An overview of available frameworks and data requirements to account for direct, indirect and intangible flood costs for business-case development

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ABSTRACT

This report was prepared by a joint research team from GNS Science, Massey University and National Institute of Water & Atmospheric Research (NIWA) for the Greater Wellington Regional Council and the River Managers' Special Interest Group (SIG) of Te Uru Kahika Regional and Unitary Councils Aotearoa. The project was funded by the Ministry of Business, Innovation & Employment (MBIE) Extreme Weather Recovery Advice Fund. The report provides a 'cookbook' of the various methods and frameworks that are commonly used both internationally and within Aotearoa New Zealand to account for direct, indirect and intangible flood costs to support business-case development for flood mitigation in Aotearoa New Zealand. It highlights that most estimates only capture direct, insured, damages, potentially under-estimating the full economic and social costs, and discusses the challenges of quantifying indirect and intangible losses, including social and cultural impacts and data-accessibility issues. A case-study application of the April 2017 Edgecumbe Flood is also presented to demonstrate the data requirements and aspects of modelling to estimate some indirect and intangible costs relating to housing and habitability.

The summary herein is presented in reverse order of the report sections so that key findings from the review of methods and results for measuring intangible losses is presented first, as this was of most interest to Greater Wellington Regional Council and the River Managers' SIG.

Measuring Intangible Losses (or Costs)

Effort has been made to improve the quantification of disaster losses by focusing on increasing consideration of indirect losses in relation to the typical focus on direct losses; however, conflicted approaches to including or excluding intangible losses in either the direct or indirect categories make it difficult to determine whether and how these efforts are considering intangible losses specifically. Given the challenge of quantifying, and in particular costing, intangible impacts of natural hazard events such as floods, a comprehensive resource on intangible costs (loss) estimation does not appear to exist. The difficulty in estimating the magnitude of the various potential losses ranges from relatively straightforward (e.g. number of injuries can be estimated based on treatment access, although not all injured individuals will seek treatment) through to virtually impossible (e.g. reduced trust in local agencies).

Valuation methods have been classified and applied for valuating cultural goods and services in the context of disaster assessment and ecosystems, such as Contingency Valuation, Multi-Attribute Valuation, Replacement Cost Method and Enhanced Replacement Cost Method, Substitute Cost Method, Preventive Expenditure Method, Hedonic Pricing Method, Travel Cost Method, Market Price Method, Benefit Transfer Method, etc. Each method comes with pros and cons; however, most of these methods, aside from the Enhanced Replacement Cost Method, are based on costs associated with the physical asset (such as a cultural building), and thus capture only part of the cultural value of the asset (i.e. they exclude the spiritual and social values). The Enhanced Replacement Cost method attempts to incorporate some of these values by calculating the costs and value based on the creation of new and enhanced cultural assets. The appropriateness of each method depends on the cost-benefit of undertaking the assessments, time constraints and data availability.

Other less-resource-intensive approaches have been developed for estimating intangible losses. **Work in the United Kingdom has explored how much the mental health impacts of a flood event might cost; however, this value ranges considerably (from £1,878 to £4,136 per adult) and depends on context, such as the size of the flood event.**

One approach to putting a value on intangible losses is to use non-economic court awards, such as payouts from companies to individuals injured due to error or negligence that led to impacts on their quality of life. For example, **the Australian Bureau of Transport Economics estimated (in 2000) that the cost of loss of quality of life due to a serious injury in a disaster was AUD $127,000 and a minor injury was AUD $8,450. These figures could be adjusted for inflation and exchange rate to give a starting point for impacts on quality of life due to injury.** The lower rates of such litigation in Aotearoa New Zealand due to schemes such as ACC (Accident Compensation Corporation) limit the availability of data to conduct such analyses here. Other work in Australia has adapted 'willingness to pay' data from other studies. This data is collected via surveys of the public, asking how much they would be willing to pay for intangible items such as access to a park (AUD $35 per household per year), avoiding electricity outages (AUD $71 per household per 12 hours) or avoiding being displaced (AUD $5.4 per household per hour). This data contains meaningful uncertainties but may be better included than ignored.

A final method for estimating the cost of intangible losses is to apply a ratio. The steps involved are to (1) identify how many people were impacted, (2) determine the magnitude of impacts, (3) define the per case cost per annum and (4) multiply the incidence and per case cost for each impact to estimate the total intangible cost. **A recent evaluation from Australia suggests that, of the total cost of a flood, 37% are social costs**. Reviewing this approach **from an Aotearoa New Zealand perspective, NZIER** (New Zealand Institute of Economic Research) **recently suggested a multiplication factor of 1.1 (i.e. intangible losses are 1.1 times the direct costs)**, although the reliability of this ratio is low.

Measuring Indirect and Tangible Flood Losses (or Costs)

Several methodologies have been developed and recommended by international literature. The Post-Disaster Needs Assessment (PDNA) Framework is a global economic assessment framework that captures the full extent of a disaster's impacts and is consistent with national systems of accounting. The PDNA is built upon the Disaster Loss Assessment methodology, which covers impact on various sectors, and details collection procedures such as surveys and interviews for estimating costs.

Modelling approaches for calculating indirect impacts or losses can use either macro- or micro-economic approaches. The micro-economic approach focuses on individuals, households or firms using detailed, small-scale data to examine specific impacts, such as lost income due to business closures, reduced wages for affected workers or financial losses for businesses from damaged infrastructure (as well as direct costs, such as building damages). This granular data helps design targeted policies, such as financial aid or recovery grants for those directly impacted. Common micro-economic approaches include Regression Discontinuity, Panel Data Regression, Difference-in-Differences and Propensity Score Matching to assess how individuals, businesses or regions are affected by a disaster (including flood). The primary goal of these models is to estimate the 'average treatment effect' of a disaster by comparing key variables – such as revenue, net income ratios or operational efficiency – between the affected group and unaffected group. This is to estimate the non-market indirect tangible (as well as intangible) costs of the disaster in dollar terms. Non-market values refer to the costs and benefits in which there is no explicit market and no observable prices (e.g. business disruption, unemployment); as opposed to the market values that are derived from goods or services that are bought and sold directly in the market (e.g. reconstruction costs of infrastructure). Other methods can infer non-market economic impacts, such as stated-preference techniques like Contingent Valuation, Contingent Behaviour and Discrete Choice

Experiments. These methods require primary data collection through surveys or questionnaires, making them more resource-intensive but valuable for capturing public preferences and perceived costs of natural hazards.

In contrast, the macro-economic approach looks at the broader economy, analysing large-scale indicators such as GDP (gross domestic product), unemployment and inflation. It captures how major disasters affect regional or national wealth measures, including declines in national economic output, inflation spikes from supply-chain disruptions and widespread unemployment. Macro-economic models, such as Input-Output (I-O), Social Accounting Matrix (SAM) and Computable General Equilibrium (CGE), analyse broad economic changes, capturing the ripple effects of disasters across sectors and markets. These tools help quantify the macro-economic disruption for different purposes. I-O tables typically represent monetary flows, not physical quantities (often measured in a country's currency). SAM extends I-O models by considering the entire economy, capturing interactions between multiple institutional accounts, such as households, businesses, government and the rest of the world. It does so by considering not only production linkages but also income-expenditure feedback and interactions among economic agents. CGE models extend general equilibrium models by using actual economic data to simulate how an economy might react to changes, such as a disaster. CGE models are a multi-market simulation models that are especially well suited to distributional impact analysis.

Direct asset-damage metrics can be used to formulate relationships with indirect costs. For example, the habitability of buildings typically relies on the outputs of direct damage modelling to buildings, with the damage state serving as a proxy for habitability (whether a building is safe and healthy to occupy, represented by placarding in actual events). Generally, where floodwaters reach about the floor height of a building, it is rendered uninhabitable, although upper storeys may still be utilised in some cases. Household impacts, including displacement, can be modelled by using the outputs of building damage and loss of habitability modelling combined with data on dwelling occupants. A household impacts model applicable to any natural hazard event has recently been developed for the Aotearoa New Zealand context. A household population model with key characteristics, including number of individuals, number of children, household composition, household income and tenure, is available with households distributed to residential dwellings within the national building inventory.

Measuring Direct Losses (or Costs)

In flood-risk analyses, the standard approach for estimating direct costs/damages employs vulnerability functions that relate asset characteristics to water depth. These so called 'depth-damage functions' (or 'curves') describe a monotonic relationship whereby direct damage (i.e. physical damage or monetary loss) increases with increasing water depth. There are potentially additional factors such as velocity, duration of inundation and contamination that may exacerbate flood damage as well, but these factors are hard to be measured at a sufficient accuracy. Direct economic losses are estimated from this vulnerability relationship as either the absolute economic cost to restore a building to a pre-damage condition or as relative physical damage represented by a non-dimensional parameter such as a percentage or ratio. In Aotearoa New Zealand, flood vulnerability models for direct loss estimation have primarily focused on buildings. A suite of 12 depth-damage curves has been developed using a judgement-based approach to estimate relative damage to residential and non-residential buildings based on multiple variables (i.e. use category, age, structural frame, storeys and inundation depth above floor level).

2017 Edgecumbe Flood Case Study

This report presents a damage and loss assessment framework for costs resulting from the 2017 Edgecumbe Flood. Estimated figures, as well as anecdotal evidence, were collated from multiple sources, including reports from local councils, insurance councils and the media. The flood costs are categorised into ‘direct’, ‘indirect’ and ‘intangible’ following existing frameworks.

Cost estimates are also assessed based on their data quality (e.g. good quality with full estimation and dollar amount, average quality with full estimation but no dollar amount and low quality with incomplete estimation or anecdotal evidence). While there are abundant data on the direct physical damages (e.g. damaged assets such as homes, residential lands, farmland and stock) and/or immediate evacuation and clean-up costs, some of this information is largely figurative estimations without monetary figures (i.e. no price tag apart from insurance claims, house repurchase costs and reconstruction costs).

We found a significant gap in much of the information related to indirect and intangible costs. At a micro-level, physical damages to homes and buildings led to increased insurance premiums (at least 15–30%) and rate hikes (~25%) in the short-term to recoup the reconstruction costs. However, when we applied a Difference-in Differences assessment, this showed a seemingly negative price effect of locating inside the flood zone after the flood event (-0.069 to -0.089, or 7–9%). This signifies that the price effects of the Edgecumbe Flood either have not materialised on the real-estate market due to small sample and sparse transactions, or that there are unaccounted and/or unobservable characteristics that the hedonic model did not account for.

Challenges

Accounting for indirect and intangible losses presents many challenges. The first primary challenge relates to the difficulty, if not impossibility, of quantifying and costing intangible losses that are, by nature, intangible and deeply qualitative, such as social, cultural and wellbeing impacts. Our review of methods for accounting for such impacts sheds some light on current international efforts made to address this challenge, but there is no ‘silver bullet’ solution. The second primary challenge relates to data availability. In the cases where quantitative data has been collected or captured for either indirect or intangible losses, challenges continue to inhibit the access to or use of these data due to commercial/ proprietary restrictions and inter-operability issues, as these were not necessarily collected for the purpose of accounting for losses.

There is a need for baseline data collection for pre- and post-event comparison (including frequent and consistent pre- and post-event assessments, interviews, case studies and longitudinal surveys). This would allow for causal links to be drawn between flood events and the impacts, as well as for the long-term impacts of these events on individuals, communities and society to be grasped. Additionally, a long-term database of these impacts may help to develop metrics for measuring/quantifying intangible impacts/losses. Furthermore, different timeframes of data collection would affect the results of measurement that could influence decision making. For example, short-term impact assessment results may differ from long-term impact assessment results. Thus, decisions according to the results of the short- versus long-term impact assessments may differ; this should be considered when making decisions.

KEYWORDS

Flood, loss and damage, direct cost, indirect cost, intangible cost

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1.0 INTRODUCTION

Flooding is Aotearoa New Zealand's most frequent hazard (Mason et al. 2021) and is one of the costliest. Several estimates of insured losses caused by the combined effects of the 2023 Auckland Anniversary Weekend flood and Cyclone Gabrielle place these events as the costliest non-earthquake event in the country to date. Based on estimates from the Insurance Council of New Zealand, the New Zealand Institute of Economic Research (NZIER) documented the total insured damages for these two consecutive events at NZD $1.84 billion and NZD $1.65 billion, respectively (NZIER 2024).

These values only refer to the insured economic costs that have been reported and accounted for. Often, these result from direct and/or some indirect costs that can be monetised. However, other indirect and intangible costs are more difficult to quantify and monetise, and consequently often remain unaccounted for in damage and loss assessments (for example, post-disaster needs assessment [UNDP 2013]). This typically results in inaccurate and downward-biased estimates of the total impact of an event (Markantonis et al. 2012). According to Banerjee et al. (2024), it is estimated that at least 62% of the global economic losses resulting from natural catastrophes in 2023 remains uninsured. This fraction can exceed the 90% threshold in emerging economies with low-insurance penetration or biggest catastrophic events.

Regional councils in Aotearoa New Zealand are mandated to manage natural hazards and need to prepare business cases for all of their proposed flood-risk-management projects. For co-funding projects, these need to be based on the Treasury's Better Business Case model, with a need to provide evidence-based information cases to access the available funding approved at a high level by Ministers/Cabinet.

To date, these business cases have been largely based on readily quantified direct costs, with minimal accounting for the large indirect and intangible social and economic costs resulting from floods. International research suggests that these costs could be as much as, or exceed, the direct costs, especially in high-impact, low-probability events (Tanoue et al. 2020; Koks et al. 2015). This report will address this shortfall by providing an overview of the methods currently available to support regional councils to account for these indirect and intangible losses.

This report provides a 'cookbook' of the methods and frameworks that are commonly used both internationally and within Aotearoa New Zealand to account for direct, indirect and intangible flood costs to support business-case development for flood mitigation in Aotearoa New Zealand. To do this, we first define direct, indirect and intangible costs in Section 1. We then provide an overview of existing assessment frameworks, available methods for estimation and required data for each type of cost in Section 2. A case-study application of the April 2017 Edgecumbe Flood of some of these methods using readily available data is presented in Section 3. Conclusions and recommendations for next steps are provided in Section 4.

The scope of this report is focused on the direct, indirect and intangible flood costs arising from the impact of flood hazards on the economy, society (people) and the built environment. While it may include discussions of indirect and intangible costs related to the natural environment, environmental damage and loss require a separate assessment with appropriate expertise that was not available for this report (see Gautam and van der Hoek [2003]). Additionally, this report does not cover the positive impacts of floods that cannot be translated into costs for business-case development purposes. For example, floods generally have a negative gross domestic product (GDP) effect on the manufacturing, wholesale and retail sectors but tend to have a positive effect on the construction sector – see Ashizawa et al. (2022). Due to the limited time capacity available to complete this report, we could not account for both positive and negative impacts. As such, costs are the focus of this report.

Finally, the report focuses on the costs associated with flood hazards in general. It is widely acknowledged that climate change will increase the frequency and intensity of weather-related hazards, including flooding. The change in flood hazards is typically estimated through various channels, generally climate models, which are downscaled to regional or local models. There is a large body of literature on *incorporating* or *attributing* the effects of climate change on extreme events, including flooding (Perkins-Kirkpatrick et al. 2022; Newman and Noy 2023; Frame et al. 2020). This is beyond the scope of this report.

1.1 Types of Costs

Four general types of flood costs have been identified in the literature. These are direct, indirect, tangible and intangible costs, as shown in Figure 1.1. These costs are typically categorised based on the ability to quantify and/or assign monetary value to them (i.e. economic costs versus non-economic costs) and whether they are directly caused by the flood (e.g. physical damage) or are an additional outcome of those direct damages (e.g. business disruption due to damages and road closures). Some costs cannot be easily quantified in dollar terms and are thus considered intangible (e.g. mortality and injuries, psychological trauma, impacts to cultural sites and artifacts). The categorisation of direct/indirect or tangible/intangible costs is not always straightforward. Direct and indirect costs may be either intangible (e.g. mortality and injuries, environmental losses) or tangible (e.g. infrastructure and business disruption), as visualised in Figure 1.1.

In discussing flood-cost categorisation, it is useful to relate to the concept of Damage and Loss Assessment (DaLA) in the field of disaster risk management. First introduced by the Economic Commission for Latin America and the Caribbean (ECLAC)[1] in the 1970s, DaLA is a key tool used to categorise and quantify the costs associated with disasters instigated by natural hazards (ECLAC 2014). This concept was later formalised by the World Bank and applied worldwide to evaluate the full impact and recovery needs of disasters, including floods. DaLA measures not only the direct *damage* (e.g. destruction of physical assets) (*direct costs*) but also *losses*, such as the change in economic flows arising from the disaster (e.g. decline in output, lower revenue and higher operation cost), as well as additional costs and financial needs for recovery (*indirect costs*). The introduction of the Human Recovery Needs Assessment in the Post-Disaster Needs Assessment (PDNA) further expanded this framework to identify the social impacts and society-recover needs of disasters (*intangible costs*). Combined, these assessments provide a holistic view of the total impact of disasters that goes beyond the economic realm (UNDP 2013) (more detailed in Section 2).

Further definitions and methods have been developed for accounting for some of these costs and are described next.

1 The Economic Commission for Latin America and the Caribbean (ECLAC) is one of the five regional commissions of the United Nations.

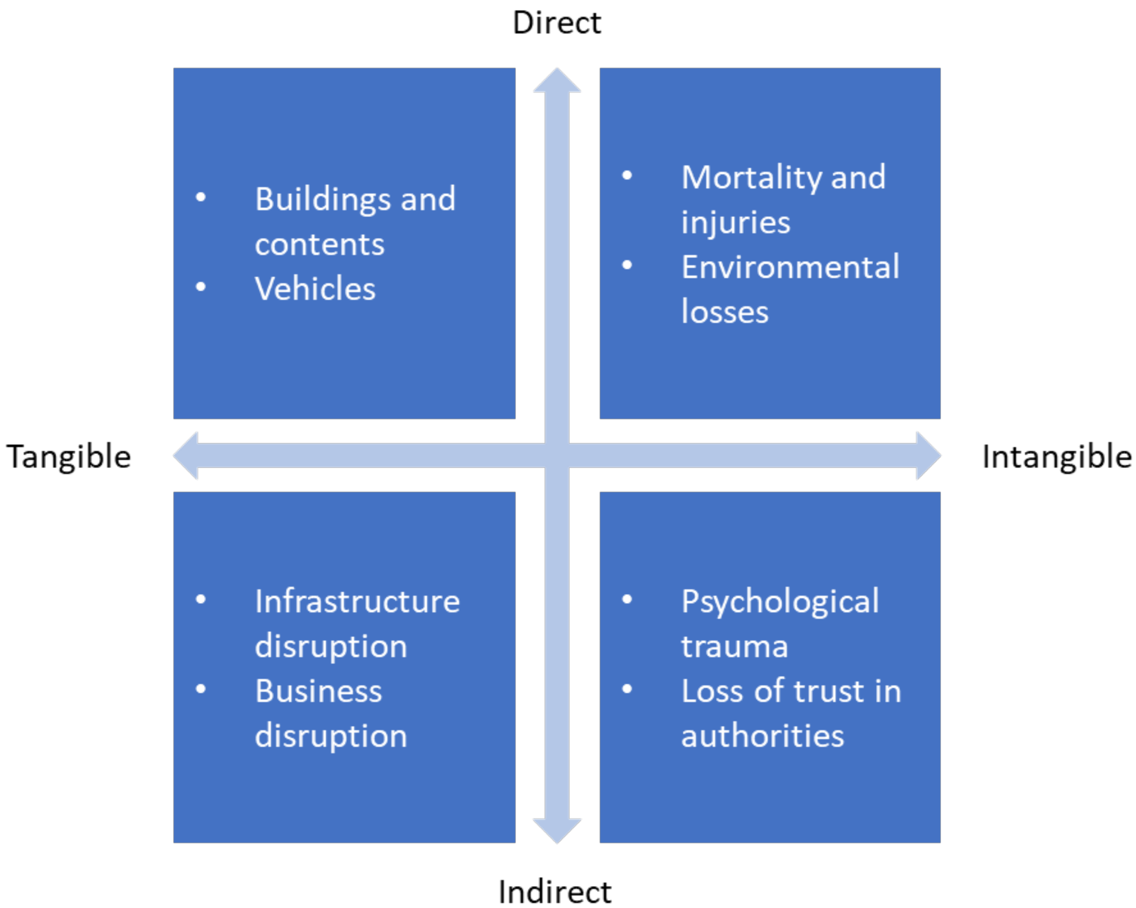

Figure 1.1 Distinction between tangible, intangible, direct and indirect flood costs (adapted from Nicklin et al. 2019).

1.1.1 Direct Tangible Costs

Direct (economic) costs are "the monetary value of total or partial destruction of physical assets existing in the affected area" (UNGA 2016). In this sense, direct costs are nearly equivalent to physical damage and typically occur during the event or within the first few hours after the event (equivalent to *damage* in DaLA/PDNA). Direct costs can arise from (but are not limited to) physical damage to building infrastructure and other tangible assets (business assets and industrial plants), lost agricultural production (e.g. livestock fatalities, crop damage), earth system / environment degradation (i.e. ocean, land and atmosphere) and loss of natural resources (Merz et al. 2010). Direct losses are generally tangible and relatively easy to measure.

1.1.2 Indirect Tangible Costs

While direct costs, such as physical damage to infrastructure, are often visible, costs from the indirect losses can significantly affect communities and businesses and sometimes even surpass direct costs (Tanoue et al. 2020; Koks et al. 2015). In disaster risk management, indirect (economic) costs are defined as "a decline in economic value added as a consequence of direct economic loss and/or human and environmental impact", which "occur inside or outside of the hazard area and often have a time lag" (UNGA 2016) (equivalent to *loss* in DaLA/PDNA). Additionally, definitions of indirect costs vary in both international and local literature (see Box 1).

Box 1 – More on Definition of Indirect Costs

- Hallegatte and Przyluski (2010) defined indirect losses as “all losses that are not provoked by the disaster itself, but by its consequences”. They proposed two criteria to define indirect losses: (1) the losses are caused by secondary effects, not by the hazard itself and (2) the losses span across a longer period of time, a larger spatial scale or a different economic sector than the disaster itself.
- Rose (2004) noted that the distinction between ‘direct’ and ‘indirect’ effects in natural hazard loss estimation can be confusing. He proposed the use of the term ‘high-order effect’ instead to cover all economic-flow losses beyond direct losses (such as curtailment of output as a result of hazard-induced property damage in the producing facility itself).
- Okuyama (2007) noted that indirect effects of disasters includes a wide array of consequences caused by direct losses such as the interruption of economic activities, production and/or consumption and losses from business disruption.
- UNGA (2016) noted that indirect economic losses include microeconomic impacts (e.g. revenue declines owing to business interruption), meso-economic impacts (e.g. revenue declines owing to impacts on assets, interruptions to supply chains or temporary unemployment) and macroeconomic impacts (e.g. price increases, increases in government debt, negative impact on stock market prices, decline in GDP).

Here, instead of the direct/indirect typology, we use an alternative (and complementary) terminology. Like the National Research Council (2011, 2012) and Rose (2007), we distinguish between *asset losses* (i.e. the *stock* of assets that is reduced) and *output losses* (i.e. a reduction in an income *flow*). Output losses include different categories that often overlap:

- Business disruption, which refers to the interruption in production during the event (e.g. income loss for days of close operation or evacuation costs).
- Production losses, which are directly due to asset losses (as damaged or destroyed assets cannot produce during a period that is much longer than the event itself).
- Supply-chain disruptions, which occur when lack of input or reduced demand for intermediate inputs is responsible for a reduction in production from a production site that is not directly affected.

Additionally, disasters impact businesses through reduced demand.

Indirect effects extend to society, impacting households and communities in terms ofhealth, education, labour, income and consumption. A comprehensive definition should encompass all indirect costs, although detailed discussion of impacts on the natural environment is excluded here due to scope limitations.

1.1.3 Intangible Costs

While it is unlikely, if not impossible, that intangible costs (losses) will ever be fully accounted for in disaster loss modelling, it is vital to improve how this category is considered in risk reduction, mitigation and post-disaster compensation (Dassanayake et al. 2012); such losses can be more significant at a household-level than tangible damage (Green and Penning-Rowsell 1989) without including the broader community, society, cultural and environmental impacts. Currently, no official disaster-related agency in Aotearoa New Zealand provides a workable definition of intangible costs (as far as our review of available resources could find); meanwhile, intangible costs have a relatively narrow scope within solely economic discussions (see Box 2). From a broader perspective, there is relative consensus that intangible losses include any impacts of a disaster that cannot be easily quantifiable in monetary terms, typically due to there being no market for them (e.g. BTE 2001; AIDR 2002; Doktycz and Abkowitz 2019; Markantonis et al. 2012).

Box 2 – More on Definition of Intangible Costs

- **In Aotearoa New Zealand disaster risk management:** The National Emergency Management Agency (NEMA) National Disaster Resilience Strategy (MCDEM 2019) mentions intangible impacts of disasters in the context that these impacts “aren’t factored into decision-making”. The document gives social and cultural impacts as examples of indirect and intangible impacts, and implicitly aligns ‘intangible costs’ with ‘longer-term outcomes’. However, academic literature, as well as international government frameworks (e.g. that of Australia’s Bureau of Transport Economics) proposes that intangible losses can be both a direct and indirect result of the disaster (e.g. flood), and can be both immediate and long-term (Nicklin et al. 2019). The United Nations Office for Disaster Risk Reduction (UNDRR) official terminology does not define intangible costs except to say that indirect economic loss can be “intangible or difficult to measure”. The Natural Hazards Commission Toka Tū Ake (formerly the Earthquake Commission / Toka Tū Ake EQC) includes modelling of intangible costs of disasters as one of its over-arching goals but does not provide a clear definition. A single example of intangible ‘property’ (computer data) could be found in its publicly available documents (EQC 2021).
- **In economic discussions:** These could include revenue declines, interruptions to supply chains, increases in government debt (UNGA 2016), skills and distributions networks (Demmou and Franco 2021). The New Zealand Accounting Board describes ‘intangible assets’ as non-physical resources on which an entity has either spent money or incurred liability, including technical knowledge and intellectual property (XRB 2014). Similarly, the New Zealand Treasury defines an intangible asset as one that could provide future service potential or economic return. While it is possible that a flood could lead to the loss of these assets, these definitions from an economic perspective do not comprise all potential types of intangible loss. For example, NZIER (2024) states that “intangible social costs, like health, environmental and cultural impacts” also need to be estimated and compensated.

The conceptualisation of losses differs widely across literature and practise. In some approaches, intangibles are considered a third class of their own, separate from direct and indirect, while other approaches consider indirect and intangible together (e.g. Dassanayake et al. 2015). However, in other cases, these are only distinct from *tangible* losses and therefore can either be direct or indirect (e.g. Nicklin et al. 2019). This introduces complexities with estimating intangible losses. By looking across the various definitions provided in both academic and non-academic sources, we have produced the following working definition for the purpose of this report whereby intangible costs (losses) are:

> *“Losses (both direct and indirect) of things without physical substance which cannot be bought and sold, are not easily measurable in monetary terms, and for which there is no commonly-agreed method of evaluation.”*

These losses can be experienced by individuals (e.g. ongoing physical and mental health impacts), communities (e.g. disruption caused by the rebuilding process), cultures (e.g. disruption to traditions and cultural activities) and the environment (e.g. loss of soil nutrients). These losses are therefore diverse in the spheres of society that they impact, the timeframe of their impact (e.g. chronic versus acute, response versus recovery phases), and whether they result from direct or indirect consequences of the disaster (in this case, a flood). Estimating these losses is challenging (e.g. Newman and Noy 2023), yet several attempts have been made to at least improve our ability to estimate the magnitude of the impacts of these losses. A review and proposed synthesis of these methods is presented in Section 2.3.

2.0 AVAILABLE LOSS-MEASUREMENT FRAMEWORKS AND METHODS

This section outlines frameworks and methods to assess direct, indirect and intangible flood costs to the economy, society (people) and the built environment, with some light touches on costs related to the natural environment (specifically for intangible losses; Section 2.3). Additionally, the incorporation or attribution of climate change to increasing flood hazards is beyond the scope of this report (see Section 1). Note that direct loss frameworks were not the priority focus for this project; rather, indirect and intangible losses were. However, we brought in direct losses because it is worthy to draw links between all types of losses and how one builds on the other. Section 2.1 (Direct Costs) is shorter and less detailed than the other sections for indirect tangible (Section 2.2) and intangible costs (Section 2.3).

2.1 Direct Costs

In flood-risk analyses, the standard approach for estimating direct costs/damages employs vulnerability functions that relate asset characteristics to water depth (Smith 1994; Meyer et al. 2009; Scorzini and Frank 2017). These so called 'depth-damage functions' (or 'curves') describe a monotonic relationship whereby direct damage (i.e. physical damage or monetary loss) increases with increasing water depth. There are potentially additional factors such as velocity, duration of inundation and contamination that may exacerbate flood damage as well, but these factors are hard to be measured at a sufficient accuracy (Thieken et al. 2005). Direct economic losses are estimated from this vulnerability relationship as either the absolute economic cost to restore a building to a pre-damage condition (Penning-Roswell et al. 2003) or as relative physical damage represented by a non-dimensional parameter such as a percentage or ratio (Jongman et al. 2012). The vulnerability relationship is modelled from flood-event (i.e. empirical) or expert (i.e. synthetic) -derived information (Merz et al. 2010). Empirical vulnerability models, which are based on damage assessments via direct observation and aerial-image analyses, are often represented using basic linear and non-linear mathematical functions (e.g. Arrighi et al. 2020; Martínez-Gomariz et al. 2020), probability distributions (e.g. McGrath et al. 2019) or machine-learning methods such as Bayesian networks (e.g. Sairam et al. 2019; Mohor et al. 2021), artificial neural networks (Amadio et al. 2019) or decision-tree ensembles (e.g. Wagenaar et al. 2018; Rözer et al. 2019; Paulik et al. 2023a). Synthetic models are developed from 'what-if' scenarios informed by expert or heuristic interpretations of damage processes and translated into mathematical functions (e.g. Dottori et al. 2016; Naumann and Golz 2018). Models to estimate direct damages in either case require detailed information on the factors influencing flood damage for local building contexts.

In Aotearoa New Zealand, flood-vulnerability models for direct loss estimation have primarily focused on buildings. Reese and Ramsay (2010) developed a suite of 12 depth-damage curves using a judgement-based approach to estimate relative damage to residential and non-residential buildings based on multiple variables (i.e. use category, age, structural frame, storeys and inundation depth above floor level). Similarly, URS (2006) applied judgement to derive uni-variable depth-damage curves to estimate absolute monetary loss (2006 NZD) for eight building-use classes in response to water depth above floor level. These studies do not assess the predictive performance of depth-damage curves using empirical damage information from Aotearoa New Zealand flood events. More recently, Paulik et al. (2023a, 2024a, 2024c) used empirical damage data from six flood events (Paulik et al. 2022; 2024a) and regression-based learning methods to train and evaluate linear and non-linear functions to predict residential building-damage response to water depth both above ground and floor level. Significant improvements to model precision were observed when floor height was considered for damage prediction.

Empirical model approaches that consider multiple explanatory variables attempt to resolve complex interactions between hazard and non-hazard variables, causing a damage outcome. Multi-variable models predict a direct damage-response variable (e.g. damage ratio) response from multiple flood hazard (e.g. water depth, flow velocity, contamination), physical (e.g. structural frame, condition) and non-building (e.g. year of construction, replacement value, precautionary measures, warning time) asset variables. Paulik et al. (2023a, 2023b, 2024a, 2024c) evaluated supervised and unsupervised multi-variable learning-model performance in different flood risk contexts in Aotearoa New Zealand. While decision-tree ensembles (i.e. Random Forests) often demonstrated higher damage-prediction precision, models are sensitive to hyper-parameter settings (e.g. number of trees, tree depth), number and quality of damage samples and inclusion of hazard and non-hazard variables important for damage. Damage-prediction precision often reduces when models include variables that are not important for damage and when models transfer between different flood-hazard contexts (e.g. urban stormwater, riverine and levee breach events). These findings demonstrate that accurate damage prediction is reliant on models representing local factors driving flood damage, and current practises to apply unvalidated or proxy damage models (e.g. depth-damage curves developed in other countries) need to be carefully considered when using direct loss estimation to inform flood risk management decisions.

Potential direct flood-damage assets can be assessed using risk-modelling software such as RiskScape™ (Paulik et al. 2023b). Essential data inputs include a hazard layer of flooding extent and intensity (usually water depth), an appropriate vulnerability function for the context and the locations and characteristics of assets exposed to the hazard (Paulik et al. 2024b). For the latter, an inventory of spatial information for features such as buildings is used. A building inventory with national coverage has been developed by Scheele et al. (2023) for use in RiskScape™ and contains buildings represented by Land Information New Zealand (LINZ) building outlines with key attributes for direct flood-loss assessment, including floor height and replacement cost. Depending on the resolution of assessment required, the attributes can be improved with local databases (e.g. district valuation roll) or observations from field or desktop building surveys.

2.2 Indirect Tangible Costs

2.2.1 Assessment Framework

Unlike direct costs, which mostly involve damages of physical assets, indirect tangible costs (losses) span through several dimensions. As such, it would be useful to refer to a mix of structured assessment frameworks to organise and fully account for the indirect costs of flood hazards and their relationship to direct and intangible costs.

In the past, the primary global framework for economic assessment of disasters such as floods has tended to be Post-Disaster Needs Assessment (PDNA), an approach to capture the full extent of a disaster's impact (including direct, indirect and intangible costs), consistent with national systems of accounting (UNDP 2013). As discussed in Section 1.1, PDNA is built upon the damage and loss assessment (DaLA) concept introduced in the Handbook for Disaster Assessment (ECLAC 2014), a methodological tool developed to assess the socio-economic and environmental impacts of disasters. The DaLA framework is a structured methodology, starting with basic concepts and definitions, including hazard, vulnerability and risk. It outlines the evaluation methodology, which involves assessing direct damages (physical damage to infrastructure and basic services), indirect costs (economic disruptions and increased operational costs) and intangible costs (mental health impacts and loss of cultural heritage).

The DaLA framework, as outlined in ECLAC (2014), covers the impact on various sectors (Figure 2.1): the social (education, health, housing, social services), infrastructure (transportation, water and sanitation, energy) and economic sectors (agriculture, manufacturing, commerce, tourism). It details data-collection procedures, such as surveys and interviews, and techniques for estimating costs. The guide also includes methods for analysing and presenting results and provides case studies with practical examples and lessons learned, making it an essential reference for effective disaster response and recovery planning.

Appendix 2 showcases how ECLAC (2014) can be used to classify sector-specific indirect tangible costs due to a flooding event. However, a caveat with this framework is that it requires data that are qualitatively and quantitatively accurate, up to date and suited to the methodology. In practise, it has been found that these requirements are not met because the available data are consolidated in a way that does not comply with ECLAC (2014).

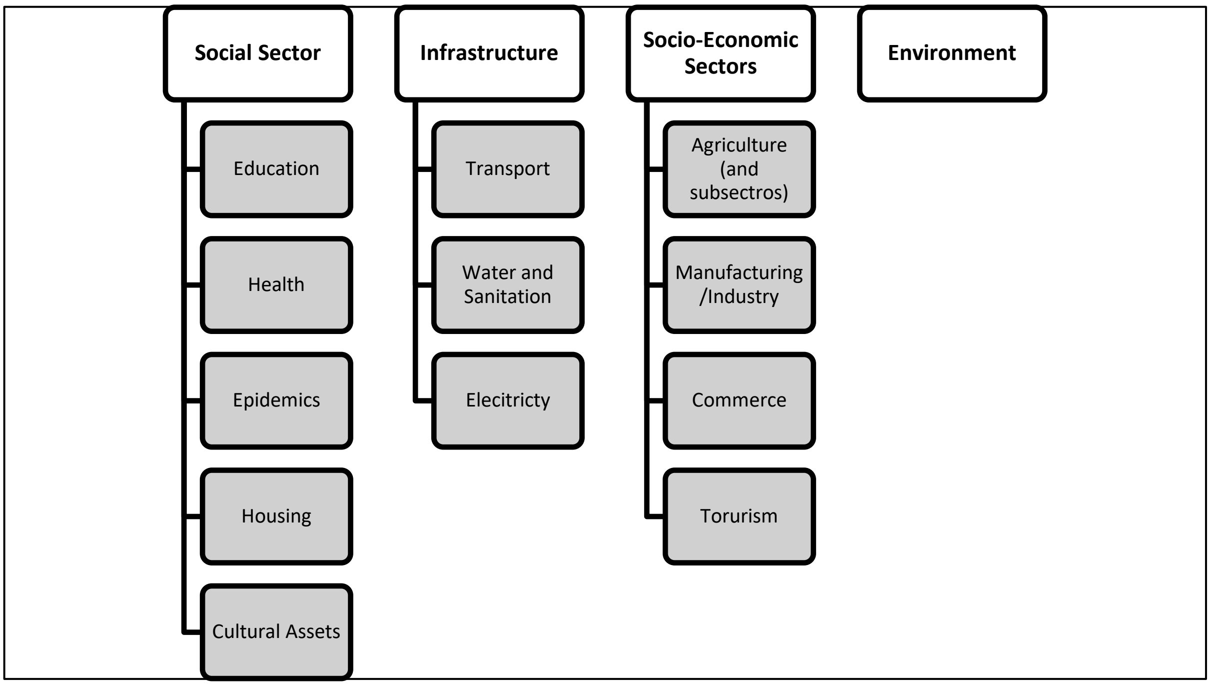

Figure 2.1 Sectors covered in the Damage and Loss Assessment framework. Adapted from ECLAC (2014).

In practise, DaLA can be implemented independently or as part of a PDNA framework. As aforementioned, the main goal of PDNA is to assess the full extent of a disaster's impact and identify recovery needs. It includes, alongside the main elements of the DaLA method, a Human Recovery Needs Assessment that enables an integrated assessment of disasters' effect and impact across all sectors (i.e. social, infrastructure, productive, macro-economy, human and social development, finance, cross-cutting themes) (see Appendix 2). These assessments ultimately facilitate the creation of a recovery strategy that effectively and sustainably addresses recovery and reconstruction needs. Both ECLAC/PNDA frameworks are widely used by governments, international organisations and development agencies.

Beside sector-specific impacts, the PDNA/DaLA framework also includes an assessment of the macro-economic consequences of a disaster (i.e. GDP, employment, public finance and national accounts). Here, the System of National Accounts (SNA), a comprehensive framework that provides a systematic and detailed description of an economy, is linked into a PDNA/DaLA framework. SNA is an internationally recognised standard set by the International Monetary Fund (IMF) for measuring economic activity, including production, income, consumption and wealth. The SNA helps policymakers, economists and researchers understand the economic conditions of a country and make policy decisions. The framework is organised into several key accounts: Production, Income, Expenditure, Capital, Financial and Balance Sheet accounts (see Table 2.1). This guide can help users systematically evaluate the indirect and direct impacts of flooding using the SNA framework, drawing on practical examples to illustrate the process (see Appendix 2 for some examples of indirect costs due to flood hazards identified within the SNA framework).

Table 2.1 Summary of System of National Accounts. Adapted from Statistics New Zealand (2014) and IMF.

Account	Description	Key Components
Production	Record the value of goods and services produced by industries and sectors of the economy.	GDP and its components (consumption, investment, government expenditure, net exports).
Income	Record the distribution of income generated from production.	Compensation of employees; gross operating surplus (profits); taxes on production and imports minus subsidies
Expenditure	Record the final uses of goods and services produced.	Household consumption; government expenditure; gross fixed capital formation (investment); exports minus imports (net exports)
Capital	Record transactions related to the acquisition and disposal of non-financial assets.	Land; buildings; machinery; intellectual property
Financial	Record transactions in financial assets and liabilities between residents and non-residents.	Changes in financial assets and liabilities due to saving; investment; financial flows
Balance Sheets	Provide a snapshot of the stock of assets and liabilities held by sectors of the economy at a specific point in time.	Financial assets; non-financial assets; liabilities

Traditional SNAs primarily focus on financial and physical capital, income and expenses. In contrast, the Living Standards Framework (LSF; Treasury 2021) is a flexible framework primarily designed to integrate intergenerational wellbeing in the Aotearoa New Zealand context. It is used to assess economic policy, fiscal policy and climate-change policy (see Figure 2.2). It operates on three levels: individual and collective wellbeing, institutions and governance and the overall wealth of the country. The last level defines how wealthy we are as a country, including aspects of wealth not fully captured in traditional SNAs (including human capability and the natural environment).

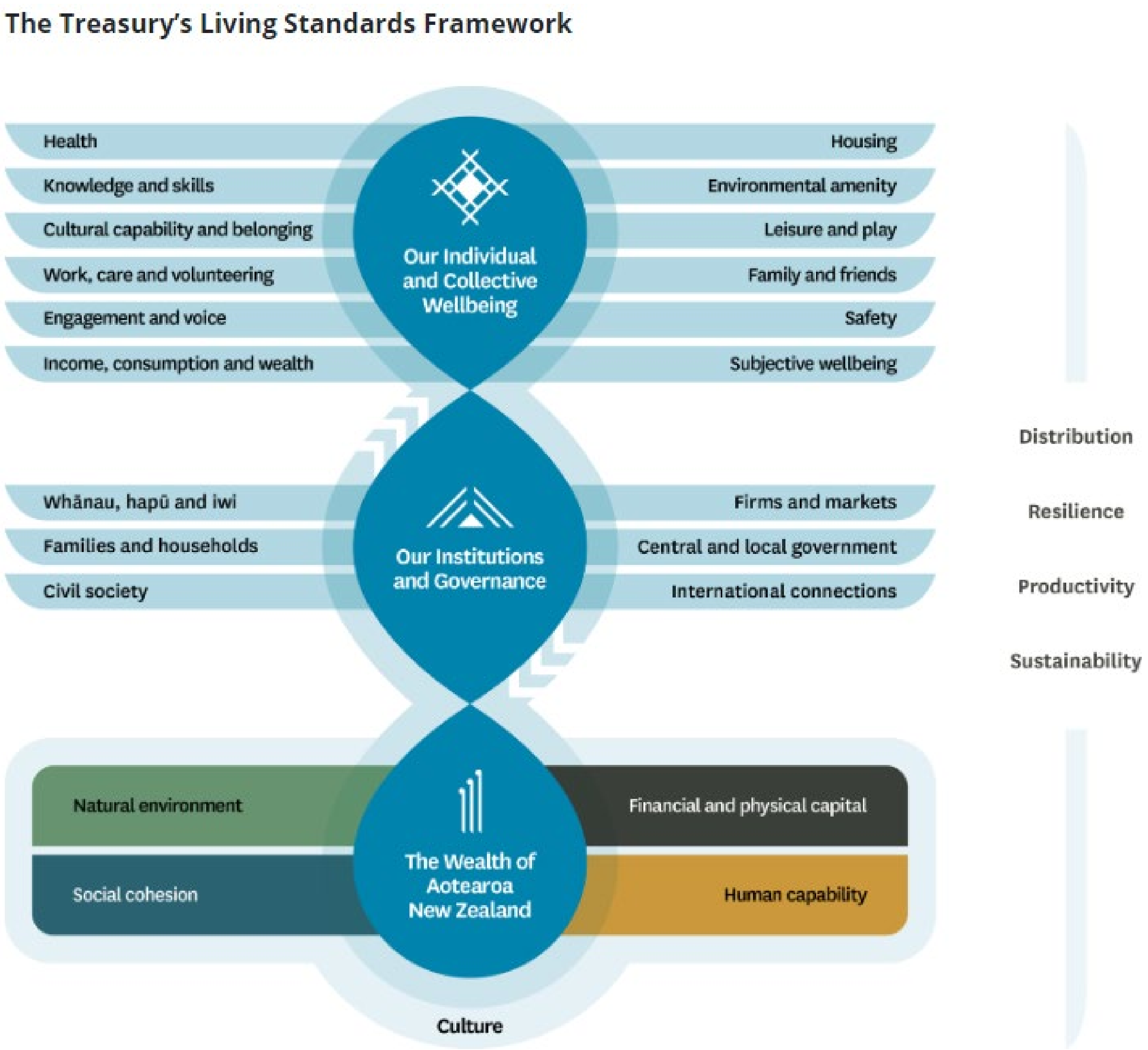

Figure 2.2 The Treasury's Living Standards Framework. Sourced from Treasury (2021).

While the LSF is not inherently an accounting framework for evaluating the impacts of hazards, it could be adapted for such purposes. Given its relevance in the public-policy arena, we believe it is important to mention here. As a flexible, generic accounting framework, the LSF helps identify, organise and structure impact assessments that go beyond economic realms. It is hazard-agnostic, meaning that it can be applied across various contexts, making it a versatile tool to understand societal wellbeing and organise responses in a structured manner. In the case of flood hazards – whether surface, sub-surface, riverine or coastal – the LSF can offer a structured way to assess the complex indirect impacts across various aspects of society and guide policymakers and institutions in organising responses and interventions (see Appendix 2 for some examples of indirect costs due to flood hazards identified within the LSF Framework).

2.2.2 Modelling Approaches

Okuyama and Chang (2004) presents a comprehensive review of methods used to calculate the indirect impacts of disasters. Meyer et al. (2009) also provides a categorisation of methods. We rely on both and categorise them into micro-economic and macro-economic approaches. These approaches are key methods for assessing the economic impacts of natural hazards such as floods. The micro-economic approach focuses on individuals, households or firms using detailed, small-scale, data to examine specific impacts such as lost income due to business closures, reduced wages for affected workers, or financial losses for businesses from damaged infrastructure (as well as direct costs such as building damages). This granular data helps design targeted policies, such as financial aid or recovery grants for those directly impacted.

In contrast, the macro-economic approach looks at the broader economy, analysing large-scale indicators such as GDP, unemployment, and inflation. It captures how major disasters affect regional or national wealth measures, including declines in national economic output, inflation spikes from supply-chain disruptions and widespread unemployment. Macro-economic models inform policy decisions for disaster recovery at a national or regional level. Together, macro- and micro-economic approaches provide a comprehensive understanding of the economic impacts of hazards, from individual-level consequences to economy-wide effects.

Okuyama (2013) also describes the strengths and weaknesses associated with each method, which we have summarised below. Building on that review, we outline the necessary steps, data and methodological requirements for implementing a quantification method for indirect losses.

2.2.2.1 Micro-Economic Approaches

Microeconomic approaches focus on specific impacts using natural experiments and quasi-experimental designs, such as Regression Discontinuity, Panel Data Regression, Difference-in-Differences, Propensity Score Matching and other matching methods to assess how individuals, businesses or regions are affected by a disaster (including flood). These methods, which have become more prevalent due to data availability, offer a comprehensive view of disaster impacts from the granular to the national scale (see Table 2.2).

In the case of disaster impact, the primary goal of these models is to estimate the ‘average treatment effect’ of a disaster by comparing key variables – such as revenue, net income ratios, or operational efficiency – between the affected group and the unaffected group. This is to estimate the non-market indirect tangible (as well as intangible) costs of the disaster in dollar terms. Non-market values refer to the costs and benefits, in which there is no explicit market and no observable prices (e.g. business disruption, unemployment), as opposed to the market values that are derived from goods or services that are bought and sold directly in the market (e.g. reconstruction costs of infrastructure) (Rogers et al. 2019). In addition, other methods can infer non-market economic impacts, such as stated-preference techniques such as Contingent Valuation, Contingent Behaviour and Discrete Choice Experiments. These methods require primary data collection through surveys or questionnaires, making them more resource-intensive but valuable for capturing public preferences and perceived costs of natural hazards.

Table 2.2 Summary of micro-economic methods.

Models	Description	Implementation Steps	Data
Regression Discontinuity Design (RDD)	This technique is a quasi-experimental impact evaluation method that assesses the effect of an intervention (such as a treatment, policy or natural hazard) by assigning a cut-off or threshold that determines which observation receives the intervention. It compares two groups that are nearly identical except for the intervention. RDD was used to estimate flood risk on floodplains, farmland values and political support (Wang 2021; Hilbig and Riaz 2024).	• Identify a cut-off point (for example, using distance to a floodplain boundary) that separates the treatment group (affected by the disaster) from the control group (unaffected). • Collect data on outcomes for individuals or regions just above and just below the cut-off. • Estimate the RDD model to evaluate the impact by comparing outcomes on either side of the threshold.	• **Data requirements:** Data inside and outside the cut-off point. • **Variables:** Outcomes of interest (e.g. property values, political support, etc.).
Panel Data Regression (PDR)	PDR models analyse data that vary across both time and individuals (businesses). These models help understand the dynamic effects of disasters on business recovery over time, accounting for individual heterogeneity. PDR can be used to estimate a hedonic pricing model where the non-market impact of flood hazard is isolated on the price of good and services.	• Collect panel data on businesses over multiple time periods. • Estimate fixed or random effects models to analyse the impact of disasters. • Interpret coefficients to understand the long-term effects.	• Longitudinal data on businesses. • Variables on business performance and characteristics.
Propensity Score Matching (PSM)	PSM is a statistical matching technique to estimate the effect of a treatment, policy, intervention or natural hazard. It does so by creating a control group that is statistically similar to the treatment group based on observed characteristics (balanced group). This method reduces selection bias and allows for a more accurate estimation of the disaster's impact on businesses. PSM is one of multiple statistical matching techniques to reduce model dependence (see Rosenbaum and Rubin 1983; Ho et al. 2007). It can be used a data-processing tool in combination with other models (e.g. RDD, DiD).	• Estimate propensity scores using logistic regression. • Match treated and control units based on propensity scores. • Compare outcomes between matched pairs to estimate the impact.	• Data on business characteristics and outcomes. • Variables to match treated and control businesses (e.g. size, industry).

Models	Description	Implementation Steps	Data
Difference-in-Differences (DiD)	This technique compares the changes in outcomes over time between the affected group (treatment group) and an unaffected group (control group). It helps isolate the impact of the disaster from other confounding factors. DiD is different from RDD, as it allows pre-existing difference between the two groups. DiD was used to assess the impact of flood on house prices (Nguyen et al. 2022) and the impact of community flood adaptation capacity on flood losses (Pecharroman 2023).	• Identify treatment and control groups. • Collect data on outcomes before and after the disaster for both groups. • Estimate the DiD model to isolate the disaster's impact.	• Pre- and post-disaster data for both treatment and control groups. • Variables on business performance (e.g. revenue, employment).

2.2.2.2 *Macro-Economic Approaches*

Macro-economic models, such as Input-Output (I-O), Social Accounting Matrix (SAM) and Computable General Equilibrium (CGE), analyse broad economic changes, capturing the ripple effects of disasters across sectors and markets. These tools help quantify the macro-economic disruption for different purposes. For example, I-O models can be used to analyse the interdependencies between sectors to quantify the economic impacts of disasters; SAM can be used to consider the entire economy, capturing the interactions between multiple markets; and CGE models with actual economic data can be used to simulate how an economy might react to changes, such as a disaster. The pros and cons of each approach are presented in Table 2.3. Step-by-step instructions and data requirements for each approach follow this.

Table 2.3 Pros and cons for each macro-economic approach described in this section.

Models	Pros	Cons
Input-Output (I-O)	• **Data Availability:** National statistics offices produce I-O tables annually, ensuring that data is readily available. • **Established Procedure:** The methodology for I-O analysis is well established and widely referenced in academic studies. • **Comprehensive Analysis:** These models provide a detailed view of economic interactions across sectors.	• **Reliance on Aggregated Data:** I-O models depend on aggregate figures of total output or final demand per sector, generally at national level, which diminishes the ability to identify which industries, and where, were affected by a hazard, e.g. a flood. • **Linearity:** I-O models rely on linearity as a neat way of outlining inter-sector linkages and demand structure by imposing specific structural constraints. This is opposed to a CGE model with higher flexibility and representing a larger spectrum of demand and supply side elasticities. As a result, I-O models often over-estimate economic losses, while CGE models often under-estimate the impacts because of possible extreme price and quantity changes due to the included elasticity (Galbusera and Giannopoulos 2018). • **Rigidity on import substitution.** • **Does not reflect changes in prices.**
Social Accounting Matrix (SAM)	• **Comprehensive Scope:** Includes more economic interactions than I-O models. • **Policy Analysis:** Useful for assessing distributional impacts of disasters.	• **Complexity:** More data-intensive and complex to implement. • **Data Availability:** Requires detailed data on household incomes, expenditures and production factors.
Computable General Equilibrium (CGE)	• **Flexibility:** Can model a wide range of economic scenarios. • **Policy Analysis:** Useful for examining the effects of different policy interventions.	• **Complexity:** Requires advanced economic and computational skills. • **Data Requirements:** Needs detailed baseline data for calibration.

Input-Output Model

I-O models are static, linear models of all purchases and sales between sectors of the economy (also known as economic industries, or economic sectors) and are used to illustrate and quantify the economic interdependencies between sectors (Rose et al. 2004). These models help in understanding how the output of one sector affects others, making them well-suited to examine the potential ripple effects of a disaster such as a flood event. Examples of this application can be found in Rose et al. (2004) and Cochrane (1997).

I-O tables typically represent monetary flows, not physical quantities (often measured in a country's currency). A simplified I-O table is presented in Table 2.4 with its elements. Each number represents the monetary value of intermediate inputs from one sector used by another sector to produce output. In addition, the I-O table presents (a) the total output value of goods and services produced by an industry or sector during a specific period and (b) the final demand for goods and services by the end consumers. In Aotearoa New Zealand, the latest I-O table available is quite outdated (as of March 2020) – and data is broken down into 109 industries and 197 product groups.[2] Notice that gaps in data collection may hinder the validation of I-O models in assessing disaster impacts, as multiple events can occur in between such periods. Therefore, I-O models are generally used to *simulate* the flow-on indirect effects from one sector to another in the entire economy on top of the baseline data (see Zeng and Guan [2020]) for discussion on accounting for hypothetical multiple flood events in I-O analysis).

Table 2.4 The input-output model.

	Agriculture	Manufacturing	Services	Final Demand	Total Output
Agriculture	30	20	10	40	100
Manufacturing	10	50	30	60	150
Services	10	10	40	40	100

To understand the impact of flooding, we need to estimate how much the disaster reduces output in each sector. This information can be challenging to gather and often relies on data from past events or specialised surveys conducted after the disaster. For example, Brown et al. (2019) collected post-event data through specialised surveys following the Canterbury Earthquake Sequence (CES). Using business impact and recovery data from the 2010/11 CES, along with qualitative validation, their study presents an empirically derived, transferable model for estimating business recovery after infrastructure and non-infrastructure disruptions caused by earthquakes.

An extension of the I-O model in the context of natural hazard is the dynamic inoperability input-output model (DIIM), first developed by Haimes and Jang (2001) and refined by Santos and Haimes (2004). DIIM builds upon the conventional I-O model to track the cascading effects of production inoperability across sectors, estimating the potential economic impact of natural hazards on interconnected infrastructures. These models aim at bridging the inter-temporal and intra-temporal inoperability. Such a model has been used in flood hazard context globally (Samimi et al. 2020; Avelino and Dall'erba 2019) and locally (McDonald et al. 2018) in a suite of MERIT models[3] (see Section 3 for an example case study of the 2017 Edgecumbe flood).

2 https://www.stats.govt.nz/information-releases/national-accounts-input-output-tables-year-ended-march-2020/
3 https://www.merit.org.nz/

Social Accounting Matrix

SAM extends I-O models by considering the entire economy, capturing interactions between multiple institutional accounts, such has households, businesses and government, and the rest of the world. It does so by considering not only production linkages but also the income-expenditure feedback and interactions among economic agents.

Besides the I-O table, SAM requires additional detailed data on supply and use of products and data on income, saving, assets and liabilities of the economic agent.[4] SAM can be constructed at a national level or refined to regional level, but the process to produce regional SAMs requires significant time and resources (see Andrew et al. [2009]; Smith et al. [2015]). To employ SAM in analysing indirect flood costs, detailed data on transactions between households, businesses and government need to be collected alongside the I-O table. Then, the direct flooding impacts are estimated on different sectors and economic agents. In the past, SAM has been used in isolation to analyse the impact of natural hazard on economic flow (i.e. production loss, see Okiyama [2017]). However, most often, SAM is often used as a core data for the CGE model.

Computable General Equilibrium Models

CGE models extend general equilibrium models by using actual economic data to simulate how an economy might react to changes, such as a disaster. CGE models are a multi-market simulation tool that is especially well suited to distributional impact analysis (Rose 2004). At the core, CGE models are extensively calibrated upon the SAM datasets to ensure that these accurately present the economy and its disaggregated institutional accounts. CGE models also rely on actual data or estimation or calibration of the impacts of the disaster on different sectors and markets (see Gertz et al. [2019]). The economic shock from disasters (such as flooding) are often modelled by adjusting the capital (built capital) and sectoral outputs in a shock scenario. Then, simulations of the baseline scenarios and shock scenarios are run to see how the economy adjusts over time. A limitation of these CGE models is that they rely on the assumption that all economic agents (such as household or business) optimise in response to the price signals, subject to economic account balances and resource constraints. An alternative of CGE model is a system dynamic model that allows time lag, disruption and non-equilibrium behaviour (i.e. businesses may be operating at a loss) (MERIT; see Section 3 for more details).

2.2.3 Using Direct Costs to Model Indirect Habitability Impacts

Direct asset damage metrics can be used to formulate relationships with indirect costs. For example, the habitability of buildings typically relies on the outputs of direct damage modelling to buildings, with the damage state serving as a proxy for habitability (whether a building is safe and healthy to occupy, represented by placarding in actual events). As a general rule, where floodwaters reach about the floor height of a building, it is rendered uninhabitable, although upper storeys may still be utilised in some cases.

4 https://www.stats.govt.nz/experimental/national-accounts-income-saving-assets-and-liabilities-march-2024-quarter/

Household impacts, including displacement, can be modelled by using the outputs of building damage and loss of habitability modelling combined with data on dwelling occupants. A household impacts model applicable to any natural hazard event has recently been developed for the Aotearoa New Zealand context (Scheele et al., in prep). The model is agent-based and considers the decision-making of each household as to whether to re-locate given certain conditions (e.g. loss of habitability, mandatory evacuation, school or workplace disruption). Further, displaced households decide the accommodation type, location and duration of alternative accommodation. As conditions change, such as the repair of residential dwellings restoring habitability, some residents choose to return over time. Alternative accommodation choice is informed by surveys of household experiences following the 2017 Edgecumbe (Scheele et al. 2021a) and 2021 Westport (Scheele and Paulik 2024) flooding events, which led to widespread household displacement.

A household population model with key characteristics, including number of individuals, number of children, household composition, household income and tenure, is available with households distributed to residential dwellings within the national building inventory (Scheele et al. 2021b). Combined with a flood hazard layer, the data exists to model household displacement for flooding events anywhere within the country.

2.2.4 Data Sources for Indirect Cost Assessment

The availability of information will determine what assessment method is possible. Below is a comprehensive overview of various data sources applicable for both macro-economic and micro-economic analysis of indirect disaster impacts.

- **National and regional statistics** provide aggregated economic data essential for macro-economic methods such as I-O models, SAM and CGE models. These statistics typically include I-O tables, national accounts and SAM data, which are produced annually by national statistics offices. These offer a detailed view of the interdependencies between different economic sectors, enabling comprehensive economic impact analysis.
- **Administrative records**, including business registration and tax records, are vital for both macro-economic and micro-economic analyses. These records, maintained by government agencies and local councils, offer granular insights into the operational and financial health of businesses, helping to assess the broader economic impacts of disasters.
- **Surveys**, including business and household surveys, provide critical data for both macro-economic and micro-economic methods. Conducted by national statistics offices or independent survey agencies, these surveys gather detailed information on business performance, household income and expenditure patterns. Interviews, as a qualitative data-collection method, can supplement survey data by providing in-depth insights from stakeholders.
- **Geospatial Information Systems (GIS) data** are crucial for mapping and analysing the spatial distribution of economic activities and the impacts of disasters. GIS data, available from regional planning authorities and specialised GIS databases, support both macro-economic and micro-economic methods by providing detailed geospatial context to economic data.
- **Remote sensing data**, including satellite imagery and aerial photographs, offer real-time and historical perspectives on the physical and environmental impacts of disasters. These data are indispensable for assessing the extent and severity of disaster impacts, supporting both macro-economic and micro-economic analyses.

- **Economic censuses** provide comprehensive data on economic activities across various sectors. Collected periodically by national statistics offices, these offer detailed insights into business operations, employment and sectoral output, which is critical for micro-economic analysis.
- **Population and dwelling censuses**, conducted by national statistics offices, provide data on population distribution, housing conditions and demographics. These data are essential for understanding the human and social dimensions of disaster impacts, particularly in micro-economic analyses focusing on household-level effects.
- **GIS surveys** combine traditional survey methods with GIS technology to collect spatial data. These surveys, conducted by local councils or specialised agencies, provide detailed geospatial and socio-economic data, supporting both macro-economic and micro-economic analyses.
- **Interviews with business owners, community leaders and other stakeholders** provide qualitative data that complement quantitative survey data. Conducted by independent researchers or survey agencies, interviews offer nuanced insights into the indirect impacts of disasters, helping to validate and enrich quantitative findings.
- **The Economic values of Ecosystems and Biodiversity** (TEEB) is a global initiative aimed at highlighting and making nature's values visible. Its core objective is to integrate the value of biodiversity and ecosystem services into decision-making processes at all levels. To achieve this, TEEB follows a structured approach to valuation that enables decision-makers to recognise the diverse benefits provided by ecosystems and biodiversity, quantify these benefits in economic terms, and, where relevant, incorporate them into policy and planning.

Table 2.5 Summary of data sources for indirect loss assessment.

Data Source Type	Description	Application in Methods	Key Sources
National and regional statistics	Aggregated economic data, including I-O tables, SAM data and national accounts.	Macro-economic	National statistics offices
Administrative records	Business registration, tax records and other administrative data maintained by government agencies.	Both macro-economic and micro-economic	Local council records, business registries
Surveys	Data collected through business surveys, household surveys and interviews.	Both macro-economic and micro-economic	National statistics offices, independent surveys
GIS data	Geospatial data detailing the physical and economic landscape of affected areas.	Both macro-economic and micro-economic	GIS databases, regional planning authorities
Remote-sensing data	Satellite imagery, aerial photographs, and other remotely-sensed data.	Both macro-economic and micro-economic	Satellite data providers, remote-sensing agencies

Data Source Type	Description	Application in Methods	Key Sources
Economic census	Detailed data on economic activities	Micro-economic	National statistics offices
Population and dwelling census	Data on population distribution, housing and demographics.	Micro-economic	National statistics offices
GIS surveys	Surveys conducted using GIS technology to gather spatial data.	Both macro-economic and micro-economic	GIS databases, local councils
Interviews	Qualitative data collected through direct interviews with stakeholders.	Micro-economic	Independent researchers, survey agencies
Primary sources	Data collected directly from fieldwork, administrative records and targeted surveys.	Both macro-economic and micro-economic	National and regional statistics offices, local councils, surveys and interviews

Accessing high-quality data is crucial for implementing effective assessment methods. Several platforms and organisations provide valuable data for research and analysis:

- **Statistics New Zealand:** Offers integrated data and access to microdata for research purposes: https://www.stats.govt.nz/integrated-data/apply-to-use-microdata-for-research/
- **GWRC Open Data:** Provides open geospatial data from the Greater Wellington Regional Council: https://gwrc-open-data-11-1-gwrc.hub.arcgis.com/
- **LINZ Data Service:** Supplies land and geographic data from LINZ: https://data.linz.govt.nz/
- **Koordinates:** Hosts various geospatial datasets: https://koordinates.com/data/?q=wellington
- **S-Map Online:** Offers soil maps and data from Manaaki Whenua Landcare Research: https://smap.landcareresearch.co.nz/maps-and-tools/app
- **NIWA Climate Data:** Provides climate data from the National Institute of Water & Atmospheric Research: https://cliflo.niwa.co.nz/
- **NIWA High Intensity Rainfall Design System (HIRDS):** Supplies rainfall data and projections: https://hirds.niwa.co.nz/

By leveraging these data sources, regional councils can enhance their understanding of the indirect impacts of disasters and develop targeted strategies to mitigate these effects, ultimately building more resilient communities and economies.

2.3 Intangible Costs

As described in the preceding section, effort has been made to improve the quantification of disaster losses by focusing on increasing the consideration of indirect losses in relation to the typical focus on direct losses. However, given conflicted approaches to including or excluding intangible losses in either the direct or indirect categories, it can be difficult to determine whether and how these efforts are considering intangible losses specifically. Given the challenge of quantifying and, in particular, costing intangible impacts of natural hazard events such as floods, a comprehensive resource on intangible costs (loss) estimation does not appear to exist. Several different types of sources broach the subject, with a varying level of detail and practicality. As described in the above section discussing how we arrived at a working definition, we considered a range of perspectives. Some of the documents were specifically chosen for review due to their significance to the current context (e.g. key Aotearoa New Zealand policy documents), while the others were obtained through searches of academic databases for key terms (‘intangible’; ‘loss’ or ‘impact’; and ‘flood’, ‘hazard’, ‘disaster’).

The documents reviewed included policy frameworks and guidelines from international organisations, such as the United Nations General Assembly, as well as national-level documents such as the NEMA National Disaster Resilience Strategy (MCDEM 2019) and Australian Bureau of Transport Economics framework, which has been drawn on in Aotearoa New Zealand to understand impacts of past events such as the 2002 Waikato ‘weather bomb’ (Walton et al. 2004). The challenge of costing intangible losses has also been considered from economic and accounting perspectives, including the New Zealand Accounting Standards Board (2022) and ECLAC (2014). Finally, we reviewed a range of academic literature addressing the question of assessing, quantifying or costing intangible losses in the context of natural hazards generally, and floods specifically, given the relatively small amount of material on the latter.

Across the academic and non-academic sources reviewed, a large range of intangible losses were identified. These could be broadly considered as losses to an individual, a community, the culture or the environment (see Table 2.6). The difficulty in estimating the magnitude of the various potential losses ranges from relatively straightforward (e.g. number of injuries can be estimated based on treatment access, although not all injured individuals will seek treatment) through to virtually impossible (e.g. reduced trust in local agencies). For example, trust is a difficult concept to measure let alone quantify or value (Bonfanti et al. 2024), but reduced trust in local agencies and authorities can have detrimental impacts on communities, such as complicating response and recovery efforts (Paton et al. 2014). However, tools have been developed for measuring trust in public institutions (OECD 2024) and in various actors of flood-risk communication (e.g. volunteers, local government, emergency services, neighbours) (Seebauer and Babcicky 2018), as well as its influence on flood-risk perceptions and preparedness actions (Terpstra 2011). Critical in the uptake of preparedness advice and action, and in heeding warnings and disastrous impacts from floods, as well as other external factors – erosion of the public’s trust in the authorities responsible for communicating and mitigating flood risk can in turn inhibit uptake in protective action advice (Richard Eiser et al. 2012; Mahdavian et al. 2020) and may result in worse consequences, such as impeding response and recovery efforts (Bonfanti et al. 2024), subsequently worsening or lengthening physical and mental health issues (Thoresen et al. 2018); or civil unrest (Grande and Saldivia Gonzatti 2024). However, trust does not have an economic value, and the far-reaching impacts of eroded trust in authorities is difficult to cost when accounting for flood losses.

Sense of place is another vague concept that can be simply described as “the emotional, psychological, and physical attachment of people with a specific place” (Hidalgo and Hernández 2001). Disasters such as floods can affect individuals’ sense of place with the area that experienced the event; these effects can manifest as psychological impacts, including feelings of isolation and a loss of a sense of security within individuals’ communities and homes (Tapsell and Tunstall 2008).

Table 2.6 Potential intangible costs based on a review of the literature.

Individual	Community	Cultural	Environmental	Other
• Long-term mental health impacts (e.g. depression, psychological trauma). • Short-term mental health impacts (e.g. stress, anxiety). • Loss of lives. • Injuries. • Bereavement. • Household disruption. • Loss of memorabilia. • Loss of gardens. • Reduced income earning capacity. • Reduced land values. • Increased dependence. • Disruption to living (e.g. isolation and evacuation). • Loss of pets. • Relationship breakdowns. • Increased substance abuse.	• Disruption generated by the rebuilding process. • Increased demand on existing services. • Disruption to education. This is an indirect value that can be estimated using student days lost and proxies, such as school fees or teacher salaries. • Loss of leisure. • Loss of community (e.g. access to networks, services and assets, including recreation areas). • Sense of place.	• Damage to cultural and heritage sites (including cemeteries). • Damage to cultural and heritage artefacts. • Loss of non-use values for cultural and environmental sites and collections. • Disruption to traditions and cultural activities. • Loss of traditional knowledge.	• Environmental damage. • Ecological damage (e.g. changed habitats). • Soil contamination and pollution. • Water contamination and pollution. • Loss of soil nutrients. • Soil erosion. • Aesthetic impacts. • Interruptions in water supply.	• Loss of image (e.g. location's reputation). • Loss of information stored on computers/servers. • Loss of organisation and distribution networks. • Loss of trust in authorities.

How to quantify the economic value of intangible costs is by no means a new question, having been discussed in the academic literature for decades (e.g. Green and Penning-Rowsell 1989). While valuation methods have been classified and applied for valuating cultural goods and services in the context of disaster assessment (Vecvagars 2006), and efforts are ongoing to valuate ecosystems and biodiversity through, for example, the TEEB initiative (described in Section 2.2.4, although further discussion on environmental and ecological losses are out of scope of this report), little progress seems to have been made in the quantification and costing of intangible losses for many other intangible losses listed in Table 2.6. This may in part be due to the challenges around applying data across contexts (i.e. the costing of a loss in one country may not be accurate in another), the fact that response and recovery measures influence intangible losses (i.e. if good decisions are made during response and recovery, then intangible *impacts* do not necessarily become intangible *losses*) and the fact that often intangible losses either only become visible, measurable and potentially costable over timeframes of years or cannot be measured in measurable units (e.g. dollar values). For example, the Canterbury Wellbeing Index developed by the Canterbury Earthquake Recovery Authority has a vast number of metrics for the quantification (if not costing) of a range of intangible impacts to domains such as subjective wellbeing, health, civic engagement, education, employment and environmental. However, many of these metrics only have data available yearly, which limits their usefulness in terms of identifying shorter-term impacts.

2.3.1 Assessment Frameworks

Many different cost-assessment methods can be used to try to estimate the value of intangibles and impacts on them, depending on the nature of the impact. Such methods include the Hedonic Pricing Method, Replacement Cost Method, the Enhanced Replacement Cost Method, Benefit Transfer Method, Travel Cost Method, Cost of Illness Approach, Contingent Valuation Method, Life Satisfaction Analysis and Choice Modelling Method (Markantonis et al. 2012; Vecvagars 2006). Whether any of these methods can be used depends on the data available both pre- and post-event, as well as their suitability. Some pros and cons for methods relating to valuating cultural losses are provided in Table 2.7.

Additional approaches have laid out a quantitative process to assess disaster losses, such as the Australian Institute for Disaster Resilience's 'Disaster Loss Assessment Process' (see Figure 2.3; AIDR 2002). While these processes tend to provide some detail about the actions needed at each step, there is still ambiguity and a considerable level of effort required to achieve the key action points (e.g. identifying, measuring and calculating). Other work in Australia has suggested methods to estimate intangible costs, including some of the methods described above, which are contingent on the ability to access or collect the relevant data (Figure 2.4; BTE 2001). Other assessment processes often require detailed data about pre-event baselines to estimate the magnitude of losses, as well as intensive post-event data-collection methods such as surveys (e.g. ECLAC 2014). Therefore, these processes are perhaps not appropriate for attempting to calculate losses after an event in the short-term, when resources are limited.

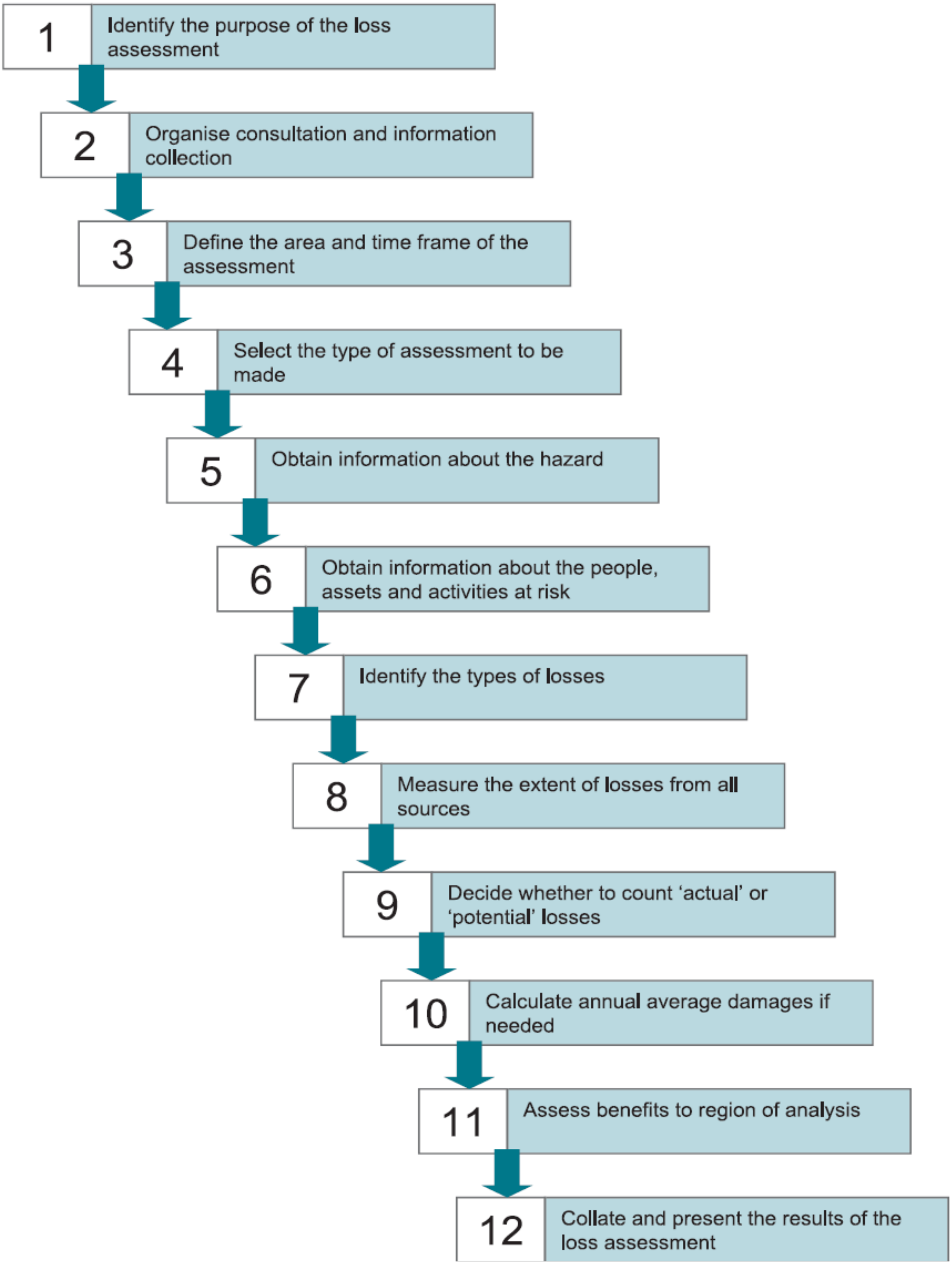

Figure 2.3 Australian Institute for Disaster Resilience’s ‘Disaster Loss Assessment Process’. Sourced from AIDR (2002).

SUMMARY OF DISASTER COST ESTIMATION – INDIRECT AND INTANGIBLE COSTS

Cost category	Estimation principle	Data sources
Indirect costs		
Business disruption	Loss of value added (usually not estimated if a national perspective is taken)	1. Survey
Loss of public services	Cost of provision	1. Service providers
Non-residential clean-up	Cost of materials plus opportunity cost of labour used	1. Survey 2. table 4.7 for commercial buildings 3. $10 000 for public buildings
Residential clean-up	Cost of materials plus opportunity cost of labour used	1. Survey 2. $330 per household for materials and AWE for household labour (20 person days (a)
Household alternative accommodation	Additional costs of accommodation plus any transport costs	1. Survey 2. $53 per person plus $26 per person-night
Agriculture	Costs such as fodder, agistment, loss of productivity due to pests	1. Survey
Transport networks	Increased vehicle operating costs. Value of time for delayed people and freight	1. Survey to estimate vehicle-hours of day 2. Unit costs from table 4.8
Disaster response relief	Marginal costs incurred by relevant agencies. Opportunity costs of volunteer labour.	1. NDRA 2. Survey of volunteer organisations
Intangible costs Fatalities	Human capital approach	$1.3 million (Appendix I)
Injuries	Human capital approach	$317 000 for serious injury and $10 600 for a minor injurty (Appendix I)
Health effects	Days of debilitations X AWE	1. Survey 2. Average proportion affected
Environmental damage, memorobilia & cultural heritage	Ideally one of: 1. Travel cost method 2. Hedonic prices 3. Contingent evaluation 4. Least cost alternative Otherwise proportion of direct costs	Survey if one of the analytic methods is used.

(a) There a is considerable variation in material costs

Source See preceding text.

Figure 2.4 Methods for estimating intangible costs. Sourced from BTE (2001). Note: References here to 'Appendix I' are in relation to the appendix of the original source (e.g. BTE 2001).

2.3.1.1 Methods for Valuating Cultural Losses

Valuation methods have been developed, classified and applied for both qualitatively and quantitatively valuating cultural goods and services in the context of disaster assessment (Dassanayake et al. 2015; Vecvagars 2006). These methods are listed in Figure 2.5. The pros and cons for these methods are listed in Table 2.7, based on an analysis of the methods by Vecvagars (2006).

While these valuation methods differ in their approaches and have varying strengths and weakness, they all follow the same general steps, as described by Vecvagars (2006):

1. Identify the cultural asset.
2. Determine the level of significance of the lost or damaged cultural asset.
3. Identify the beneficiaries to whom the benefits from the cultural assets accrued and identify such benefits.
4. Identify the appropriate valuation method based on the results of Step 3.
5. Include the valuation itself and compile the results.

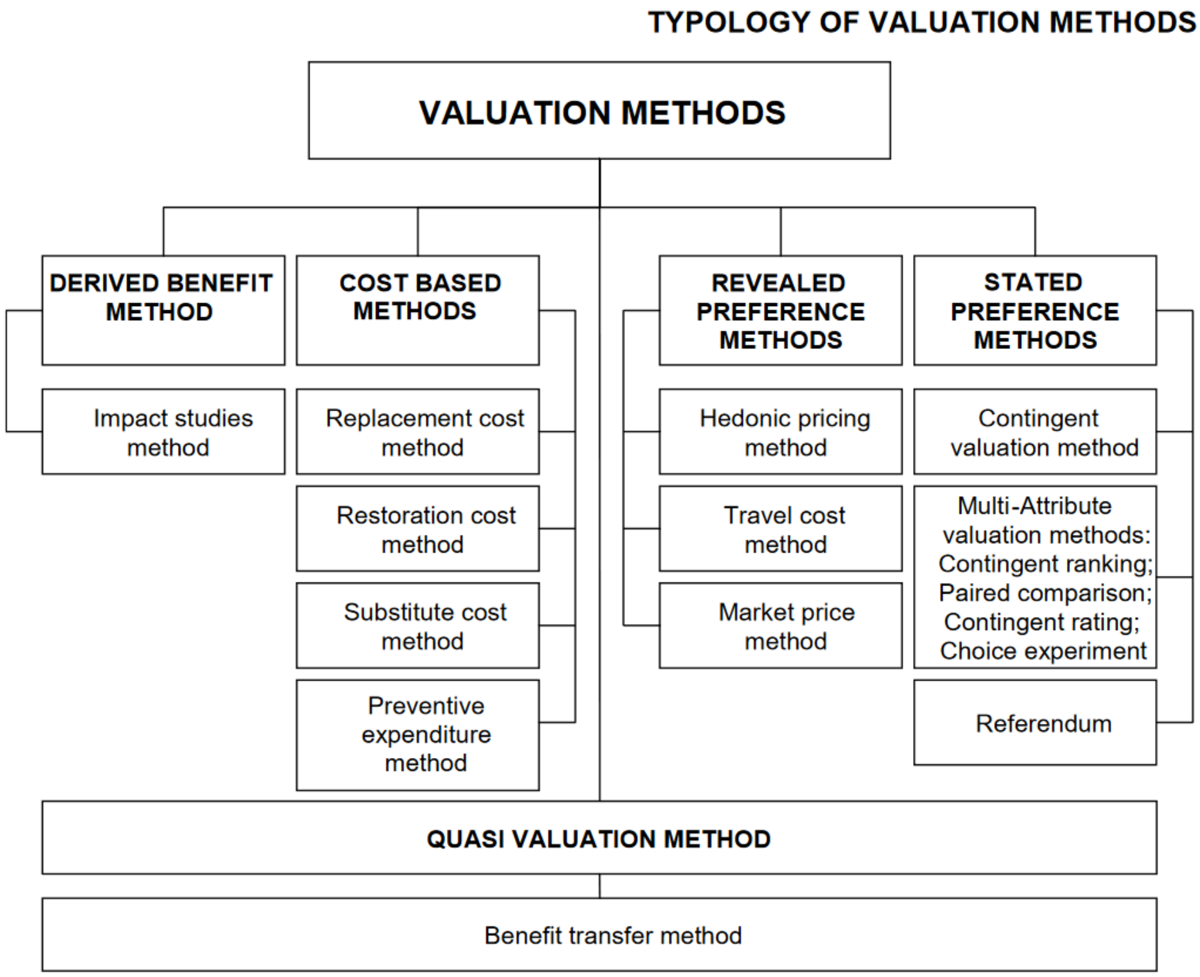

Figure 2.5 Typology of quantitative valuation methods of cultural losses (Vecvagars 2006).

Table 2.7 Summary of quantitative valuation methods of cultural losses and their pros and cons (Vecvagars 2006).

<table>
<tr><th>Method</th><th>Description</th><th>Pros</th><th>Cons</th></tr>
<tr><td>Contingency valuation</td><td>Questionnaires ask respondents about their willingness to pay for the benefits of a particular good or their willingness to accept compensation for the loss of the benefits from a particular good.</td><td>Useful in assessing the total value of the damaged asset, including use and non-use values.</td><td rowspan="3">Expensive and time-consuming to carry out.</td></tr>
<tr><td>Referendum</td><td>People are asked to vote on one or another public expenditure question, which informs important policy decisions.</td><td>Used as a democratic decision-making tool.</td></tr>
<tr><td>Multi-attribute valuation</td><td>A family of survey-based methodologies for modelling preferences for goods. Respondents are presented with various alternative descriptions of a good differentiated by attributes and attribute levels. Respondents are asked to rank or rate the various alternatives or choose their most preferred version. If price/cost is included as one of the attributes, people’s rankings, ratings or choices will also indicate their willingness to pay.</td><td>Useful when there are several cultural assets damaged and it is necessary to set priorities and determine which of the cultural assets is the most valuable to respondents.</td></tr>
<tr><td>Replacement cost method</td><td>Estimates the cost of replacing the good or service, which is then used as a proxy for the good’s/service’s value</td><td rowspan="4">Less time-consuming and costly.</td><td rowspan="4">These methods include only costs and not the embodied value; inability to recreate/restore the original; require information and data, which might be limited.</td></tr>
<tr><td>Restoration cost method</td><td>Assesses the value of a good or service by estimating the costs of restoring the good or service to its original condition. The difference from replacement cost method is that restoration costs can be used when the cultural asset is only partially damaged.</td></tr>
<tr><td>Substitute cost method</td><td>Establishes the market price of an asset that could be a substitute to the damaged one.</td></tr>
<tr><td>Preventive expenditure method (also known as mitigation or defensive expenditure)</td><td>Focuses on the costs of preventing the damages or losses from occurring.</td></tr>
</table>

<table>
<tr><th>Method</th><th>Description</th><th>Pros</th><th>Cons</th></tr>
<tr><td>Enhanced replacement cost method</td><td>Based on the replacement cost method, but the costs of replacing the damaged or lost cultural asset with a new and enhanced cultural asset are assessed and used to value the damaged/lost cultural asset.</td><td>The costs and value are calculated based on the creation of a new, possibly different and/or enhanced, cultural asset. Suitable for situations when time to completion is a non-issue and there is need for a more detailed assessment.</td><td>The assumption that the cost of replacing the cultural asset or service is equal to the value of such an asset or service; more time-consuming and expensive than the cost replacement method.</td></tr>
<tr><td>Hedonic pricing method</td><td>The price of a marketed good includes and reflects its characteristics. In the context of cultural heritage goods, the most likely market good for such an analysis is housing, either privately owned or rented. The hedonic pricing model assumes a housing market where consumers are mobile and there is a variety of housing units with different combinations of characteristics.</td><td rowspan="3">Less time-consuming and costly.</td><td rowspan="3">Requires detailed information and data, which might be limited or unavailable; captures only part of the total cultural value of the asset but does not include spiritual and social values.</td></tr>
<tr><td>Travel cost method</td><td>People visiting cultural sites derive some benefit from the visit, suggesting that it has a positive net value, i.e. the benefits equal or exceed the costs of travel, entry, etc. Thus, these costs can be used as an approximation of the lower boundary of the benefit value of the cultural asset.</td></tr>
<tr><td>Market price method</td><td>When the market price is available, it is used for estimating the asset’s value.</td></tr>
<tr><td>[Economic] Impact studies method</td><td>Assesses economic significance of a cultural asset/service based on the direct and indirect income that it generates.</td><td>Allows for a quick and objective assessment of the use values of the cultural assets.</td><td>Lack of common definition of industry boundaries; difficulty obtaining data; determining linkages between the inputs and outcomes and measuring them.</td></tr>
<tr><td>Benefit transfer method</td><td>Estimates the value of goods and/or services based on an already assessed value of another good/service.</td><td>Less time-consuming and resource-demanding.</td><td>The most difficult tasks could be finding an appropriate ‘substitute’ to the cultural asset being evaluated with as similar characteristics as possible.</td></tr>
</table>

Dassanayake et al. (2015) propose a qualitative method for assessing cultural loss, with an assessment matrix considering level of cultural value and level of physical damage (Figure 2.6). While this method can be used to assign a 'loss level' to a particular cultural asset, it still requires data on how much cultural value that asset has and requires a further step of then converting that loss level into a cost. This process may therefore allow the magnitude of cultural loss to be estimated, assuming that some value level is able to be assigned to the asset.

Level of Cultural value	Level of Physical Damage				
	Very low	**Low**	**Medium**	**High**	**Very high**
Very low	Very low	Low	Low	Medium	Medium
Low	Low	Low	Medium	Medium	High
Medium	Low	Medium	Medium	High	High
High	Medium	Medium	High	High	Very high
Very high	Medium	High	High	Very high	Very high

Figure 2.6 Cultural loss assessment matrix. Sourced from Dassanayake et al. (2015).

2.3.2 Existing Identified Values

The cost of a single, common impact can range considerably; for example, a review recently found that the value of statistical life can range from approximately a USD $100,000 to USD $15 million (Kharb et al. 2022). While Aotearoa New Zealand has methods for valuing a statistical life (Denne et al. 2023), this example of an order of magnitude difference in the value of a statistical life shows that even when an impact is 'costable', the value can range considerably depending on contextual factors. This perhaps limits the usefulness of international efforts to quantify and cost various specific intangible losses.

Work in the United Kingdom has explored how much the mental health impacts of a flood event might cost; however, this value again ranges considerably (from £1,878 to £4,136 per adult) and depends on context, such as the size of the flood event (UNDRR [2024]). One approach to putting a value on intangible losses is to use non-economic court awards, such as payouts from companies to individuals injured as a result of its error or negligence and that led to impacts on their quality of life. For example, the Australian Bureau of Transport Economics estimated (in 2000) that the cost of loss of quality of life due to a serious injury in a disaster was AUD $127,000 and a minor injury was AUD $8,450. These figures could be adjusted for inflation and exchange rate to give a starting point for impacts on quality of life due to injury. The lower rates of such litigation in Aotearoa New Zealand, due to schemes such as ACC (Accident Compensation Corporation), limit the availability of data to conduct such analyses in the local context.

More recent work in Australia has again attempted to place economic values on social impacts of disaster triggered by natural processes (Deloitte Access Economics 2016). This methodology applies a ratio of tangible to intangible losses to calculate the total cost (see Section 2.3.3 next),and also uses a cost per annum factor. Within this process, Deloitte Access Economics (2016) were able to quantify a range of intangible impacts, including fatalities and injuries, mental health impacts (including alcohol mis-use), crime (family violence and property) and a portion of the impacts of damage to the environment (see Figure 2.7).

Unit cost of social impact (2015 dollars)

Outcome	Average unit cost per year
Death	$189,200[*]
Physical injury (minor)	$11,600[†]
Physical injury (serious)	$325,000[†]
Mental health issue	$36,500[‡]
Alcohol misuse	$2,000[§]
Family violence	$25,000[¶]

Source(s): Deloitte Access Economics using * OBPR, † BTE (2001), ‡ Access Economics (2009), § Access Economics (2009), ¶ Access Economics (2004)

Figure 2.7 Estimates of annual cost per individual impacted. Sourced from Deloitte Access Economics (2016).

These values could be adjusted for inflation and exchange rate and are likely a relatively safer comparison than the above United Kingdom values, given the greater similarity between Australia and Aotearoa New Zealand. However, it is important to note that the *maximum* value in the United Kingdom study is approximately half the *average* unit cost in the Australian study, suggesting that processes by which these values are calculated, including the data on which they are based, can lead to vastly different results between country and disaster contexts.

Other work in Australia has adapted ‘willingness to pay’ (Johnston et al. 2015) data from other studies (Florec et al. 2017). This data is collected via surveys of the public, asking how much they would be willing to pay for intangible items such as access to a park (AUD $35 per household per year), avoiding electricity outages (AUD $71 per household per 12 hours) or avoiding being displaced (AUD $5.4 per household per hour). This data contains meaningful uncertainties but may be better included than ignored (Pannel and Gibson 2016).

2.3.3 Estimates of Magnitude in Proportion to Other Costs

A final method for estimating the cost of intangible losses is to apply a ratio. The steps involved are to:

1. Identify how many people were impacted.
2. Determine the magnitude of impacts (using an evidence base).
3. Define the per case cost per annum.
4. Multiply the incidence and per-case cost for each impact to estimate the total intangible cost.

This method is complicated by the above-mentioned problem of different approaches classifying intangible losses differently (i.e. as either discrete from direct and indirect, or comprising both and instead only being discrete from tangible losses). Several attempts at quantifying intangible losses have said that both intangible and indirect losses are typically at the same magnitude, if not greater, than direct losses (BTE 2001; Handmer et al. 2018). Other studies have said that intangible impacts are at least as large as direct intangible impacts (with a similar, separate multiplication factor for indirect losses [NZIER 2024]).

The approach to conceptualising and operationalising intangible losses influences how the multiplication factor is identified, calculated and applied. The BTE (2001) framework suggested that indirect and intangible losses combined tend to be the same, if not more than, direct losses. This suggests that, if indirect losses can be calculated, the difference between direct and indirect losses may be an appropriate baseline estimate of intangible loss.

A recent evaluation from Australia suggests that, of the total cost of a flood, 37% is social cost (examples listed in Figure 2.7)[5] (Deloitte Access Economics 2021). Reviewing this approach from an Aotearoa New Zealand perspective, NZIER (Clough and Hensen 2024) recently suggested a multiplication factor of 1.1 (i.e. intangible losses are 1.1 times the direct costs), although the authors note that the reliability of this ratio is low. Future work applying the Deloitte Access Economics method to Aotearoa New Zealand flood events, including to ones that are on a smaller scale than the Australian case studies, could help to refine this multiplication factor.

2.3.4 Estimates of Magnitude Using Existing Data Sources

To put an economic value on intangible losses, it is first important to estimate their magnitude. This could be individuals impacted, as discussed in the previous section. However, many of the other impacts are broader and their magnitude cannot be estimated solely based on the number of people impacted. For example, changes in the socioeconomic deprivation index between pre- and post-event could indicate the magnitude of the impact of the flood event. However, there are several limitations to this method that would need considerable research to address. The main issue is whether the data are available at fine enough scale both temporally and spatially to identify changes in anything other than the most major flood events. For example, Census data are not collected frequently enough (e.g. for pre-post comparison for economic impact assessments), while other data are only available at the level of Territorial Authority.

The Statistics New Zealand Integrated Data Infrastructure (IDI) may have metrics that could be used to estimate the magnitude of change in proxies for intangible losses. For example, a reduction in rates of applications for university student loans may reflect flow-on impacts to schooling and education. However, these data would again need to be on an appropriate temporal and spatial scale for the specific flood event. An alternative to using existing data is to conduct post-event surveys in the affected area (e.g. Scheele and Paulik 2024; Scheele et al. 2021a); this has the benefit of addressing temporal and spatial scale, although intangible losses can either persist or only appear well after the flood has ended, and this method requires significant resources to prepare, run and analyse the survey. Further, without baseline data from prior to the event, it would be difficult and potentially unreliable to estimate the magnitude of some types of loss (e.g. ones that result from reduction rather than destruction of an asset).

The second challenge with this approach, assuming that estimates of magnitude for some types of intangible losses (via proxy metrics) could be calculated, is that these estimates still need to be quantified into actual economic loss. The scale of that challenge is far beyond the scope of this report. Each of these steps introduces more uncertainty into the loss estimate (Handmer 2003).

5 Deloitte Access Economics (2021) uses 'intangible' and 'social' costs interchangeably and does not specify between indirect and direct intangible losses.

2.3.5 Caveats, Limitations and Future Work Needed

Many intangible losses only become visible, measurable and potentially quantifiable over timeframes of years, partly due to data availability in most countries, including Aotearoa New Zealand, but also due to the time that it takes for impacts such as mental health challenges to manifest and have secondary effects on wellbeing and productivity. Further, many intangible losses depend on measures taken during response and recovery. That is, intangible *impacts* of a flood event do not need to become intangible *losses* if they are managed well. For example, school closures do not need to lead to psychological harm for children or worsened educational impacts if the appropriate mental health support and alternatives for teaching delivery are quickly and effectively put in place.

Another reason for the challenges of quantifying intangible losses is that the value lost is not attributed by a market but rather by individuals, communities and societies. As such, the financial loss caused by an intangible impact must often be estimated using averages. Another challenge is that intangible losses are often relative; while a house is worth a (fairly) consistent amount, such that, if it is destroyed, the economic cost is easily quantifiable, many intangible losses are in the form of *reductions* to non-physical aspects of community or society, such as community cohesion. In this case, Vecvagars (2006) recommend using the Enhanced Replacement Cost Method, whereby:

> *"the costs and, hence, the value would not be calculated based on the creation of a replica or reconstruction of the original, but rather based on the creation of a new, possibly different and/or enhanced cultural asset."*

In addition to the general steps to valuation of cultural assets described in Section 2.3.1.1, this method would also include (Vecvagars 2006):

1. Organising the competition of new projects for the replacement asset/service after key stakeholders to the damaged/lost asset have identified the most important benefits/values. The scope of the project is determined by the characteristics of the lost or damaged cultural asset and the values attributed by the stakeholders. It is important to make sure that the replacement includes a similar type and level of benefits as those previously provided by the lost or damaged asset.
2. Selecting the project through applicating one of the multi-attribute valuation methods; asking respondents to rank, rate or choose their most preferred option among different alternatives. By including price as one of the characteristics, respondents' willingness to pay could also be indirectly ascertained.
3. Assessment of the value of the lost or damaged cultural asset based on the respondents' willingness to pay as a proxy. It is also possible to use the general replacement cost method to find the proxy for the value. However, this will not include the people's willingness to pay and, therefore, the value of the cultural asset to the respondents.

Future work in Aotearoa New Zealand could use a pre-post design to create locally relevant, contemporary estimates of the average cost of intangible impacts over time. This would require using existing data, and potentially collecting supplemental data, to create a picture of 'business as usual' functioning within a community and then, following an event, track changes in these measures over time to estimate the relative magnitude of impacts. However, this kind of work would likely incur significant costs. Given that some previous research has found a low proportion of intangible losses in flooding events (e.g. Florec et al. 2017), the decision to do this work should fully consider the expected costs and benefits. Instead, it may be better to use scaling or ratio values as identified above, with the important caveat that these contain a large amount of uncertainty. Another option would be to track changes through specialised surveys or administrative record data, such as the Statistics New Zealand IDI, which contains information of individuals, households and businesses over time. However, the benefits of this would again need to out-weigh the resources required.

3.0 CASE-STUDY APPLICATION

3.1 The April 2017 Edgecumbe Flood

On the morning of 6 April 2017, the Rangitāiki River breached a stop bank following heavy rain from the remnants of ex-Tropical Cyclone Debbie, resulting in widespread flooding within the town of Edgecumbe, Bay of Plenty, Aotearoa New Zealand. Despite being a clear day, the river level was high due to recorded persistent heavy rainfall during 4–5 April (137 mm in Whakatāne, the wettest April day since 1952; 186 mm in Te Puke, Western Bay of Plenty, the wettest April day since 1973) (ADR Knowledge Hub [2024]). Residents received very little warning (typically only a few minutes) before water began flowing into streets and properties within Edgecumbe. The water flows exceeded the designed parameters of the stop bank by at least 30%, resulting in large parts of the town lying below the water level.

A mandatory evacuation was called for the entire town, forcing residents out of their homes for a minimum of 10 days, depending on the level of property damage. The order of evacuation affected approximately 580 households and 1600 people. Over 250 homes were rendered uninhabitable until repairs could be completed, and around 15 homes were damaged beyond repair (RRSR 2017). The evacuation of the town and housing damage led to major disruption for residents. Many residents were forced into temporary accommodation for weeks to months until their homes were repaired. In some cases, residents did not return to their original addresses or re-located out of Edgecumbe permanently.

Figure 3.1 A satellite image of the Edgecumbe flood taken on 6 April 2017 after floods (Morton 2017).

3.2 Accounting Framework for Flood Costs

This section presents a damage and loss assessment framework for costs resulting from the Edgecumbe Flood (Table 3.1). Estimated figures, as well as anecdotal evidence, were collated from multiple sources, including reports from local councils, insurance councils and the media. The flood costs are categorised into 'direct', 'indirect' and 'intangible' following existing frameworks (i.e. from NZIER [2024] and the PDNA guideline [UNDP 2013]) (see Appendix 1 and Sections 1 and 2). In addition, cost estimates are also assessed based on their data quality.

We find that, while there are abundant data on the direct physical damages (e.g. damaged assets such as homes, residential lands, farmland and stocks) and/or immediate evacuation and clean-up costs, some of this information is largely figurative estimations without monetary figures (i.e. no price tag apart from insurance claims, house re-purchase costs and reconstruction costs). Insurance data (NZD $63 million) can only provide a partial figure, as some homeowners are uninsured (at least 17 damaged houses) and/or have assets that are difficult to quantify (e.g. livestock and pets). Furthermore, much of the re-purchase costs (NZD $1.7 million) and infrastructure reconstruction costs (NZD $3.3 million on stop bank reconstruction, but up to NZD $45 million on long-term remedial work) are financed via other indirect channels, such as rate hikes from local government or footed by the central government, but the flow-on impact of such financing decisions to the local economy over the long term is unknown. Other information, such as labour costs or soil erosion, are largely unquantifiable in dollar terms.

Meanwhile, there is a significant gap in much of the information related to indirect and intangible costs. At the micro-level, physical damages to homes and buildings led to increased insurance premiums (at least 15–30%) and rate hikes (~25%) in the short-term to recoup the reconstruction costs, but, in the long term, these may also lead to reduction in property values or lead to a flow-on impact to the economy. At the meso-level, business disruption and infrastructure inoperability seem to be largely unaccounted, although there is anecdotal evidence that these could amount to significant costs. In a similar manner, it is observed that there is the loss of quality of life due to mental-health impacts (post-trauma anxiety, insomnia), education-related activities (school closure, loss of playgrounds, and loss of access to supermarket and health centres (especially for the old population group). However, these losses are not being accounted.

In the next sections, we present the two analyses to demonstrate how we can obtain more accurate estimations of direct losses, such as physical-asset damages or displacement (via a survey-based approach), and of indirect losses, such as house devaluations (via an average treatment effect model and a micro-econometric hedonic pricing model). We then discuss avenues for further accounting of indirect losses on the macro-economy model using macro-economic methods such as the CGE or System Dynamic models (i.e. MERIT).

Table 3.1 Framework for assessing direct, indirect and intangible costs associated with the 2017 Edgcumbe flood (green = good quality with full estimation and dollar amount; yellow = average quality with full estimation but no dollar amount; red = low quality with incomplete estimation or anecdotal evidence).

Categories	Items	Description	Estimated Loss	Source
Panel A: Direct Costs				
Physical assets	Homes and buildings	>550 properties were assessed for flood damage.	550 damaged properties	1
		>250 homes were severely damaged in the flood.	250 severed damaged properties	1
		>300 homes needed repair to be habitable again.	300 repaired properties	1
		15 homes were severely damaged and deemed unsafe.	15 permanent damaged properties	1
		12 homes were left uninhabitable after they took the full force of floodwaters.	12 properties uninhabitable	1
	Residential land	70% of the town was inundated.	70% land area	1
	Farmland	1400 ha of farmland was under water for 10–14 days.	1400 ha of farmland	1
	Stock	4086 cows were trucked out of the area in the first 48 hours after the stop bank breach.	4086 cows	1
	Content	[*Anecdotal evidence*] The SuperValue store: About half a metre of water rushed through the store; $250,000 worth of stock had to be thrown away, requiring $1 million fit-out.	NZD $1 million of fit-out cost; NZD $0.25 million of content loss	3
	Riverbank erosion	1 ha of riverbank erosion deposited 24,000 m^3 of soil into the Waimana river.	1 ha of erosion	1
	Infrastructure	[*Anecdotal evidence*] Numerous roads were closed as a result of the damage sustained during the ex-cyclones, cutting off lifelines to some remote rural communities for more than a week.	>1 week of road closures	3
		[*Anecdotal evidence*] Many of the repairs take months to complete and many of the roads suffering damage are critical to the areas' communities, workers and a growing number of tourists and other users.	Months of road repairs	3
		Overall roading costs are estimated at $15 million, with special-purpose roads suffering $11.2 million worth of damage over the course of the two events.	NZD $15 million of repair costs	3
Recovery/ treatment costs	Insurance costs	1080 claims were received as a result of flooding, with 98% of the claims partially or fully settled. The total amount paid for these claims so far is NZD $62.6 million.	NZD $62.6 million of insurance cost	2

Categories	Items	Description	Estimated Loss	Source
	Uninsurance costs	Around 17 damaged homes had no insurance / no means to repair and were supported via the Liveable Homes Project.	17 damaged non-insured properties.	1
	Rebuild costs	265 free-building consent applications for flood repairs.	265 building consents	1
Panel B: Indirect and Intangible Economic Costs				
Business and infrastructure	Business disruption	The only supermarket in Edgecumbe was closed since the flood; most people needed to travel to Whakatāne (>20 km away) to do their food shopping.	Need survey or cost-assessment methods, such as travel cost method, contingent valuation method or the dynamic inoperability input-output model.	3
		The only medical centre in Edgecumbe was closed for 10 months after the flood.		3
		Approximately 80 businesses were directly or indirectly impacted, including all businesses in Edgecumbe.		3
		[*Anecdotal evidence*] In an Edgecumbe store, several former staff members gradually left after the flood, some moved out of town, which required re-hiring and re-training from scratch.		3
	Infrastructure interoperability	The temporary bus services were stopped at the end of 2018.		3
	Managed-retreat costs	Around 12 homes, directly across from the stop bank breach, were left uninhabitable after they took the full force of floodwaters and were purchased and removed (NZD $1.7 million).	NZD $1.7 million of purchase cost	3
	Flood mitigation/ adaptation costs	The cost of the stop bank construction, which included installation of services and road reconstruction, came in under its NZD $3.3 million budget.	NZD $3.3 million of budgeted stop bank construction cost	3
		Bay of Plenty Regional Council identified 520 other locations across the region requiring repairs. The repair bill was estimated to be more than NZD $50 million, a cost shared by Central Government, the council and insurance.	NZD $45 million of remedial work	1
Social	Education	Edgecumbe Primary School was closed before the flood hit.	Need surveys or analytic methods, such as cost of illness approach,	3
		Edgecumbe Primary School lost its playground. Fields were out of service for months.		3

Categories	Items	Description	Estimated Loss	Source
	Physical and mental health effects	[*Anecdote evidence*] Post-trauma experienced by Edgecumbe Primary School students and staff (>90% of its community). Trauma support and counselling for staff and students was provided.	life satisfaction analysis and choice modelling method	3
		[*Anecdotal evidence*] Citizens experienced losing sleep over the flood as parts of their property were destroyed.		3
Human and social development	Human mobility	[*Anecdotal evidence*] Edgecumbe town has a high elderly population, many of whom cannot or do not drive or do not have the financial means or ability to travel to other supermarkets, medical centres or businesses. "Please specify what the cost is that needs to be valued here. Is it the inability of residents to access amenities due to damage to the transport network?"	No information – need Census information before and after flood	3
	Human migration and displacement from the community	[*Anecdotal evidence*] A number of families did not return to Edgecumbe after the flood; the number of residents who left the town for good is unclear. "I think you need to correctly name this cost."	No information – need Census information before and after flood	3
Finance	Insurance premiums	Due to higher re-insurance costs and the increased risk, customers in the Edgecumbe region could expect insurance premium prices to increase by ~15–30%, with customers in areas of significant risk experiencing larger increases. In some cases, residents in the Edgecumbe flood have to pay three times the usual insurance premium ($1,500 ≥ $5,300).	15–30% increase in insurance premium (up to 3x)	4
	Council rate	Bay of Plenty residents faced a rates hike to pay for flood damages. As 80% of the $50 million repair bill came from rate-payers, a rates increase of ~25% in flood-hit areas was necessary to pay for the remainder.	25% increase in rates	5
	Legal costs	A class action lawsuit against the Bay of Plenty Regional Council with 272 resident signatures; argued that the stop bank failure could have been prevented and sought NZD $3.95 million in damages.	NZD $3.95 million in damages.	6
	House prices	No evidence of reductions in house prices was observed, but evidence of reduction in estimated capital values was observed in the Edgecumbe flood (see Tables 3.11 and 3.12).	Need micro-economic modelling – such as hedonic pricing or DiD model.	-

Categories	Items	Description	Estimated Loss	Source
Macro-economics	Macro GDP	No evidence of change in GDP is observed.	Need macro-economic modelling or the DIIM	-
Disruption costs	Evacuation costs	580 households and 1600 residents are evacuated.	580 evacuated households; 1600 evacuated residents	1
		Ministry of Social Development provided assistance to over 3200 people.	3200 assisted residents	1
	Clean-up costs	>7000 tonnes of waste were sent to landfill from clean-up in Edgecumbe.	7000 tonnes of landfill waste	1
		~3500 tonnes of sediment were taken to landfill from the Toka Tū Ake EQC section-clearing operations.	3500 tonnes of sediment	1
		> 7 tonnes of whiteware and steel were recycled.	17 tonnes of whiteware	1
		Some 1500 registered volunteers contributed more than 6800 hours of work to the clean-up.	6800 volunteer hours	1

Sources [accessed 2024 Jul 18]

1 https://www.whakatane.govt.nz/sites/www.whakatane.govt.nz/files/documents/district_recovery_insert_-_april_2018_-_web.pdf

2 https://www.icnz.org.nz/industry/media-releases/edgecumbe-flood-almost-all-mopped-up/

3 https://www.nzherald.co.nz/bay-of-plenty-times/news/edgecumbe-flood-two-years-on-loneliness-trauma-and-hope/BPES4IPVFXFCUUDEPMI5OP6EJE/

4 https://www.rnz.co.nz/national/programmes/checkpoint/audio/201860050/insurance-premiums-hiked-after-edgecumbe-flood

5 https://www.rnz.co.nz/news/national/354455/bop-residents-face-rates-hike-to-pay-for-flood-damage

6 https://www.nzherald.co.nz/bay-of-plenty-times/news/edgecumbe-floods-residents-renew-case-against-bay-of-plenty-regional-council-seeking-395m-in-damages/MLHOUTEHEREO5D5Y5IFPQY6EHY/

3.3 Direct Flood Cost from Household Survey Results

To gather data on the experiences of affected residents during the evacuation and recovery phases following the flooding, a paper-based survey was previously delivered to all households within Edgecumbe in November 2020 (Scheele et al. 2021a). The survey was hand-delivered to all residential addresses within Edgecumbe that appeared occupied on 9 November 2020. A postage-paid reply envelope was included with the surveys. All residential addresses were chosen to capture the experiences of residents that were both within and out of the area of direct flooding impact, as well as those who may have moved to another address within the town.

The following tables and graphs describe a selection of the results from the household survey. As the results are quantified and demographics were captured, each of the aspects presented can be probabilistically modelled for future events.

The reasons for displaced households seeking alternative accommodation are summarised by count in Figure 3.2 (multiple reasons are possible). Tables 3.1–3.5 describe the number, type, location, duration and suitability of alternative accommodation, and Figure 3.3 shows the total duration that households were displaced. The importance of factors influencing the choice of alternative accommodation are summarised in Table 3.7, indicating the needs of displaced households.

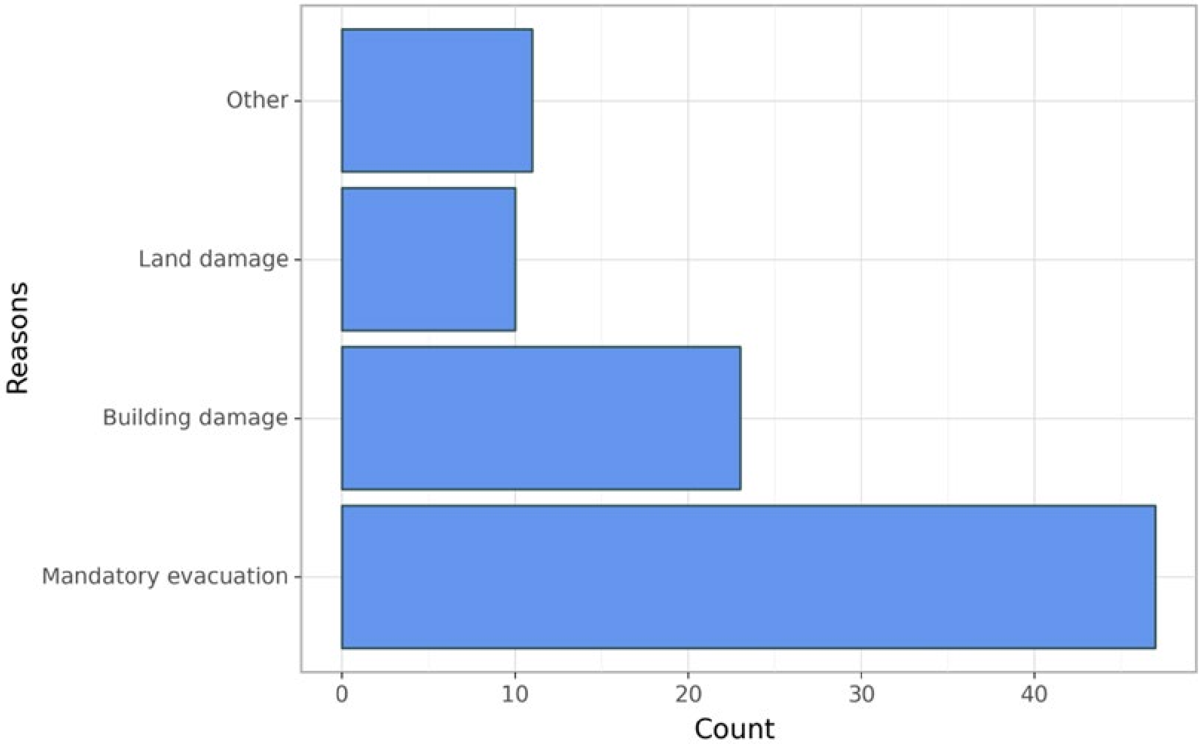

Figure 3.2 Reasons for households seeking alternative accommodation (Scheele et al. 2021a).

Table 3.2 Number of alternative accommodation locations (Scheele et al. 2021a).

Answer	Count	%
One	63	54.8%
Two	37	32.2%
Three	9	7.8%
Four	6	5.2%

Table 3.3 Types of alternative accommodation per location (Scheele et al. 2021a).

	Count (%)			
Accommodation Type	**Location 1**	**Location 2**	**Location 3**	**Location 4**
Friend or family member	100 (87%)	29 (55.8%)	5 (33.3%)	1 (16.7%)
Hotel or motel	6 (5.2%)	8 (15.4%)	2 (13.3%)	1 (16.7%)
Emergency accommodation	-	1 (1.9%)	1 (6.7%)	1 (16.7%)
Other	9 (7.8%)	14 (26.9%)	7 (46.7%)	3 (50%)
Total responses	115	52	16	6

Table 3.4 Locations of alternative accommodation (Scheele et al. 2021a).

	Count (%)			
Location	**Location 1**	**Location 2**	**Location 3**	**Location 4**
Within or near Edgecumbe	49 (42.6%)	20 (38.5%)	5 (38.5%)	2 (40%)
Within Bay of Plenty	63 (54.8%)	30 (57.7%)	7 (53.9%)	3 (60%)
Outside Bay of Plenty	3 (2.6%)	2 (3.8%)	1 (7.7%)	-
Total responses	115	52	13	5

Table 3.5 Duration (days) at each alternative accommodation location (Scheele et al. 2021a).

Location	Minimum	Maximum	Mean	Std. Dev.	Count
Location 1	1	608	59.2	106.4	112
Location 2	0	730	81.7	126.8	51
Location 3	3	548	154.5	154.4	15
Location 4	76	330	184.8	95.4	6

Table 3.6 Was the alternative accommodation suitable for the needs of the household? (Scheele et al. 2021a).

	Count (%)			
Answer	**Location 1**	**Location 2**	**Location 3**	**Location 4**
Yes	75 (66.4%)	30 (62.5%)	8 (66.7%)	4 (66.7%)
Mostly	32 (28.3%)	16 (33.3%)	4 (33.3%)	2 (33.3%)
No	6 (5.3%)	2 (4.2%)	-	-
Total responses	113	48	12	6

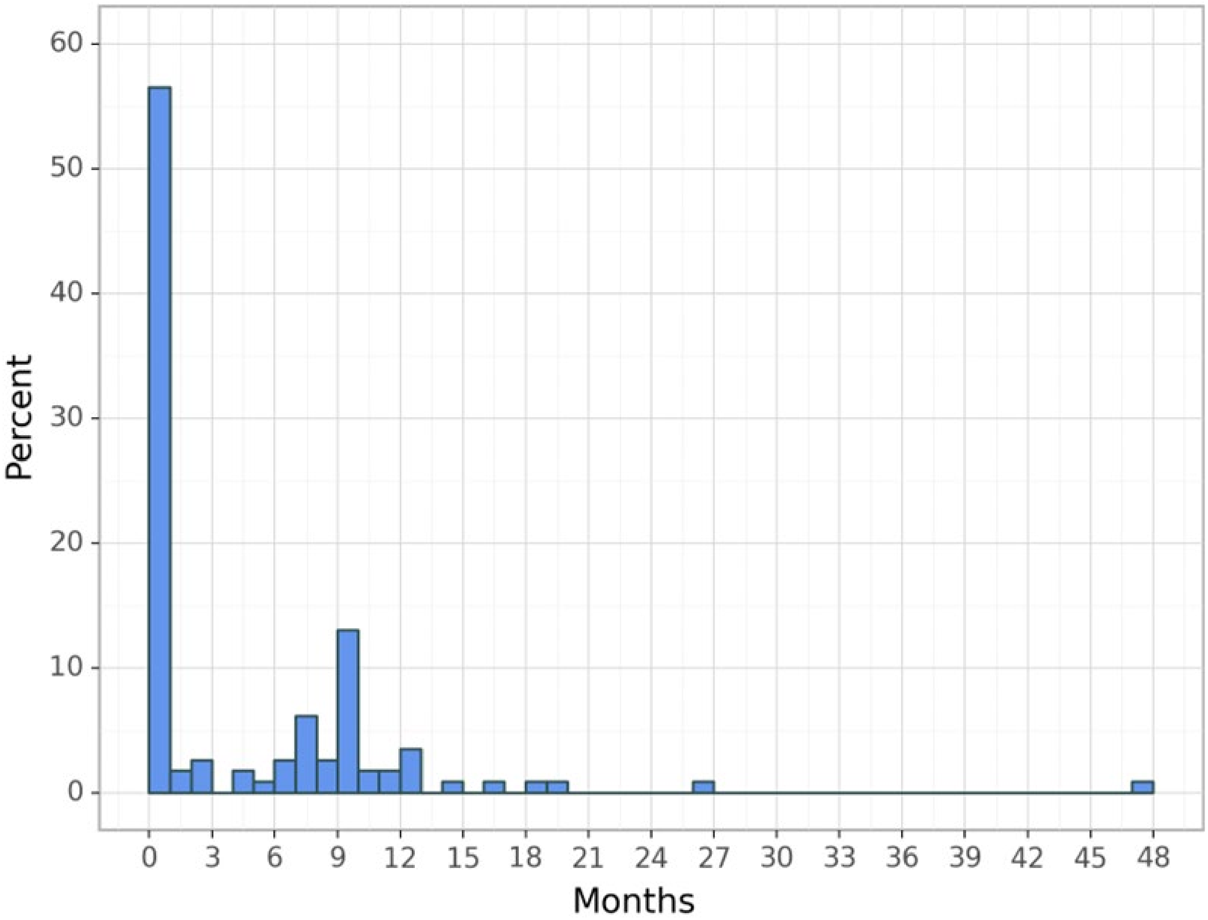

Figure 3.3 The total duration that households were displaced (Scheele et al. 2021a).

Table 3.7 The importance of factors influencing the choice of alternative accommodation (Scheele et al. 2021a).

Answer	N/A	Not Important	Somewhat Important	Very Important	Count
My family could stay together	16 (16.5%)	1 (1%)	3 (3.1%)	77 (79.4%)	97
My animals could stay with me	35 (39.8%)	7 (8%)	9 (10.2%)	37 (42%)	88
Friends/relatives lived nearby	17 (18.9%)	12 (13.3%)	22 (24.4%)	39 (43.3%)	90
My workplace was located nearby	23 (25%)	11 (12%)	21 (22.8%)	37 (40.2%)	92
It was close to my children's school	53 (64.6%)	12 (14.6%)	6 (7.3%)	11 (13.4%)	82
It was free or subsidised	32 (38.6%)	13 (15.7%)	13 (15.7%)	25 (30.1%)	83
It was close to my usual residence	19 (20.4%)	15 (16.1%)	23 (24.7%)	36 (38.7%)	93
There was appropriate access for people with disabilities	53 (67.1%)	11 (13.9%)	7 (8.9%)	8 (10.1%)	79

Whether pets were taken to evacuation points or left behind during the evacuation is shown in Tables 3.8 and 3.9, respectively. Table 3.10 indicates whether the ability to bring animals to alternative accommodation locations was a factor.

Table 3.8 Were pets taken to the evacuation point? (Scheele et al. 2021a).

Answer	Count	%
Yes	37	45.7%
No	44	54.3%
Total	81	100%

Table 3.9 Were animals left behind during the evacuation? (Scheele et al. 2021a).

Answer	Count	%
Yes	30	52.6%
No	27	47.4%
Total	57	100%

Table 3.10 Were animals a factor in alternative accommodation choice? (Scheele et al. 2021a).

Answer	Count	%
Yes	25	43.9%
No	32	56.1%
Total	57	100%

The percent of residents reporting whether their workplace was affected by the flooding – directly, indirectly or both – is shown in Figure 3.4.

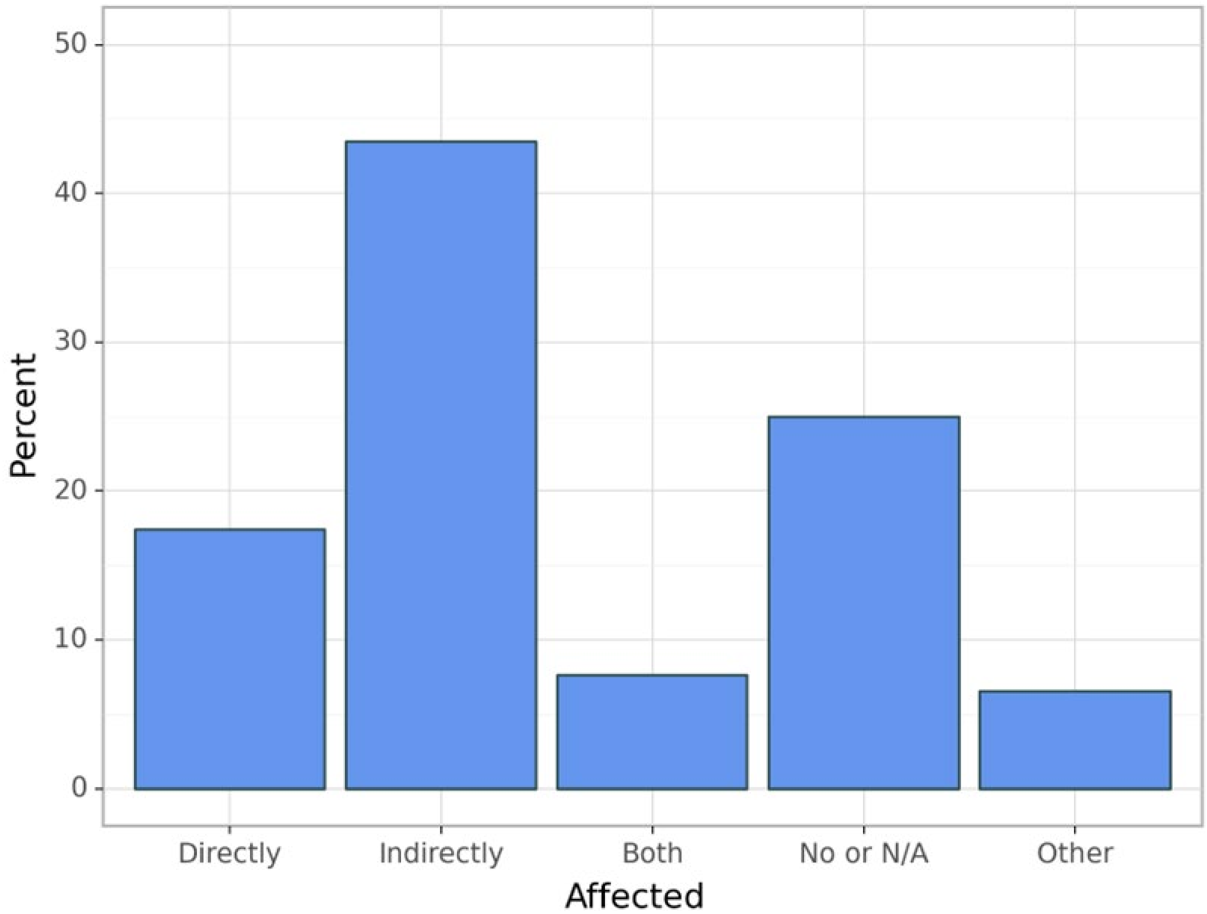

Figure 3.4 The percent of residents reporting whether their workplace was affected by the flooding (Scheele et al. 2021a).

3.4 Indirect Micro-Economic Flood Loss – Impact on Property Values

Here, we conduct a micro-econometric analysis to understand the post-disaster impact of the 2017 Edgecumbe flood on residential property values. The impact on house values is an indirect cost, arising after the flood from risk perceptions among homeowners and homebuyers, and this impact will carry on far beyond the flood event.

Two alternative measures are used to proxy for property values: sale transaction prices (2015–2020, from the CoreLogic dataset) and rateable values (as of 2016 and 2019, from the local council rateable value dataset). Of these two measures, sale prices have the advantages of reflecting the 'true' market appetite to flood risk, but sale transactions are less frequent (~60 transactions per year) and thus may not capture the true changes in price. Meanwhile, rateable values are just approximated from house valuation models, but these are completed due to the mass appraisal by the council every three years.

An important step of this analysis is to identify the residential properties affected by the flood (the treatment group) and compare their values against the equivalent unaffected properties (the control group). As there are no official geo-datasets on the Edgecumbe flood depth and extent, we rely on the satellite image of Edgecumbe town taken on 6 April 2017 after the flood to delineate the flood zone (blue area/polygon in Figure 3.5). This crude delineation results in a treatment group of 258 houses inside the flood zone, as compared to 553 houses outside the flood zone. This result is comparable with the official figures of >250 severe damaged/uninhabitable homes, as in Table 3.11. However, note that it is still a conservative estimation, as the water level may have reduced by the time this satellite image was captured and thus houses located around the flood zone may have been affected as well (>500 properties were assessed for flood damage).

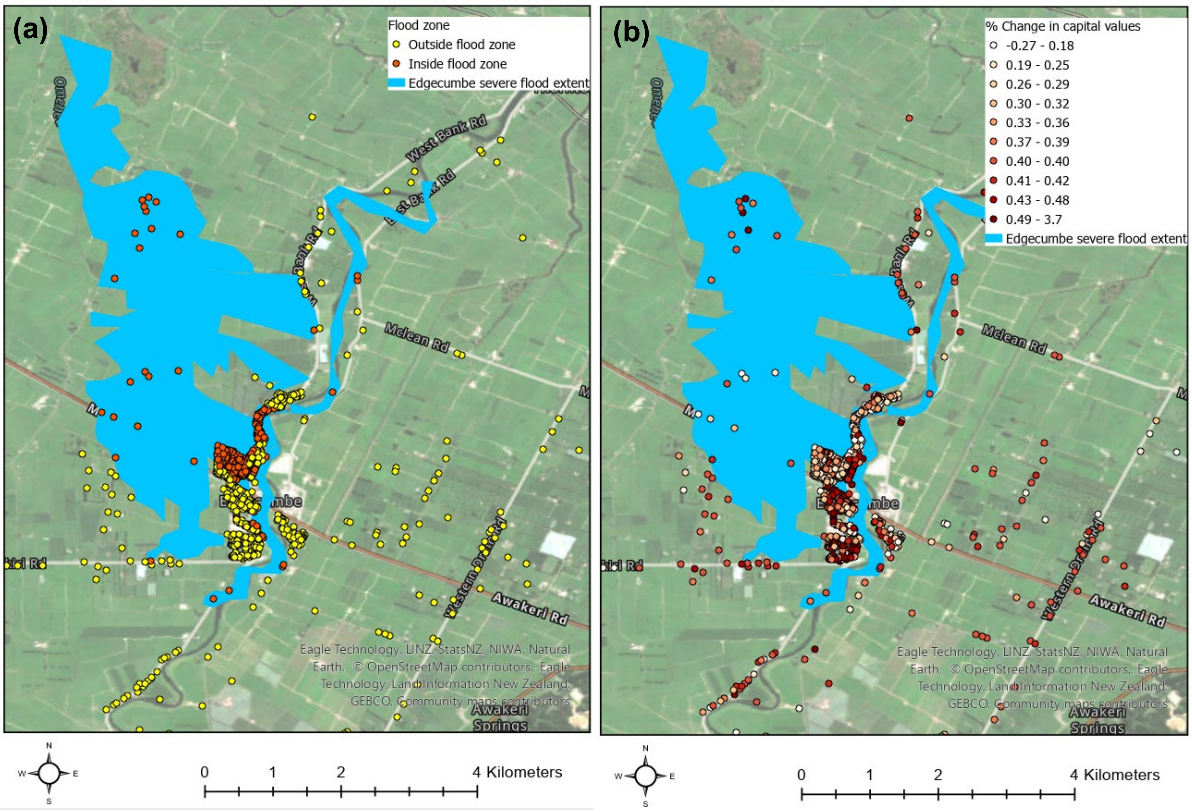

Figure 3.5 Change in capital values among affected and unaffected properties. (a) Treatment versus control group. (b) Percentage change in capital values of each property (2019–2016).

In the first part of our analysis, we conduct a basic statistical comparison on rateable values – where the change in capital values of properties within the flood zone is compared to those of the rest of Edgecumbe. We find that houses inside the flood zone have, in general, lower capital values as compared to their equivalent unexposed houses prior to the flood (NZD $305,000 versus NZD $318,000 in 2016), but this gap deepened between 2016 and 2019 (NZD $393,000 versus NZD $425,000). In particular, the flood-exposed houses only have an average increase in capital values of 31%, lower than that of their peers (of 38%) by at least 7% (significant at 1% level of confidence using a Student's two-sample T-test[6]). Importantly, this gap is driven mostly by the change in improvement values (7%) and not by the land values (-2%). This signifies that the averaged impact of the Edgecumbe flood is at least 7%.

Table 3.11 The average treatment effect of flood risk on ratable values.

Group	**Treatment Group:** House Inside the Flood Zone (n= 258)	**Control Group:** House Outside the Flood Zone (n = 553)	**Difference between Groups** (Treatment – Control Group)
2016 Rateable Values			
Mean capital values	305,682	318,398	-12,716
Mean improvement value	216,791	198,838	17,953
Mean land values	129,035	172,459	-43,424
2019 Rateable Values			
Mean capital values	392,891	425,686	-32,795
Mean improvement value	263,857	253,227	10,630
Mean land values	88,891	119,560	-30,668
Change in Rateable Values			
Change in capital values (%)	31	38	-7*
Change in improvement values (%)	24	31	-7*
Change in land values (%)	46	48	-2

* Significant at 1% level of confidence.

In the second part of our analysis, we estimate a standard hedonic sale-price analysis model to explore the observed flood price discount of the Edgecumbe flood. Similar to existing studies (MacDonald et al. 1987; Atreya et al. 2013; Bin and Landry 2013; Shr and Zipp 2019), our strategy is to estimate the price differential on sale transactions in each of these areas subject to the current flood zone as compared to other areas in Edgecumbe not subjected to this risk of flooding. Specifically, the sale price of a residential property *j* sold at time *t* can be expressed as a function of its structural characteristics, neighbourhood characteristics and locational attributes, as well as environmental amenities/disamenities. Two models were used – a standard hedonic model to estimate the generic discount of locating in the flood zone and a DiD model to estimate the change in this discount after the flood zone. These models are estimated on a dataset of 349 sale transactions in the Edgecumbe area from 2015 to 2020.

Figure 3.6a presents a preliminary look at the sale price per metre across the Edgecumbe area. Unlike that of capital values, we do not observe a clear price pattern among houses in the flood zone. In fact, the relationship between capital values and real sale prices is relatively low at 40% (Figure 3.6b).

6 Used to test whether the difference between the values of two groups is statistically significant or not.

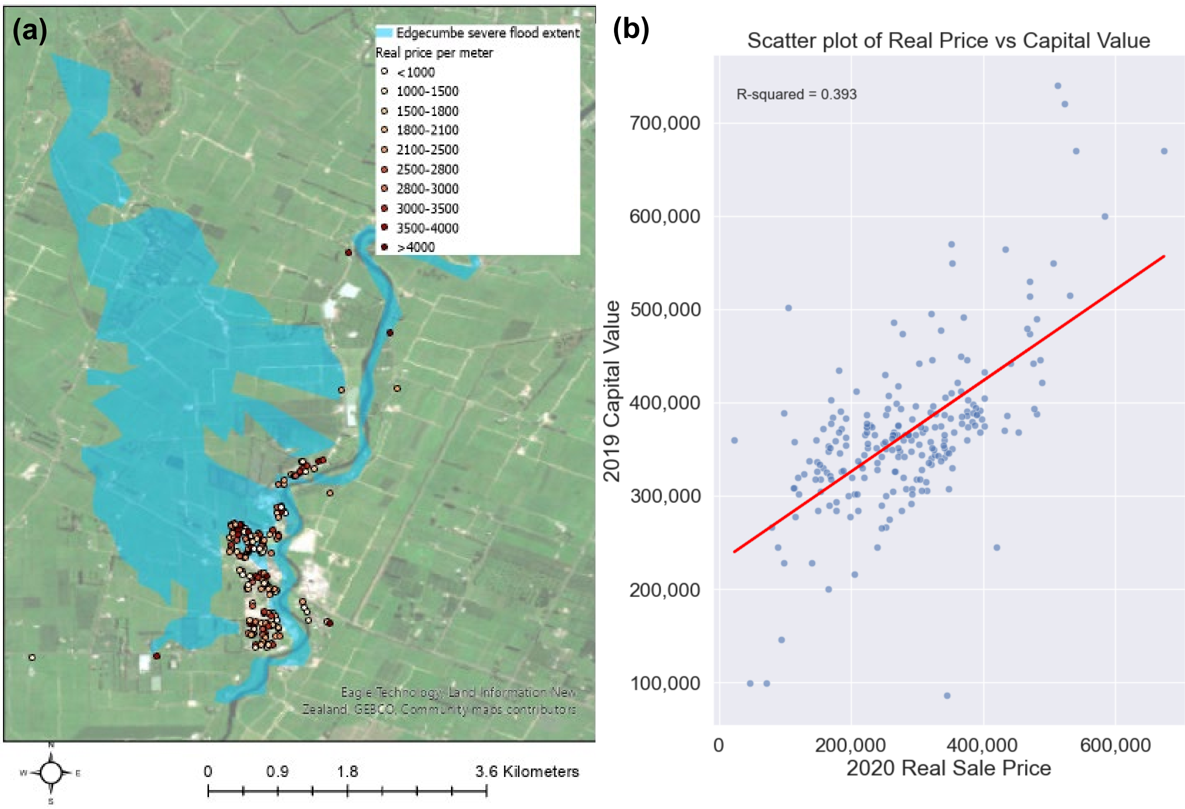

Figure 3.6 Sale price per metre and the relationship with capital values. (a) Sale price per metre. (b) Sale price versus capital values.

Table 3.12 presents the price effects of locating inside the flood zone. Using the Ordinary Least Squares regression to estimate the hedonic pricing model, we do not find a significant price impact from the Edgecumbe flood risk. This result is consistent across all model designs.

In a naïve model, where the log-transformed house prices are fitted using only flood risk indicator (column 1), there is a discount of -0.029 (log-scale) or -3% (absolute scale). This price effect reduces and disappears when we account for the land area (m^2) (-0.0148, or 1.5%) and eventually becomes positive (0.0388, or 4%) once all structural, neighbourhood and locational characteristics are accounted for. All results are not statistically significant.

Similarly, when we apply a DiD setting, there seems to be a negative price effect of locating inside the flood zone after the flood event (-0.069 to -0.089, or 7–9%).

This signifies that the price effects of the Edgecumbe flood either have not materialised on the real-estate market due to small sample and sparse transactions or that there are unaccounted and/or unobservable characteristics that the hedonic model did not account for.

For example, potential indicators such as number of bedrooms, number of bathrooms, deck (%), number of under-the-main-roof car parks, off-street parking (%), property category (apartment, bungalow, townhouse, cottage, unit, villa) and wall and roof condition (average, fair, good, mixed, poor) were not obtained for this analysis. Similarly, there are potential amenity characteristics (such as open view, distance to river, contours and air quality), as well as re-building activities after the flood event (affected houses are rebuilt after the flood event with better characteristics), that may co-influence the selling prices.

Table 3.12 The price effect of Edgecumbe flood risk. Coefficients are bolded and standard deviations are in italics.

Variable	Standard Hedonic Pricing Model			DiD Model		
	Naïve Model	Control for Floor Area	Full Model	Naïve Model	Control for Floor Area	Full Model
Inside Flood zone	**-0.0299**	**-0.0148**	**0.0388**	**0.0173**	**0.0332**	**0.0643**
	0.0633	*0.0594*	*0.0786*	*0.0770*	*0.0701*	*0.0782*
Inside Flood zone x Post-flood event	-	-	-	**-0.0892**	**-0.0903**	**-0.0699**
	-	-	-	*0.1094*	*0.0995*	*0.1006*
Post-flood event	-	-	-	**0.4866***	-	**0.522***
	-	-	-	*0.064*	-	*0.060*
Land area	-	**0.0035***	**0.0025**	-	**0.0036***	**0.0018**
	-	*0.0006*	*0.0019*	-	*0.0005*	*0.0015*
Adjusted R-squared (%)	-0.3	12.0	10.6	25.1	38.1	41.2

* Significant at 1% level of confidence.

3.5 Toward a Macro-Economic Modelling of Indirect Flood Costs

As described in Sections 2.2 and 2.3, there are several (unaccounted) aspects of indirect/ intangible costs resulting from a major disaster such as the 2017 Edgecumbe flood event. These include, but are not limited to, micro-and meso-economic costs such as displacement costs, infrastructure inoperability, business disruptions and reconstruction costs in the short and medium terms. These costs will eventually have a flow-on impact on the macro-economic picture of Edgecumbe town and the larger Bay of Plenty region, impacting GDP growth, unemployment rate and population migration over the long term.

Quantifying these long-term impacts requires sophisticated macro-economic modelling tools (such as the I-O, SAM and CGE / System Dynamic models) alongside extensive data calibration at the local level (ideally from surveys and analytical methods discussed in Sections 4.3 and 4.4). Here, we summarise the analytical methods from two studies that attempted to tackle similar problems in different contexts. These serve as a foundation for future models on the macro-economic impacts of the 2017 Edgecumbe flood.

In the international context, Gertz et al. (2019) attempted to model the economics of flooding and subsequent reconstruction recovery in a large urban area (Vancouver, British Columbia, Canada) using a forward-looking CGE model. They found that the GDP loss relative to a no-flood scenario is relatively long-lasting: 2.0% in the first year after flood, 1.7% in the second year and 1.2% in the fifth year (see Figure 3.7 for the impact on GDP growth, investment, capital, imports and government services)[7]. Their *N*-sector recursive dynamic model is an extension of the static CGE model with multiple modules (households, government, investment and trade and production). *N* sectors use capital, labour and immediate goods as inputs for domestic production, which is then combined with the substitutable imported goods to create a representative composite good. Within the model, each agent, such as household/ government optimises its consumption of the representative good within a period (not across the period) over an infinite horizon. At the high level, the analytical approach of Gertz et al. (2019) on two scenarios (balanced growth path and flood) proceeds accordingly:

7 According to the PDNA guideline (UNDP 2015), the recovery strategy for a disaster should be designed for the short term (six months), medium term (6–18 months) and long term (18 months to five years).

- **Initial-stage calibration:** The SAM was derived from the 2010 British Columbia I-O table and associated final demand table to derive the initial stage of the agents. It is available for 25 private sectors, five government sectors and one non-profit sector.
- **Dynamic calibration:** Exogenous parameters were set for both scenarios, such as growth rate, depreciation rate, interest rate, discount rate and elasticity of substitutions (across capital and labours, domestic and import goods and individual commodities and composite goods).
- **Direct capital-damage due to flood:** For the flood scenario, direct flood damages to population, assets and economic activities by each sector were estimated by overlaying a historical floodplain map on Vancouver exposure data. 4.4.% of total capital stock is lost, of which the transportation and warehouse sectors are mostly exposed.
- **Disaster compensation:** Two channels are modelled via private flood insurance and public-disaster assistance from provincial states, which are then subsidised by the federal government (similar to the Natural Hazards Commission Toka Tū Ake in Aotearoa New Zealand). It is assumed that public-disaster assistance and private insurance will cover a fixed fraction of capital damage (75%).
- **Business disruption:** Business interruption is found to be severe in the short-term but declines quickly (indicated by temporary job loss or temporary unemployment insurance coverage). Here, it is assumed to be equivalent to three weeks of complete interruption of all economic activity in the flood zone.
- **Simulation:** Macro-economic indicators, such as GDP growth, investment, import/export and government services, are compared from the flood scenario against the baseline (growth balanced scenario), with sensitivity analysis on assumptions of fraction of capital damages and business disruption.

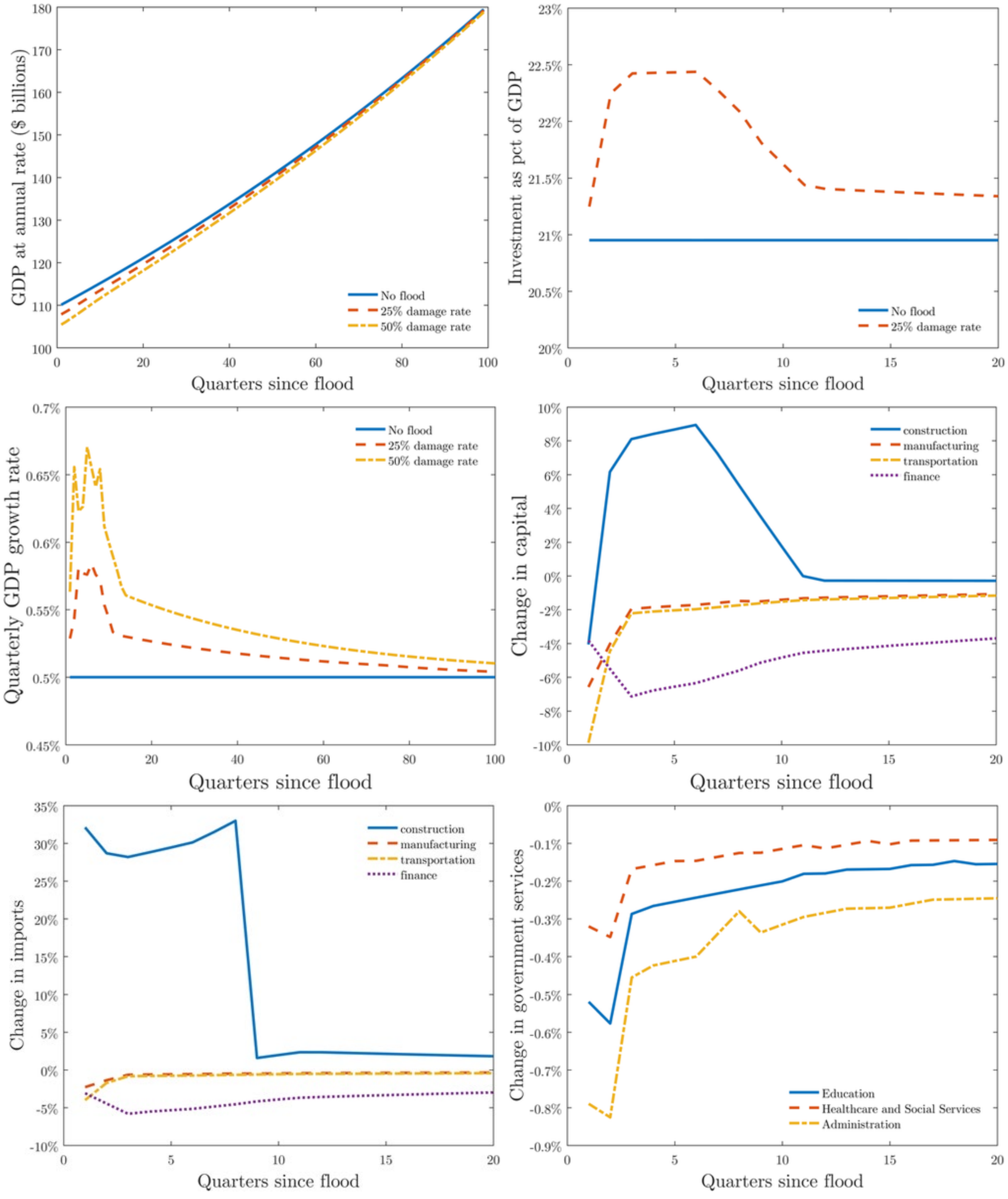

Figure 3.7 Macro-economic indicators of flood loss. Excerpts from Gertz et al. (2019).

In the Aotearoa New Zealand context, a suite of MERIT models (discussed in Section 2.2) was employed to analyse the macro-economic consequences of a major disaster. Much of MERIT's applications are on geological hazards (earthquake and volcanoes) or the result of policy intervention (such as climate retreat). For example, Brown et al. (2019) employed MERIT on a M_W 7.5 Wellington Fault earthquake case study. The paper combines several modules, such as a direct damage model (using RiskScape^{TM}), an infrastructure transportation model, a population and business relocation model and a system dynamic economic model. At a high level, their analytical approach involves two scenarios: baseline (balanced growth path scenario) and disaster (the Māngere Bridge volcanic-eruption scenario). The process is as follows:

- **Physical disruption:** Direct damages to infrastructure (road, rail port, airport, electricity, water, etc.) and buildings are estimated by combined spatial hazard scenarios and asset exposure and asset vulnerability. Hazard-scenario modelling provides the spread of hazard intensities, damage modelling provides the likely damage to buildings and infrastructure and outage modelling provides the estimated time to restore infrastructure services. Specifically for outage modelling, surveys were conducted with infrastructure providers to obtain information on network characteristics and describe the recovery stages.
- **Business and population behaviours:** Businesses and residents within the regions may respond to different levels of physical disruption (largely continue as normal, temporary relocation and closure of business, large-scale movement of people and business out of the region). A behaviour model was calibrated following the survey for the Canterbury Earthquake Sequence.
- **Economic modelling:** At the core of MERIT is the multi-sector and multi-region dynamic economic model (Smith et al. 2017), which shares many similarities with the regular CGE model. However, the key distinction is that, unlike the CGE model that seeks optimisation toward equilibrium, the system dynamics framework evolves over time and allows 'out-of-equilibrium' following a disaster but ultimately equilibrium over the long horizon. This is achieved using finite difference equations and built-in time lags and delays in the model.
- **Calibration of economic modelling:** A regional SAM was derived from the 2007 national supply use tables. The basic SAM is available for 15 regions, 41 industries, 54 commodities, one household, one enterprise and for local and central government.
- **Dynamic calibration:** Exogenous parameters are set for both scenarios, such as working-age population, multi-productivity, world commodity prices and GDP, labour and capital productivity. Specifically for the disaster scenario, parameters related to business operability and transportation costs were calculated and added to the margins on export, import and domestic scenarios.
- **Simulation:** Outputs from both physical disruption and business/population behaviours are linked to the economic modelling. The business and population module provides input of out-migration, corresponding household-expenditure changes and labour-availability changes, as well as business out-migration and business operability. The physical disruptions provide building and infrastructure damages, as well as cost of freight routing and loss of tourism demand over time.

To model the macro-economic impacts of the 2017 Edgecumbe flood, the analytical process from these two studies can be combined. For example, the Edgecumbe household surveys could be used to re-calibrate the business and population behaviours, the change in rates and insurance premiums can be used to re-calibrate the disaster compensation process and the change in property values in the flood zone can be used to re-calibrate the change in capital and investments of the macro-economic model. We leave these as an avenue for future research.

3.6 Edgecumbe Flood Event Intangible Losses

Many of the potential intangible losses that can be caused by flooding events (see Section 2.3) manifested in the 2017 Edgecumbe flood event. For most of these impacts, data does not exist to quantify or cost these losses. Suggestions for ways to measure such impacts are presented in Table 3.13.

Table 3.13 Potential intangible losses of the 2017 Edgecumbe flood and measures that might be used for quantifying and costing.

	Ways of Measuring
Individual	
Ongoing physical health effects (e.g. respiratory illness, leptospirosis in flood context)	• Interviews and/or focus groups with the community and/or individuals. • Increase in medical presentations or access to services.
Long-term mental health impacts (e.g. depression, psychological trauma)	• Interviews and/or focus groups with the community and/or individuals. • Increase in medical presentations or access to services.
Short-term mental health impacts (e.g. stress, anxiety)	• Interviews and/or focus groups with the community and/or individuals. • Increase in medical presentations and/or access to services.
Loss of memorabilia	• Interviews and/or focus groups with the community and/or individuals.
Loss of pets	• Interviews and/or focus groups with the community and/or individuals. • Number of vet visits.
Relationship breakdowns	• Interviews and/or focus groups with the community and/or individuals. • Increase in access of professional services.
Increased substance abuse	• Interviews and/or focus groups with the community and/or individuals. • Reported drug-substance abuse and related crime numbers. • Increase in medical presentations or access to services.
Community	
Disruption generated by the re-building process	• Interviews and/or focus groups with the community and/or individuals.
Disruption to education	• Interviews and/or focus groups with the community and/or individuals. • Educational achievement rates for the years following the flood. • Costs of student days lost x staff salaries.
Loss of leisure	• Interviews and/or focus groups with the community and/or individuals. • Participation rates in sports and other leisure activities. • Attendance at events.
Loss of community (e.g. access to networks, services and assets, including recreation areas)	• Interviews and/or focus groups with the community and/or individuals. • Rates of volunteering.
Sense of place	• Interviews and/or focus groups with the community and/or individuals.
Cultural	
Damage to cultural and heritage sites (including cemeteries)	• Interviews and/or focus groups with the community and/or individuals.
Damage to cultural and heritage artefacts	• Interviews and/or focus groups with the community and/or individuals.
Loss of non-use values for cultural and environmental sites and collections	• Interviews and/or focus groups with the community and/or individuals.
Disruption to traditions and cultural activities	• Interviews and/or focus groups with the community and/or individuals.

	Ways of Measuring
Environmental	
Environmental damage	• Non-market valuation measurement of ecosystem services. • Willingness to pay. • Interviews and/or focus groups with the community and/or individuals.
Ecological damage (e.g. changed habitats)	• Non-market valuation measurement of ecosystem services. • Willingness to pay. • Surveys, interviews and/or focus groups with the community and/or individuals.
Aesthetic impacts	• Willingness to pay. • Choice experiment. • Surveys, interviews and/or focus groups with the community and/or individuals.
Other	
Loss of image (e.g. location's reputation)	• Willingness to pay. • Surveys, interviews and/or focus groups with the community and/or individuals.
Loss of information stored on computers	• Interviews and/or focus groups with the community and/or individuals.
Loss of organisation and distribution networks	• Interviews and/or focus groups with the community and/or individuals.
Loss of trust in authorities	• Interviews and/or focus groups with the community and/or individuals. • Voter-turnout rates.

4.0 CONCLUSION

This report reviews the methods and frameworks on quantifying direct, indirect and intangible losses associated with flooding in the Aotearoa New Zealand context. Historically, this type of natural hazard has caused significant insured losses, especially during recent events (i.e. the Auckland Anniversary flood and Cyclone Gabrielle). However, much of these figures only account for direct and quantifiable damages, leaving out a large fraction of second-order flood losses that are largely indirect, intangible and unmeasured. This may under-estimate the full economic and social costs of such events, suggesting that a systematic approach to account for all dimensions of losses is critical for business-case development for flood mitigation in Aotearoa New Zealand.

However, accounting for indirect and intangible losses presents many challenges. The first primary challenge relates to the difficulty, if not impossibility, of quantifying and costing intangible losses that are, by nature, intangible and deeply qualitative, such as social, cultural and wellbeing impacts. Our review of methods for accounting for such impacts sheds some light on current international efforts made to address this challenge, but there is no ‘silver bullet’ solution. The second primary challenge relates to data availability (e.g. Meyer et al. 2013). In the cases where quantitative data has been collected or captured for either indirect or intangible losses, challenges continue to inhibit the access to or use of these data due to commercial/proprietary restrictions and inter-operability issues, as these were not necessarily collected for the purpose of accounting for losses.

There is a need for baseline data collection for pre- and post-event comparison (including frequent and consistent pre- and post-event assessments, interviews, case studies and longitudinal surveys). This would allow for causal links to be drawn between flood events and the impacts and for the long-term impacts of these events on individuals, communities and society to be grasped. Additionally, a long-term database of these impacts may help to develop metrics for measuring/quantifying intangible impacts/losses. Furthermore, different timeframes of data collection would affect the results of measurement that could influence decision-making. For example, short-term impact assessment results may differ from long-term impact assessment results. Thus, decisions according to the results of the short- versus long-term impact assessments may differ; this should be considered when making decisions.

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APPENDICES

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APPENDIX 1 EXISTING CATEGORISATION FRAMEWORK ON FLOOD COSTS

Table A1.1 The NZIER framework: flood costs that can be lessened by protection works. Source: NZIER (2024).

Category	Items	Direct, Indirect and Intangible
Property damages and losses	Buildings	Direct
	Homes	Direct
	Infrastructure	Direct
	Vehicle	Direct
	Stock	Direct
Disruption costs	Temporary infrastructure closure	Intangible
	Business: lost revenue	Indirect
	Business: added cost	Indirect
	Other added costs	Indirect
	Ongoing production loss	Indirect
Recovery/treatment costs	During-event costs	Direct
	Post-event costs	Indirect
	Reputational costs	Intangible
Human costs	Deaths	Intangible
	Injuries	Intangible
	Persons and days in evacuation	Intangible
	Rescue operations	Direct
	Hospitality and treatment costs	Direct
	Lost productivity from injury	Indirect
	Mental anxiety/insecurity	Intangible
	Heritage degradation	Intangible
	Environmental health	Intangible

Table A1.2 The post-disaster needs assessment (PDNA) guidelines. Source: Category and cost items are from UNDP (2015). Categorisation of 'direct', 'indirect' and 'intangible' costs is by the authors of this report.

Category	Items	Direct, Indirect and Intangible
Social	Housing	Direct
	Education	Indirect
	Health	Direct
	Culture	Intangible
	Nutrition	Indirect
Infrastructure	Water and sanitation	Indirect
	Community infrastructure	Direct
	Energy and electricity	Direct
	Transport and telecommunication	Direct
Productive	Agriculture, livestock and fishery	Indirect
	Commerce and industry	Indirect
	Commerce and trade tourism	Indirect
Macro-economy	Gross Domestic Product (GDP)	Indirect
	Balance of Trade (import-export-revenue-expenditure)	Indirect
Human and social development	Millenium Development Goals	Intangible
	Human Development Index	Intangible
	Poverty	Intangible
Finance	Banks	Indirect
	Financial institutions	Indirect
Cross-cutting sectors/themes	Governance	Intangible
	Disaster risk reduction	Indirect
	Environment	Intangible
	Gender	Intangible
	Employment and livelihoods	Indirect

APPENDIX 2 APPLICATION OF EXISTING FRAMEWORKS TO ASSESS FLOOD COSTS

A2.1 Examples of Indirect Costs Identified within the ECLAC Framework

The ECLAC (2014) manual can be applied to assess disaster impacts. Here, we present how it can help classify impacts across different sectors using idealised impact categories in the case of a flooding event. These suggested impact categories are not exhaustive but intended to guide the user in exploring further granularity within sectors (e.g. social) and sub-sectors (e.g. education), such as school attendance, school closures, educational attainment, etc.

Social Sector

- **Education:** When schools are closed due to flood damage, students miss days or weeks. This disruption can delay exams, postponing graduations and job placements. In some areas, particularly rural regions with fewer educational options, the disruption may even cause students to drop out permanently.
- **Health:** Flood survivors often face increased mental-health issues, including stress, anxiety and trauma. This puts a strain on healthcare facilities, which may already be overwhelmed by post-flood injuries. Additionally, health centres may face operational difficulties if infrastructure is damaged.
- **Epidemics:** Floodwaters can stagnate, creating the perfect environment for disease outbreaks, such as cholera or dengue fever. The resulting increase in patient numbers can overwhelm healthcare systems, raise healthcare costs and potentially lead to quarantines or restrictions, which further slows economic recovery.
- **Housing:** Flooding often destroys homes, displacing families and forcing them into temporary shelters for months or even years. Overcrowded living conditions can lead to health and safety risks, while slow insurance payouts and re-building efforts keep many families in a prolonged state of homelessness or instability.

Infrastructure

- **Transport:** Floods wash away roads and bridges, cutting off communities and disrupting supply chains. As delivery trucks are unable to reach affected areas, shortages of essential goods, such as food and medical supplies, occur. Businesses may face increased transportation costs due to re-routed deliveries and delays, which impacts production and sales.
- **Water and Sanitation:** Contaminated water sources are common during floods, leading to a scarcity of clean drinking water. Local governments often need to spend significantly more on water treatment and residents may have to boil or purchase water, which increases living costs. Additionally, the risk of waterborne diseases rises, further straining sanitation systems.
- **Electricity:** Floodwaters damage power lines and transformers, leading to prolonged blackouts. Factories may have to halt production, leading to layoffs, and households could lose perishable goods without refrigeration. In some cases, power outages persist for weeks, disrupting both daily life and business operations.

Socio-Economic Sectors

- **Agriculture:** Flooding can destroy crops and erode soil, leading to reduced yields and leaving farmers to face months of recovery to re-plant and repair equipment. Livestock may also die from disease or lack of feed. Food shortages lead to price increases, and many small-scale farmers could lose their livelihoods as a result of mounting debt and financial losses.
- **Manufacturing:** Factories located near rivers may need to shut down due to flood damage, with equipment and raw materials submerged. The resulting production delays break down supply chains and cause missed delivery deadlines. This may lead manufacturers to lose contracts or face penalties, resulting in long-term financial losses.
- **Commerce:** Small businesses, especially those without flood insurance, may face permanent closure due to weeks of lost income from damaged inventory and a lack of customers. When businesses do re-open, the reduced purchasing power of the affected community slows recovery, which could lead to further layoffs or business shutdowns.
- **Tourism:** Flooding destroys tourist sites and infrastructure, causing cancellations and sharp drops in tourist arrivals. Hotels, restaurants and travel agencies face reduced revenue for months, leading to layoffs or closures. Some businesses, particularly those dependent on seasonal tourism, may shut down entirely due to the prolonged impact.

A2.2 Examples of Indirect Costs Identified within the System of National Accounts (SNA) Framework

Production Accounts

Objective: Measure changes in economic output due to indirect impacts of flooding.

- **Reduction in retail sales:** Following a major flooding event, businesses in affected areas see a drop in customer traffic and sales. This reduction in retail activity lowers regional GDP. For example, if a flood disrupts shopping districts, the decrease in retail sales revenue can be tracked to estimate the decline in economic output.
- **Manufacturing disruption:** Flooding can halt production in factories by damaging infrastructure and equipment. The extent of these disruptions can be measured by comparing manufacturing output before and after the flood. This disruption can significantly reduce industrial output.
- **Rebuilding and repair:** Post-flood recovery often leads to increased activity in construction and repair sectors, which can be tracked through investments in re-building infrastructure and in repairing damaged properties. This surge in economic activity may temporarily boost output in these sectors, but it can be offset by reduced output elsewhere.

Income Accounts

Objective: Assess how income distribution and generation are affected indirectly by flooding.

- **Loss of wages:** Flooding can lead to job losses or reduced working hours as businesses close or scale back operations. Employment data can be analysed to identify sectors experiencing wage cuts or unemployment and measure the impact on household incomes.
- **Reduced profits:** Businesses face losses due to halted operations and increased repair costs. Changes in business profits can be tracked to assess how these reductions impact the gross operating surplus of affected sectors.

- **Government support:** Increased government expenditure on disaster relief and unemployment benefits can alter income distribution, which can be analysed through changes in government spending on flood relief and how these expenditures impact overall income re-distribution.

Expenditure Accounts

Objective: Analyse changes in expenditure patterns and their indirect effects.

- **Shift in household consumption:** Flooding forces households to spend more on emergency supplies and repairs, reducing discretionary spending on non-essential goods. Changes in household-expenditure patterns can be tracked to understand shifts from luxury items to immediate needs.
- **Increased government spending:** Governments often increase spending on emergency response and recovery efforts, which can be measured through the rise in public expenditure on disaster relief, temporary housing and infrastructure repairs.
- **Repair versus expansion:** Businesses may re-allocate investment funds from expansion projects to repair and recovery efforts. These shifts in business investment can be tracked to assess their impact on overall capital formation and future growth.

Capital Accounts

Objective: Evaluate the impact on non-financial assets and investment patterns.

- **Asset replacement:** Flooding necessitates the replacement or repair of damaged buildings and machinery, which can be measured through the costs associated with these repairs and adjustments in asset valuations due to the flood's impact.
- **Delayed investments:** Planned capital expenditures may be postponed or cancelled as resources are diverted to recovery efforts, which can be tracked through changes in investment plans and assessment of how delays affect long-term capital formation.

Financial Accounts

Objective: Analyse changes in financial assets and liabilities resulting from indirect impacts.

- **Increased borrowing:** To finance repairs and recovery, households and businesses may increase borrowing, which can be tracked through changes in borrowing levels and assessment of how increased debt affects financial stability.
- **Changes in savings:** Savings rates may decline as funds are re-directed to immediate recovery needs, which can be measured through changes in savings patterns and analysis of the impact on household financial health.

Balance Sheets

Objective: Provide a snapshot of the economic impact on assets and liabilities.

- **Depletion of assets:** Flooding reduces the value of both financial and non-financial assets. Balance sheets should be adjusted to reflect decreased asset values and analyse the impact on overall economic stability.
- **Accumulation of liabilities:** Increased borrowing for recovery efforts can lead to higher debt levels. Increases in liabilities should be recorded, as well as assessment of how these changes affect the financial position of affected sectors.

A2.3 Examples of Indirect Costs Identified within the Living Standards Framework

Below, we provide an example for each level of the Living Standards Framework (LSF; Treasury 2021) in the context of flooding events.

1. **Individual and Collective Wellbeing:** Flooding can negatively affect health through water contamination and lead to loss of wages due to disrupted work. Households may experience increased expenses for repairs and temporary housing, resulting in decreased consumption and financial stress.
2. **Institutions and Governance:** Businesses may face operational disruptions from damaged assets and loss of customers, while local governments may struggle to mobilise resources for mitigation and recovery efforts. The LSF supports evaluating institutional responses such as business-recovery grants, loans and market interventions, enhancing resilience and governance.
3. **The Wealth of Aotearoa New Zealand:** Floods strain physical and natural capital, including machinery, buildings and infrastructure, shifting resources from desirable social programmes to reconstruction. Additionally, the loss of human capital through fatalities or incapacitation reduces a society's capacity for recovery, highlighting both direct and intangible losses from flooding events.

A2.4 Example of Using an Input-Output Table in Quantifying Flood Losses

As an example, to quantify flood losses using an input-output table, we will assume a 30% reduction in the agricultural sector's output based on data from previous events, such as the Historic Weather Events Catalogue published by NIWA. This reduction will propagate to other sectors dependent on agricultural output. To analyse these impacts across interconnected sectors, follow these steps:

1. **Define the direct requirements matrix:** This matrix shows the proportion of inputs each sector requires from other sectors to produce its output. Calculate these proportions by dividing each sector's input by its total output.
2. **Calculate the Leontief matrix:** Subtract the direct requirements matrix from the identity matrix (a matrix with '1's on the diagonal and '0's elsewhere).
3. **Calculate the Leontief inverse matrix:** This step involves inverting the Leontief matrix to see the size of the impacts across sectors.
4. **Calculate total impacts:** Using the Leontief inverse matrix, determine the total impact of the flooding on the economy.

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