Economics of flood risk mitigation

NZIER report to Greater Wellington Regional Council

May 2024

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Key points

Flood risk reduction programmes in the 2020 (completed) and 2023 (prospective) lists are mostly small, averaging around $4–$5 million capital spending, with a few larger projects above that (19 above mean in 2020, 26 in 2023) and a long tail of smaller ones below (36 in 2020 and 54 in 2023). These are mostly small upgrades of existing schemes, reducing the annual (flood) exceedance probability (AEP)and associated expected damage.

Flood insurance claims[1] show there has been an increase in the size and frequency of flood claim events since 2010, but Cyclone Gabrielle and the Auckland Anniversary Day floods in 2023 were orders of magnitude bigger (albeit both were multi-hazard events, with combinations of fluvial flood, pluvial flood and landslides sharing the damage).

Fatality risks from flooding have been low, averaging 0.4 deaths a year over the past 100 years, but Cyclone Gabrielle's 9 deaths (excluding 2 from landslide) were exceptional.

A rapid review of the literature shows an evolving approach to economic assessment of flood mitigation, but converging on cost benefit analysis based on avoided costs of:

- Direct impacts of contact with floodwaters, in which insurance claims provide a reliable basis for valuing damage but are incomplete in omitting uninsured costs
- Indirect impacts resulting from flooding, including disruption of activities that reduce outputs or increase costs of doing business (which directly affects the flow accounts from which GDP is calculated) and government responses & recovery – indirect impacts can be very big but are rarely directly measured and usually valued as some multiple of direct impacts based on earlier research
- Intangible impacts covering costs of physical and mental health, damage to natural habitats and historic and cultural capital – these could be valued using non-market valuation, but rarely are and more often included as a multiple of direct impacts, with several reports suggesting at least as big as direct tangible impacts.

While the USA, UK and Australia have developed standard approaches to assessment around accumulated databases, there is no such uniformity in New Zealand, with ad hoc studies by different authors taking varied approaches. RiskScape modelling, which overlays building and infrastructure over areas at risk of floods, provides a means of measuring impacts at specific locations but covers only direct impacts (plus clean-up costs) and does not consider the economic costs of disruption.

Case studies show that projects need a combined reduction in direct and indirect impacts to break-even on the basis of average costs of floods with and without investment. Lower discount rates raise benefit-cost ratios (BCRs). Most project applications for funding do not have a quantified assessment of net benefits, often because they are components of a much larger scheme. Accordingly, our analysis depends on assumptions drawing on New Zealand and elsewhere, if necessary, with varying reliability of inputs used.

Floods are localised, as are many of the benefits of avoidance, but there are various reasons for central government to be involved in local flood mitigation:

1 See Figure 3 based on NZIER analysis of data from Insurance Council of New Zealand.

- To reduce costs of deploying government emergency services and reduce demands on other government social services for people adversely affected or displaced by floods
- To reduce damage to government-owned and managed infrastructure
- To co-ordinate and expedite clean-up operations and disposal of wastes
- To reduce economic disruption that detracts from gross domestic product (GDP)
- To lower government liability as the de facto insurer of last resort by reducing the likelihood of insurers removing cover from at-risk areas
- To accelerate the completion of mitigation works where local communities struggle with the affordability of the works required.

In short, which government intervention can help realise in a more timely fashion; as well, government investment in mitigation can reduce the government's own future liabilities for services and infrastructure it provides and reduce down time in economic activity.

Local flood protection has positive externalities for other areas and the nation at large.

Case studies suggest the split of benefits between direct and indirect cost avoidance is similar to that between local and national government funding input.

Following the case studies, the 55 completed projects can be assessed by assuming an average BCR in the range of 2 to 4 to provide a range of low, medium and high estimates of return on investment. Where project upgrades have been completed in time to ward off the costs of large flood events, as happened at Awanui and Taradale, the programme net benefits would be higher, as in the years of those flood events, the cost avoided would be the full cost of the flood event, not the probability-adjusted average expected annual value.

The 55 completed projects can be assessed by assuming an average BCR in the range of 2 to 4.

The BCR range we found for these projects represents value for money and favourable spending choices over other infrastructure projects where BCRs tend to be closer to 1. Around 55% of tangible benefits are attributable to indirect costs of disruption of activity, which contributes to regional and national value added benefits outside the locality.

The same BCRs can be applied to the 80 prospective projects seeking government support in *Before the Deluge 2.0* (Regional and Unitary Councils of New Zealand 2023). Pro rata splits between local and central government funding would show a similar split between reductions in direct impacts (largely affecting local property values) and indirect impacts (affecting business activity and GDP).

Similar BCRs can be applied to the 80 projects seeking government support in *Before the Deluge 2.0*

Table 1 Summary of flood risk reduction programmes in 2020 and 2023

Benefits of flood risk reduction programmes under a range of BCRs: Benefits from direct and indirect impacts avoided; funding split between local and national government.

BCR range	Item	Total	Direct impact	Indirect impact
1.7	Benefit $m	**505**	227	278
2.6	Benefit $m	**773**	348	425
3.8	Benefit $m	**1130**	508	621
2020 Programme	Cost $m	**297.3**	**78**	**217**
1.7	Benefit $m	**560**	252	308
2.6	Benefit $m	**856**	385	471
3.8	Benefit $m	1252	563	688
2023 Programme	Cost $m	**329.3**	**131.7**	**197.6**

Note: The BCR ranges in Table 1 are not statistical conclusions. They are taken from case studies and drawn from relevant literature. RiskScape data and analysis are required to generate a project-specific BCR.

Source: NZIER drawing Regional and Unitary District Councils (2020a) and Regional and Unitary Councils of New Zealand (2023a)

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1 Executive Summary

A suite of 55 flood risk reduction projects have been completed between 2020 and 2023 with a benefit-cost ratio (BCR) between 2 and 4. Completed on time, on budget, and to specification, a return between 2 and 4 times the investment represents good value compared to many other infrastructure projects. The benefits include direct costs, such as reduced first responder costs, clean-up costs and damage, and indirect costs, such as business disruption. The benefits do not include preventing loss of life, which would further increase the BCR.

With this success in mind, a further 80 prospective projects represent similar value. Projects range from $4–$5 million in capital costs, and many are situated in areawith significant economic/export activity and sizeable populations at the higher end of the BCR.

Facing fewer supply chain and labour cost risks compared to more complex infrastructure projects, recent experience suggests that flood risk reduction remains a low-risk, value for money investment.

The remaining suite of projects is best viewed as a whole programme because of the uncertainty related to the specific probability and magnitude of any specific flood event in any one location.

2 Introduction

2.1 This is a programme-level assessment of future investments drawing on the experience of past investments

The Rivers Group of regional councils is after a robust assessment of the economic value of the first tranche of 55 completed flood risk reduction projects outlined in *River Management for Flood Protection – Spade-Ready Projects* (Regional and Unitary District Councils 2020) to inform the case for government support for the second tranche of 80 projects outlined in *Before the Deluge 2.0* (Regional and Unitary Councils of New Zealand 2023).

Our approach to this programme-level assessment, supplemented by some case studies, focuses on three high-level research questions:

1. *What is the overall benefit-cost ratio for the suite of completed projects?*
2. *How do the three selected case studies demonstrate this value?*
3. *What is the potential gain from further investment in similar projects?*

Investment in flood risk reduction reduces the frequency and severity of damaging flood events, conferring at least a benefit of averted-costs as well as broader benefits like peace of mind and improved confidence in investing in flood-protected areas. The benefit attributable to the investment is the difference in the expected value of activities in floodable areas with and without the investment being made.

Two types of economic analysis are commonly applied to investment proposals:

- Economic impact analysis (EIA) typically measures total economic activity in a country or region by identifying a project's impact in a given year on total expenditures, incomes earned, or jobs created, and contribution to national or regional economic value added or gross domestic product (GDP), consistent with the system of national economic accounts
- Cost-benefit analysis (CBA) typically treats projects as a societal investment in comparing the costs outlaid with the beneficial returns obtained over the lifetime of the investment; it has a broader scope than EIA in being able to measure effects not covered by national accounts (such as damage to environmental assets) and effects across more than one time period.

There are some areas of overlap and commonality between CBA and EIA, but the methods are distinct approaches that provide complementary insights. This report is primarily about CBA, with EIA as a secondary consideration.

Flood costs can be divided between:

- Direct tangible costs incurred as a result of a flood event that has a market value, such as damage to private properties and infrastructure
- Indirect tangible costs which are not directly caused by the flood event itself but arise as a flow-on consequence of direct damage, such as business and network disruptions
- Intangible costs include both direct and indirect impacts that cannot be easily monetised, such as death and injury, and impacts on health, wellbeing, and the environment.

All of these direct and indirect costs and impacts count from an economics perspective because they have value, whether readily monetisable or not. The nature of indirect and intangible costs and impacts varies by the context of each flood mitigation project.

We take a community-wide perspective, accounting for costs and benefits wherever and on whoever they fall. As the purpose of this report is to support a bid for government funding, we consider the size of government contribution involved and build a case for benefits wider than those accruing to local ratepayers (such as inter-city connectivity, reductions in supply chain disruptions) that justify national taxpayer funding.

The key to estimating costs and benefits and demonstrating the worth of all completed and prospective projects is the compilation of summary information about the probability of flood events, the exposure of assets and people (value at risk) and their vulnerability (susceptibility to disruption or loss). Programme-level assessment can be approached by bottom-up compilation of data for each individual project and checking for consistency or top-down by applying representative values to the common elements of each project's outcomes. Given the size of the programmes, we adopt a top-down approach.

2.2 We focus on fluvial floods, not pluvial floods or coastal inundation

This report focuses on fluvial floods and mitigation measures to reduce their frequency and severity of impact. A fluvial flood is caused by the overflow of water from a river channel onto normally dry land, which can be mitigated by building stopbanks or channel modifications to improve flow and capacity. Such floods may be caused by rainfall creating 'runoff' into rivers or flash floods down river channels caused by dam breaches. But fluvial floods exclude pluvial floods caused by heavy rain that results in surface pooling and overwhelming stormwater systems, excluding storm surge and coastal flooding.

A flood hazard is the potential risk to life, property and infrastructure resulting from flooding. It is expressed in terms of the probability of flooding of given magnitudes occurring, their average exceedance probability or average return interval. Other factors significant in assessing flood risk reduction are:

- The exposure of people and valued assets to flood hazards can be determined from flood-risk mapping, which has been carried out in New Zealand (Paulik, Craig, and Collins 2019)
- The vulnerability of those people and assets at risk, which determines the susceptibility to economic loss if a flood should occur, which can be partly inferred from mapping but also depends on the organisation of activities on flood-prone sites, their dependence on continuity of supplies from outside and their susceptibility to system failure if temporarily inundated by floodwater
- The performance and effectiveness of flood risk reduction that modifies the frequency and severity of floods, which is an empirical question that varies with each scheme.

Data on flood damage does not always distinguish between types of floods, and ascribing costs to fluvial floods depends on assumptions.

2.3 The projects in the programmes under consideration are mostly small

The two programmes of local flood risk reduction work under consideration are summarised in Table 2. *River Management for Flood Protection* (Regional and Unitary District Councils 2020) identifies $300 million spent on 58 projects split 27:73 (on average) between local and central government sourcing. *Before the Deluge 2.0* (Regional and Unitary Councils of New Zealand 2023) lists $329 million for 80 projects split 40:60 between local and central government.

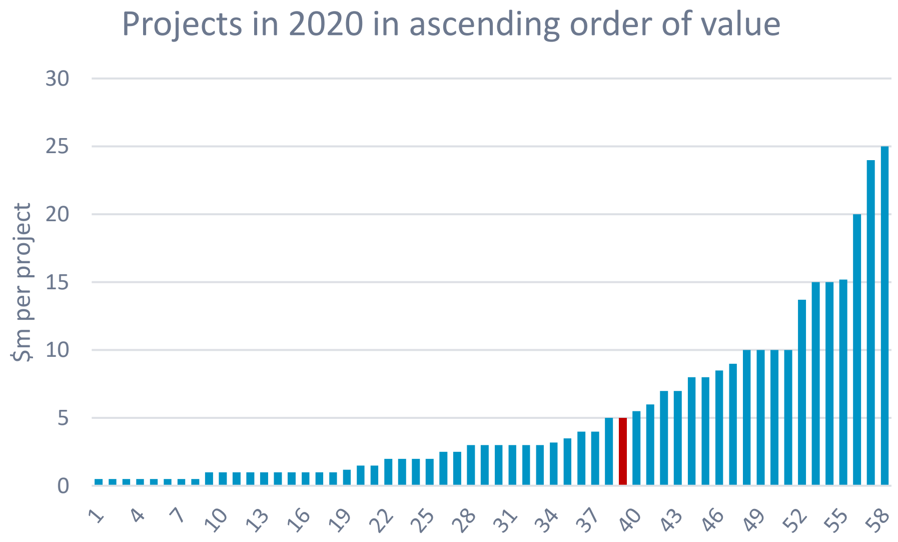
Table 2 Summary of flood risk reduction programmes in 2020 and 2023

	Total cost	Local funding	Support sought
Aggregate programme 2020 $m	300.8	82.3	218.5
Average over 58 projects $m/project	5.19	1.42	3.77
Percentage split of funding	*100%*	*27%*	*73%*
Aggregate programme 2023 $m	329.4	131.7	197.6
Average over 80 projects $m/project	4.12	1.65	2.47
Percentage split of funding	*100%*	*40%*	*60%*

Source: NZIER drawing Regional and Unitary District Councils (2020a) and Regional and Unitary Councils of New Zealand (2023a)

On average, projects are relatively small, with means (graphed in red) about $5 million per project in the 2020 programme (Figure 1 below) and $4.1 million in the 2023 list (Figure 2).

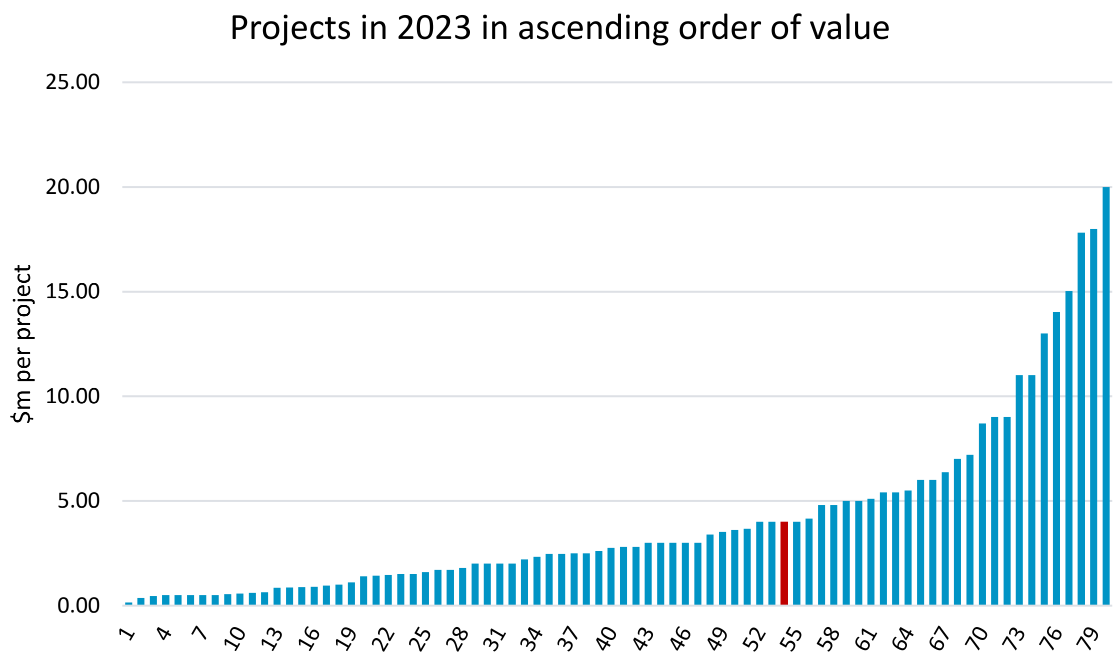
Figure 1 Scale of projects in the 2020 selection



Source: NZIER, drawing Regional and Unitary District Councils (2020a)

There are more larger projects in 2023 up to a lower maximum value than in the 2020 projects.

Figure 2 Scale of projects in the 2023 selection



Source: NZIER drawing from Regional and Unitary Councils of New Zealand (2023a)

The small size of many of these projects means they are unlikely to appear significant in an economic impact analysis at either the regional or national level. The largest projects, around $20 million, would add very little to regional economies even before accounting for the money that leaves the region almost immediately to pay for the supply of imported inputs.

> The cumulative benefit of projects over time helps manage the uneven probability and magnitude of flood events.

These projects' cumulative benefit in protecting value at risk of flooding over a period of years is potentially larger than their relatively modest outlays. As the occurrence of floods in particular places and times is unpredictable, even though their frequency and probability may be known, the projects are better viewed as contributors to a programme of protection than individually.

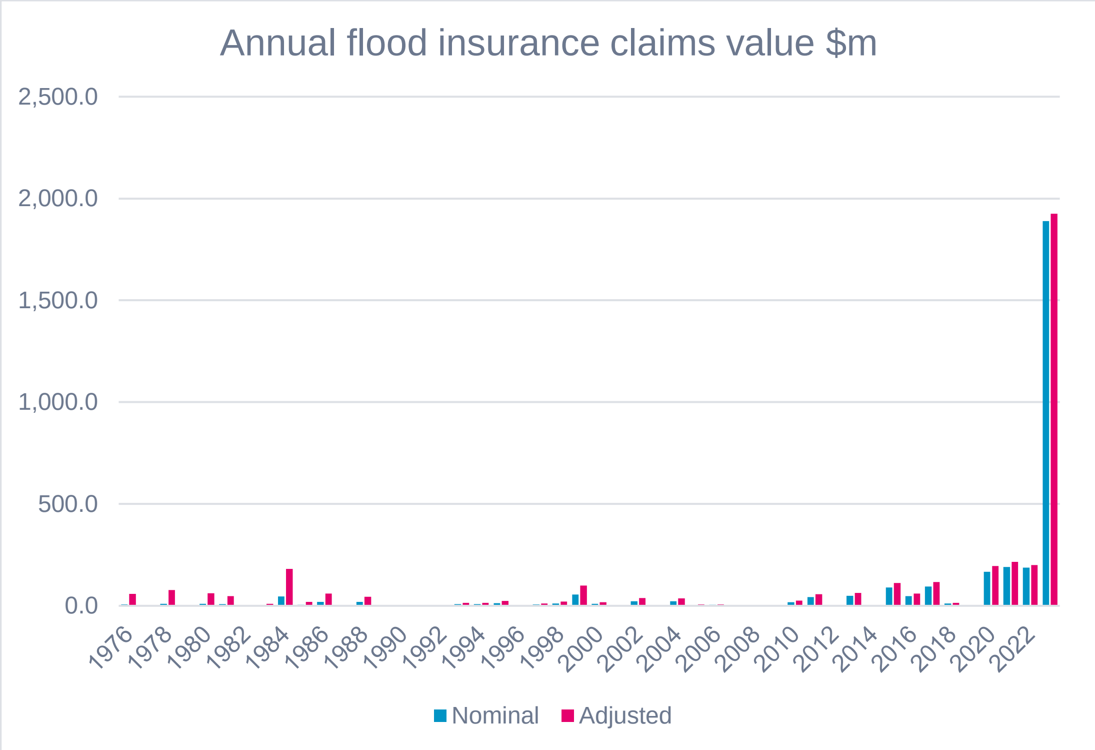
2.4 Flood damages have been increasing

Insurance claims are an often quoted measure of the value of flood damage, although they do not represent the full costs of flooding for a number of reasons. Some properties may be uninsured, some costs, such as disruption to current activities, are practically impossible to insure, and some property owners may decide insurance is not affordable. However, claim numbers are readily available and useful as a quick indicator of the scale of flood damage.

Figure 3 shows flood claims over the past 47 years as identified by the Insurance Council of New Zealand, focusing on those events described as "flooding" rather than those described as "Storms and flooding", which include wind damage, pluvial floods and landslides. Not every year experiences a flood significant enough to be identified as a flood event, and the extent of damage from flood claims varies from year to year. The most prominent feature of Figure 3 is the large increase in claims in 2023 due to the intense flooding in Auckland's Anniversary Day floods in that year.

The costs for 2023 would be even higher if the data included the damage wrought by Cyclone Gabrielle in flooding, especially in Hawke's Bay and Tairāwhiti/Gisborne District. When writing this report, the total insurance claims attributed to Cyclone Gabrielle amounted to $1.73 billion, compared to $1.89 billion for the Auckland Anniversary Day flood. Both these events triggered multi-hazard damage (pluvial floods, landslides on sodden ground) and cannot be used at face value as figures for fluvial floods. But it is apparent from Figure 3 that the value of flood claims has increased in real terms over the past decade, which is consistent with predictions of the effects of climate change of increasing energy and moisture content of rainfall events, which will increase the frequency (reduce the average return period) of larger fluvial floods which will become less infrequent than they have been in the past.

Figure 3 Annual flood insurance claims, in contemporary dollars and adjusted to 2023 dollars



Source: NZIER drawing on Insurance Council of NZ (2023)

2.5 Fatality risk from flooding has been low in recent years

Table 3 lists fatalities associated with flooding events addressed by flood risk reduction investments. Excluded are pluvial flood events such as the 2023 Auckland Anniversary Day floods in 2023, the Mangetopopo canyoning event in 2008, and the 2 deaths by landslide among the Cyclone Gabrielle fatalities. The 21 fatalities in the flash flood that swept through the Kopuawhara railway workers camp were caused by a river overtopping its banks following a cloudburst, so it could be described as a pluvial flood, but the fundamental cause was the inappropriate location of buildings close to a river which were swept away, but lives might have been saved had there been mitigation in place.

Table 3 shows some very high fatality flood events in the early stages of New Zealand's colonial development. As the details of how these events occurred are obscure, we focus on the last 100 years in which 40 fatalities can be attributed to fluvial flooding. There was an average of 0.4 deaths per year over the past 100 years, compared to 1.61 over the full 165 years in the table, or 3.42 per year over the period 1858–1923.

Table 3 Fatalities associated with flooding events

Year	Fatalities	Event
2023	9	Cyclone Gabrielle
2015	1	Petone
2014	2	Northland
1938	21	Kopuawhara
1936	6	Great Storm
1924	1	Kaiwaka
100 Year Total	**40**	
1897	12	Clive
1863	200	Central Otago
1858	14	Hutt valley
165 Year Total	**266**	

Source: NZIER drawing on Te Ara – Encyclopaedia of New Zealand (McSavenay, n.d.)

At 1.6 deaths per year over a 165-year period and 0.4 deaths over 100 years, flood-related fatalities in New Zealand are lower than those recorded recently in Australia (2 per year over the past 40 years) (Deloitte Access Economics 2016).

3 Rapid review of literature

We undertook a rapid search and review of literature on flood risk reduction investments relevant to New Zealand, seeking insights for high-level assessment of flood risk reduction programmes. As was stated in a recent presentation to the Ministry for the Environment on a research programme for flood information, “the current level of flood risk across New Zealand cannot be stated with any accuracy…in addition, there is no way to assess or collate comparable information around the country to make this level of analysis possible” (Lane 2020). While steps are underway to improve the scientific data on flood events, economic data on floods is less evident, much of it ad hoc and somewhat dated.

3.1 River management for flood risk reduction – Spade-ready projects (Regional and Unitary District Councils 2020)

This report appears to be the basis of the 55 successfully completed projects under the COVID Recovery (Fast-track Consenting) process (Regional and Unitary District Councils 2020). This programme had a total cost of $297.3 million, of which $217.3 million was government-funded and $77.6 million regional ratepayer-funded, with attributed job creation of 951 (headcount or full-time equivalents is not specified).

The 2020 report has slightly different total figures, with a total cost of $300.8 million, government funding of 218.5 million and ratepayer funding of $82.3 million spread across

58 projects. Attributed job creation is the same at 951. Of the 58 projects, 27 have no ratepayer contribution recorded.

The report has some tables describing each project in terms of the workforce required and the timing and sequencing of work. But it has no information on how the work would change the probability of flooding, and none on the value at risk of property that could be flooded, or of infrastructure disruption that would drive the scale and duration of disruption costs. (Information on the probability of flooding and flooding impact was not required as part of the consenting process.)

3.2 Before the Deluge 2.0 (Regional and Unitary Councils of New Zealand 2023)

This report is the basis of the 80 prospective projects seeking further government funding (Regional and Unitary Councils of New Zealand 2023). That tranche finalised in 2023 consists of 80 projects that would have a value of $329.35 million, with funding split 60:40 between central and local government, i.e. $97.61 m from government and $131.74 million from ratepayers.

The report gives details of each project: total cost, timing of commencement and the number of years over which the spending will be spent and also provides qualitative information about the generic benefits of the projects. But with few exceptions, it has no quantitative information on how the work would change the probability of flooding and none on the value at risk of property that could be flooded or of infrastructure disruption that would drive the scale and duration of disruption costs.

After the Deluge also cites benefit-cost ratios (BCRs) for flood risk reduction investment of 5:1 to 8:1 ascribed to the NZIER 2020 report, which in turn cited a US National Institute of Building Science report. This is a misinterpretation of the NIBS (2018) report (see 2.11.1 below).

3.3 Hiding in Plain Sight (Tonkin & Taylor Ltd 2018)

This report presents itself as an overview of current practices, national benefits, and future challenges in flood risk reduction, river control, and land drainage schemes in New Zealand. Amongst other things, it estimates a total value of flood risk reduction across New Zealand. It finds over 350 flood risk reduction, river control and drainage systems protect 1.5 million hectares of land, both urban areas and highly productive rural land. The schemes have a combined capital and operation value of $3.6 billion and provide $13 billion in benefits to New Zealand annually, in aggregate avoiding $55 of loss for every $1 invested.

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Covec Consultants provides the economic estimates in the report's Appendix E. The estimation of benefits from avoided damage costs and increased land value (for drainage and rural flood risk reduction) appears sound, and it also includes an allowance for non-market and intangible costs, which follows assumptions used by Greater Wellington Regional Council, Sapere and Deloitte Access Economics in Australia (see below) that the intangible loss is 100% of the direct damage estimate (i.e. the intangibles doubles the benefit estimate). But this report's BCRs are found by comparing these benefit estimates to costs which are described as "the present value of a council's stated annual operating expenditure on flood defence" (page 26). The capital costs of establishing the schemes are treated as sunk costs and do not enter into the calculation, so the BCR of 55:1 does not represent an investment appraisal of new or upgraded investments in flood control and river management and are simply not credible for use in supporting bids for government funding of new or expanded flood mitigation.

3.4 New Zealand fluvial and pluvial flood exposure (Paulik, Craig, and Collins 2019)

Prepared for the Deep South Challenge at Niwa by Ryan Paulik, Heather Craig and Daniel Collins, this report compiles a nationwide Flood Hazard area map from historical flood records and flood-prone soil maps for all New Zealand. It draws on local flood hazard maps to develop a national-scale flood exposure assessment methodology that gives aggregate order-of-magnitude estimates of exposure on a national basis. This identifies locations at risk of fluvial and pluvial flooding and overlays them with mapped data on buildings, infrastructure, land use activities, and residential populations to illustrate the value of assets at risk from flooding across the regions of New Zealand.

The paper includes high-level maps of the main flood-plain areas in New Zealand with a history of, or future likelihood of, fluvial flooding. It also has a table showing for each of the 16 regional councils and unitary authority jurisdictions in New Zealand the volume and some value of the social assets at risk in these areas. It shows the total flood-prone area is 8% of New Zealand's total land area, within which farmland accounts for 5.7%, urban land for 0.1% and undeveloped or natural landcover for 2%.

This report would be a useful depiction of the areas and assets at risk at a high level of regionally aggregated data. However, it does not yet appear to have progressed to the stage of estimating the damage value of floods of different durations or depths, nor enable linkage to the schemes identified in the 2020 and 2023 flood risk reduction lists.

3.5 RiskScape

RiskScape – a website containing geographically referenced information, more suited to detailed assessment of individual projects than programme-level analysis. It is maintained and copyrighted to the Institute of Geological and Nuclear Sciences and the National Institute of Water and Atmospheric Research (NIWA & IGNS, n.d.).

It is built on maps showing topographical features on which overlays of buildings, infrastructure, resident population and sources of natural hazard are placed. Flood risk maps have been produced showing the buildings and infrastructure in proximity to floodable rivers and coastal areas, allowing modelling of frequency, depth and duration of inundation from different types of events.

Monetary values can be attached to locations, such as rateable values of property and repair and replacement costs for buildings and contents in the event of flood damage. It can also be used to estimate some indirect impacts associated with flooding, such as clean-up costs and displacement costs, but to date, it has not had wider economic effects, such as disruption costs, in its datasets.

RiskScape has been used to build up and compare scenarios of inundation in particular locations, enabling quantification of buildings exposed to floods of different scales, and the number of residents exposed to and likely to be displaced by different types of floods. It can be used to estimate the number of residents exposed to flood risks, the number likely to be displaced by specific risks and the duration of that displacement that has implications for the costs of social services. It has been used to compare pre-scheme and post-scheme outcomes for flood risk reduction, but not yet for all localities at risk of flooding.

3.6 The economic cost of the social impact of natural disasters (Deloitte Access Economics 2016)

Prepared by Deloitte Access Economics for the Australian Business Roundtable for Disaster Resilience and Safer Communities, this report estimates economic values for the social impacts following natural disasters, including less visible and more intangible costs, such as increased mental health issues, family violence, alcohol consumption, chronic and non-communicable diseases and short-term unemployment. The report follows earlier sources that found intangible costs to be as high as the tangible costs and possibly higher in some devastating natural disasters (but based on a period of spectacularly devastating natural disasters, both wildfires and flood and storm events, which may not be applicable to fluvial flooding alone). The report concludes that a better understanding of the full costs of natural disasters strengthens the case for increased mitigation measures.

An updated report by Deloitte Access Economics (2021) revises cost estimates and forecasts likely future annual costs under low and high emissions scenarios. Floods away from the coastal zone are predicted to be the largest source of disaster costs in 2060 and have the largest difference between low and high climate change emission scenarios ($30.7 to $40.2 billion). Attribution of that increase is 31% to climate change, 7% to property value growth and 62% due to population growth. The report concludes there is a strong case for investing in resilience alongside emission reduction, but provides little detail on costs per hazard type or context that could be assessed for transferability to New Zealand conditions.

> By 2060 floods away from the coastline will be the largest source of disaster costs.

3.7 Submission to the Queensland Floods Commission of Enquiry (Lustig 2011)

This paper argues that most flood mitigation works are designed to provide only up to 1% Average Exceedance Probability (AEP), and that protection against rarer but larger events is rarely considered economical. Yet, on average, only about half of flood losses are from events with less than 1% AEP, leaving substantial damage liabilities beyond the protection currently provided. Communities that are prepared for floods tend to experience lower damages when floods occur, but attempts to reduce costs of future floods are hampered by communities' flood preparedness declining after adverse events have passed, and by lack of co-ordination among public emergency and land management agencies, among which high staff turnover leads to decline in experience about large infrequent floods.

3.8 Proposed Waipaoa River Flood Control Scheme Upgrade (Bevin 2010)

This report, described as a community economic benefit-cost assessment of upgrading options, presents a hybrid analysis with direct benefits that include construction and operating expenditure contributions to GDP, savings in damage and production losses and indirect benefits of flow-on impacts of construction, operations and savings on GDP. It compares these direct and indirect benefits with direct costs of the flood scheme. It conforms with neither CBA nor EIA methodology as established in the economics literature.

3.9 Urban Flood Protection Benefits – a project appraisal guide (Parker, Green, and Thompson 1987)

This manual from the Flood Research Centre at the University of Middlesex, in the UK, provides a detailed description of how to value flood damage and mitigation measures. It outlines a generalised framework distinguishing direct and indirect effects and tangible and intangible effects. This framework remains the basis for UK flood management and mitigation assessment, although it has been updated with UK-specific data.

This paper postulates vulnerability to flood losses (V) as a function of three variables:

$V = f(D, T, S)$

Where

V = vulnerability to flood disruption
D = dependence, the degree to which an activity requires an input to function
T = transferability, the ability to sidestep dependence by substitution, relocating etc
S = susceptibility, the probability and extent to which water affects the activity

3.10 Assessing intangible flood damages for evaluation urban floodplain management options (Handmer, Lustig, and Smith 1986)

This Australian paper proposes assessing intangible flood damage in terms of time lost to floods – with dollar values attached where that can be done reliably and uncontentiously. It examines intangible damages under three main headings: health effects, disruption and deaths. Health effects include physical injuries and conditions attributable to flooding events. Disruption impacts vary with a community's preparation (less for areas "used to" flooding) and duration of inundation, which disrupts travel to school, work, and business in town. The shorter the flood duration, the greater the relative share of clean-up and recovery activities in total disruption. Deaths from flooding due to drowning or induced stress have a low incidence – 80 such deaths in 40 years of flood records in Australia. Such deaths are commonly attributable to the sudden collapse of levees, overspilling urban creeks or flash flooding of transport arteries (the last two being more likely from pluvial than fluvial flooding). The authors advocate not using monetary valuations for flood-related fatalities because of deficiencies in the probability data and because monetary valuation can lead to decisions that are contrary to prevailing community values (e.g. discounted valuation methods may place low value on avoiding fatalities of the very young or very old, contrary to social preferences for protecting the frail and dependant members of society).

3.11 Investment in natural hazards mitigation (NZIER 2020)

This paper for the Department of Internal Affairs (DIA) reviewed natural hazard events over the previous decade to identify costs and unfunded liabilities that were borne by the government. Given a warming climate, it made forecasts of how the incidence of events could change in future decades. It found weather-related hazard events to be the most frequent, but large earthquakes were the most damaging, and two large earthquake sequences dominated government costs over the period. Future risks are likely to rise with climate change. Meteorological hazards are ubiquitous, but it is hard to predict where and when adverse events will occur. But fluvial flooding is oriented around existing river channels and flood plains, and it is relatively predictable to identify where social impacts are largest and most in need of mitigation. The report also cited research from the US National Institute of Building Science that found riverine flooding had some of the highest-yielding options for mitigation investment (see below).

3.11.1 Clarification on benefit-cost ratios

The *Before the Deluge 2.0* (Regional and Unitary Councils of New Zealand 2023) document cites achievable BCRs of 8:1 for riverine floods, which is attributed back to NZIER's (2020) report to DIA on *Investment in natural hazard mitigation*. The figures are indeed from that report, which in turn attributes them to the US National Institute of Building Science's report *Mitigation Saves* (NIBS 2018a).

However, the cost-benefit ratios should not be quoted verbatim as feasible in New Zealand, as they are calculated in the USA with different building codes and land use patterns than those found in New Zealand. But, they are the result of analysis of a much larger data series of projects and outcomes than are available in New Zealand, and their conclusions around the relative returns from mitigation of different hazards may be transferrable to New Zealand. A detailed guide on how to interpret the reported BCR for the USA flood risk reduction schemes is included in Appendix A.

3.12 Economic impacts on New Zealand of climate change-related extreme events – focus on freshwater floods (NZIER et al. 2004)

This report, prepared with researchers from GNS Science and the Cambridge University Centre for Risk in the Built Environment, provided recommendations to the Climate Change Office on how to better understand the economic impacts of climate change-related adverse events. It provides a broad review of methods and approaches used for quantifying the social impacts of floods and the critical role of depth-damage functions that can provide generalised values for expected losses for particular types of properties. But it also found that these are not available in New Zealand, the most comprehensive analysis of New Zealand flood loss had been undertaken in 1986, and that knowledge of more recent floods was scattered across separate regional councils and some academic researchers and research institutes, creating challenges in consistency and scope in building the bigger picture of trends in flood occurrence and societal impacts.

3.13 Impact of Natural Disasters on Production Networks and Urbanisation in New Zealand (Layton 2015)

This paper reviews New Zealand's history of natural disasters and its preparation for managing risks and responding to natural hazard events when they occur. With particular reference to the largest natural disasters caused by earthquakes it looks at estimates of tangible direct costs on property and indirect costs for GDP, and also at diverse effects of events on the population, labour market, reported crime, urbanisation and business location. It cites US studies of big natural hazard events causing a problem for investor confidence: insurance converts cover for a fixed asset into a payout of cash that is more mobile, enabling reinvestment to relocate out of damaged areas. The incentives on private businesses may work against rebuilding in situ, as in pursuit of agglomeration benefits from being close to other businesses, recipients of insurance payouts may relocate to where agglomeration already exists, rather than stay put to recreate conditions for agglomeration which depend on decisions by numerous other private parties. There are positive externalities in early commitments to restore infrastructure and keystone facilities, which may create liabilities for government, the risk of which is lessened by the mitigation of natural hazards.

3.14 Takeouts from the literature

The literature shows broad agreement with the flood cost framework used by Middlesex University's Flood Research Centre (see Figure 4), which distinguishes between direct and indirect and tangible and intangible components. A lot of quantified literature focuses on the most readily quantified direct and tangible area occupied by damage to insured property and infrastructure. The direct and tangible areas of damage are largely covered by insurance, but there are also at-risk items that are not insured, including:

- The excesses on insurance cover chosen by insured parties, a potential loss they are prepared to risk to reduce the cost of insurance cover
- Self-insurance by companies or individuals who consider this a more cost-effective option than paying for insurance
- Items for which insurance companies are unwilling to offer insurance at competitive rates because risks are too high or unpredictable, such as most agricultural crops
- Items for which insurance is unaffordable for their owners.

Figure 4 shows a long list of avoidable flood costs with more variable quantification and valuation, many of which are not practical to include in the analysis of net benefits for consistent comparison across options.

Figure 4 Flood costs that can be lessened by protection works

<table>
<tr><td colspan="2"></td><td colspan="2">Dimension</td></tr>
<tr><td colspan="2"></td><td>Tangible</td><td>Intangible</td></tr>
<tr><td rowspan="3">Form of loss</td><td rowspan="2">Direct</td><td rowspan="2">Damage to buildings, contents & infrastructure</td><td>Loss of heritage sites</td></tr>
<tr><td>Human cost & injury</td></tr>
<tr><td>Indirect</td><td>Loss of industrial production</td><td>Disruption of post-flood recovery</td></tr>
</table>

Avoided costs	Direct	Indirect	Intangible
Human costs			
Deaths			√
Injuries			√
Persons & Days in evacuation			√
Rescue operations	√		
Hospital & treatment costs	√		
Lost productivity from injury		√	
Mental anxiety/insecurity			√
Heritage degradation			√
Environmental health			√
Property damage & losses			
Buildings	√		
Homes	√		
Infrastructure	√		
Vehicles	√		
Stock	√		
Disruption costs			
Temporary infrastructure closure			√
Business lost revenue		√	
Business added cost		√	
Other added costs		√	
On-going production loss		√	√
Recovery/treatment cost			
During event costs	√		
Post-event costs		√	
Reputational costs			√

Source: NZIER drawing Parker, Green, and Thompson (1987)

Some flood-related impacts cross the boundaries between the direct, indirect and intangible categories: medical costs can be valued in monetary terms where they relate to hospitalisation or other treatments, but not where they relate to emotional trauma or loss of security and peace of mind.

Fatalities can be assigned an economic value according to public willingness to pay to reduce risks, as is done in NZTA's value of statistical lives saved. The NZTA figure of $13.5 million per fatality is a survey-based value of public aversion to transport risks. It is supposed to be specific to transport risk and the losses felt by relatives and associates of the transport casualties, but it does not necessarily reflect the societal cost of untimely deaths from other causes.

The literature allows for the enumeration of the values at risk to buildings and land uses within flood-prone areas across New Zealand. Table 4 draws from the NIWA 2019 report, which itemises rateable values of properties within areas at risk of flooding. It includes estimates of hectares of flood-prone areas that support buildings, productive agricultural or forestry use, and undeveloped status, but it provides no basis for ascribing dollar value to these last two categories of land (Paulik, Craig, and Collins 2019). For illustrative purposes, we update NIWA's 2016 dollar values to 2023 dollar terms using RBNZ's GDP deflator, value production land area at an all-classes 2023 average farmland price of $30,330/ha, and undeveloped land at the value of marginal grazing land of $13,230/ha. This results in the property value at risk of fluvial flooding is 76% in built-up areas, 20% in productive rural land, and 4% in undeveloped land.

Table 4 Property values at risk of fluvial flooding

	Built area value at risk $M	Production land value at risk $M	Undeveloped land value at risk $M
Northland	4,951	2,718	240
Auckland	35,444	1,887	301
Waikato	19,263	6,940	664
Bay of Plenty	4,238	940	379
Gisborne	2,825	692	53
Hawke's Bay	4,495	1,611	199
Taranaki	514	294	39
Manawatu-Whanganui	6,678	4,683	394
Wellington	17,722	1,550	313
Tasman	3,724	1,286	200
Nelson	2,697	64	20
Marlborough	1,284	1,195	238
West Coast	1,926	3,148	2,051
Canterbury	51,368	9,072	1,612
Otago	11,173	3,370	697
Southland	5,394	6,612	1,663
Total value for all regions	**173,112**	**46,059**	**9,063**

Source: NZIER, drawing on NIWA 2019 flood risk areas & Real Estate Institute of NZ farm sales data

4 Cost benefit framework for fluvial flood mitigation

4.1 Economic methods of evaluation

Economic impact analysis (EIA) typically measures the impact of macroeconomic measures of activity, such as economic value added, GDP, incomes, and employment. GDP can be measured as the total expenditure on final consumption goods in a given year, as total income derived from economic activity in that year, or as the total value of gross outputs of goods and services in that year minus the total costs of producing them. It counts only market values of goods and inputs, so it would count the costs of flood risk reduction and recovery work, but not the mental anguish of dealing with flood hazards and consequences.

The main alternative method of evaluation is CBA, which compares the stream of value gained from a given activity to the counterfactual situation without that activity. It is an adaptation of investment analysis to the public sphere, identifying all costs and benefits attributable to an activity wherever they fall, both for the proponents and third parties directly or indirectly affected. Benefits are any gains in value or costs avoided from the activity (compared to the counterfactual). Costs are losses or detriments compared to the counterfactual and specific costs of the activity valued at the opportunity cost of inputs used up. CBA can potentially incorporate non-market effects of an activity (such as flood damage to cultural, historic or natural heritage sites) if they can be valued. It provides a measure of social return from an activity and is the logical method for assessing flood mitigation investments, supplemented by EIA, where investment is likely to have an impact on macroeconomic matters.

The two programmes of flood risk reduction works are seeking government support to implement them or accelerate them for completion earlier than would otherwise be possible if left to affected communities to self-fund the work. The appropriate analysis to determine the social return on investment is CBA. Economic impact analysis provides useful context but will not identify a return on the investment. As the projects seeking funding have an average capital expenditure of around $5 million, most will not significantly impact the local economies in which they arise.

4.2 Steps in a cost-benefit analysis

CBA proceeds through a series of steps:

4.2.1 Define the counterfactual and the issue addressed by investment

In these programmes, the counterfactual is a risk of flooding likely to rise with climate change. The projects in the programmes reduce the risk and impacts of such flooding.

4.2.2 Define the scope of analysis, its viewpoint, and the area and timeframe covered

Flood risk reduction primarily benefits the area directly affected by the flood risk. But indirect effects of floods spread beyond the area directly affected, and there are positive externalities for wider regions and the country at large from projects that would not be undertaken by communities that directly benefit if unaffordable for them.

4.2.3 Identify the benefits of investment and when and where they occur

The benefits of flood risk reduction are primarily in the avoided costs of flood damage that would occur in its absence and in increased value for production or consumption realised by the reduced risk of flooding. See the section below.

4.2.4 Quantify benefits attributable to investment and when and where they occur

Quantification of benefits is most feasible for direct impacts of floods for which effects can be clearly measured; but more challenging for indirect impacts and impossible for intangible impacts such as effects on mental anxiety and sense of security.

4.2.5 Monetise benefits to the extent feasible or use defensible assumptions

Valuation of benefits can be based on changes in outcomes at market prices if available or at non-market values where feasible for intangibles or other effects not traded in markets.

4.2.6 Forecast outcomes under the counterfactual and with the project enacted

Subtracting one from the other identifies the net benefit of investment compared to the counterfactual.

4.2.7 Construct a discounted cash flow identifying net benefits over the cost of investment

Benefits are entered in the year in which they occur, as are capital expenditures and any maintenance or capital renewals expected throughout the project time frame.

4.2.8 Discount the values at different time periods into common present values

We use 5% as the public sector discount rate, as is currently recommended in the Treasury's CBAx model. CBAx also suggests 2% as an alternative rate for comparison, more aligned to the social rate of time preference than the social opportunity cost of capital.

4.2.9 Apply decision criteria to determine whether benefits exceed costs of the activity

Common criteria are the Net Present Value (NPV) obtained from Present Value Total Benefit less present Value of Total Costs; or Benefit-Cost Ratio (BCR) obtained by Present Value Total Benefit divided by Present Value Total Costs. A project produces net benefits if its NPV is greater than zero or its BCR is 1 or higher, but prudence may require a target for NPV that is greater with a margin over costs or BCR greater than 1 to allow for high uncertainty over outcomes or the inputs into the analysis.

The NPV represents the net value of benefits over the opportunity cost of resource inputs used in obtaining, and in general, choosing projects with the greatest NPV among all projects available maximizes the net value of investment. However, should there be excess projects for the constrained funding budget available, the highest programme NPV would be obtained by funding projects down the project list ranked by BCRs from highest to the point where funding is exhausted. That would enable more funding for small projects with a high return per dollar invested, whereas funding projects by their ranking by NPV would select fewer, larger projects with lower individual returns per dollar invested.

4.2.10 Apply sensitivity analysis to test the robustness of results to changes in key input values

As project CBAs may be strongly influenced by the choice of input values used in analysis, it is useful to test the robustness of results to changes in significant input values used in them. This may be done by using upper and lower bound alternative values for the most influential inputs into the analysis and interpreting how results change under low, medium and high input assumptions. Sensitivity tests can also be run on assumptions about the costs of inputs into the analysis, to test the results for robustness against changes in the cost side of the benefit-cost calculation.

4.3 Components of flood impacts and mitigation

Table 5 provides a framework of potentially quantifiable effects of flooding when they occur in a flooding event and what precautionary steps may be taken to avoid them.

Table 5 A framework of potentially quantifiable effects of flooding

Precautionary actions before the event	Impacts and actions during the event	Impacts and actions for 1-5 years after the event	Secondary effects on the macroeconomy
Protect		Losses of output due to reduction of capacity	Macroeconomic impacts
Reduce frequency and/or extent of flood hazard with stop-banks, riparian planting, pump stations, overflow paths	Damage to immovable assets and buildings	Forgone income	In the short term, reduced output and contribution to local value added and maybe to nationwide GDP
Accommodate			Reduced employment and incomes
Reduce the consequences and costs of flooding by elevating and wet-proofing structures, flood barriers and storage	Disruption of normal activities during event	Higher costs	Balance of payments
Retreat			Fiscal account balances
Permanent relocation of critical assets & people aware from flood-prone areas, through land buy-outs, wetland restoration, withdrawal of public services			Prices of goods, services and insurance
Avoid	Emergency services and rescue activity	New spending to accelerate recovery	In the longer term, stimulus from recovery spending
Ensure new development of assets not unduly exposed to flood hazard through planning restraints			Prices of insurance and properties change
Risk transfer			
Shift liabilities to where risk can be more readily			

Precautionary actions before the event	Impacts and actions during the event	Impacts and actions for 1-5 years after the event	Secondary effects on the macroeconomy
borne via insurance, in which many contribute little into a large pool that can be drawn on by the few who incur high cost from a high impact event			

Source: NZIER

The precautionary measures match those in the common PARA framework of Protect, Accommodate, Retreat and Avoid. To this is added a further step of residual Risk transfer through insurance, in recognition that there is always some residual risk that cannot be eliminated, and that the collective safety net of insurance can be useful in providing cover for subscribers from a pool of funds to which all contribute, and available to draw on by those who face costs of flood impacts beyond their capacity to recover independently.

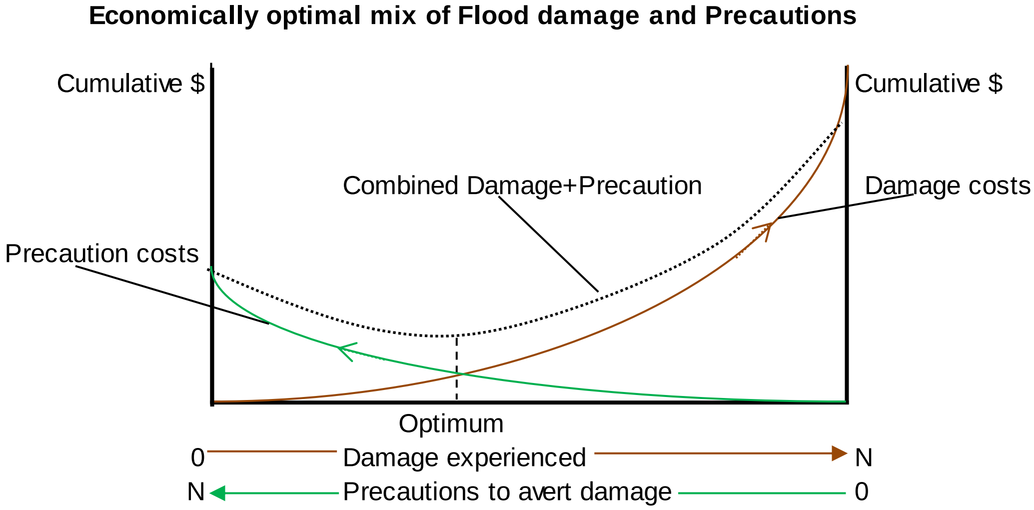
4.3.1 Impacts on the wider economy

Macroeconomic impacts are described as secondary effects in Table 5, not because they are unimportant but because they are further removed from the risk of flood losses and costs being incurred. Floods impact at a micro level, directly damaging property and disrupting activities in the affected area, less directly affecting supply chains into and out of the area and causing lingering loss of normal capacity, forgone income and higher costs until that capacity is restored. A big disruption may cause a reduction in regional economic value added or even national GDP, but economies adjust with other sectors, partially offsetting the losses. Floods provide opportunities for some sectors and stimulate those involved in post-flood reconstruction, which leads to the perverse result that big floods can appear to enhance GDP.

That is because GDP has well-documented limitations as a measure of general economic well-being (Stiglitz, Sen, and Fitoussi 2008) and should not be viewed as the sole metric of flood loss. GDP measures flows of value created by productive activity in a given period but does not measure the loss of flood-damaged buildings and infrastructure, which are stock assets that embody future value flows of a different order of magnitude from the annual production flows. As a measure of production, GDP does not explicitly account for non-production related transactions, the value of goods and services not sold in markets, or consumption that people and communities derive from the natural environment that would detract from their well-being if flood-damaged and not restored.

As flood risks cannot be eliminated – there is always a possibility of a larger flood occurring than has been experienced before that overwhelms all protection and precautions – an economically optimal balance for society is one that minimises the combined cost of precautions taken and residual flood costs experienced. This point can be found by pursuing precautionary measures in the PARA framework up to the point where the marginal value of additional precaution is equal to the marginal flood cost avoided by it. Figure 5 illustrates how the tracks of incremental changes in precautionary measures and flood damage move in opposite directions, as precautions increase from right to left while damage costs decline from right to left. This equi-marginal principle depends on an accurate assessment of costs of precaution and of costs of the expected value of floods, which is easier stated in principle than demonstrated in practice.

Figure 5 Finding the minimum combined cost of flood damage and precautions



Source: NZIER

4.3.2 Applications to flood risk and river management

Riverine floods are relatively well known to the extent that river courses and flood-prone areas can be identified, and the frequency of floods of different sizes can be discerned from historical records. Generally, the larger the flood, the less frequently it occurs, and with recurring floods of different sizes, it is possible to build up relationships between flood damage and likelihood. This allows floods of different sizes to be assigned a probability or frequency of expected occurrence, expressed as an average return interval (ARI) of floods of size X or an annual exceedance probability (AEP, i.e. the probability of a flood of size X being exceeded in any one year). These can be converted into annual average expected values of floods of different sizes.

Going beyond this to calculate the Annual Average Damage from floods of different sizes and Risk Density Curves of particular locations is explained in Appendix E of *Hiding in Plain Sight* (Tonkin & Taylor Ltd 2018). For the flood risk reduction schemes in the two report lists examined here, it is not necessary to attempt to estimate the total value of protection of existing schemes; rather, it should focus on the marginal gain in value from new scheme investment. As *Before the Deluge* is concerned with investment in new scheme upgrades, the benefit will be defined by the change in potential flood impacts avoided. For instance, some schemes are aimed at improving protection from a 1:30-year flood (3.3% AEP) to a 1:100-year flood (1% AEP). The benefits of avoided flood costs are driven by the difference between the annual expected cost of 100-year floods and that of 30-year floods.

The direct impact of change in flooding will be a function of the difference between:

- The area inundated and the share of land uses of different value (residential, commercial, industrial, agriculture)
- The loss ratio of inundated areas under each land use, reflecting a damage function for each land use

- The expected loss value attached to the areas of each land use suffering damage.

A larger flood will likely cover a larger area at greater depth than a smaller but more frequent flood. Applications like RiskScape can provide estimates in some detail of the areas and land cover affected by the inundation of various sizes of floods, but measures such as loss ratios or depth-damage functions, which are used overseas, are not widely available in New Zealand.

4.4 Benefits for inclusion in cost-benefit analysis

The broad components of flood damages are outlined in Figure 4 above. The following section indicates how to account for them in an analysis.

4.4.1 Direct impact, property damage and losses

These are frequently the major components of quantified cost-benefit analyses because they are most readily measured through insurance claims and payouts. To the extent that insurance claims attributable to floods are those caused by fluvial flooding as distinct from storm-related rainfall or coastal surges, insurance payout data is a high-reliability source on property damage and losses.

In addition to private insurance, Toka Tū Ake EQC covers damage to land around privately insured property, which is not included in standard buildings and contents insurance. This includes cover for claims of flood damage, such as erosion by flood waters and removal of sediment laid down by floods. Individual claims are capped under a limit of $300,000 per claim, and the area covered is limited to a small radius around buildings. Toka Tū Ake EQC Annual Report for 2023 suggests that for the combined weather events in early 2023 (principally Auckland Anniversary weekend floods and Cyclone Gabrielle), it paid out $486 million on claims, roughly 8% of the private insurance claims paid out for those events (Toka Tū Ake EQC 2023). As the data on payouts is less accessible than that from the Insurance Council, 8% can be used to mark up the insurance costs to account for Toka Tū Ake EQC-covered damage from floods. As Toka Tū Ake EQC does not currently have loss models for weather events and acknowledges significant uncertainty regarding outstanding claims in its Annual Report (p89), this can be considered a medium-high reliability source for damage adjustment.

However, insurance does not cover all such losses. While New Zealand has a high rate of insurance penetration among residential house owners by international standards, some properties subject to flood damage may be uninsured for reasons of unavailability, unaffordability or the excesses chosen by policyholders to reduce the cost of their cover. Even if insured, property may be under-insured, some of which is rational to the extent that a homeowner may want insurance to cover the replacement of essential home content lost to adverse events but may not want to cover all the contents accumulated throughout their occupancy of the house, some of which may hold sentimental value and be practically irreplaceable. Some under-insurance may be caused by error, such as homeowners underestimating the sum insured necessary to enable the repair or replacement of damaged structures. The Insurance Council of NZ has estimated between 25% and 40% of property (33–67% property damage) is under-insured (NZIER et al. 2004). That may be used as a basis for adjusting up the value of damages evident from insurance data but is of medium reliability.

In addition, insurance typically cannot compensate for losses that do not have a market value, such as damage to sites with heritage or cultural values.

4.4.2 Indirect impacts

Indirect impacts are those that are not directly caused by contact with floodwaters but are a consequence of disruptions to transport, power supply and water services, resulting in lost productivity during and after the flood and other extra costs incurred in working around the flood. Some business losses may be covered by insurance, but not all are insurable and added costs incurred by businesses, government agencies and the general public are generally not covered. Without a readily obtainable measure of such impacts, studies may survey businesses to estimate them or infer them in some other way.

Literature provides mixed evidence on how large indirect impacts are likely to be relative to direct impacts. This may be due to variations in the context in which these impacts arise or the method by which they have been inferred. In the NZIER et al. (2004) estimate of the Waikato weather bomb in 2002, direct costs accounted for 96.6% and indirect costs for 3.4%, but that included no estimate for business disruption. That report did cite estimates in an earlier study of Nelson and New Plymouth floods in 1970/71, which cited indirect losses at 13% of total cost and direct costs at 87%, in which 63% of total costs were incurred on roading, railways, power supply and river management infrastructure and termed direct.

In its recent update on economic costs of natural disasters in Australia, Deloitte Access Economics (2021) attributes the cost of floods 35% to (direct) property damage, 28% to other (indirect) financial costs and 37% to (intangible) social costs. Its proportional split for floods is similar to what it gives for bushfires. It is distinct from that for other natural disasters, such as storms, cyclones, earthquakes, and coastal inundation, in each of which the indirect costs are at least as large as, but mostly greater than, the direct costs on property. That may represent a revision in method from Deloitte Access Economics (2016) in which a breakdown of costs of the 2011 Queensland floods shows relief payments for businesses to get through the flood and recovery process, a proxy for indirect costs, to be 23%.

An adjustment factor of 1.2 to 1.3 could be used to estimate indirect costs of the direct property costs (i.e. indirect=1.2 or 1.3 x direct costs). However, this would have only low reliability.

4.4.3 Intangible impacts

Several studies have used a rule of thumb that unquantifiable or intangible impacts will be worth at least as much, if not more, than the value of tangible costs of floods. This appeared in Deloitte Access Economics (2016) report on the cost of Australian natural disasters, in which it cited estimates of the 2011 Queensland floods, which ascribed to intangibles 52% of total costs (a slightly lower share than for similar estimates for earthquakes and bushfires of around 55% of total costs). In their 2021 updated report (cited in section 3.4.2 above), Deloitte Access Economics still suggest that intangible social costs account for 52% of the combined total of direct and intangible costs (i.e. excluding indirect cost impact). Intangibles include cases of flood-attributed fatalities, injuries, exacerbated chronic illness, mental health impacts, high risk alcohol consumption and family violence.

While we do not have evidence to refute the idea that intangible costs are as large or larger than direct flood costs, we note that these Australian applications are associated with large-scale natural disasters and may not be so applicable to small flood risk reduction improvements. There is some support in the literature cited in NZIER et al. (2004) for treating indirect effects as insignificant for avoidance of small flood events, and the same could apply to indirect intangible effects that are not caused by direct contact with floodwaters.

An adjustment factor of 1.1 could be used to estimate intangible costs off direct property costs (i.e. intangibles=1.1 x direct costs). However, this would have only low reliability.

Values of protecting life, health and safety

Risks to life, injuries to people and exacerbation of chronic health conditions are all safety issues that can be associated with flood events. They can all be valued in economic terms by estimating the costs of treatments for injuries caused by floods, by the opportunity costs and value of lost production due to time off work for those injured by flood, or by applying a value for preventing fatalities based on survey responses about aversion to risk, as used by Waka Kotahi in its project appraisal procedures.

Some sources advocate that monetary values should not be placed on deaths due to flooding because of the controversy around methods and paucity of data for estimating the probability of drowning (Handmer, Lustig, and Smith 1986). Moreover, assigning dollar values to human lives may lead to decisions contrary to prevailing community values, such as not placing pedestrian crossings outside older people's homes because the discounted net benefit does not justify the cost. However, the valuation of preventing fatalities has moved on since this venerable literature. It is routinely used in other contexts of government programmes, so the reason for not valuing lives in dollar terms is less one of principle than one of practicality and whether there is a sound basis on which to assign safety risks to flood schemes.

As indicated above, the number of reported deaths from flooding in New Zealand is very small, and the value attached to them is open to debate in contexts other than road transport (in which the number of annual fatalities is relatively large, and it is possible to quantify risks faced by road users). We do not propose valuing fatalities and injuries separately beyond noting that safety is implicitly part of the generalised intangible impact.

Values of security for investment certainty

Increasing the protection of land from flooding is likely to increase the confidence in investing in the land to improve its productivity. This can be modelled in two ways:

- Increase in annual expected productivity above the current level of productivity
- Increase in the value of the land per unit area, which in principle is the capitalisation of expected future values in production for any (not just the current) uses.

These provide alternative ways of estimating value gain from investment certainty, and they cannot be used together without double counting the benefit. Flood risk is only one contributory factor to changes in land values, and the land value change attributable to a small change in flood risk can be overwhelmed by other factors affecting the value of an area of land.

Much literature suggests the impact of flood risk on property values tends to be rather small. Even when houses are flooded, and the market temporarily halts sales, with time, affected properties enter the market and achieve sale prices that recover to the level of similar properties outside the flood-affected areas. Short-term impact and long-term recovery have been observed in New Zealand in flooded areas in Kapiti, Coromandel and Manawatu (Aliyu et al. 2016; Keys 2015), as well as overseas. That limited consideration of flood risk may change for highly destructive events that leave highly risk-exposed properties uninsurable, but for flood risk reduction that results in small changes in risks, property valuation may not reveal appreciable differences in values with or without flood risk reduction. Estimates of annual increases in productivity may be a more reliable means of assessing benefits attributable to flood risk reduction changes than property values.

A counteractive effect of increasing security for investment certainty is that it may increase the value of property at risk of inundation should the flood protection be over-whelmed. Over the long term, damaging flood events have decreased in frequency but increased in magnitude after flood risk reduction schemes were built in New Zealand because of increased development and value at risk close to stop-bank protected areas (Ericksen 1986). The expected value of damage to that new development is likely to be smaller than the annualised value of the new development.

There is likely to be a positive value from investment certainty created by flood risk reduction, but no simple way of calculating that across a programme of project improvements other than a bottom-up aggregation of estimates for individual projects within the programme.

4.4.4 Government response spending

The avoidance of spending by governments (both central and local) in response to floods can be a legitimate benefit of flood risk reduction investments. When floods occur, costs are incurred in deploying emergency services, evacuating people at risk and finding temporary accommodation for them. Governments also face the liability for damage to their own public assets and infrastructure and the costs of repairing them back to working order, and they may also need to coordinate and assist in the clean-up of damaged areas. To the extent that these use up resources with opportunity cost reflecting their value used for other things which would be well-being enhancing rather than well-being restoring, those are legitimate flood losses that can be avoided by well-designed flood risk reduction work.

Governments may also be involved in relief payments for flood victims, providing income support to those who have lost their normal source of income due to flooding or those severely impacted by the flood and needing assistance to get back to a stable situation. While these sorts of payments have financial and fiscal implications for the government agencies involved, they are primarily distributional and should be treated as a transfer payment for CBA, which do not count towards either the costs or benefits of floods.

Therefore, the treatment of government response spending is complicated, and different components need to be disentangled from figures commonly seen on government response costs. For CBA, a distinction should be drawn between:

- Incremental resource costs incurred because of a flood:
  - this includes consumables like fuel used on flood-related call-outs, wear and tear on assets and costs for additional labour called in to attend to flood call-outs and should be counted in a CBA

    - but excludes the fixed costs of emergency services that would be incurred even if no flood occurred – including most labour if not called on to work overtime.

- Transfer payments made to provide relief for the flood affected and enable them to continue to access consumption goods and get on with living until the flood is over – these are distributional payments with no effect on long-term productive capacity, so they are excluded from an economic CBA (in the same way that social welfare payments are), although they would be included in a government analysis of its financial liability.
- Payments to accelerate recovery of economic activity and system, usually involving payments for spending of capital renewal and repairs, which is designed to restore economic activity to normal quicker than leaving infrastructure owners or regions to do so on their own resources: these can be included in a CBA as costs, along with expected benefits of restored capacity over the lifetime of infrastructure.

Emergency service costs have previously been estimated has been estimated as a proportion of property damage costs at 11% (Middlesex University 2001 referenced in Tonkin & Taylor Ltd (2018)), 5.6% (Middlesex 2007 referenced in Tonkin & Taylor Ltd (2018)) and 4% (Deloitte Access Economics 2013).

Deloitte Access Economics (2013, 36) identify Emergency response costs as 2.5% of the A$5.7 billion cost of the Queensland floods in 2010/11, and recipients of Category B relief payments accounted for A$26.3 billion, but it is not clear how much of that is income support and how much comprises recovery support. The Waikato Weather Bomb estimates cited in NZIER et al. (2004) had response costs at 21% of total direct cost.

A generalisable value for emergency flood response costs is not currently identifiable. It could be entered into analysis at between 2.5% and 20% of direct costs, with low reliability, and subject to sensitivity testing of impacts of different values on results.

4.4.5 Insurance

Insurance does not reduce the risks to the community or mitigate the actual damages of a flood; it simply redistributes the costs — many people pay to cover the losses of a few. This makes it a transfer payment that is not normally included in a CBA’s net benefit calculation from funds invested. But, in some jurisdictions, impacts on the insurance market have been included as a benefit of flood risk reduction, particularly in Australia.

The pretext for this is the impact that flood mitigation can have on insurance markets. While private insurance markets pool costs of losses from natural hazards across a wider group (policy-holders, insurers and reinsurers), concerns have been raised about the availability and affordability of flood insurance for households and small businesses in parts of Australia. That raises concerns about over-reliance on disaster assistance from the government as an ‘insurer of last resort’. That can affect post-flood costs for taxpayers and create expectations of continuing taxpayer assistance.

Some Australian consultants have included reductions in insurance premia as a benefit of flood mitigation schemes. The rationale is that flood mitigation makes insurance in those areas more affordable and widens the pool of private insurance cover, which makes it a relevant component in the business case for flood mitigation. In some of these analyses, better insurance cover is a dominant component of net benefits, up to 59% of gross benefits in one instance (Urbis 2014). While removing these insurance benefits may not overturn these positive CBA results, it does look like mixing a financial issue (who pays for cover?) with an economic one (does it improve protection of production and consumption assets?) to give a larger apparent NPV.

It is unclear from these reports how flood risk reduction translates into savings in premiums for policyholders and benefits for new policyholders. In this report:

- Insurance payouts on claims are a useful available indicator of direct costs incurred from flooding, albeit not total costs, and hence of the benefits of avoided costs from flood mitigation.
- Insurance premium payments by policyholders are the price they pay for the cover they receive, but we do not expect these to change significantly with the enhancement of flood schemes of the scale indicated by programmes of small upgrades.
- Insurance costs are part of the cost of security for communities across New Zealand and, in the long term, may rise with changes in climate risks, which will increase the value of mitigation installed to reduce these rising costs – however, forecasting how the value of mitigation will change is beyond the scope of this current investigation.

In other words, insurance payouts are transfers and irrelevant for CBA in the short term, except as indicators of the damage incurred in flood events. People are willing to pay each year for insurance coverage they hope they'll never use, but it's there to cover extreme impacts. Individuals can reduce their insurance costs by choosing low-risk locations, but the societal risk of damage does not diminish if high-risk houses remain in use. In the long term, rising risks, insurance premiums and payouts are costs for society. However, risk reduction cannot be attributed to flood risk reduction schemes being too small, individually or in combination, to shift that risk – unless there is a large programme of schemes that collectively reduce damage risk for a significant proportion of properties. The above analysis also applies to situations where private insurers withdraw offers to cover areas with increased flood risk which increases reliance on disaster assistance from government as "insurer of last resort."

4.5 Framework for estimates

From the above, a framework for compiling estimates of the costs of floods and the change in costs with flood risk reduction upgrades is outlined in Table 6. This draws explicit connections between the items that appear in the cost-benefit analysis of flood risk reduction and those that appear in an economic impact assessment. The presentation of data in the two assessments can vary because of the different focus of CBA and EIA.

Insurance claim data provide some of the most reliable data about flood losses, but additional estimates are required to account for damage to uninsured property and also perhaps for direct production losses that are not covered by insurance. Previous estimates commonly drive indirect disruption off a factor adjustment to direct costs, and indirect government costs need a bespoke estimate that will likely vary with the scale of the flood event. Intangible effects covering costs on human health and safety and environmental impacts have also been widely assumed to be about the same as estimated direct impacts. That completes the categories of impact, the reduction of which can be compared with spending on protection upgrades in the cost-benefit analysis.

The table also shows the main connections between inputs into the CBA and an EIA. Most insurance claims do not fit with an EIA, as they represent losses to the stock value of property and equipment, which has little connection to the annual production inputs and outputs in the national economic accounts. Insurance doesn't cover all agricultural crops and stock losses that contribute to the outputs of agriculture and its dependent industries. Indirect disruption, which results in output forgone or additional costs incurred during the flood event, directly affects the outputs and costs that drive economic value added. Indirect government responses can also be significant, albeit often spread over more than one year. Spending on the upgrade will hence appear simultaneously as an investment cost but also as a stimulant to the economy that positively contributes to GDP.

Table 6 A framework of potentially quantifiable effects of flooding

Benefit and cost items	Impacts and sources	Reliability	Connections	Secondary effects on the macroeconomy
Benefits (avoided cost)				
Direct Property losses	Insured property losses (from claims data)	High	→	Loss of saleable stock, crops and other outputs (but not buildings)
	Uninsured property losses (factor adjustment)	Medium		
Direct Production losses not covered above	Bespoke estimates (press reports, etc.)	Medium	→	Loss of saleable stock, crops and other outputs (but not buildings)
Indirect Government response spending	Emergency services rescue and recovery support (rate from previous events)	High (after event)	→	Daily cost of service call-outs; lump sum payments towards restoring capacity
Indirect disruption	Output losses or Additional costs incurred by reduced infrastructure capacity while flooded or being repaired (factor adjustment from previous studies or bespoke estimates)	Low	→	Lost output or additional costs incurred from disruption of infrastructure and distribution chains
Intangible effects	Factor adjustment on direct losses (2 x direct losses in earlier studies)	Low		
Costs of protection				
Spending on upgrade	Investment total, local and national split	High	→	Impact on expenditure, incomes, jobs

Source: NZIER

5 Case studies

In this section, we apply the cost-benefit framework outlined above to three case studies of recent flood risk reduction projects that have been completed. There is more quantitative information about project costs and who funds them than there is about what benefits the projects provide, so the following analysis relies on default values and assumptions drawn from what's known about other flood risk reduction works done in the past.

5.1 Kaitaia – Awanui River

Before the Deluge (2) describes how Northland Regional Council's 2018–2028 long-term plan prioritised upgrading flood risk reduction schemes from a 1:30 year (3.3% AEP) to 1:100 year (1% AEP) flood level with funding split 30:70 between regional and local rates. With a cost of $15.5 million, work started in 2019 and was due for completion in 2027. However, an injection of $8.5 million from the central government accelerated the work by five years to completion in 2022. This was very timely as it offered protection against a 1:100-year storm event, Kaitaia's largest since 1958, when there was widespread flooding in the town. With the new upgrades, despite heavy rain, power outages and slips on roads, no one needed evacuation. The town averted an estimated $50 million damage cost, implying a BCR of around 3.62 over 30 years at a 4% discount rate.

This case study illustrates two aspects of the economics of flood risk reduction works. One is that the general value of flood risk reduction in averting damages is much greater than the work put in place. The other is the importance of timely intervention in building upgrades: had government money not been available to advance the completion of the upgrade from 2027 to mid-2022, Kaitaia would have endured a flooding event with $50 million in damages.

5.1.1 Analysis

Good timing meant that Kaitaia's upgrade avoided a $50 million damage cost flood after completing its 1:100 year flood defence upgrade. If the weather had not supplied a flood of that size, there would remain an annual risk of such a flood being experienced every year until protective works were upgraded. That provides a basis for examining the net benefit of the upgrade and the effect of delay in installing such works.

A NIWA (2020) report to the Northland Regional Council used the RiskScape model to identify building exposure and losses with and without completion of the Awanui scheme. It estimated building losses before the scheme completion of around $25.8 million would reduce by 63% to around $9.6 million after scheme completion, the latter figure reflecting the residual probability of damage and loss from even larger but lower probability events than the 1% AEP floods. The building losses included costs of repair, content replacement, plant replacement, stock replacement, clean-up costs and displacement.

With this information, we can construct a cost-benefit analysis of flood risk reduction upgrades in the Awanui River, with a timeframe of 30 years, using discount rates of 5% and 2% as recommended by Treasury's CBAx model. We estimate the average annual expected value of flood costs with and without the upgrade as follows:

- Direct impact to property is $0.78million without the upgrade and $0.096 million with it

- Uninsured damage, at 33% of insured damage value, adds 0.26 million without and $0.03 million with the upgrade
- EQC payouts on damage to land, at 8% of insured damage, add $0.06 million without and $0.008 million with the upgrade
- Indirect impacts of emergency call-out cost at 4% of direct damage, add $$0.03 million without, $0.003 million with the upgrade
- Indirect disruption costs at 1.25 times the direct damage costs, add $1.37 million without and $0.17 million with the upgrade
- Intangible costs, at 104% of direct tangible costs, add $1.19 million without and $0.15 million with the upgrade
- The annual total cost is $3.69 million without or $2.37 million with upgrade; in both cases, the split is 30% Direct, 38% Indirect and 32% Intangible.

The difference between the without and with figures is a saving in expected costs in the future and provides an economic benefit from the project.

The analysis results depend on what's included in it and the discount rate[2] applied, as shown in Table 7. Applying a 5% discount rate,[3] the upgrade does not quite break even over 30 years when only direct costs are averted compared to costs. However, including indirect costs pushes it comfortably into positive territory with an NPV of $17.6 million and a BCR of 2.14. Including a value for Intangibles would almost double the NPV to $33.6 million and raise the BCR to 3.16.

When applying a lower discount rate of 2%, all the results are more strongly positive, with the highest NPV reaching $55 million NPV with a BCR of 4.55.

2 Discount rates are used to reflect the preference of society or individuals to use resources now rather than at some time in the future. For society to regard a benefit in the future to be equal to a benefit today, the amount of the benefit of the future has to be higher to compensate society for having to wait. For example a discount rate 5% reflects the idea that society places the same value on a $100 benefit now as a $105 benefit in one year ($100 plus compensation for waiting of 5%). Discounting uses discount rates to convert the value of future benefits to their value today by allowing for the cost of waiting. As part of the discounting calculation the discount rates are compounded. This has two effects. First, the present value of future benefits declines rapidly as the time at which the benefit received increases. For example at a discount rate of 5%, $100 in 10 years is worth $61 today and $100 in 20 years' time is worth $38 today. Second, lower discount rates produce higher present values. For example at a discount rate of 2%, $100 in 10 years is worth $82 today and $100 in 20 years' time is worth $67 today.

3 The technical arguments about the choice of discount rate are complex and beyond the scope of this report. The United Kingdom takes a more granular approach to discounting the benefits of by applying different discount rates for economic effects as opposed to selected impacts on people and then lowering the discount rate over time. For economic impacts the discount rates are: 3.5% for years 0 to 30, 3.0% for years 31 to 75 and 2.5% for years 75 to 125. For valuations of 'risk to life', 'mental health', 'human-related intangible costs to stress and health' and 'emergency services' the discount rates are valuations', 1.5% for years 0 to 30, 1.286% for years 31 to 75 and 1.071% for years 75 to 125. See 'Guidance FCERM grant-in-aid: discount rates, price indices and capping Published 22 November 2021' available at https://www.gov.uk/government/publications/fcerm-grant-in-aid-discount-rates-price-indices-and-capping/fcerm-grant-in-aid-discount-rates-price-indices-and-capping . *This guidance is for flood and coastal erosion risk management (FCERM) project teams who need to apply for government flood defence grant-in-aid (FDGIA) for projects or strategies.*

Table 7 Results of the Awanui flood risk reduction upgrade

	Units	Direct Benefit	Direct & Indirect Benefit	Direct, Indirect & Intangible Benefit	Direct Benefit	Direct & Indirect Benefit	Direct, Indirect & Intangible Benefit
Direct cost averted	$M	27.9	27.9	27.9	27.9	27.9	27.9
Indirect cost averted	$M	0.0	35.6	35.6	0.0	35.6	35.6
Tangible cost avoided	$M	**27.9**	**63.5**	**63.5**	**27.9**	**63.5**	**63.5**
Intangible cost averted	$M	0.0	0.0	30.2	0.0	0.0	30.2
Total benefit	$M	**27.9**	**63.5**	**93.7**	**27.9**	**63.5**	**93.7**
Project costs	$M	**15.5**	**15.5**	**15.5**	**15.5**	**15.5**	**15.5**
PV Benefits	***PV$M***	**14.55**	**33.16**	**48.92**	**21.00**	**47.84**	**70.58**
PV Costs	***PV$M***	**15.50**	**15.50**	**15.50**	**15.50**	**15.50**	**15.50**
Net present value	***PV$M***	**-0.95**	**17.66**	**33.42**	**5.50**	**32.34**	**55.08**
Benefit-cost ratio		**0.94**	**2.14**	**3.16**	**1.35**	**3.09**	**4.55**
PV breakeven in Year			10	7	21	9	6
Discount rate		5%	5%	5%	2%	2%	2%

Source: NZIER

These results show the importance of net benefits of accounting for indirect impacts of flooding avoided by upgraded flood risk reduction, which literature suggests are usually larger than the direct impacts on property, albeit difficult to measure precisely. Indirect impacts are dominated by disruption to normal activities, and they particularly affect impacts on infrastructure and its role in supporting other economic activity. Floods reduce the capacity of transport infrastructure, completely for those stretches while inundated with water and partially for periods after flooding due to repairs of flood damage. Flood risk reduction is infrastructure that protects other infrastructure, including power, telecommunications and water services, as well as transport networks. As observed in previous studies, the method of assigning value to indirect effects as a ratio applied to damages is approximate but is widely applied and may be moderately reliable in the context of this valuation.

Accounting for intangible values also makes a significant difference to NPV and BCR results. As observed elsewhere, the method of assigning value to intangibles as a ratio applied to damages is approximate. However, if widely applied, it may be moderately reliable in the context of this valuation. However, the range of physical and mental health effects included under intangibles is more likely to be associated with major disaster events, involving widespread evacuation and displacement of people and loss of homes and livelihoods more than with smaller, more average floods, which would make this method of low reliability applied to such smaller floods. Many intangible effects relate more to a community's well-being and consumption possibilities than its production possibilities, but they also relate to long-term government liabilities for social services spending in a more attenuated way than the more obvious direct and indirect flood impacts.

Economic impacts

While Table 7 shows the benefits and costs of the Awanui project, it also results in economic impacts for the Northland region. This arises from the $15.5 million capital spending input into the project, but more particularly with the benefit of avoiding disruptions to economic activity in future years, which has a present value of $18.6 million with a 5% discount rate or $26.8 million with a 2% discount rate.

Treating these expenditures as outputs, we convert them to economic value added and its components using ratios from Statistics NZ Input-Output tables. This results in:

- Economic value added (GDP contribution) of $5.1 million from the construction stage and $8.7 million value added from the avoidance of average flood disruption
- Employee compensation (salaries and wages) of $3.5 million from the construction stage and $4.2 million employee compensation from avoidance of flood disruption.

These need to be viewed in the context of the Northland economy, which Statistics NZ's regional GDP figures show contributed $9.3 billion to New Zealand's total GDP of $361 billion in the year ending March 2022. Based on this conservative assessment, the flood risk reduction project can be expected to make a positive but modest contribution to regional economic wellbeing. By fortuitously averting a large flood event in late 2022, the Awanui upgrade has already exceeded that modest contribution: assuming the $50 million cost cited in *Before the Deluge* (Regional and Unitary Councils of New Zealand 2022) covers direct costs and indirect response costs only, indirect disturbance averted could amount to around $62 million costs, that would translate to $29 million positive gain in GDP contribution and $14 million gain in employee compensation.

Economic impact analyses often refer to the flow-on effects of how projects stimulate more businesses backwards up their supply chains and forward into businesses supplying additional consumer demand from those affected by the projects. Such multipliers derived from input-output tables of inter-industry transactions often show GDP impacts 2–3 times larger than the project's direct impact and employment ratios even higher. However, these multipliers drawn from static tables of industry transactions usually overstate the size of the impact of new projects as they do not reflect the dynamic responses of the economy to new demands on its resources. If new projects increase demand for labour or other locally constrained inputs, that pushes up their price for all industries that use them, reducing profitability for some and partially offsetting the benefit of the new project. It is possible to estimate impacts with price changes using computable general equilibrium modelling, a complex process best applied to projects larger than the Awanui upgrades.

In the case of the Awanui stopbanks, there will be positive, indirect flow-on impacts, but the exact scale is difficult to determine, and they will, in any case, not be significant in the context of the Northland economy.

Distribution of costs and benefits

The $15.5 million cost of the Awanui upgrades was funded by local government ($7 million) and central government ($8.5 million), which is a 45:55 split.[4] Present value benefits could also be split by the same ratio: for example, splitting the $33.16 million present value benefits of direct+indirect cost averted (discounted at 5%) would provide a gross benefit of

[4] The Central Government contribution to this project is lower than the 60% Central Government contribution proposed in 'Before the Deluge 2.0' see page 91.

$14.6 million for local government input and $18.6 million for central government input, providing a return on investment as measured by BCR of 2.1 for both parties. Applying a lower discount rate and/or including a value for intangibles would increase the returns for both funding parties.

The 45:55 funding split is very close to the split between direct and indirect benefits (44:56) in the Table 7 analysis. So local funding is roughly proportional to the protection of local assets from direct flooding damage, while national funding is roughly proportional to the averting of indirect flooding disruption, which has a direct impact on local economic activity and contribution to regional value added, a constituent part of national GDP.

Some economic analyses of natural disasters and protection investments include a fiscal analysis in which central or local government funding is matched against the fiscal return from the protection provided, such as tax paid on additional activity enabled by the investment. This is more a form of financial analysis than economic analysis. It focuses on who pays and who gains and applies a more detailed lens to cause and effect and stringent criteria on what gets funded as it requires a higher range of benefits to recover funds on tax taken. To do such an analysis would require examining the government tax expenditures to deal with harms attributable to flooding that could be alleviated by flood risk reduction, an exercise which does not appear to have been comprehensively done in the literature reviewed. This analysis follows the international literature on costs and benefits of flooding, focusing on the total benefits and costs of funds invested.

Investment timing can be critical

An injection of funding from central government accelerated the completion of the Awanui flood risk reduction upgrades, which would otherwise not have happened because of local funding constraints. The effect of acceleration is to increase the net benefits of the upgrade. Table 8 compares the effect of delaying completion with the results in Table 7, focusing on the costs and direct plus indirect benefits only.

Using the same analysis frame as Table 7, the Table 8 analysis defers realisation of benefits until the 6th year of analysis and also spreads the $15.5 million costs evenly across the first 5 years. The effect of so doing is to reduce both the present value benefits realised and the costs of completing the project. Using the 5% discount rate, the NPV of $8.15 million is less than half that in the Table 7 results, and BCR falls to 1.58 from 2.14. Using a 2% discount rate is slightly less aggressive in reducing future benefits, so the NPV of $17.66 million is slightly greater than half the Table 7 result, and BCR falls to 2.32 from 3.09.

Table 8 Effects of delaying the Awanui flood risk reduction upgrade

	Units	Direct Benefit	Direct & Indirect Benefit	Direct, Indirect & Intangible Benefit	Direct Benefit
		5 year delay		As per Table 6	
Direct cost averted	$M	24.0	24.0	27.9	27.9
Indirect cost averted	$M	24.0	24.0	35.6	35.6
Tangible cost avoided	$M	**48.1**	**48.1**	**63.5**	**63.5**
Intangible cost averted	$M	0.0	0.0	0.0	0.0
Total benefit	$M	**48.1**	**48.1**	**63.5**	**63.5**
Project costs	$M	**15.5**	**15.5**	**15.5**	**15.5**
PV Benefits	***PV$M***	**22.29**	**34.67**	**33.16**	**47.84**
PV Costs	***PV$M***	**14.14**	**14.92**	**15.50**	**15.50**
Net present value	***PV$M***	**8.15**	**19.75**	**17.66**	**32.34**
Benefit-cost ratio		**1.58**	**2.32**	**2.14**	**3.09**
PV breakeven in Year		19	15	10	9
Discount rate		5%	2%	5%	2%

Source: NZIER

As the table indicates, deferring completion reduces the present value cost of a scheme upgrade, but it reduces the present value benefits by a greater amount and lowers the overall return from the investment. In the case of the Awanui upgrade, such a delay would not have avoided damage from the late 2022 flooding event with its estimated $50 million cost. With hindsight, it appears that central government's intervention with $8.5 million to accelerate the completion averted a cost of $50 million. In such cases, relatively small investments in flood risk reduction upgrades can yield big returns.

5.2 Taradale – Tūtaekurī River

The Taradale stopbank beside the Tūtaekurī River in Hawke's Bay was recently upgraded to increase its level of service from a 1% AEP (against 100-year flood) to 0.2% AEP (against 500-year flood). This involved raising 2.5 km of the stopbank by 1 metre in height and increasing its slope from 1:2 to 1:4 metres. The work cost $4 million and was completed in November 2022, in time to protect Cyclone Gabrielle in February 2023.

There were nearly 10,000 properties with a capital value of $7.6 billion in the floodplain protected by this stopbank. In other parts of Hawke's Bay, there were 30 breaches or over-toppings of stopbanks across 5 km of the stopbank network during Cyclone Gabrielle, including some on the Tūtaekurī River. The 10,000 properties behind the Taradale Stopbank escaped significant damage by the timely completion of this upgrade, aided by government co-funding, and contributed to Napier having only 132 damaged properties 'stickered' for damage during the cyclone, compared to 920 in Hastings and 530 in Wairoa.

Aside from the flood risk reduction benefits, this project was associated with creating 32 jobs during construction work and planting 37,000 native plants across 11.4 hectares of riparian land.

In May 2023, Hawke's Bay Regional Council (2023) estimated the cost of the damage[5] caused by Cyclone Gabrielle to amount to $4 billion due mainly to losses for the primary sectors (mainly agriculture, horticulture and viticulture), damage to local government infrastructure, central government response and relief costs and cancelled events. Adding private insurance claims of just over $979 million would bring the total identified damage to $5 billion.

Analysis

Table 9 shows the results of a cost-benefit analysis of the Taradale stopbank prepared using the same framework as that for Awanui. Without RiskScape modelling showing property damage under the two states of flooding risk with and without the upgrade, we estimate annual values under the different states of protection based on 1% of the capital value at risk in the area. The results are slightly less positive than Awanui's, with direct costs not breaking even and BCR at 1.13 for direct + indirect costs.

Table 9 Results of the Taradale stopbank upgrade

	Units	Direct Benefit	Direct & Indirect Benefit	Direct, Indirect & Intangible Benefit	Direct Benefit	Direct & Indirect Benefit	Direct, Indirect & Intangible Benefit
Direct cost averted	*$M*	10.9	10.9	10.9	10.9	10.9	10.9
Indirect cost averted	*$M*	0.0	13.6	13.6	0.0	13.6	13.6
Tangible cost avoided	*$M*	**10.9**	**24.6**	**24.6**	**10.9**	**24.6**	**24.6**
Intangible cost averted	*$M*	0.0	0.0	11.8	0.0	0.0	11.8
Total benefit	*$M*	**10.9**	**24.6**	**36.4**	**10.9**	**24.6**	**36.4**
Project costs	*$M*	**11.4**	**11.4**	**11.4**	**11.4**	**11.4**	**11.4**
PV Benefits	***PV$M***	**5.70**	**12.83**	**19.00**	**8.22**	**18.50**	**27.41**
PV Costs	***PV$M***	**11.40**	**11.40**	**11.40**	**11.40**	**11.40**	**11.40**
Net present value	***PV$M***	**-5.70**	**1.43**	**7.60**	**-3.18**	**7.10**	**16.01**
Benefit-cost ratio		**0.50**	**1.13**	**1.67**	**0.72**	**1.62**	**2.40**
PV breakeven in Year			24	14		17	12
Discount rate		5%	5%	5%	2%	2%	2%

Source: NZIER

This analysis based on differences in average risk underestimates the value of the project built, as it omits the benefit of averting far higher costs in the year of Cyclone Gabrielle. The

5 page 25, Table 1: Costs of Cyclone Gabrielle to Hawke's Bay (as at May 2023) See Appendix See Appendix F for sources and more information.

Insurance Council of New Zealand estimates the cost of claims for Cyclone Gabrielle to be $1.7 billion, of which house claims account for 39%, business claims account for 46%, house claims account for 39%, contents claims for 7% and motor vehicle claims for 6%. The average claim per house is $25,925 and for contents, $10,677. If, by way of illustration, the upgraded stopbank had not been built before the Cyclone arrived, and if Napier experienced another 400 stickered houses, bringing its total similar to that of Wairoa, and if these new buildings attracted the average claims value for house and contents of around $36,500, that would result in additional claims value of $14.6 million. Applying the adjustments for EQC claims, uninsured claims and indirect impacts to that base, these 400 stickered homes would raise direct impacts in Napier by $19 million and generate indirect impacts of around $24 million in 2024 alone. Avoiding additional impacts of that single event alone would yield a BCR of 2.1 by the end of 2024, so the stopbank upgrade more than paid its way in averted costs in its first year of operation.

Economic impacts

The $11.4 million capital spending input into the project injects money into the regional economy during the project's construction phase and the $7.1 million present value of averted flood disruption over the stopbank's operational life. Converting these to economic value added using ratios from Statistics NZ input-output tables results in:

- Economic value added (GDP contribution) of $3.8 million from the construction stage and $3.4 million value added from the avoidance of average flood disruption
- Employee compensation (salaries and wages) of $2.6 million from the construction stage and $1.6 million employee compensation from avoidance of flood disruption.

These need to be viewed in the context of a Hawke's Bay economy, which Statistics NZ's regional GDP figures show contributed $10.7 billion to New Zealand's total GDP of $361 billion in the year ending March 2022. On this conservative assessment based on average risk values, the flood risk reduction project can be expected to contribute positively but modestly to regional economic wellbeing. By fortuitously averting the adverse impacts of Cyclone Gabrielle, the Taradale upgrade has already exceeded that modest contribution.

Distribution of costs and benefits

Although *Before the Deluge* 2.0 refers to central government co-funding, no details have been found of the funding split between local and central government input for this project. However, 'Before the Deluge 2.0' proposes government co-funding of 60% of the project cost:

> *As outlined in the Economic Case, the total cost of the 80 projects amounts to $329.35 million, with a proposed cost-apportionment of 60:40 between central government and regional councils.* (Regional and Unitary Councils of New Zealand 2023, 91)

5.3 Tairāwhiti – Waipaoa River

The Gisborne District Council sought an investment of $6.0 million from the Provincial Growth Fund to match its ratepayer contributions towards strengthening 21 kilometres of stopbanks to protect the Poverty Bay Flats, parts of Gisborne City, Gisborne Airport and an area that includes 20,000 ha of agricultural/horticultural land, $7.0 billion worth of assets, major transport networks and homes for more than 10,000 people. It described the existing structures as well maintained but needing upgrading to counter the intensity and increasing frequency of climate change-induced weather events that were placing the risk reduction capability of the scheme under stress.

Of the $12 million sought, physical works and construction would require $10.8 million, $1 million would cover detailed design and project management, and $200,000 would cover archaeological investigations and securing planning consent and land access. Physical changes would involve raising stopbanks by 1-2 metres in height and widening the crest top from 2 to 4 metres to accommodate a cycle track along the stop banks. Such an upgrade would retain the stopbank's current service standard as protecting against a 100-year flood (1% AEP flood), whereas without an upgrade, it is expected protection will fall to around 1 in 20 (5% AEP) or 1 in 40 years (2.5% AEP) flood by 2090.

With work proposed to start in 2019, it would have taken Gisborne District 6 years to complete, leaving Gisborne at risk of floods until completion. With Government assistance, it was completed in 4 years. Apart from protection of people and assets, the application cited greater certainty for investment from reducing risks of flooding, providing security to landowners to get or retain their insurance cover, greater diversity of businesses attracted to the location by greater standard of flood risk reduction, and development of amenity features such as the cycle trail and bankside plantings to improve resilience against climate change effects.

An update on project progress indicated the government funding sought from the Ministry of Business, Innovation & Employment’s Regional Economic Development and Investment Unit, Kānoa, had risen from $6 million to $7.5 million, covering work from 2020 to 2023. Around 20.6 km of stopbank construction had been completed by March 2022, and a further 3 km was completed by April 2022. An additional 1.2 km would be completed by January 2023, bringing the total upgraded to 25 km. This is the first part of upgrading 64 km of stopbanks on the Waipaoa River; the rest will be progressed after 2023 for completion by 2030/31, for a total cost (2019–2030) of $32–$35 million.

The key benefits identified for the scheme were boosting local employment (12 new staff employed by contractors), climate change adaptation and protection, contributing to community infrastructure (the cycleway), money flowing back into the local economy and enabling affordability for communities unable to absorb increased rates to pay for upgrade work (i.e. benefit of government support rather than on the flood risk reduction itself).

An economic analysis of upgrades was prepared in 2010, claiming to show benefits ranging from 5.3 (for retaining 1% AEP) to 6.9 (raising protection to 0.5% AEP) (Bevin 2010). However, this was not a conventional CBA, as its benefits included savings in damage to property and production losses, as well as the GDP impact of construction and operation and maintenance, in effect, counting a portion of the costs as a benefit.

Analysis

The Waipaoa analysis is challenging as it is required to arrest the deterioration of the level of service of the stopbanks from a current 100-year flood standard to 20 to 40-year flood levels by 2090. That is a relatively long period, implying a slow rate of deterioration and change, much of it occurring decades hence when the present value of any financial impact will be vanishingly small. The Waipoua upgrades completed in 2023 (25 km of stopbank) were also part of a much larger scheme (64 km of stopbank), which raises the question of how the two parts of the works affect each other and how their linkages affect the benefits provided. For instance, the effectiveness of downstream flood risk reduction can be affected by how upstream river management works to slow and dissipate energy in surges of water moving downstream.

To model this flood risk reduction, we assume the AEP changes at a constant amount each year as the current structures deteriorate from protecting against 100-year floods now to protection against a 40-year flood in 70 years' time. On that assumption, the AEP rises from 1% now to 1.62% in year 30 at the end of the current analysis period. The difference in annual expected damage of direct insured moves from very small ($0.15 million in year 2) to $0.435 million in year 30. Those small differences in annual average direct costs drive the scale of indirect and intangible costs expected under the with and without protection standards.

Table 10 presents the analysis results of the Waipaoa stopbank with rising AEP over time. It shows a weaker performance than the other two case studies, with substantial negative NPV when comparing costs with direct benefits alone and only a small positive outcome when adding indirect benefits. The results are slightly better when dropping the discount rate from 5% to 2%, but the central analysis of direct plus indirect benefits divided by cost still results in a BCR of less than 2. This is to be expected when the benefits of the upgrade are growing slowly over time from a starting point identical to no upgrade situation, i.e. where the upgrade is counteracting future deterioration in scheme condition rather than providing a lift in condition to a new, improved level.

Table 10 Results of the Waipaoa stopbank upgrade with AEP rising over time

	Units	Direct Benefit	Direct & Indirect Benefit	Direct, Indirect & Intangible Benefit	Direct Benefit	Direct & Indirect Benefit	Direct, Indirect & Intangible Benefit
Direct cost averted	$M	15.2	15.2	15.2	15.2	15.2	15.2
Indirect cost averted	$M	0.0	19.5	19.5	0.0	19.5	19.5
Tangible cost avoided	$M	**15.2**	**34.7**	**34.7**	**15.2**	**34.7**	**34.7**
Intangible cost averted	$M	**0.0**	**0.0**	**16.5**	**0.0**	**0.0**	**16.5**
Total benefit	$M	**15.2**	**34.7**	**51.1**	**15.2**	**34.7**	**51.1**
Project costs	$M	**13.5**	**13.5**	**13.5**	**13.5**	**13.5**	**13.5**
PV Benefits	**PV$M**	**6.19**	**14.11**	**20.81**	**10.40**	**23.71**	**34.98**
PV Costs	**PV$M**	**13.50**	**13.50**	**13.50**	**13.50**	**13.50**	**13.50**
Net present value	**PV$M**	**-7.31**	**0.61**	**7.31**	**-3.10**	**10.21**	**21.48**
Benefit-cost ratio		**0.46**	**1.05**	**1.54**	**0.77**	**1.76**	**2.59**
PV breakeven in Year			29	22		22	18
Discount rate		5%	5%	5%	2%	2%	2%

Source: NZIER

The economic impact of this analysis suggests the $13.5 million scheme costs would convert to about $4.5 million of annual value added and about $3 million in employee compensation within this. Unlike the other schemes examined, the contribution to value added by indirect costs averted would be less than the scheme costs because the averted disruption grows slowly and is increasingly discounted into future years. The upgrade's costs need to be viewed in the context of regional GDP in Gisborne District, which Statistics NZ estimates to be $2.6 billion in the year ending March 2022. The upgrade project's $13.5 million costs equate to 0.5% of that regional GDP, a higher proportion than the other case study schemes in the rather larger economies of Northland and Hawke's Bay.

The weaker performance of this cost-benefit analysis arises from the description of the current Waipaoa stopbanks being still at 1% AEP but expected to deteriorate over time. If the stopbanks have already deteriorated somewhat from the 1% AEP standard, the benefits of the upgrade would be larger.

Table 11 shows the results of a cost-benefit analysis using the same framework as that for Awanui, with the starting assumption that the deterioration at Waipaoa has already occurred, so the upgrade aims to restore the level of protection to that of a 100-year flood. Without RiskScape modelling showing property damage under the two states of flooding risk with and without the upgrade, we estimate annual values under the different states of protection based on 0.5% of the capital value at risk in the area. Using a 5% discount rate, the results are more positive than Awanui, with direct costs alone breaking even with a BCR of 1.22 and BCR of 2.74 with direct+indirect costs.

Table 11 Results of the Waipaoa stopbank upgrade

	Units	Direct Benefit	Direct & Indirect Benefit	Direct, Indirect & Intangible Benefit	Direct Benefit	Direct & Indirect Benefit	Direct, Indirect & Intangible Benefit
Direct cost averted	*$M*	31.5	31.5	31.5	31.5	31.5	31.5
Indirect cost averted	*$M*	0.0	39.4	39.4	0.0	39.4	39.4
Tangible cost avoided	*$M*	**31.5**	**70.9**	**70.9**	**31.5**	**70.9**	**70.9**
Intangible cost averted	*$M*	0.0	0.0	34.1	0.0	0.0	34.1
Total benefit	*$M*	**31.5**	**70.9**	**105.0**	**31.5**	**70.9**	**105.0**
Project costs	*$M*	**13.5**	**13.5**	**13.5**	**13.5**	**13.5**	**13.5**
PV Benefits	***PV$M***	**16.45**	**37.00**	**54.82**	**23.73**	**53.38**	**79.09**
PV Costs	***PV$M***	**13.50**	**13.50**	**13.50**	**13.50**	**13.50**	**13.50**
Net present value	***PV$M***	**2.95**	**23.50**	**41.32**	**10.23**	**39.88**	**65.59**
Benefit-cost ratio		**1.22**	**2.74**	**4.06**	**1.76**	**3.95**	**5.86**
PV breakeven in Year		21	8	6	16	7	5
Discount rate		5%	5%	5%	2%	2%	2%

Source: NZIER

The economic impact associated with Table 11 is also higher, with value added associated with averted disruption more than twice as large as that associated with the upgrade construction itself ($9.7 million from disruption averted, $4.5 million from construction). This analysis illustrates how the perceived performance of a project depends on the definition of the counterfactual and assessment of starting position: a project protecting the same area and values at risk will appear a higher performer if the protecting infrastructure is assessed to be degraded to start with, than if it is assessed to be well maintained but needing strengthening to protect against future degradation.

5.4 Westport opportunity missed

Before the Deluge reports that in 2021, a major flooding event in Buller led to an estimated $100 million in direct damage and similar value loss in indirect intangible value, which it has been suggested could have been averted with an earlier investment of $10–$20 million flood risk reduction upgrade, with a suggested BCR of 9:1. That example speaks to the benefits of timely investment in protection to avert large impact events. However, the BCR is unlikely to be 9:1.

According to the information given, had the upgrade been installed ahead of the flood, it would have provided a benefit of $100 million plus another $28 million over 30 years, assuming it provides 1% AEP protection. It is unclear what level of protection existed before the upgrade, which would need to be deducted from the upgrade's benefit[6]. If the upgrade cost $10 million in the year before the flood, the upgrade would provide a $155 million benefit over 30 years from reduced expected value of damages in the years after averting the big flood, which discounted at 5% would have a present value of $122.6 million over 30 years. If the cost is $10 million in present value terms, the NPV would be $112.6 million and BCR 12.3. If the cost is $20 million, the NPV would be $102.6 million and BCR 6.1.

5.5 Caveats and limitations

This is a high-level analysis of flood risk reduction schemes in New Zealand. Basic details of the schemes have been put into an analysis framework that combined information on changes in flood risk, area data on costs incurred should flooding occur, and various adjustment factors used in other analyses in New Zealand or overseas to account for changes in the direct, indirect and intangible impacts of floods caused by upgrades, for comparison against upgrade costs.

Some simplifying assumptions have been made to remove the noise of compounding assumptions and to clarify the focus on net benefits of flood risk reduction. Monetary values have been projected into the future in real dollar terms (i.e. no allowance made for inflation). Similarly, the areas and associated values at risk have been held static, except where evidence suggests that the with and without comparison would involve changes in the area of inundation. We do not attempt to forecast regional populations or changes in demands that might change property values and costs of direct impacts.

[6] We understand that protection on the Buller may have been adequate near Westport but that there was no protection either upstream on the Buller or on the Orowaiti. The largest floods are expected in these unprotected locations.

6 Implications for new projects

This report provides a robust assessment of the economic value of 55 completed flood risk reduction projects outlined in *River Management for Flood Protection – Spade Ready Projects* (Regional and Unitary District Councils 2020) to inform implications for government support for the second tranche of 80 projects outlined in *Before the Deluge* 2.0 (Regional and Unitary Councils of New Zealand 2023). It is a programme-level assessment informed by case studies of particular projects

In it, we:

- Outline approaches to economic assessment of flood risk reduction projects and a rationale for government support of localised projects
- Review literature on flood risk reduction assessment, frameworks of analysis and how to use them
- Outline a framework for cost-benefit analysis fluvial flood risk reduction assessment
- Apply that framework to three selected case studies,
- Drawing implications from the case studies to inform assessment of the Spade Ready Projects programme and the 80 in the second tranche.

New Zealand faces a wide range of natural hazards, but fluvial floods, along with coastal flooding, provide opportunities for targeted intervention to reduce risks because their geographical location can be predicted. For ubiquitous risks, like storms and earthquakes, mitigation options in the PARA framework are largely limited to accommodation and learning to live better with the hazard, as protection, avoidance, or retreat are not practical against hazards that can take effect anywhere. Flooding is different in that it is locationally determined so all the PARA options become available – including protection against frequent but minor incursions of water onto dry land with resulting costs that can be reduced by raising stop-banks or managing channels to enable excess water to flow quicker away from choke points, or slowing it down before reaching inhabited areas.

> Fluvial floods, along with coastal flooding, provide opportunities for targeted intervention to reduce risks because their geographical location can be predicted.

Assessment methods have evolved into a common framework

International and New Zealand literature shows an evolving range of methods for assessing flood risk mitigation measures. Early cost-benefit analyses focused on reducing damage to government infrastructure and perhaps some private costs, such as loss of farmland or growing crops, but this has evolved to a broader social cost-benefit analysis to estimate the societal return on investment, including damage to private property and disruption of business and social activities.

The purpose of cost-benefit analysis is to examine whether an investment yields a stream of benefits that, over time, exceed its costs. It is a modified investment appraisal method and is the principal assessment method for determining the worth of flood risk reduction projects. Inputs are valued at their opportunity cost in other uses, and benefits are valued in terms of the gain in economic surpluses generated from the inputs.

Another commonly encountered method is economic impact analysis, which quantifies how a project stimulates business across other sectors, ultimately raising GDP. This is not an investment appraisal method and confusingly treats costs (such as spending on flood defences) as benefits. The method is framed in terms of national accounting concepts such as economic value added or GDP but is not designed to estimate a return on investment. It is oriented to flow measures of economic activity and weak on dealing with changes in stocks, and it can give the perverse impression that floods are good for the economy as they stimulate activity in repair work rather than disasters that destroy long-accumulated wealth and capacity.

For flood mitigation, the benefits are some function of avoided costs or enhanced value realised by reducing the frequency and severity of flooding. Flood costs include:

- Direct costs of damage caused by contact with water, much of which can be estimated with high certainty after floods from insurance claims, but there will also be uninsured losses that can be valued at lower certainty
- Indirect costs are those incurred as consequences of flooding, including disruption of transport and other activities due to infrastructure blockages or damage; these can be the most significant component of flood costs, and they directly feed into economic impact analysis but are difficult to measure and commonly estimate as a ratio or multiple of direct costs, at medium certainty
- Intangible costs are those that are not traded in markets and include a wide range of human health and mental anxiety conditions and environmental damages; these can be measured through bespoke non-market valuation techniques but are more commonly estimated as some multiple of direct tangible costs

A crucial finding of the literature is the importance of indirect costs of disruption in comparing costs and benefits, as these often exceed the more obvious direct costs largely based on property damage. Indirect costs need to be estimated by observation of changes in value achieved and costs incurred in production during and after flood events, but such empirical estimates are not undertaken for most floods. Economic analyses commonly factor these costs in as a multiple or ratio of direct costs which are more directly observed through insurance claim payouts. Disruption costs directly affect the flows of goods and money that feed into an estimation of GDP.

Literature shows flood mitigation can have high returns on investment

Both international and New Zealand literature suggest investment in flood risk reduction and mitigation can have positive and high returns on investment, but these arise from varied assessment methods and contexts. For instance:

- The US National Institute of Building Science estimates river flood mitigation can return $8 for every $1 invested where it is aimed at protecting transport and utility infrastructure, and slightly lower returns in meeting or exceeding building standards against flooding
- The UK's National Flood Hazard Research Centre at Middlesex University maintains a database of damage caused by floods of different sizes on different land uses that can be used to show positive net benefits from flood mitigation measures, but differences in building styles and climate give it limited applicability to New Zealand conditions

- An estimated benefit-cost ratio of 55:1 for flood control schemes in Tonkin & Taylor's *Hiding in Plain Sight* compares the estimated total benefit of the country's flood schemes against local authorities' budgeted expenditure to maintain them, i.e. it does not account for the cost of building schemes from scratch and provides no guidance on the value of new flood schemes of scheme upgrades
- The Ministry for the Environment's (2022) National Climate Adaptation Plan cites BCRs of 6:1 from investment in flood mitigation[7]
- High-level CBA estimates of case studies from the 55-project programme of Spade-Ready Projects made with conservative assumptions suggest BCRs slightly lower, between around 1.7 and 4 depending on the items included in analysis (direct, indirect, intangible) and the discount rate chosen
- Case studies also show there is a cost in delaying completion of flood mitigation upgrades, and hence a benefit in intervention to accelerate completion
- While flooding affects localities, there is a rationale for wider government intervention:
  - To protect and maintain the integrity of government-owned infrastructure
  - To accelerate recovery and return to normal activity levels after floods, where local communities affordability constrains rapid restoration
  - To open opportunities for enhanced production in flood risk areas, but increase the confidence in investing with the expectation of undisrupted operation

Small upgrades to existing schemes can provide big benefits

With few exceptions, the 55 *Spade-ready* projects that have been funded and completed were relatively small projects upgrading existing flood schemes. The average across all projects was $5 million in capital expenditure. While some projects were larger, with two around $25 million, all but 6 of the 55 were below $15 and all but 11 were below $10 million.

A few of the existing *Spade-Ready* projects include a lot of quantitative information in their funding bid applications to enable cost-benefit analysis to be performed. The case studies indicate they can achieve BCRs greater than 2 when considering the upgrade's effect in reducing direct and indirect costs. They would be even higher if intangible harms avoided could be taken into account with more reliable methods than those currently available. Depending on input assumptions and the discount rate chosen, BCRs can reach in excess of 6 in reducing combined cost impacts.

The 55 completed *Spade-ready* projects could, therefore, be assessed by assuming an average BCR of 2 to 4 to provide a range of low, medium and high estimates of return on investment. The BCR for flood risk reduction compares very favourably with BCRs for other infrastructure investments, which often have a BCR around 1. Where project upgrades have been completed in time to ward off the costs of large flood events, as happened at Awanui and Taradale, the programme net benefits would be higher than shown by the average, as in the years of those flood events, the cost avoided would be the full cost of the flood event, not the probability-adjusted average expected annual value. The same BCRs could be

[7] Page 88, CASE STUDY, Adapting to flood risk in Westport. The comment about the 6:1 BCR is a standalone observation without explanation of the schemes to which it applies or any supporting reference. We have included the comment for completeness but consider the BCRs calculated from case studies a more robust and realistic indicator of the BCR for flood protection schemes.

applied to the 80 prospective projects seeking government support in *Before the Deluge 2.0.*

Floods are localised events, and flood risk reduction provides localised benefits, but it can efficiently draw support from a wider community. Insurance provides private benefits to property owners who make claims, but it draws from a wider pool of premium payers who all get the benefit of cover, although only a few suffer damages and need to make a claim in any year. Central government is also interested in reducing the incidence and severity of floods, particularly in reducing indirect disruption costs, which are a direct drag on economic activity, GDP and growth. Government funding that accelerates flood risk reduction upgrades faster than local communities could afford to complete them is good for the national economy and the localities that primarily benefit.

The potential quality of spending on the next tranche of potential pluvial flood risk reduction projects remains high based on our assessment of the preceding 55 projects and the surrounding literature. To the extent that the original 55 had been prioritised based on 'shovel readiness', there are likely to be some significantly high return projects in the remaining candidates.

Table 12 shows estimates of the likely benefits of the 2020 and 2023 flood risk reduction upgrade programmes, assuming costs can achieve BCRs in the range of those identified for protection in New Zealand. The benefits are based mainly on avoided costs and divided between those from direct impacts and indirect impacts of flooding; the split is based on the ratio used in the case studies (Direct:Indirect is 45:55). The costs show the total divided between the funding from local government (in the Direct column) and central government (in the Indirect column), as given in the programme documentation.

Table 12 Summary of flood risk reduction programmes in 2020 and 2023

Benefits of flood risk reduction programmes under a range of BCRs: Benefits from direct and indirect impacts avoided; funding split between local and national government

Benefit cost ratio range	Item	Total	Direct Impact	Indirect Impact
1.7	Benefit $m	505	227	278
2.6	Benefit $m	773	348	425
3.8	Benefit $m	1130	508	621
2020 Programme	Cost $m	**297.3**	**78**	**217**
1.7	Benefit $m	560	252	308
2.6	Benefit $m	856	385	471
3.8	Benefit $m	1252	563	688
2023 Programme	Cost $m	**329.3**	**131.7**	**197.6**

Note: The BCR ranges in Table 12 are not statistical conclusions. They are taken from case studies and drawn from relevant literature. RiskScape data and analysis are required to generate a project-specific BCR.

Source: NZIER drawing on Regional and Unitary District Councils (2020)and Regional and Unitary Councils of New Zealand (2023)

The table indicates that under a range of discount rates, the programme can be expected to produce benefits in excess of costs if accounting for both direct and indirect flood impacts avoided. Floods occur locally but have wider and national ramifications, as mitigation is about protecting local property values and avoiding indirect flood impacts that directly affect economic activity and GDP. Present estimates of indirect benefits are of only medium reliability and could be improved with more detailed and consistent estimates of observed disruptions in New Zealand flood situations. Similar comments can be made about intangible impacts, the estimation of which could be improved with a more detailed study of links between flood events and various social harms that impact physical and mental health and environmental and cultural heritage. Using relationships between direct and indirect flood impacts observed in other countries, the flood risk reduction programmes can be expected to provide net benefits broadly spread across the many localities in which they apply.

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Appendix A USA BCR explainer – limited relevance to New Zealand

The *Before the Deluge 2.0* (Regional and Unitary Councils of New Zealand 2023) document cites achievable BCRs of 8:1 for riverine floods, which is attributed back to NZIER's (2020) report to DIA on *Investment in natural hazard mitigation*. The figures are indeed from that report, which in turn attributes them to the US National Institute of Building Science's report *Mitigation Saves* (NIBS 2018b). However, the interpretation of the figures is not quite as it seems.

Figure 6 shows the summary of BCRs from the NIBS report. In short, it shows that for riverine flood:

- Meeting 2015 building code requirements for flood mitigation can return $6 for every $1 invested, which is lower than the average return of $11 across all classes of hazard, which is elevated by some very cheap but effective measures against wind and earthquake damage, such as affixing roofing iron with screws instead of nails and securing large furniture against walls to avoid their toppling over in seismic shaking.
- Exceeding 2015 building code requirements can return $5 for every $1 invested, better than the all hazards average return of $4
- Investing in flood mitigation for utilities and transportation can return $8 for every $1, double that of the all hazards average return of $4 on utilities and transportation
- The return from flood mitigation attributable to Federal funding is $7 for every dollar invested, slightly above the all hazards average return of $6.

In other words, mitigating riverine floods shows a better dollar return than the all hazards average except for meeting the building code requirements.

Figure 6 National benefit-cost ratios by hazard and mitigation measure in the USA

National Benefit-Cost Ratio Per Peril *BCR numbers in this study have been rounded	Exceed common code requirements	Meet common code requirements	Utilities and transportation	Federally funded
Overall Hazard Benefit-Cost Ratio	4:1	11:1	4:1	6:1
Riverine Flood	5:1	6:1	8:1	7:1
Hurricane Surge	7:1	Not applicable	Not applicable	Too few grants
Wind	5:1	10:1	7:1	5:1
Earthquake	4:1	12:1	3:1	3:1
Wildland-Urban Interface Fire	4:1	Not applicable	Not applicable	3:1

Table 1. Benefit-cost ratio by hazard and mitigation measure.

Source: NIBS (2018)

The NIBS table is somewhat counter-intuitive in placing exceeding code requirements to the left of meeting code requirements. Table 17 in NZIER's 2020 report rearranged the column ordering to read from left to right, first Transport and utilities, second meeting the code, third exceeding the code and fourth return on federal government funding, on the basis that transport and utilities returns are probably the most generic, whereas the other returns are more specific to US rules and less applicable to New Zealand. However, in the transcription from the spreadsheet into the document, the term "Benefit-cost ratio", which was intended as an indicator of what the figures signified, instead occupied the second column heading, pushing all other headings one column to the right. Pulling those headings all back by one column would lead to mitigation of riverine flood, showing the highest investment return from transport and utilities (8:1), then meeting building code (6:1), then exceeding building code (5:1). The last column on the right with 7:1 ratio is the return from federal government funding, a column that subsumes all the other investment categories of meeting code, exceeding code or focusing on infrastructure.

Table 13 Benefit-cost ratios for building improvements

Hazards and headings as per NZIER 2020	BCR	Transport and utilities	Meet code	Exceed code
Correct column headings	Transport and utilities	Meeting code	Exceeding code	Return on federal funds
Riverine flood	8:1	6:1	5:1	7:1
Hurricane surge	NA	NA	7:1	NA
Wind	7:1	10:1	5:1	5:1
Earthquake	3:1	12:1	4:1	3:1
Urban-wildland interface	NA	NA	4:1	3:1
Overall BCR per option	**4:1**	**11:1**	**4:1**	**6:1**

Source: NZIER (2020), drawing on NIBS 2018

This transcription error does not change the conclusions of NZIER (2020) in finding that riverine flood provides some of the best investments in natural hazard mitigation, both because of its relatively high BCRs in the table above, and because it is relatively easy to target where the flood risks arise and what's needed to mitigate them, in contrast to other hazards like earthquakes or storms where the risk is more ubiquitous and less easy to pinpoint particular locations. However, the ratio of 8:1 should not be inferred to be a general expected return from all flood mitigation because it strictly applies to the protection of utilities and transportation. The benefits of such investments are high because of the disruption costs that can be caused and spread widely by infrastructure closures.

The investments in infrastructure and transportation with the highest return identified by NIBS 2018 are in descending order of ratio:

- Protecting water and wastewater treatment plant from inundation or relocating them
- Elevating road approaches and reconstructing bridges to reduce flow impedance
- Mitigating electric and telecommunications substations
- Elevating roads and railway lines.

The cost-benefit ratios should not be quoted verbatim as feasible in New Zealand, as they are calculated in the USA with different building codes and land use patterns than those found in New Zealand. But, they are the result of analysis of a much larger data series of projects and outcomes than are available in New Zealand, and their conclusions around the relative returns from mitigation of different hazards may be transferrable to New Zealand.