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Final report

Economic impacts on New Zealand of climate change-related extreme events

Focus on freshwater floods

Report to the New Zealand Climate Change Office

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Preface

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Authorship

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Executive Summary

The aim of this project is to provide recommendations on how to better understand the economic impacts in New Zealand of climate change-related extreme events. The project focuses on New Zealand flood events, and presents a framework in which such events may be assessed in terms of economic costs. By comparing the cost of past events with the costs of possible future events occurring under hypothesised climate change scenarios, this work aims to provide the basis for estimating future costs of climate change.

The most comprehensive analysis of New Zealand flood losses was undertaken in 1986.[1] Although nearly two decades old, many of its observations regarding New Zealand flood loss estimation hold true today. The study notes that despite the vulnerability of a large number of New Zealand communities to flooding, flood losses are "poorly documented, with no one agency seeming to have responsibility for them". Little has changed since those words were written.

The present study outlines a framework for estimating New Zealand flood losses, drawing from the 1986 work and similar, more recent, overseas work. Several practical issues with respect to flood loss estimation are identified:

1. The use of depth-damage functions is a desirable long-term framework for national average estimates. However, because of the significant quantity of data (and hence potentially high costs) required in the construction of depth-damage curves, surveying of flood losses will play an important part in gathering cost information, at least in the short term.

2. Flood hazard maps are an important partner to depth-damage curves, allowing identification of specific buildings with a given flood risk. The combination of depth-damage curves and flood hazard maps would be particularly useful for projecting future flood losses under a changing climate.

3. Survey information provides validation of depth-damage relationships, and has the potential to be a key direct source of flood loss information. The consistency of survey methodology, in terms of questionnaire layout, question wording, etc, is a desirable characteristic for ensuring comparability of results between events.

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[1] Ericksen (1986)

4. Depth-damage curves tend to focus on a single flood action (that is, slow-rising inundation), and thus are likely to be weak in estimating losses from floods characterised by other actions (e.g. high velocity flood waters, waves and surging). Investigation of the typical actions of New Zealand floods would provide the basis for functions that more realistically reflect the damage-causing properties of those floods. It also will not generally be possible to apply overseas depth-damage curves to New Zealand conditions.

5. The most appropriate mix of survey information, depth-damage estimation and economic modelling for a specific event will depend on the size and nature of the event under examination (as well as available resources). The greater the homogeneity of flood-affected buildings, for instance, the more likely it is that modelling techniques can provide realistic flood loss estimates. Indirect losses of small events may be too small to warrant separate estimation. Insurance claim information can be an important data source for flood losses provided adjustment for underinsurance can be made.

Both climatic and non-climatic factors have the potential to affect future flood losses. Thus, modelling of future flood losses should account for both of these factors. Non-climatic factors can be modelled as described above – that is, via use of detailed flood hazard maps (in which urbanisation and land-use changes can be depicted) and depth-damage curves.

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Abbreviations used in this report

EQC	(New Zealand) Earthquake Commission
FHRC	Flood Hazard Research Centre, Middlesex University, U.K. http://www.fhrc.mdx.ac.uk
ICNZ	Insurance Council of New Zealand
IPCC	Intergovernmental Panel on Climate Change
GDP	Gross Domestic Product
NZD	New Zealand Dollar
UNFCCC	United Nations Framework Convention on Climate Change
USACE	United States Army Corps of Engineers http://www.usace.army.mil
USD	United States Dollar, On 12 April 2004 1 USD ≈ 1.52 NZD

1. Introduction: this project

1.1 Aim

The aim of this project is to provide recommendations on how to better understand the economic impacts in New Zealand of climate change-related extreme events. The project focuses on New Zealand flood events, and presents a framework in which such events may be assessed in terms of economic costs. By comparing the cost of past events with the costs of possible future events occurring under hypothesised climate change scenarios, this work aims to provide the basis for estimating future costs of climate change.

The requisite outputs of this project, as outlined in the terms of reference, are as follows:

1. A description of the applicability of international flood cost assessment frameworks for New Zealand and, where relevant, possible steps towards, and barriers in, implementing such schemes in New Zealand.
2. A method for quantifying the yearly and decadal costs of major freshwater flood events to New Zealand, potentially containing an evaluation of the data available and a statement of further data needed for this task. An initial estimate of these costs will be made with limitations and assumptions clearly stated and the sensitivity of the results to the assumptions made quantified.
3. A description of how different climate change scenarios (i.e. different frequencies, locations, and severities of freshwater flood events) and known changes in the future to New Zealand's demographics, economics, and climate could be incorporated into the model which calculates flood costs.
4. A list of research needs; for example, the monitoring of event impacts, economic assessment models, and operational steps which could be taken by government departments to make the results more robust and meaningful. The contribution of identified research in reducing uncertainties of the study results would also be indicated. In particular, the need for and value of more studies of the economic impacts of individual events would potentially be clarified.

1.2 Context

New Zealanders generally accept that climate change is happening and that it will affect them. For this report, climate change refers to "statistically significant variations that persist for an extended period, typically decades or longer" in "classical measures of climate (e.g. temperature, precipitation, sea level, plus extreme events including floods, droughts, and storms)" (IPCC, 2001). IPCC (2001) makes a clear statement that observed changes in climate over the past 50 years are likely to be principally a consequence of human activity. Attribution of climate change to human activities clearly matters in the discussion regarding reduction of greenhouse gas emissions, and the projection of future climate changes under continued emissions, but adaptation to the effects of climate change needs to happen regardless of the source of climatic changes.

Notwithstanding the uncertainties and unknowns in the physical science and the sometimes rapid shifts in public opinion on and political interest in climate change, better understanding and quantification of potential impacts would help to communicate the expected severity of the problem as well as what could and should be done by individuals, communities, and organisations in order to adapt. Such work needs to be detailed, scientifically sound, and transparent yet be translatable into simple, accurate, effective messages for politicians, the media, the public, and education and awareness programmes.

A useful start would be a scope examining the economic impacts of recent freshwater flood events because they are readily quantifiable by generally accepted methods. Extrapolations could then indicate potential future costs. In the future, economic impacts of freshwater flood events in New Zealand are likely to be influenced by climate change. Four links exist:

1. Climate change results in weather changing.
2. The weather changing results in changes to the frequencies, severities, and locations of freshwater floods.
3. Changes in freshwater floods change the economic consequences of freshwater floods.
4. Simultaneously, changes in human activity—such as where people live and work, how their houses and businesses are built, the social networks they form, and how they invest their resources and money—change the economic consequences of freshwater floods.

For each link, several assumptions must be made. As long as sensitivities to these assumptions are quantitatively examined, climate change scenarios could be used to estimate how the economic impacts on New Zealand of freshwater floods might change in the future. This report does so, thereby providing a scientific contribution along with simple, effective messages on the topic of economic impacts on New Zealand of climate change-related extreme events.

1.3 Scope

1.3.1 New Zealand

This report focuses on the North Island and South Island of New Zealand. Other locations, particularly non-New Zealand past work, are considered in order to provide an appropriate comparison for New Zealand.

1.3.2 Freshwater Floods

Many types of floods from the environment occur, including flash floods, groundwater rise, tsunami, storm surges, dam/levee/reservoir failure, river flooding, seiching (the formation of waves in a body of water), and jökulhlaups (outbreak floods caused by the rupture of a glacial dam). Regarding property damage, floods can also include sewers backing up due to blockage, pipes bursting, baths overflowing, or laundry machines breaking. This report focuses on freshwater floods of meteorological origin because (a) they are liable to be most impacted by climate change and (b) these types of floods have the similar origin of rainfall.

The relevant floods are grouped into two categories:

- Flash floods and groundwater rise: Continuous rainfall or a sudden downpour overwhelm the natural and urban drainage systems leading to water ponding and rise. Flash flooding often includes a high velocity component and follows the natural or artificial topography, such as river beds, gulleys, ravines, streets, and alleys. Groundwater rise tends to be slow and can come up through houses, sewers, or pastures. Groundwater rise can also occur as a nearby waterway's level increases, thereby causing the water table to rise underneath the surrounding land. If the surrounding land is lower than the river's banks, the water table appears as surface water.
- Dam/levee/reservoir failure and river flooding: Water from a defined waterway (e.g. river, stream, brook, creek, or rill) or body of freshwater (e.g. lake or pond) escapes the normal limits, sending water over land which is normally dry.

Freshwater floods have some related extreme natural events including mudflows, debris flows, lahar, ice slides, waves (e.g. breaking over a sea wall or throwing debris to damage properties), and driving rain. Similarly, wind, landslides, subsidence, and heave damage to properties often occur during freshwater floods and separating the flood-related impacts from other storm impacts is not always feasible. These events are not explicitly included in this study, but will be mentioned or factored when appropriate or when the data available make that necessary. One other water-related extreme natural event occurs which is specifically excluded from this study: drought.

1.3.3 Economic Impacts

A working definition of “the economy” would be “the system managing resources, such as money, materials, or labour”. A working definition of “economics” would be “the social science that deals with the production, distribution, and consumption of goods and services and with the theory and management of economies or economic systems” (both are based on definitions at http://www.dictionary.com and http://www.yourdictionary.com). Thus, the “economic impacts” of an event are defined here as “the difference between what did happen and what would have happened without the event regarding the consumption of goods and services and the management of resources”.

It is important to distinguish between *economic* and *financial* losses. Financial losses typically relate to the value of property damage of individual homes or businesses, without consideration of the impact of these losses on other agents in the economy. Financial losses from natural disasters are often equated to the value of insurance claims arising from that event, although they clearly ignore the value of non-insured losses.

Economic losses are much broader in scope. As well as accounting for the initial damage resulting from a hazard event, they also incorporate the flow-on effects of that damage on other sectors of the economy. A lifeline breakage is perhaps the most obvious example of how an impact in one sector – for instance, electricity transmission – can have potentially significant consequences for the remainder of the economy. This study is concerned with estimating the economic losses of New Zealand floods.

The variable of interest in assessing the economic losses of natural hazards, including floods, is often GDP. However, as an accounting measure, GDP on its own may not capture the full extent of flood impacts. Property damage, aid payments by government agencies and insurance claim payouts are examples of hazard-related effects that occur “below the line” i.e. outside of the calculation of GDP. Choosing the most appropriate measures for assessing the economic losses of floods is discussed below.

1.3.4 Summary of Scope

This study quantifies in monetary terms the effects of rainfall-triggered floods on the consumption of goods and services and the management of resources in New Zealand and how climate change could alter those effects.

2. Freshwater Flood Cost Assessment Frameworks

2.1 Costing floods

The economic consequences of a flood can be many and varied. Some of the broad categories of impact are as follows:

- Damage to buildings: residential, commercial, and industrial buildings.
- Damage to goods (including vehicles): residential, commercial, and industrial goods.
- Economic productivity lost: business interruption and days lost from work.
- Damage to infrastructure and government services: mainly lifelines.
- Alternative accommodation for families and alternative facilities for businesses.

Arguably, time spent cleaning up after a flood may restrict affected residents' opportunity for consumption spending. However, it seems likely that these impacts will be insignificant in comparison to the impact on consumption via lost income (as a result of time away from work, for instance). Furthermore, it is equally possible that in such a circumstance, purchases are merely delayed, not foregone. This is particularly likely to be true for large items, the purchase of which tends to follow a deliberate, well-reasoned decision, and is thus less likely to be swayed by a temporary hiccup.

Consistently estimating flood losses across events requires implementation of a framework for classifying these impacts. As noted in BTE (2001), the method typically used to estimate the costs of a natural disaster is to categorise the losses into tangible and intangible losses, which are each further subdivided into direct and indirect losses. This framework is equally applicable to flood events.

The standard distinction between tangible and intangible losses is that the former relate to losses which can be relatively easily valued via some market price; intangible losses, on the other hand, affect items for which no observable market exists, and are thus considerably more difficult to accurately estimate. The direct costs of a flood event result from the physical contact of flood water with damageable property. Indirect costs reflect the flow-on impacts of property damage throughout the remainder of the economy. Examples of impacts in these four categories are:

- Tangible, direct: damage to food and electrical appliances, collapse of residential structures.

- Tangible, indirect: business disruption from lifeline breakages, lost wages of employees unable to attend work.
- Intangible, direct: loss of photographs and family heirlooms, drownings.
- Intangible, indirect: lessening of quality of life due to stress, delays in formal education.

Although difficult, placing a value on intangible losses is possible. Values placed on family heirlooms and memorabilia may be established via willingness-to-pay type questioning. Value may even be assigned to the loss of a human life. However, these valuations are nearly always subjective, if not arbitrary, and thus may vary widely between flood events and the individuals affected. Variation in intangible loss values makes for fraught comparisons, whether between the tangible and intangible losses of a particular flood event, or between flood events.

Given the difficulties surrounding their estimation, intangible losses are often considered ancillary to the central issue of estimating tangible losses, or they are excluded from study estimates entirely. This is not to discount their significance, especially relative to that of tangible costs. Given the difficulty associated with estimating intangible losses, risk management decisions are almost always based solely on estimates of tangible losses. This is despite the fact that the tangible losses are often not the only (or even prime) driver for the adoption of a particular flood risk management strategy.

Both BTE (2001) and Kelman (2004) question the merit of separating intangible losses into direct and indirect components. With respect to non-drowning flood deaths, Kelman (2004) writes that “any death which would not have occurred without the disaster event counts as a direct death from that event”. The present study avoids the ethical and practical concerns in assigning monetary values to intangible impacts by not discussing them. The focus is on tangible impacts of freshwater floods.

The methodologies available for estimating the value of flood losses lend themselves to a distinction between direct and indirect losses. Although all losses, both direct and indirect, may be assessed via surveys of affected households and businesses, a more practical approach is to only survey directly-affected parties and use economic modelling techniques to estimate the indirect effects. This modelling typically relies on the use of background data about the inter-linkages contained in the affected economy, such as that contained in input-output tables. Either by multiplier-type analysis or computable general equilibrium modelling, the indirect, or flow-on, effects of property damage can be determined.

Consideration of the most appropriate measure (or measures) of loss should be given when estimating flood losses. GDP (or, at a sectoral level, value added) is often used as a measure of the economic loss arising from a hazard event. However, there are subtle but significant differences between the value of assets damaged or destroyed in a flood event, and the change in GDP caused by that event. In essence, the former measures changes to the affected region's balance sheet (i.e. the change in a "stock" variable), while the latter measures the change in production-based income accruing to the region (i.e. a "flow" variable). There are clear links between balance sheet and production impacts that must be considered when estimating the losses accruing from any natural hazard. Nonetheless, care must be taken not to simply add stock and flow impacts together in order to arrive at an estimate of the total loss.

As a measure of loss, GDP may also ignore many of the sectoral transfers that arise following a flood. GDP is a measure of production.[2] It thus does not explicitly account for any non-production related transactions, including the payment of insurance claims by insurers and disaster relief by government or non-profit organisations. In the national accounting framework, these non-production flows are recorded in the income-outlay accounts, "below the line" of the GDP calculation. Thus, explicitly accounting for these flows, which can often be substantial in the context of a flood event, requires consideration of more than GDP alone.

Floods also provide the opportunity for increases in activity for some sectors, *viz*, those involved in the reconstruction effort. These increases have a positive impact on GDP. In fact, since many of the losses caused by a hazard affect non-GDP variables (in particular, assets i.e. balance sheet items), these increases in activity can be enough to more than offset any reductions brought about by the flood. This gives rise to the seemingly perverse result that floods (and hazards generally) can be GDP-enhancing! Again, the remedy is simply to not use GDP as the sole metric of loss.

Finally, GDP may not capture the full effect of flood-induced price changes. Increases in demand for particular goods and services – for example, construction and flood clean-up services – provide the opportunity for the suppliers of those services to increase their prices. Price increases as they affect households can be captured by economic welfare measures. A change in the economic welfare of a household is effectively defined as the change in the cost of the household's consumption bundle, relative to the change in that household's income. If the price of the consumption bundle increases while income remains unchanged, the household is worse-off in welfare terms. However, in the short-term at least, the quantity of goods and services consumed by households, and hence real GDP, may not change (where, say, the household can finance the increased value of consumption

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[2] Alternatively, given the national accounting identity GO-IC=C+I+G+X-M, GDP equates to a measure of the income earned via production (i.e. GO-IC = VA) and to the value of final expenditure necessary to achieve that production (i.e. C+I+G+X-M). Regardless of the GDP measure used – production, income or expenditure – all GDP flows relate directly to the production activity of a particular period.

via savings). So while welfare has clearly declined, GDP remains unchanged. The influence of price changes on economic welfare is explicitly accounted for in CGE modelling output.

2.1.1 Ex-ante flood loss estimation

The discussion regarding flood loss frameworks above is predicated on the basis of a flood event having actually occurred. Via a combination of ex-post surveying and economic modelling techniques, the total economic cost of a past event can be ascertained.

However, flood losses can also be estimated ex-ante. For a hypothetical flood event, characterised by values for flood depth, water velocity, etc, and given a relationship between those flood characteristics and likely damage, ex-ante flood costs can be determined.

Perhaps the most common example of this estimation in practice is the use of depth-damage curves. A depth-damage curve depicts the relationship between the level of water in a building and the typical level of damage that results from that water level. Buildings are grouped as homogeneously as possible, so that distinct curves can be constructed for each building type.

Depth-damage relationships can be established in one of two ways:

1. Via analysis of past flood events: the correlation between flood depth and damage of previous flood events is used as the basis for estimating the depth-damage relationship.
2. Via analysis of “synthetic” data: sample surveys are conducted to establish typical household contents, associated values and height above floor level. This data can then be used to determine the value of likely losses for varying flood depths.

Depth-damage curves constructed by either method can be used ex-ante to predict the damages that will occur following a flood of a given depth. The advantage of the latter method is that curves can be constructed independently of actual flood damage data.

One of the key determinants of the usefulness of depth-damage curves is the degree to which they represent the buildings under scrutiny. The greater the homogeneity of each building class for which curves are constructed, the greater the degree of usefulness of that family of curves. Thus, depth-damage curves are perhaps most applicable to residences, where properties can be more easily categorised according to value, number of floors, number of rooms, etc. Conversely, the content and construction of commercial and industrial buildings varies to such an extent that defining representative building classes, and thus determining depth-damage curves, is not practicable in many instances.

In principal, the equivalent of depth-damage curves can be constructed for a host of other flood characteristics. Some studies also include average flood velocity, flood duration or sediment load as the defining parameter. A comprehensive framework classifying parameters which define floods and which lead to flood damage has been developed by Kelman and Spence (2004). They use "flood actions" to describe the characteristics of floods which could lead to flood damage. The summary of their scheme is:

1. Hydrostatic actions (actions resulting from the water's presence):
    - Lateral pressure from flood depth differential between the inside and outside of a building.
    - Capillary rise.
2. Hydrodynamic actions (actions resulting from the water's motion):
    - Velocity: moving water flowing around a building imparting a hydrodynamic pressure.
    - Velocity's localised effects, such as at corners.
    - Velocity: turbulence.
    - Waves changing hydrostatic pressure.
    - Waves breaking.
3. Erosion actions (water moving soil; the water's boundary becomes dynamic and moves into the adjacent solids).
4. Buoyancy action: the buoyancy force.
5. Debris actions (actions from solids in the water):
    - Static actions.
    - Dynamic actions.
    - Erosion actions.
6. Non-physical actions:
    - Chemical actions.
    - Nuclear actions.
    - Biological actions.

Each of the above flood actions has a factor related to the time for which the flood action applies. This factor thus considers duration.

Defining a flood by all the above flood actions would be unwieldy. As noted, above flood cost models therefore select specific flood actions to examine. These models are discussed in the following sections.

2.2 Data requirements for flood-loss estimation

Flood-loss estimation is typically a data-intensive exercise. Even if flood losses are estimated via some modelling exercise (as opposed to surveying affected individuals), valuations of the pre-event asset base are typically required to determine the significance of a flood (as say, value of damage as a percentage of the value of the pre-event asset base). Pre-event valuations of existing assets may be determined from building databases – where they exist – of city and district councils. However, such databases are likely to have been established on ad hoc bases, and will almost certainly vary in the extent to which they have been maintained.

Variance in the quality and availability of flood-loss data will clearly affect loss estimates. Even where a single estimation framework has been applied consistently to different flood events, incomparable estimates of flood losses may arise through differences in the quality of the available data.

As noted above, the focus of this study are the tangible costs of flood events. Potential data sources for estimating direct and indirect tangible costs are discussed in this section.

2.2.1 Direct cost estimation

a) Survey data

Surveying households and businesses which have directly experienced damage is arguably the most effective means of gathering accurate flood impact information. In fact, depending on the required accuracy of loss estimates, surveying may be the only means of collecting sufficient flood impact data. The key advantages of surveying are (i) that it captures information that may have no alternative source and (ii) the quality of data collected, can, with careful questioning, be controlled.

Survey questions should be designed with the variable (or variables) of interest in mind. If the aim of the study is to place a value on the level of property damage suffered, then questions should be focused accordingly. Alternatively, if valuing lost production is the prime motivation, questions need to be phrased so that respondents are clear about the distinction between property damage and production losses. Questions must also seek to determine the level of uninsured and insured losses. Property owners with insurance cover clearly face different consequence to those without following a flood. Provision of insurance effectively spreads the value of the flood loss across all policy holders, so that although the total value of loss is the same whether insurance cover is provided or not, the distribution of that loss may differ significantly. This is particularly relevant when considering a regional flood event, for which insurance cover is provided by national (or international) insurers.

One often overlooked issue when surveying flood victims is that of accurately determining the economic value of property immediately prior to flood damage. Surveys typically question respondents about asset loss (or damage) without supplementary questions aimed at determining the remaining useful life of those assets. Thus, respondents will conceivably respond by recording the replacement value – that is, the value of a brand new equivalent – for a damaged asset, rather than the estimated value of that asset given its age. The consequence of this is an overstatement of the value of loss caused by the flood since the value of the pre-flood asset base has effectively been overstated. This issue has a parallel in insurance claim data as discussed below.

As with all sample surveys, the selection of a representative sample is crucial to the applicability of survey results to the population under scrutiny. For floods with non-uniform flood depth across the total affected area, it may be prudent to stratify the total affected area depending on flood depth, with sample weights for each sub-area equal to the number of affected residences in that sub-area.

Separate household and business surveys are likely to be required where both are affected. The consequences of property damage will be quite different for businesses and households, with the former potentially facing greater ongoing costs in terms of business interruption. In such cases, specific questioning of businesses regarding lost sales, production activity and/or labour constraints will be needed. Where service providers with significant connections throughout the economy are affected by flooding, such as in the case of breakages to electricity, communications or roading networks, separate questioning will be required to accurately ascertain the extent and duration of outages.

Finally, surveying needs to take place at a time when the flood event and its impacts can still be accurately recalled by victims: as time passes, memories tend to fail. Although no guidelines exist, it seems plausible that surveying within two years of the event will produce the most reliable flood impact information.

Although these pitfalls of surveying flood-affected households and businesses tend to be unique to flooding, there remedies are not. More accurate survey data can nearly always be obtained, regardless of the motivation for the survey, via careful sample design, questionnaire layout and wording of questions. The recommended approach includes:

- Face-to-face trial questioning of a small selection of households (and businesses if applicable), used to finalise question wording and questionnaire layout.
- Ideally, surveying of the entire affected population. If this is not possible, stratified sampling can only be undertaken with reference to known

characteristics of the entire population. Population census data may provide data on the number of rooms per house, for instance, which would provide the basis for stratification of flood losses by house size.

- Use of a combination of surveying methods to provide respondents with a range of options for participation. These may include delivered questionnaires, face-to-face interviews, telephone interviews and community focus groups. Mixing these methods (for example, using mail-out questionnaires for the majority of the population or sample, and face-to-face interviews for a small selection of affected households) can be a useful way of validating survey results.
- For population surveying, a post-enumeration survey should be considered to evaluate, inter-alia, the consistency of responses across those questioned and the level of under- or over-valuation ascribed to flood losses.

b) Insurance claim data

Surveying is not always a practicable option. Time and cost considerations may prevent surveying at the required level of detail and coverage. Community sensitivity may also limit the scope and timing of flood damage surveying.

One common alternative to surveying is the use of claim data of insurance companies. Insurance data has several distinct advantages over surveying. Most relevant is the easy accessibility of claims information, relative to the process of survey development, distribution, enumeration, etc. Many insurance companies publish aggregated claims information for hazard events, either independently or via an industry body (as is the case with ICNZ in New Zealand). Governments that provide top-up cover (again using New Zealand's EQC as an example) are also likely to publish payout information.

Many potential disadvantages exist in insurance data which affect the extent to which it represents economic losses. Perhaps the biggest issue is that of under- or uninsurance. ICNZ estimate that as many as one-quarter of New Zealand households are underinsured, with that figure increasing to 40% in smaller communities.[3] In some instances, the cost of obtaining insurance cover is prohibitively high. This is perhaps best illustrated with the recent floods in the lower North Island, where most farmers suffered uncovered losses due to prohibitively high premium payments. Under-insurance is a related but arguably lesser problem in which sums insured are not adequate to cover the assets protected.

The usefulness of insurance data cannot be denied. However, further research – perhaps via surveying of "typical" New Zealand communities and suburbs – should be undertaken to gauge the magnitude of uninsurance.

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[3] National Business Review, "Under Insurance Tackled", April 16, 2004, p10.

Even without estimates of the value of uninsurance, sensitivity analysis could be applied to flood loss analysis in order to better understand the impact of uninsurance on the community of interest.

For individual policy holders, insurance data can actually overstate the true value of loss, since household contents policies typically offer full replacement of many items, regardless of their age. In practice this issue is likely to have lesser impact than that of uninsurance; however, it is still worthy of consideration when relying solely on insurance data for estimating flood losses.

c) Depth-damage curves

As noted above, depth-damage curves (known also as depth-loss and stage-damage curves, amongst other similar sounding names) provide a means of estimating the loss of actual and potential future flood events. Provided a reasonably accurate catalogue of homes and contents, homogenously classified on the basis of building features (such as size, number of levels, income of residents, etc), provides the basis for their construction, using depth-damage curves is a valid method for estimating flood losses.

Synthetic curves have the advantage of being able to be constructed independently of any actual flood data. As such, however, they relate to potential rather than actual damage. Differences between potential and actual damage depend on factors such as previous disaster experience and amount of warning time provided. Increased warning time, for instance, allows affected households to take preparatory action, thus limiting the actual damage below the potential damage implied by a synthetic depth-damage curve. These factors thus need to be considered when using synthetic curves to assess actual flood losses.

As noted above damage curves that relate solely to water depth are generally only applicable to flooding that is characterised by slow-rising, low-silt and low-flow in nature. Damage curves for other flood actions can be derived, but the complex nature of many of these actions increases the difficulty of doing so. Nonetheless, attempts have been made to establish the relationship between other flood actions (i.e. other than simply inundation) and loss.[4]

2.2.2 Indirect cost estimation

Indirect losses may be experienced by both households and businesses. If a town's only supermarket is flooded and forced to close, households which were otherwise unaffected by the flood may be forced to travel to the next town to secure food supplies. The costs to the household include additional travel expenditure as well as any difference in prices of food items. Lifeline

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[4] See, for example, Kelman (2002)

breakages may only be an inconvenience to households but may prohibit production of businesses. Electricity outages, for instance, may make life a little uncomfortable for affected households, but may not have any economic impact (the loss of frozen food being an exception). Many manufacturing businesses, on the other hand, would struggle to continue production in the face of such an interruption.

Surveying of affected households and businesses to establish indirect losses is possible. However, given the likely large variation in the actual indirect effects – for instance, an electricity outage will affect businesses in different sectors in vastly different ways – a large and carefully structured sample will be required to ensure meaningful results. The logistics of undertaking such an exercise often deem it prohibitively expensive.

Fortunately, cheaper alternatives exist. Input-output tables (and their more detailed counterparts, social accounting matrices) are essentially databases of the production and consumption flows between all agents of an economy, including business, government and households. Input-output modelling has an established history of being used to analyse the impact of economic 'shocks'. These shocks can include natural disasters.

In broad terms, input-output tables (and/or SAMs) can be used to assess indirect flood costs in one of two ways:[5]

1. *Via multiplier-type analysis.* The input-output table can be manipulated in order to derive the total (direct and indirect requirements) matrix, which in turn can be made to yield industry-specific 'multipliers'. Multipliers are measures of how a change in demand for one industry's output (i.e. the direct effect) flows through the remainder of the economy (i.e. the indirect effects). The major disadvantage of multiplier analysis is that the economy is assumed to expand or contract linearly, and is thus best suited for relatively small shocks.
2. *Via general equilibrium analysis.* Input-output tables and social accounting matrices form the basis for computable general equilibrium (CGE) models. CGE models are composed of equations representing industrial production and household consumption functions, and parameters representing substitution elasticities. Input-output data provide the benchmark values for production and consumption functions. Shocks to a CGE model are worked through the modelled economy via price changes which serve to return the shocked economy (in which one or more markets are unbalanced) to a state of balance in all markets – goods and services, labour and capital, and income and expenditure.

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[5] Econometric models are not generally considered to be an appropriate tool for estimating economy-wide impacts of hazard losses. VAR models (in which each variable can be written as a function of its own lagged values and the lagged values of all the other variables in the model) are considered to be more applicable to macro-economic modelling and forecasting exercises. Econometric analysis often does, however, play a useful role in parameterising the relationships that underpin flood depth-damage and earthquake damage models.

> Dynamic variants of CGE models can be configured to capture longer-term hazard impacts – such as the time taken to return flooded farmland to a productive state. However, introducing an inter-temporal dimension requires the use of additional parameters which frame economic agents' savings vs consumption decisions. Like substitution elasticities, parameters of inter-temporal decision making are not well estimated.

Regional input-output tables are not available from Statistics New Zealand. However, the national tables produced by Statistics New Zealand can be regionalised using, *inter alia*, regional employment and population census data. Derivation of regional input-output tables in this manner is a common practice for modellers of regional impacts, including natural disasters, in many countries.

No one has yet undertaken the task of preparing a comprehensive flood cost assessment framework before an event, so that it is ready to go when an event happens. When a standardised approach has been proposed for collecting certain flood damage data (e.g. the FASTER Form in Appendix A), it has rarely been adopted. Calls for comprehensive, standardised impact assessment frameworks for specific aspects of disasters such as deaths and injuries (e.g. Combs *et al.*, 1999; Hajat *et al.*, 2003; Pollander and Rund, 1989) have so far also gone unheeded. A useful future project would be to create a stakeholder panel which will review the disaster impact assessment literature and develop, accept, and implement a comprehensive flood cost assessment method.

Naturally priorities other than data collection occur during a flood, particularly when an immediate threat to life exists. Nonetheless, calls (e.g. Blong, 2004) for more systemised real-time information form a logical corollary from the need for preparing a comprehensive flood cost assessment framework before an event. With a tested system in place, when an event occurs, data collection as the event is ongoing should assist rather than hinder the response. The proposed stakeholder panel's mandate should include such issues.

2.3 Use of the framework overseas

Residential properties are selected as an illustrative example of approaches outside of New Zealand. The main reason is that this impact has been studied to the most detail. The weaknesses, limitations, and inconsistencies of the work presented here are thus the minimum which would be expected for other cost assessment frameworks, such as those for business interruption, infrastructure losses, and losses in commercial premises.

In fact, detailed studies which did not include residential properties were few (Davis, 1985 is a notable exception), although some are in progress (e.g. McManus, c. 2005). Insurance and reinsurance companies often state that they have sophisticated cost assessment models for all flood damage, but the details are not public domain and private discussions with the modellers frequently lead to significant concerns about the methods.

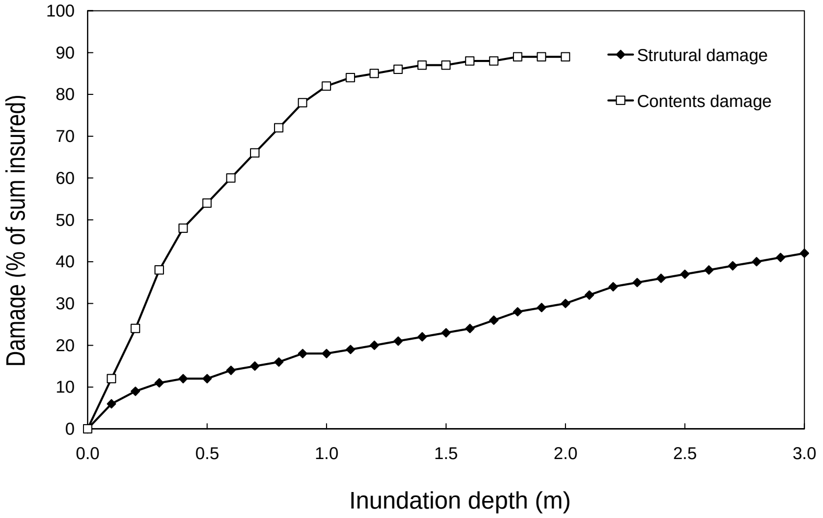
The most extensive studies which are available have been conducted in Australia, the U.K., and USA. Examples from a range of countries are provided in Table 1 below.

Table 1 Examples of Studies on Freshwater Flood Damage to Dwellings Outside the U.K. and U.S.A.

References	Geographic Area	Hazard Considered	Measure of Impacts
Beck *et al*. (2002)	Luxembourg.	Depth and velocity.	Potential impacts noted as a degree of acceptability.
“Child of ANUFLOOD” (1998), Smith (1991), and Zerger (2004)	Australia.	Depth with velocity as an optional input.	Money. Building failure is predicted from Black (1975).
DeGagne (1999)	Manitoba, Canada.	Depth.	Money and percentage of value.
Green and Parker (1994)	Australia, Germany, Japan, and the U.S.A.	Depth. The Japanese studies also consider sediment load.	The authors compare depth-damage curves, concluding that the shape of the curves is reasonably similar for depths of less than 1.2 m.
Hubert *et al*. (c. 1996)	France.	Depth and duration.	Money
Islam (1997)	Bangladesh.	River: Depth and duration. Flash: Velocity. Tidal: Velocity and salinity.	Money and percentage of total value. Some social variables were considered.
Risk Frontiers (2002)	Australia.	Depth.	Insurance losses.
Smith and Greenaway (1980)	Lismore, New South Wales, Australia	Depth.	Money.
Smith *et al*. (1981)	South Africa	Depth.	Money
Torterotot *et al*. (1992)	France.	Depth and duration.	Money. Warning type, action taken, and building and occupancy characteristics were also considered.

Examples of depth-damage curve derivation in Australia include that of Risk Frontiers (2002) and the construction of the ANUFLOOD model at the Centre for Resource and Environmental Studies at the Australian National University (1983). Risk Frontiers curves are synthetic and thus relate to potential, rather than actual losses. The examples shown in Figure 1 are integrated contents and structure loss curves which relate inundation depth with damage expressed as a percentage of the sum insured.

Figure 1 Risk Frontiers depth-damage curve

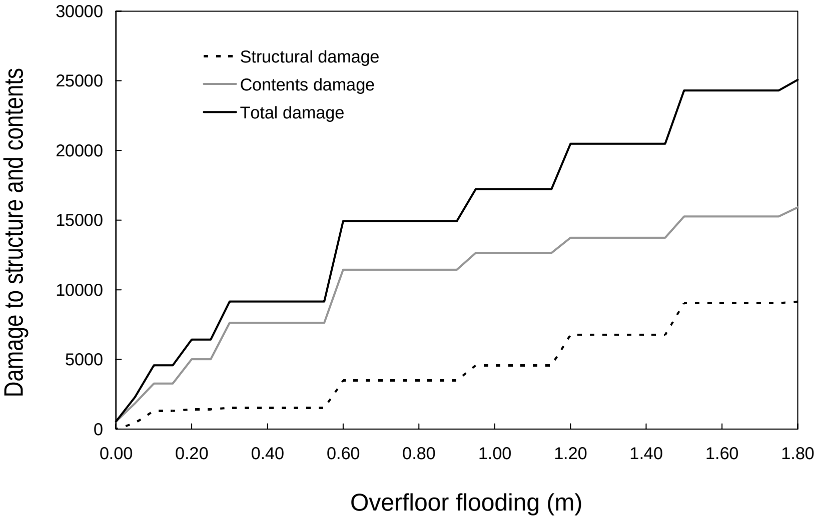


Source: Risk Frontiers-NHRC, from EMA (2002)

Synthetic depth-damage curves also support the ANUFLOOD model. ANUFLOOD is a widely used method of assessing flood loss vulnerability in Australian communities, both in terms of potential losses (i.e. what the damage value could be if a flood to occur) and actual losses (i.e. what value of damage occurred for an actual event). Typical ANUFLOOD curves are illustrated in Figure 2.

Figure 2 Potential direct stage-damage values for single-storey houses in NSW

A$, 2003 (originally 1983 dollars)



Source: Ericksen, *et al* (1988)

Depth-damage analysis of flood losses have typically focused on residential and commercial losses. Depth-damage curves have not been considered suitable for assessment of industrial losses due to the lack of homogeneity of ground-level assets across different businesses. A study of flooding in Kempsey, NSW (Gissing, 2002), which in part compared losses estimated via depth-damage modelling with those reported via surveying, confirmed that the relationship between flood depth and industrial asset losses is not well defined. Gissing writes: "Stage-damage analysis found damage data to be variable and uncertain. Coefficients of determination indicated a very weak relationship between direct damage and over floor depth."[6]

In the U.K., the Flood Hazard Research Centre (FHRC) at Middlesex University, London has completed studies estimating the vulnerability of U.K. residences to floods in monetary terms. FHRC calculated curves of monetary damage as a function of slow-rise flood depth. Their first major publication (Penning-Rowsell and Chatterton, 1977) systemised the assessment of the benefits of flood alleviation for both urban areas and agricultural land using synthesised data for direct flood water damage. Nine sectors, categorised as land use types, were examined including residential properties.

Depth-damage curves were developed for:

- No flood warning along with flood warnings of 0.5 h, 2 h, and 4 h.
- Two arbitrary flood durations, short which is less than 12 hours and long which is more than 12 hours.

The curves for residences are reported for five depths above floor level and one depth below floor level. Smooth interpolation between the depth values is assumed for all curves.

Using this work as the main basis, subsequent reports update the various land use categories while refining the methods in order to produce software packages for desktop computers. The next major FHRC work (Parker *et al.*, 1987) used synthesised data to estimate flood protection benefits for urban areas, including indirect benefits, again on a depth-damage basis. Subsequently, Suleman *et al.* (1988) incorporated clean-up costs into the depth-damage calculations.

N'Jai *et al.* (1990) formed part of these continued pricing and assessment updates from FHRC, presenting further revisions to the land use classifications. The most recent FHRC manual is Penning-Rowsell *et al.* (1992) which lists percentages by which to increase the flood damage values in the case of a salt water flood. The assumption is a simple contrast between salt water flooding and fresh water flooding. Penning-Rowsell *et*

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[6] Commercial losses are also less likely to be suited to depth-damage estimation than residential losses. The value of stock held by different types of retailers, for instance (compare a supermarket with an electronics and appliance retailer) may differ massively, suggesting that a depth-damage curve specific to retailers would not be sufficient for robust loss estimation.

al. (1992) briefly mention velocity's impact on flood damage, slightly misquoting Clausen's (1989) research.

The work of N'Jai *et al.* (1990) was updated by FHRC during the 1990s and was eventually redeveloped by Experian (2000) who updated the values to October 1998. Experian's (2000) most prominent change was to provide the depth-damage values for lifestyle, rather than residence, classes. Separate tables are provided for depth-damage curves for each of the two flood durations (less than and more than 12 hours) and for each of 52 lifestyle types clustered in 12 lifestyle groups. These lifestyle classes were built using 86 demographic and housing variables for Great Britain. Demographic variables include the occupants' ethnicity, age, employment sector, and principal transport mode. Housing variables include financial status (e.g. rent, own outright, or mortgaged), rooms per person, presence or absence of central heating, and WC type (e.g. shared or not inside). Some of the descriptions by Experian (2000) are questionable, such as stating the alcoholic beverage preferred by certain lifestyle types.

Black and Evans (1999) undertook an empirical exercise which analysed insurance claims from seven floods in the U.K. during the 1990s for which a loss adjuster was needed. Floods were characterised by depth, duration, velocity, contaminating substances, salinity, and season (summer or winter) but comprehensive data were available for only depth and season. Losses, which covered any alternative accommodation needed for occupants of flooded properties, were reported in monetary terms as a function of total sum insured in monetary terms.

Commercial firms develop and apply flood loss models for U.K. residences, including Risk Management Solutions, Inc (Muir-Wood, 1999) and ABS Consulting (Toothill and Bovy, 2002). Most details are confidential, but losses are usually reported in monetary terms and as a percentage of the total sum insured.

The most detailed U.K. studies on damage and loss for residences in floods have considered almost exclusively depth-damage curves, although velocity and duration are considered at times. The flood depth is assumed to rise slowly so that damage occurs only due to water touching the damaged item or structure and not due to any physical force, pressure, or energy imparted or due to substances other than water in the flood. In contrast, many non-U.K. studies listed in Table 1 and Table 2 (below) indicate the importance of flood characteristics other than depth.

In the U.S.A., the United States Army Corps of Engineers dominates the recent work on flood cost assessment frameworks (Davis, 1985 and Davis and Skaggs, 1992 are also USACE documents). USACE (1998) proposes a flood proofing matrix delineating thresholds believed to be important for different damage scenarios:

- Depth: shallow (< 0.9 m), moderate (0.9 m to 1.8 m), or deep (> 1.8 m).
- Velocity: slow (< 0.9 m/s), moderate (0.9 m/s to 1.5 m/s), or fast (> 1.5 m/s).
- Flash flooding: yes (less than 1 hour) or no.
- Ice and debris: yes or no.
- Site Location: coastal or riverine.
- Soil Type: permeable or impermeable.

Three sets of structural characteristics are also provided.

Justification for these categories is not provided. USACE (1988) provides experimental data on which the depth characteristics appear to be based. USACE (1995) describes water loads (hydrostatic and hydrodynamic), debris impact loads, soil loads, wave loads, and uplift pressures as factors in structural flood damage costs but provides little quantification.

Table 2 Examples of Studies on Freshwater Flood Damage to Dwellings in the U.S.A

References	Geographic Area	Hazard Considered	Measure of Impacts
Appelbaum (1985)	Baltimore District, U.S.A.	Depth.	Money, as a percentage of replacement value.
Black (1975)	U.S.A.	Depth and velocity.	Structure moves or does not move.
CH2M Hill (1974)	Willamette Valley, Oregon, U.S.A.	Depth and velocity.	For depth, money and in percentage of total value. For depth and velocity, collapse or no collapse.
Davis and Skaggs (1992)	U.S.A.	Depth.	Money and percentage of value.
Sangrey *et al*. (1975)	Elmira, New York, U.S.A.	Depth and velocity.	Structure destroyed or survived.
USACE (1993)	U.S.A.	Depth.	Money and percentage of total value.
USACE (2000)	U.S.A.	Depth.	Percent of value.

Some freshwater flood cost assessment frameworks outside of New Zealand are detailed but they provide cost estimates for only specific characteristics of floods. The most detail is afforded to depth-damage functions, insurance losses, and residential buildings. Although some models use residential building damage as a proxy for other forms of damage, sometimes including a multiplier to estimate non-residential building damage, little public domain work has been completed on obtaining accurate and precise full cost estimates for floods.

Use of synthetic depth-damage curves results in estimates of potential damage, where no account is taken of warning time, population preparedness and emergency action. Thus, a major issue with using synthetic curves to estimate losses arising from an actual event is the adjustment from potential to actual losses.

The key to this adjustment is the estimation of the extent to which warning time and previous flood experience affects community preparedness, and hence lessens flood losses. One of the few studies where the difference between actual and potential losses has been explicitly measured was that of the Lismore, NSW, flooding of 1974 (Smith, 1981). The ratio of actual to potential damages for Lismore's residential, commercial and industrial sectors were estimated to be 50%, 24% and 6%, respectively. Lismore had around 12 hours warning time and was experienced in major flooding at the time of the 1974 event, thus allowing households to limit their actual losses to 50% of their potential. Higgins and Robinson (1981) developed this idea further by producing indices of flood loss incorporating flood warning time and preparedness parameters.

2.4 Use of the framework in New Zealand

Although now somewhat dated, arguably the most comprehensive study of flooding in New Zealand is Neil Ericksen's *Creating flood disasters?: New Zealand's need for a new approach to urban flood hazard* (1986). Ericksen presents the tangible/intangible, direct/indirect framework for assessing flood losses as described above. However, due to lack of information about the consequences of past flood events, the framework is largely presented as a potential methodology rather than one that is put into practice. Ericksen notes:

> *In New Zealand…estimates of community flood losses or potential flood losses are few and far between in spite of there being nearly 100 flood-prone places. It follows that at national level, the aggregate of flood losses is poorly documented, with no one agency seeming to have responsibility for them.* (p. 264)

Ericksen does however use claims against Insurance Council companies and the Earthquake and War Damage Commission (as it was then) to examine the trend in flood losses between the early 1950s and 1984. This analysis is discussed below.

As part of a related series of papers, Ericksen, Handmer and Smith also evaluated the applicability of the ANUFLOOD to New Zealand flood loss assessment.[7] This is discussed in the next section.

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[7] See, in particular, Ericksen, *et al.* (1988).

2.5 Applicability of Non-New Zealand Methods to New Zealand

Two significant concerns exist regarding the suitability of overseas damage curves to New Zealand flood events: the flood actions which occur and the nature of the losses calculated.

Regarding flood actions, past studies focus on clean water doing damage from slow-rise depth. New Zealand freshwater floods tend to have high sediment loads, high debris loads, and high velocities (Table 3, below) which can cause more damage than depth alone. A recent analysis of New Zealand freshwater flood losses (Walton *et al.*, 2004) showed a weak relationship between over-floor depth of flooding and damage.[8] No other attempts at estimating actual depth-damage curves were found for floods with fewer flood actions, such as the 1998 Waikato flood.

Table 3 Examples of Flood Actions in Recent New Zealand Freshwater Floods

Flood	Main Flood Actions	Other Hazards	Sources
1998, March 7, Cyclone Bola	Slow-rise depth, fast-rise depth, sediment, debris, velocity, waves.	Landslips. Wind.	Adye (2001) Cook County Council (1988). http://library.christchurch.org.nz/Childrens/NZDisasters/CycloneBola.asp Photographs by Dave Jack, Hutt City Council.
1998, July, Waikato River System	Slow-rise depth, sediment.	Landslips.	Thompson (2001)
November 1999, Queenstown and Clutha River	Slow-rise depth, sediment, velocity.	Landslips.	Metservice: http//www.metservice.co.nz/severe_weather/spring99_1.asp
2002, June 21, Waikato Weather Bomb	Slow-rise depth, sediment, debris, velocity.	Landslips. Wind.	Walton *et al.* (2004)
2004, February, North Island	Slow-rise depth, fast-rise depth, sediment, debris, velocity.	Landslips. Wind.	Media reports and photographs. Interviews with flood-affected people in Scott's Ferry.

Regarding the nature of losses calculated, past studies focused on residential properties, the most detailed of which are from the U.K. and the U.S.A. New Zealand dwellings are quite different from U.K. dwellings due to the

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[8] Note, however, that derivation of actual depth-damage curves was not an explicit objective of this study.

age, architecture, and materials used. As well, many New Zealand dwellings are built to withstand earthquakes in contrast to the U.K. New Zealand dwellings are more similar to American houses, particularly those built in earthquake-prone zones. Significant differences would be that New Zealand houses tend to have lower floor area, will frequently be single storey, and in rural areas tend to be more closely spaced. Thus, U.K. depth-damage functions are unlikely to be applicable to New Zealand while American depth-damage functions might be more indicative of New Zealand's situation but could not be used with confidence.

One study was found which examined the transferability of depth-damage functions to different locations (Green and Parker, 1994). They compared depth-damage curves for Australia, Germany, Japan, and the U.S.A., concluding that the shape of the curves is reasonably similar for flood depths of less than 1.2 m. Given the wide diversity of properties in those countries, transferability of depth-damage functions might be a reasonable assumption. Nonetheless, this study was not peer-reviewed, does not address several assumptions which appear to be implicit, and suggests that the curves are not transferable for flood depths above 1.2 m.

Similarly, the three Australian studies in Table 1 would be the most likely to be transferable to New Zealand. These studies consider only depth and neither empirical evidence nor modelling work exists for New Zealand which would permit testing of the transferability of the curves to New Zealand. Furthermore, Smith and Greenaway (1980) is dated and was developed for a specific locale while the curves from the other two studies are not public domain.

As noted above, Ericksen *et al.* (*op cit*), evaluated the use of the ANUFLOOD model for New Zealand flood loss estimation. The authors applied ANUFLOOD to the case of Paeroa, estimating actual losses from flooding of 1981 (resulting from a 'downstream' stop-bank failure), and the potential losses from a hypothetical 'upstream' stop-bank failure at Centurion Bridge.

Ericksen *et al.* (*op cit*) outline their findings in some detail. In summary, however, they state:

> *ANUFLOOD provides a useful technique for assessing potential tangible direct urban flood damages; both actual and potential. Its capacity to quickly compare the tangible benefits for a wide range of flood mitigation options is a valuable contribution to urban floodplain planning. The method can be standardised so that comparisons of flood damage throughout New Zealand would be on a common base, although any significant regional differences could be incorporated. The ANUFLOOD inputs highlight deficiencies in the information base that is currently available. The greatest of these if the lack of flood hazard maps which, for their production, also require a study of flood frequencies, and development of detailed contour maps.*[9]

Floodplain management thinking has developed significantly in the past twenty years and territorial authorities of some flood-prone areas have now developed detailed flood hazard maps.[10] Floodplain hazard maps are still not uniformly available for all flood-prone areas in New Zealand, however, which limits the extent to which ANUFLOOD-type assessment can be consistently used to assess potential losses for floods in different parts of the country.

Despite this limitation, the widespread use of depth-damage curves overseas, and the qualified success of their Paeroa application, suggest that depth-damage curves have a role to play in assessing New Zealand flood losses. As depth-damage curves relate only to direct tangible losses, they must be used in conjunction with other techniques if more comprehensive loss estimates are required. The framework in Figure 3 (below), adapted from Ericksen, *et al.* (*op cit*), illustrates how these techniques can link together to assess New Zealand flood losses.

Most of the elements of Figure 3 have been discussed above. However, several specific practical issues are worthy of further discussion:

1. The use of depth/stage-damage functions is a desirable long-term framework for national average estimates. However, establishment of such a system requires time and cost to build a sufficient database of depth-damage curves for New Zealand conditions, and to validate those curves for specific events. In the short term, surveys will therefore have to continue to play an important part in gathering cost information about specific events.

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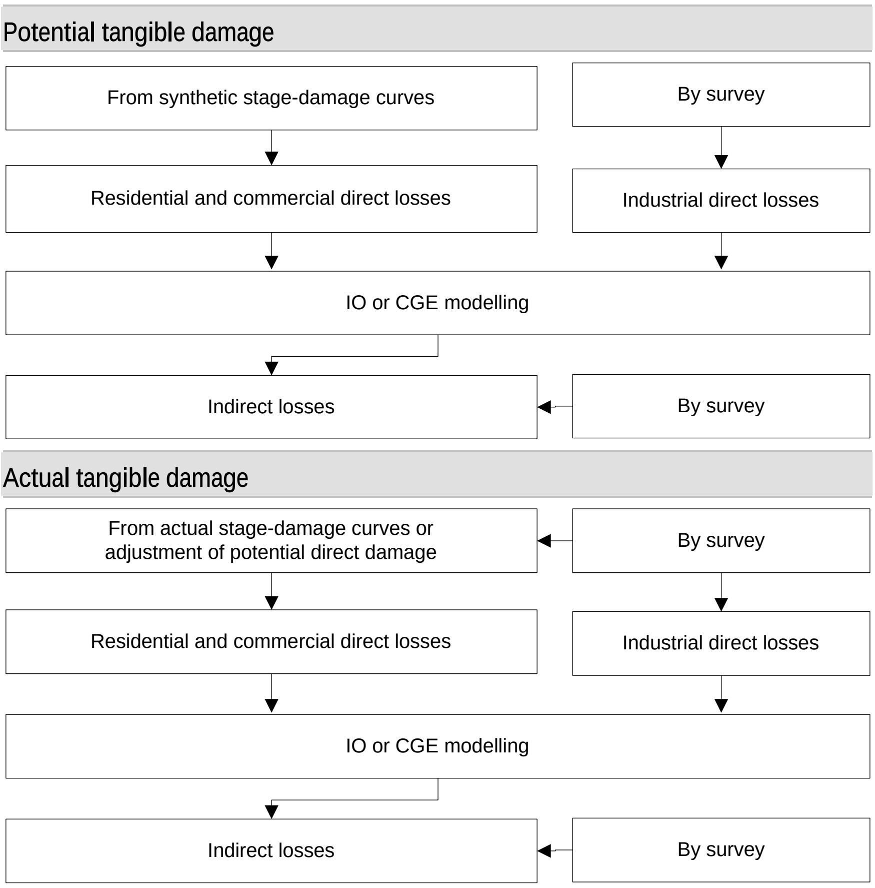
[9] Ericksen, *et al.* (*op cit*), p.81

[10] See, for instance Wellington, Waikato and Bay of Plenty, as described in Berghan and Westlake (2001).

Figure 3 Flood loss assessment framework



Source: Adapted from Ericksen, *et al.* (*op cit.*), p.46

2. Estimates of national average flood costs will not only require availability of flood-action damage curves, but also a consistent set of flood hazard maps across the country, including probabilities for a range of flood severities. This information base would be particularly useful for attempts to make projections about future changes in flood costs under a changing climate.

3. Survey information has the potential to serve a dual purpose in flood loss estimation. First, it provides a key data source for losses which are not easily estimated via other methods (e.g. industrial losses). Second, it can fulfil a useful role in validating both depth-damage curves and indirect losses (particularly business disruption losses). The former is particularly important in New Zealand applications, where the use of depth-damage curves does not have a long pedigree.

4. Consistency of survey approach – questionnaire layout, question wording, consistent use of postal versus telephone interviews, etc – should be encouraged across flood events. The FASTER questionnaire (see Appendix A) provides a template for a single questionnaire structure.

5. Examination of actual New Zealand flood losses should be undertaken to determine the extent to which losses can be attributed to a particular flood action and, in particular, whether factors other than inundation and sedimentation contribute significantly to flood losses. Such information provides the basis for flood-action damage curves that more appropriately suit New Zealand flood actions. It will not generally be possible to 'import' overseas flood-action damage curves and apply them to New Zealand events without some adaptation to national conditions.
6. The precise mix of techniques will depend on the nature of those affected. The greater the homogeneity of affected households or businesses, the greater the ability of depth damage curves to robustly assess flood losses; conversely, the greater the variation in affected households and businesses, the more reliance will be placed on survey data for loss assessment. Areas where uninsurance is particularly common (e.g. rural farmland) will require more comprehensive surveying.
7. It is important to note that for smaller events indirect costs may be insignificant. Events: of short duration; which affect only a small portion of residents; where no lifeline interruptions occur; and where no significant supply constraints arise are unlikely to give rise to significant flow-on tangible effects.
8. For larger events, where census survey costs are prohibitively high, insurance data can provide a useful data source. Sample surveying of selected urban areas, with the explicit purpose of establishing the extent to which New Zealand households and businesses are under- or uninsured, would narrow the suggested anecdotal range of 25%-40%.
9. Finally, Ericksen *et al.* (*op cit*) have suggested the following steps in constructing depth-damage curves (for a single class of residential property):

   Step 1. Draw up check list of household items.

   Step 2. Interview representative sample of households.

   Step 3. Analyse the sample to obtain ownership costs for individual items.

   Step 4. Allocate monetary values for each item, with allowance for quality and condition.

   Step 5. Allocate heights above floor level at which items suffer flood damage.

   Step 6. Assess susceptibility of items to flood damage.

   Step 7. Combine information to obtain depth-damage curves.

3. Costs of New Zealand Floods

3.1 Overall Cost

At least 93 major freshwater floods have struck New Zealand since 1858. Cost estimates, via Insurance Council data, begin in 1968 with the storm in which the Wahine was sank (see Appendix B).

Table 4 shows aggregated (ICNZ and EQC) data for flood costs in New Zealand (BTE, 2001).

Table 4 Aggregated Data for Flood Costs in New Zealand

Insurance costs based on ICNZ and EQC data, rounded to nearest $5m.

Year	Cost of Floods	Year	Cost of Floods
1976	40	1988	25
1977	0	1989	0
1978	40	1990	5
1979	0	1991	5
1980	40	1992	0
1981	30	1993	10
1982	0	1994	10
1983	5	1995	25
1984	110	1996	0
1985	10	1997	10
1986	35	1998	15
1987	0		

Source: BTE, 2001

BTE (2001) notes significant concerns with the data, most notably:

- Uncertainties regarding the nature of the EQC data: "It was impossible to determine whether the data provided by the EQC represented total insurance cost, total residential insurance cost or the insurance cost for residents who held insurance policies with the Commission."
- Data gaps—e.g. no floods are recorded prior to 1976—indicating events not recorded or a lack of significant insurance coverage where the event occurred.
- Incomplete information on the inflation-adjustment procedure used by ICNZ and EQC. BTE (2001) combined the ICNZ and EQC datasets by estimating an inflation-adjustment method, noting that their choice might or might not be appropriate.

Further evidence, as shown in Appendix B, supports BTE's cautions. Some events in Appendix B are listed in years where BTE's (2001) combination of ICNZ and EQC data yielded zero losses. Similarly, the 1988 figures in Table 4 do not include the Cyclone Bola insurance payout listed in Appendix B . These disparities highlight the challenge in separating storm costs from flood costs.

The data available are incomplete in that the insurance costs dominate the values given. Furthermore, to expand BTE's (2001) critique of the EQC data available, the insurance cost does not indicate what items are included. Insured business interruption costs, life and medical insurance payouts, and insured agricultural losses cost might or might not be included in the ICNZ values. Given that some of the ICNZ events in Appendix B (those labelled "floods assumed") are identified by location only, not by disaster type, detailed research into ICNZ's archives would be necessary to fully answer the questions regarding their data.

EM-DAT (2004) is the only other source providing cost estimates for many flood events, but those values are suspect. For example, for the 14 January 2002 Canterbury flood, EM-DAT (2004) reports that 300 people were affected for a total cost of USD500. A cost of less than NZD5 per person seems unlikely, particularly with an insurance payout of NZD21.5 million not including EQC claims (ICNZ, 2004).

To explore some of these costing issues in detail, specific events were sought to try to establish the breakdown in costs (refer section 3.2).

3.1.1 Flood-loss trends

Ericksen (1986) evaluated Earthquake and War Damage Commission (now EQC) and insurance claims from the early 1950s through to 1984 to attempt to establish the trend in flood losses over the period. The data from his analysis, with losses measured in 1984 dollars, is replicated in Table 5 below.

Ericksen hypothesised from discussions with EQC that the contribution of the Disaster Fund to total insured losses may have been declining over the period. However, as he notes, the percentage of losses covered by EQC shown in Table 5 is highly variable, and not immediately suggestive of a declining trend. Furthermore, he describes a number of deficiencies in the data sources employed, and as a consequence is unable to identify with confidence a trend in the level of flood losses.

Table 5 Total flood damage, 1957-84

Claim and damage values are in 1984 dollars

Flood	Disaster Fund Claims ($)	Percent-age	Insurance Council Claims ($)	Hydrology Annual Estimates ($)	Total Flood Damages ($)
May 1957 Bay of Plenty	180,527(1)	16.5	-	911,560	1,092,087
December 1957 Canterbury	361,084(1)	17.7	-	1,683,790	2,044,874
December 1957 Otago	225,674(1)	2.3	-	9,583,000	9,808,674
February 1958 Waikato	2,265,850(1)	13.5	-	14,539,200	16,805,050
September 1960 Hauraki	57,065(1)	1.7	-	3,345,000	3,402,065
July 1961 Canterbury	134,720(1)	7.3	-	1,709,840	1,844,560
April 1968 Wahine storm	9,214,660	11.7	69,660,000	-	78,874,660
August 1975 Canterbury	12,308,300	38.2	19,880,000	-	32,188,000
December 1976 Wellington	8,505,000	36.1	15,066,000	-	23,571,000
October 1978 Otago/Southland	4,239,500	17.8	19,570,000	-	23,809,520
January 1980 Otago/Canterbury/ Westland	1,465,100	28.0	3,760,000	-	5,225,100
June 1980 Otago/New Plymouth	840,000	6.8	11,440,000	-	12,280,000
April 1981 Thames Valley	1,240,000	15.0	7,020,000	-	8,260,000
July/October 1983 Nelson/ Marlborough	1,362,000	37.0	2,300,000	-	3,662,500
January 1984 Southland	6,500,000	11.9	48,000,000	-	54,500,000

Notes: (1) Estimated from average claim
(2) Percentage of Disaster Claims of the Earthquake and War Damage Commission to total flood damages

Source: Replicated from Ericksen, 1986, p. 85

Ericksen concludes by saying:

> *[Between 1968 and 1984] about $0.25 billion (1984 dollars) was paid out by the insurance industry for 9 major floods, including nearly $50 million from the Disaster Fund of the Earthquake and War Damage Commission. On this basis, the cost to the nation for direct losses may have been over $1 billion, and perhaps $1.5 billion overall – an average annual loss of around $90 million (1984 dollars). The losses seemed to be increasing throughout the 16 year period.* (p. 264)

Ericksen's valuation in 1984 dollars of $1.5 billion translates to over $2.1 billion in today's prices. Similarly, Ericksen's annual cost estimate is equivalent to around $128 million in today's prices.

By comparison, BTE (2001) estimate that floods in Australia cost A$10.4 billion (in 1999 dollars) between 1967 and 1999. The average annual cost is therefore a little more than A$452 million, which in today's terms equates to around A$510 million per annum (or around NZ$580 million per annum).[11]

BTE (2001) also estimate the cost of natural disasters, including floods, in New Zealand. They find that the total cost of all natural disasters in New Zealand from 1962 to 1998 is approximately NZ$1.2 billion, with an approximate annual average cost since 1980 of NZ$43 million. They state, however, that "the severe limitations of the data mean that this is likely to be a significant underestimate".

It is difficult to assess the accuracy of Ericksen's estimate of annual average New Zealand flood losses. If we assume though that BTE's estimate of Australian losses is robust, then the relative sizes of the two countries, as proxied by relative populations or economy sizes, then Ericksen's estimate would at least appear to be in the right order of magnitude.

Table 6 presents an amalgam of Ericksen's (1986) data (covering 1957-1984) and BTE's (2001) data (covering 1976-1998), all expressed in 2004 dollars.

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[11] Strictly speaking, each event's loss should be converted to the New Zealand dollar at the rate prevailing at the time that the event took place. The conversion here is thus indicative only.

Table 6 New Zealand flood losses, 1957-1998

2004 NZ$

Year	NZ$	Year	NZ$
1957	23,864,180	1978	57,927,777
1958	40,886,133	1979	0
1959	0	1980	12,712,496
1960	8,277,112	1981	20,096,308
1961	4,487,754	1982	0
1962	0	1983	8,910,742
1963	0	1984	132,596,703
1964	0	1985	11,036,889
1965	0	1986	38,629,113
1966	0	1987	0
1967	0	1988	27,592,223
1968	191,899,448	1989	0
1969	0	1990	5,518,445
1970	0	1991	5,518,445
1971	0	1992	0
1972	0	1993	11,036,889
1973	0	1994	11,036,889
1974	0	1995	27,592,223
1975	78,312,343	1996	0
1976	57,347,466	1997	11,036,889
1977	0	1998	16,555,334

Source: Ericksen (1986), BTE (2001), SNZ

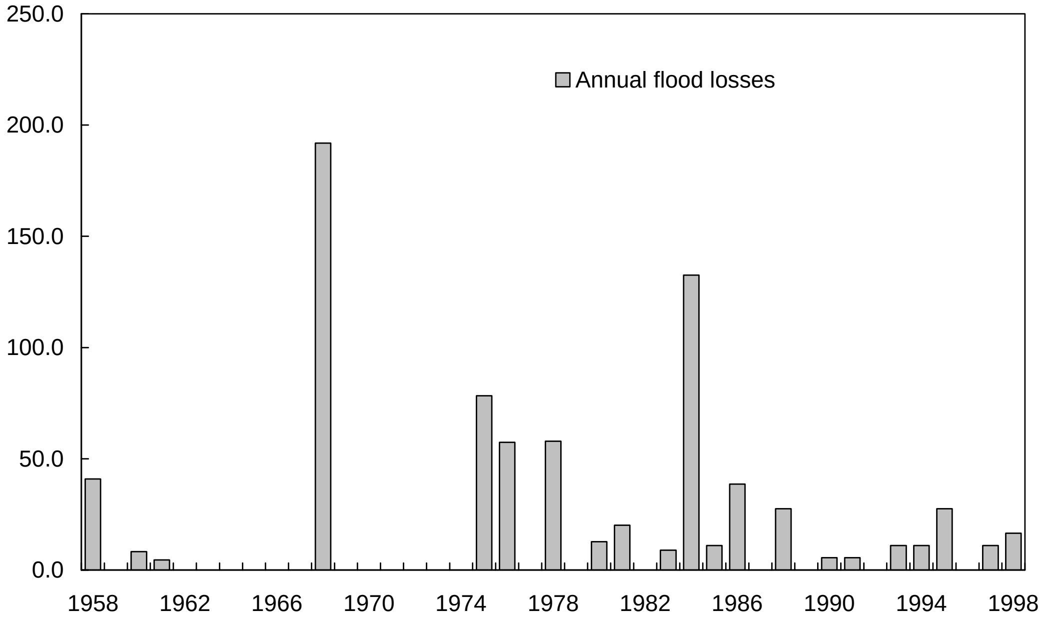
The absence of any discernible trend in these values is highlighted in Figure 4. However, it is also evident that there are clear gaps in the data series. As noted by BTE (2001):

> *Another problem with the data was the large gap in the number of events recorded in the Insurance Council's database between 1968 and 1975. Considering the frequency of events that occurred after this period, it is highly unlikely that no disasters occurred during this time. For example, flooding in New Zealand is a significant problem with an impact almost every year. However, the first record of a flood in the database is 1976. Some possible reasons why the data lacks records for this period are the lack of media attention, the availability of residential flood insurance or flooding occurring in non-residential areas.*

Another particularly notable exclusion is Cyclone Bola (1988). This is almost certainly recorded in Insurance Council data as a severe storm rather than a flood event. This illustrates the problems associated with pigeon-holing events with varying impacts into a single category.

Figure 4 New Zealand flood losses 1958-1998

NZ$ million, 2004 dollars



Source: Ericksen (1986), BTE (2001), SNZ

3.2 Distribution of losses

This section draws on two detailed flood event analyses to illustrate the possible distribution of flood losses. Given the discussion thus far regarding the paucity of New Zealand flood loss assessments, it is probably unsurprising that in-depth analyses of the impacts of individual events are rare indeed. Ericksen (1986) combines the effects of the Nelson and New Plymouth floods of 1970 and 1971 into a single event to illustrate the disbursement of flood losses. This is re-presented here. This section also draws on the analysis by Walton *et al* (2004) of the Waikato Weather Bomb event of June 2002.

3.2.1 Nelson and New Plymouth, 1970 and 1971

The following table shows the estimates presented in Ericksen (1986), which were in turn based largely on Howard (1973).

Table 7 Flood losses for Nelson and New Plymouth, 1970 and 1971

NZ$ million, 2004 dollars

Direct losses		
Central government works and services		
Roading	28.0	
Railways	3.7	
Bulk power supply	0.7	
Flood control and drainage works	11.4	
Sub-total		43.8
Local government works and services		
Roading	4.0	
Flood control and drainage	3.9	
Water, sewage and telecommunications	2.7	
Sub-total		10.6
Private sector		
Farm land	0.5	
Disaster Fund payouts	5.7	
Insurance industry payouts	17.1	
Uninsured property	11.4	
Sub-total		34.7
Total direct losses		89.1
Indirect losses		
Income and production(1)	13.3	
Total flood losses		102.5

Notes: (1) Based on the view that the value of indirect losses probably conservatively equates to around 15% of direct losses (Ericksen, 1986, p. 82)

Source: Adapted from Ericksen (1986), Howard (1973), SNZ

Briefly, Nelson and New Plymouth experienced severe flooding in August 1970 and February 1971, respectively. In Nelson losses were caused by a 50 year flood, while New Plymouth was struck by a 100 year flood event.

Notably, this flood event is absent from the Insurance Council and EQC data presented in Table 4 and Table 6. Further, the values of losses from the Nelson and New Plymouth events show that losses backed by private insurance and Disaster Fund claims represent around 65% of total direct losses and just 22% of the estimated total flood losses.

3.2.2 The Waikato Weather Bomb, 2002

The following table, drawn from Walton *et al* (2004), shows similar analysis of the Waikato Weather Bomb event of June 2002.

Table 8 Flood losses for the Waikato Weather Bomb, 2002

NZ$ million, 2004 dollars

Direct costs	
Insured losses	8.0
Uninsured losses	2.1
Response agency costs	3.1
Total direct costs	13.2
Indirect costs	
Business disruption losses	0.0
Insurance excess payments	0.5
Total indirect costs	0.5
Total costs	13.7

Source: GNS/NZIER

EQC payouts for the Weather Bomb were slightly less than $1 million, and are additional to costs listed above. The Weather Bomb event provides a useful contrast to the Nelson/New Plymouth floods in terms of flood loss distribution. Of the $14.7 million total cost of the Weather Bomb, $9.0 million, or over 60%, was borne by private insurance or EQC. This compares to 22% for the much larger Nelson/New Plymouth events. Further, the percentage of indirect costs to total costs for the Weather Bomb flood was much lower (at less than 4%) than that for the Nelson/New Plymouth flooding (at 15%). Although this latter difference reflects in part the differing methodologies used to determine the indirect losses, it seems plausible that the greater the extent of the flooding, the greater the likely incidence of business disruption and lifeline breakages i.e. as a general rule, the greater the extent of flooding, the greater the indirect effects.

3.2.3 Generalised loss distribution

Ericksen (1986) assumes that the loss distribution of the Nelson/New Plymouth flooding holds for nine major floods from 1968 to 1984 to provide an indication of the magnitude and direction of loss disbursement. From this generalisation exercise, Ericksen concludes that:

> *Setting aside the human misery and anguish caused by flood disasters, the key point to emerge…is that most of the direct flood losses are ultimately borne by agencies beyond the stricken community, perhaps as much as 85 percent. Only about 15 percent of direct property losses are borne by the territorial local government.*

The Weather Bomb event is a good example of the distribution of loss from flooding. Table 8 shows that of the $13.7 million total cost, $8 million, or 58% of the total, was borne by insurers. Further, although response agency costs are listed as being $3.1 million, it is not known how much of this was offset by central government disaster funding. Of the direct costs, therefore, it is only certain that $2.1 million, or around 16% of the total direct costs, were incurred locally.

By comparison, a study of the Queensland January 1998 floods, found that roughly 50% of losses arising from the flood were borne by the local community.[12] Of the $A245.1 million total loss, $A69.4 million was covered by private insurance, and A52.6 million by the Natural Disaster Relief Arrangements fund.

The Insurance Council's own estimates are that between 25% and 40% of property is under- or uninsured. The converse suggests that anywhere between 60% and 75% of all direct losses are covered by insurance policies, and are thus not incurred within the region of the event. Indirect tangible losses are more likely to be met locally; business disruption losses are typically not well insured against.

Ericksen (*op cit*) also notes that many of the resources required to restore a flood-affected community come from outside the region. In effect, communities externalise many of the costs of its floodplains development. Ericksen argues, however, that much of the flood loss is caused by the "locational decisions" of central government agencies, and thus "agencies from the outside, including central government, must share the blame for creating community flood hazards and consequent losses along with the local community."

3.3 Limitations

These events' indicativeness of what to expect from climate change is unknown. Indicativeness must also be considered of the storm system, the resultant flooding, and the costs caused by the flooding—one being normal

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[12] J.W. Handmer and O. Percovich (2002)

does not necessarily imply that the other two would be normal and vice versa. Finally, in dealing with extreme events, describing how “normal” or “expected” they would be is somewhat incongruous. The short data set published for New Zealand adds to the challenge: effectively 150 years of observations, although proper examination of Māori history could significantly expand that, but only approximately 50 years of systematic observations. A systematic investigation of Māori history to extract and describe flood events over the centuries of settlement would be a useful future project.

For the February 2004 floods, NIWA (2004) writes:

> *Traditionally, February is a settled month for the North Island, dominated by anticyclones (but with a small risk of a subtropical low bringing heavy rain). It is usually the warmest and driest time of year for many parts of the North Island. But February 2004 was one for the record books – the monthly rainfall was four to six times typical February amounts from the Waikato to Wellington, and also in the Wairarapa. It was very cold, with record-low February temperatures recorded in some inland and southern parts of the South Island. And consistently strong westerly winds affected the country – it was the windiest month over the North Island since monitoring started in 1941.*

Thus, the inclusion of the February 2004 floods as a “normal” or indicative extreme event could be questioned. Care must be taken before reaching such a conclusion. The weather around North Island in February 2004 was unprecedented compared to past the Februarys for which data exist, but was merely extreme compared to winter months (NIWA, 2004). Economic impacts depend on the month in which an extreme event strikes and the effects on tourism and agriculture were likely exacerbated by (a) the event striking in February and (b) the lack of expectation of, and preparation for, a major flood occurring in February. Classifying the floods as abnormal and unprecedented for New Zealand, though, might be less accurate than classifying the economic impacts as abnormal and unprecedented for New Zealand.

Table 9 illustrates the situation for four locations. February 2004 rainfalls which were 3-4 times the normal February rainfall are far less extreme when compared to winter month rainfalls. If climate change increases winter rainfall by 10-20%, as is feasible in these locations, the February 2004 rainfall levels could become relatively common in winter months even if they never again recur in February.

Table 9 Monthly Rainfall Statistics for some North Island Locations

Location	Mean February Rainfall (mm)	February 2004 Rainfall (mm)	Highest Mean Winter Month Rainfall (mm)
Hamilton	85	332	126
Kaitaia	82	309	166
Taupo	77	181	109
Wellington	72	291	147

Source: NIWA, 2004

Given the above discussion, the February 2004 floods should not be dismissed as an outrageously unusual event, but the economic impacts are likely to be higher than what would occur in most circumstances given the present state of vulnerability. Thus, the February 2004 floods are accepted as establishing an upper limit to the economic impacts which would be expected from a storm-related freshwater flood in New Zealand.[13]

4. Climate Change in New Zealand

4.1 Impacts on Freshwater Floods

NZCCO (2001) frequently suggests increased frequency and severity of freshwater floods associated with heavy rainfall is one of the dominant extreme event issues to consider for climate change in New Zealand. Issues identified are:

- Increased general risk of flooding, landslides, avalanches, mudslides, and soil erosion.
- Stormwater and wastewater sewers backing up leading to increased property flooding.
- Increased flood risk for properties near river banks and lake shores.
- Increased rainfall leading to more erosion and hence more road repair work, and the need to incorporate climate change projections in bridge design.
- Health impacts through effects of flood waters on high-risk and non-reticulated water supplies in rural areas.

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[13] Initial estimates by MAF suggest that the cost of the February 2004 floods to farmers will touch $180 million and the Government pledged $130 million in relief funding. A more comprehensive analysis has been commissioned by Horizons Regional Council, and is due for release soon.

Quantification of those statements is rare. In fact, NZCCO (2001) notes "Many climate models indicate a greater future variability of rainfall with an increased risk of droughts, but no quantitative predictions are possible at this stage." While changes in drought risk are subject to on-going research, the report states that "the frequency of heavy precipitation events over the entire area [Australia and New Zealand] could increase up to fourfold by 2070, although it was not ruled out that no discernible increase could occur."

Providing some more detail, NZCCO (2001) states:

> *Rainfall is projected to increase in the west of the country and decrease in many eastern regions. While these general trends are considered relatively robust findings, the magnitude of the projected changes depends on the global greenhouse gas emission scenario and also varies considerably between different climate models, particularly for local rainfall patterns…extremely heavy rainfall events could become more frequent in many areas, increasing the risk of flooding and erosion. No predictions about frequency and intensity of mid-latitude storms are currently available.*

More recently, NZCCO (2004) has examined potential effects on the New Zealand's weather system of climate change.[14] Table 10 illustrates the main features of change in their projections. projected changes cover a wide range, however, mid-range projections in terms of annual average temperature and precipitation are:

- temperature increase of 0.6 to 0.7°C from 1990s to 2030s, and 1.6 to 2.0°C from 1990s to 2080s.
- rainfall change between about -5 to +5% from 1990s to 2030s, and about -10 to +15% from 1990 to 2080s.

Rainfall projections vary considerably across regions, as shown in Table 11, and even more so for specific seasons. What isn't clear from the literature is whether the variability of New Zealand's climate will increase as a consequence of global climate change. New Zealand weather is influenced heavily be two 'local' phenomena: the El Niño Southern Oscillation (ENSO), which oscillates every 2-3 years; and the Interdecadal Pacific Oscillation, which (as the name suggests) stays 'in phase' for 2-3 decades. Although New Zealand's weather history of the past 50 years is characterised by clear changes in the frequency of specific events (for example, a reduction in the frequency of frosts), many of these changes can

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[14] NZCCO (2004)

be attributed to regional weather systems (at least qualitatively), rather than an outcome of global warming.[15]

Table 10 Main features of New Zealand climate change projections for 2030s and 2080s

Climate variable	Direction of change	Magnitude of change	Spatial and seasonal variation
Mean temperature	Increase (VH)	Mid-scenario 0.5–0.7°C by 2030s, 1.5–2.0°C by 2080s (M)	Strongest warming in winter, tendency for slightly more warming in E and N
Daily temperature extremes (frosts, hot days)	Fewer cold temperatures and frosts (VH), more high temperature episodes (VH)	Whole frequency distribution moves right	
Mean rainfall	Varies around country. By 2080s Taranaki, Manawatu-Wanganui, West Coast, Otago and Southland show increases; Hawke's Bay Gisborne, eastern Canterbury, eastern Marlborough show decreases (M)	Substantial variation around the country	Tendency to increase in south and west, decrease in N and E. Largest projected seasonal decreases in spring in N and E of North Island
Extreme rainfall	Heavier and/or more frequent extreme rainfalls, especially where mean rainfall increase predicted (M)	No change through to halving of heavy rainfall return period by 2030s; no change through to fourfold reduction in return period by 2080s (L) [See note 2]	Increases in heavy rainfall most likely in areas where mean rainfall is projected to increase
Snow	Snow cover decrease, snowline rise, shortened duration of seasonal snow lying (all M)		
Glaciers	Continuing long-term reduction in ice volume and glacier length (M)		Reductions delayed for glaciers exposed to increasing westerlies
Wind (average)	Increase in the mean westerly windflow across New Zealand (M)	By 2080s, could be from slight increase up to doubling of mean annual westerly flow (L)	
Strong winds	Increase in severe wind risk possible (L)	Little change up to double the frequency of winds above 30m/s by 2080s (L)	
Storms	More storminess possible, but little information available for New Zealand		
Sea level	Increase (VH)	9–88 cm rise (New Zealand average) between 1990 and 2100 (VH)	See Coastal Guidance Manual
Waves	Increased frequency of heavy swells in regions exposed to prevailing westerlies (M)	See Coastal Guidance Manual	
Storm surge	See Coastal Guidance Manual		
Ocean currents	Various changes plausible, but little research or modelling yet done	No estimates made	

Source: NZCCO (2004)

No detailed modelling has been undertaken to date to provide estimates of changes in the return periods for events such as cyclone Bola, the 2002 weather bomb, or the February 2004 floods under future climate change scenarios.

Current understanding of climate change, and the likely trends in weather patterns that it implies, suggests that as the risk of heavy rainfall increases in a warmer atmosphere, the frequency of flood events such as the 2002 weather bomb or the 2004 February floods is likely to increase by up to a

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[15] Though, of course, the underlying cause of the change in climatic conditions is irrelevant from a loss estimation point of view.

factor of four by the year 2100. There are large uncertainties associated with such estimates because of the importance of regional weather patterns and the specific evolution of individual heavy rain events. The above estimate makes the assumption that climate change will not significantly alter the structure and generation of regional weather patterns that have historically led to flooding in New Zealand. Further research is necessary to test and validate this assumption.

With regard to changes in events such as cyclone Bola, current research indicates that while there may be a decrease in the number of cyclones reaching New Zealand, the average strength of cyclones that do make landfall could increase. On this basis, it is possible that a cyclone Bola-type event may become moderately more common in New Zealand by 2100 (perhaps 1.5 time more probable). However, current uncertainties are too large to allow robust estimates of changes in return frequencies for a specific event such as cyclone Bola to be made.[16]

Table 11 Projected % changes in annual rainfall precipitation

Region	Location	2030s	2080s
Northland	Kaitaia	-5 to +3	-11 to -1
	Whangarei	-8 to +2	-16 to 0
Auckland	Warkworth	-6 to +2	-13 to 0
	Mangere	-4 to +3	-8 to +7
Waikato	Ruakura	-4 to +7	-2 to +19
	Taupo	-5 to +3	-6 to +10
Bay of Plenty	Tauranga	-9 to +2	-15 to +2
Taranaki	New Plymouth	-4 to +9	0 to +22
Manawatu-Wanganui	Wanganui	-4 to +11	0 to +26
	Taumarunui	-4 to +14	-1 to +32
Hawkes Bay	Napier	-19 to +1	-32 to +3
Gisborne	Gisborne	-17 to 0	-31 to +4
Wellington	Masterton	-8 to +2	-13 to +4
	Paraparaumu	-4 to +10	+1 to +26
Nelson	Nelson	-7 to +2	-7 to +4
Marlborough	Blenheim	-5 to +3	-4 to +5
West Coast	Hokitika	-4 to +14	+1 to +40
Canterbury	Christchurch	-10 to +1	-17 to +4
	Hamner	-12 to +3	-21 to +3
	Tekapo	-3 to +13	+2 to +31
Otago	Dunedin	-2 to +6	+2 to +14
	Queenstown	-4 to +22	+2 to +57
Southland	Invercargill	-2 to +15	+1 to +37

Source: NZCCO (2004)

Other issues which are addressed in little detail in the literature are:

- Freshwater floods arising from climate change-induced glacier melt. This change will be relevant only until the glaciers have melted and applies to South Island only.

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[16] These estimate s are based on personal communications from NIWA scientists. They represent braid estimates of potential future changes based on current scientific understanding, but they should not be relied on for any detailed modelling for specific regions or types of weather events.

- Freshwater floods being influenced by changes in cyclone tracks. NZCCO (2001) explains that "The intensity of wind and rainfall of tropical cyclones is expected to increase with global warming, but there is little agreement between current climate models about whether the intensity or frequency of mid-latitude storms is likely to increase".

To better understand the potential of cyclones, a future project could analyse cyclones (tropical and extra-tropical) by examining their past tracks and conducting statistical analyses to see if trends emerge. The combination of Kerr (1976), Revell (1981), and Thompson *et al.* (1992) provide cyclone track data back to 1939 which can be used to extract New Zealand landfalls and landfall intensity. Sinclair (1997) and Sinclair *et al.* (1997), for example, provide useful starting points, but would need to be extended beyond cyclone tracks into cyclone landfall potential, such as through strike probabilities, and rainfall intensity, possibly using methods such as that in Sinclair (1993). One issue is that cyclones bring both wind and rain to New Zealand. This report is interested in only the latter, but little material is available analysing cyclone intensity and potential intensity in terms of wind and rain separately. The correlation between wind and rain might be interesting to explore too, particularly with regards to one form of damage exacerbating the other.

Camilleri (2000) provides an overview of some of the above issues, reviewing the available literature and concluding:

> *It is not possible at this stage to quantify the change in inland flooding risk or damage with climate change beyond the crude statement that changes in the flooding return period match those of rainfall return period. Some recent Australian work of highlights the importance of climate change for flooding, and gives some possible directions for future research.*
>
> *Scenarios for New Zealand are:*
>
> *2030: No change through to a halving of the return period of flooding.*
>
> *2070: No change through to a fourfold reduction in the return period of flooding.*
>
> *…a four-fold reduction in the 1 in 50-year flood (2% AEP) is not detectable over a 50-year period. So even if the high end of these reductions in flooding return period occur, it might be only in the closing years of the 21st century that they could be confirmed for a given catchment area.*

This statement was the basis for the comment by Hargreaves *et al.* (2002) that for New Zealand, "any building with an existing flood risk may flood up to four times more often than before, and there may be increases in building damage from coastal flooding, erosion and rising water tables. In addition, there is a possibility that tropical cyclone activity could increase, increasing the likelihood and intensity of severe weather, primarily in the North Island."

4.2 Limitations

NZCCO (2001) sums up the statistical limitations of the quantitative suggestions given here:

> *More than 50 years of observations would be required to test whether a '1-in-100 year' flood has in fact become more frequent and now occurs, for example, every 25 years. If the flood did become more frequent, substantial damage would occur while waiting 50 years for proof.*

With a likely changing baseline due to climate change, determining the frequencies of floods of given severities and then predicting how those frequencies might be changing is challenging without large errors and uncertainties.

Another significant limitation is that the calculations here assume no change in New Zealand demographics, properties, infrastructure, or flood management policy and practices. That is, the assumption is that vulnerability is constant. This assumption is unrealistic due to the continuing changes witnessed in New Zealand demographics, buildings, and infrastructure.

Predicting these changes to 2100 is fraught with even more difficulties than predicting the climate to 2100. Rather than introducing further uncertainties by trying predict changes in vulnerability characteristics of New Zealand, enacting this assumption means that a baseline is established by which mitigation and adaptation measures could be compared. Considering different vulnerability scenarios would be appropriate for future work.

Similarly, considering floods specifically, if ten major floods were experienced at a location over a twenty-year period, then it is likely that adaptation measures would be enacted. Examples are moving out of the area of adapting lifestyles and properties to minimise the impacts of a flood (Kelman, 2001). Thus, it is feasible that rainfall, storms, and floods will increase, yet human adaptation means that the economic costs of freshwater floods will decrease. Alternatively, the decision might be to follow the traditional paradigm of reliance on only structural flood defences, an unsustainable solution (Fordham 1999). In such a scenario, flood costs would be likely to decrease in the short-term while increasing in the long-term (Etkin, 1999; Mileti *et al.*, 1999).

As above, these human decisions are not considered. This “do nothing” assumption provides a baseline to which “do something” options could be compared in future work.

Another area not examined by this study is that energy use. 57.8% of New Zealand’s electricity is produced by hydro power (ODCI, 2004). Increased rainfall in reservoir areas due to climate change could mean that the percentage of hydroelectric power increases, thereby impacting the economy through lower energy costs. On the other hand, increased intensity of rainfall in reservoir areas due to climate change might lead to higher hydroelectric infrastructure repair costs and even the low-probability events of dam failure leading to floods. Thus, we would expect energy and flood costs to increase. Finally, seasonal extremes of rainfall such as drier summers and wetter winters could lead to seasonally oscillating energy prices. This uncertainty, coupled with higher energy prices during the tourist season, could lead to an overall negative impact on the economy.

The latter comment further implies that such spillover effects from the economic costs of flood damage to the wider New Zealand economy are also not considered in this report. For example:

- How would increased frequency and severity of winter floods affect the ski industry? How would increased frequency and severity of summer floods affect the tourist industry?
- If continual flooding leads to a decline in agricultural output necessitating more food imports, would New Zealanders have less money to spend on non-essential items?
- How would increased storminess affect air and ship transportation?
- If certain roads or railway lines are frequently blocked by flooding or flood-related events such as landslides, would the government incur the capital expenditure of constructing a new route? Instead, would some routes be abandoned with alternative routes upgraded? What would the economic consequences be for industries dependent on land transport? Would these industries shift to modes less dependent on land transport or transport?
- How would the impacts of floods on public health spillover into the economy? If increased flood-related illnesses, injuries, and deaths occur, the tragic human consequences are paramount, but lost productivity in the workforce would be an effect that would need to be factored into any economic analysis.
- Changes in flood damage would also bring economic opportunities (e.g. NCCES, 2002). In particular, the construction and flood recover industries would do well. How would those economic impacts, and the increased entrepreneurship required to make those industries take advantage of the opportunity, affect the wider New Zealand economy?

As well, all the above effects must be put into the context of the other changes which climate change will bring. For example, certain roads might require more water- and landslide-related maintenance but less frost- and snow-related maintenance. Farmers might need to abandon livestock due to flood dangers, but shift to lucrative crops which had previously thrived in only tropical environments. Would winter tourism losses be offset by summer tourism gains—or vice versa—and would the losses be equivalent magnitudes or would an overall loss or gain result? Would the public health impacts of increased ultraviolet radiation dwarf those from increased floods?

An illustrative example arises from Cyclone Bola. In 2003, it was determined that the scouring caused by the intense flooding in 1988 has eliminated the need to upgrade the Waipaoa River Flood Control Scheme, a task which would have cost over NZD6 million (Jones, 2003). Understanding the spillovers and connections which are likely and which are not likely, and quantitatively and qualitatively analysing each one, would be useful future projects.

4.3 Implications for future flood loss estimation

Sensible analysis of how the costs of flooding may change as a result of future climate change scenarios can only be undertaken if we have some understanding of past and current flood losses. As described above, past estimation of New Zealand flood losses has been sporadic, and at no time has a consistent flood loss estimation methodology been employed across a number of events. Thus, current flood costs, in terms of (say) average annual costs, can not be known with certainty.

Priority, therefore, must be given to establishing baseline costs. As noted earlier, the development of national standard flood hazard maps, in conjunction with depth-damage analysis provides the starting point for estimating current potential losses. They also provide the basis for assessing the influence of non-climatic changes to the environment, such as increased urbanisation, changing commercial and industrial land-use, and the construction of specific mitigation measures such as stop-banks.

Systematic and centralised recording of floods and their impacts is necessary if reliable, consistent estimates of actual losses are to be made. Comprehensive estimates of loss need not be made at the time of the flood. However, as a minimum, information from which retrospective estimates can be made must be collected. This will include: a description of the event; flooding depths marked on map showing buildings and land use by type; population of affected area and proportion of population actually affected; number and type of businesses affected; and insurance claims paid out. Clearly, if survey information is required either to support other estimates or to fulfil a central role in the estimation method, this should be gathered in the period following the event during which memories can still be considered to be reliable.

Finally, consistent application of a single loss estimation framework should be promoted so that measures of changes in the losses arising from floods are not distorted by inconsistent methods. In particular, intangible losses, which are more open to subjectivity than their tangible counterparts, should be separately identified. Most importantly, perhaps, is the need for appropriate documentation surrounding each flood loss estimate; studies of flood losses should be sufficiently transparent so that results are replicable.

Modelling of future flood losses should account for both climatic and non-climatic factors. Non-climatic factors can be modelled as described above – that is, via use of detailed flood hazard maps (in which urbanisation and land-use changes can be depicted) and depth-damage curves.

Losses from changes in climatic conditions are arguably more difficult to assess. A 2004 study by the UK's Office of Science and Technology illustrates the variability inherent in future flood loss estimation, finding that annual average losses from flooding may increase anywhere from £1 billion to £28 billion between now and the 2080s.[17] In 'real' terms (i.e. as a percentage of GDP) flood losses are projected to decline under some scenarios.

The OST study employs the RASP (Risk Assessment of Flood and Coastal Defence for Strategic Planning) methodology. RASP in turn makes use of the UK Environment Agency's new National Flood and Coastal Defence Database, which contains information on defence location, type and condition. It uses geographically indexed land use and occupancy data, and social flood vulnerability indices The method produces geographically indexed estimates of economic and social flood risk due to failure of flood defences on coasts and main rivers. These estimates can be aggregated to regional and national scales. The method does not estimate the impacts of local pluvial or urban sewer flooding, nor does it address the environmental impacts of flooding. The accuracy of the resulting risk assessment is limited by the availability of data on a national scale, but when aggregated nationally the results are believed to be reasonably unbiased.

Such a methodology is not replicable in New Zealand, at least in the short term, due to the current non-existence of a coherent and validated set of depth-damage curves applicable to New Zealand, or a self-consistent set of flood hazard maps and flood return frequencies that would allow estimation of the relative effects of climate change on future flood risk. Nonetheless, findings from the OST work may provide insights into the nature of future New Zealand flood losses. OST finds that the rate of increase in flood risk

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[17] Foresight (2004)

will be influenced by three factors: climate change; the rate at which the value of the properties and infrastructure at risk increase; and the rate at which building takes place in flood-risk areas.[18] Further, the study finds that climate change has a high impact in every scenario.[19] Coastal flooding is likely to be particularly affected, with the risk of costal floods increasing by as much as 4 to 10 times above current levels. Increased rainfall will also have an influence, increasing average (national) flood risk by 2 to 4 times above existing levels.

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[18] Risk is defined as the product of probability and consequence.

[19] Four scenarios are considered, combining variations of socioeconomic and climate change parameters.

5. Future research

The highest priority to advance New Zealand's understanding of the potential changes in flood costs under climate change should be to develop a firmer understanding of current flood costs. As outlined above, this could be achieved through the development of New Zealand-specific depth-damage curves in parallel with surveys to validate those curves and estimate industry losses for specific events. Depth-damage information could then be combined with a consistent set of flood hazard maps, population and property maps, and flood return frequencies to provide 'synthetic' estimates of flood costs. Costs of specific events could also be estimated using this technique, without the need for a dedicated survey, where events are considered to be sufficiently 'normal' for standard depth-damage curves to apply and specific industry losses are assumed to be minor.

Further research into the likely quantitative changes in heavy rainfall events under climate change, on a regional basis, and the impact of such rainfall events on specific catchments, would be vital to provide greater certainty of any projections of changes in future flood risk and associated costs.

In addition to filling in the gaps in this report and the possible projects mentioned throughout the text, other related projects would help in better understanding and quantifying the economic impacts on New Zealand of climate change-related extreme events, particularly freshwater floods.

Policy implications

What are the policy implications of changed flood intensity and frequency arising from climate change? The closing chapters of Ericksen (1986) discuss policy implications for floods in general, but not in the context climate change.

Floods and impacts database

As Ericksen (1986) notes, no one single agency seems to maintain a consistent and comprehensive database of flood events, their impacts and losses. The key role that accurate flood loss assessments play in making policy decisions regarding mitigation measures, flood awareness education, etc. cannot be stressed enough. A systemised, centralised database would provide the backdrop to sound flood management policy making.

Construction of New Zealand depth-damage curves

Survey-based inventories of household contents: their value, height above floor level and susceptibility to flood damage, as per Section 2.5 above. Consistent, New Zealand-wide depth-damage analysis also relies on the availability of flood hazard maps produced to a national standard. This work could also include the re-assessment of the ANUFLOOD model to New Zealand flooding.

Insurance loss analysis

It has emerged through this and other studies that insurance – either private or that provided via EQC – covers just a part of flood losses. However, to date, insurance data has been the main data source for making flood loss estimates. The losses additional to those met by insurance are often estimated with little real world information about the extent of under- and uninsurance. An examination of the gap between sums insured and total asset values would provide a vital component of flood loss estimation.

Literature and project database

Currently, literature on New Zealand hazards tends to be scattered amongst various private researchers, government departments and academic institutions. Establishment and maintenance of a centralised library (or at least register) of all such work would create an invaluable resource for future research, as well as providing some expectation that wheels are not reinvented.

Socio-economic scenarios to help define exposure to flood-risk

Estimates of future flood risk and costs rely not only on the climate, but also (and perhaps more importantly) on socio-economic scenarios describing developments of population density, housing types and land-uses. Currently, no consistent such scenarios exist for New Zealand over the time scales relevant to climate change projections (i.e. 30 years or more). Any estimates of future flood costs would have to either rely on the (non-realistic) baseline assumption in the present report, that socio-economic conditions would not change, or a set of socio-economic scenarios for climate change impact assessment would need to be developed.

Mitigation Information

Construction and maintenance of a database of flood mitigation projects (or climate change adaptation projects) with their costs and benefits quantified. A cost-benefit analysis would be developed and the results could be analysed for best targeting mitigation funds.

North Island Response Analysis

Use of MCDEM evacuation information and sitreps plus MSD Floodline data to map out the amount and types of warnings people received, where people went when, and their needs.

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Appendix A : The FASTER System

The form on the following pages was developed by Professor David Crichton, mainly for loss adjusters in the U.K. but the strong research advantages of such a system are clear from the amount of systematic data which would be collected. This form could be easily adapted for New Zealand or other locations.

The "FASTER System"

(Flood And STorm Event Report Form)

For quicker, but more detailed reporting on major flood and storm events.

© David Crichton (david@crichton.sol.co.uk), 2000

Form completed by (name or initials);_______________
Adjuster/contractor file reference;__________________
Event date; (dd/mm/yy): _ _ / _ _ / _ _
Please fax/post/email a copy of the completed form to:-
1. Insurer (Policy No______________________) AND
2. Geography Dept, University of Dundee, DD1 4HN
Fax 01382 344434 email; a.z.black@dundee.ac.uk

From*(Company Name and address)*

PART ONE: GENERAL INFORMATION about affected premises

Floors affected

1.1 Postcode*; _ _ _ _ _ _ _ House No* ___ ☐ Basement ☐ Ground ☐Other

(the University of Dundee is registered under the Data Protection Act to hold this information.)*

1.2 **Location** (please tick all that apply)

☐ Built up area ☐ Industrial estate ☐ Suburb ☐ Rural area
☐ On a hill crest ☐ Near a cliff edge ☐ Near the coast ☐ Near a river

1.3 **Nature of occupation by policyholder** (please tick all that apply)

☐ Residential ☐ Industrial ☐ Retail ☐ Office ☐ Motor trade
☐ Unoccupied ☐ Other (

PART TWO: INFORMATION ABOUT THE PROPERTY

☐ non conventional, (e.g. caravan, boat, site cabin etc.,) - in such cases, go to Part Five. **Otherwise,**

2.1 Walls (please tick any of the following which apply).

External ☐ Brick ☐ stone ☐ concrete ☐cladding ☐ Other
Internal ☐ As for external ☐ Plaster board ☐ Lath/plaster ☐ Other

Comments on any external/internal materials likely to be particularly vulnerable

2.2 Height and type of building (tick the predominant one from <u>each column</u>)

Height	**Type**
☐ Mixed heights	☐ Residential type (even if business use)
☐ Single storey (not counting attic)	☐ Purpose built retail type building
☐ Single storey, lofty	☐ Purpose built office type building
☐ Two storeys (excl. attic)	☐ Industrial/agricultural shed type
☐ Over two - **Insert numb**	☐ Recreation hall/cinema/theatre type

2.3 Date of Construction (Approximately) -tick the box for the oldest substantial part of the building

☐ Pre 1918 ☐1918 to 1938 ☐ 1939 to 1970 ☐ 1971 to 1989 ☐ post 1990

comments –for example, is a significant part of the building of more recent construction? Or is the building a listed heritage building?

2.4 History of previous damage from flood, storm or freeze (if any)

Year	Flood	Storm	Freeze	Brief details (continue on a separate sheet if necessary)
....	☐	☐	☐	....
....	☐	☐	☐	....
....	☐	☐	☐	....

PART THREE: FLOOD AND FREEZE (If no flood or freeze damage, go to Part Four.)
Please tick ☑ all that apply.

3.1 Type of Claim

☐ Burst water pipe or tank due to freeze (if this is the sole cause go to question 3.6)
☐ Freshwater Flood from rainfall, snowmelt, blocked drains, burst water main, etc.
☐ Saltwater Flood due to coastal storm surge/ failure or overtopping of sea defences etc.

3.2 Immediate source or cause of flood: (please tick ☑ all that apply)

☐ Sea/Tidal Estuary
☐ Roof failure
☐ Rising groundwater
☐ Burst water main
☐ Stream/River/Lake/Loch (insert name)
☐ Failure of sea/river defences at
☐ Blocked drains or culverts outside the building
☐ Backup into toilets or bath etc. inside the building

How far away was the nearest source? ☐ metres

3.3 Factors contributing to damage: (please tick ☑ all that apply)

1. **Contamination**:- ☐ Salt ☐ Silt ☐ Oil/Chemicals ☐ Sewage
2. Any **impact** damage caused by rapid flows of water and floating debris? ☐ yes ☐ no

3.4 Warning received: Hours - If none, insert zero and go to question 3.6.

1. Source of warning; ☐ telephone ☐ TV/radio ☐ neighbour ☐ other
2. Any action taken? ☐ yes ☐ no (if "no", go to question 3.6

3.5 Action taken by occupier or others to reduce damage: (please tick ☑ all that apply)

Type of action	**Action taken?**	**Effective?**
movement of portable items/ vehicles	☐ yes ☐ no	☐ yes ☐ no
use of sandbags, flood screens etc.	☐ yes ☐ no	☐ yes ☐ no

other - please give details

3.6 Internal inundation / humidity damage

1. Durat ☐ ☐ Days Hours. Were pumps used? ☐ yes ☐ no
2. Any damage from ☐ condensation ? ☐ capillary action? ☐ humidity?
3. What proportion of total damage costs is likely to be due to increased humidity ? %
4. Were/are dehumidifier machines available? ☐ yes ☐ no
5. Were the waters topped up by successive tides? ☐ yes ☐ no

Other comments:

3.7 Maximum depth of water (Please use metric measures)

Conversion to centimetres
multiply inches by 2.54
multiply feet by 30.48
e.g. 4" =10 cm, 6' = 182cm

External ground level ☐ cm.

Internal ground floor level ☐ cm

Internal basement level ☐ cm

Show the maximum depth based on marks on walls.

Additional comments:

PART FOUR: WINDSTORM (If no windstorm damage, go to part five.)
Please tick ☑ all that apply.

4.1 Roof construction. If no roof damage go to 4.2

Pitch ☐ Steep ☐ Medium ☐ Shallow ☐ Flat (if flat, go to 4.2)

Structure ☐ Timber rafters and trusses ☐ Steel rafters and trusses ☐ Sarking boards

Cladding ☐ Slates/tiles ☐ Felted timber ☐Sheeting

4.2 Wall, chimney, door or window damage (If none, go to 4.3)

☐ Gable wall ☐ Chimney ☐ Other wall of building ☐ Door/windows

4.3 Factors contributing to the storm damage. Please tick ☑ all that apply

☐ Inadequate ties between wall/roof and structure
☐ Normal ageing/wear and tear
☐ Premature ageing indicating inappropriate materials/design/construction
☐ Fatigue/corrosion etc. indicating lack of maintenance (see 5.5)
☐ Aggravation of previous unrepaired damage
☐ Building under construction/repair- inadequately supported
☐ Falling trees/branches (delete as appropriate)
☐ Falling chimney(s)/aerials/satellite dish (delete as appropriate)
☐ Other flying debris causing impact damage. Type?
☐ Failure of the roof cladding fixings
☐ Failure of the wall cladding fixings
☐ Local failure of the cladding - insert cause if known
☐ Partial roof or wall failure creating a dominant opening
☐ Other (please state)

4.4 Maximum Windspeeds at nearest weather station (if known)

Conversion to mph

1. maximum mean windspeed mph *multiply knots by 1.15*
2. maximum gust speed mph *multiply metres/second by 2.2*
3. distance from weather station? Miles *multiply Km/hour by 0.6*

4.5 Other details of the windstorm

Duration: ☐ less than 2 hours ☐ 2 to 6 hours ☐ over 6 hours
Was the storm accompanied by heavy rain, hail, or snow? ☐ yes ☐ no

4.6 Isolated incidents

Was there similar damage to <u>other</u> property in the vicinity?
☐ Yes, extensive ☐ Limited ☐ Virtually none (see 5.5)

4.7 If possible, assess general condition of the property before the storm

☐ In good repair ☐ Signs of neglect ☐ In poor condition (see 5.5)

Additional comments:

PART FIVE: COSTS - Damage or loss estimates, before average

Please ignore the effect of any deductibles or excesses when completing this section.

Please insert an approximate figure for each item affected, assuming that any repairs will be done by a preferred contractor (but see questions 5.4 and 5.5).

5.1 BUILDINGS, Domestic, Commercial and Industrial

Reinstatement costs before average (Please comment on any unusual features)
Foundations £_ _ __ _ _
Building walls £_ _ __ _ _
Roof, chimneys, aerials £_ _ __ _ _
Doors, stairs, windows £_ _ __ _ _
Fixtures and fittings £_ _ __ _ _
Outbuildings £_ _ __ _ _
Alternative accommodation £_ _ __ _ _
TOTAL (before excesses) £________ Excess (if known) £______
Total buildings sum insured for this property... £_____________
If this is too low, what would be a reasonable sum insured? £_____________

5.2 CONTENTS, Domestic and commercial, excluding stock etc., (see 5.3)

Replacement costs before average ("new for old" basis) (Please comment on any unusual features)
Carpets, curtains, etc. £_ _ __ _ _
Furniture £_ _ __ _ _
TV, VCR, stereo, etc. £_ _ __ _ _
White goods £_ _ __ _ _
Clothing and personal effects £_ _ __ _ _
Alternative accommodation £_ _ __ _ _
Other clean up/dry out £_ _ __ _ _
TOTAL (before excesses) £________ Excess (if known) £_________
Total contents sum insured for this property..............................£______________
If this is too low, what would be a reasonable sum insured?......£_______________

5.3 STOCK IN TRADE, PLANT AND MACHINERY, Commercial and industrial.

Total claim cost before average......£_ _ __ _ _ Total sum insured for these items......£_ _ __ _ _
If this is too low, what would be a reasonable sum insured?......£_ _ __ _ _

5.4 CLAIMS INFLATION (due to high demand for contractors, materials etc.)

Please comment; e.g., the likelihood of having to use a non preferred contractor and the possible effect of this on costs.

5.5 GENERAL COMMENTS

Are further enquiries needed before you can be satisfied that the claim may proceed?
☐ yes ☐ no (if "yes", a contact phone number would be appreciated.)

Other comments:

Thank you very much for completing this form.

Appendix B : Cost Data Available for New Zealand Freshwater Floods

* means that the value has been adjusted to March 2000 and that it is an insurance industry payout not including EQC payouts.

Year	Months	Days	Location	Economic Cost	Sources
1968	4	10	Cyclone Giselle: Gore, Mataura, Wyndahm, Wellington	NZD42.23 million * plus NZD120.67 million (adjusted to March 2000) for the loss of the Wahine ferry.	EM-DAT, 2004; ICNZ, 2004; MCDEM, 1999
1975	8	1	Canterbury Storms	NZD52.22 million *	ICNZ, 2004
1976	12	20	Lower Hutt	NZD40.25 million *	EM-DAT, 2004; ICNZ, 2004
1978	10	16	Otago Floods	NZD49.83 million *	ICNZ, 2004
1979	8	6	Abbortford (Dunedin)	USD2466	EM-DAT, 2004
1980	1	17	South Island Summer Floods	NZD8.97 million *	ICNZ, 2004
1980	6	5	Silverpeaks county; Taieri/Otago/New Plymouth Floods	NZD31.22 million *	EM-DAT, 2004; ICNZ, 2004
1981	3		Kerikeri	NZD6.62 million *	ICNZ, 2004; MCDEM, 1999
1981	4	12	Paeroa Borough, Ohinemuri county, Thames/Coromandel	NZD23.17 million *	ICNZ, 2004; EM-DAT, 2004
1983	7	10	Malborough, Golden Bay Floods	NZD5.66 million *	ICNZ, 2004; EM-DAT, 2004
1983			Christchurch Storm	NZD8.67 million *	ICNZ, 2004
1984	1	27	Invercargill/Southland Floods	NZD103.93 million *	ICNZ, 2004
1984			Greymouth Floods	NZD7.95 million *	ICNZ, 2004
1984			Auckland Floods	NZD4.09 million *	ICNZ, 2004
1985	5		South Auckland Flood	NZD6.27 million *	ICNZ, 2004

1985			Thames/Coromandel/Te Aroha (floods assumed)	NZD12.79 million *	ICNZ, 2004
1985			Wellington/Hutt Valley (floods assumed)	NZD3.03 million *	ICNZ, 2004
1985			Auckland Floods	NZD7.8 million *	ICNZ, 2004
1985			Chatham Islands (floods assumed)	NZD1.72 million *	ICNZ, 2004
1985			Gisborne Floods	NZD3.68 million *	ICNZ, 2004
1985			Hawkes Bay/Wairarapa (floods assumed)	NZD1.95 million *	ICNZ, 2004
1986	3	13	Aorangi, Strathallan county, Waimate Borough, Temuka Borough, Timaru, North Otago/South Canterbury Floods	NZD39,000; NZD34.39 million *	ICNZ, 2004; EM-DAT, 2004
1986			Auckland Floods	NZD0.74 million *	ICNZ, 2004
1986			Nelson Floods	NZD0.74 million *	ICNZ, 2004
1988	3	7-8	Cyclone Bola, Gisborne District	NZD52.41 million *	ICNZ, 2004; EM-DAT, 2004; MCDEM, 1999
1988	5	20	Greymouth Borough (floods assumed)	NZD4.55 million *	ICNZ, 2004; EM-DAT, 2004
1988	7	24-25	Palmerston North, Manawatu Floods	NZD3.54 million *	ICNZ, 2004; EM-DAT, 2004
1988	9	13	Greymouth, West Coast (Inangahua county) (floods assumed)	NZD18.97 million *	ICNZ, 2004; EM-DAT, 2004; MCDEM, 1999
1990	8	8	Taranaki/Wanganui Floods	NZD2.3 million *	ICNZ, 2004
1991	2	18	Otago Area Floods	NZD1.9 million *	ICNZ, 2004; EM-DAT, 2004
1993	12	24	Kaikoura Flood	NZD8.68 million *	ICNZ, 2004
1994	2	19	South Canterbury Floods	NZD1.69 million *	ICNZ, 2004
1994	11	8	North and South Island Floods and Storms	NZD6.76 million *	ICNZ, 2004; EM-DAT, 2004
1995	4	25	New Plymouth Floods	NZD4.01 million *	ICNZ, 2004

1995	7	18	Thames/Kaiaua Floods	NZD3.13 million *	ICNZ, 2004
1995			Whangarei & District Floods	NZD1.89 million *	ICNZ, 2004
1995			North and South Island Floods and Storms	NZD5.02 million *	ICNZ, 2004
1996	12	30	Cyclone Fergus, Thames/Bay of Plenty	NZD1.64 million *	ICNZ, 2004; EM-DAT, 2004; MCDEM, 1999
1996	10-12		Weather-related losses	NZD2.15 million *	ICNZ, 2004
1997	1	11	Cyclone Dreena, Thames/Bay of Plenty	NZD3.29 million *	ICNZ, 2004; EM-DAT, 2004; MCDEM, 1999
1997	1	21	South Island Storms	NZD1.13 million *	ICNZ, 2004
1997	5	24	Auckland Floods	NZD3.8 million *	ICNZ, 2004
1997	6	30	Northland Floods	NZD1.23 million *	ICNZ, 2004
1997	6	2-3	Wairoa Floods	NZD0.51 million *	ICNZ, 2004
1997	9	24-25	Coromandel Floods	NZD0.51 million *	ICNZ, 2004
1997	9	27-28	Auckland Floods	NZD0.71 million *	ICNZ, 2004
1998	7	15	North Island	NZD150,000	EM-DAT, 2004
1998	7		North and South Island Floods and Storms	NZD11.85 million *	ICNZ, 2004
1998	10	28-30	North and South Island Storms	NZD2.02 million *	ICNZ, 2004
1998	10	19-22	North and South Island Storms	NZD6.27 million *	ICNZ, 2004
1998	11	28-29	Upper North Island Storms	NZD5.06 million *	ICNZ, 2004
1999	1	21-22	Northland and Pukekohe Floods	NZD5.08 million *	ICNZ, 2004
1999	4	18	Dargaville Floods	NZD1.72 million *	ICNZ, 2004
1999	7	2	South Canterbury Storms	NZD0.61 million *	ICNZ, 2004
1999	4-5		Whangarei/Rotorua Floods	NZD2.13 million *	ICNZ, 2004

1999	11-12		Queenstown Lakes District Floods	NZD46.42 million *	ICNZ, 2004
2000	4	8-10	Tauranga/Eastern Bay of Plenty Floods	NZD1.9 million *	ICNZ, 2004
2000	8	20	Canterbury	USD1,000	EM-DAT, 2004
2000	9	25-26	North Island Severe Weather	NZD4.2 million *	ICNZ, 2004
2000	10	12	Canterbury Storms	NZD9.4 million *	ICNZ, 2004
2000	6-7		Auckland/Coromandel Floods	NZD7.6 million *	ICNZ, 2004
2001	11	3-4	North Island Storms	NZD0.5 million *	ICNZ, 2004
2002	1	10	Wellington/Wairarapa Flooding	NZD0.6 million *	ICNZ, 2004
2002	1	14	Canterbury Flooding	NZD0.25 million *	EM-DAT, 2004; ICNZ, 2004
2002	1	17	Dunedin Flooding	NZD0.3 million *	ICNZ, 2004
2002	6	20-21	North Island Flooding and Storms	NZD21.5 million *	ICNZ, 2004
2003	6	9-10	Lower North Island Storms	NZD1.0 million *	ICNZ, 2004
2004	2-3		North Island and the north part of South Island	At least NZD200 million	news reports