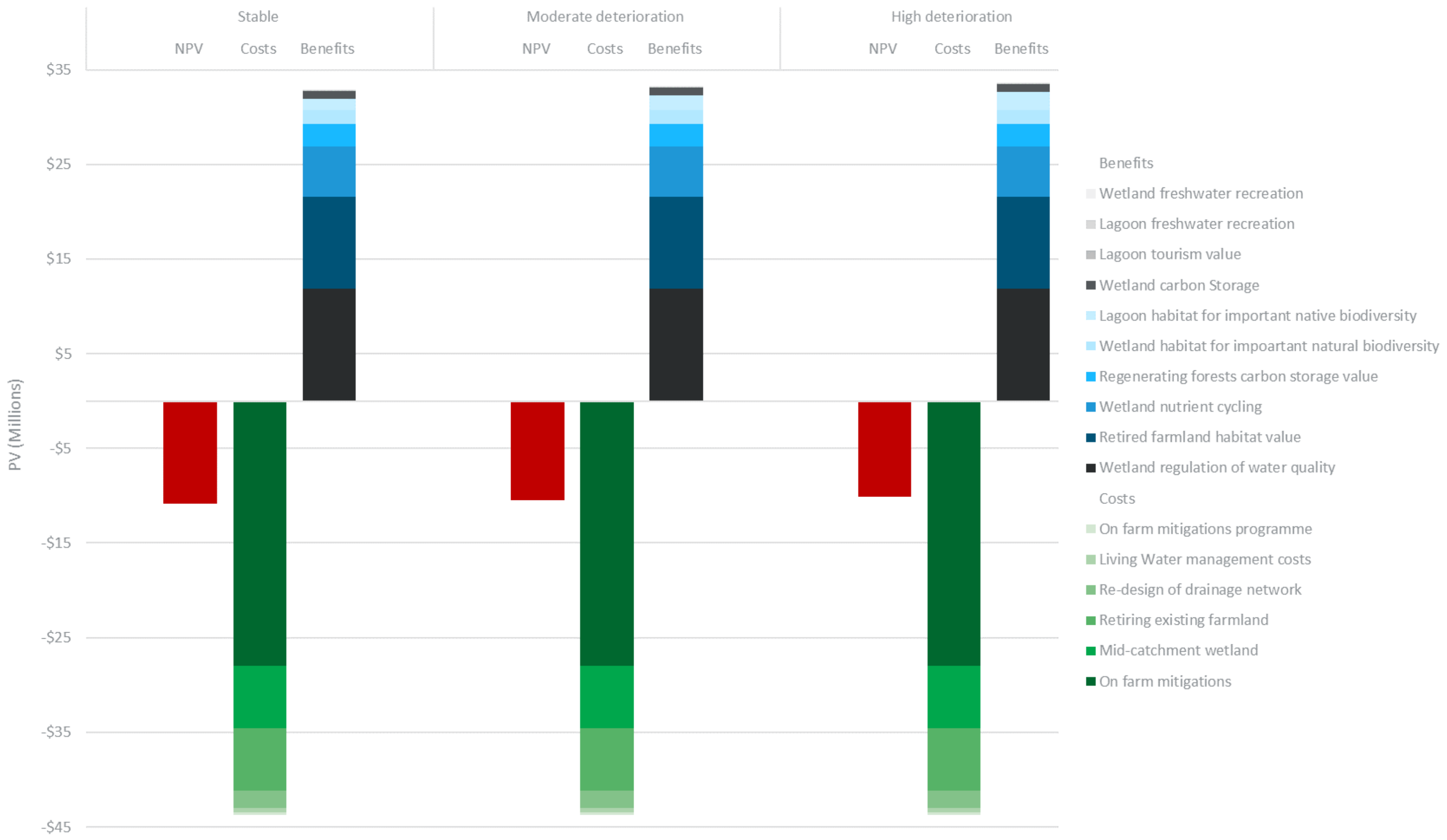


Figure 0.2: NPV of catchment-level interventions scenario

Most of the quantified benefits are derived directly from implementing mitigation measures

In the catchment-level interventions scenario, the specific benefits of mitigation measures account for over 97 percent of the total quantified benefits of the Whakamana Te Waituna Contaminant Intervention Project. In the farm-level interventions scenario, these benefits account for over 94 percent. The benefit of reducing the risk of a regime shift to an algal-dominated state make up only a small fraction of the benefits in each scenario.

The NPV is lower in the farm-level interventions scenario than in the catchment-level interventions scenario

There are two main reasons why the quantified economic cost of the farm-level interventions scenario is greater than the catchment-level interventions scenario:

- The catchment-level interventions scenario assumes more wetlands are constructed, and more farmland is returned to its natural state. Most of the quantified economic benefits of the Whakamana Te Waituna Contaminant Intervention Project result from implementing these mitigation measures rather than from reducing the probability of a regime-shift in the lagoon.
- The farm-level interventions programme includes “medium” on-farm mitigations as described in the Aqualinc report. The Aqualinc report estimates the reduction in cash operating surplus (COS) of “medium” on-farm mitigations is significantly greater than the “low” on-farm mitigations assumed in the catchment-level interventions scenario.

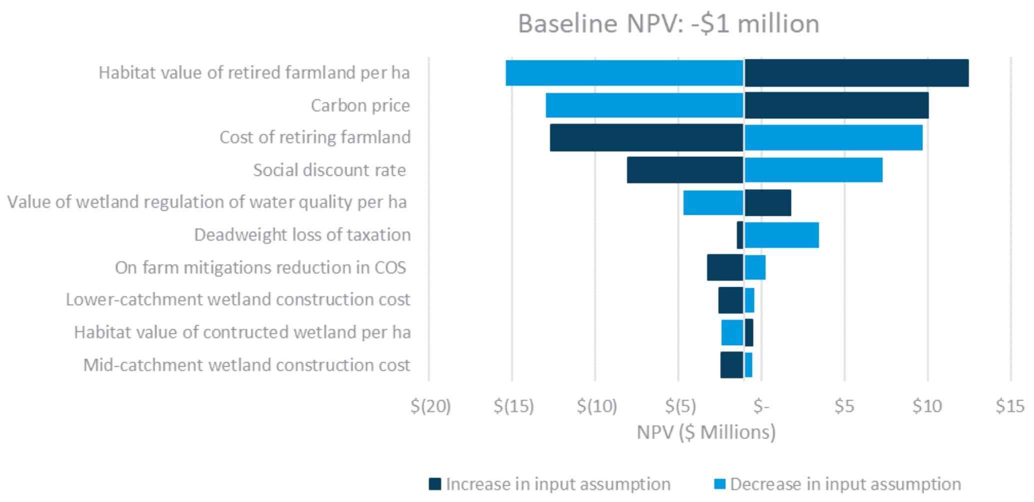
The results highlight important values that could be monetised to drive better environmental outcomes

Retired farmland habitat value was identified as an important benefit of the Whakamana Te Waituna Contaminant Intervention Project in both Whakamana Te Waituna Scenarios. Currently, the habitat value provided by retired farmland is largely a public good, and there are no large-scale mechanisms to encourage farmers to provide natural habitats on their land. This could be changed by the introduction of innovative mechanisms for monetising ecosystem services, such as the adoption of biodiversity credits, nature-based solutions accounting, or public procurement funds for environmental outcomes.

The NPV of the quantified costs and benefits depend on some key assumptions

We conduct sensitivity analysis on our estimates of individual costs and benefits and other modelling assumptions. Figure 0.3 provides a visual representation of the sensitivity analysis on key assumptions made in the catchment-level interventions scenario relative to the moderate deterioration counterfactual. Because only a small proportion of the quantified economic benefits are specific to the risk of a regime shift, variance in the probabilities used do not significantly impact the results.

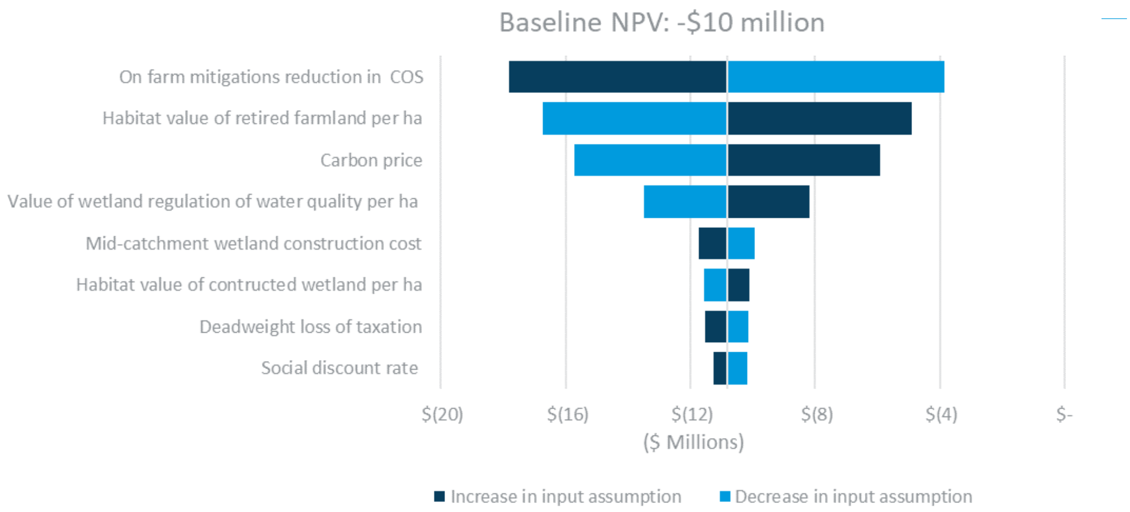
Figure 0.3: Catchment-level interventions scenario sensitivity analysis (moderate counterfactual)



Uncertainty in the habitat value of retired farmland has the greatest impact on the quantified NPV of the catchment-level interventions scenario. This is unsurprising, given that the habitat value of retiring farmland is the largest individual benefit in this scenario. Uncertainty in the carbon price has the next greatest impact on the quantified NPV of the catchment-level interventions scenario. Similarly, this is because a large area of farmland is retired and restored to its natural state in the catchment-level interventions scenario.

Figure 0.4 provides a visual representation of the sensitivity analysis on key assumptions made in the farm-level interventions scenario relative to the moderate deterioration counterfactual.

Figure 0.4: Farm-level interventions scenario sensitivity analysis (moderate counterfactual)



If interventions follow the farm-level interventions scenario, then it will be most important to monitor the impact of on-farm mitigations on farm cash operating surplus. This is the largest cost of the interventions in this scenario, and it drives much of the resulting Net Present Value, meaning that the impact of inaccuracies in estimating these costs may be highly significant.

Extending the analysis period of the CBA to 40 years provides a more comprehensive view of the costs and benefits of the Whakamana Te Waituna Contaminant Intervention Project

Extending the analysis period to 40 years results in a positive Net Present Value (NPV) and a Benefit Cost Ratio (BCR) of greater than one in the catchment-level intervention scenario:

- The NPV increases because the benefits outweigh the costs in the extended analysis period – this is because most of the costs in this scenario are investment costs that occur in the first years of the programme, whereas the benefits continue for a longer period
- The BCR increases because the ratio of benefits to costs is greater in the extended analysis period – this is because the BCR in the extended analysis period is greater than in the first 10 years.

Extending the analysis period to 40 years in the farm-level intervention scenario increases the BCR and the NPV:

- The NPV and the BCR increase because the benefits outweigh the costs in the extended analysis period

Figure 0.5 and Table 0.3 show the impact of extending the analysis to 40 years on the NPV and the BCR in both Whakamana Te Waituna Scenarios.

Figure 0.5: Comparison of the NPV in both Whakamana Te Waituna Scenarios to an extended analysis period

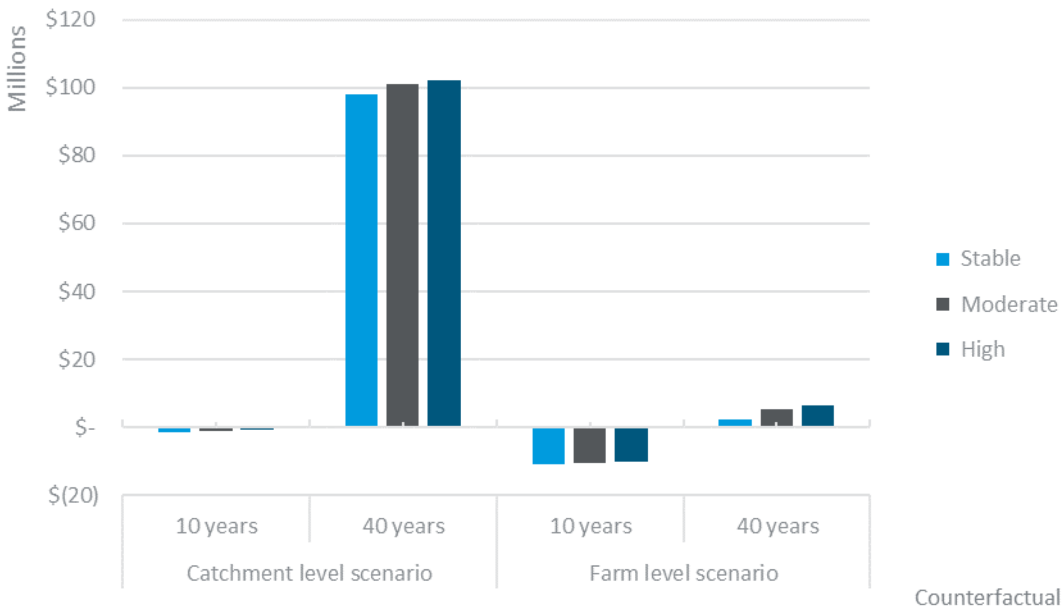


Table 0.3: Comparison of the BCR in both Whakamana Te Waituna Scenarios to an extended analysis period

Social discount rate	Stable counterfactual	Moderate counterfactual	High counterfactual
	catchment-level interventions scenario		
10 years	0.98	0.98	0.99
40 years	2.26	2.29	2.31
	Farm-level interventions scenario		
10 years	0.75	0.76	0.77
40 years	1.03	1.06	1.08

The Whakamana Te Waituna Contaminant Intervention Project appears more economically attractive under alternative approaches to social discounting

The NPV and BCR in the catchment level intervention scenario are higher under all alternative approaches to social discounting when using a 40-year analysis period:

- **Social Rate of Time Preference (SRTP) approach to social discounting**–in the catchment-level intervention scenario, the benefits outweigh the costs in the later years of the analysis period. The lower discount rate derived from the SRTP approach places greater emphasis on the net benefit in the later years of the analysis period and results in an increase in both the NPV and BCR
- **Hyperbolic discounting–**the NPV and BCR are higher because the hyperbolic discount rate applies the lower discount rate derived from the SRTP approach for the first 30

years. The results are only marginally more favourable than the SRTP approach above because the decline in discount rates only begins after 30 years

- **Dual discounting–**Dual discounting applies a lower discount rate to natural capital, placing greater emphasis on the benefits of the Whakamana Te Waituna Contaminant Intervention Project that occur in the later years of the analysis period. The NPV and BCR are significantly higher because the benefits of the Whakamana Te Waituna Contaminant Intervention Project are derived from natural capital and occur far in the future.

The BCR in the Ffarm-level intervention scenario is higher under all alternative approaches to social discounting when using a 40-year analysis period. However, the NPV is only higher under the dual discounting approach:

- **SRTP approach to social discounting**–in the farm-level intervention scenario, the costs outweigh the benefits in the later years of the analysis period. Therefore, the lower discount rate derived from the SRTP approach places greater emphasis on the net-cost in later years and results in a decrease in the NPV. The BCR increases because the significant investment costs in the early years of the Whakamana Te Waituna Contaminant Intervention Project have less influence on the overall results
- **Hyperbolic discounting–**the NPV decreases, and the BCR increases because the hyperbolic discount rate applies the lower discount rate derived from the SRTP approach for the first 30 years. The results are marginally different from the SRTP approach because the decline in discount rates only begins after 30 years
- **Dual discounting–**the NPV that is positive and a BCR that is greater than one. This is because the ongoing benefits of the Whakamana Te Waituna Project are derived from natural capital, whereas the ongoing costs are derived from manufactured capital.

Figure 0.6 and Table 0.4 show the NPV and BCR in each of the Whakamana Te Waituna Scenarios using the New Zealand Treasurys recommended Social Discount Rate (SDR) and the alternative approaches to social discounting provided in the PCE report.[5]

[5] The moderate deterioration counterfactual is assumed for each result shown. The counterfactual scenarios estimate a state of the world in which the Whakamana Te Waituna Contaminant Intervention Project does not go ahead. To account for the uncertainty about the impacts of this on the Waituna Lagoon, we compare the costs and benefits against three potential counterfactual scenarios. The moderate deterioration counterfactual assumes the probability of a regime shift to an algal dominated state increases moderately over time.

Figure 0.6: Comparison of the NPV in both Whakamana Te Waituna Scenarios using the NZ Treasurys guidance and alternative approaches to social discounting

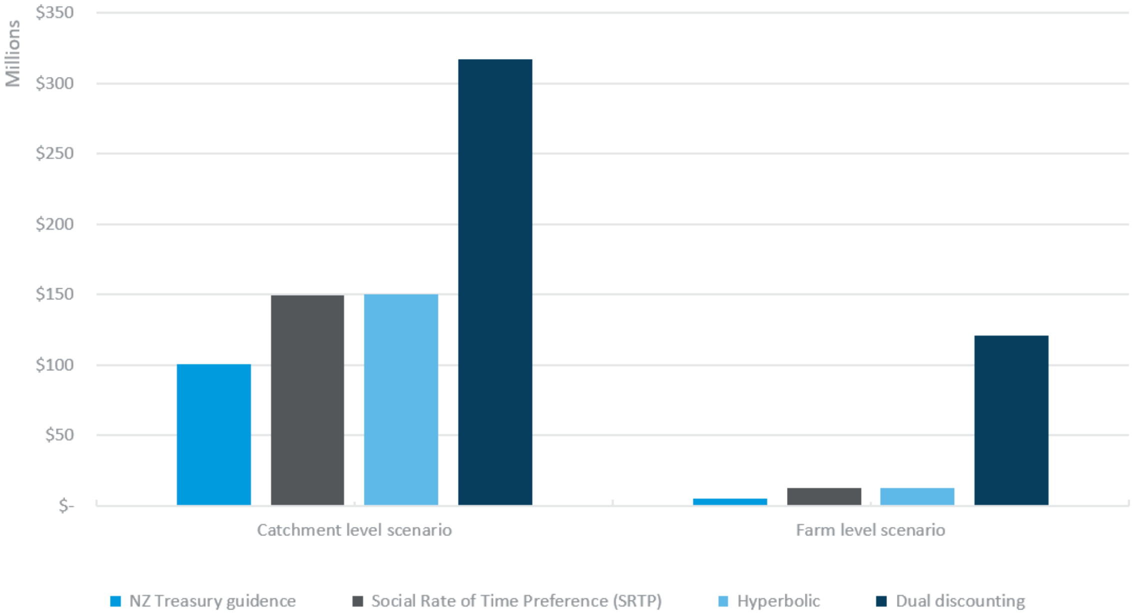


Table 0.4: Comparison of the BCR in both Whakamana Te Waituna Scenarios using the NZ Treasurys guidance and alternative approaches to social discounting

Analysis period	BCR
catchment-level interventions scenario	
NZ Treasury guidance	1.74
SRTP approach	2.10
Hyperbolic discounting	2.11
Dual discounting	3.81
Farm-level interventions scenario	
NZ Treasury guidance	1.06
SRTP approach	1.11
Hyperbolic discounting	1.11
Dual discounting	2.36

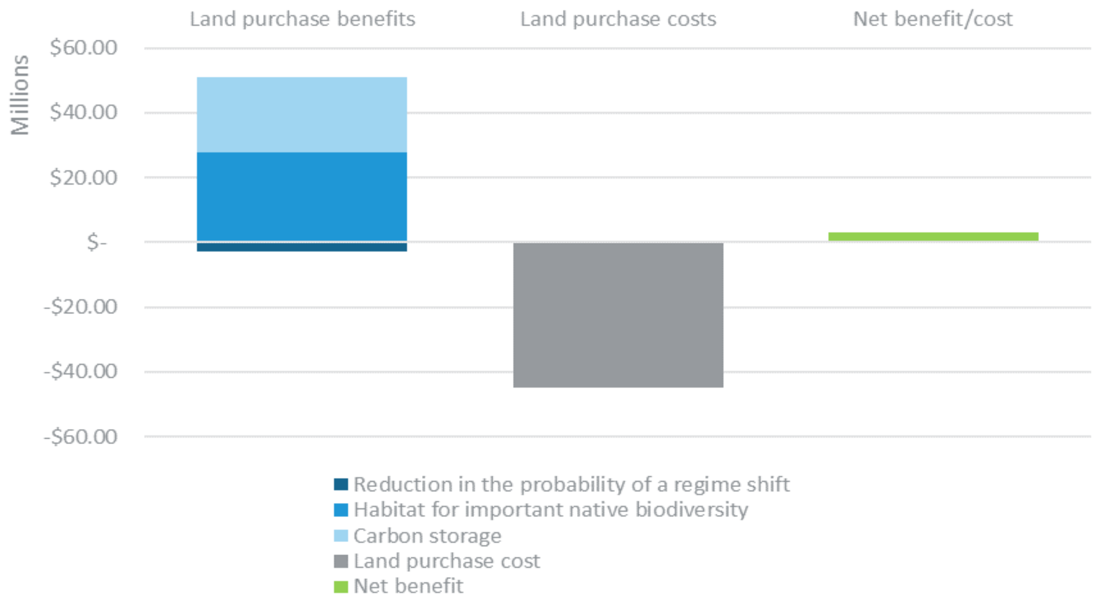
A no-land purchase scenario produces a lower NPV and BCR than the two Whakamana Te Waituna Scenarios

A third Living Water scenario, that is identical to the farm-level intervention scenario but without the land purchase around the lagoon, produces a lower NPV and BCR than the two

Whakamana Te Waituna Scenarios.[6] This is because the benefits of land purchase outweigh the costs over the 10-year analysis period.

Figure 0.7 illustrates the benefits and costs of the land purchase alone in the farm-level intervention scenario.

Figure 0.7: Comparison of the direct costs and benefits of land purchase around the lagoon



There are several promising avenues for extending the current evaluation and existing research on freshwater quality in the Waituna catchment

A separate assessment of cultural and passive values[7] provided by freshwater restoration in the region would make this analysis more complete. This would need to be co-designed with tangata whenua. While cultural and passive values were left out of the numerical CBA, their relevance is highlighted throughout this report. In reality it may not be feasible or appropriate to estimate the monetary value of cultural values. Therefore, it may be preferable to combine the results of this study with a range of other considerations in a multi criteria analysis which would combine both monetised and non-monetised values.

Ecological restoration activities and alternative management approaches under the Whakamana Te Waituna Contaminant Intervention Project are expected to reduce the likelihood of this regime shift in the lagoon to an algal-dominated state. However, the probabilities attached to the Lagoon shifting regime under each assessment scenario were 'best guess' estimates, formed in consultation with the Living Water team. Greater

[6] To aid comparison with the farm level and catchment level scenarios, we evaluate the no-land purchase scenario over a 10-year analysis period.

[7] Passive value otherwise known as "non-use value" is the value derived from the existence of an environmental resource without on-site use. This may be motivated by an ecological ethic, altruism toward others, or bequests to future generations.

understanding of the link between nutrient inflows and risk of a regime shift would help to understand the scale of the generic benefits of the Whakamana Te Waituna Contaminant Intervention Project.

A logical way to extend this initial work would be to undertake a commercial analysis that considers only those costs and benefits that affect landowners. This commercial analysis would show whether alternative water management interventions are commercially beneficial for farmers or whether the programme is requiring farmers to undertake changes that cost them commercially.

This CBA lays out a template that could be used elsewhere to identify other restoration programmes that could provide a net economic benefit

The results of the CBA reflect the geographic idiosyncrasies of the catchment. The results indicate that it would be highly likely that freshwater restoration efforts in other catchments would have net economic benefits.

For example, the flood mitigation benefits of constructed wetlands in the Waituna catchment were deemed immaterial because the wetlands are located in the lower catchment with few downstream residents or structures. If constructed wetlands in the Waituna Catchment provided flood mitigation benefits at the ‘average’ level expected in New Zealand, the catchment-level interventions scenario would provide net benefits in excess of $10 million. There are likely to be many catchments in New Zealand where the economic benefits of constructing wetlands vastly outweigh the costs.

Sensitivity analysis also shows that the cost of retiring farmland has a large impact on the quantified NPV. The net economic impact of restoration programmes in other catchments is likely to be more positive where the cost of acquiring and retiring farmland is lower.

1 Introduction

The Waituna Lagoon (The Lagoon) lies at the bottom of a small catchment in Southland and forms part of the Awarua Wetlands. It is one of New Zealand's last remaining natural coastal lagoons and is renowned for its cultural and scientific values. The Lagoon gained Scientific Reserve status in New Zealand in 1983 and is recognised internationally as a Ramsar site[8]. The cultural significance to the local Ngāi Tahu iwi was recognised under a Statutory Acknowledgement with the Ngāi Tahu Claims Settlement Act 1998. The Department of Conservation (DOC) has identified the lagoon as a priority ecosystem for the conservation of New Zealand's natural heritage.

Increased farming intensity In Southland has degraded the quality of the lagoon

The Lagoon is located within a catchment that has experienced substantial land-use intensification over the last century. European farming practises have resulted in changes to the landscape, such as wetland clearance, drainage enhancement and fertiliser inputs. Large-scale developments began in the 1960s and dairy farming and other pastoral land use now make up over 70 percent of the total land area in the catchment.[9]

Land development to increase agricultural productivity in the Waituna catchment has increased the export of nutrients and fine sediment into the lagoon. Sediment flow into the lagoon has increased by 10 times since the onset of European farming practises.[10]

Increased sediment and nutrient loading increase the abundance of algae. Algal blooms undermine mahinga kai and endangered flora and fauna species. Under certain circumstances, certain types of algae can produce toxins which can cause rashes, nausea and be potentially deadly for dogs to drink.

The extent of aquatic plant (Macrophyte) cover, and in particular a species of native macrophyte (Ruppia) is thought to be a good indicator of the health and resilience of the lagoon and is monitored annually. Increased sediment and nutrient loading also reduce the abundance of Ruppia. Ruppia is vital to safeguard the lagoon as it protects water quality, dampens wave action, and stops the bed being stirred up.

Since the 1950s, local authorities have mechanically opened the lagoon to the sea on a periodic basis to drain the surrounding farmland and flush nutrient-rich lagoon water. Mechanical opening currently operates based on resource consent, which allows opening when the water level reaches specified thresholds.[11]

While the science is uncertain, experts believe that the Lagoon is at risk of a regime shift from a macrophyte-dominant state to an algal-dominant state

It is difficult to identify the state of the lagoon and the long-term trend because of a lack of quantifiable long-term monitoring data. The Lagoon is a complex ecosystem. It is classified as

[8] A Ramsar site is a wetland site designated to be of international importance under the Ramsar Convention, an intergovernmental environmental treaty established in 1971 by UNESCO, which came into force in 1975.

[9] Environment Southland Lagoon Technical Group (2013). Ecological Guidelines for Waituna Lagoon.

[10] Cadmus, R.W. 2004. What Is, What Was, and What Will Be: Environmental History as a Basis of Sustainable Wetland Restoration, unpublished thesis (M.Sc.), University of Otago.

[11] Tait, A., & Pearce, P. (2019). *Impacts and implications of climate change on Waituna Lagoon, Southland.* Department of Conservation, Science for Conservation Series 335

an Intermittently Closed and Open Coastal Lake or Lagoon (ICOLL). The biological, chemical, and physical state of the lagoon changes constantly in response to both internal and external variables. The lagoon will fluctuate between trophic levels due to interactions between managed land and water uses, human interventions, and natural environment variability.

The consensus of scientific studies is that the lagoon remains in a macrophyte-dominated state and is at risk of a regime shift to an algal-dominated state. If the lagoon experiences a regime shift to an algal-dominated state, it will likely be permanent because a regime-shift would alter the fundamentals of the Lagoons ecology. A regime shift to an algal-dominated state would undermine many of the values the lake provides.

Climate change is likely to increase the risk of a regime shift

Climate change is expected to affect the lagoon's ecosystem and have a material impact on the water quality in the lagoon. A DOC report describes three effects of climate change that will impact the resilience of the lagoon. [12]

- The Waituna area is expected to experience more variable weather conditions and become warmer over the coming decades. This is likely to reduce lagoon-bed light levels and increase sediment loading in the Waituna lagoon
- Sea-level rise is likely to reduce the efficacy of lagoon openings. The intertidal lagoon area would decrease by 64% with a 1m sea-level rise, compared with present. The mechanical lagoon opening threshold level would need to be higher than today's level to generate enough hydraulic gradient to flush the lagoon
- The lagoon is expected to experience increased inflows in the winter, autumn, and spring. This will require an increase in the threshold for mechanical lagoon opening, or more frequent lagoon opening under current thresholds, to flush the lagoon.

The trajectory of climate change and the response of the lagoon system is uncertain due to the complexity of the lagoon system. Overall, it is expected that climate change will increase algae growth and inhibit Ruppia growth in the Waituna lagoon, increasing the risk of a regime-shift.

The Living Water Programme (LWP) aims to improve the resilience of the lagoon

The LWP *is a 10-year partnership between DOC and Fonterra to enable farming and freshwater to thrive together.*[13] The programme is working with iwi and several local organisations as part of the Whakamana Te Waituna Partnership to improve the health and resilience of the Waituna Lagoon. Whakamana Te Waituna is a coordinated catchment management effort that aims to maintain and enhance the Waituna Lagoon ecosystem.

One of the goals of Whakamana Te Waituna is to increase the resilience of the lagoon by reducing the sediment and nutrient losses originating from on-farm and off-farm activities and subsequently reaching Waituna Lagoon. [14]

Living Water hired Castalia to evaluate the economic impacts of the Whakamana Te Waituna Contaminant Intervention Project (the Project) to help broaden understanding about the costs

[12] Tait, A., & Pearce, P. (2019). *Impacts and implications of climate change on Waituna Lagoon, Southland.* Department of Conservation, Science for Conservation Series 335

[13] Living Water website. Available online at: / http://livingwater.net.nz

[14] Bright, J., Legg, J., Irving, C., Ingle, A., & Parshotam, A. (2021). *Whakamana Te Waituna: Containment Load Reduction Plan.* Aqualinc Research Limited, Prepared for Whakamana Te Waituna Trust. RD18020/1

and benefits of freshwater stewardship. In addition, we will develop a 'best-practice economic evaluation framework' to help guide the setup, monitoring, and evaluation of future work on freshwater quality.

2 Approach to the economic evaluation

We will use a tailored version of the standard Treasury guide to Social Cost-Benefit Analysis (CBA)[15] to evaluate the Whakamana Te Waituna Contaminant Intervention Project (the Project)

A CBA is based on the principles of welfare economics and seeks to quantify the net value to society of an intervention compared to the business as usual. It includes all significant costs and benefits that affect the welfare and wellbeing of the entire population, not just market effects.

Costs and benefits must be measured in terms of the impacts on people, including environmental impacts that cause costs and benefits to people. It is not just a financial assessment but rather an assessment that includes all the non-financial (and often non-monetary), public, and private benefits and costs that the Project could impact. Economic costs and benefits must be net changes and only include the costs and benefits over and above the business as usual of the option being assessed.

CBA is a powerful tool to evaluate planning decisions and compare the costs of a proposed activity against its potential benefits. A CBA organises information in a consistent and systematic way, making the best use of the information available. The purpose of CBA is not to precisely calculate "the" benefits and "the" costs, but to reduce the degree of uncertainty that would otherwise exist around estimates. It removes the reliance on intuition or prejudices. The results can provide crucial insights for decision-makers.

An economic evaluation requires a complete assessment of all the costs and benefits measured over the analysis period. As agreed with DOC and Fonterra, the time horizon of this assessment will be 10 years.

2.1 Assessment scenarios

We evaluate the impact of the Project by defining and analysing different scenarios that change the risk of the Waituna Lagoon shifting to an algal-dominated regime.

One of the goals of Whakamana Te Waituna Partership is to improve the health and resilience of the Waituna lagoon. The programme aims to prevent a regime shift in the lagoon, from a macrophyte-dominated to an algal-dominated state, where the health of the lagoon and the value it provides is significantly compromised.

We evaluate two alternative Whakamana Te Waituna Scenarios against three counterfactual scenarios that account for uncertainties about the future status of the Lagoon under business

[15] The Treasury. (2015). Guide to Social Cost Benefit Analysis. New Zealand Government. Available online at: https://www.treasury.govt.nz/publications/guide/guide-social-cost-benefit-analysis

as usual. Both Whakamana Te Waituna Scenarios are expected to significantly reduce the risk of the lagoon shifting to an algal-dominated regime.

2.1.1 Counterfactual scenarios

The counterfactual scenarios estimate a state of the world in which the Project[16] does not go ahead. Only the cost and benefits that occur over and above each respective counterfactual can be attributed to the Project.

The Waituna Lagoon has consistently not met targets for lagoon health during annual monitoring. It is clear the Lagoon is at risk of a regime shift to an algal-dominated state. It is not clear how this risk is changing over time. The results of multiple scientific studies do not clearly represent a trend in the health of the Waituna Lagoon. As an ICOLL, the relationships between ecosystem heath variables are complex and uncertain with the level of analysis undertaken to date.

To account for the uncertainty of the trend in the health of the Waituna Lagoon, we compare the costs and benefits against three potential counterfactual scenarios

The three counterfactual scenarios are:

- **Stable –** The risk of a regime shift to an algal-dominated state remains equal over time at 5 percent per year. At this level of risk, the lagoon has a 40% chance of a regime shift to an algal-dominated state over the ten years from 2023-2033[17]
- **Moderate deterioration –** The probability of a regime shift to an algal-dominated state increases moderately over time from 5 percent per year at a rate of 0.5 percent per year. At this level of risk, the lagoon has a 53 percent chance of a regime shift to an algal-dominated state over the ten years from 2023-2033[18]
- **High deterioration –** The impacts of nutrient inflows are compounded by the impacts of climate change (including increased summer low flows and winter high flows).[19] The probability of a regime shift to an algal-dominated state increases rapidly over time from 5 percent per year at a rate of 1 percent per year to reach 15 percent per year in 2033.At this level of risk, the lagoon has a 63 percent chance of a regime shift to an algal-dominated state over the ten years from 2023-2033[20]

2.1.2 Whakamana Te Waituna scenarios

We estimate the risk-adjusted benefit of the Lagoon remaining in a macrophyte dominated state

The main purpose of the Project is to reduce the risk of the lake shifting to an algal-dominated regime. We quantify the benefits of the Waituna lagoon remaining in a macrophyte-dominated state. We attach probabilities to the risk of a regime shift to an algal-dominated state in each

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[16] In this case, the 'Living Water Programme' is assumed to be synonymous with the broader Whakamana Te Waituna project. Therefore, it includes actions and activities from this broader project, even if they aren't directly led or funded by the Living Water partnership.

[17] Assuming the probability of a regime shift to an algal dominated state is independent in time can only occur once.

[18] Assuming the probability of a regime shift to an algal dominated state is independent in time and can only occur once

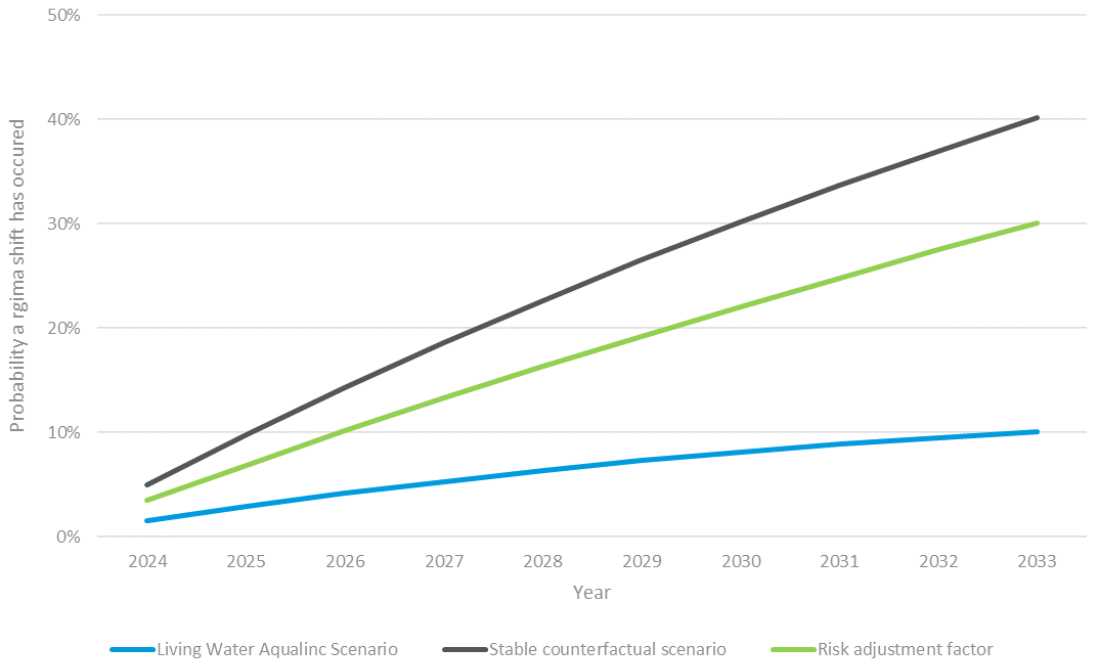
[19] Tait, A., & Pearce, P. (2019) recommend that climate change impacts and implications should be factored into future ecological research plans for Waituna Lagoon.

[20] Assuming the probability of a regime shift to an algal dominated state is independent in time and can only occur once.

scenario. We then calculate the risk-adjusted benefits of the Project scenarios that will manifest as reductions in the probability of the lake experiencing a regime-shift.

Figure 2.1 below illustrates how the risk adjustment factor is calculated. We use a geometric statistical distribution to calculate the probability that a regime shift has occurred, given assumptions about the probability of a regime shift occurring over time in each scenario. The risk adjustment factor in each year is then the decrease in the probability that a regime shift has occurred before each year.

Figure 2.1: Risk adjustment factor calculation in the catchment-level interventions scenario



Castalia model (2022)

We also estimate the economic benefit derived directly from implementing mitigation measures

The mitigations proposed in the Project will provide economic benefit beyond improving the lagoon's health and resilience, which should be included in the evaluation. For example, restoring farmland to its natural state will increase the carbon storage value of the land.

We define the catchment-level interventions scenario as the most favourable scenario presented in the Aqualinc report

In 2020, the Whakamana Te Waituna Trust commissioned an assessment of options to reduce contaminant load entering the lagoon (the Aqualinc Report[21]). This study aimed to design a model for catchment interventions that would reduce nitrogen loads (N load) entering the lagoon by 50 percent without negating the commercial viability of farming in the catchment. Overseer nutrient modelling was used to model the impact of various mitigation measures on nutrient loading in the lagoon.

[21] Bright J, Legg J, Irving C, Ingle, A, Parshotam, A, 2020. Whakamana Te Waituna: Contaminant Load Reduction Plan. Whakamana Te Waituna Trust, RD18020/1. Aqualinc Research Limited.

The Aqualinc report suggests achieving a 50% reduction in N load would stabilise the lake and significantly reduce the chance of experiencing a regime-shift to an algal-dominated state over time. The Aqualinc report identified six scenarios (combinations of mitigation measures) that would achieve the objective of a 50 percent reduction of N load. Of which, four scenarios would require 'high' levels of on-farm mitigations, which the report estimates would reduce the COS of farms by 30% and "would almost certainly put a lot of farmers out of business."[22] Therefore, only two of the Aqualinc Report scenarios achieve the N load reduction target of 50 percent whilst maintaining the commercial viability of farming in the catchment.

For this economic evaluation, we have focused on the scenario that is expected to meet the twin objectives at least cost. We refer to this scenario as the 'catchment-level interventions scenario'. The catchment-level interventions scenario requires the construction of two wetlands at the mid and lower Waituna Creek, retirement of selected dairy and sheep and beef farms near the lagoon, and 'low' levels of on-farm mitigations.[23] The Aqualinc report also recommends additional cost-effective mitigation measures that could not be modelled by Overseer nutrient modelling. These are included in the catchment-level interventions scenario.

We assume that the catchment-level interventions scenario achieves a 50% N load reduction and in this case the probability of a regime shift to an algal-dominated state starts at 1.5% per year, and this risk drops by 0.1% per year to reach 0.5% in year 10.

We define the farm-level interventions scenario based on subsequent responses to the Aqualinc advice, and discussion with experts

The 'farm-level interventions scenario' includes adjustments to the interventions outlined in the Aqualinc report that were decided upon in consultation with local stakeholders.

Unlike the catchment-level interventions scenario, the farm-level interventions scenario interventions are not expected to reduce N load by 50 percent. Therefore, the lagoon will be at higher risk of a regime-shift to an algal-dominated state. Under the farm-level interventions scenario, we assume that the probability of a regime shift to an algal-dominated state starts at 1.5% per year, and this risk drops by 0.05% per year to reach 1% in year 10.

We also modelled a third scenario, which was identical to the farm-level interventions scenario, but without additional land purchase adjacent to the Waituna Lagoon. The interventions modelled in each of these three scenarios are shown in Table 2.1.

Table 2.1: Interventions modelled in each scenario

Scenario name	Level of on-farm mitigations[24]	Drainage network modifications	Retirement of farmed areas near the lagoon
Catchment-level interventions	Low	Two constructed wetlands (one mid-catchment and one in lower Waituna Creek) with a total area of 200 ha	Retirement of 1,937 ha of land adjacent to the Waituna Lagoon

[22] Bright J, Legg J, Irving C, Ingle, A, Parshotam, A, 2020. Whakamana Te Waituna: Contaminant Load Reduction Plan. Whakamana Te Waituna Trust, RD18020/1. Aqualinc Research Limited.Page 58

[23] Bright J, Legg J, Irving C, Ingle, A, Parshotam, A, 2020. Whakamana Te Waituna: Contaminant Load Reduction Plan. Whakamana Te Waituna Trust, RD18020/1. Aqualinc Research Limited.Pages 38-42

[24] The level of on-farm mitigations are taken from the Aqualinc report and are detailed in Tables 4.2 and 4.5.

Scenario name	Level of on-farm mitigations[24]	Drainage network modifications	Retirement of farmed areas near the lagoon
Farm-level interventions	Medium	One constructed wetland in the mid-catchment with a total area of 150 ha	Retirement of 1,937 ha of land adjacent to the Waituna Lagoon
No-land purchase	Medium	One constructed wetland in the mid-catchment with a total area of 150 ha	Retirement of 451 ha of land adjacent to the Waituna Lagoon

2.2 Parameters and outputs of the CBA

We estimate the Net Present Value (NPV) and the Benefit Cost Ratio (BCR) of the Project

We qualitatively assess the economic costs and benefits that may occur if the remediation options are implemented and identify which are material enough to be quantitively valued in the CBA model. Except for cultural and passive values,[25] we quantify all the significant costs and benefits of the Project using various valuation techniques. We then discount all the costs and benefits using the social discount rate.

As advised in the Treasury Guide to Social Cost-Benefit Analysis, we use the social discount rate to discount the costs and benefits. The social discount rate used in CBA is an interest rate applied to benefits and costs that are expected to occur in the future to convert them into a present value. It is used across central and local government to 'weight' future costs and benefits when agencies carry out CBA and estimate the cost to the Crown of investing in public assets (the capital charge calculation). This conversion is done to ascertain what the costs and benefits are worth today, recognising that in general, society prefers consumption in the present over consumption in the future. It is the rate at which society would be willing to trade present for future consumption. A higher social discount rate will favour projects with net benefits further in the future and a lower social discount rate will favour projects with net benefits that are more immediate.

The 5 percent social discount rate reported by Treasury and advised in the Treasury Guidance on Social Cost Benefit Analysis is determined using the Social Opportunity Cost (SOC) approach. This determines the social discount rate to be the rate of return that a decision-maker could earn on a hypothetical 'next best alternative' to a public investment. An alternative approach to determining the social discount rate is the Social Rate of Time Preference (SRTP) approach. This defines the discount rate as the rate of return that a decision-maker requires in order to divert resources from use in the present, to a public investment. Assuming perfect markets, these two approaches would be equal. Given market failures, the SRTP is typically lower. The SRTP method may be more appropriate approach to discounting public investments which span longer time horizons. Treasury does not report a social discount rate using the SRTP. It is likely New Zealand has a STRP social discount rate comparable to the UK which reports 3.5 percent. Sensitivity analysis conducted in section 5.2

[25] The quantification of cultural and passive values is outside the scope of the current assessment, and would require a separate economic assessment of cultural value in the region.

reports the NPV given a variance in the social discount rate that is likely to cover both possible discount rates.

We then sum all of the benefits and all of the costs for the next 10 years into a single value, referred to as present values (PV). The PV of costs is taken away from the PV of benefits to reach the NPV. The NPV indicates the total economic value that can be attributed to the material and quantifiable impacts of the intervention. Given the modelling assumptions, a positive NPV implies the quantified benefits outweigh the quantified costs.

The BCR is the PV of benefits divided by the PV of costs. A BCR ratio of greater than one indicates the options benefits outweigh the costs, given the assumptions of the model.

We also conduct sensitivity analysis on key input assumptions to account for uncertainty. The main purpose of this is to identify which assumptions the model is most sensitive to. This indicates which variables should be considered in more detail and whether further work should be undertaken to improve the accuracy of these variables.

3 What are the economic benefits of the Project?

3.1 What ecosystem services does the Lagoon provide?

We categorise the benefits of the Project using the standard breakdown of ecosystem services. This breakdown of ecosystem services has been rigorously established in the field of environmental valuation, so it comes with the benefits of both theoretical soundness and rich empirical support. This framework has been applied previously to estimate the value of ecosystem services in New Zealand's primary sector (see, for example, Paterson and Cole 2013; Patterson et al. 2019; Cameron et al. 2020).

Within each category, we assess the materiality of the benefit due to the Project. Factors that are expected to have a material impact are then quantified.

We use various valuation techniques and use data collected on the impacts of the Project to quantify the benefits of the Project in monetary terms. For benefits that cannot be estimated using the data available, we will attribute values from existing studies using the 'benefit transfer' method. Where it is not possible to reliably estimate values using project data or existing studies, we acknowledge this clearly and re-state the conceptual description of the ecosystem service in question when presenting the final cost-benefit assessment.

Table 3.1 and Table 3.2include the PV of each of the quantified benefits in the catchment-level interventions scenario and the Farm-level interventions scenario respectively, against all three of the counterfactual scenarios.

Table 3.1: PV Benefits of the catchment-level interventions scenario

Benefit	Stable	Moderate	High
	Avoided Costs		
Lagoon freshwater recreation	$ 65,000	$ 85,000	$ 102,000
Lagoon tourism	$ 9,000	$ 12,000	$ 14,000
Lagoon Habitat for important biodiversity	$ 1,238,000	$ 1,616,000	$ 1,952,000
	Specific Benefits		
Wetland recreation	$24,000	$24,000	$24,000
Wetland habitat for important biodiversity	$1,793,000	$1,793,000	$1,793,000
Wetland regulation of water quality	$6,469,000	$6,469,000	$6,469,000
Wetland carbon storage	$1,032,000	$1,032,000	$1,032,000
Wetland nutrient cycling	$2,893,000	$2,893,000	$2,893,000
Regenerating forests carbon storage value	$27,829,000	$27,829,000	$27,829,000
Retired farmland habitat value	$23,008,000	$23,008,000	$23,008,000
Total Benefits	**$64,360,000**	**$64,761,000**	**$65,116,000**

Castalia model (2022)

Table 3.2: PV Benefits of the farm-level interventions scenario

Benefit	Stable	Moderate	High
	Avoided Costs		
Lagoon freshwater recreation	$ 62,000	$ 82,000	$ 100,000
Lagoon tourism	$ 9,000	$ 12,000	$ 14,000
Lagoon Habitat for important biodiversity	$ 1,186,000	$ 1,564,000	$ 1,899,000
	Specific Benefits		
Wetland recreation	$ 19,000	$ 19,000	$ 19,000
Wetland habitat for important biodiversity	$ 1,466,000	$ 1,466,000	$ 1,466,000
Wetland regulation of water quality	$ 5,289,000	$ 5,289,000	$ 5,289,000
Wetland carbon storage	$ 844,000	$ 844,000	$ 844,000
Wetland nutrient cycling	$ 2,366,000	$ 2,366,000	$ 2,366,000
Retired farmland habitat value	$ 11,840,000	$ 11,840,000	$ 11,840,000
Regenerating forests carbon storage value	$ 9,788,000	$ 9,788,000	$ 9,788,000
Total Benefits	**$32,868,000**	**$33,269,000**	**$33,624,000**

Castalia model (2022)

3.2 Generic benefits (avoided costs) of maintaining a macrophyte-dominated system

3.2.1 Qualitative description

The generic benefits listed in the Table 3.3 below describe benefits to people that depend on the Lagoon remaining in a macrophyte-dominated regime. These benefits are assumed to accrue over time, provided the lagoon remains in a macrophyte-dominated regime.

Table 3.3: Qualitative description of the generic benefits of the Whakamana Te Waituna Project

Category of Ecosystem Service	Description	Materiality
Provisioning **Direct provision of goods and services**	**Freshwater Recreation** Maintaining a macrophyte-dominated system will safeguard the value people derive from freshwater recreation in the Waituna Lagoon. Freshwater recreation in the Lagoon mainly comprises fishing (primarily for brown trout, but also for eel and flounder) and duck shooting. In an algal-dominated system, fish populations would fall, and the algal sludge and poor water quality would make the lagoon far less attractive for anglers. More frequent blooms of cyanobacteria would also produce toxins that are a risk to	Material

Category of Ecosystem Service	Description	Materiality
	human and animal health[26] and would severely limit boating and duck shooting.	
Regulating **Regulation of biophysical and ecological processes**	Tourism Maintaining a macrophyte-dominated system will safeguard the value visitors derive from day walks and birdwatching in the Waituna Lagoon. DOC maintains walking tracks for visitors to the Waituna Lagoon – a 500m boardwalk and a 5km loop track. More than 80 bird species have been recorded in the Waituna Lagoon area, some of which migrate from as far away as Siberia to seek food in the Austral summer.[27]	Material
	Property Value Properties in close vicinity to the Lagoon are likely to derive amenity value from the waterbody remaining in a macrophyte-dominated state. Various studies have tried to estimate the effect that water quality can have on housing value. A recent meta-analysis assessed over 40 studies investigating housing and water quality and found that over all the studies, water quality in the local vicinity had a statistically significant relationship to house price.[28] However, there are few houses directly adjacent to the Waituna Lagoon, and much of the amenity value influencing house prices would be explained by the recreational benefits the Lagoon provides. These recreational opportunities are already accounted for under the 'Freshwater Recreation' and 'Tourism' categories above.	Immaterial (with double-counting risk)
	Coastal Protection and Erosion Control While aquatic vegetation in a macrophyte-dominated coastal wetland provides some value from wave attenuation and erosion control, the benefits from this over and above what an algal-dominated coastal wetland would provide are modest. Furthermore, there are few residents in close proximity to the Waituna Lagoon, and these residents may be at higher risk of riverine flooding than from coastal flooding via the Lagoon.	Immaterial
Supporting **Processes that support regulating and provision services**	**Carbon storage** Coastal wetlands are known to store substantial quantities of carbon. For example, a recent study in South Korea found that salt marshes store between 146 and 255 tonnes of carbo per hectare, while tidal flats store between 182 and 286 tonnes of carbon per hectare.[29] While the value of this carbon storage is significant, the extent to which carbon	Immaterial

[26] Ryder Environmental Ltd. Status of the Waituna Lagoon: 2021. Report prepared for the Department of Conservation.

[27] Environment Southland Lagoon Technical Group (2013). Ecological Guidelines for Waituna Lagoon.

[28] Nicholls, S. and Crompton, J. (2018). A Comprehensive Review of the Evidence of the Impact of Surface Water Quality on Property Values. Sustainability., 10(2), 500.

[29] Byun, C., Lee, S. Kang, H. (2019) Estimation of carbon storage in coastal wetlands and comparison of different management schemes in South Korea. Journal of Ecology and the Environment. 43 (8).

Category of Ecosystem Service	Description	Materiality
	storage would change if the Waituna Lagoon changes to an algal-dominated regime is uncertain and may be small.	
	Nutrient Cycling Estimates of the value of nutrient cycling in coastal wetlands range between US$139 and US$33,745 per hectare per annum.[30] While this indicates the importance of biogeochemical processes in coastal wetlands, these figures are estimated relative to scenarios in which wetlands are drained and cease to exist. In the current study, a scenario in which the Waituna Lagoon ceases to exist is not plausible. While a regime shift to an algal-dominated Lagoon would likely alter some of the biogeochemical processes in the system, many will continue to function in substantially similar ways as they would under a macrophyte-dominated system. Therefore, the impact of a regime shift on the supporting service provided by nutrient cycling may be modest. Furthermore, segments of this value have already been captured under other benefits, including Carbon Storage, Freshwater Recreation, and Mahinga Kai.	Immaterial
Cultural* **Goods and services that support maintenance of cultural wellbeing**	**Mahinga Kai** The Waituna Lagoon is an important site for traditional food gathering for Ngāi Tahu. Historically, the area was an important food basket, supporting seasonal and permanent Ngāi Tahu settlements. While collection of native fish species and harvesting of harakeke is prohibited within the scientific reserve of the Waituna Lagoon, the area remains important as a site for teaching and passing on traditional knowledge.	Material
	Historic and Traditional Association As well as supporting seasonal and permanent Māori settlements, numerous Ara Tawhito (traditional trails) run to and around the Waituna Lagoon, and there are several wahi tapu (sacred places) and wahi taonga (treasured resources) located in the area.[31] The importance of the Waituna Lagoon to local Māori was recognised by the Crown in the Ngāi Tahu Claims Settlement Act 1998.	Material
	Mauri Mauri represents the essence and spiritual life force underlying all things, including the physical environment. The mauri of the Lagoon is a critical element of the spiritual relationship of Ngāi Tahu with the Waituna, and this Mauri is upheld by the natural ecological health of the system. Deterioration in the ecological health of the system would deplete the mauri of the system and would undermine this critical facet of cultural value	Material

[30] De Groot RS, Wilson MA, Boumans RM. A typology for the classification, description and valuation of ecosystem functions, goods and services. Ecological economics;41(3):393-408

[31] Environment Southland Lagoon Technical Group (2013). Ecological Guidelines for Waituna Lagoon.

Category of Ecosystem Service	Description	Materiality
Passive* **All types of value that do not relate directly to the actual use of the ecosystem**	**Ecological and Scientific Significance** The significance of ecological diversity in the Waituna Lagoon and surrounding peatlands was recognised internationally when it became a Ramsar site in 1976, and again nationally when it became a Scientific Reserve in 1983. These designations indicate passive values provided by the Lagoon. These passive values include existence values, which is the value people derive from knowing that such ecosystems exist, even if they never visit or interact with them directly. These values are culturally determined and may be =different for different people. In this case, a separate cultural assessment, co-developed with tangata whenua, would be required to comprehensively evaluate these passive values.	Material

3.2.2 Quantitative estimates

Table 3.4 below presents quantitative estimates of the value of the material ecosystem services provided by maintaining the Waituna Lagoon in a macrophyte-dominated regime. Cultural and passive values are excluded from this analysis, as these would require a separate cultural assessment co-developed with tangata whenua, which was deemed outside the scope of the current analysis.

Table 3.4: Quantitative estimates of the generic benefits of the Project

Description	Estimation Method	Value Estimate
Freshwater Recreation	Freshwater recreation in the Waituna Lagoon is dominated by fishing and duck shooting. **Value of Fishing** According to Fish & Game Southland, the Waituna Lagoon receives approximately 2,240 angler visits per annum. The value of a one-day fishing licence issued by Fish & Game Southland is $22. Therefore, the annual value of fishing in the Waituna Lagoon is approximately $49,280. Assuming that a regime shift to a macrophyte dominated state would reduce fishing in the Waituna lagoon by 90 percent, the value of maintaining a macrophyte-dominated regime to recreational fishers is **$44,352 per annum**. **Value of Duck Shooting** According to Fish & Game Southland, 50 duck shooting licences/permits were issued for the Waituna Lagoon in 2017. The value of a seasonal hunting licence issued by Fish & Game Southland is $98. Therefore, the annual value of duck shooting in the Waituna Lagoon is approximately $4,900. Assuming that a regime shift to a macrophyte-dominated state would reduce duck shooting in the lagoon by 50 percent, the value of maintaining a macrophyte-dominated regime to recreational duck shooters would be **$2,450 per annum**.	$46,802 per annum
Tourism	Walking, sightseeing, and birdwatching are the main activities that tourists visit the Waituna Lagoon for.	$6,570 per annum

Description	Estimation Method	Value Estimate
	Uncalibrated track counter data collected by DOC between 2010 and 2021 suggest that two people per day use the walking tracks to visit the Waituna Lagoon, on average. This equates to 730 visits per year. The value of walking, sightseeing, and birdwatching is difficult to estimate, and will be different for different people. A recent study on the ecosystem values provided by Lake Hayes[32] estimated the value of walking around the lake as $10 per person, which was equivalent to the willingness-to-pay for a hire bike in the vicinity (which was viewed as a competing recreational opportunity. Assuming that visitors to the Waituna Lagoon enjoy a similar value to those who visit Lake Hayes, the annual value of the Lagoon to walkers, sightseers, and birdwatchers could be $7,300. Assuming that a regime shift to a macrophyte-dominated state would diminish this value by 90%, the value of maintaining a macrophyte-dominated regime walkers, sightseers, and birdwatchers would be $6,570 per annum.	
Habitat for Important Native Biodiversity	The habitat/refugia value provided by estuarine wetlands in New Zealand was estimated by Patterson and Cole (2013) as $34 million per annum.[33] This value is spread across roughly 100,000 hectares of estuarine wetlands nationwide, suggesting that the habitat/refugia benefits of estuarine wetlands in New Zealand is approximately $340 per hectare. Based on these estimates, the total habitat/refugia value provided by the 3,500-hectare Waituna Lagoon would be $1,190,000. Assuming that a regime shift to a macrophyte-dominated state would diminish the habitat/refugia value of the lagoon by 75%, the value of maintaining a macrophyte-dominated regime would be $892,500 per annum.	$892,500 per annum

3.3 Specific Benefits of the catchment-level interventions scenario

3.3.1 Qualitative description

Table 3.5 below describes benefits to people of the actions taken to improve water quality under the catchment-level interventions scenario.

Table 3.5: Qualitative description of the specific benefits of the catchment-level interventions scenario

Category of Ecosystem Service	Description	Materiality
Provisioning Direct provision of goods and services	**Freshwater Recreation** Constructing two new wetlands in the Waituna catchment will create new opportunities for freshwater recreation in	Material

[32] Castalia (2018) Economic Assessment of Lake Hayes Remediation. Report to Otago Regional Council.

[33] Patterson, M.G. and Cole, A.O. (2013)"Total economic value" of New Zealand's land-based ecosystems and their services. In Dymond JR ed. Ecosystem services in New Zealand – conditions and trends. Manaaki Whenua Press, Lincoln, New Zealand.

Category of Ecosystem Service	Description	Materiality
	the catchment. Recreation opportunities are likely to be similar to those in the Waituna Lagoon itself, namely: fishing (primarily for brown trout, but also for eel and flounder) and duck shooting.	
Regulating Regulation of biophysical and ecological processes	**Habitat for Important Native Biodiversity** Constructing two new wetlands in the Waituna catchment will provide new habitat for a wide range of flora and fauna. This may include valuable native species that exist in the Waituna Lagoon, including Giant and Banded Kokopu, Shortfin and Longfin Eels and Common Bully. While constructed wetlands would also support introduced bord and fish species, the value associated with these species is primarily captured in the recreation (fishing and shooting) category above, therefore this value is not counted again here. The retirement of farmland adjacent to the Waituna Lagoon would also provide habitat for native flora and fauna.	Material
	Regulation of Water Quality Constructing two new wetlands in the Waituna catchment will help to improve water quality in the Waituna Creek. In addition to the benefits for the Waituna Lagoon (captured in the 'Generic' benefits), this will improve the habitat for aquatic species living in the Waituna Creek.	Material
	Flood Protection In principle, constructing two new wetlands in the Waituna catchment would help to moderate streamflow in the Waituna Creek. Wetlands act as natural sponges, absorbing runoff and creating large surface pools that drain slowly over time, lowering peak flows and increasing low flows.[34] However, in this case, the wetlands will be constructed in the lower reaches of the catchment, meaning that few downstream properties would benefit from the streamflow moderation. Furthermore, the constructed wetlands would likely increase the water table in the lower reaches of the catchment, which may contribute to increased flood risk for adjacent properties in certain conditions. Given this ambiguity caused by competing impacts, this analysis views the flood risk benefits of the two constructed wetlands as immaterial.	Immaterial
Supporting Processes that support regulating and provision services	**Carbon storage** The two new wetlands constructed under this scenario will store substantial quantities of carbon. A meta-analysis by de Groot et al. estimated the mean annual value of carbon storage from inland wetlands globally to be US$488 per hectare per annum.[35]	Material

34 Convention on Biological Diversity Secretariat (CBD) (2015). Wetlands and Ecosystem Services. World Wetlands Day CBD Press Brief.

35 De Groot et al. (2012). Global estimates of the value of ecosystems and their services in monetary units. Ecosystem Services, 1 (1) 50-61.

Category of Ecosystem Service	Description	Materiality
	The retirement of farmland adjacent to the Waituna Lagoon would also help to store carbon.	
	Nutrient Cycling The two new wetlands constructed under this scenario will contribute substantially to nutrient cycling. A meta-analysis by de Groot et al. estimated the mean annual value of nutrient cycling in inland wetlands to be US$1,713 per hectare per annum. To avoid double-counting, estimates of the value of carbon storage and Freshwater Recreation are subtracted from this total in our analysis, because these benefits depend on the nutrient cycling processes estimated.	Material
Cultural* Goods and services that support maintenance of cultural wellbeing	**Mahinga Kai** The construction of two new wetlands in the Waituna Catchment would provide traditional food and resource gathering opportunities. Before drainage for farming, wetlands once covered a far greater proportion of the Waituna catchment. The construction of two new wetlands may therefore be understood as re-establishment of historical features of the Waituna landscape.	Material
	Mauri Mauri represents the essence and spiritual life force underlying all things, including the physical environment. The re-establishment of two wetlands in the Waituna catchment and the retirement and reforestation of farmland adjacent to the Waituna Lagoon may help restore the wider landscape's mauri, particularly if done sensitively and with appropriate native species.	Material
Passive* All types of value that do not relate directly to the actual use of the ecosystem	**Ecological and Scientific Significance** The construction of two new wetlands in the catchment would contribute passive values, including existence and bequest values. These values are unlikely to be as significant as the passive values provided by the Waituna Lagoon because the latter is an internationally recognised natural ecosystem. Furthermore, these values are culturally determined and may be different for different people. In this case, a separate cultural assessment, co-developed with tangata whenua, would be required to comprehensively evaluate these passive values.	Material

3.3.2 Quantitative estimates

Table 3.6 below outlines the quantifiable and maternal benefits of the actions taken to improve water quality under the catchment-level interventions scenario.

Table 3.6: Quantitative estimates of the specific benefits of the catchment-level interventions scenario

Description	Estimation Method	Value Estimate
Freshwater Recreation	Recreation opportunities in the two constructed wetlands are likely to be similar to those in the Waituna Lagoon itself, namely: fishing (primarily for brown trout, but also for eel and flounder) and duck shooting. The per-hectare value of these recreation opportunities in the Waituna Lagoon is $15.48. Assuming that the recreational value per hectare of constructed wetland is the same as the recreational value per hectare in the Lagoon, constructing two new wetlands in the catchment with a total area of 200 hectares, would add recreational value of $3,069 per annum.	$3,069 per annum
Habitat for Important Native Biodiversity	**Habitat value from Constructed Wetlands** The habitat/refugia value provided by wetlands in New Zealand was estimated by Patterson and Cole (2013) as $195 million per annum.[36] This value is spread across roughly 166,000 hectares of wetlands nationwide, suggesting that the habitat/refugia benefits of wetlands in New Zealand is approximately $1,175 per hectare. Based on this estimate, the total habitat/refugia value provided by the two constructed wetlands with a total area of 200 hectares would be $235,000 per annum. **Habitat Value from Retired Farmland** While it is widely recognised that reverting native forests provide greater support and habitat to native flora and fauna than modified agricultural landscapes, there is little empirical data on the value of this habitat provision, and no monetary estimates exist in New Zealand at present.[37] A global meta-analysis by Grammatikopoulou and Vačkářová (2021)[38] estimated the mean value of forest habitat maintenance as $658 per hectare per annum. Based on this estimate, the total habitat value provided by retiring 1,937 hectares of land adjacent to the Waituna Lagoon[39] would be $1,274,546 per annum.	$1,509,546 per annum
Regulation of Water Quality	The water treatment[40] value provided by wetlands in New Zealand was estimated by Patterson and Cole (2013) as $743 million per annum.[41] This value is spread across roughly 166,000 hectares of wetlands nationwide, suggesting that the water treatment benefits of wetlands in New Zealand is approximately $4,476 per hectare. This compares to a water	$847,600 per annum

36 Patterson, M.G. and Cole, A.O. (2013)"Total economic value" of New Zealand's land-based ecosystems and their services. In Dymond JR ed. Ecosystem services in New Zealand – conditions and trends. Manaaki Whenua Press, Lincoln, New Zealand.

37 Aimers, J., Bergin, D., Horgan, G. (2021). Review of Non-Timber Values in sustainably-managed native forest in New Zealand. Tāne's Tree Trust bulletin, Hamilton, New Zealand. 119 pages.

38 Grammatikopoulou, I, and Vačkářová, D. (2021).The value of forest ecosystem services: A meta-analysis at the European scale and application to national ecosystem accounting, Ecosystem Services, Volume 48, 2021, 101262.

39 This is the area of land adjacent to the Waituna Lagoon assumed to be retired in the catchment-level interventions scenario, displayed in Figure 29 of the Aqualinc report.

40 Patterson and Cole (2013) define this field as 'Waste treatment', however it is referred to as water treatment in this report for simplicity. This field includes the filtration of dissolved nutrients and the removal of suspended sediment.

41 Patterson, M.G. and Cole, A.O. (2013)"Total economic value" of New Zealand's land-based ecosystems and their services. In Dymond JR ed. Ecosystem services in New Zealand – conditions and trends. Manaaki Whenua Press, Lincoln, New Zealand.

Description	Estimation Method	Value Estimate
	treatment value of $238 per hectare for agricultural pasture.[42] Therefore the net water treatment value of changing from pasture to wetland is $4,238 per hectare per annum. Based on this estimate, the total water treatment value provided by the two constructed wetlands with a total area of 200 hectares would be $847,600 per annum.	
Carbon storage	**Carbon Stored in Constructed Wetlands** The two new wetlands constructed under this scenario will store substantial quantities of carbon. A meta-analysis by de Groot et al. (2012) estimated the mean annual value of carbon storage from inland wetlands globally to be $676 per hectare per annum.[43] Based on this estimate, carbon storage value provided by the two constructed wetlands with a total area of 200 hectares would be $135,200 per annum. **Carbon Stored in Regenerating Forest** The retirement of farmland adjacent to the Waituna Lagoon would also help to store carbon. A recent review by Aimers et al. (2021) estimated that regenerating native forest in New Zealand sequesters carbon at approximately 6.4 tonnes per hectare per annum (averaged over the first 50 years of growth). Assuming a carbon price of NZ$85 per tonne,[44] the carbon storage value provided by retiring 1,937 hectares of farmland and allowing it to revert to native forest would be $1,053,728 per annum.	$1,188,928 per annum
Nutrient Cycling	The two new wetlands constructed under this scenario will contribute substantially to important nutrient cycles. A meta-analysis by de Groot et al. (2012) estimated the mean annual value of nutrient cycling in inland wetlands to be $2,587 per hectare per annum.[45] Based on this estimate, nutrient cycling value provided by the two constructed wetlands with a total area of 200 hectares would be $517,400 per annum. To avoid double-counting, estimates of the value of carbon storage ($135,200 per annum) and Freshwater Recreation ($3,069 per annum) are subtracted from this total in our analysis because these benefits depend on the nutrient cycling processes estimated. Therefore, the additional value of nutrient cycling from the two constructed wetlands in this scenario would be $379,131 per annum.	$379,131 per annum

42 This estimate is calculated using the value of water treatment from pastoral farmland estimated by Patterson and Cole (2013). This estimate was divided by the total area of pastoral farmland in New Zealand (10,453,000 hectares).

43 De Groot et al. (2012). Global estimates of the value of ecosystems and their services in monetary units. Ecosystem Services, 1 (1) 50-61.

44 This is the middle of a range of shadow carbon prices recommended by the World Bank's 'Guidance note on shadow price of carbon in economic analysis' (available at https://documents1.worldbank.org/curated/en/621721519940107694/pdf/2017-Shadow-Price-of-Carbon-Guidance-Note.pdf).

45 De Groot et al. (2012). Global estimates of the value of ecosystems and their services in monetary units. Ecosystem Services, 1 (1) 50-61.

3.4 Specific Benefits of the farm-level interventions scenario

3.4.1 Qualitative description

Table 3.7 below describes benefits to people of the actions taken to improve water quality under the farm-level interventions scenario. Many of these benefits repeat benefits outlined in the catchment-level interventions scenario. This repetition is intentional and aims to make this report an efficient reference document. We encourage those reading the full document to skip past descriptions they have already read in the previous section.

Table 3.7: Qualitative description of the specific benefits of the farm-level interventions scenario

Category of Ecosystem Service	Description	Materiality
Provisioning Direct provision of goods and services	**Freshwater Recreation** Constructing a new wetland in the Waituna catchment will create new opportunities for freshwater recreation in the catchment. Recreation opportunities are likely to be similar to those in the Waituna Lagoon itself, namely: fishing (primarily for brown trout, but also for eel and flounder) and duck shooting.	Material
Regulating Regulation of biophysical and ecological processes	**Habitat for Important Native Biodiversity** Constructing a new wetland in the Waituna catchment will provide new habitat for a wide range of flora and fauna. This may include valuable native species in the Waituna Lagoon, including Giant and Banded Kokopu, Shortfin and Longfin Eels and Common Bully. While constructed wetlands would also support introduced bord and fish species, the value associated with these species is primarily captured in the recreation (fishing and shooting) category above; therefore, this value is not counted again here. The retirement of land adjacent to the Waituna Lagoon would also provide habitat for native flora and fauna.	Material
	Regulation of Water Quality Constructing new wetland in the Waituna catchment will help to improve water quality in the Waituna Creek. In addition to the benefits for the Waituna Lagoon (captured in the 'Generic' benefits), this will improve the habitat for aquatic species living in the Waituna Creek.	Material
	Flood Protection Constructing a new wetland in the Waituna catchment will help to moderate streamflow in the Waituna Creek. Wetlands act as natural sponges, absorbing runoff and creating large surface pools that drain slowly, lowering peak flows and increasing low flows.[46] However, in this case, the wetland will be constructed in the lower reaches of the	Immaterial

[46] Convention on Biological Diversity Secretariat (CBD) (2015). Wetlands and Ecosystem Services. World Wetlands Day CBD Press Brief.

Category of Ecosystem Service	Description	Materiality
	catchment meaning that there are few downstream properties to benefit from the streamflow moderation. Furthermore, the constructed wetland would likely increase the water table in the lower reaches of the catchment, which may contribute to increased flood risk for adjacent properties in certain conditions. Given this ambiguity caused by competing impacts, this analysis views the flood risk benefits of the constructed wetland as immaterial.	
Supporting Processes that support regulating and provision services	**Carbon storage** The new wetland constructed under this scenario will store substantial quantities of carbon. A meta-analysis by de Groot et al. estimated the mean annual value of carbon storage from inland wetlands globally to be US$488 per hectare per annum.[47] The retirement of farmland adjacent to the Waituna Lagoon would also help to store carbon.	Material
	Nutrient Cycling The new wetland constructed under this scenario will contribute substantially to important nutrient cycles. A meta-analysis by de Groot et al. estimated the mean annual value of nutrient cycling in inland wetlands to be US$1,713 per hectare per annum. To avoid double-counting, estimates of the value of carbon storage and Freshwater Recreation are subtracted from this total in our analysis, because these benefits depend on the nutrient cycling processes estimated.	Material
Cultural* Goods and services that support maintenance of cultural wellbeing	**Mahinga Kai** The construction of a new wetland in the Waituna Catchment would provide traditional food and resource gathering opportunities. Before drainage for farming, wetlands once covered a far greater proportion of the Waituna catchment. The construction of two new wetlands may therefore be understood as re-establishment of historical features of the Waituna landscape.	Material
	Mauri Mauri represents the essence and spiritual life force underlying all things, including the physical environment. The re-establishment of a wetland in the Waituna catchment and the retirement and reforestation of farmland adjacent to the Waituna Lagoon may help restore the wider landscape's mauri, particularly if done sensitively and with appropriate native species.	Material
Passive* All types of value that do not relate directly	**Ecological and Scientific Significance** The construction of a new wetland in the catchment would contribute passive values, including existence and bequest values. These values are unlikely to be as significant as the passive values provided by the Waituna Lagoon, because the	Material

[47] De Groot et al. (2012). Global estimates of the value of ecosystems and their services in monetary units. Ecosystem Services, 1 (1) 50-61.

Category of Ecosystem Service	Description	Materiality
to the actual use of the ecosystem	latter is an internationally recognised natural ecosystem. Furthermore, these values are culturally determined and may be different for different people. In this case, a separate cultural assessment, co-developed with tangata whenua, would be required to comprehensively evaluate these passive values.	

3.4.2 Quantitative estimates

Table 3.8 below, outlines the quantifiable and material benefits of the actions taken to improve water quality under the farm-level interventions scenario.

Table 3.8: Quantitative estimates of the specific benefits of the farm-level interventions scenario

Category of Ecosystem Service	Description	Materiality
Freshwater Recreation	Recreation opportunities in the two constructed wetlands are likely to be similar to those in the Waituna Lagoon itself, namely: fishing (primarily for brown trout, but also for eel and flounder) and duck shooting. The per-hectare value of these recreation opportunities in the Waituna Lagoon is $15.48. Assuming that the recreational value per hectare of constructed wetland is the same as the recreational value per hectare in the Lagoon, constructing one new wetland in the catchment with a total area of 150 hectares, would add recreational value of $2,322 per annum.	$2,322 per annum
Habitat for Important Native Biodiversity	**Habitat value from Constructed Wetlands** The habitat/refugia value provided by wetlands in New Zealand was estimated by Patterson and Cole (2013) as $195 million per annum.[48] This value is spread across roughly 166,000 hectares of wetlands nationwide, suggesting that wetlands' habitat/refugia benefits in New Zealand is approximately $1,175 per hectare. Based on this estimate, the total habitat/refugia value provided by the 150-hectare constructed wetland would be $176,250 per annum. **Habitat Value from Retired Farmland** While it is widely recognised that reverting native forests provide greater support and habitat to native flora and fauna than modified agricultural landscapes, there is little empirical data on the value of this habitat provision, and no monetary estimates exist in New Zealand at present.[49] A global meta-analysis by Grammatikopoulou and Vačkářová (2021)[50] estimated the mean value of forest habitat maintenance as $658 per hectare per annum. Based on this	$1,450,796 per annum

[48] Patterson, M.G. and Cole, A.O. (2013)"Total economic value" of New Zealand's land-based ecosystems and their services. In Dymond JR ed. Ecosystem services in New Zealand – conditions and trends. Manaaki Whenua Press, Lincoln, New Zealand.

[49] Aimers, J., Bergin, D., Horgan, G. (2021). Review of Non-Timber Values in sustainably-managed native forest in New Zealand. Tāne's Tree Trust bulletin, Hamilton, New Zealand. 119 pages.

[50] Grammatikopoulou, I, and Vačkářová, D. (2021).The value of forest ecosystem services: A meta-analysis at the European scale and application to national ecosystem accounting, Ecosystem Services, Volume 48, 2021, 101262.

Category of Ecosystem Service	Description	Materiality
	estimate, the total habitat value provided by retiring 1,937 hectares of land adjacent to the Waituna Lagoon would be $1,274,546 per annum.	
Regulation of Water Quality	The water treatment[51] value provided by wetlands in New Zealand was estimated by Patterson and Cole (2013) as $743 million per annum.[52] This value is spread across roughly 166,000 hectares of wetlands nationwide, suggesting that the water treatment benefits of wetlands in New Zealand are approximately $4,476 per hectare. This compares to a water treatment value of $238 per hectare for agricultural pasture.[53] Therefore the net water treatment value of changing from pasture to wetland is $4,238 per hectare per annum. Based on this estimate, the total water treatment value provided by the 150-hectare constructed wetland would be $635,700 per annum.	$635,700 per annum
Carbon storage	**Carbon Stored in Constructed Wetlands** The two new wetlands constructed under this scenario will store substantial quantities of carbon. A meta-analysis by de Groot et al. (2012) estimated the mean annual value of carbon storage from inland wetlands globally to be $676 per hectare per annum.[54] Based on this estimate, carbon storage value provided by the 150-hectare constructed wetland would be $101,400 per annum. **Carbon Stored in Regenerating Forest** The retirement of farmland adjacent to the Waituna Lagoon would also help to store carbon. A recent review by Aimers et al. (2021) estimated that regenerating native forest in New Zealand sequesters carbon at approximately 6.4 tonnes per hectare per annum (averaged over the first 50 years of growth). Assuming a carbon price of NZ$85 per tonne,[55] the carbon storage value provided by retiring 1,937 hectares of farmland and allowing it to revert to native forest would be $1,053,728 per annum.	$1,155,128 per annum
Nutrient Cycling	The two new wetlands constructed under this scenario will contribute substantially to important nutrient cycles. A meta-analysis by de Groot et al. (2012) estimated the mean annual value of nutrient cycling in inland wetlands to be	$284,328 per annum

51 Patterson and Cole (2013) define this field as 'Waste treatment', however it is referred to as water treatment in this report for simplicity. This field includes the filtration of dissolved nutrients and the removal of suspended sediment.

52 Patterson, M.G. and Cole, A.O. (2013)"Total economic value" of New Zealand's land-based ecosystems and their services. In Dymond JR ed. Ecosystem services in New Zealand – conditions and trends. Manaaki Whenua Press, Lincoln, New Zealand.

53 This estimate is calculated using the value of water treatment from pastoral farmland estimated by Patterson and Cole (2013). This estimate was divided by the total area of pastoral farmland in New Zealand (10,453,000 hectares).

54 De Groot et al. (2012). Global estimates of the value of ecosystems and their services in monetary units. Ecosystem Services, 1 (1) 50-61.

55 This is the middle of a range of shadow carbon prices recommended by the World Bank's 'Guidance note on shadow price of carbon in economic analysis' (available at https://documents1.worldbank.org/curated/en/621721519940107694/pdf/2017-Shadow-Price-of-Carbon-Guidance-Note.pdf).

Category of Ecosystem Service	Description	Materiality
	$2,587 per hectare per annum.[56] Based on this estimate, nutrient cycling value provided by the 150-hectare constructed wetland would be $388,050 per annum. To avoid double-counting, estimates of the value of carbon storage ($101,400 per annum) and Freshwater Recreation ($2,322 per annum) are subtracted from this total in our analysis, because these benefits depend on the nutrient cycling processes estimated. Therefore, the additional value of nutrient cycling from the constructed wetland in this scenario would be $284,328 per annum.	

[56] De Groot et al. (2012). Global estimates of the value of ecosystems and their services in monetary units. Ecosystem Services, 1 (1) 50-61.

4 What are the economic costs of the Project?

The interventions described in the Aqualinc report for the farm-level interventions scenarios will incur a number of costs during the evaluation period. These costs are primarily the financial costs of mitigation measures, but wider costs such as unintended environmental damage are also considered.

In an economic evaluation, costs of inputs to a project should reflect the opportunity cost, which is the value of the best alternative use a good or service could be put to. Costs should be categorised in terms of their impact on people.

We assume market prices of goods and services equal their opportunity cost in competitive markets. If there is a good reason to assume a market is not competitive, we would use shadow pricing. These are calculated prices that reflect a competitive market.

We ignore gainers and losers who are parties to transfer payments, such as taxes, subsidies, and welfare payments. This is because we assume the benefits of the recipient are equally offset by the cost of the payers and the transfer does not involve creation or destruction of total economic value.

Additional costs arise when funds from a project come from taxation due to the deadweight welfare cost of taxation. This concept assumes a welfare loss occurs from taxation because consumption choices are distorted. This should be recognised when the tax is spent through public expenditure. Treasury guidance recommends a 20 percent premium should be charged to public expenditure to account for the deadweight welfare loss of taxation. The Living Water Partnership is part-funded by public expenditure, so we apply the 20 percent premium to 50 percent of Living Water expenditure to account for the deadweight welfare loss of taxation.

4.1 Costs of the catchment-level interventions scenario

Table 4.1 below presents a summary of the estimated PV of all monetised economic costs of the Project in the catchment-level interventions scenario over the 10-year evaluation period. The costs are the same in all three counterfactual scenarios because the costs of the Project do not depend on the risk of the lagoon experiencing a regime-shift.

Table 4.1: PV of all economic costs of catchment-level interventions scenario against all counterfactual scenarios

Cost	PV of costs over 10 years ($)
Mid catchment wetland	$6,633,000
Lower-catchment wetland	$4,954,000
Retiring existing farmland	$44,727,000
On farm mitigations	$6,988,000
On farm mitigations programme	$294,000
Re-design of the drainage network	$1,814,000
LW management costs	$424,000
Total costs	**$65,834,000**

Castalia model (2022)

Table 4.2 below describes the costs identified in the catchment-level interventions scenario and whether they are material for this economic evaluation.

4.1.1 Qualitative description

Table 4.2: Qualitative description of the economic costs of the catchment-level interventions scenario

Category of Ecosystem Service	Description	Materiality
On-farm mitigations	The Aqualinc report recommends the following on-farm mitigations. ▪ A reduction in autumn fertiliser applications by 50 percent - reduce milk solid production and lower producing cows in autumn to compensate for loss in pasture production ▪ A reduction in fertiliser applications on effluent area – taking the effluent nitrogen content into account ▪ Application of maintenance phosphorus fertiliser, using low water-soluble fertiliser, i.e., the use of reactive phosphorus rock – ensuring same amount of phosphorus and sulphur ▪ An increase in the duration that cows are on the feed pad by one hour per day ▪ A reduction in autumn nitrogen fertiliser by 50 percent (from 18 to 9 kgN/ha in April), reduce silage made and exported to the dairy platform to compensate for loss in pasture ▪ Use of direct drill kale (instead of conventional cultivation) ▪ Exclusion of all cattle from streams. The opportunity cost of the on-farm mitigations is the reduction in farmers' profits due to increased production costs and reduced farming intensity.	Material
On-farm mitigations programme	The Project will trial and implement small scale mitigations. This includes further mitigations recommended in the Aqualinc report but not modelled in Overseer. For example, peak run-off control structures, wetlands restoration, and riparian planting and fencing.	Material

Category of Ecosystem Service	Description	Materiality
	The opportunity cost of the on-farm mitigations programme is the consumption of real resources that could otherwise have been used for another purpose.	
Management costs	Management and operating costs across DOC, Fonterra, Environment Southland, and Iwi. This includes project planning, coordination and contract management for the duration of the project. The opportunity cost of managing the Project is the use of skilled labour that could otherwise have been employed for another purpose.	Material
Retirement of existing farmland	The Aqualinc report recommends the retirement of strategic areas of land within the catchment. This would generate a permanent reduction in contaminant losses to natural-state levels over time. The opportunity cost of retiring existing farmland is the reduction in farming profits that farmers would otherwise have made on this land.	Material
Wetland construction	The Aqualinc report recommends two large wetlands would be constructed to treat the flow in the Waituna Creek at two locations: lower Waituna Creek (between 100ha and 200ha in area) and mid catchment (~50ha in area). The opportunity cost of constructing the wetlands is the consumption of real resources that could otherwise have been used for another purpose. This includes the materials, labour, and land consumed in constructing the wetlands.	Material
Wetland planning and assessment costs	The Aqualinc report states that construction of wetlands will require detailed design and consenting. It will also require site investigation and project management. The opportunity cost of wetland planning and assessment is the consumption of skilled labour that could otherwise be employed for another purpose.	Material
Redesign of drainage network	The Aqualinc report recommends drain and waterway management be re-designed to minimise the risk of sediment inputs to flowing waterways. This includes bank reshaping along the entire 23km length of the Waituna creek rated drainage district to reduce erosion the drainage network. It also includes temporary sediment filters to support the construction of wetlands by limiting the flow of sediment from construction sites. The Aqualinc report recommends a low-cost solution, constructed from hay bales and geotextile fabric, inserted downstream of drain clearing operations. Temporary sediment filters would be placed into position prior to clearing upstream sections of channels and left in position until the sediment has settled out of the water upstream of the bales. The opportunity cost of re-designing the drainage network is the consumption of real resources that could otherwise have been used for another purpose. This includes the materials, labour and land consumed in redesigning the drainage network.	Material
Fish passage issues	Fish passage may be disrupted when operating the temporary sediment filters during the clearing operation. Ensuring fish passage is protected and enhanced throughout the catchment is important	Immaterial

Category of Ecosystem Service	Description	Materiality
	to realise the full potential benefits of improved water quality and hydrological management regimens. This is likely to be a minor disruption occurring infrequently and therefore not material in this economic evaluation.[57]	
Reduction in milk supply to milk processors	On farm mitigations reduce the intensity of milk farming leading to a reduction in the supply to farm processors. It is important farm processors run at near capacity because they exhibit large fixed capital investments. A reduction in milk supply reduces their ability to recover the cost of their capital investment. However, in this case, processors have been planning for flat and even declining milk volumes to account for future changes, including expanding regulations; therefore, reductions under the Living Water interventions are unlikely to be a material change from business as usual.	Immaterial
Visual impact of temporary sediment filters	Temporary sediment filters are large manmade structures, constructed from hay bales and geotextile fabric. Once contracted they could visually impede the natural landscape that people enjoy in the Waituna catchment. Sediment filters will mostly be on private land and in locations that do not compromise the scenery of the Waituna catchment.[58]	Immaterial

4.1.2 Quantitative estimates

Table 4.3 below outlines the costs of the actions taken to improve water quality under the catchment-level interventions scenario.

Table 4.3: Quantitative estimates of the economic costs of the catchment-level interventions scenario

Category of Cost	Valuation technique	Value Estimate
On-farm mitigations	We can quantify the opportunity cost of on-farm mitigations by estimating the reduction in farm COS that occurs as the intensity of farming reduces. The Aqualinc report estimated the reduction in annual COS in the catchment due to the on-farm mitigations described for the Catchment-level interventions scenario to be **$752,220**. Our assumption of the reduction in COS is consistent with the Aqualinc report.	**$752,220**
On-farm mitigations programme	The following costs were included in the DOC proposal for the Jobs for Nature fund, which proposed the construction of one wetland. Some support for on farm plantings in the catchment = 176,000 Roll out of 40 structures in the catchment, $20,000 x 40 = $80,000 Construction and Project management = $20,000 Total cost= **$276,000**	**$270,000**

[57] Pers con Living Water staff

[58] Pers con Living Water staff

<table>
<tr><th>Category of Cost</th><th>Valuation technique</th><th>Value Estimate</th></tr>
<tr><td>Management costs</td><td>To estimate the opportunity cost of labour, we consider the level of skill the work requires and the unemployment rate in the projects region.

This work will be undertaken by skilled labour and the unemployment rate in Southland is 3.3 per cent.[59]

The opportunity cost of management is, therefore, the required work hours and the going wage rate.

3.0 FTE x $150,000</td><td>$450,000</td></tr>
<tr><td>Retire existing farmland</td><td>The Aqualinc report provides an estimate of the cost of purchasing the farmland recommended for retirement and an estimate of the reduction in farmer COS (assuming the COS reduces to 0).

Land purchase cost is a good proxy for the opportunity cost if we can assume a competitive price. We do not include the reduction in farmer COS to avoid double counting the opportunity cost. We also remove interest payments, representing the time value of money already accounted for in the social discount rate.

The total cost of land purchase in the Aqualinc report is nearly: $42,000,000</td><td>$42,000,000</td></tr>
<tr><td>Wetland construction</td><td>The Aqualinc report provides cost breakdowns of each wetland. Due to limited financial information on wetland construction in New Zealand, the report uses generalisations from Tanner (2013). This is based on the design and construction costs for the Lake Okaro wetland in the Bay of Plenty.

To exploit cost savings by learning from experience, one wetland is likely built in one year and then the second is built two years later.

The cost of financing the construction of wetlands is included in the Aqualinc reports financial assessment. We do not include financing costs in the economic evaluation because this is a payment for the time value of money and the discount rate accounts for this. Therefore the cost of wetland construction appears lower in our analysis than in the Aqualinc report.

We assume the land was purchased at a competitive price. It is, therefore, reasonable to assume the land purchase is equal to the opportunity cost of the retired farmland.

The Aqualinc report provides the cost breakdown below.

Mid-catchment wetland:
Wetland construction, $3,375,000
Bioreactor and peak runoff control structure, $625,000
Fish pass, $250,000
Land purchase, $1,000,000
We assume an annual maintenance cost of $30,000

Lower- catchment wetland:
Wetland construction, $4,375,000
Fish pass, $250,000
We assume an annual maintenance cost of $30,000 for each wetland.</td><td>Capex = $9,905,000

Maintenance = $60,000 per annum</td></tr>
</table>

[59] https://figure.nz/chart/r9PsV2REYkH4yuj5-pJRjtp01mao0dErz

Category of Cost	Valuation technique	Value Estimate
Wetland planning and assessment costs	We assume payments to suppliers represent the opportunity cost of wetland planning and assessment costs. While technically financial transfers, it serves as a good proxy for the consumption of real resources. The opportunity cost of labour for skilled workers when the unemployment rate is low can be assumed to be the going wage rate. The following costs were included in the DOC proposal for the Jobs for Nature fund, which proposed constructing one wetland. ▪ Site investigation, $30k ▪ 0.5 FTE Project manager for 3 yers, $200,000 ▪ Detailed design and consenting costs, $400,000 We scale this cost to estimate the corresponding costs of the second wetland. ▪ Site investigation, $10,000 ▪ 0.5 FTE Project manager for 3 years, $66,667 Detailed design and consenting costs, $133,334	**$840,000**
Redesign of the drainage network	We assume the payments to suppliers represent the opportunity cost of redesigning the drainage network. While technically financial transfers, this provides a good proxy for the consumption of real resources. The following costs were included in the proposal for the Jobs for Nature fund. ▪ Bank reshaping, $1,650,000 ▪ Sediment filter, $50,000	**$1,700,000**

4.2 Costs of the farm-level interventions scenario

4.2.1 Qualitative description

Table 4.4 below summarises the estimated PV of all monetised economic costs in the farm-level interventions scenario over the 10-year evaluation period. Consistent with the Aqualinc Living Water scenario, the costs are the same in all three counterfactual scenarios.

Table 4.4: PV of all economic costs in the farm-level interventions scenario against all counterfactual scenarios

Cost	PV of costs over 10 years
Mid catchment wetland	$663,000
Retiring existing farmland	$6,577,000
On farm mitigations	$27,950,000
On farm mitigations programme	$294,000
Re-design of the drainage network	$1,814,000
LW management costs	$424,000
Total costs	**$43,693,000**

Castalia model (2022)

On-farm mitigations account for nearly 64 percent of the total cost of the farm-level interventions scenario.

Table 4.5 below describes the costs identified in the farm-level interventions scenario and whether they are material for this economic evaluation. Many of these costs repeat benefits outlined in the catchment-level interventions scenario. Again, we encourage those reading the full document to skip past descriptions they have already read in the previous section.

Table 4.5: Qualitative description of the economic costs of the farm-level interventions scenario

Category of Cost	Qualitative Description	Materiality
On-farm mitigations	The Farm-level interventions scenario proposes farmers be required to implement the on-farm mitigations described below. ▪ Reduce stocking rate by 10 percent and increase per animal milk production by 5 percent ▪ Dry off cows a week early ▪ Reduce replacement rate from 23 to 21 percent ▪ Apply effluent solids on crop area (while continuing to apply solids to the non-effluent block) ▪ Reduce spring nitrogen fertiliser applications by 50 percent - increase imported silage to compensate for loss in pasture production ▪ Remove all autumn fertiliser (9 kgN/ha in April) - reduce silage made and exported to the dairy platform by a further 18 tDM to compensate for loss in pasture ▪ Reduce all other urea fertiliser by 10 percent - reduce heifer numbers by 20 (to 130 total heifers) to compensate for loss in pasture ▪ Reduce swede crop area by a third (from 15 to 10ha) - increase baleage production by 70 tDM, to feed to stock over winter to account for loss in dry matter from swede crop. The opportunity cost of the on-farm mitigations is the reduction in farmers profits which occur as production costs increase and farming intensity reduces.	Material
On-farm mitigations programme	The Project will trial and implement small-scale mitigations. This includes further mitigations recommended in the Aqualinc report but not modelled in Overseer. For example, peak run-off control structures, wetlands restoration, and riparian planting and fencing. The opportunity cost of the on-farm mitigations programme is the consumption of real resources that could otherwise have been used for another purpose.	Material
Management costs	Management and operating costs across DOC, Fonterra, ES and Iwi. This includes project planning, coordination and contract management for the duration of the project. The opportunity cost of managing the Project is the use of skilled labour that could otherwise have been employed for another purpose.	Material
Retirement of existing farmland	Whakamana Te Waituna has purchased 451 hectares of dairy and beef farmland adjacent to the Waituna lagoon to restore, over time,	Material

Category of Cost	Qualitative Description	Materiality
	to its natural state.[60] We assume no further land is retired in the farm-level interventions scenario. The opportunity cost of retiring existing farmland is the reduction in farming profits that farmers would otherwise have made on this land.	
Wetland construction	In the farm-level interventions scenario, one large wetland is constructed to treat the flow in the lower Waituna Creek (between 50ha and 200ha in area). The wetland is situated on the western end of the catchment to ensure it will intercept the majority of the catchment's nitrogen load coming from Waituna Creek.	Material
Wetland planning and assessment costs	The Aqualinc report states that construction of wetlands will require detailed design and consenting. It will also require site investigation and project management. The opportunity cost of wetland planning and assessment is the consumption of skilled labour that could otherwise be employed for another purpose.	Material
Redesign of drainage network	The Aqualinc report recommends drain and waterway management be re-designed to minimise the risk of sediment inputs to flowing waterways. This includes bank reshaping along the entire 23km length of the Waituna creek rated drainage district to reduce erosion of the drainage network. It also includes temporary sediment filters to support the construction of wetlands by limiting the flow of sediment from construction sites. The Aqualinc report recommends a low-cost solution, constructed from hay bales and geotextile fabric, inserted downstream of drain clearing operations. Temporary sediment filters would be placed into position prior to clearing upstream sections of channels and left in position until the sediment has settled out of the water upstream of the bales. The opportunity cost of re-designing the drainage network is the consumption of real resources that could otherwise have been used for another purpose. This includes the materials, labour and land consumed in re designing the drainage network.	Material
Fish passage issues	Fish passage may be disrupted when operating the temporary sediment filters during the clearing operation. Ensuring fish passage is protected and enhanced throughout the catchment is important to realise the full potential benefits of improved water quality and hydrological management regimens. This is likely to be a minor disruption occurring infrequently and therefore not material in this economic evaluation.[61]	Immaterial
Reduction in milk supply to milk processors	On-farm mitigations reduce the intensity of milk farming, leading to a reduction in the supply to farm processors. It is important farm processors run at near capacity because they exhibit large fixed capital investments. A reduction in milk supply reduces their ability to recover the cost of their capital investment. However, in this case, processors have been planning for flat and	Immaterial

[60] Data provided by DOC.

[61] Pers con Living Water staff

Category of Cost	Qualitative Description	Materiality
	even declining milk volumes to account for future changes, including expanding regulations and, therefore, reductions under the Living Water interventions are unlikely to be a material change from business as usual.	
Visual impact of temporary sediment filters	Temporary sediment filters are large manmade structures, constructed from hay bales and geotextile fabric. Once constructed they could visually impede the natural landscape that people enjoy in the Waituna catchment. Sediment filters will mostly be on private land and in locations that do not compromise the scenery of the Waituna catchment.[62]	Immaterial

Quantitative estimates

4.2.2 Quantitative estimates

Table 4.6 below outlines the costs of the actions taken to improve water quality under the farm-level interventions scenario.

Table 4.6: Quantitative estimate of the costs of the farm-level interventions scenario

Category of Cost	Valuation technique	Value Estimate
Wetland construction	The Aqualinc report provides the cost breakdown below. Mid-catchment wetland: ▪ Wetland construction $3,375,000 ▪ Bioreactor and peak run off control structure, $625,000 ▪ Fish pass $250,000 ▪ Designs $375,000 Land purchase $1,000,000 We assume an annual maintenance cost of $30,000	Capital cost = **5,600,000** Maintenance cost = **$30,000 per annum**
On-farm mitigations	We can quantify the opportunity cost of on-farm mitigations by estimating the reduction in farm COS due to increased production costs and a reduction in farming intensity. On-farm mitigations proposed in the farm-level interventions scenario are based on the "medium" on-farm mitigations described in the Aqualinc report. The report estimates a reduction in COS due to these mitigations The Aqualinc report estimated the reduction in annual farmer COS due to "medium" on-farm mitigations to be $3,008,888. Our assumption of the reduction in COS is consistent with the Aqualinc report. Over the 10 year analysis period, the nominal economic cost of on farm mitigations would be $3,080,888 x 10 = $30,808,888.	**$ 31,000,000**
On-farm mitigations programme	Support for on farm planting in the catchment = $176,000 Roll out of approximately 30-40 structures in the catchment = $100,000 for construction and project management, each structure costs ~$2000 to build Total of $276,000	**$276,000**

[62] Pers con Living Water staff

Category of Cost	Valuation technique	Value Estimate
Management costs	To estimate the opportunity cost of labour, we consider the level of skill the work requires and the unemployment rate in the projects region. This work will be undertaken by skilled labour and the unemployment rate in Southland is 3.3 percent.[63] The opportunity cost of management is, therefore, the required work hours and the going wage rate. 3.0 FTE x $150,000	$450,000
Retire existing farmland	Whakamana Te Waituna has already purchased land for the following costs: ▪ 120 ha of land purchased for $2,165,000 ▪ 331ha of land purchased for $4,000,000 We assume the land was purchased at a competitive price. It is, therefore, reasonable to assume the land purchase is equal to the opportunity cost of the retired farmland. 104ha of land was purchased for $1,906,940 with a 5 year + 5 year lease back to famers. We assume farming continues during the 10 year analysis period. Therefore, this payment is considered a wealth transfer where no opportunity cost is incurred. It is not included as an economic cost of the Project.	**$ 6,165,000**
Wetland planning and assessment costs	We assume payments to suppliers represent the opportunity cost of wetland planning and assessment costs. While technically financial transfers, this provides a good proxy for the consumption of real resources. The opportunity cost of labour for skilled workers when the unemployment rate is low can be assumed to be the going wage rate. The following costs were included in the DOC proposal for the Jobs for Nature fund, which was for one wetland at the cost of the large wetland. ▪ Site investigation, $30k ▪ 0.5 FTE Project manager for 3 years, $200,000 ▪ Detailed design and consenting costs, $400,000 We scale this cost by a factor of 1/3 given the size of the second smaller wetland in the lower catchment. Total cost $210,000	**$210,000**
Redesign of the drainage network	We assume the payments to suppliers represent the opportunity cost of redesigning the drainage network. While technically financial transfers, this provides a good proxy for the consumption of real resources. The following costs were included in the proposal for the Jobs for Nature fund. ▪ Bank reshaping, $1,650,000 ▪ Sediment filter, $50,000	**$1,700,000**

[63] https://figure.nz/chart/r9PsV2REYkH4yuj5-pJRjtp01mao0dErz

5 What is the net value of the Project?

The present values (PV) of costs and benefits of the remediation options are used to calculate the overall net present value (NPV) of each scenario and the associated benefit cost ratios (BCR).

The NPV is the result of the total PV of benefits minus the total PV of costs. The result is net value of all the monetised costs and benefits of the Project over the next 10 years measured in current value.

The total benefits divided by total costs give you the BCR. A BCR ratio of higher than one shows that the option is economically beneficial given only the monetised costs and benefits. A BCR of less than one indicates the monetised economic benefits do not outweigh the costs.

Sensitivity analysis is undertaken to test key assumptions within plausible ranges to see how important they are to the analysis and what a realistic range of possible outcomes might be.

5.1 What is the Net Present Value and Benefit Cost Ratio of the Project?

The NPV of the Project is negative in all scenarios evaluated

Table 5.1 below shows the estimated NPV of the Project in both the catchment-level interventions scenario and the Farm-level interventions scenario against all three counterfactual scenarios.

Table 5.1: Estimated NPV of the Project in each scenario

Scenario	Stable	Moderate	High
Catchment-level interventions scenario	-$1,474,000	-$1,073,000	-$718,000
Farm-level interventions scenario	-$10,825,000	-$10,424,000	-$10,068,000

The BCR is less than one in all Whakamana Te Waituna scenarios evaluated

Table 5.2 below shows the estimated BCR of the Project for both the catchment-level interventions scenario and the farm-level interventions scenario against the three counterfactual scenarios.

Table 5.2: Estimated BCR of the Living Water Programme in each scenario

Scenario	Stable	Moderate	High
Catchment-level interventions scenario	0.98	0.98	0.99
Farm-level interventions scenario	0.75	0.76	0.77

Figure 5.1 and Figure 5.2 illustrate the NPV, quantified economic costs, and quantified economic benefits of the farm-level interventions scenario and the catchment-level interventions scenario respectively.

Figure 5.1: NPV of farm-level interventions scenario

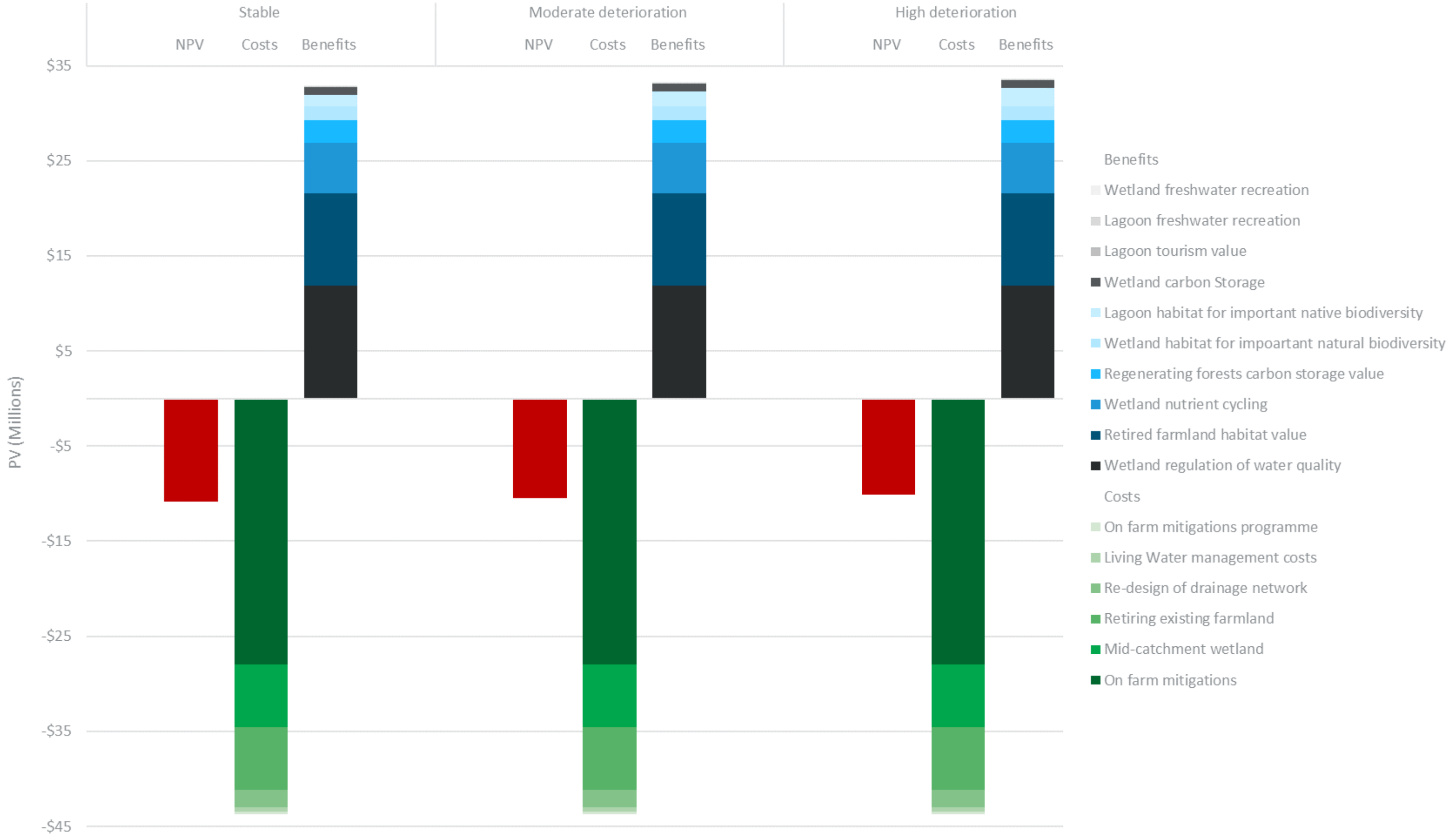


Figure 5.2: NPV of catchment-level interventions scenario

The NPV should be compared to the benefits that sit outside the CBA

We have not estimated some important benefits in dollar terms and they have not been included in the numerical CBA. The following benefits were not quantified because their assessment was outside the scope of the current report:

- Cultural values, including historic and traditional association and mauri
- Ecological and scientific significance

The NPV should not be interpreted as a definitive estimate of the value of the Project because it needs to be compared against these benefits that sit outside the CBA. Given that the net present value of each of the scenarios tested is negative, the question for decision makers is:

Is the net present cost of undertaking the Whakamana Te Waituna interventions justified by the combined benefits of:

- ***Protecting cultural values including historical and traditional association and preserving and enhancing the mauri of the area***
- ***Preserving the ecological and scientific significance of the Waituna Lagoon?***

Analysis of the results also provide an indication of strategies that will provide a higher NPV and therefore a more positive net impact on society.

Most of the quantified benefits are derived directly from implementing mitigation measures

In the catchment-level interventions scenario, the specific benefits of mitigation measures account for over 97 percent of the total quantified benefits of the Project. In the farm-level interventions scenario, these benefits account for over 94 percent. The benefit of reducing the risk of a regime-shift to an algal-dominated state make up only a small fraction of the benefits in each scenario.

The NPV and BCR is lower in the farm-level interventions scenario than in the catchment-level interventions scenario

There are two main reasons why the quantified economic cost of the farm-level interventions scenario is greater than the catchment-level interventions scenario:

- The catchment-level interventions scenario assumes more wetlands are constructed, and more farmland is returned to its natural state. Most of the quantified economic benefits of the Project result from implementing these mitigation measures rather than from reducing the probability of a regime-shift in the lagoon.
- The farm-level interventions programme includes “medium” on-farm mitigations as described in the Aqualinc report. The Aqualinc report estimates the reduction in COS of “medium” on-farm mitigations to be significantly greater than the “low” on-farm mitigations assumed in the catchment-level interventions scenario.

The value of constructed wetlands is unusually low in the Waituna catchment

The wetlands planned for construction in the Waituna catchment are located in the lower catchment. Because there are few downstream farms or structures, these wetlands do not provide material flood mitigation benefits. In general, the flood mitigation benefits are among the most significant economic advantages of constructing wetlands, so we would expect them to dominate the benefits provided by similar interventions in other catchments.

Many of the benefits of the Project extend beyond the time horizon of the CBA

Unlike most of the costs, which are investment cost and are incurred in year 0, the benefits of the Project accrue over time. If the lifetime of the capital investments exceeds the evaluation time horizon, then there are benefits from the capital investment which are not accounted for in our analysis. For the catchment-level interventions scenario, increasing the evaluation time horizon by 10 years is likely to result in a positive NPV. For the farm-level interventions scenario, it would make the NPV more negative because on-farm mitigations alone outweigh the annual benefits of the interventions.

5.2 What are the sensitivities to key input assumptions?

Sensitivity analysis tests how sensitive the NPV is to changes in assumptions about individual costs and benefits and other modelling assumptions such as the discount rate. We test the sensitivity of the model to changes in each assumption, holding all others constant.

First, we test the sensitivity of the modelling results to the probabilities attached to the Lagoon shifting regime under each scenario. For assumptions that have low uncertainty, we vary the assumption by 25 percent. For assumptions that are more uncertain, we vary the assumption by 50 percent. For economic assumptions such as the discount rate, we vary the input assumptions within reasonable ranges.

Variance in the probability of a regime-shift in each scenario does not significantly impact quantified NPV

We recognise the uncertainty in the probabilities attached to the Lagoon shifting regime under each scenario. The probabilities are 'best guess' estimates, formed in consultation with the Living Water team. Because only a small proportion of the quantified economic benefits are specific to the risk of a regime shift, variance in the probabilities used does not significantly impact the results. Figure 5.3 and Figure 5.4 below illustrates the impact of changing the probabilities on the quantified NPV of the farm-level interventions scenario and the catchment-level interventions scenario, respectively. The results presented in the graph assume a constant probability of a regime-shift in each year of the evaluation period. Varying the probability of a regime shift each year between 0 and 1.5 percent has minimal impact on the NPV in both the farm-level and catchment-level interventions scenarios.

Figure 5.3: Quantified NPV of the farm-level interventions scenario under alternative regime-shift probabilities

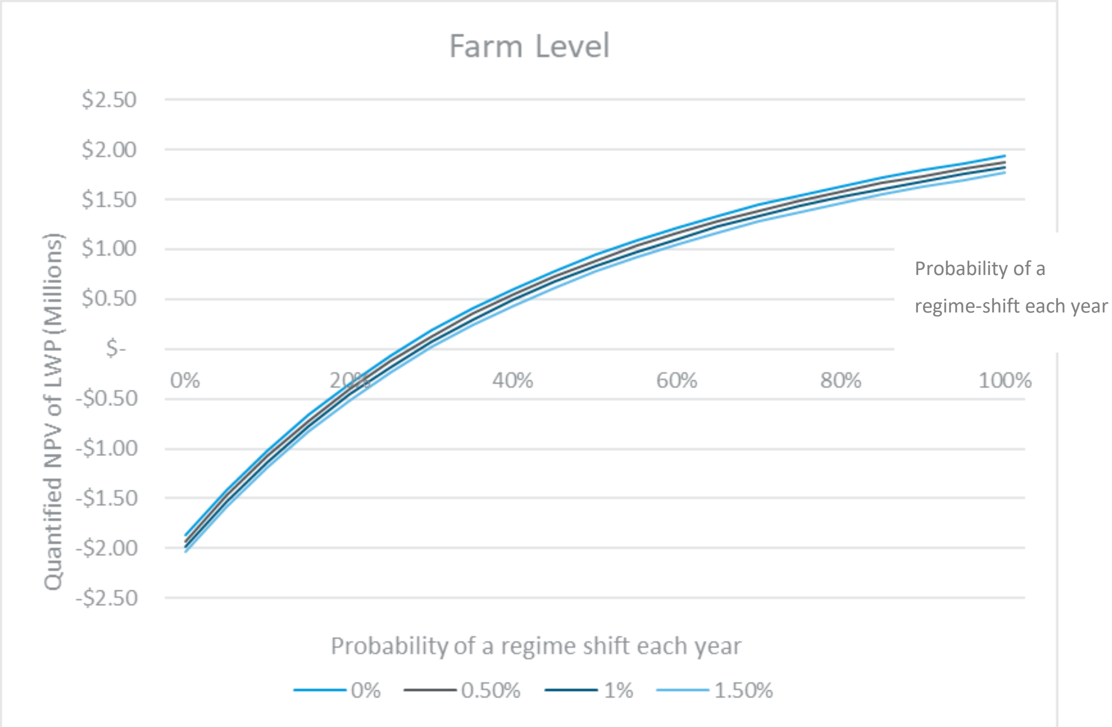
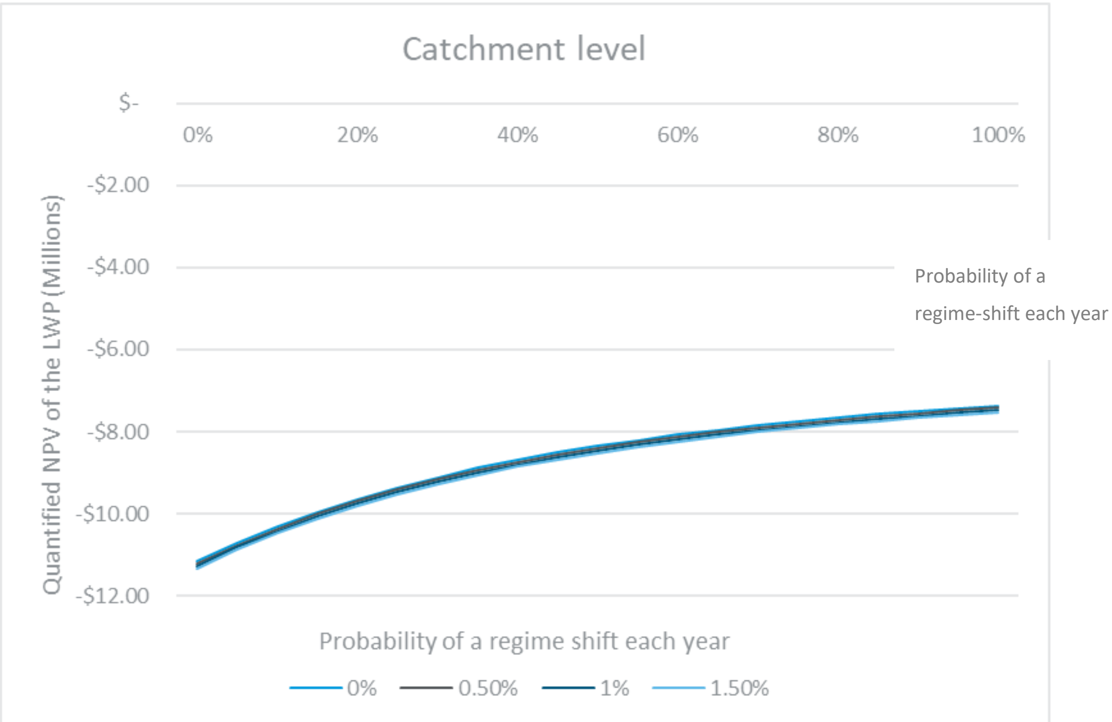


Figure 5.4: Quantified NPV of the catchment-level interventions scenario under alternative regime-shift probabilities



5.2.1 Catchment-level interventions scenario

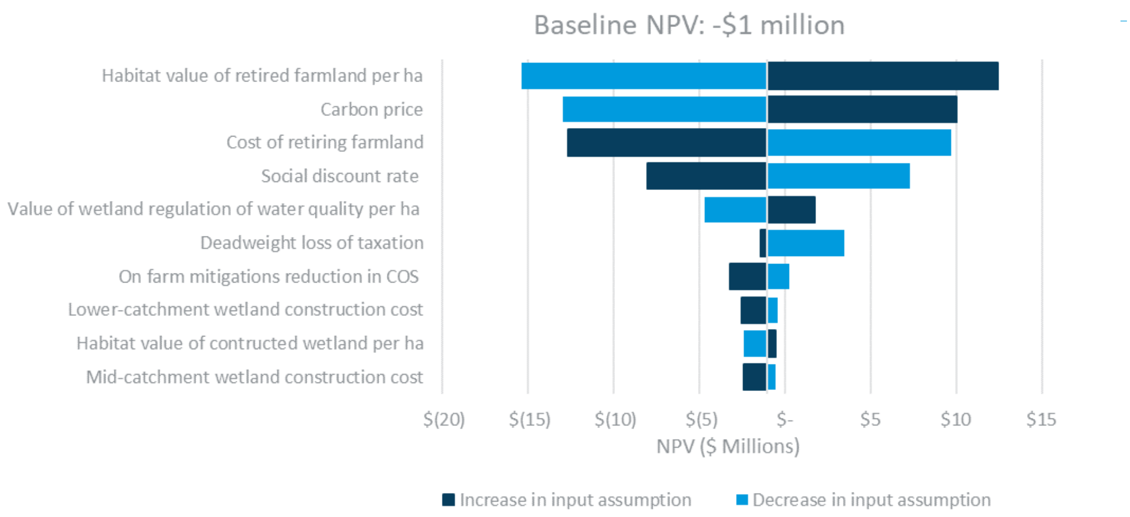
Table 5.2 presents the results of sensitivity analysis on key assumptions made in the catchment-level interventions scenario relative to the moderate deterioration counterfactual. We then provide a visual representation of the sensitivity analysis in Figure 5.5.

Table 5.2: Results of sensitivity analysis: catchment-level interventions scenario against moderate deterioration counterfactual

Input assumption	Low estimate	High estimate	Sensitivity
Mid-catchment wetland construction cost	-$ 574,080	-$ 2,374,375	+- 25 per cent
Habitat value of constructed wetland per ha	-$ 2,370,941	-$ 577,514	+- 50 per cent
Lower-catchment wetland construction cost	-$ 401,736	-$ 2,546,718	+- 25 per cent
On farm mitigations reduction in COS	$ 272,663	-$ 3,221,118	+- 25 per cent
Deadweight loss of taxation	$ 3,479,530	-$ 1,400,595	+- 10 per cent
Value of wetland regulation of water quality per ha	-$ 4,708,501	$ 1,760,047	+- 50 per cent
Social discount rate	$ 7,300,437	-$ 8,039,281	+- 3 per cent
Cost of retiring farmland	$ 9,707,575	-$ 12,656,029	+- 25 per cent
Carbon price	-$ 12,978,186	$ 10,029,731	+- 50 per cent
Habitat value of retired farmland per ha	-$ 15,388,942	$ 12,440,487	+- 50 per cent

Castalia model (2022)

Figure 5.5: Catchment-level interventions scenario sensitivity analysis (moderate counterfactual)



Uncertainty in the habitat value of retired farmland has the greatest impact on the quantified NPV of the catchment-level interventions scenario. This is unsurprising, given that the habitat value of retiring farmland is the largest individual benefit in this scenario. Uncertainty in the carbon price has the next greatest impact on the quantified NPV of the catchment-level interventions scenario. Similarly, this is because a large area of farmland is retired and restored to its natural state in the catchment-level interventions scenario.

Variance in the cost of retiring farmland and in the discount rate has a material impact on the NPV of the catchment-level interventions scenario. The cost of retiring farmland is the largest individual cost in this scenario. The discount rate is important because all the benefits of the Project accrue over time, while many of the costs are incurred in the first year. Therefore, the benefits are heavily discounted by the end of the analysis period. For example, the current value of carbon storage in retiring farmland reduces by 25 percent in 10 years due to the discount rate alone.

Only three variables (habitat value of constructed wetlands, lower catchment wetland construction costs, and mid-catchment wetland construction costs) had no impact on the sign of the NPV, with the NPV remaining negative across the range of values tested.

5.2.2 Farm-level interventions scenario

Table 5.3 presents the results of sensitivity analysis on key assumptions made in the farm-level interventions scenario relative to the moderate deterioration counterfactual. We then provide a visual representation of the sensitivity analysis in Figure 5.6.

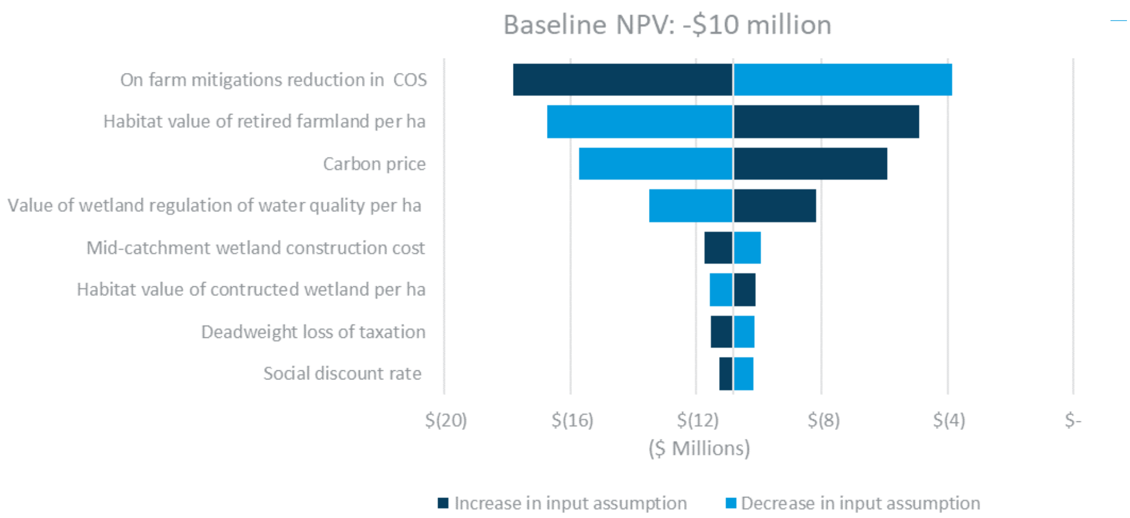
Table 5.3: Results of sensitivity analysis: farm-level interventions scenario against moderate deterioration counterfactual

Input assumption	Low estimate	High estimate	Variance
Social discount rate	-$ 10,172,404	-$ 11,250,678	+- 3 per cent
Deadweight loss of taxation	-$ 10,128,482	-$ 11,521,034	+- 10 per cent

Input assumption	Low estimate	High estimate	Variance
Habitat value of constructed wetland per ha	-$ 11,557,905	-$ 10,091,611	+- 50 per cent
Mid-catchment wetland construction cost	-$ 9,924,610	-$ 11,724,905	+- 25 per cent
Value of wetland regulation of water quality per ha	-$ 13,469,078	-$ 8,180,438	+- 50 per cent
Carbon price	-$ 15,718,930	-$ 5,930,585	+- 50 per cent
Habitat value of retired farmland per ha	-$ 16,744,547	-$ 4,904,968	+- 50 per cent
On farm mitigations reduction in COS	-$ 3,837,178	-$ 17,812,338	+- 25 per cent

Castalia model (2022)

Figure 5.6: Farm-level interventions scenario sensitivity analysis (moderate counterfactual)



Uncertainty in the reduction in farmer COS due to on-farm mitigations has the greatest impact on the quantified NPV of the farm-level interventions scenario. This is not surprising because on-farm mitigations are the largest cost in the farm-level interventions scenario. None of the adjustments tested were sufficient to return a positive NPV in the farm-level interventions scenario.

6 Further investigation

In this section, we investigate an extended analysis period and alternative approaches to social discounting. We also evaluate a third Whakamana Te Waituna scenario. This section is structured as follows:

- In Section 6.1, we test the sensitivity of the analysis to an extended analysis period of 40 years
- In Section 6.2 we test the sensitivity of the analysis to alternative approaches to social discounting
- In Section 6.3, we evaluate a third scenario that is identical to the farm-level intervention scenario but without any land purchase around the lagoon.

6.1 Extending the analysis period to 40 years

The analysis period, or the length of time being studied, is a crucial factor in CBA. A longer analysis period gives a more comprehensive view of the long-term effects of the project, but it is more difficult to estimate costs and benefits that occur further in the future. It is important to find the right balance between having a complete view and being accurate by choosing a suitable analysis period.

There is a strong case for using a long analysis period when evaluating environmental costs and benefits because the benefits from environmental measures often accrue over long time periods. We compare the results in Whakamana Te Waituna Scenarios to an extended analysis period of 40 years. Figure 6.1 and Table 6.1 show the impact on the NPV and the BCR in both Whakamana Te Waituna Scenarios.

The results suggest that extending the analysis period to 40 years provides a more comprehensive view of the costs and benefits of the Project. This is because most of the costs of the Project are investment costs, whereas the benefits continue far into the future. Therefore, we use a 40-year analysis period for the rest of this extended analysis.

These results also indicate that, despite significant up-front costs, catchment-level interventions are likely to be more economically beneficial than farm-level interventions in the long-term.

Figure 6.1: Comparison of the NPV in both Whakamana Te Waituna Scenarios to an extended analysis period

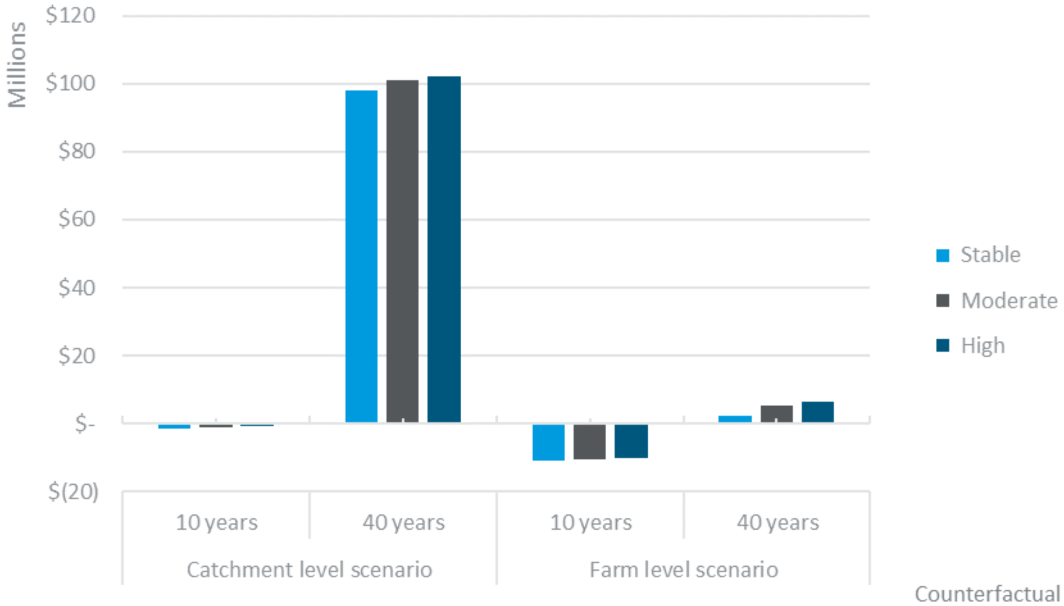


Table 6.1: Comparison of the BCR in both Whakamana Te Waituna Scenarios to an extended analysis period

Social discount rate	Stable counterfactual	Moderate counterfactual	High counterfactual
	Catchment-level interventions scenario		
10 years	0.98	0.98	0.99
40 years	2.26	2.29	2.31
	Farm-level interventions scenario		
10 years	0.75	0.76	0.77
40 years	1.03	1.06	1.08

In the catchment-level interventions scenario, both the NPV and the BCR improve substantially as the analysis period is extended

The NPV increases because the benefits outweigh the costs in the extended analysis period. The BCR increases because the ratio of benefits to costs is greater in the extended period than in the initial 10-year period. This is because significant investment costs occur at the beginning of the programme, whereas all the benefits continue accumulating in the extended analysis period.

In the farm-level interventions scenario, both the BCR and the NPV improve as the analysis period is extended

The NPV Of the farm-level interventions scenario switches from being negative over a 10 year time horizon to being slightly positive over a 40 year time horizon. This shows that the ongoing benefits slightly outweigh the ongoing costs of farm-level interventions.

The BCR increases from below one to slightly above one because the ratio of benefits to costs is greater in the extended period than in the initial 10-year period. The farm-level interventionsscenario also encompasses significant investment costs that occur at the beginning of the programme, whereas all the benefits continue accumulating in the extended analysis period.

6.2 Alternative approaches to social discounting

The social discount rate (SDR) is used in CBA to discount economic costs and benefits, reflecting the time value of money. It represents the social view of how future benefits and costs are to be valued against present ones. It is an integral part of CBA, and the choice of SDR can greatly impact the results.

The social discount rate is particularly important for environmental-related expenditures. Environmental-related expenditures typically incur large costs in the near term and accumulate benefits far in the future. Therefore, the wrong SDR can significantly impact the outcome of the analysis.

The New Zealand Treasury publishes guidance on public sector CBA, including what SDRs to apply. This guidance was reviewed by the Parliamentary Commissioner for the Environment (PCE) in his report "Wellbeing Budgets and the Environment" (the PCE Report) published in December 2021. The PCE report found that Treasury's guidance on social discounting is problematic for environment-related expenditures and is materially different from guidance on social discounting published by a range of other OECD countries. The PCE report proposes alternative approaches to social discounting that could improve the allocation of public spending, particularly for decisions involving the environment.

The PCE report proposes the following approaches to social discounting:

- Social rate of time preference approach (SRTP)
- Hyperbolic discounting
- Dual discounting.

In this section, we explain the alternative approaches to social discounting proposed in the PCE. We then test the sensitivity of each Whakamana Te Waituna Scenarios to the alternative approaches to social discounting.

6.2.1 Social Rate of Time Preference approach to social discounting

The Treasury's recommended SDR can be problematic for environmental-related expenditures because it is estimated using the Social Opportunity Cost (SOC) approach so SDR estimation.

The SOC approach is generally biased towards higher estimates of the SDR.[64] This underestimates the economic benefit of environmental-related expenditures that incur costs in the near term and generate benefits over long time periods. The PCE report recommends that an alternative approach to SDR estimation, known as the SRTP approach, is better aligned with a wellbeing approach to social discounting.

The SOC approach defines the discount rate as the rate of return that a decision-maker could earn on a hypothetical 'next best alternative' to a public investment with similar risk. This approach is based on the idea that public investments displace private investments. Therefore, according to this approach, the return from the public investment should be at least as big as the one that could be obtained from private investment.

The SOC is generally biased towards higher estimates of the SDR; it is underpinned by assumptions that are often not true in practice. For example:

- Externalities and market failures distort private investment returns and may generate private investment returns higher than the social ones
- The SOC approach assumes that governments should trade-off the future for public sector investments in the same way that individuals and businesses do when making decisions about their own personal consumption and investment–this may not be appropriate for spending on environmental projects where benefits (or costs) span multiple generations
- The SOC approach assumes that the government is concerned about the same types of risk, and prices risk in the same way as markets. The observed private return on investments usually includes a risk premium. However, this is not to be included in the SDR because society as a whole (or the government) has a much larger portfolio than any private investor and consequently can exploit risk pooling.

Another approach to estimating the social discount rate is the SRTP approach. The logic of this approach is that the government should consider the welfare of both the current and future generations and solve an optimal planning programme based on individual preferences for consumption.

The SRTP approach is better aligned with a wellbeing approach than the current SOC approach because it requires the value of future time preference to be made explicit. However, specifying these considerations requires subjective decisions about somewhat abstract concepts.

Many OECD countries employ the SRTP approach to estimating the SDR. Table 6.2 presents a number of OECD countries that employ the SRTP approach and the discount rates that they recommend. In this analysis, we applied a discount rate of 3.5 percent, consistent with the UK government's advice, which is estimated using the SRTP approach.[65]

[64] European Commission (2014) Guide to Cost-Benefit Analysis of Investment Projects: Economic appraisal tool for Cohesion Policy 2014-2020.

[65] The SDR is a socially derived metric using attributes like per capita growth of consumption, elasticity of marginal utility of consumption, and the utility discount rate. It is likely that a build-up in New Zealand would produce a slightly different number. We use the UKs SRTP discount rate as an example.

Table 6.2: Examples of OECD countries that employ the SRTP to social discounting

Country	Social discount rate (real)	Source
Denmark	3 percent	Hepburn, C. (2007) 'Use of Discount Rates in the Estimation of the Costs of Inaction with Respect to Selected Environmental Concerns', OECD.
France	4.5 percent (declining after 30 years)	Quinet E. (2013) 'L'évaluation socioéconomique des investissements publics Tome 1 Rapport final', Commissariat Generale a la strategie et a la Prospective
Germany	3 percent	Florio, M. (2006) 'Cost-benefit analysis and the European Union Cohesion Fund: On the Social Cost of Capital and Labour', Regional Studies, Vol. 40(2): 211-224.
Italy	5 percent	Florio, M. (2006) 'Cost-benefit analysis and the European Union Cohesion Fund: On the Social Cost of Capital and Labour', Regional Studies, Vol. 40(2): 211-224.
Portugal	4 percent	Florio, M. (2006) 'Cost-benefit analysis and the European Union Cohesion Fund: On the Social Cost of Capital and Labour', Regional Studies, Vol. 40(2): 211-224.
Spain	5 percent for the evaluation of environmental projects	Hepburn, C. (2007) 'Use of Discount Rates in the Estimation of the Costs of Inaction with Respect to Selected Environmental Concerns', OECD.
United Kingdom	3.5 percent (declining after 30 years)	Martin Hurst (Dr.) (2019) 'The Green Book: Central Government Guidance on Appraisal and Evaluation, Journal of Mega Infrastructure & Sustainable Development'
USA (requires both the SOC and SRTP approach to be used)	3 percent for the SRTP approach	Hepburn, C. (2007) 'Use of Discount Rates in the Estimation of the Costs of Inaction with Respect to Selected Environmental Concerns', OECD.
Canada (requires both SOC and SRTP approach to be used)	3 percent for the SRTP approach	NZ Treasury (2017) 'Public Sector Discount Rates: A Comparison of Alternative Approaches'

The impact of using a discount rate estimated using the SRTP approach is illustrated below. Figure 6.2 and Table 6.3 compare the NPV and BCR in each of the Whakamana Te Waituna Scenarios under a discount rate consistent with the NZ Treasury's guidance (5 percent) and a discount rate estimated using the SRTP approach (3.5 percent).

Figure 6.2: NPV of Whakamana Te Waituna Scenarios using a 3.5 percent discount rate derived from the SRTP approach to SDR estimation

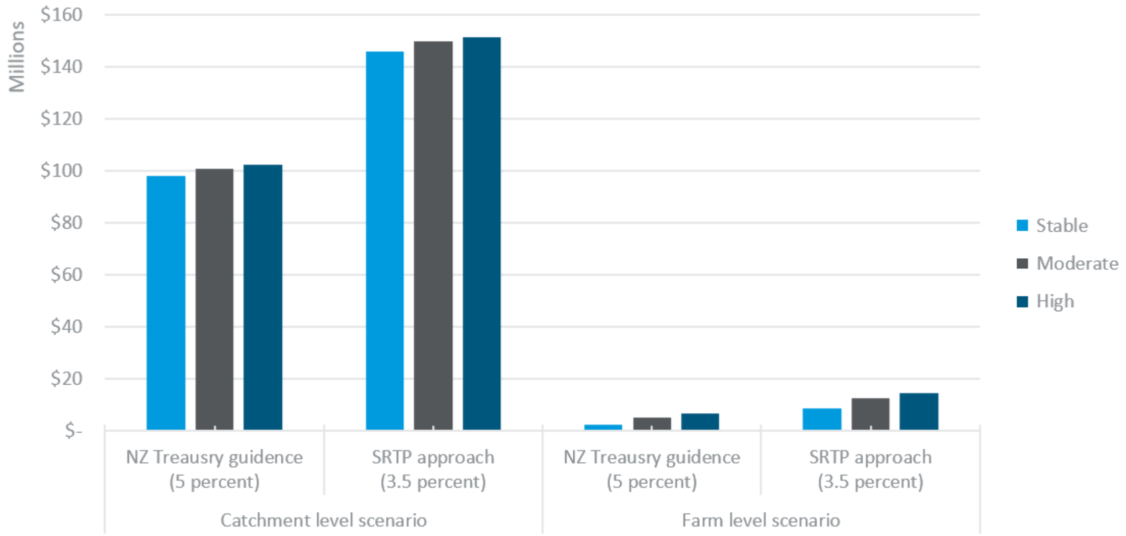


Table 6.3: Comparison of the BCR in both Whakamana Te Waituna Scenarios using a 3.5 percent discount rate derived from the SRTP approach to SDR estimation

Social discount rate	Stable counterfactual	Moderate counterfactual	High counterfactual
	Catchment-level interventions scenario		
NZ Treasury guidance (5 percent)	2.26	2.29	2.31
SRTP approach (3.5 percent)	2.72	2.76	2.78
	Farm-level interventions scenario		
NZ Treasury guidance (5 percent)	1.03	1.06	1.08
SRTP approach (3.5 percent)	1.08	1.11	1.13

In the catchment level interventions scenario applying a discount rate derived from the SRTP approach increases both the BCR and the NPV

Both the NPV and BCR increase when the SRTP discount rate is applied because the benefits are greater than the costs in the later years of the analysis period. The lower discount rate derived from the SRTP approach places greater emphasis on the future costs and benefits. Therefore, when the benefits are greater than the costs in the later years, the net benefit makes a larger contribution to the overall NPV and increases the overall ratio of benefits to costs.

In the farm-level interventions scenario applying a discount rate derived from the SRTP approach increases the BCR and the NPV

Both the NPV and the BCR increase because the benefits outweigh the costs in the latter years of the analysis period. The lower discount rate under the SRTP approach places more emphasis on future benefits and costs. This magnifies the contribution of net benefits received later in the analysis period.

6.2.2 Hyperbolic discounting

The Treasury's recommended SDR is problematic for environmental-related expenditures because it recommends an exponential discount rate. This is the traditional approach to social discounting, where the SDR is constant through time. Insights from behavioural economics suggest that individuals have time-inconsistent preferences and that individuals' discount rates decline as they look further into the future.[66] Further, there is a precautionary intuition that discount rates should be lowered to adjust for uncertain or riskier futures.[67] Hyperbolic discounting is an alternative approach to social discounting that applies a progressively lower rate as the benefits and costs become more distant in time.

The impact of using hyperbolic discounting can be substantial for environmental-related expenditures where benefits occur far into the future. Hyperbolic discounting still places greater emphasis on the short-term costs and benefits, but because the rate reduces over time, higher costs and benefits are being placed on the medium to long term.

Hyperbolic discounting is well established in both the academic literature and public policy. It is increasingly used to evaluate public projects in several OECD countries. Table 6.4 below provides a summary of OECD countries that use hyperbolic discounting.

Table 6.4: Examples of OECD countries that recommend hyperbolic discounting

Country	Rate	Reference
United Kingdom	3.5 percent for the first 30 years and a declining discount rate in each year beyond 30 years.	Martin Hurst (Dr.) (2019) 'The Green Book: Central Government Guidance on Appraisal and Evaluation, Journal of Mega Infrastructure & Sustainable Development'
France	4 percent for costs and benefits accruing within 30 years, falling to 2% for costs and benefits beyond 30 years	Hepburn, C. (2007) 'Use of Discount Rates in the Estimation of the Costs of Inaction with Respect to Selected Environmental Concerns', OECD.
Norway	4 percent for years 0-40 years 3 percent for years 40-75 years, and 2 percent for years 75+ years	NZ Treasury (2017) 'Public Sector Discount Rates: A Comparison of Alternative Approaches'
Denmark	4 percent for years 0-35 years 3 percent for years 36-70 years, and 2 percent for years 71+ years	NZ Treasury (2017) 'Public Sector Discount Rates: A Comparison of Alternative Approaches'

[66] Soman et al., (2005) The Psychology of Intertemporal Discounting: Why are Distant Events Valued Differently from Proximal Ones?

[67] HM Treasury (2008) Intergenerational wealth transfers and social discounting: Supplementary Green Book guidance

We test the sensitivity of our analysis to the hyperbolic discount rate used in the United Kingdom. For the first 30-year period this is the same discount rate as the discount rate in section 6.2.1 estimated using the SRTP approach to social discounting. After 30 years, the discount rate reduces to 3 percent.

Figure 6.3 and Table 6.5 compare the NPV and BCR in each of the Whakamana Te Waituna Scenarios using the NZ Treasury's recommended discount rate (5 percent) and a hyperbolic discount rate consistent with the UK governments guidance shown in Table 6.4.

Figure 6.3: Comparison of the NPV in both Whakamana Te Waituna Scenarios using the NZ Treasurys guidance and a hyperbolic discount rate

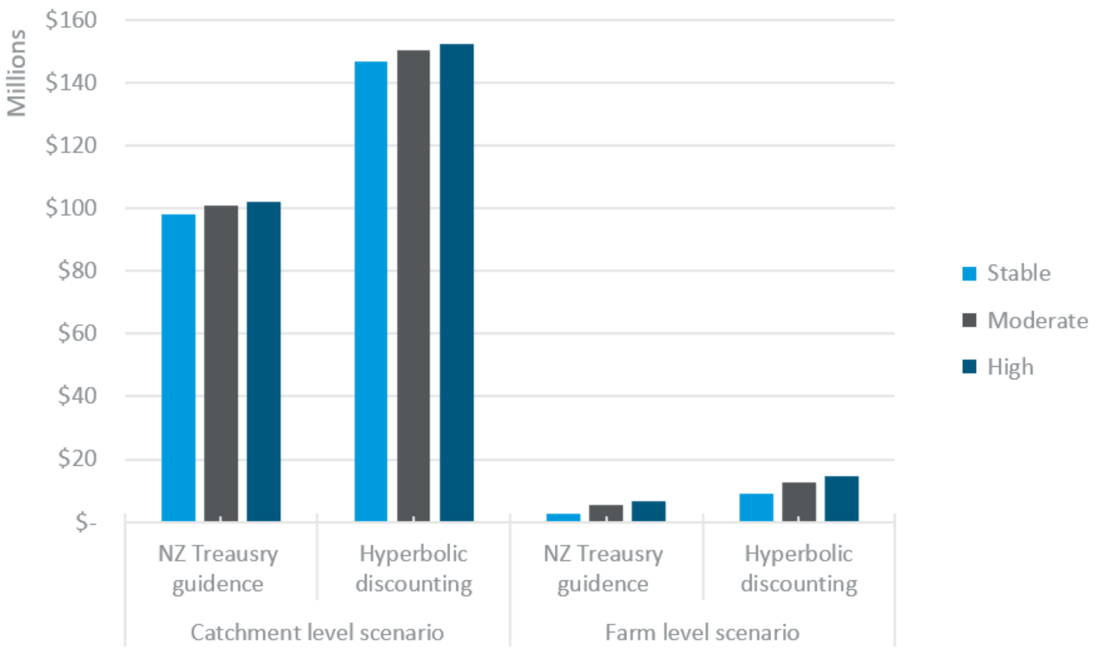


Table 6.5: Comparison of the BCRTable 6.5 in both Whakamana Te Waituna Scenarios using the NZ Treasurys guidance and a hyperbolic discount rate

Social discount rate	Stable counterfactual	Moderate counterfactual	High counterfactual
	Catchment-level interventions scenario		
NZ Treasury guidance	2.26	2.29	2.31
Hyperbolic discounting	2.73	2.77	2.79
	Farm-level interventions scenario		
NZ Treasury guidance	1.03	1.06	1.08
Hyperbolic discounting	1.08	1.11	1.13

In the catchment-level interventions scenario applying a hyperbolic discount rate increases the NPV and BCR

The NPV and BCR are higher under hyperbolic discounting because the hyperbolic discount rate applies a lower discount rate than the discount rate recommended under the NZ Treasury's guidance.

The results are only moderately more favourable than the SRTP approach in section 6.2.1 above because the decline in discount rates only begins after 30 years and only reduces by 0.5 percent. The impact of applying a hyperbolic discount rate is not significant because the lower rate only applies to the final 10 years of the analysis period.

In the farm-level interventions scenario applying a hyperbolic discount rate increases the NPV and BCR

In the farm-level interventions scenario, the NPV and the BCR increase because the ongoing benefits slightly outweigh the ongoing costs and the lower discount rate put more weight on the net benefits later in the analysis period.

6.2.3 Dual Discounting

Dual discounting involves using discount rates that vary for different types of capital and is typically used to separate between natural capital and manufactured capital. Dual discounting may be appropriate where there is a clear argument for considering the costs and benefits of environmental impacts as distinct from other costs and benefits.

It may be inappropriate to assume a common discount rate for both natural capital and man-made as natural capital is finite and limited, whereas man-made capital is not limited. The discount rate for natural capital should be set at a rate that considers the depletion of natural capital and the value to future generations.[68]

There is little consensus on the discount rate that should be used for the valuation of natural capital. The Stern Review (2006) derived at a relatively low discount rate of 1.4 percent. In its

[68] There are alternative views on how to discount natural capital. Some economists argue that the discount rate for natural capital should be set such that natural capital depletion maximising consumption utility of current and future generations. Others argue that discount rate should be set to maintain the current level of natural capital and preserve that option value for future generation.

reports, ‘The Wealth of Nations’ (2006) and ‘The Changing Wealth of the Nations’ (2011), the World Bank applied four percent as the SDR to estimate the natural capital in their wealth accounts. Other reports, such as The Economics of Ecosystem and Biodiversity, recommended that zero or negative discount rates could also be applicable when valuing environmental assets.

We test the sensitivity of the CBA to dual discounting. We apply a 5 percent discount rate to manufactured capital and a 1.5 percent discount rate to costs and benefits derived from natural capital. Table 6.6 below shows the costs, benefits, and discount rates applied.

Figure 6.4 and Table 6.7 compare the NPV and BCR in each of the Whakamana Te Waituna Scenarios under a discount rate consistent with the NZ Treasury’s guidance (5 percent) and the dual discounting approach.

Table 6.6: Discount rate applied to costs and benefits under dual discounting

Benefits/ costs	Type of capital	Discount rate
	Benefits	
Freshwater recreation	Natural capital	1.5 percent
Habitat for important native biodiversity	Natural capital	1.5 percent
Regulation of water quality	Natural capital	1.5 percent
Carbon storage	Natural capital	1.5 percent
Nutrient cycling	Natural capital	1.5 percent
	Costs	
Wetland construction and maintenance	Manufactured capital	5 percent
Land purchase	Natural capital	1.5 percent
On-farm mitigation costs	Manufactured capital	5 percent
Redesign of drainage network	Manufactured capital	5 percent
Whakamana Te Waituna Project management costs	Manufactured capital	5 percent

Figure 6.4: Comparison of the NPV in both Whakamana Te Waituna Scenarios using the NZ Treasurys guidance and dual discounting

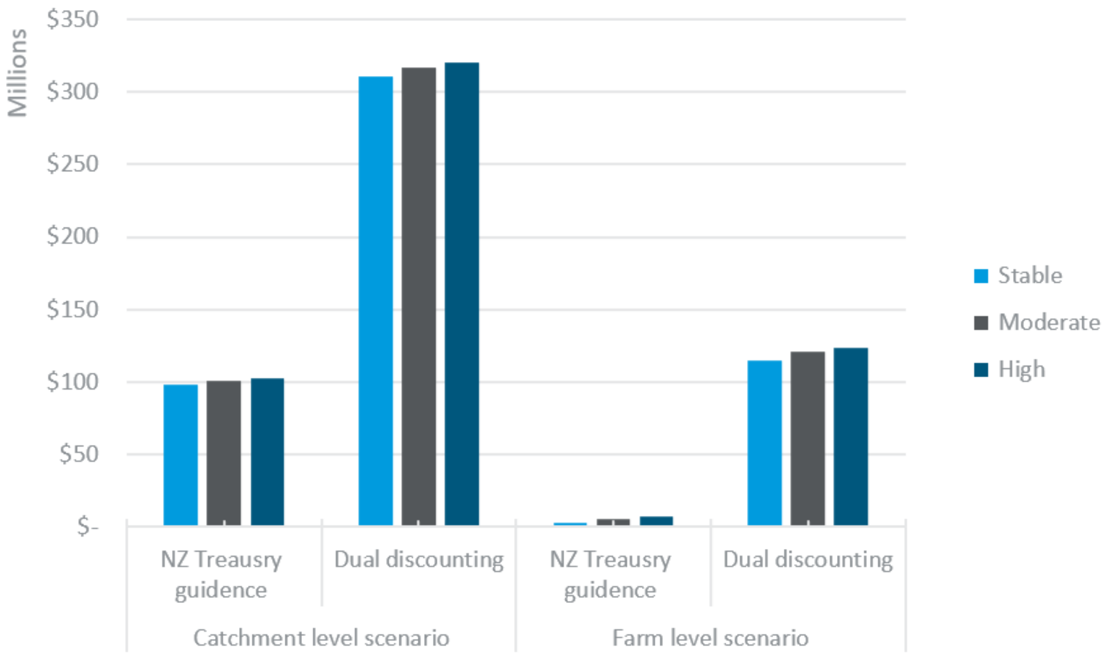


Table 6.7: Comparison of the BCR in both Whakamana Te Waituna Scenarios using the NZ Treasurys guidance and dual discounting

Social discount rate	Stable counterfactual	Moderate counterfactual	High counterfactual
	Catchment-level interventions scenario		
NZ Treasury guidance	2.26	2.29	2.31
Dual discounting	4.90	4.98	5.02
	Farm-level interventions scenario		
NZ Treasury guidance	1.03	1.06	1.08
Dual discounting	2.28	2.36	2.39

Applying the dual discount rate increases the BCR the NPV in both the farm-level interventions scenario and catchment-level interventions scenario

The NPV and BCR increase in both Whakamana Te Waituna Scenarios because the benefits of the Project are mostly derived from natural capital, whereas the costs are mostly derived from manufactured capital. Because the discount rate for natural capital is lower than for manufactured capital, the benefits derived from natural capital are given a higher weight in the later years of the analysis period.

6.3 No-land purchase scenario

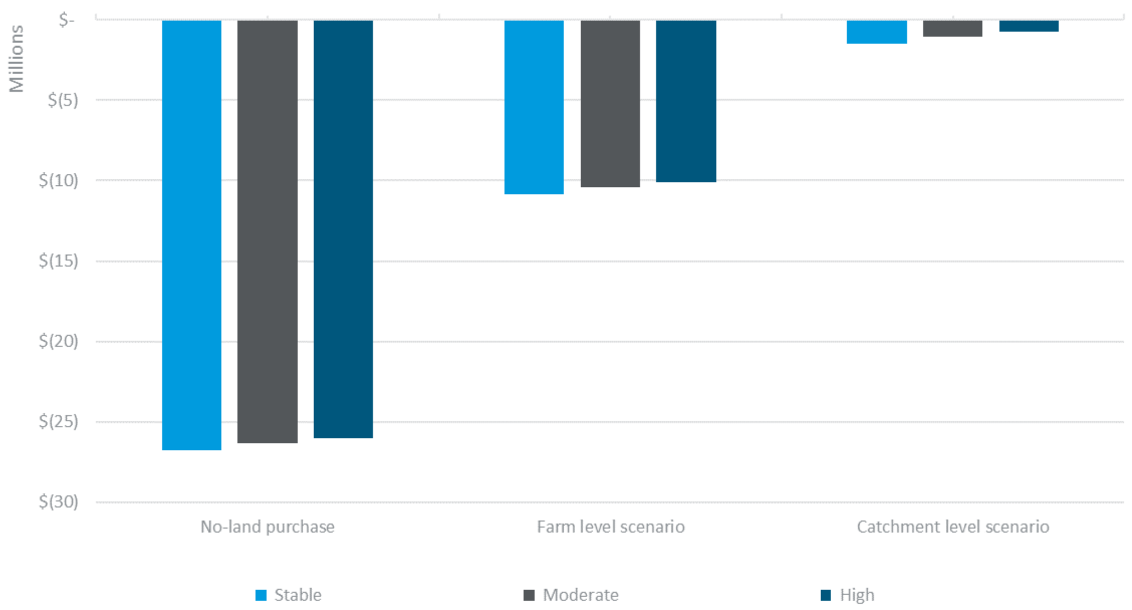
In this section, we evaluate a no-land purchase scenario that is identical to the farm-level interventions scenario but without the land purchase around the lagoon. To aid comparison with the farm level and catchment level scenarios, we evaluate the no-land purchase scenario over a 10-year analysis period.

The no-land purchase scenario required the following modifications to the farm-level interventions scenario:

- The cost of the farmland retirement is reduced to zero
- The direct benefits of retiring farmland are reduced to zero
- The probability of a regime shift after 10 years is increased from 1 percent to 1.4 to reflect the less severe containment measures[69] .

Figure 6.5 and Table 6.8 compare the NPV and BCR in the no-land purchase scenario to the two Living Waters scenarios.

Figure 6.5: Comparison of the NPV in the no-land purchase scenario and the two Whakamana Te Waituna Scenarios



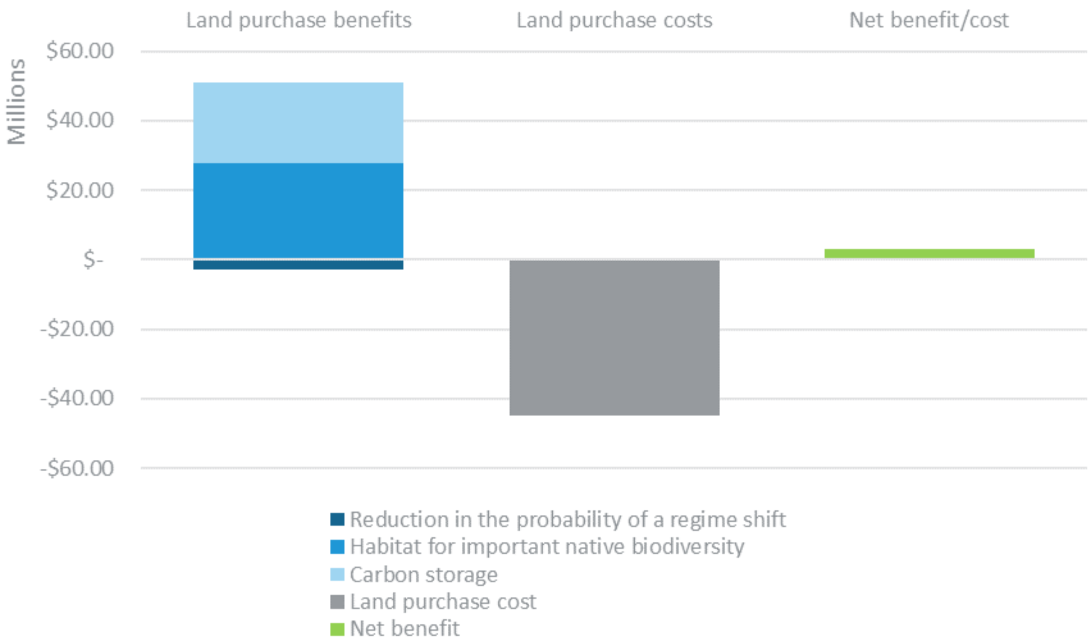
[69] We assumed that retiring farmland adjacent to the lagoon is only 0.75 percent as effective in reducing the probability of a regime shift as the constructed wetland per unit area. We then used the relationship between the area of the wetland, the area of retired farmland, and the probability of a regime shift in each of the Living Water scenarios to estimate a regime shift probability in the no-land purchase scenario.

Table 6.8: Comparison of the BCR in the no-land purchase scenario and the two Whakamana Te Waituna Scenarios

Scenario	Stable	Moderate	High
No-land purchase	0.28	0.29	0.30
Farm Level Intervention	0.75	0.76	0.77
Catchment Level Intervention	0.98	0.98	0.99

Figure 6.6 illustrates the benefits and costs of the land purchase alone in the farm-level interventions scenario. [70]

Figure 6.6: Comparison of the direct costs and benefits of land purchase around the lagoon



The no-land purchase scenario produces a lower NPV and BCR than the two Whakamana Te Waituna Scenarios because the benefits of land purchase outweigh the costs over the analysis period. This is because the benefits of the land purchase continue to accrue over the course of the analysis period. Over a 10-year analysis period, this results in the benefits of the land purchase marginally outweighing the cost of the land already purchased under the Project.

[70] The moderate deterioration counterfactual is assumed for the results shown. The counterfactual scenarios estimate a state of the world in which the LWP does not go ahead. To account for the uncertainty about the impacts of this on the Waituna Lagoon, we compare the costs and benefits against three potential counterfactual scenarios. The moderate deterioration counterfactual assumes the probability of a regime shift to an algal dominated state increases moderately over time

There are three benefits of the land purchase:

- **A reduction in the probability of a regime shift–**we assumed that retiring farmland adjacent to the lagoon is only 0.75 percent as effective in reducing the probability of a regime shift as the constructed wetland per unit area. We then used the relationship between the area of the wetland, the area of retired farmland, and the probability of a regime shift in each of the Whakamana Te Waituna Scenarios to estimate a regime shift probability in the no-land purchase scenario
- **Habitat for important native biodiversity–**in the farm-level interventions scenario, we assume a mean value of forest habitat maintenance as $658 per hectare per annum. This is the mean estimate from a global meta-analysis by Grammatikopoulou and Vačkářová (2021). Based on this estimate, the total habitat value provided by retiring 1,937 hectares of land adjacent to the Waituna Lagoon is estimated to be $1,274,546 per annum
- **Carbon storage–**The retirement of farmland adjacent to the Waituna Lagoon would also help to store carbon. We estimate the carbon storage value provided by retiring 1,937 hectares of farmland and allowing it to revert to the native forest would be $1,053,728 per annum. [71]

The cost of land purchase reflects the cost of the land already purchased by Whakamana Te Waituna.[72] Whakamana Te Waituna has purchased 451 hectares of dairy and beef farmland adjacent to the Waituna lagoon to restore, over time, to its natural state.

[71] A recent review by Aimers et al. (2021) estimated that regenerating native forest in New Zealand sequesters carbon at approximately 6.4 tonnes per hectare per annum (averaged over the first 50 years of growth). Assuming a carbon price of NZ$85 per tonne.

[72] Whakamana Te Waituna has already purchased land for the following costs:

- 120 ha of land purchased for $2,165,000
- 331ha of land purchased for $4,000,00.

7 Recommendations for future evaluation

Future evaluation of the impacts of the Wakamana Te Waituna Contaminant Intervention Project in the Waituna Catchment could be strengthened by reducing uncertainties in the most significant parameters, and more detailed assessment of the physical, cultural, and commercial impacts of the interventions.

7.1 Priority parameters

The sensitivity analysis, outlined in the previous section, shows which parameters the overall impact of the Living Water programme is most sensitive to. Under the catchment-level interventions scenario, habitat value provided by constructed wetland and retired farmland dominate the overall impacts of the programme, and warrant further examination. Under the farm-level interventions scenario, the cost of medium on-farm mitigations are the most important parameter, suggesting these should be monitored carefully.

If interventions follow the catchment-level interventions scenario, it will be important to monitor the habitat value provided by the constructed wetlands and the retired farmland adjacent to the Waituna Lagoon

This habitat value represents the largest economic benefit in the catchment-level interventions scenario. However, the current estimates are based on a generic national-level assessment from Patterson and Cole (2013) for wetlands, and a global meta-analysis by Grammatikopoulou and Vačkářová (2021) for restored forests. The value provided by wetland and retired farmland habitats in the Waituna catchment could be significantly lower or higher than these generic estimates, depending on the nature of species and ecosystems present. A recent review of non-timber values from native forests in New Zealand by Aimers, Bergin, and Horgan (2021)[73] provides a valuable conceptual foundation for further assessment of the habitat value provided by native forests in New Zealand. However, a quantitative assessment of this value would need to push beyond previous analysis and would require primary research on characteristics such as species diversity, species abundance, and pest management in the retired farmland.

If interventions follow the farm-level interventions scenario, then it will be most important to monitor the impact of on-farm mitigations on farm Cash Operating Surplus (COS)

This is the largest cost of the interventions in this scenario, and it drives much of the resulting NPV, meaning that the impact of inaccuracies in estimating these costs may be highly significant. The impact of medium on-farm mitigations on farm cash operating surplus could be estimated empirically using a longitudinal financial survey that includes a ‘treatment’ group of farmers in the Waituna catchment as well as a ‘control’ group of farmers in surrounding regions that are not impacted by the Project. Significant changes in the COS of farmers in the ‘treatment’ group could then be compared against performance over time in the ‘control’

[73] Aimers, J., Bergin, D., Horgan, G. (2021). Review of non-timber values in sustainably managed native forest in New Zealand. Tāne’s Tree Trust bulletin, Hamilton, New Zealand. 119 pages.

group to test whether the medium on-farm interventions significantly impact farmers' bottom lines.

7.2 Priorities for further research

There are several promising avenues for extending the current evaluation and existing research on freshwater quality in the Waituna catchment. Greater understanding of the link between nutrient inflows and risk of a regime shift would help to understand the scale of the generic benefits of the the Project. A separate assessment of cultural and passive values provided by freshwater restoration in the region would make this analysis more complete. It may also be valuable to separate the commercial impacts of the Whakamana Te Waituna interventions from the economic impacts, to better understand the impacts on landowners and the case for incentives or compensation.

Greater understanding of the link between nutrient inflows and the risk of a regime shift would reduce uncertainties

All of the generic benefits of freshwater restoration outlined in Section 5.2 are quantified based on changes in the likelihood that the lagoon will shift from a macrophyte-dominated state into an algal-dominated state due to continued nutrient inflows. Ecological restoration activities and alternative management approaches under the Living Water programme are expected to reduce the likelihood of this regime shift, as outlined in Section 2.1. However, the probabilities attached to the Lagoon shifting regime under each assessment scenario were 'best guess' estimates, formed in consultation with the Living Water team. Greater scientific certainty about the link between nutrient inflows and the risk of regime shift would help to reduce uncertainties about the scale of the generic benefits of freshwater restoration in the Waituna catchment. This would require more detailed computer simulation of lagoon dynamics that includes the most important physical parameters affecting the floral regime of the Lagoon. This will include ongoing monitoring of characteristics, including lagoon water depth, flow through the lagoon, wind velocity and direction, inflow nutrient profiles, macrophyte bed cover, sediment inflow from the creeks, and lagoon bed sediment properties.

Future evaluation should focus on better understanding cultural and passive values

As explained in Section 5.1, several material benefits of conserving the Waituna Lagoon were not included in the numerical CBA. The cultural and passive values left out of the CBA were described in Section 3 and their relevance to the decision framework was highlighted again in Section 5.1. However, by design, this analysis did not attempt to quantify cultural and passive values. Doing so would require a separate economic analysis of cultural values, co-designed with tangata whenua. In practice, it may not be feasible or appropriate to estimate the monetary value of cultural values. Therefore, it may be preferable to combine the results of this study with a range of other considerations in a multi criteria analysis which would combine both monetised and non-monetised values.

A logical way to extend this initial work would be to undertake a commercial analysis that considers only those costs and benefits that affect landowners

This would build on initial work undertaken by Aqualinc which quantified the financial cost of alternative mitigation options to landowners by estimating the reduction in COS. Commercial analysis would help to clarify which costs and benefits are realised by landowners and which are realised by the public in general. It would show whether water alternative water management interventions are commercially beneficial for farmers, or whether the programme is requiring farmers to undertake changes that cost them commercially. If the net impact of interventions is costly to farmers, then there may be a case for incentivising or compensating landowners for the public benefits these interventions generate.

Future CBA may want to include Monte-Carlo simulation to better understand the risk of uncertainty in input assumptions

Monte-Carlo simulation provides a systematic assessment of the combined effects of uncertainties in input assumptions. A Monte Carlo simulation is a computer-based technique that uses statistical sampling and probability distributions to simulate the effects of uncertain variables on model outcomes. Simulation would provide a better understanding of uncertainty in input assumptions by illustrating the impact of input assumptions varying together.

This CBA lays out a template that could be used elsewhere to identify other restoration programmes that could provide a net economic benefit

While the subset of quantified costs outweigh the subset of quantified benefits over a 10-year timeframe in the Waituna catchment, this reflects the geographic idiosyncrasies of the catchment, and it is reasonable to expect freshwater restoration efforts in other catchments would have net economic benefits.

For example, the flood mitigation benefits of constructed wetlands in the Waituna catchment were deemed immaterial because the wetlands are located in the lower catchment with few downstream residents or structures. Many other agricultural catchments in New Zealand have significant amounts of downstream property, and sometimes entire settlements. A generic estimate from Patterson and Cole (2013) suggests that the average wetland in New Zealand provides flood mitigation value of approximately $19,500 per hectare per annum. If the wetlands planned for the Waituna catchment provided typical levels of flood protection benefits, these benefits would equate to $2.9 - $3.9 million per annum, depending on the intervention scenario. This would be among the largest benefits with a PV of $24.3 million and $29.8 million in the farm-level and catchment-level interventions scenario respectively. This would be sufficient to generate a net present value of greater than $25 million in the catchment-level interventions scenario relative to each of the three counterfactual scenarios, as shown in Table 6.1.

Table 6.1: PV of Costs and Benefits of the catchment-level interventions scenario with hypothetical average flood mitigation benefit

PV	Stable	Moderate	High
Hypothetical flood mitigation benefit	$29,763,000	$29,763,000	$29,763,000
Costs	$65,834,000	$65,834,000	$65,834,000
Total Benefits	$64,360,000	$64,761,000	$65,116,000
NPV	**$28,289,000**	**$28,690,000**	**$29,045,000**
BCR	1.43	1.44	1.44

Castalia model (2022)

In the farm-level interventions scenario ‘typical’ flood mitigation benefits would be large enough to change the NPV from approximately negative 10 million to more than (positive) 13 million, as shown in Table 6.2.

Table 6.2: PV of Costs and Benefits of the farm -evel interventions scenario with hypothetical flood mitigation benefit

PV	Stable	Moderate	High
Hypothetical flood mitigation benefit	$24,334,000	$24,334,000	$24,334,000
Costs	$43,693,000	$43,693,000	$43,693,000
Total Benefits	$32,868,000	$33,269,000	$33,624,000
NPV	**$13,509,000**	**$13,910,000**	**$14,266,000**
BCR	1.31	1.32	1.33

Castalia model (2022)

It is worth considering that, for catchments with higher than average property downstream of existing or proposed wetlands, flood mitigation benefits would be higher than the generic estimates of Patterson and Cole (2013). Therefore, there are likely to be many catchments in New Zealand where the economic benefits of constructing wetlands vastly outweigh the costs.

Sensitivity analysis also shows that the cost of retiring farmland has a large impact on the quantified NPV. The net economic impact of restoration programmes in other catchments is likely to be more positive where the cost of acquiring and retiring farmland is lower.

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