Economic Evaluation of National-Scale Lowland Drainage Restoration

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

JANUARY 2024

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Definitions

bgl	Below ground level
CBA	Cost Benefit Analysis
DOC	Department of Conservation
FTE	Full-time equivalent
NPV	Net Present Value
TA	Territorial Authority
TSC	Two-stage channel

Executive summary

Lowland drainage networks provide an effective way to manage high water tables and enable farming. However, lowland drainage networks have traditionally been managed as network utilities rather than waterways, requiring frequent management (and in particular, mechanical clearing) which can cause significant environmental and ecological harm to freshwater biodiversity in lowland areas. This has left many lowland drainage networks and their receiving environments in degraded ecological states.

Under Fonterra and DOC's Living Water Programme, significant work has been done in the last decade to find ways for lowland farming to coexist with healthy waterways. These efforts have led to a detailed understanding of the costs of restoring the lowland drainage networks in a way that maintains drainage function, while enhancing other values, and an increased understanding of the range of benefits this restoration work provides. However, before this project, there had been no comprehensive attempt to aggregate and compare the costs and benefits of restoring lowland drainage networks.

This project aims to assess the costs and benefits of restoring Aotearoa/New Zealand's lowland drainage networks at a national scale.

The aim of this project is not to provide a definitive answer for whether it is economically cost justified to restore lowland drainage networks, but rather to simplify the decision-making space. By estimating values where possible, this analysis reduces the reliance on intuition and the impact of bias within the decision-making process. The results must still be interpreted in the context of the material unquantified benefits and large confidence intervals for the estimated benefits.

The analysis used a detailed pilot study in the Ararira/LII catchment in coastal central Canterbury to estimate the individual costs and benefits of lowland drainage restoration. The results of this pilot study were then extrapolated to other regions across Aotearoa/New Zealand to form estimates of the costs and benefits of lowland drainage restoration at the national scale.[1]

Lowland drainage network restoration has a negative Net Present Value in our numerical analysis, but this does not imply that restoration is economically unjustified

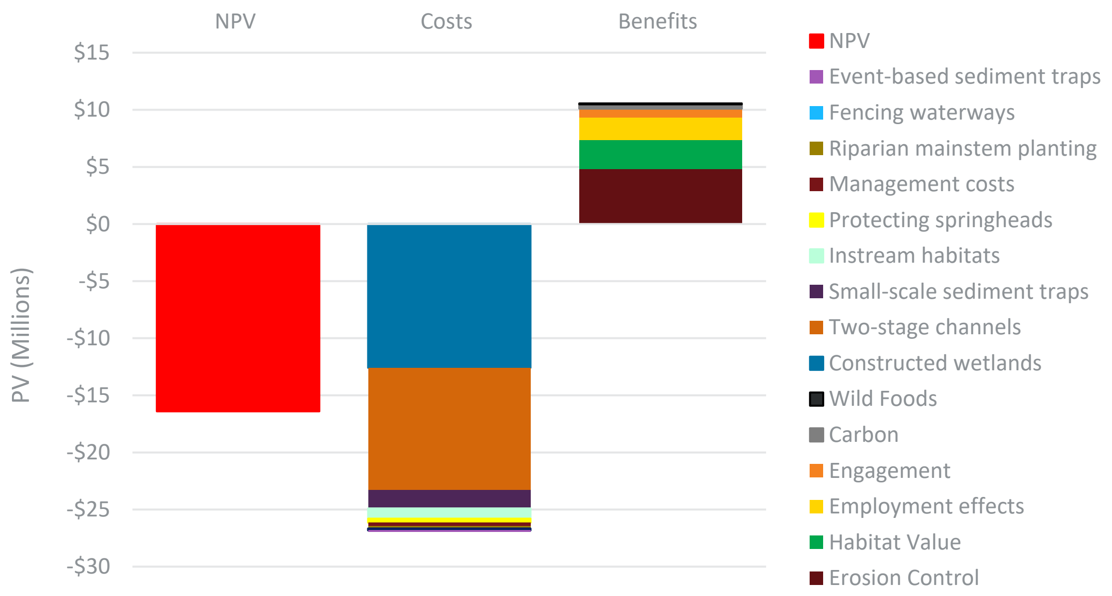
The total present cost of restoring the lowland drainage network in the Ararira/LII is $26,965,670. Comparing this to the benefits we were able to quantify, the Net Present Value (NPV) of drainage restoration is -$16,406,146. This NPV needs to be judged against the likely value of the following suite of unquantified material benefits:

- Reduced flood risk
- Ethical and spiritual values
- Inspirational and education values
- Community knowledge and skills development
- Reduced regulatory pressure

[1] This project focused on the drainage network restoration activities described in Sections 5 and 6 of the Ararira/LII Catchment Management Plan (Transforming lowland waterway networks – a catchment management plan for reimagining the Ararira/LII. Plan prepared by EOS Ecology, Aqualinc, Cawthron & Learning for Sustainability April 2023). It did not consider restoration and management activities such as sediment bunding that are used in other catchments in Aotearoa/New Zealand. The restoration and management activities in the Ararira/LII catchment also focus on land drainage for water table control, so they do not capture the types of large-scale flood management and water pumping schemes that are important in some other catchments.

The CBA results are shown below graphically in Figure 1.1.

Figure 1.1: Ararira/LII CBA graph

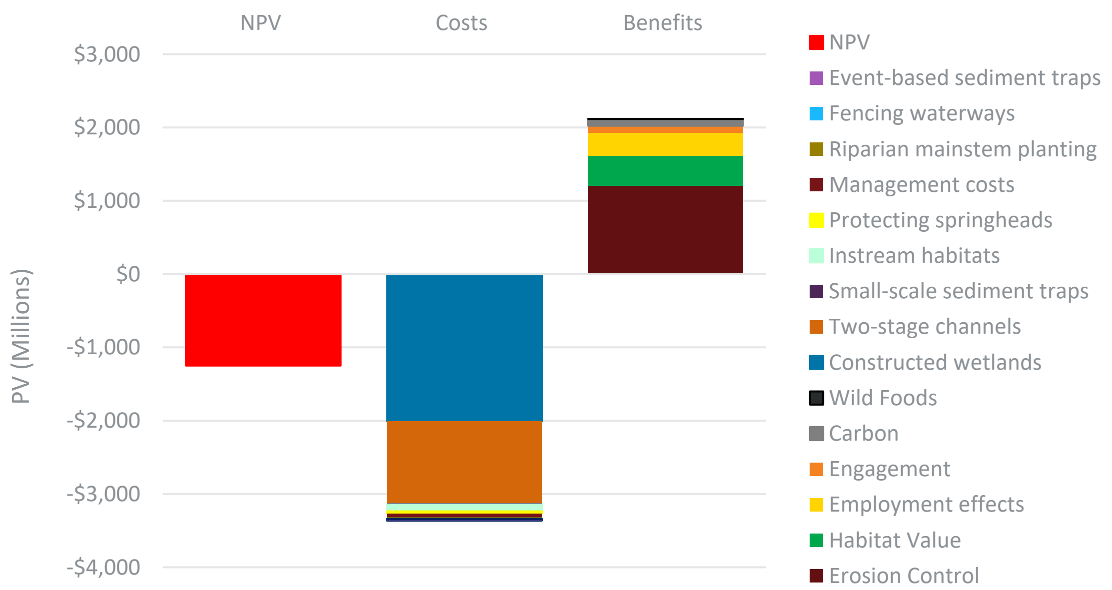


The cost of constructed wetlands and two-stage channels dominate the costs and are large contributors to the negative NPV. The most significant benefits are erosion control, habitat value, and employment effects.

We estimate the total cost of restoring lowland drainage networks at the national level to be $3,365,529,775. Comparing this cost to the benefits we were able to quantify, the NPV of national-scale lowland drainage restoration is -$1,247,743,082. Again, this value must be understood in the context of the material benefits that were not quantified.

The nationwide CBA results are shown graphically below in Figure 1.2.

Figure 1.2: Nationwide CBA graph



The cost of constructed wetlands and two-stage channels dominate the costs and are large contributors to the negative NPV. The most significant benefits are erosion control, habitat value, and employment effects.

There are large variations in CBA results across individual regions due to different soil erosion rates

When comparing the results across the individual regions, there are large variations. The primary driver of this is variations in the erosion control benefit. Erosion control is the most significant benefit in the Ararira/LII CBA and it was scaled to other regions by comparing the differences in regional soil erosion rates. This caused large variations in results since there are large regional differences in soil erosion rates within Aotearoa/New Zealand. The West Coast region has by far the highest average soil erosion rate which results in a positive NPV for the West Coast region CBA without considering the unquantified material benefits. The NPVs and average soil erosion rates by region are shown below in Table 1.1.

Table 1.1: NPVs and average soil erosion rates by region

Region	Average soil erosion rate (tonnes/km2/year)	NPV
Northland	106	-140,250,072
Auckland	92	-43,543,532
Waikato District	59	-165,837,864
Rest of Waikato	83	-175,209,992
Bay of Plenty	112	-50,919,040
Gisborne District	111	-5,909,717
Hawkes Bay	69	-30,649,676
Taranaki	60	-21,485,323
Horizons (Manawatu-Whanganui)	55	-57,306,392
Wellington	83	-18,550,773
Tasman District	199	-464,516
Marlborough District	55	-13,038,785
West Coast	631	81,942,203
Selwyn District	57	-99,894,453
Ashburton District	55	-58,574,396
Rest of Canterbury	59	-135,155,600
Otago	42	-60,508,826
Southland District	86	-201,823,009
Rest of Southland	65	-34,157,174

While the NPVs of restoring lowland drainage networks is negative in all but one region covered in our analysis, this does not imply that lowland drainage restoration is economically unjustified

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 quantification was either impractical or inappropriate:

- Reduced flood risk
- Ethical and spiritual values
- Inspirational and education values
- Community knowledge and skills development
- Reduced regulatory pressure

The NPVs should therefore **not** be interpreted as definitive estimates of the value of the lowland drainage network restoration in each region because they need to be compared against unquantified benefits listed above.

It is reasonable to expect that lowland drainage restoration would be economically justified in many regions if the non-quantified benefits could be included

In addition to unquantifiable benefits, the costs of constructed wetlands and two stage channel development are large contributors to the negative NPV in most regions. Two stage channel development would help to mitigate flood risk. The benefit of flood risk mitigation is likely to be substantial,[2] but it was not practical to quantify in dollar terms in this analysis. It may, however, be reasonable to assume that the benefit of flood risk mitigation would at least match the cost of two-stage channel development in most regions. If this were the case, the economics of national-scale lowland drainage restoration would be finely weighted, with a benefit cost ratio of 96% and a NPV of -$132,347,661 which would need to be considered in the context of the remaining unquantified benefits above. If flood mitigation benefits were assumed to match two stage channel development costs at the regional level, the analysis would show positive NPVs for Northland, Bay of Plenty, Gisborne, Tasman, and West Coast, and several other regions would have NPVs very close to $0.

[2] While drainage networks provide flood mitigation benefits, they are not designed as flood protection schemes. Improved drainage networks with two-stage channels are likely to help mitigate nuisance flooding, but are unlikely to reduce the damage from catastrophic flooding events.

1 Introduction

Lowland drainage networks provide an effective way to manage high water tables and enable farming. These networks are typically characterised by straight, channelised waterways that often represent a significant proportion of the remaining habitats for freshwater biodiversity in lowland areas of Aotearoa/New Zealand. Lowland drainage networks have traditionally been managed as network utilities rather than waterways, requiring frequent management (and in particular, mechanical clearing) which can cause significant environmental and ecological harm to freshwater biodiversity in lowland areas. This has left many lowland drainage networks and their receiving environments in degraded ecological states.

Under Fonterra and DOC's Living Water Programme, significant work has been done in the last decade to find ways for lowland farming to coexist with healthy waterways. In the Ararira/LII catchment in coastal central Canterbury, Living Water has been focussing on restoring the lowland drainage network through a range of measures and interventions aimed at improving environmental and ecological health. Through this experience, the organisations involved in Living Water have gained a more detailed understanding of the costs of restoring the lowland drainage network. These efforts have also led to increased understanding of the range of benefits this restoration work provides. However, before this project, there had been no comprehensive attempt to aggregate and compare the costs and benefits of restoring the lowland drainage network.

This project aims to assess the costs and benefits of restoring Aotearoa/New Zealand's lowland drainage network at a national scale. The approach to this study involves estimating restoration costs and benefits at the catchment level in the Ararira/LII catchment and then extrapolating these estimates to regional and national levels using scaling metrics. We then conduct a Social Cost Benefit Analysis (CBA) to further clarify the economic viability of a restoration programme from a whole-of-society point of view.

This report presents the findings of our study, and proceeds through the following six Sections:

- Section 2 outlines our approach to the economic evaluation
- Section 3 provides qualitative descriptions of all the costs and benefits of lowland drainage restoration
- Section 4 provides quantitative estimates of the material costs and benefits, and includes a clear outline of how we calculated each
- Section 5 details the scaling metric we used to extrapolate estimates for the Ararira/LII catchment to other regions in Aotearoa/New Zealand
- Section 6 presents the results of our economic analysis, starting with the Ararira/LII catchment then presenting results at the national level before presenting results at the individual region level
- Section 7 discusses some of the main findings and insights from the project.

2 Approach to the economic evaluation

To better understand the economics of restoring the lowland drainage network in Aotearoa/New Zealand, we undertook a cost-benefit analysis (CBA) built on a detailed assessment of a pilot catchment (the Ararira/LII catchment) in coastal central Canterbury. CBA is based on the principles of welfare economics and seeks to quantify the net value to society of an intervention compared to business as usual. It includes all significant costs and benefits that affect the welfare and wellbeing of the entire population, not just those commercially impacted by a decision.

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 reduces the reliance on intuition or prejudices. The results can simplify trade-offs for decision-makers.

This section introduces the Ararira/LII pilot catchment and outlines the parameters of the CBA. It then explains the regional breakdown of the analysis, and the use of scaling metrics to scale the costs and benefits to each of the regions of Aotearoa/New Zealand.

2.1 Parameters of the Cost-Benefit Analysis

An economic evaluation requires a complete assessment of all the costs and benefits measured over the analysis period. The time horizon of this assessment was 50 years.

CBA must evaluate a project or action against a counterfactual scenario. 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. For this analysis, the project being evaluated is restoration of the lowland drainage network in Aotearoa/New Zealand (at both the regional and national scales). Restoration of the lowland drainage network is being explored in detail, and is starting to take place in some parts of the Ararira/LII pilot catchment. A suite of potential actions has been developed for the area, and these actions are described in the Ararira/LII catchment management plan.[3] The costs and benefits of these actions are described in qualitative terms in Section 3.

The counterfactual scenario estimates the state of the catchment if lowland drainage restoration does not take place. Under this counterfactual scenario, it is assumed that Aotearoa/New Zealand's lowland drainage networks continue existing in their current state.

The material costs and benefits of lowland drainage restoration are quantified in Section 4. The quantitative estimates are formed by estimating the difference between the lowland drainage restoration scenario and the counterfactual for each material cost and benefit.

2.2 Ararira/LII pilot catchment

To make the analysis tractable, we focused first on analysing the economics of lowland drainage restoration in the Ararira/LII pilot catchment in coastal central Canterbury. Restoration of the drainage network in the Ararira/LII catchment has been extensively studied, planned, and costed at a concept level,[4] and actions are following a detailed Catchment Management Plan[5] and Implementation Guide developed by Aqualinc, EOS Ecology, Cawthron & Learning for Sustainability under the Fonterra and DOC Living Water Programme. This made it possible to comprehensively understand the costs of lowland drainage restoration (described in Sections 3 and 4). It also helped us to identify, and where possible, quantify the benefits or restoring the drainage network. The cost-

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[3] Transforming lowland waterway networks – a catchment management plan for reimagining the Ararira/LII. Plan prepared by EOS Ecology, Aqualinc, Cawthron. & Learning for Sustainability April 2023.

[4] Concept level costings have been benchmarked against other restoration projects, including other Living Water projects.

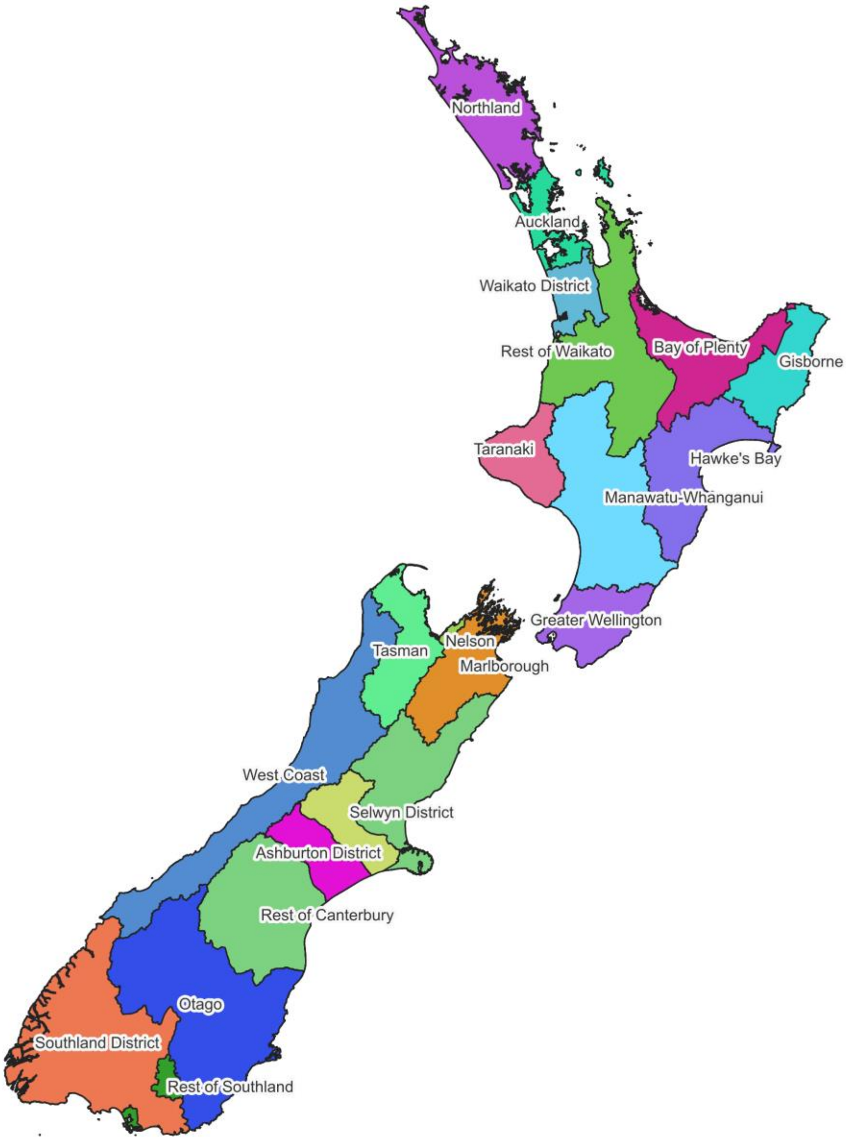
[5] Aqualinc, Learning for Sustainability & EOS Ecology 2023. Transforming Lowland Waterway Networks – An Implementation Guide for Reimagining the Ararira/LII. Prepared in co-design with the Ararira Catchment Management Plan Project Team (Selwyn District Council, Te Taumutu Runanga, LII Drainage Committee, Living Water (Fonterra, Department of Conservation), Environment Canterbury, Cawthron). 78 p. https://bit.ly/3AIVwFI.

benefit analysis undertaken in the Ararira/LII pilot catchment (presented in Section 6.1) provided the basis for estimating the costs and benefits of restoring the drainage network throughout Aotearoa/New Zealand.

2.3 Regions of analysis

To estimate the economics of lowland drainage restoration at the national level, we applied a range of scaling metrics (outlined in Section 2.4, below) to calculate costs and benefits by region. We separated regions for analysis by considering drainage length against regional and territorial authority extents. In an effort to strike a balance between providing granular analysis where most drainage occurs, and avoiding the an overly granular approach in other regions, we identified the regions for analysis using regional council boundaries, and included separate regions based on Territorial Authority (TA) boundaries in cases where the TA individually contains more than five percent of the total national drain length. This resulted in 19 regions of analysis, shown in Figure 2.1.

Figure 2.1: Regions of analysis



Source: Aqualinc

Figure 2.2 shows the location and extent of drains in each of the regions of analysis. We determined this extent using two datasets; a national drainage dataset[6] and Manaaki Whenua's national estimated extent of artificially drained land.[7]

The drainage dataset was extracted from the Topo50 map series. This map series does not show all privately or publicly (i.e. councils) managed drainage systems and schemes due to limitations of scale and approach. It also includes channels such as stockwater races that are not related to land drainage.

More extensive drainage data is held by Councils for the drains that they manage, but it was outside the scope of this project to obtain these, and we are aware that the completeness and accuracy of these datasets is variable. These Council datasets are generally limited to only showing drainage systems that are managed by councils, not by private landowners. Owing to the lack of a nationally complete drainage dataset at the level of detail held by some Councils, we chose to use a nationally consistent dataset to ensure comparability between regions in approach and limitations.

Manaaki Whenua determined the extent of artificially drained land in three stages. First, suitability for artificial drainage was determined using soil properties in the Fundamental Soils and S-Map datasets. This dataset was refined to reflect likelihood of artificial drainage. This was determined based on land cover, land slope, and distance from known drains (as defined using the Topo50 drains dataset, and Council-provided drainage information). This resulted in a national extent of land which is estimated to be:

1. Undrained
2. Drained, but with low confidence (probability 50-55%)
3. Drained, but with moderate confidence (probability 55-60%)
4. Drained, but with high confidence (probability >60%).

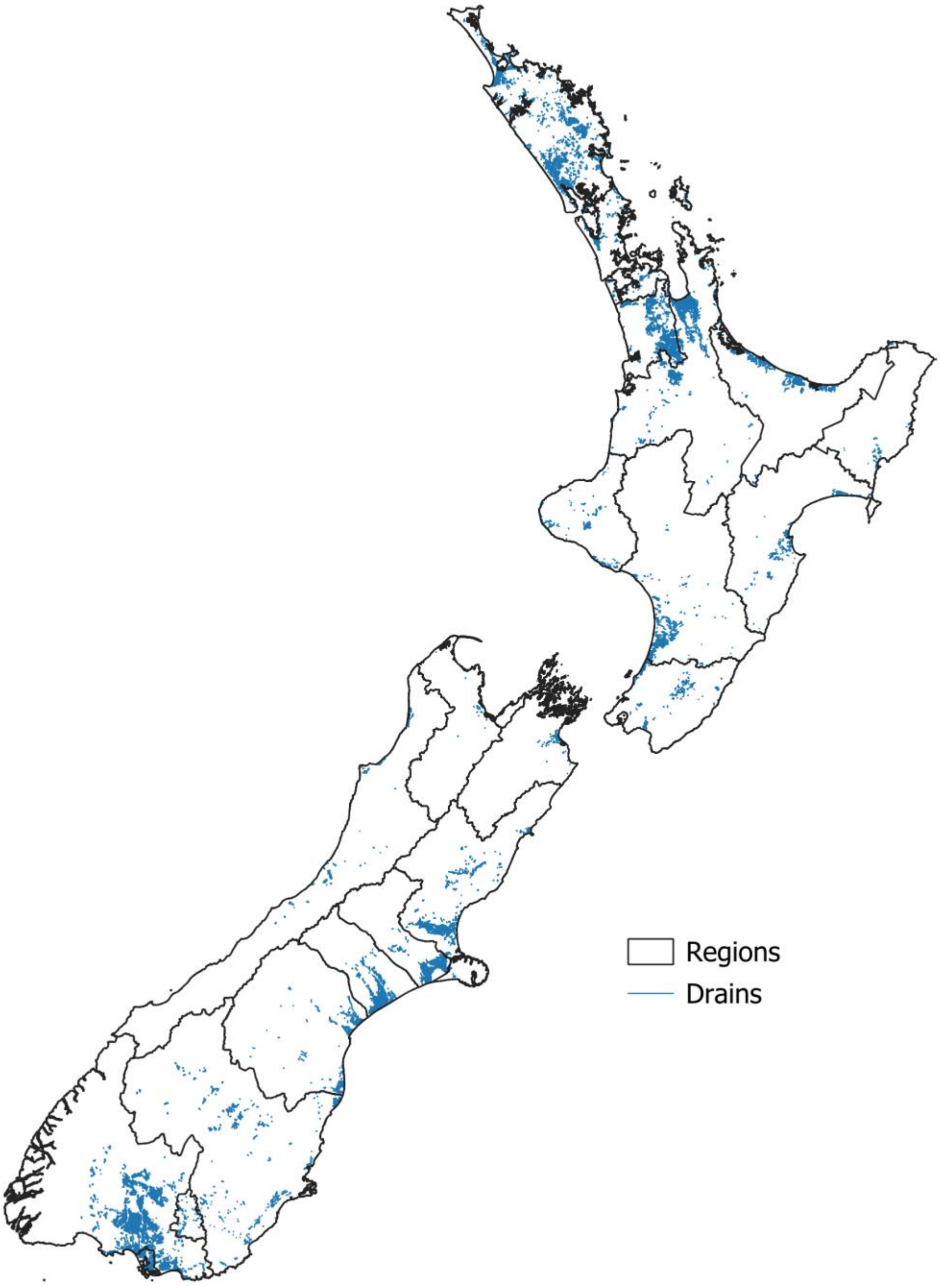
We refined the extent of the national drainage dataset to coincide with areas with moderate to high confidence only as these are areas where there is reasonable confidence of artificial surface drainage.

Drains from the Topo50 layer that coincide with areas of moderate to high likelihood of artificial drainage represent the dataset used to undertake our economic evaluation.

[6] https://data.linz.govt.nz/layer/50262-nz-drain-centrelines-topo-150k/

[7] https://www.landcareresearch.co.nz/assets/Discover-Our-Research/Projects/IDA/Manderson_2018_mapping_extent_artificial_drainage_NZ.pdf

Figure 2.2: Location and extent of trains in each of the regions of analysis



Source: Aqualinc

The total drain length and percentage share of the national total drain length for each region is shown in Table 2.1.

Table 2.1: Drain length for each region of analysis

Region	Drain length (km)	Percent of total drain length
Northland	2,401	13.5%
Auckland	487	2.7%
Waikato District	1,837	10.3%

Region	Drain length (km)	Percent of total drain length
Rest of Waikato	2,046	11.5%
Bay of Plenty	880	4.9%
Gisborne District	76	0.4%
Hawkes Bay	296	1.7%
Horizons (Manawatu-Whanganui)	791	4.4%
Taranaki	225	1.3%
Greater Wellington	334	1.9%
Marlborough District	106	0.6%
Tasman District	35	0.2%
West Coast	234	1.3%
Rest of Canterbury	1,520	8.5%
Selwyn District	1,021	5.7%
Ashburton District	926	5.2%
Otago	648	3.6%
Southland District	3,426	19.2%
Rest of Southland	548	3.1%
Total	**17,831**	

Source: Aqualinc

2.4 Scaling metrics

To scale the value of the costs and benefits from the Ararira/LII pilot catchment to each of the regions of analysis, we used the scaling metrics described in Section 5. These scaling metrics were chosen as they represent catchment characteristics that can be calculated in a nationally consistent manner and have the most impact on each of the costs and benefits in question. For example, the cost of fencing the drainage network can be expected to scale with the total length of the drainage network in each region. Therefore, the total length of the drainage network was used as the scaling metric for the costs of fencing waterways.

The use of scaling metrics in our approach is similar to the benefit transfer method, which is well-established in environmental economics. The benefit transfer method is used to take benefits (or more general values) estimated empirically in one area and apply them to another area by making careful adjustments based on differences between the two areas. The robustness of this approach (and the approach we have taken to defining scaling metrics) rests on whether the metrics used to scale costs and benefits represent the most important drivers of these costs and benefits in each area.

3 Qualitative descriptions of costs and benefits

This section qualitatively describes the costs and benefits of restoring the lowland drainage network in the Ararira/LII catchment. Section 3.1 describes all costs in qualitative terms and section 0 describes all benefits in qualitative terms along with a determination of materiality for the CBA.

3.1 Qualitative descriptions of all costs

Table 3.1 below shows the costs associated with the Ararira/LII Catchment Management Plan.

Table 3.1: Costs associated with the Ararira/LII Catchment Management Plan

Item	Description
Management costs (including social and change management)	Management and operating costs across organizations involved. Includes planning, coordination, administration, and others.
Small and large-scale wetland construction	Materials, land, and labour costs involved in constructing new wetlands.
Monitoring and compliance costs	Financial and labour costs required to monitor progress and outcomes, such as soil moisture, water quality, and bank conditions.
Bank/channel reshaping	Material, labour, and resource costs needed for bank/channel reshaping.
Small-scale sediment traps	Material, labour, and resource costs needed for small scale sediment traps, where cost estimates exist (perennial drains entering mainstem, second-order perennial drains, and ephemeral drains entering permanent drains).
Riparian planting for 75 percent of mainstem habitat	Material, labour, and resource costs needed for riparian planning covering 75 percent of mainstem habitats, excluding headwaters and the river mouth.
Large-scale sediment traps	Material, labour, and resource costs needed for large scale sediment traps associated with constructed wetlands.
Springhead protection	Material, labour, and resource costs needed for springhead protection.
Waterway fencing	Material, labour, and resource costs needed for waterway fencing.
Instream habitats	Material, labour, and resource costs needed for instream habitat restoration

The proposed interventions in the Ararira/LII Catchment Management Plan were chosen to be specific to different waterway types in the catchment. Waterway types were mapped based on existing datasets and field verification, and include: perennial drains, intermittent / ephemeral drains, and the headwaters, mid- and lower reaches of the Ararira/LII mainstem. Note that some but not all drainage networks will have the equivalent of the “mainstem” channel.

3.2 Qualitative descriptions of all benefits

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 Aotearoa/New Zealand's primary sector (see, for example, Paterson and Cole 2013; Patterson et al. 2019; Cameron et al. 2020).

The ecosystem service benefits of restoring the lowland drainage network in the Ararira/LII Catchment are described below in Table 3.2. Within each category, we assess the materiality of the benefit due to the Project.

Table 3.2: Ecosystem service benefits of restoring the lowland drainage network in the Ararira/LII Catchment

Category	Description	Materiality
Regulating services Processes that support regulation and provision of services	**Air quality regulation** Increase in vegetation will help filter and absorb harmful air pollutants. Immaterial as poor air quality in the Ararira/LII catchment is not a significant issue and the impact that additional vegetation will have on air quality will likely be small.	Immaterial
	Local climate regulation New vegetation could provide local temperature and wind control benefits. The microclimatic benefits of restoring the drainage network in the Ararira/LII catchment are likely to be immaterial because the overall area of new vegetation and water bodies is small, and climate in Aotearoa/New Zealand is dominated by synoptic scale weather patterns.	Immaterial
	Carbon Storage The new riparian planting and constructed wetlands will sequester carbon.	Material
	Erosion control Channel/bank reshaping will strengthen banks and decrease erosion. Floodplains and wetlands will also decrease heavy flows and thus decrease erosion. Smart systems for drainage monitoring will also reduce the incidence of over-maintenance of drainage channels, reducing disturbance and associated runoff and erosion. Restoration of riparian areas will also reduce the need for	Material

Category	Description	Materiality
	mechanical clearing of sediment and macrophytes.	
	Water purification and waste treatment Farmland retirement, waterway fencing, and channel/bank reshaping will decrease nutrient runoff. Drainage channel restoration and construction of new wetlands will help recycle nutrients. Improved water quality will help prevent excessive algae and macrophyte growth, particularly in receiving environments. This was judged by the project team as immaterial in the Ararira/LII as most nutrients come from outside the catchment so reducing nutrient runoff in the catchment will have little effect on overall nutrient levels.	Immaterial (potentially material in other catchments)
	Disease regulation Reduced runoff will improve water quality and prevent diseases related to contact with or consumption of contaminated water. Immaterial as water supply bores in the catchment are relatively deep meaning they are mostly influenced by what happens further up the Canterbury Plains rather than within the catchment.	Immaterial (potentially material in other catchments)
	Pollination Habitat restoration will increase the amount of pollinating wildlife.	Immaterial
	Reduced flood risk Channel/bank reshaping will increase flood capacity. New wetlands, increased floodplain areas and designated overflow areas will provide further flood protection. Six percent of the Ararira/LII catchment is urban, and this could grow to nearly ten percent with planned urban growth. Material but unable to quantify meaningfully without comprehensive inundation modelling of the area.	Material

Category	Description	Materiality
	Pest control Restoration of lowland drainage areas with native vegetation may help to control pest plant species, such as gorse. However, stock exclusion may also provide new opportunities for pest plants to take hold. On balance, this impact is likely to be immaterial to the economics of lowland drainage restoration.	Immaterial
Cultural services Goods and services that support maintenance of cultural wellbeing	**Recreation and ecotourism** Recreation undertaken in nature, including tourism sector businesses and activities that rely on natural or managed ecosystems. Almost all recommended interventions will enhance recreation and tourism value. Potential activities include fishing, canoeing, hiking, and birdwatching. Improved management of Ararira/LII will also contribute to enhanced recreational opportunities in Te Waihora/Lake Ellesmere. Immaterial as very little eco-tourism takes place in the Ararira/LII catchment, and these low levels may not be impacted by the changes that this study is looking at. Additionally, recreation will probably occur at similar levels.	Immaterial
	Ethical and spiritual values Values attached to ecosystems, landscapes, or species; such as aesthetic, spiritual, religious, cultural, and social values. Enhanced native environments will support Mahinga Kai by providing opportunities for traditional food/resource gathering methods. Restoring native environments where they once existed will help safeguard/enhance Mauri. The act of restoring and protecting the catchment allows people to exercise Kaitiakitanga. 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 values.	Material

Category	Description	Materiality
	Inspirational and education values Information from ecosystems used for intellectual development, culture, art, design, and innovation. Improved environments could facilitate bio- or eco-inspired insights. They will also strengthen education values (such as through school trips and field visits).	Material
	Cultivated food Farmland retirement and other restrictions (such as reduced fertilizer use and waterway fencing) will reduce the amount of cultivated food. However, more sustainably produced food could fetch higher prices. The reduced amount of cultivated food is accounted for under the cost of land retirement while the price premium for cultivated foods from the lowland drainage restoration in the Ararira/LII is likely to be immaterial.	Immaterial
Provisioning services Regulation of biophysical and ecological processes	**Fibre** Habitat restoration will likely increase the amount of some fibre (such as harakeke), but decrease that of others (such as leather). These changes are likely to be immaterial in the Ararira/LII catchment.	Immaterial
	Freshwater New floodplains and wetlands will increase water storage capacity, thus increasing the amount of freshwater available to nearby farms and households. Immaterial as there is already an abundance of freshwater available to nearby farms and households.	Immaterial
	Fuel/energy Farmland retirement will likely decrease the availability of some biofuel (such as tallow) but habitat restoration and 'better than good' farm management will increase that of others (such as wood). Immaterial given the ambiguity and likely small magnitude of the effects.	Immaterial
	Wild foods Habitat restoration will likely increase the amount of wildlife in	Material

Category	Description	Materiality
	the catchment and its waterways, thus increasing the potential amount and value of wild food collected.	
	Biochemical, natural medicine, and pharmaceuticals Habitat restoration could increase the amount of chemically and medicinally useful plants, such as kawakawa. Immaterial as there are few chemically and medicinally useful plants in the Ararira/LII and increased vegetation would not yield meaningful quantities.	Immaterial
	Genetic resources Restoration of the drainage network may expand important seed sources or sources of indigenous fauna that can be used to expand populations elsewhere. Immaterial as there are few important and unique genetic resources in the Ararira/LII.	Immaterial
	Habitat Chanel and bank reshaping, riparian planting, construction of large-scale and small-scale wetlands, and fenced areas to protect spring heads will enhance native biodiversity by providing new habitat for flora and fauna. Other interventions will also enhance biodiversity in existing biomes. Potential native species include fish (such as Tuna), invertebrates (such as Waikoura), birds (such as Kaaha), and plants (such as Raupō). Smart systems for drainage monitoring will help to optimise the timing of drainage management activities to reduce habitat disturbance, particularly for important taonga species. Gradual phase-out of mechanical and chemical drainage clearing practices under changing maintenance practices will also support habitat maintenance.	Material
Supporting services	**Ecological and scientific significance** Existence value from natural ecosystems is the value people derive from knowing that such	Immaterial

Category	Description	Materiality
	ecosystems exist, even if they never visit or interact with them directly. Environmental restoration of the drainage network in the Ararira/LII catchment may provide existence value. Immaterial as the Ararira/LII is ecologically/scientifically significant but not classed as 'outstanding'.	

Not all benefits derived from the lowland drainage restoration are directly related to the ecosystem. Non-ecosystem benefits associated with the restoration are shown below in Table 3.3. For each item, we assess the materiality of the benefit due to the Project.

Table 3.3: Non-ecosystem benefits associated with the restoration of the drainage network

Item	Description	Materiality
Social engagement – regular volunteering for community outcomes	The benefits enjoyed by landowners and community members from social engagement in voluntary community activities	Material
Increasing social connections	Reduction in loneliness through interactions with catchment restoration efforts	Material
Job creation	Additional jobs created by large-scale drainage network restoration activities. These may include short-term jobs and long-term maintenance jobs.	Material
Community knowledge and skills development	Development of community knowledge and skills through engagement with catchment restoration activities	Material
Reduced regulatory pressure	Time savings and mental health benefits for farmers from reduced regulatory threats.	Material

4 Quantitative estimates of material costs and benefits

In this section, we quantify the material benefits and costs identified and described in section 3 and discuss in detail the benefits of flood risk mitigation. Quantitative estimates of the material costs are provided in section 4.1, quantitative estimates of the material benefits are provided in section 0 and flood risk mitigation is discussed in section 4.3.

4.1 Quantitative estimates of material costs

Quantitative estimates of costs associated with the Ararira/LII Catchment Management Plan are provided below in Table 4.1.

Table 4.1: Estimates of the present value of costs associated with the Ararira/LII Catchment Management Plan

Item	Description	Best estimate (present $)
Management costs (including social and change management)	Management and operating costs across organizations involved. Includes planning, coordination, administration, and others.	$324,482
Small and large-scale wetland construction	Materials, land, and labour costs involved in constructing new wetlands.	$14,618,196
Monitoring and compliance costs	Financial and labour costs required to monitor progress and outcomes, such as soil moisture, water quality, and bank conditions.	Not quantified
Bank/channel reshaping	Material, labour, and resource costs needed for bank/channel reshaping.	$12,426,978
Small-scale sediment traps	Material, labour, and resource costs needed for small scale sediment traps, where cost estimations exist (perennial drains entering mainstem, second-order perennial drains, and ephemeral drains entering permanent drains).	$1,866,234
Riparian planting for 75 percent of mainstem habitat	Material, labour, and resource costs needed for riparian planning covering 75 percent of mainstem habitats, excluding headwaters and the river mouth.	$220,500
Large-scale sediment traps	Material, labour, and resource costs needed for large scale sediment traps.	$163,888
Springhead protection	Material, labour, and resource costs needed for springhead protection.	$403,650
Waterway fencing	Material, labour, and resource costs needed for waterway fencing.	$195,083
Instream habitats	Material, labour, and resource costs needed for instream habitat restoration	$1,054,749

Source: Aqualinc

The cost estimates in Table 4.1 were built up from unit rates included in the Ararira/LII Implementation Guide. These unit rates were from concept-level construction cost estimates, cross-checked where possible against other estimates or as-built costs of specific interventions.

The total costs used information from the Implementation Guide, such as the total length of permanent and intermittent channel in the catchment, and assumptions regarding uptake. For example, riparian planting of 75% of the mainstem channel was assumed. This approach recognises that there will be areas where interventions are not feasible (for example due to space constraints) or landowners are unwilling to participate.

Key assumptions relating to the uptake / coverage of specific interventions are:

- 80% of permanently flowing channels have their banks re-shaped to a two-stage profile, with low planting to provide shade.
- Constructed wetlands are a mix of small on-farm wetlands and larger-scale wetlands on public land. Land parcels over a threshold of 30 ha were assumed to have an on-farm wetland covering 2% of the property area. The remaining area not captured by this threshold is serviced by one or more constructed wetland covering 0.7% of the area, based on a guideline value of 1% of catchment area, adjusted for 70% of the catchment being farmed.
- Inline sediment traps are situated on each permanently-flowing drain reach that discharges to the mainstem, and a proportion of the second-order permanently-flowing drains. Event-based sediment traps are situated on each intermittent / ephemeral drain that discharges into a permanently-flowing drain. Large-scale sediment traps are incorporated into the design of large constructed wetlands.
- Springhead protection is based on double the number of mapped springs in the catchment (based on anecdotal information that there are more springs than those that have been mapped).
- Instream habitat enhancements (log vanes and cobble clusters) are implemented over 75% of the permanently-flowing channels.

4.2 Quantitative estimates of material benefits

To estimate the value of benefits, we used data provided from Aotearoa/New Zealand studies and scaled it to the Ararira/LII catchment. Where benefits could not be estimated using Aotearoa/New Zealand sources, we attribute values by scaling data from international studies using the 'benefit transfer' method. Where it was not possible to reliably estimate values, we re-state the conceptual description of the material benefit in question when presenting the CBA results.

Quantitative estimates of the benefits are shown below in Table 4.2.

Table 4.2: Quantitative estimates of the specific benefits

Item	Description	Quantified Value
Habitat for Important Native Biodiversity	**Habitat value from Riparian Planting** Riparian planting for catchment restoration comprises grasses and a variety of tree species. A meta-analysis by de Groot et al. (2012) estimated the mean annual value of habitat value from grassland and woodlands globally to be USD 1,214 and USD 1,277 per hectare, respectively.[8] We adjusted these values for currency and inflation and then scaled them to a New Zealand context by multiplying them by the ratio of habitat value	$126,058 per annum

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

Item	Description	Quantified Value
	found globally vs. that found in New Zealand for wetlands.[9] . We calculated this ratio by dividing the inflation adjusted NZ hectare habitat value of wetlands provided by Patterson and Cole (2013)[10] by the inflation and currency adjusted value of wetlands globally estimated by Groot et al. (2012). This gave a ratio of 0.31. This suggests grassland and woodlands habitat benefits in New Zealand per hectare are approximately $755 and $794, respectively. We use the grassland estimate for grassland and shrubland and the woodland estimate for forest. Based on these estimates, the total habitat value in the Ararira/LII provided by the 14.4 hectares of new riparian grassland, 7.2 hectares of scrub and 2.4 hectares of forest would be $18,200 per annum. **Habitat value from Constructed Wetlands** The habitat value provided by wetlands in New Zealand was estimated by Patterson and Cole (2013) as $195 million per annum.[11] This value is spread across roughly 166,000 hectares of wetlands nationwide, suggesting that after adjusting for inflation the wetlands' habitat benefit in New Zealand is approximately $1,572 per hectare. The actions outlined in the Ararira/LII catchment management plan include the creation of approximately 67.5 hectares of constructed wetlands and the protection of approximately 3.1 hectares of spring heads (which we assume revert to wetlands over time as stock are excluded from the area). Based on this estimate, the total habitat value provided by the 67.5 hectare constructed wetlands and 3.1 hectares of protected springs would be $107,858 per annum.	
Erosion Control	**Erosion Control from Riparian Planting** Riparian planting offers erosion control. A meta-analysis by de Groot et al. (2012) estimated the mean annual value of erosion control from grassland and woodlands globally to be USD 44 and USD 13 per hectare, respectively.[12] We adjusted this for inflation and currency and multiplied by 8.5, as New Zealand experiences 8.5 times the global average for soil erosion,[13] giving an annual value of $753 per hectare and $222 per hectare, respectively. This was then scaled to the Ararira/LII by multiplying by the Ararira/LII erosion rate[14] and dividing by the New Zealand erosion rate[15]. Based on this estimate, the erosion control provided by the 21.6 hectares of grassland and 2.4 hectares of woodland would be $1,259 per annum. **Erosion Control from Wetlands and Protected Springs** The new wetlands and protected springs will offer substantial erosion control. A meta-analysis by de Groot et al. (2012) estimated the mean annual value of erosion control from wetlands globally to be USD 2,607	$237,610 per annum

[9] We are not aware of any local estimates of the habitat value of riparian grasses and trees in New Zealand. Therefore, we used the ratio of global to local habitat value of wetlands to scale global estimates of the value of woodlands and grasslands to the New Zealand context.

[10] 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.

[11] 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.

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

[13] MfE's Our Land 2018 report (available at https://environment.govt.nz/assets/Publications/Files/Our-land-201-final.pdf)

[14] Calculated from https://lris.scinfo.org.nz/layer/48176-nzeem-erosion-rates-south-island/.

[15] MfE's Our Land 2018 report (available at https://environment.govt.nz/assets/Publications/Files/Our-land-201-final.pdf)

Item	Description	Quantified Value
	per hectare.[16] We adjusted this for inflation and currency and multiplied by 8.5, as New Zealand experiences 8.5 times the global average for soil erosion,[17] giving an annual value of $44,618 per hectare. This was then scaled to the Ararira/LII by multiplying by the Ararira/LII erosion rate[18] and dividing by the New Zealand erosion rate[19]. Based on this estimate, the erosion control provided by the 67.5 hectare constructed wetland and 3.1 hectares of protected springs would be $236,352 per annum.	
Carbon storage	**Carbon Stored in Riparian Planting** Riparian planting would help to store carbon. The annual carbon sequestration rate of riparian planting in New Zealand was estimated by Manaaki Whenua as 3.4 tonnes per hectare.[20] Assuming a carbon price of $85 per tonne,[21] the carbon storage value provided by 24.0 hectares of riparian planting would be $6,929 per annum. **Carbon Stored in Wetlands and Protected Springs** The new wetlands and protected springs will store carbon. The annual carbon sequestration rate of wetlands in New Zealand was estimated by Manaaki Whenua as 2 tonnes per hectare.[22] Assuming a carbon price of NZ$85 per tonne,[23] the carbon storage value provided by 67.5 hectares of wetlands and 3.1 hectares of protected springs would be $12,007 per annum.	$18,936 per annum
Wild foods	**Wild Foods** The restoration of the lowland drainage network in the Ararira/LII would impact the amount of freshwater eel (Tuna) available to be caught. Te Wai Māori (2020) estimated that the annual customary harvest of Tuna from Te Waihora/Lake Ellesmere as 5 tonnes per year.[24] The Ararira/LII River is one of five Te Waihora/Lake Ellesmere feeder rivers so we assume that the environmental quality of the drainage network in the Ararira catchment supports approximately one-fifth of Tuna harvested from Te Waihora/Lake Ellesmere. Further, we assume that restoration of the lowland drainage network would increase productivity of this feeder ecosystem by 20%. This would provide an additional 200 kg of Tuna harvested per year and at a price of $30 per 1.5 kg[25] would result in an annual value of $4,000. This should be considered a lower-bound estimate of the commodity value of tuna provided by catchment restoration. The cultural and other	$4,000 per annum

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

17 MfE's Our Land 2018 report (available at https://environment.govt.nz/assets/Publications/Files/Our-land-201-final.pdf)

18 Data provided by Aqualinc.

19 MfE's Our Land 2018 report (available at https://environment.govt.nz/assets/Publications/Files/Our-land-201-final.pdf)

20 https://www.mpi.govt.nz/dmsdocument/32134-Carbon-sequestration-potential-of-non-ETS-land-on-farms-Sep18-FINAL

21 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).

22 https://www.mpi.govt.nz/dmsdocument/32134-Carbon-sequestration-potential-of-non-ETS-land-on-farms-Sep18-FINAL

23 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).

24 https://waimaori.maori.nz/wp-content/uploads/2020/02/Tuna-species-report.pdf

25 On 15/08/2023, New Zealand Live Fish Market Ltd was advertising 1.5 kg of live New Zealand longfin eel for $30 at https://livefish.co.nz/products/live-eel?variant=40574032019606

Item	Description	Quantified Value
	value of this catch would likely be much higher than this commodity value.	
Social engagement – regular volunteering for community outcomes	**Social engagement – regular volunteering for community outcomes** The large-scale drainage network restoration activities will create benefits enjoyed by landowners and community members from social engagement in voluntary community activities. Based on discussions with Fonterra's Living Water team we estimate the restoration would involve 30 volunteers once a week. We estimate that this engagement would take place over 5 years as the restoration plan is being implemented. Using CBAx, we estimated the value of weekly volunteering for an adult as $763 per annum.[26] Therefore, the benefit of 30 people volunteering once a week is estimated at $22,899 per annum for 5 years.	$22,899 per annum for 5 years
Increasing social connections	**Increasing social connections** The large-scale drainage network restoration activities will result in a reduction in loneliness for people through interactions with catchment restoration efforts. Based on discussions with Fonterra's Living Water team we estimated the restoration would engage roughly 50 community members on an occasional basis (this group is separate from those who would regularly volunteer as part of the active restoration efforts). We expect this social engagement will reduce loneliness among this group of 50 people over the 5 years in which the plan is implemented. Using, CBAx, we estimated the value of reduced loneliness as $3,042 per annum.[27] Therefore, the benefit of reduced loneliness in 50 people through engagement with the restoration is estimated at $152,096 per annum for 5 years.	$152,096 per annum for 5 years
Job creation	**Job creation** The large-scale drainage network restoration activities will create additional jobs whilst the reduced need for drainage clearing maintenance will decrease jobs. Based on discussions with Fonterra's Living Water team we estimated the restoration would require 2 full-time equivalents (FTE) qualified at a postgraduate level for 2 years of planning, design, and management, 15 FTE's qualified at an upper secondary school level for 5 years of planting, shaping, and earthworks. However, the restoration work would also reduce 2 FTE's qualified at an upper secondary school level progressively over 5 years due to reduced drain maintenance requirements. Using CBAx, we estimate the average income for a postgraduate degree as $81,120 per annum and the average income for an upper secondary school qualification as $50,339 per annum.[28]	$162,241 per annum for 2 years $755,084 per annum for 5 years -$162,241 per annum in perpetuity

[26] NZ Treasury 2022 – CBAx Database accessed at https://www.treasury.govt.nz/information-and-services/state-sector-leadership/investment-management/plan-investment-choices/cost-benefit-analysis-including-public-sector-discount-rates/treasurys-cbax-tool

[27] NZ Treasury 2022 – CBAx Database accessed at https://www.treasury.govt.nz/information-and-services/state-sector-leadership/investment-management/plan-investment-choices/cost-benefit-analysis-including-public-sector-discount-rates/treasurys-cbax-tool

[28] NZ Treasury 2022 – CBAx Database accessed at https://www.treasury.govt.nz/information-and-services/state-sector-leadership/investment-management/plan-investment-choices/cost-benefit-analysis-including-public-sector-discount-rates/treasurys-cbax-tool

Item	Description	Quantified Value
	Therefore, the value from job creation is $162,241 per annum for 2 years and $755,084 per annum for 5 years and the cost of job destruction is $162,241 per annum in perpetuity.	

4.3 Discussion of benefits of flood risk mitigation from restoration

As part of our assessment of the benefits of lowland drainage restoration, we paid special attention to the potential flood mitigation benefits of restoration work. While some lowland drainage networks include specific flood control elements, many (including the Ararira/LII) are designed primarily to drain land to manage the water table during normal conditions. Drainage networks designed for water table management are typically able to mitigate small floods, but they have limited ability to mitigate larger floods.

The flood mitigation benefits of lowland drainage restoration are likely to be material in most areas, however it was not feasible to quantify this benefit as part of this study. The benefits of mitigating flooding depend on characteristics of the catchment that are highly idiosyncratic. To estimate these benefits in dollar terms, it would be necessary to:

- Model flood inundation and persistence levels using precise spatial, digital elevation, and hydraulic models
- Develop precise registries of property and infrastructure exposed to flooding, estimate which property would be flooded using the inundation model, and estimate the damage to each affected asset in dollar terms.

This level of analysis was outside the scope of the current project. Moreover, even if flood mitigations benefits were estimated for the Ararira/LII pilot catchment, the results would not be generalizable to other catchments in Aotearoa/New Zealand because they would be determined by characteristics that are so specific to the catchments in question that it would not be practical to apply the scaling metric approach used in this project.

Rather than attempting to quantify flood mitigation benefits, this section describes how these benefits are likely to flow from lowland drainage restoration efforts. Restoration of the drainage network includes three changes that impact flood risk: riparian planting, channel reshaping, and wetland construction. The impacts of these changes on flood risk are described below.

4.3.1 Riparian Planting

Riparian planting slows down upslope flows and floodwaters that risk overtopping the river or stream banks. Roots extending into the channel and in-stream large woody debris also slow and redirect flows increasing the distance water must travel. This reduces flood peaks downstream, but it can increase upstream flooding and extend the duration of flooding. Additionally, the influence of riparian zones on flows is quite limited.[29] Riparian vegetation increases the amount of water

[29] DOC (1995) Managing Riparian Zones: A contribution to protecting New Zealand's rivers and streams

returned to the atmosphere by evapotranspiration however this effect is considered insignificant for flood risk.[30] This analysis views the flood risk benefits of riparian planting as immaterial.

4.3.2 Two-Stage Channel (TSC)

TSCs hold more floodwater than a conventional channel. They also decrease flow velocities during flood events reducing the chance of flooding downstream while low water level flows are unaffected. Västilä, *et al.* (2021) estimated the TSC design resulted in 50% higher discharges conveyed at a given water level compared to a conventional channel. The water levels decreased by up to 20 cm during autumn conditions and by over 25 cm during spring conditions.[31]

For permanently flowing channels in the Ararira/LII, the Ararira/LII Catchment Management Plan recommends a combination of riparian planting and two-stage channels. The impact of combining these two approaches was modelled by Aqualinc. The findings showed that even with planting added in, the two stage channels provide additional water conveyance capacity.

4.3.3 Wetlands

Wetlands help mitigate floods. They act as natural sponges, absorbing water during heavy rains and releasing it slowly over time. This process helps reduce the impact of floods by decreasing the amount and speed of water flowing downstream.[32]

5 Nationwide scaling metrics for the benefits and costs

We estimated the economics of lowland drainage restoration in 19 different areas across Aotearoa/New Zealand by scaling the benefits and costs of drainage restoration from the Ararira/LII pilot catchment to the other catchments in question. To do so, we applied a range of scaling metrics whereby the cost and benefit values for the Ararira/LII catchment were multiplied by the ratio of the scaling metric in the Ararira/LII to the scaling metric for each other catchment.[33] Cost scaling metrics are described in section 5.1 and benefit scaling metrics are described in section 5.2.

5.1 Scaling metrics for the costs

Table 5.1 shows the scaling metrics for the costs, while the following text describes how they were derived.

We estimated the extent of permanently flowing channels by comparing flow permanence as mapped in the Ararira/LII to depth to groundwater as defined by the National Water Table map.[34]

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[30] Gulliver, J.S., A.J. Erickson, and P.T. Weiss (editors). 2010. "Stormwater Treatment: Assessment and Maintenance. University of Minnesota, St. Anthony Falls Laboratory. Minneapolis, MN. https://stormwaterbook.safl.umn.edu/

[31] Västilä, K.; Väisänen, S.; Koskiaho, J.; Lehtoranta, V.; Karttunen, K.; Kuussaari, M.; Järvelä, J.; Koikkalainen, K. Agricultural Water Management Using Two-Stage Channels: Performance and Policy Recommendations Based on Northern European Experiences. Sustainability 2021, 13, 9349. https://doi.org/10.3390/su13169349

[32] https://greengoddess.co.nz/the-importance-of-wetlands-in-flood-mitigation-and-environmental-conservation/

[33] This approach assumes that the suite of interventions designed for the Ararira is applicable elsewhere. It is important to acknowledge that in reality some actions may not be applicable in all catchments, while some catchments would benefit from actions not considered or planned in the Ararira.

[34] https://www.gns.cri.nz/data-and-resources/gns-national-water-table-interactive-map/

Using an iterative approach, we identified 1 m below ground level (bgl) as the threshold within which drains would be permanently flowing and exceeding this (i.e. >1 m bgl) where drain flow would be intermittent. We transferred this assumption to other areas where we have conceptual knowledge to confirm the appropriateness of this threshold. Based on an assessment of the Hinds Drains area (Ashburton District) and the Wairau Plain (Marlborough District) we confirmed the appropriateness of 1 m bgl as an appropriate threshold for determining flow permanence and calculated the length of permanently vs intermittently flowing drains for each region.

We determined drainage network length as in section 2.3.

We estimated drainage network density using a line density analysis in ArcGIS. Using an iterative approach, we determined a search radius of 1 km gave a reasonable drainage density metric at a national scale; from <1 to ten. We completed this analysis separately for permanently and intermittently flowing areas and arrived at a regional value using area weighted averaging. We estimated total area of the drainage catchment by undertaking watershed analysis. This uses elevation data/surface topography to derive a catchment area. Our elevation data source was the national 8 m DEM[35]. We acknowledge the limitations of use of this dataset in comparison to available LiDAR coverages. However, LiDAR coverages are not nationally consistent in accuracy or nationally continuous in coverage, so using these datasets would introduce significant complexity and processing requirements. We also consider a finer resolution inappropriate for use in a national scale assessment. Derived catchments were also partitioned by permanently vs intermittently flowing area, and area aggregated by regions. The use of the national 8 m DEM ensured a nationally consistent approach, at an appropriate resolution for a national scale assessment.

Table 5.1: Scaling metrics for material costs

Category of Cost	Description	Scaling metric
Two-stage channels	Material, labour, and resource costs needed for small scale bank/channel reshaping.	Total length of permanently flowing channels (determined using depth of the water table) in each region
Constructed wetlands	Materials, land, and labour costs involved in constructing new wetlands	Total length of drainage network in each region
Small-scale sediment traps	Material, labour, and resource costs needed for small scale sediment traps	Drainage network density relative to water table depth in each region
Event-based sediment traps	Material, labour, and resource costs needed for event-based sediment traps	Drainage network density relative to water table depth in each region
Riparian mainstream[36] planting (both sides of the waterway)	Material, labour, and resource costs needed for riparian planning covering 75 percent of mainstem habitats, excluding headwaters and the river mouth.	Cost of 2-stage channel construction
Protecting springheads	Material, labour, and resource costs needed for springhead protection	Total area of the drainage catchment in which the water table is <1m deep in each region

[35] https://data.linz.govt.nz/layer/51768-nz-8m-digital-elevation-model-2012/

[36] Note: not all catchments and drainage networks will have a clear mainstream equivalent.

Category of Cost	Description	Scaling metric
Fencing waterways	Material, labour, and resource costs needed for waterway fencing	Total length of drainage network in each region
Instream habitats	Material, labour, and resource costs needed for instream habitat restoration	Total length of permanent channels (determined using depth of the water table) in each region
Management cost	Management and operating costs across organizations involved. Includes planning, coordination, administration, and others.	Total length of drainage network in the area in each region

5.2 Scaling metrics for the benefits

The scaling metrics for the benefits are described below in Table 5.2. This has an additional metric to Table 5.1; Average soil erosion rates. These were calculated using the New Zealand Empirical Erosion Model (NZEEM).[37] We estimated regional values using an area weighted average of erosion rates within each region's drainage catchment areas.

Table 5.2: Scaling metrics for material benefits

Category of Benefit	Description	Scaling metric
Habitat for Important Native Biodiversity	Chanel and bank reshaping, riparian planting, construction of large-scale and small-scale wetlands, and fenced areas to protect spring heads will enhance native biodiversity by providing new habitat for flora and fauna. Other interventions will also enhance biodiversity in existing biomes. Potential native species include fish (such as Tuna), invertebrates (such as Waikoura), birds (such as Kaaha), and plants (such as Raupō). Smart systems for drainage monitoring will help to optimise the timing of drainage management activities to reduce habitat disturbance, particularly for important taonga species. Gradual phase-out of mechanical and chemical drainage clearing practices under changing maintenance practices will also support habitat maintenance.	Total length of drainage network in each region

[37] North Island: https://lris.scinfo.org.nz/layer/48178-nzeem-erosion-rates-north-island/
South Island: https://lris.scinfo.org.nz/layer/48176-nzeem-erosion-rates-south-island/

Category of Benefit	Description	Scaling metric
Erosion Control	Channel/bank reshaping will strengthen banks and decrease erosion. Floodplains and wetlands will also decrease heavy flows and thus decrease erosion. Smart systems for drainage monitoring will also reduce the incidence of over-maintenance of drainage channels, reducing disturbance and associated runoff and erosion. Restoration of riparian areas will also reduce the need for mechanical clearing of sediment and macrophytes.	Average soil erosion rates and total length of drainage network in each region
Carbon storage	The new riparian planting and constructed wetlands will sequester carbon.	Average vegetation growth rates and total length of drainage network in each region
Wild foods	Habitat restoration will likely increase the amount of wildlife in the catchment and its waterways, thus increasing the potential amount and value of wild food collected.	Kilograms of customary harvest from each region
Social engagement – regular volunteering for community outcomes	The large-scale drainage network restoration activities will create benefits enjoyed by landowners and community members from social engagement in voluntary community activities.	Total cost of drainage restoration in each region
Increasing social connections	The large-scale drainage network restoration activities will result in a reduction in loneliness for people through interactions with catchment restoration efforts.	Total cost of drainage restoration in each region
Job creation	The large-scale drainage network restoration activities will create additional jobs whilst the reduced need for drainage clearing maintenance will decrease jobs.	Total length of drainage network in each region

6 CBA results and analysis

This section presents the results from the CBA. Ararira/LII results are presented in section 6.1, material benefits not quantified are highlighted in section 6.2, and a sensitivity analysis of the Ararira/LII results is presented in section 6.3. Nationwide results are presented in 6.4, followed by a sensitivity analysis in section 6.5. The results for the individual regions are presented in section 6.6.

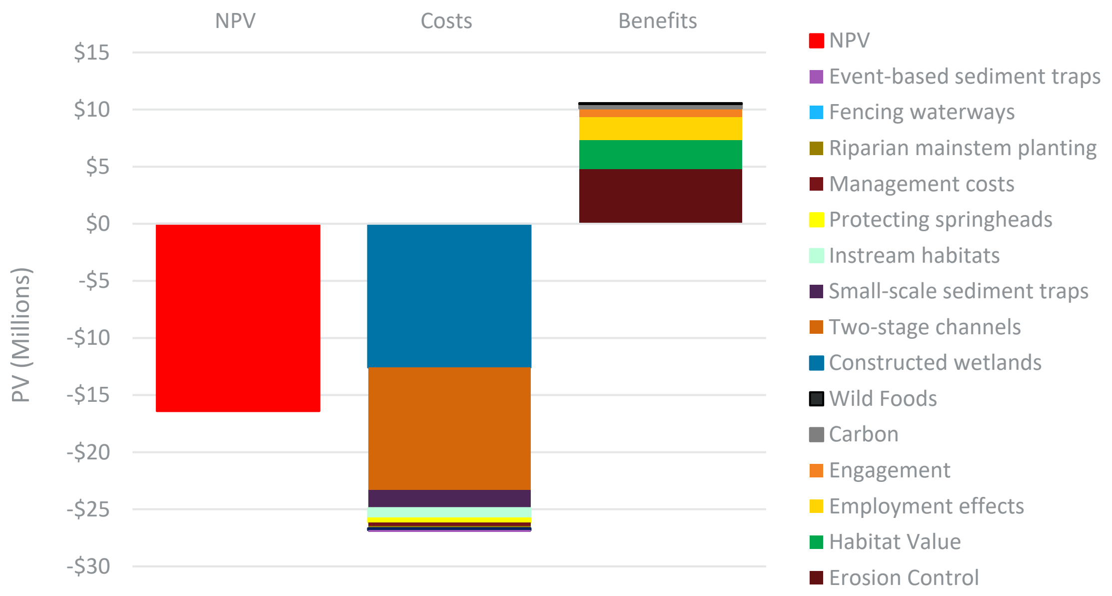
6.1 Ararira/LII results

This section shows the results from the CBA for the Ararira/LII. Net present benefits and costs are shown numerically in Table 6.1 and graphically in Figure 6.1. The net present cost of restoring the lowland drainage network in the Ararira/LII is $(26,965,6700). Comparing this to the benefits we were able to quantify, which are not comprehensive, the NPV is $(16,406,146).

Table 6.1: Ararira/LII CBA results

Description	$
Net present benefits	
Erosion Control	4,806,486
Habitat Value	2,549,948
Employment effects	1,985,749
Engagement	753,382
Carbon	383,045
Wild Foods	80,914
Net present costs	
Two-stage channels	10,700,039
Constructed wetlands	12,586,750
Small-scale sediment traps	1,606,889
Instream habitats	908,173
Protecting springheads	347,556
Management costs	317,319
Riparian mainstem planting	189,858
Fencing waterways	167,972
Event-based sediment traps	141,113
NPV	(16,406,146)

Figure 6.1: Ararira/LII CBA graph



The cost of two-stage channels and constructed wetlands dominate the costs and are large contributors to the negative NPV. The most significant benefits are erosion control, habitat value, and employment effects.

The negative NPV needs to be considered in the context of the unquantified material benefits as discussed in section 6.2. Unlike the costs, the estimated benefits are subject to greater uncertainty and several material benefits were not appropriate or feasible to quantify in this analysis. Decision makers will need to carefully consider whether the negative NPV is justified in the context of the other benefits.

6.2 Material benefits not quantified

This section highlights the benefits considered material in the economic CBA but that were not quantified as it was determined not appropriate or not feasible to do so in this analysis. Material benefits not quantified along with descriptions are shown below in Table 6.2.

Table 6.2: Material benefits not quantified

Item	Description
Reduced flood risk	Channel/bank reshaping will increase flood capacity. New wetlands, increased floodplain areas and designated overflow areas will provide further flood protection. Six percent of the Ararira/LII catchment is urban, and this could grow to nearly ten percent or more with planned urban growth. The resulting increase of impermeable area will make the catchment’s response to rainfall “flashier
Ethical and spiritual values	Values attached to ecosystems, landscapes, or species; such as aesthetic, spiritual, religious, cultural, and social values. Enhanced native environments will support Mahinga Kai by providing opportunities for traditional food/resource gathering methods.

Item	Description
	Restoring native environments where they once existed will help safeguard/enhance Mauri. The act of restoring and protecting the catchment allows people to exercise Kaitiakitanga.
Inspirational and education values	Information from ecosystems used for intellectual development, culture, art, design, and innovation. Improved environments could facilitate bio- or eco-inspired insights. They will also strengthen education values (such as through school trips and field visits).
Community knowledge and skills development	Development of community knowledge and skills through engagement with catchment restoration activities.
Reduced regulatory pressure	Time savings and mental health benefits for farmers from reduced regulatory threats.

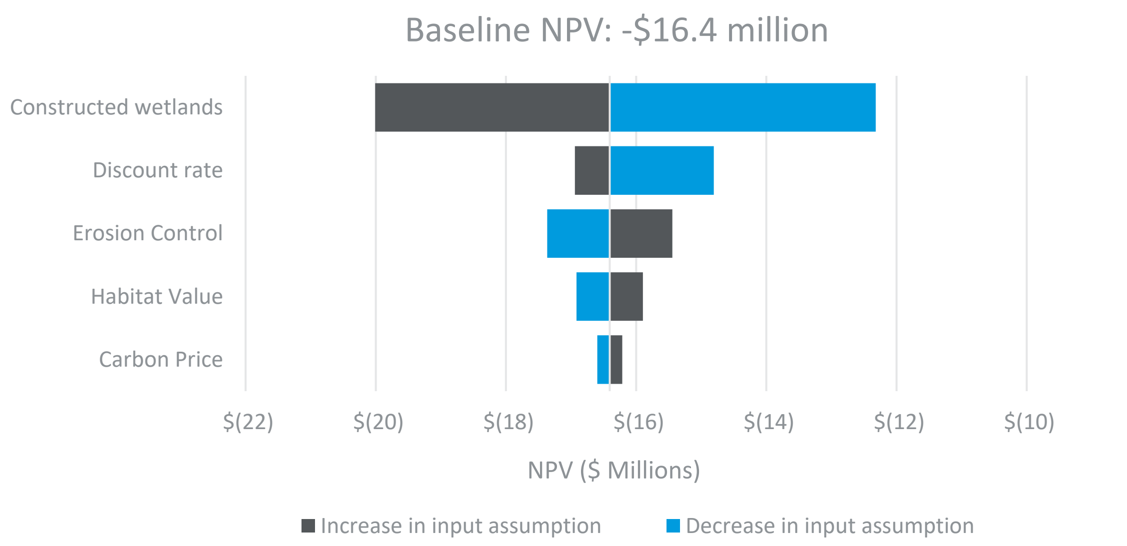
6.3 Ararira/LII sensitivity analysis

This section shows the results from the Ararira/LII sensitivity analysis. Sensitivity values are shown numerically in Table 6.3 and graphically in Figure 6.2. Costs were varied by changing the assumed level of uptake / coverage for each intervention.

Table 6.3: Ararira/LII CBA sensitivity results

Item	Decrease in input assumption	Base input assumption	Increase in input assumption
Constructed wetlands			
Unit	$9,872,371	$14,618,196	$18,802,249
Result	$(12,319,834)	$(16,406,146)	$(20,008,754)
Discount rate			
Unit	2.0%	3.5%	5.0%
Result	$(14,806,455)	$(16,406,146)	$(16,940,763)
Erosion control			
Unit change	20% decrease	Base	20% increase
Result	$(17,367,443)	$(16,406,146)	$(15,444,848)
Habitat value			
Unit change	20% decrease	Base	20% increase
Result	$(16,916,135)	$(16,406,146)	$(15,896,156)
Carbon price			
Unit	$42.5	$85	$127.5
Result	$(16,597,668)	$(16,406,146)	$(16,214,623)

Figure 6.2: Ararira/LII CBA sensitivity results graph



Varying the assumption for constructed wetlands has the biggest impact. This is not surprising given it is the largest cost in the CBA. The discount rate has the second biggest impact as it affects the present value of all costs and benefits. The impact of varying erosion control, habitat value, and carbon price inputs has an impact that corresponds to their quantitative significance in the CBA results. The overall NPV remained negative for all the sensitivity scenarios considered.

6.4 Nationwide results

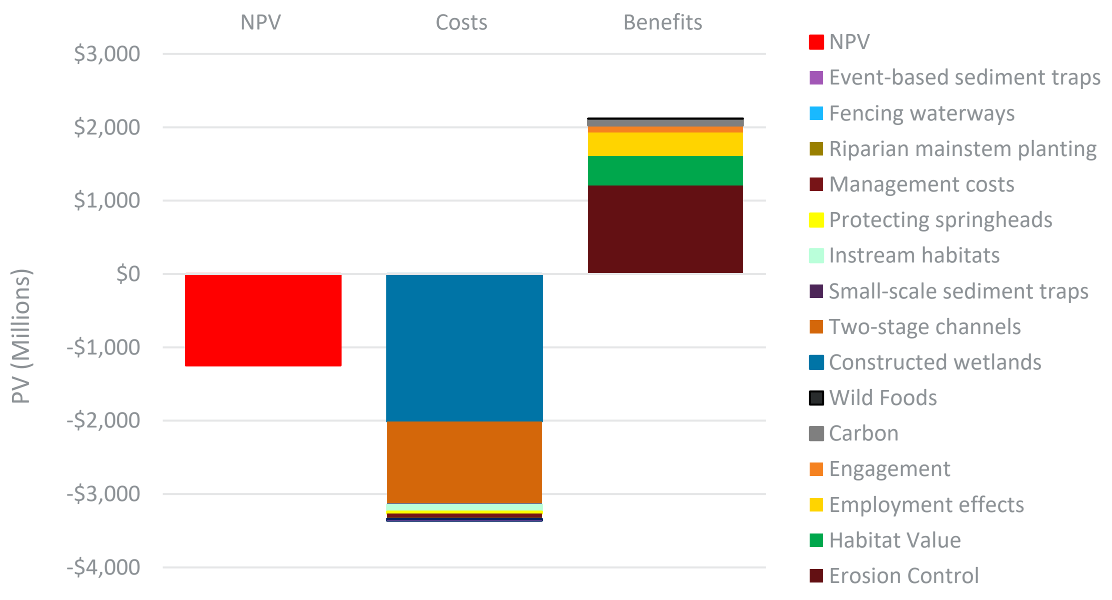
This section shows the results from the nationwide CBA. Net present benefits and costs are shown numerically in Table 6.4 and graphically in Figure 6.3. The net present cost of restoring the lowland drainage network nationwide is $(3,365,529,775). Comparing this to the benefits we were able to quantify, which are not comprehensive, the NPV is $(1,247,743,082).

Table 6.4: Nationwide CBA results

Description	$
Benefits	
Erosion Control	1,204,800,198
Habitat Value	407,127,131
Employment effects	317,046,663
Engagement	94,028,005
Carbon	92,756,066
Wild Foods	2,028,629
Costs	
Two-stage channels	1,115,395,421

Description	$
Constructed wetlands	2,009,612,537
Small-scale sediment traps	18,352,564
Instream habitats	94,669,983
Protecting springheads	28,614,340
Management costs	50,663,411
Riparian mainstem planting	19,791,191
Fencing waterways	26,818,649
Event-based sediment traps	1,611,679
NPV	(1,247,743,082)

Figure 6.3: Nationwide CBA graph



The cost of constructed wetlands and two-stage channels dominate the costs and are large contributors to the negative NPV. The most significant benefits are erosion control, habitat value, and employment effects.

The negative NPV needs to be considered in the context of the unquantified material benefits as discussed in section 6.2. Unlike the costs, the estimated benefits are subject to greater uncertainty and several material benefits were not appropriate or feasible to quantify in this analysis. Decision makers will need to carefully consider whether the negative NPV is justified in the context of the other benefits. In some local contexts, one or several of the unquantified benefits in this analysis may be quantifiable.

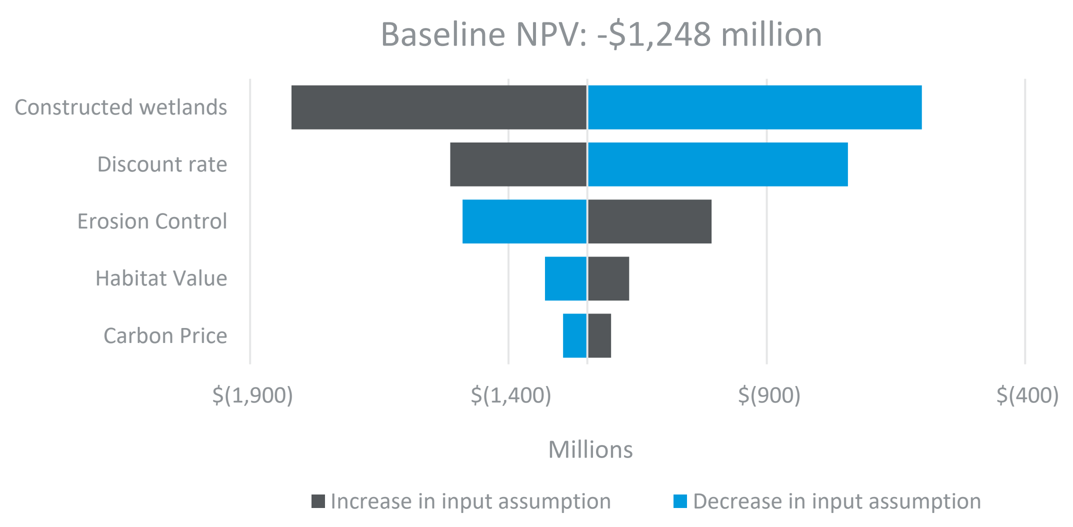
6.5 Nationwide sensitivity analysis

This section shows the results from the nationwide sensitivity analysis. Sensitivity values are shown numerically in Table 6.5 and graphically in Figure 6.4.

Table 6.5: Nationwide CBA sensitivity results

Item	Decrease in input assumption	Base input assumption	Increase in input assumption
Constructed wetlands			
Unit	$9,872,371	$14,618,196	$18,802,249
Result	$(600,008,292)	$(1,247,743,082)	$(1,819,844,421)
Discount rate			
Unit	2.0%	3.5%	5.0%
Result	$(743,100,347)	$(1,247,743,082)	$(1,512,539,239)
Erosion control			
Unit change	20% decrease	Base	20% increase
Result	$(1,488,703,122)	$(1,247,743,082)	$(1,006,783,042)
Habitat value			
Unit change	20% decrease	Base	20% increase
Result	$(1,329,168,508)	$(1,247,743,082)	$(1,166,317,656)
Carbon price			
Unit	$42.5	$85	$127.5
Result	$(1,294,121,115)	$(1,247,743,082)	$(1,201,365,049)

Figure 6.4: Nationwide CBA sensitivity results graph



Similarly to the Ararira/LII sensitivity analysis, varying the assumption for constructed wetlands has the biggest impact. This is not surprising given it is the largest cost in the CBA. The discount rate has the second biggest impact as it affects the present value of all costs and benefits. The impact of varying erosion control, habitat value, and carbon price inputs has an impact that corresponds to their quantitative significance in the CBA results. Again, the overall NPV remained negative for all the sensitivity scenarios considered.

6.6 Individual region results

This section presents the CBA results for the individual regions estimated by applying the scaling metrics described in section 5 to the Ararira/LII CBA results. The individual region results are shown both numerically and graphically followed by a short discussion. No results are shown for Nelson as there are no drains mapped for the Nelson region in the national scale drain dataset we used in this analysis. A summary of the NPVs by region is shown below in Table 6.6.

Table 6.6: NPV by region

Region	NPV
Northland	(140,250,072)
Auckland	(43,543,532)
Waikato District	(165,837,864)
Rest of Waikato	(175,209,992)
Bay of Plenty	(50,919,040)
Gisborne District	(5,909,717)
Hawkes Bay	(30,649,676)
Taranaki	(21,485,323)
Horizons (Manawatu-Whanganui)	(57,306,392)
Wellington	(18,550,773)
Tasman District	(464,516)
Marlborough District	(13,038,785)
West Coast	81,942,203
Selwyn District	(99,894,453)
Ashburton District	(58,574,396)
Rest of Canterbury	(135,155,600)
Otago	(60,508,826)
Southland District	(201,823,009)
Rest of Southland	(34,157,174)

Based on the benefits we were able to quantify, the only region with a positive NPV is the West Coast. The other negative NPVs need to be considered in the context of the unquantified material benefits as seen in section 6.2.

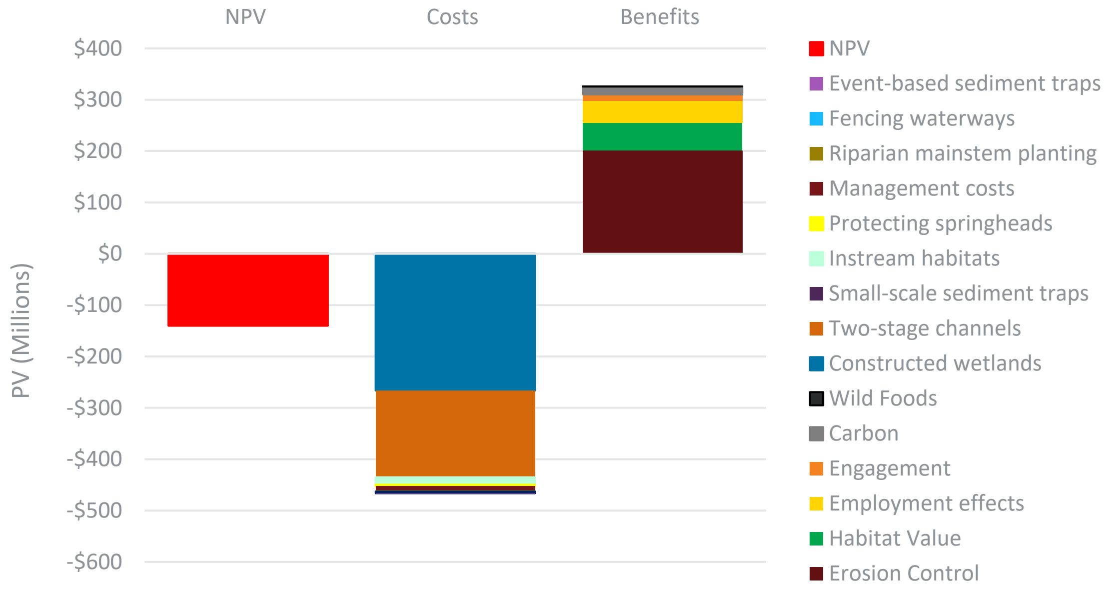
6.6.1 Northland region

This section shows the results from the CBA for the Northland region. Net present benefits and costs are shown numerically in Table 6.7 and graphically in Figure 6.5. The net present cost of restoring the lowland drainage network in the Northland region is $(466,347,098). Comparing this to the benefits we were able to quantify, which are not comprehensive, the NPV is $(140,250,072).

Table 6.7: Northland region CBA results

Description	$
Net present benefits	
Erosion Control	201,456,398
Habitat Value	53,983,121
Employment effects	42,038,879
Engagement	13,029,059
Carbon	15,209,205
Wild Foods	380,365
Net present costs	
Two-stage channels	167,832,701
Constructed wetlands	266,465,061
Small-scale sediment traps	911,317
Instream habitats	14,244,920
Protecting springheads	3,561,351
Management costs	6,717,727
Riparian mainstem planting	2,977,965
Fencing waterways	3,556,025
Event-based sediment traps	80,030
NPV	(140,250,072)

Figure 6.5: Northland region CBA graph



The cost of two-stage channels and constructed wetlands dominate the costs and are large contributors to the negative NPV. The most significant benefit is erosion control followed by habitat value and employment effects.

The negative NPV needs to be considered in the context of the unquantified material benefits as seen in section 6.2.

6.6.2 Auckland region

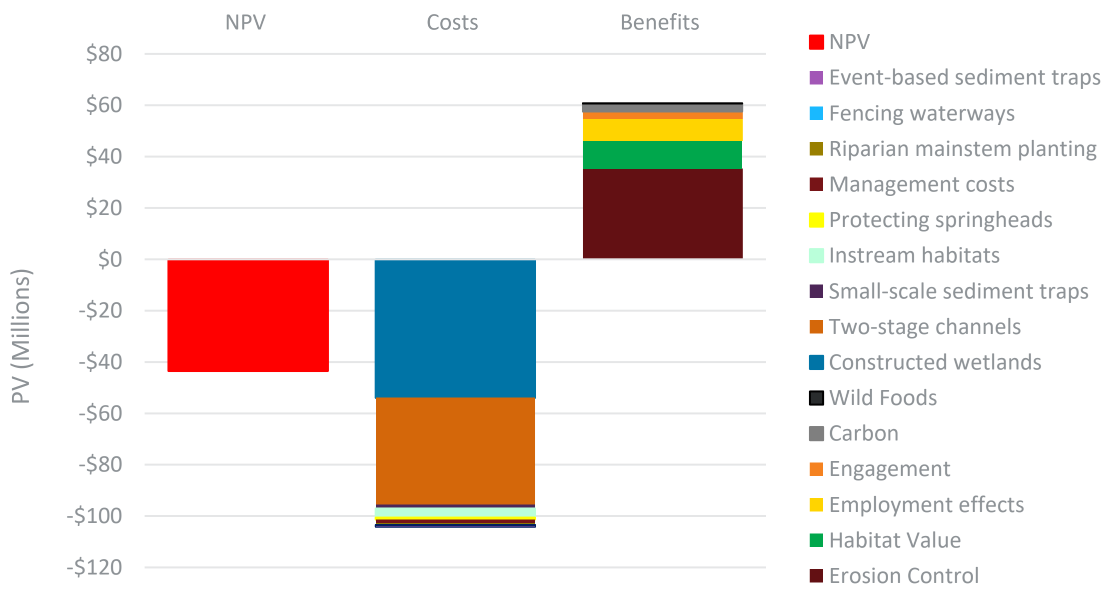
This section shows the results from the CBA for the Auckland region. Net present benefits and costs are shown numerically in Table 6.8 and graphically in Figure 6.6. The net present cost of restoring the lowland drainage network in the Auckland region is $(104,294,251). Comparing this to the benefits we were able to quantify, which are not comprehensive, the NPV is $(43,543,532).

Table 6.8: Auckland region CBA results

Description	$
Net present benefits	
Erosion Control	35,232,920
Habitat Value	10,932,852
Employment effects	8,513,862
Engagement	2,913,830
Carbon	3,080,222
Wild Foods	77,033
Net present costs	
Two-stage channels	41,687,840

Description	$
Constructed wetlands	53,965,444
Small-scale sediment traps	1,383,793
Instream habitats	3,538,285
Protecting springheads	776,995
Management costs	1,360,498
Riparian mainstem planting	739,695
Fencing waterways	720,179
Event-based sediment traps	121,521
NPV	(43,543,532)

Figure 6.6: Auckland region CBA graph



The cost of two-stage channels and constructed wetlands dominate the costs and are large contributors to the negative NPV. The most significant benefit is erosion control followed by habitat value and employment effects.

The negative NPV needs to be considered in the context of the unquantified material benefits as seen in section 6.2.

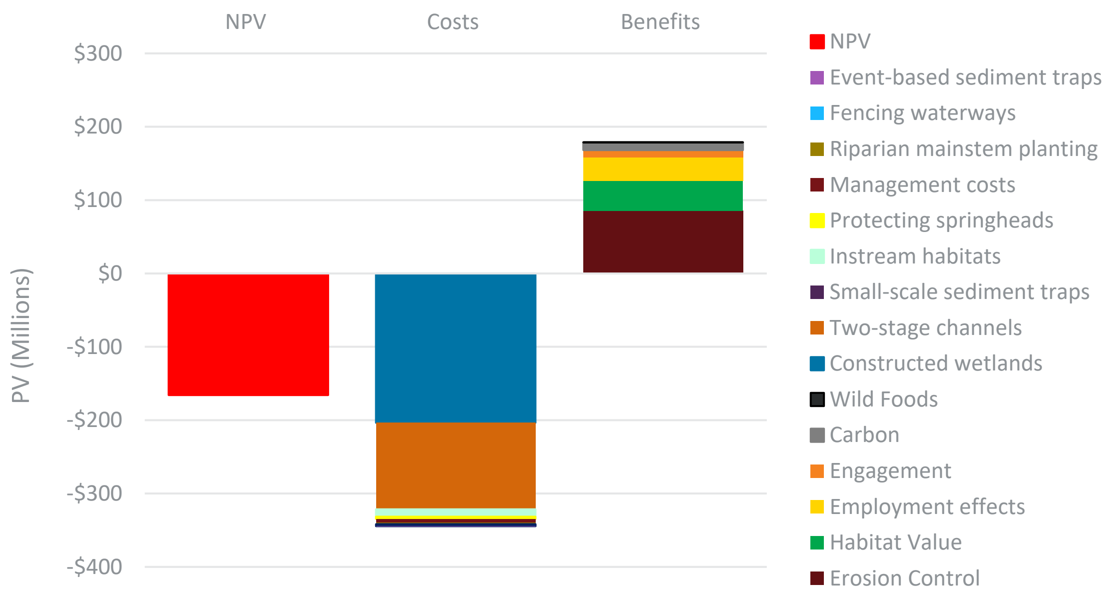
6.6.3 Waikato District

This section shows the results from the CBA for the Waikato District. Net present benefits and costs are shown numerically in Table 6.9 and graphically in Figure 6.7. The net present cost of restoring the lowland drainage network in the Waikato District is $(344,593,563). Comparing this to the benefits we were able to quantify, which are not comprehensive, the NPV is $(165,837,864).

Table 6.9: Waikato District CBA results

Description	$
Net present benefits	
Erosion Control	85,334,891
Habitat Value	41,214,511
Employment effects	32,095,437
Engagement	9,627,443
Carbon	10,313,657
Wild Foods	169,761
Net present costs	
Two-stage channels	116,964,723
Constructed wetlands	203,438,167
Small-scale sediment traps	1,117,283
Instream habitats	9,927,464
Protecting springheads	3,128,721
Management costs	5,128,785
Riparian mainstem planting	2,075,382
Fencing waterways	2,714,920
Event-based sediment traps	98,117
NPV	(165,837,864)

Figure 6.7: Waikato District CBA graph



The cost of two-stage channels and constructed wetlands dominate the costs and are large contributors to the negative NPV. The most significant benefit is erosion control followed by habitat value and employment effects.

The negative NPV needs to be considered in the context of the unquantified material benefits as seen in section 6.2.

6.6.4 Rest of Waikato region

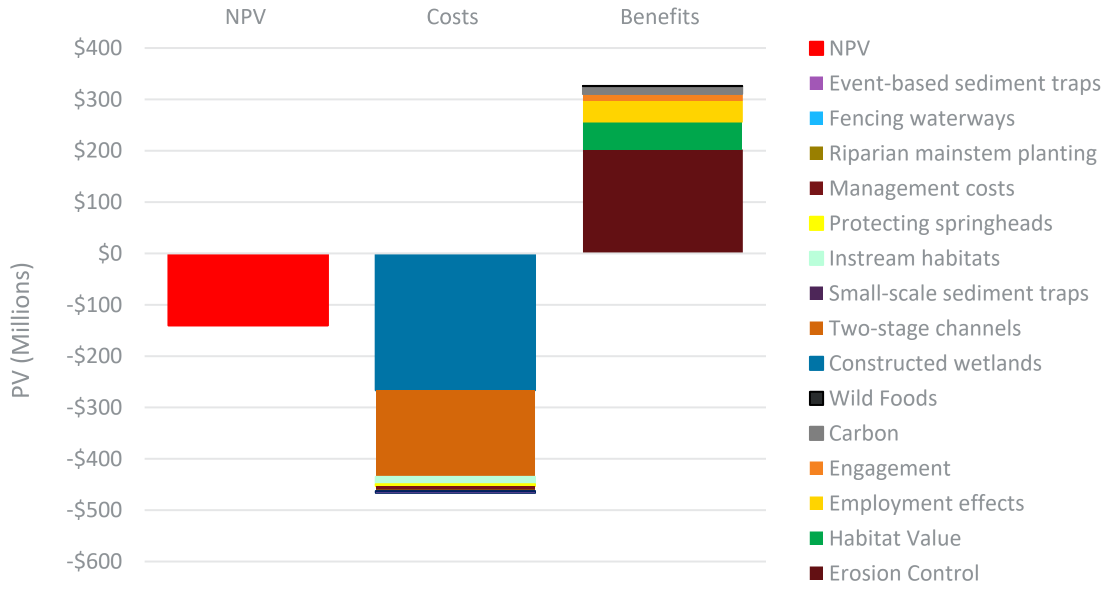
This section shows the results from the CBA for the Rest of Waikato region. Net present benefits and costs are shown numerically in Table 6.10 and graphically in Figure 6.8. The net present cost of restoring the lowland drainage network in the Rest of Waikato region is $(426,292,429). Comparing this to the benefits we were able to quantify, which are not comprehensive, the NPV is $(175,209,992).

Table 6.10: Rest of Waikato region CBA results

Description	$
Net present benefits	
Erosion Control	140,722,963
Habitat Value	48,423,253
Employment effects	37,709,181
Engagement	11,909,990
Carbon	12,117,597
Wild Foods	199,453
Net present costs	

Description	$
Two-stage channels	156,906,697
Constructed wetlands	239,021,104
Small-scale sediment traps	1,320,827
Instream habitats	13,317,568
Protecting springheads	3,610,512
Management costs	6,025,850
Riparian mainstem planting	2,784,098
Fencing waterways	3,189,781
Event-based sediment traps	115,992
NPV	(175,209,992)

Figure 6.8: Rest of Waikato region CBA graph



The cost of two-stage channels and constructed wetlands dominate the costs and are large contributors to the negative NPV. The most significant benefit is erosion control followed by habitat value and employment effects.

The negative NPV needs to be considered in the context of the unquantified material benefits as seen in section 6.2.

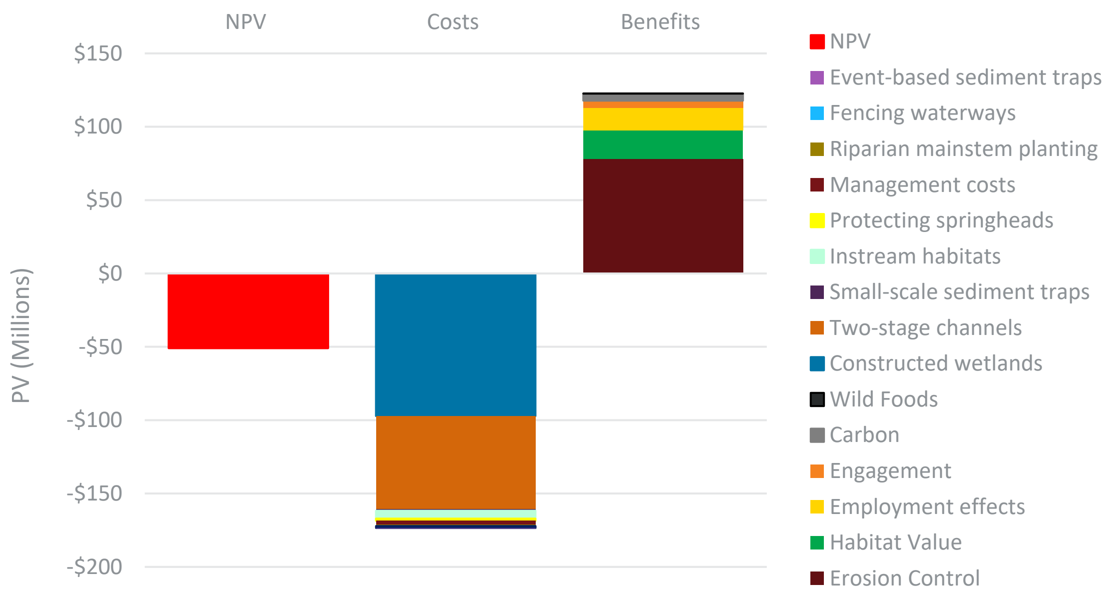
6.6.5 Bay of Plenty region

This section shows the results from the CBA for the Bay of Plenty region. Net present benefits and costs are shown numerically in Table 6.11 and graphically in Figure 6.9. The net present cost of restoring the lowland drainage network in the Bay of Plenty region is $(173,581,435). Comparing this to the benefits we were able to quantify, which are not comprehensive, the NPV is $(50,919,040).

Table 6.11: Bay of Plenty region CBA results

Description	$
Net present benefits	
Erosion Control	77,939,019
Habitat Value	19,697,241
Employment effects	15,339,053
Engagement	4,849,613
Carbon	4,756,338
Wild Foods	81,132
Net present costs	
Two-stage channels	63,219,073
Constructed wetlands	97,227,178
Small-scale sediment traps	1,274,886
Instream habitats	5,365,764
Protecting springheads	1,512,176
Management costs	2,451,149
Riparian mainstem planting	1,121,737
Fencing waterways	1,297,515
Event-based sediment traps	111,957
NPV	(50,919,040)

Figure 6.9: Bay of Plenty region CBA graph



The cost of two-stage channels and constructed wetlands dominate the costs and are large contributors to the negative NPV. The most significant benefit is erosion control followed by habitat value and employment effects.

The negative NPV needs to be considered in the context of the unquantified material benefits as seen in section 6.2.

6.6.6 Gisborne region

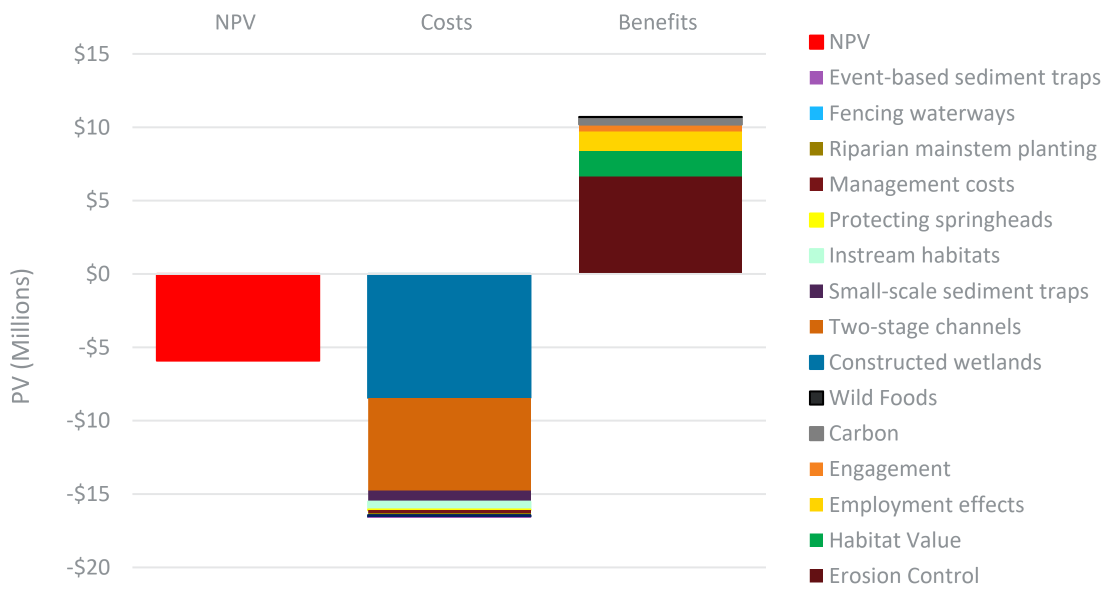
This section shows the results from the CBA for the Gisborne region. Net present benefits and costs are shown numerically in Table 6.12 and graphically in Figure 6.10. The net present cost of restoring the lowland drainage network in the Gisborne region is $(16,613,867). Comparing this to the benefits we were able to quantify, which are not comprehensive, the NPV is $(5,909,717).

Table 6.12: Gisborne region CBA results

Description	$
Net present benefits	
Erosion Control	6,669,472
Habitat Value	1,712,216
Employment effects	1,333,373
Engagement	464,167
Carbon	517,869
Wild Foods	7,053
Net present costs	
Two-stage channels	6,318,847

Description	$
Constructed wetlands	8,451,638
Small-scale sediment traps	743,967
Instream habitats	536,317
Protecting springheads	59,786
Management costs	213,070
Riparian mainstem planting	112,119
Fencing waterways	112,789
Event-based sediment traps	65,333
NPV	(5,909,717)

Figure 6.10: Gisborne region CBA graph



The cost of two-stage channels and constructed wetlands dominate the costs and are large contributors to the negative NPV. The most significant benefit is erosion control followed by habitat value and employment effects.

The negative NPV needs to be considered in the context of the unquantified material benefits as seen in section 6.2.

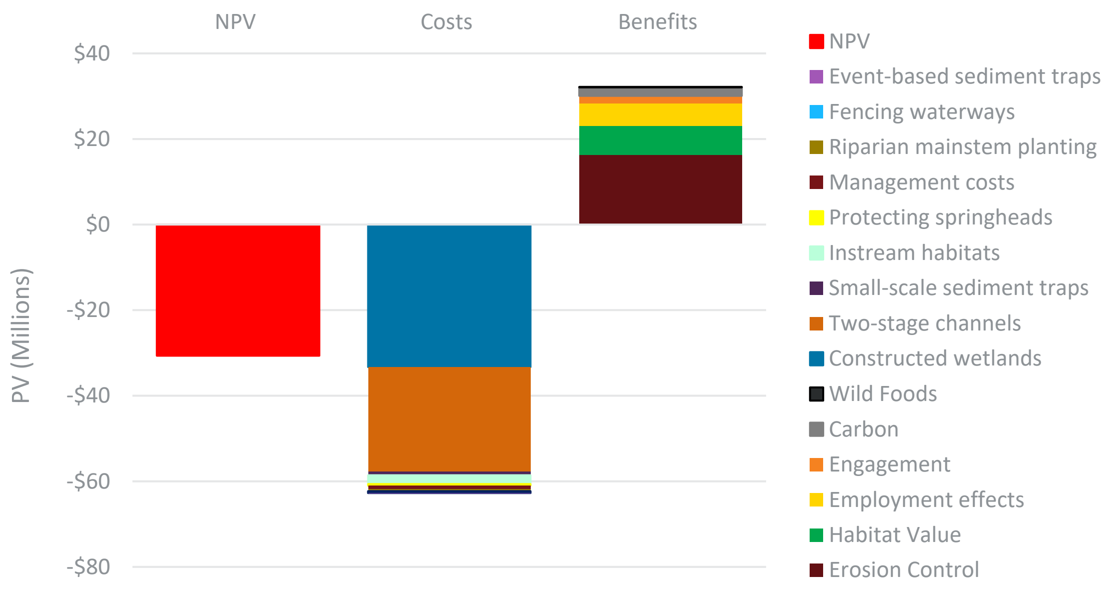
6.6.7 Hawke's Bay region

This section shows the results from the CBA for the Hawke's Bay region. Net present benefits and costs are shown numerically in Table 6.13 and graphically in Figure 6.11. The net present cost of restoring the lowland drainage network in the Hawke's Bay region is $(62,822,545). Comparing this to the benefits we were able to quantify, which are not comprehensive, the NPV is $(30,649,676).

Table 6.13: Hawke’s Bay region CBA results

Description	$
Net present benefits	
Erosion Control	16,324,587
Habitat Value	6,750,139
Employment effects	5,256,612
Engagement	1,755,170
Carbon	1,978,259
Wild Foods	108,102
Net present costs	
Two-stage channels	24,362,394
Constructed wetlands	33,319,236
Small-scale sediment traps	886,903
Instream habitats	2,067,776
Protecting springheads	391,426
Management costs	839,996
Riparian mainstem planting	432,278
Fencing waterways	444,651
Event-based sediment traps	77,886
NPV	(30,649,676)

Figure 6.11: Hawke's Bay region CBA graph



The cost of two-stage channels and constructed wetlands dominate the costs and are large contributors to the negative NPV. The most significant benefit is erosion control followed by habitat value and employment effects.

The negative NPV needs to be considered in the context of the unquantified material benefits as seen in section 6.2.

6.6.8 Taranaki region

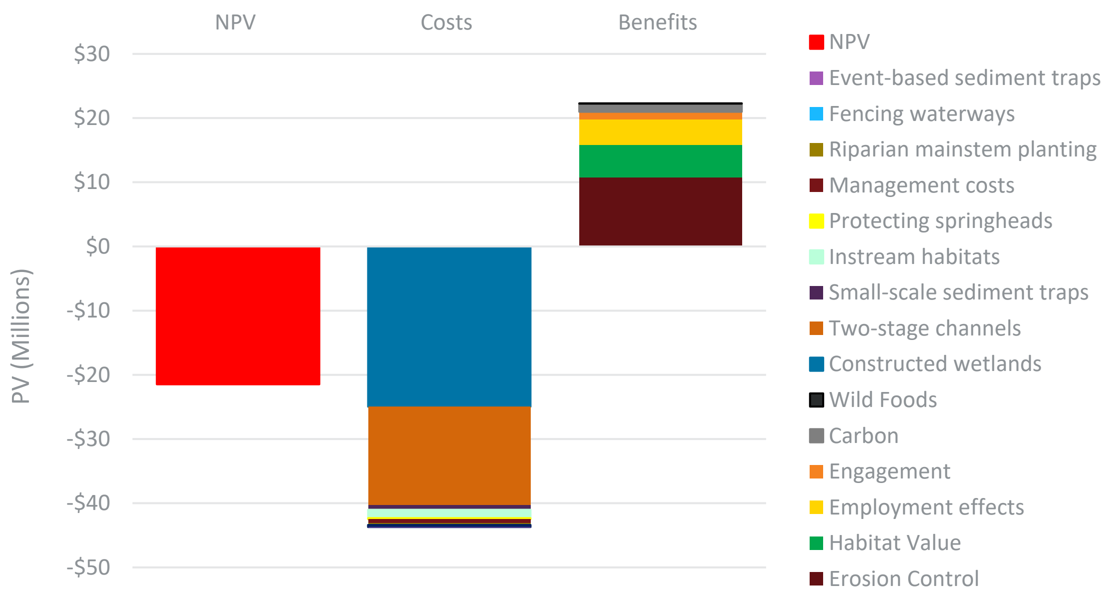
This section shows the results from the CBA for the Taranaki region. Net present benefits and costs are shown numerically in Table 6.14 and graphically in Figure 6.12. The net present cost of restoring the lowland drainage network in the Taranaki region is $(43,778,699). Comparing this to the benefits we were able to quantify, which are not comprehensive, the NPV is $(21,485,323).

Table 6.14: Taranaki region CBA results

Description	$
Net present benefits	
Erosion Control	10,754,641
Habitat Value	5,059,127
Employment effects	3,939,750
Engagement	1,223,113
Carbon	1,266,013
Wild Foods	50,732
Net present costs	
Two-stage channels	15,301,547

Description	$
Constructed wetlands	24,972,260
Small-scale sediment traps	740,150
Instream habitats	1,298,730
Protecting springheads	166,685
Management costs	629,564
Riparian mainstem planting	271,505
Fencing waterways	333,259
Event-based sediment traps	64,998
NPV	(21,485,323)

Figure 6.12: Taranaki region CBA graph



The cost of two-stage channels and constructed wetlands dominate the costs and are large contributors to the negative NPV. The most significant benefit is erosion control followed by habitat value and employment effects.

The negative NPV needs to be considered in the context of the unquantified material benefits as seen in section 6.2.

6.6.9 Manawatū-Whanganui region (Horizons)

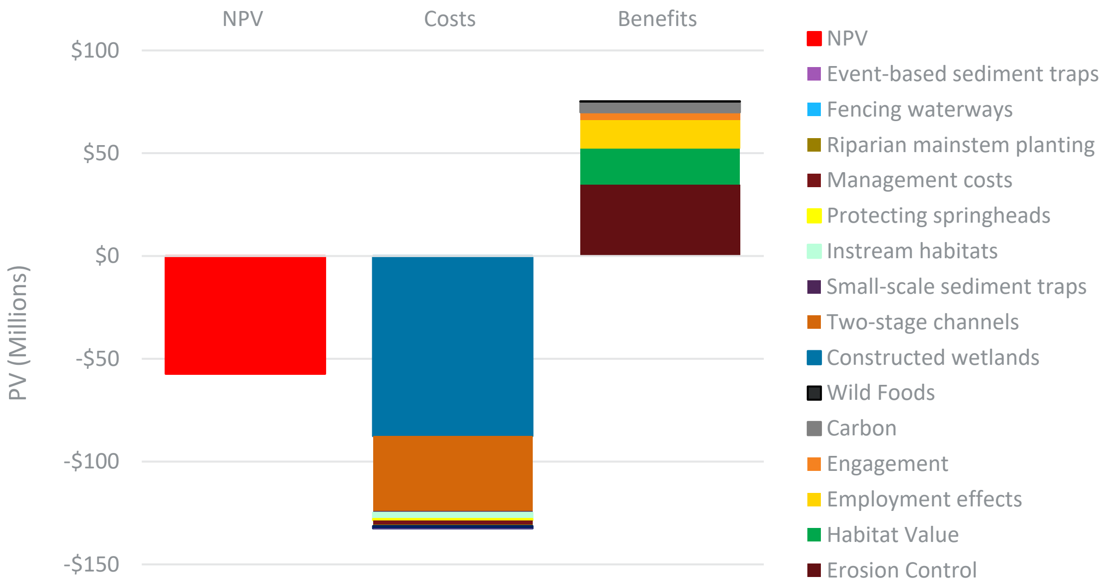
This section shows the results from the CBA for the Manawatū-Whanganui region (Horizons). Net present benefits and costs are shown numerically in Table 6.15 and graphically in Figure 6.13. The net present cost of restoring the lowland drainage network in the Manawatū-Whanganui region

(Horizons) is $(132,578,851). Comparing this to the benefits we were able to quantify, which are not comprehensive, the NPV is $(57,306,392).

Table 6.15: Manawatū-Whanganui region (Horizons) CBA results

Description	$
Net present benefits	
Erosion Control	34,621,255
Habitat Value	17,747,365
Employment effects	13,820,604
Engagement	3,704,060
Carbon	5,201,208
Wild Foods	177,967
Net present costs	
Two-stage channels	36,276,339
Constructed wetlands	87,602,433
Small-scale sediment traps	956,049
Instream habitats	3,078,980
Protecting springheads	559,841
Management costs	2,208,504
Riparian mainstem planting	643,675
Fencing waterways	1,169,071
Event-based sediment traps	83,958
NPV	(57,306,392)

Figure 6.13: Manawatū-Whanganui region (Horizons) CBA graph



The cost of two-stage channels and constructed wetlands dominate the costs and are large contributors to the negative NPV. The most significant benefit is erosion control followed by habitat value and employment effects.

The negative NPV needs to be considered in the context of the unquantified material benefits as seen in section 6.2.

6.6.10 Wellington region

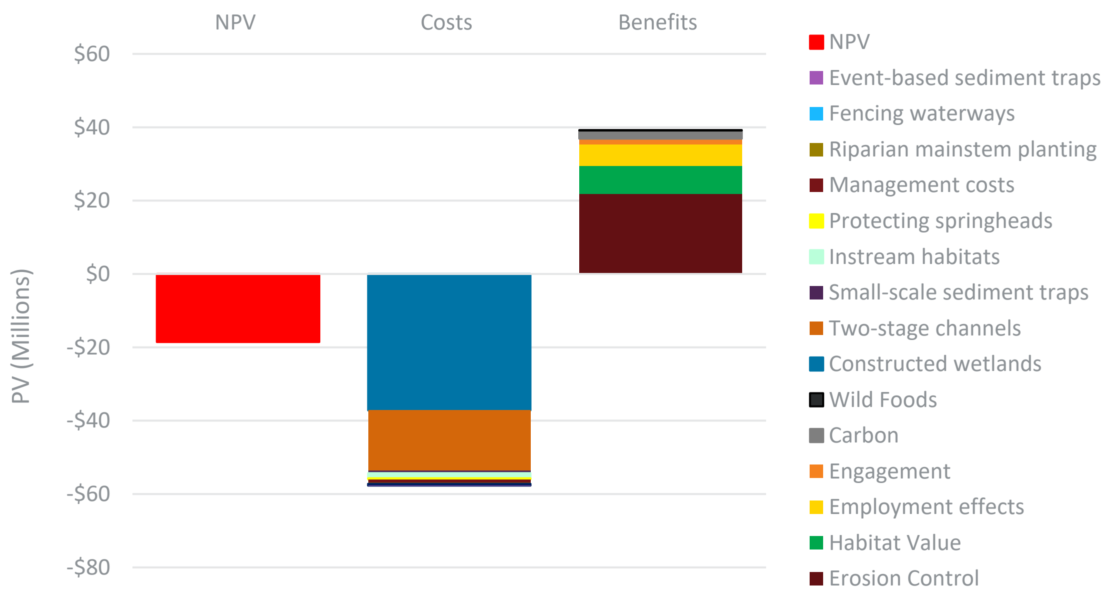
This section shows the results from the CBA for the Wellington region. Net present benefits and costs are shown numerically in Table 6.16 and graphically in Figure 6.14. The net present cost of restoring the lowland drainage network in the Wellington region is $(57,770,788). Comparing this to the benefits we were able to quantify, which are not comprehensive, the NPV is $(18,550,773).

Table 6.16: Wellington region CBA results

Description	$
Net present benefits	
Erosion Control	21,883,947
Habitat Value	7,530,341
Employment effects	5,864,187
Engagement	1,614,032
Carbon	2,206,912
Wild Foods	120,597
Net present costs	
Two-stage channels	16,367,823

Description	$
Constructed wetlands	37,170,374
Small-scale sediment traps	763,472
Instream habitats	1,389,231
Protecting springheads	289,286
Management costs	937,085
Riparian mainstem planting	290,425
Fencing waterways	496,045
Event-based sediment traps	67,046
NPV	(18,550,773)

Figure 6.14: Wellington region CBA graph



The cost of two-stage channels and constructed wetlands dominate the costs and are large contributors to the negative NPV. The most significant benefit is erosion control followed by habitat value and employment effects.

The negative NPV needs to be considered in the context of the unquantified material benefits as seen in section 6.2.

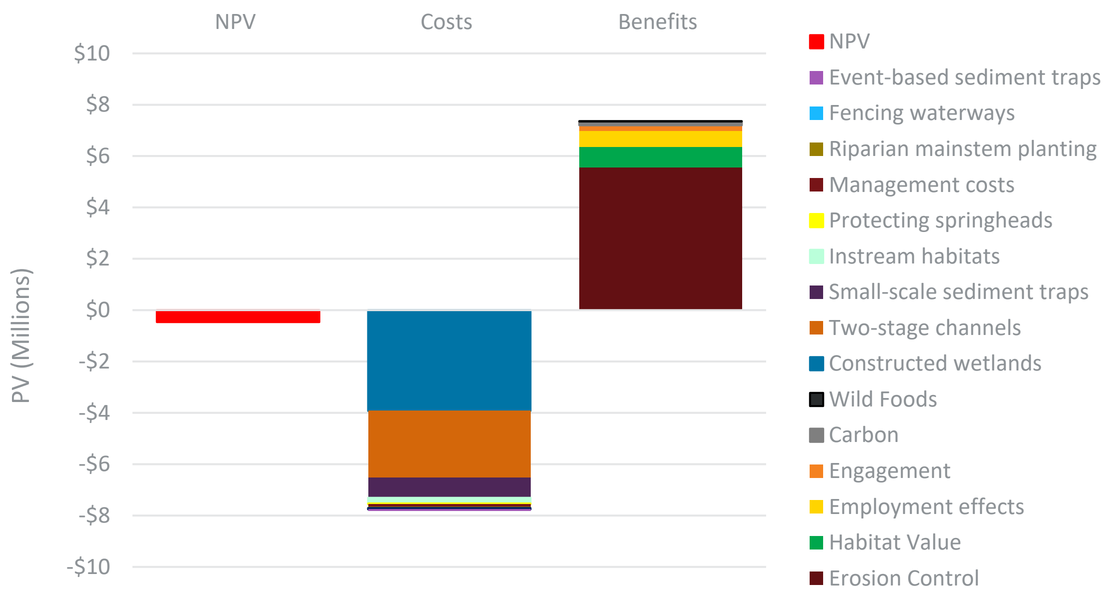
6.6.11 Tasman region

This section shows the results from the CBA for the Tasman region. Net present benefits and costs are shown numerically in Table 6.17 and graphically in Figure 6.15. The net present cost of restoring the lowland drainage network in the Tasman region is $(7,827,523). Comparing this to the benefits we were able to quantify, which are not comprehensive, the NPV is $(464,516).

Table 6.17: Tasman region CBA results

Description	$
Net present benefits	
Erosion Control	5,566,000
Habitat Value	794,831
Employment effects	618,968
Engagement	218,690
Carbon	147,670
Wild Foods	16,849
Net present costs	
Two-stage channels	2,593,615
Constructed wetlands	3,923,350
Small-scale sediment traps	791,512
Instream habitats	220,135
Protecting springheads	32,115
Management costs	98,910
Riparian mainstem planting	46,020
Fencing waterways	52,358
Event-based sediment traps	69,509
NPV	(464,516)

Figure 6.15: Tasman region CBA graph



The cost of two-stage channels and constructed wetlands dominate the costs and are large contributors to the negative NPV. The most significant benefit is erosion control because the Tasman region has high rates of soil erosion, so erosion control provided by lowland drainage restoration is significant. The quantified benefits almost outweigh the costs with the benefit cost ratio being 94%.

The negative NPV needs to be considered in the context of the unquantified material benefits as seen in section 6.2.

6.6.12 Marlborough region

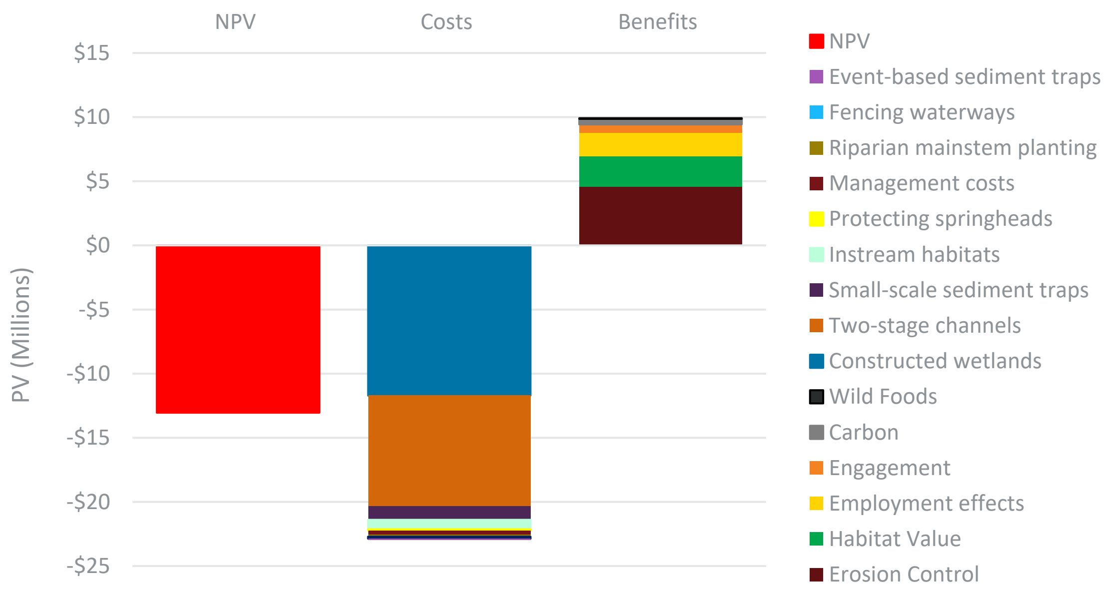
This section shows the results from the CBA for the Marlborough region. Net present benefits and costs are shown numerically in Table 6.18 and graphically in Figure 6.16. The net present cost of restoring the lowland drainage network in the Marlborough region is $(22,958,381). Comparing this to the benefits we were able to quantify, which are not comprehensive, the NPV is $(13,038,785).

Table 6.18: Marlborough CBA results

Description	$
Net present benefits	
Erosion Control	4,568,837
Habitat Value	2,371,591
Employment effects	1,846,856
Engagement	641,424
Carbon	440,614
Wild Foods	50,274
Net present costs	

Description	$
Two-stage channels	8,611,740
Constructed wetlands	11,706,366
Small-scale sediment traps	1,080,366
Instream habitats	730,928
Protecting springheads	129,955
Management costs	295,124
Riparian mainstem planting	152,804
Fencing waterways	156,224
Event-based sediment traps	94,875
NPV	(13,038,785)

Figure 6.16: Marlborough region CBA graph



The cost of two-stage channels and constructed wetlands dominate the costs and are large contributors to the negative NPV. The most significant benefit is erosion control followed by habitat value and employment effects.

The negative NPV needs to be considered in the context of the unquantified material benefits as seen in section 6.2.

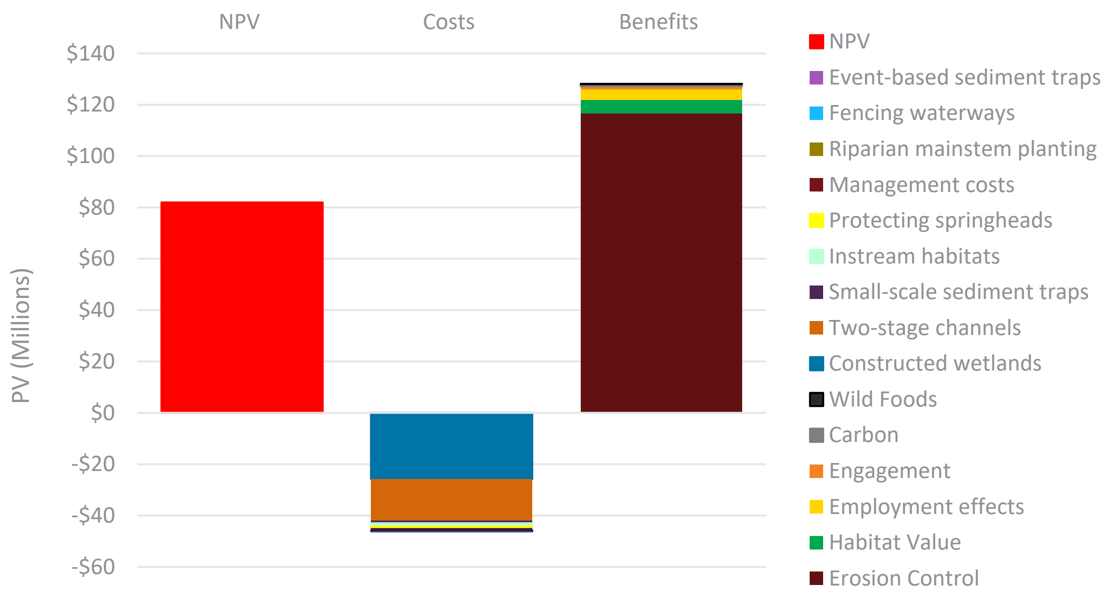
6.6.13 West Coast region

This section shows the results from the CBA for the West Coast region. Net present benefits and costs are shown numerically in Table 6.19 and graphically in Figure 6.17. The net present cost of restoring the lowland drainage network in the West Coast region is $(46,216,439). Comparing this to the benefits we were able to quantify, which are not comprehensive, the NPV is $81,942,203.

Table 6.19: West Coast region CBA results

Description	$
Net present benefits	
Erosion Control	116,591,965
Habitat Value	5,243,362
Employment effects	4,083,222
Engagement	1,291,220
Carbon	787,640
Wild Foods	161,233
Net present costs	
Two-stage channels	16,029,157
Constructed wetlands	25,881,661
Small-scale sediment traps	1,062,200
Instream habitats	1,360,486
Protecting springheads	507,353
Management costs	652,491
Riparian mainstem planting	284,416
Fencing waterways	345,396
Event-based sediment traps	93,280
NPV	81,942,203

Figure 6.17: West Coast region CBA graph



By far, the most significant benefit is erosion control which alone outweighs all the costs and results in the large positive NPV. This is because the West Coast region has very high rates of soil erosion, so erosion control provided by lowland drainage restoration is very significant. The cost of two-stage channels and constructed wetlands dominate the costs.

There are also unquantified material benefits, as seen in section 6.2, that need to be considered.

6.6.14 Selwyn District

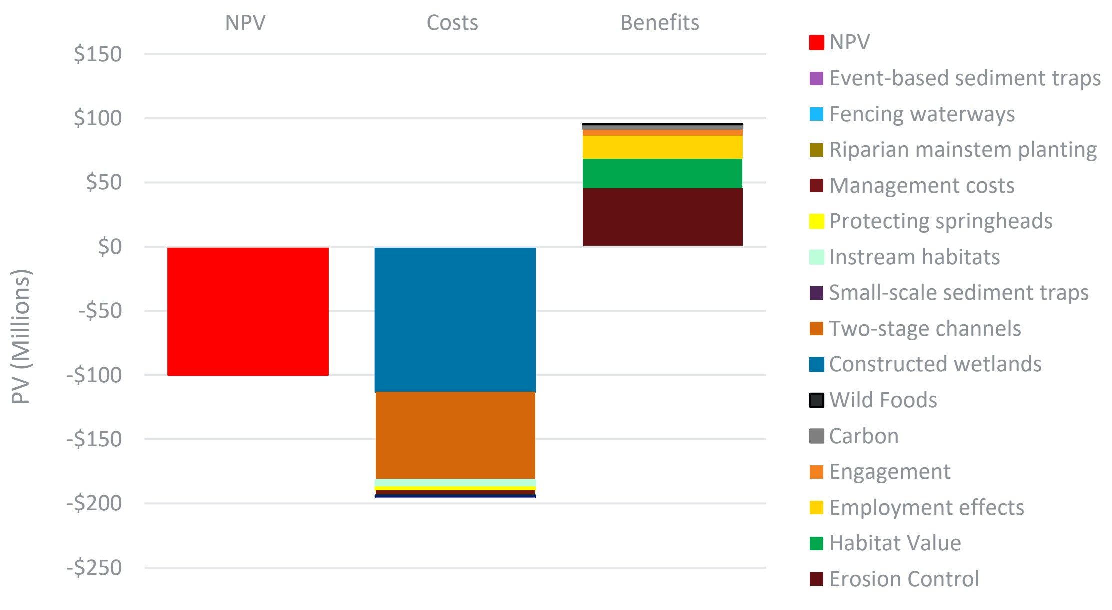
This section shows the results from the CBA for the Selwyn District. Net present benefits and costs are shown numerically in Table 6.20 and graphically in Figure 6.18. The net present cost of restoring the lowland drainage network in the Selwyn District is $(195,246,778). Comparing this to the benefits we were able to quantify, which are not comprehensive, the NPV is $(99,894,453).

Table 6.20: Selwyn District CBA results

Description	$
Net present benefits	
Erosion Control	45,674,572
Habitat Value	22,908,965
Employment effects	17,840,154
Engagement	5,454,911
Carbon	3,441,308
Wild Foods	32,416
Net present costs	
Two-stage channels	67,522,401

Description	$
Constructed wetlands	113,080,507
Small-scale sediment traps	1,100,328
Instream habitats	5,731,012
Protecting springheads	2,157,908
Management costs	2,850,820
Riparian mainstem planting	1,198,094
Fencing waterways	1,509,080
Event-based sediment traps	96,628
NPV	(99,894,453)

Figure 6.18: Selwyn District CBA graph



The cost of two-stage channels and constructed wetlands dominate the costs and are large contributors to the negative NPV. The most significant benefit is erosion control followed by habitat value and employment effects.

The negative NPV needs to be considered in the context of the unquantified material benefits as seen in section 6.2.

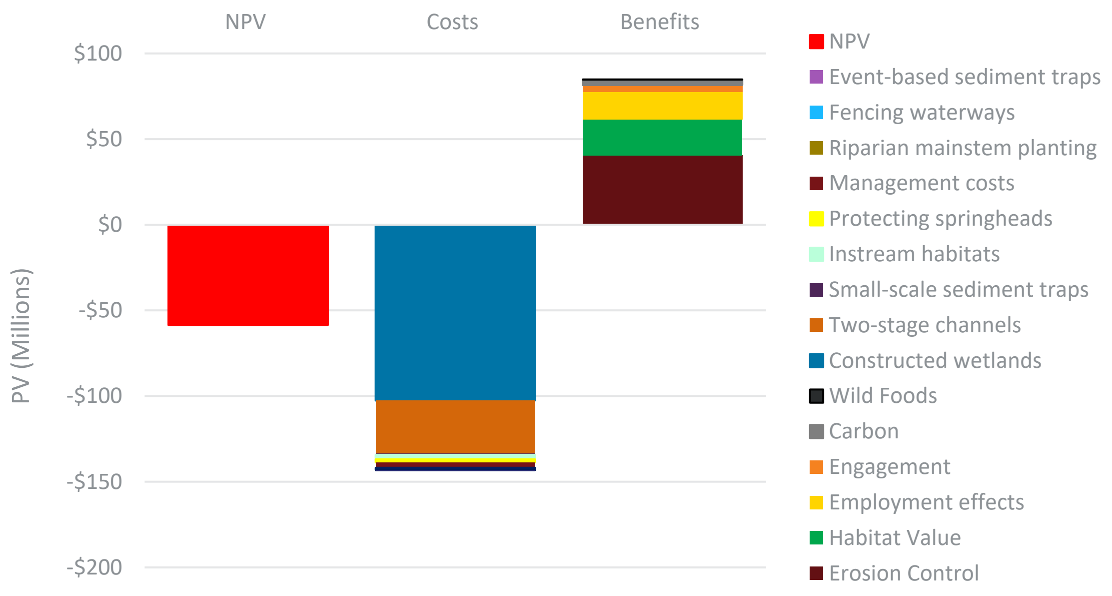
6.6.15 Ashburton District

This section shows the results from the CBA for the Ashburton District. Net present benefits and costs are shown numerically in Table 6.21 and graphically in Figure 6.19. The net present cost of restoring the lowland drainage network in the Ashburton District is $(143,305,360). Comparing this to the benefits we were able to quantify, which are not comprehensive, the NPV is $(58,574,396).

Table 6.21: Ashburton District CBA results

Description	$
Net present benefits	
Erosion Control	40,604,994
Habitat Value	20,784,703
Employment effects	16,185,905
Engagement	4,003,743
Carbon	3,122,209
Wild Foods	29,410
Net present costs	
Two-stage channels	30,848,550
Constructed wetlands	102,594,982
Small-scale sediment traps	898,346
Instream habitats	2,618,293
Protecting springheads	1,763,309
Management costs	2,586,475
Riparian mainstem planting	547,366
Fencing waterways	1,369,149
Event-based sediment traps	78,891
NPV	(58,574,396)

Figure 6.19: Ashburton District CBA graph



The cost of two-stage channels and constructed wetlands dominate the costs and are large contributors to the negative NPV. The most significant benefit is erosion control followed by habitat value and employment effects.

The negative NPV needs to be considered in the context of the unquantified material benefits as seen in section 6.2.

6.6.16 Rest of Canterbury region

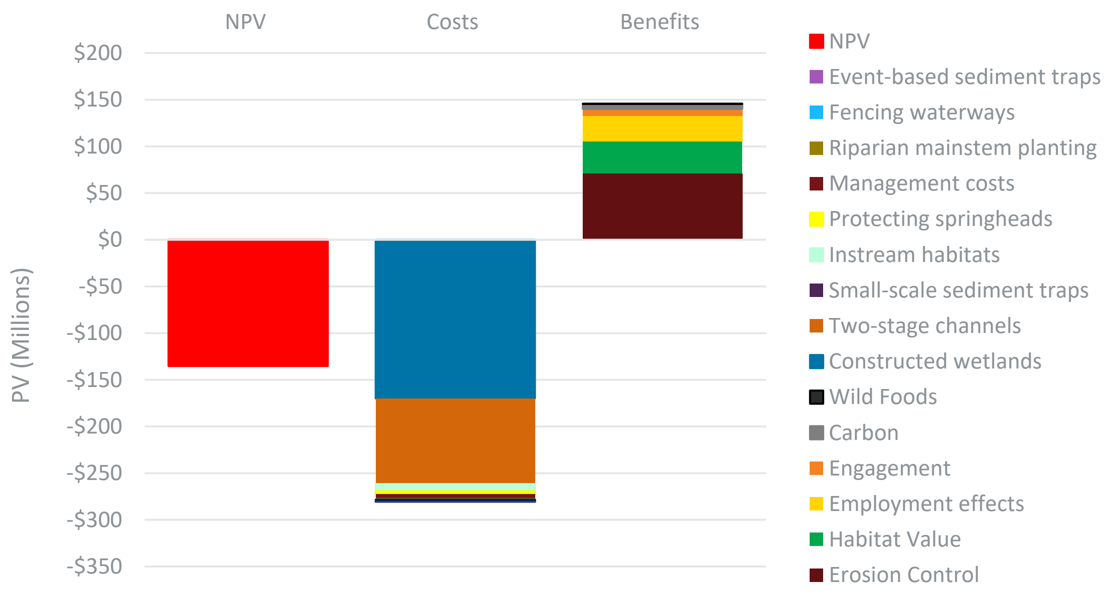
This section shows the results from the CBA for the Rest of Canterbury region. Net present benefits and costs are shown numerically in Table 6.22 and graphically in Figure 6.20. The net present cost of restoring the lowland drainage network in the Rest of Canterbury region is $(280,646,210). Comparing this to the benefits we were able to quantify, which are not comprehensive, the NPV is $(135,155,600).

Table 6.22: Rest of Canterbury region CBA results

Description	$
Net present benefits	
Erosion Control	71,141,858
Habitat Value	34,453,399
Employment effects	26,830,281
Engagement	7,840,847
Carbon	5,175,475
Wild Foods	48,751
Net present costs	

Description	$
Two-stage channels	90,940,352
Constructed wetlands	170,064,773
Small-scale sediment traps	704,542
Instream habitats	7,718,627
Protecting springheads	2,985,461
Management costs	4,287,424
Riparian mainstem planting	1,613,614
Fencing waterways	2,269,546
Event-based sediment traps	61,871
NPV	(135,155,600)

Figure 6.20: Rest of Canterbury region CBA graph



The cost of two-stage channels and constructed wetlands dominate the costs and are large contributors to the negative NPV. The most significant benefit is erosion control followed by habitat value and employment effects.

The negative NPV needs to be considered in the context of the unquantified material benefits as seen in section 6.2.

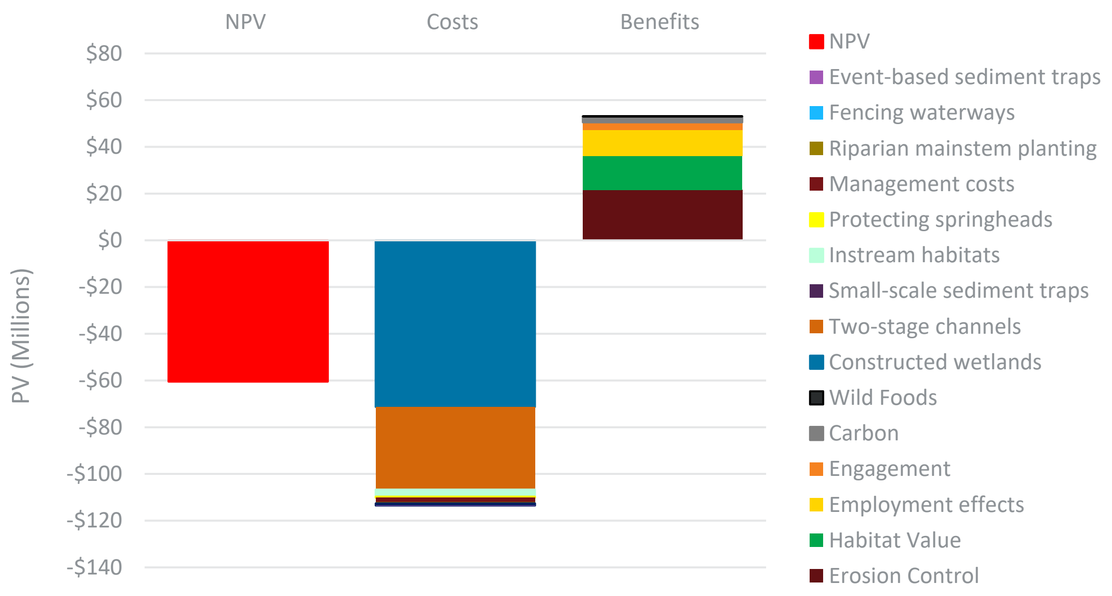
6.6.17 Otago region

This section shows the results from the CBA for the Otago region. Net present benefits and costs are shown numerically in Table 6.23 and graphically in Figure 6.21. The net present cost of restoring the lowland drainage network in the Otago region is $(113,559,152). Comparing this to the benefits we were able to quantify, which are not comprehensive, the NPV is $(60,508,826).

Table 6.23: Otago region CBA results

Description	$
Net present benefits	
Erosion Control	21,604,640
Habitat Value	14,443,198
Employment effects	11,247,513
Engagement	3,172,677
Carbon	2,549,744
Wild Foods	32,553
Net present costs	
Two-stage channels	35,150,183
Constructed wetlands	71,292,798
Small-scale sediment traps	272,554
Instream habitats	2,983,397
Protecting springheads	463,848
Management costs	1,797,330
Riparian mainstem planting	623,693
Fencing waterways	951,415
Event-based sediment traps	23,935
NPV	(60,508,826)

Figure 6.21: Otago region CBA graph



The cost of two-stage channels and constructed wetlands dominate the costs and are large contributors to the negative NPV. The most significant benefit is erosion control followed by habitat value and employment effects.

The negative NPV needs to be considered in the context of the unquantified material benefits as seen in section 6.2.

6.6.18 Southland District

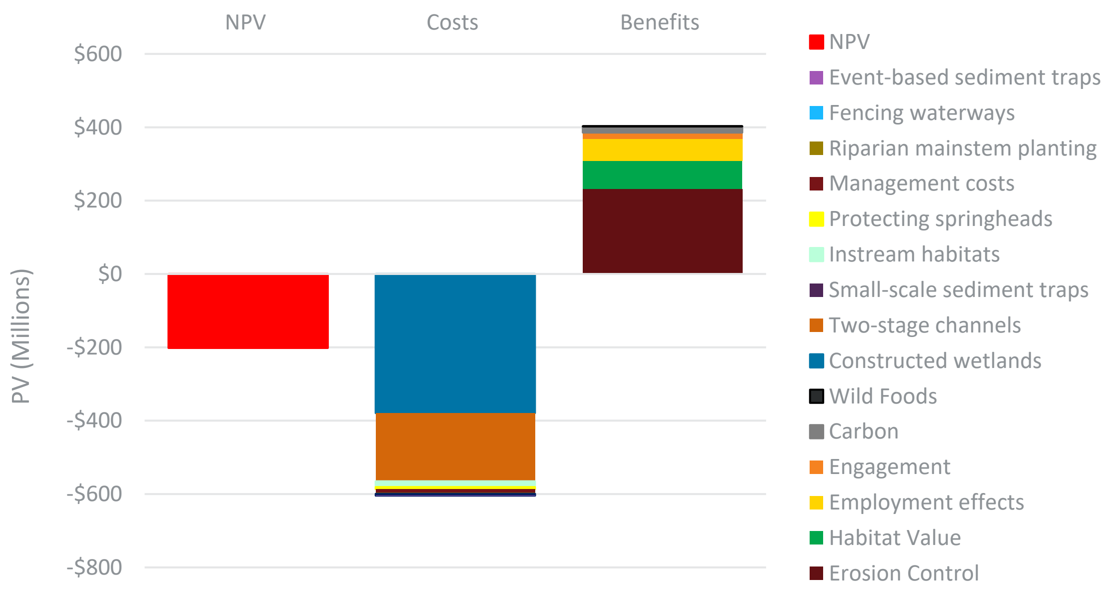
This section shows the results from the CBA for the Southland District. Net present benefits and costs are shown numerically in Table 6.24 and graphically in Figure 6.22. The net present cost of restoring the lowland drainage network in the Southland District is $(604,494,116). Comparing this to the benefits we were able to quantify, which are not comprehensive, the NPV is $(201,823,009).

Table 6.24: Southland District CBA results

Description	$
Net present benefits	
Erosion Control	231,872,951
Habitat Value	76,854,884
Employment effects	59,850,063
Engagement	16,888,686
Carbon	17,031,303
Wild Foods	173,221
Net present costs	
Two-stage channels	185,205,224

Description	$
Constructed wetlands	379,361,938
Small-scale sediment traps	457,053
Instream habitats	15,719,426
Protecting springheads	5,797,547
Management costs	9,563,918
Riparian mainstem planting	3,286,217
Fencing waterways	5,062,655
Event-based sediment traps	40,137
NPV	(201,823,009)

Figure 6.22: Southland District CBA graph



The cost of two-stage channels and constructed wetlands dominate the costs and are large contributors to the negative NPV. The most significant benefit is erosion control followed by habitat value and employment effects.

The negative NPV needs to be considered in the context of the unquantified material benefits as seen in section 6.2.

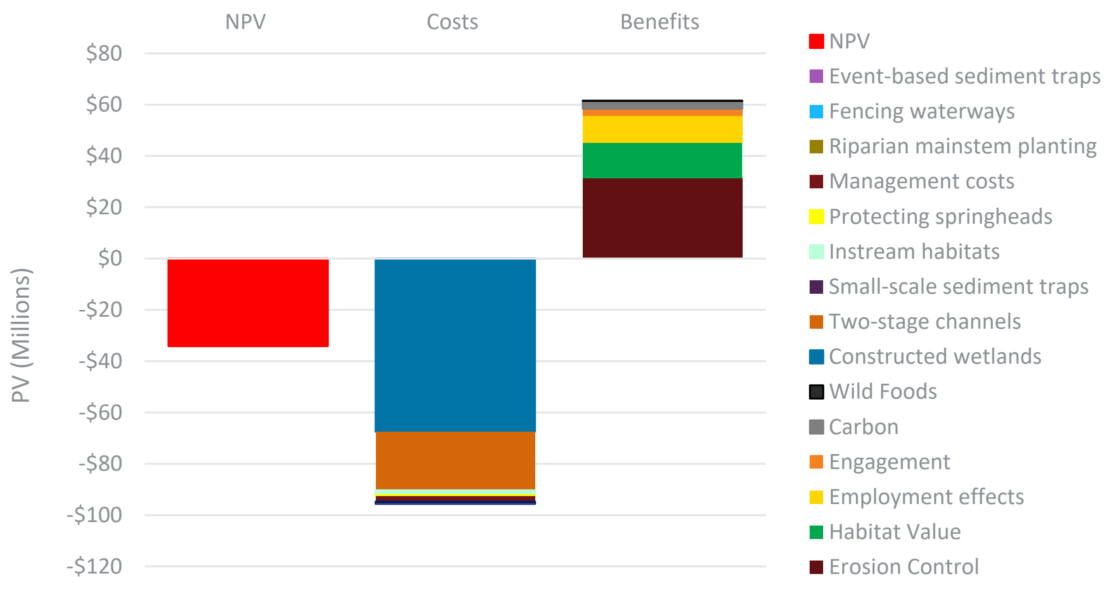
6.6.19 Rest of Southland region

This section shows the results from the CBA for the Rest of Southland region. Net present benefits and costs are shown numerically in Table 6.25 and graphically in Figure 6.23. The net present cost of restoring the lowland drainage network in the Rest of Southland region is $(95,636,618). Comparing this to the benefits we were able to quantify, which are not comprehensive, the NPV is $(34,157,174).

Table 6.25: Rest of Southland region CBA results

Description	$
Net present benefits	
Erosion Control	31,427,803
Habitat Value	13,672,084
Employment effects	10,647,015
Engagement	2,671,948
Carbon	3,029,780
Wild Foods	30,815
Net present costs	
Two-stage channels	22,556,175
Constructed wetlands	67,486,515
Small-scale sediment traps	280,127
Instream habitats	1,914,471
Protecting springheads	372,510
Management costs	1,701,371
Riparian mainstem planting	400,229
Fencing waterways	900,620
Event-based sediment traps	24,600
NPV	(34,157,174)

Figure 6.23: Rest of Southland region CBA graph



The cost of two-stage channels and constructed wetlands dominate the costs and are large contributors to the negative NPV. The most significant benefit is erosion control followed by habitat value and employment effects.

The negative NPV needs to be considered in the context of the unquantified material benefits as seen in section 6.2.

7 Discussion

There are large variations in CBA results across individual regions due to different soil erosion rates

When comparing the results across the individual regions there are large variations with the primary driver of these variations being the erosion control benefit. Erosion control is the most significant quantified benefit in the Ararira/LII CBA and it was scaled to other regions by comparing the differences in soil erosion rates between the drainage network catchments.[38] This caused large variations in results since there are large regional differences in soil erosion rates within Aotearoa/New Zealand. The West Coast region has by far the highest average soil erosion rate which results in a positive NPV for the CBA without considering the unquantified material benefits.

While the results presented in Section 6 show that the quantified costs of lowland drainage restoration outweigh the quantified benefits in most cases, this must not be interpreted as meaning that lowland drainage restoration is not economically justified. The numerical analysis compared a near complete estimate of the costs of restoring the lowland drainage network with a partial estimate of the benefits of this work. The negative net present values for lowland drainage restoration must be viewed in the context of (and judged against) the suite of material benefits that were not feasible or appropriate to quantify in dollar terms.

[38] We used erosion rates within the drainage network catchments to avoid skewing numbers by including high alpine/hill country areas, which typically have very high erosion rates.

It is reasonable to expect that lowland drainage restoration would be economically justified in many regions if the non-quantified benefits could be included

The costs of constructed wetlands and two stage channel development are the main reason for the negative NPV in most regions. Two-stage channel development would help to mitigate flood risk, as discussed in Section 4.3. The benefit of flood risk mitigation is likely to be substantial, but it was not practical to quantify in dollar terms in this analysis. It would, however, be reasonable to assume that the benefit of flood risk mitigation would at least match the cost of two-stage channel development in most regions. If this were the case, the economics of national-scale lowland drainage restoration would be finely weighted, with a benefit cost ratio of 96% and a NPV of -$132,347,661 which would need to be considered in the context of the remaining unquantified benefits above. If flood mitigation benefits were assumed to match two stage channel development costs at the regional level, the analysis would show positive NPVs for Northland, Bay of Plenty, Gisborne, Tasman, and West Coast, and several other regions would have NPVs very close to $0.

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