# FLOOD RISK ANALYSIS FOR SUSTAINABLE RIVER SCHEMES

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## ABSTRACT

Bay of Plenty Regional Council (BoPRC) is responsible for five main River and Drainage 'Schemes'. The stopbanks are designed to provide '100-year' Level of Service (LoS) to urban areas. Council is concerned whether this LoS is sustainable into the future.

The challenges predominantly relate to the reality of diminishing LoS caused by factors outside of Council control. This includes (but is not limited to) climate change, sea level rise, sinking floodplains, rising rivers, deforestation, and increasing development demand within low-lying floodplains.

BoPRC has developed a 100-Year River Sustainability Strategy (RSS) to assist in addressing these challenges. The RSS aims to achieve the following:

- A reduction in flood risk for Bay of Plenty region.
- Introduction of environmentally and economically sustainable land use practices.
- Adaption to climate change.
- Affordability for river scheme ratepayers into the future.

Research that underpinned the strategy focused on flood risk modelling, options assessment and economic analysis.

The existing river scheme rating zones are well defined according to the schemes' varied levels of protection anticipated for urban and rural land. The RSS formed an economics workstream in order to analyse the river schemes' tangible benefits. Flood depth analysis developed an understanding of the benefits provided by the river schemes for both rural areas and urban properties.

Flood risk analysis required the development of a combined one and two-dimensional model specifically for this project. Categorisation of flood depths with and without the stopbank systems in place was fundamental to the economic analysis. This enabled economic analysis using cost-damage curves to be completed by Sapere Research Group.

This paper will focus on describing the RSS project scope and progress, followed by an overview of the economic assessment and flood risk analysis stages of the project. This work is continuing to increase understanding and awareness of river scheme sustainability challenges throughout the Bay of Plenty.

## KEYWORDS

Flood Risk, Sustainability, Climate Change, River Scheme, Level of Service, Rating, Stopbank, River Management

**PRESENTER PROFILES**

Katalin Maltai has a degree in Environmental Engineering with experience working for Territorial Authorities as well as consultancies in both the United Kingdom and New Zealand. Her main areas of expertise include hydrological and hydraulic investigations and environmental impact studies.

Colin Meadowcroft is a chartered civil engineer with over 18-years experience working in 4-water related projects in construction, consultancy and local government both in the UK and New Zealand. Colin has a particular passion for conceptualising solutions to complex flood risk projects utilising his vast experience in hydrological modelling.

# 1 BACKGROUND

Historically, central government has recognised that flooding and drainage problems were best managed on a full ‘catchment’ basis. Major catchments frequently traverse territorial authority boundaries. The existing river scheme ownership resulted from Local Government Act provisions.

Regional authorities were delegated responsibility for the provision and control of these assets. As with many river schemes throughout New Zealand, they were established under the Soil Conservation Rivers Control Act 1941. Catchment Commissions were set up with specialist engineering and soil conservation skills to administer flood control functions.

The Eastern Bay of Plenty Catchment Commission was created in 1962 in response to flooding in the region. In 1964 it became the Bay of Plenty Catchment Commission. In 1989 around 850 local bodies were consolidated into 86 multi-purpose local authorities. These included regional councils with broad environmental responsibilities and that’s when the Bay of Plenty Regional Council was established.

Bay of Plenty Regional Council (BoPRC) currently manage five main river and drainage schemes (Figure 1). The ‘Schemes’ typically involve stopbank and pumping to protect farmland and towns from flooding. The level of flood protection provided ranges from 2 to 100 years. These flood protection schemes were mainly constructed in the 1970s following extensive floods in the 1960s.

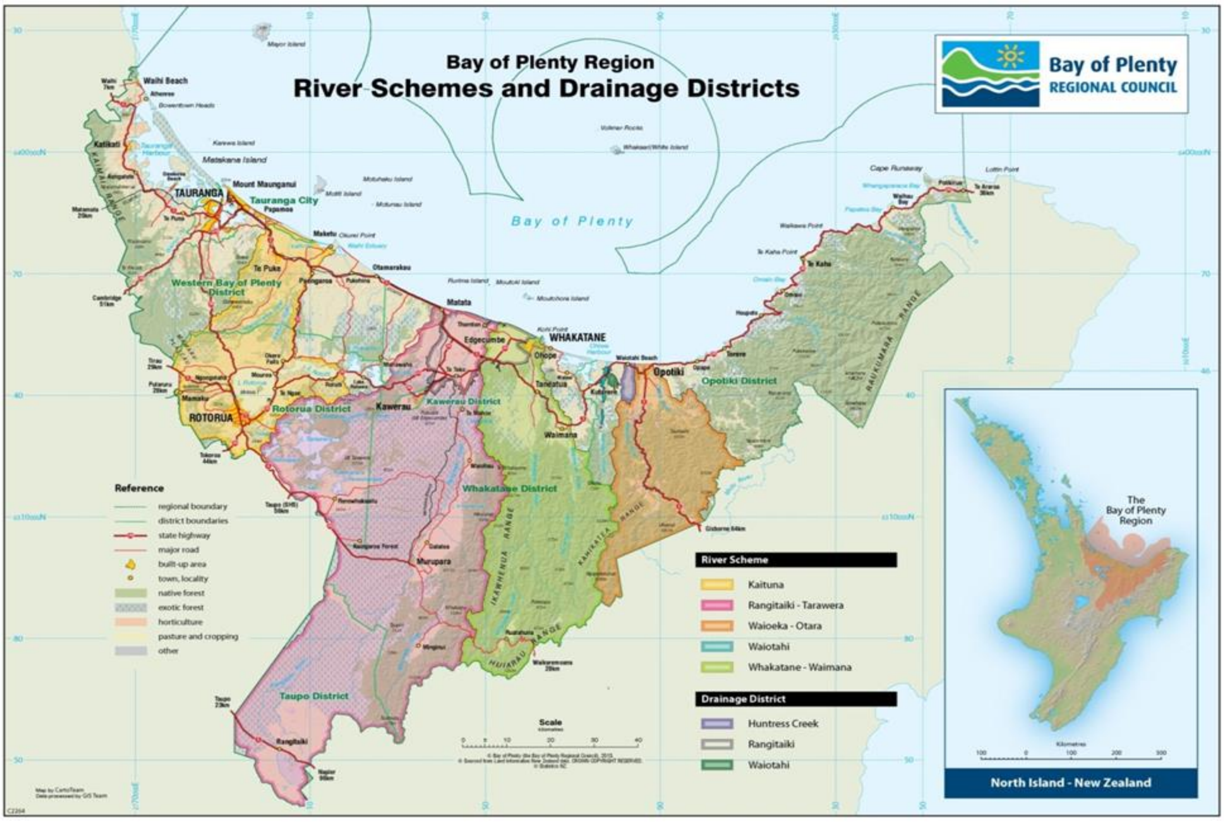


**Figure 1:** BoPRC River Flood Protection Schemes within the Bay of Plenty region

The structural stopbank systems are designed to constrain river flows. The drainage schemes drain former wetlands to allow productive farming within the fertile floodplain. Dairy is the main agricultural industry within the floodplain, where ground levels are commonly below mean sea level.

# 2 CHALLENGES

BoPRC currently strive to achieve 100-year LoS for their urban areas, such as Opotiki township (shown within red boundary lines on Figure 2 below). The Waioeka-Otara river scheme stopbank and drainage systems aim to provide protection for 2 to 50-year LoS for the surrounding farmland.

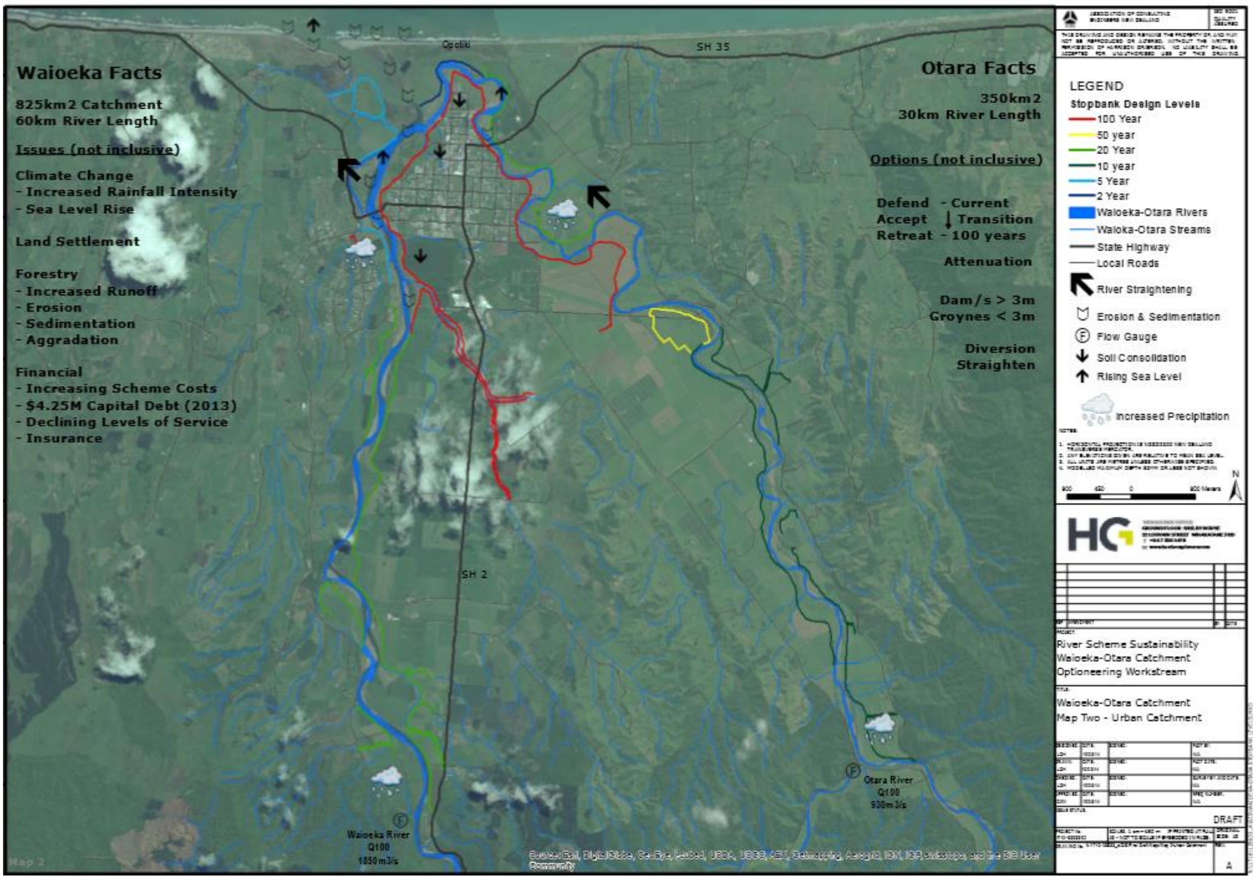

**Figure 2:** BoPRC Waioeka-Otara River Flood Protection Stopbank Scheme LoS

BoPRC is concerned that the river protection schemes for which they are responsible may become unsustainable in the future. Some of the main challenges are briefly outlined below:-

- **CLIMATE CHANGE -** Increasing rainfall intensity with climate change is increasing flood severity and frequency. LoS is effectively reducing as a result.
- **LAND USE CHANGE –** Deforestation and land development increases rainfall runoff and sediment flow into rivers and streams. This increases flood frequency and intensity downstream.
- **SEA LEVEL RISE -** Predictions for 1m sea level rise over the next 100-years is expected to increasingly challenge the economic protection using structural measures for low-lying floodplain.
- **AGGRADATION -** Rivers are rising with gravel and sediment aggrading due to the stopbanks constraining flood flows which historically spread it onto the floodplains.
- **SETTLEMENT -** The floodplain is sinking slowly with the underlying peat consolidating as it is drained. This effectively increases flood risk and flood depths.

# 3 RIVER SUSTAINABILITY STRATEGY

## 3.1 PHASE 1 – THE VISION

BoPRC has developed a 100-Year River Sustainability Strategy (RSS) in response to the above concerns. The strategy aims to achieve the following:

- A reduction in flood risk for Bay of Plenty river schemes.
- Introduction of environmentally and economically sustainable land use practices.
- Adaption to climate change.
- Affordability for river scheme ratepayers.

The aim of the RSS project is to consider the long-term risks of flood hazard whilst providing strategic direction to create sustainable river schemes into the future.

## 3.2 PHASE 2 - INVESTIGATIONS

The investigation phase established the RSS foundations which are broken down into six specific workstreams, as follows:

### 3.2.1 RATING ASSESSMENT

BoPRC is responsible for maintaining fair and justified targeted rating systems within the Bay of Plenty region. As part of the assessment, the current targeted rating system was reassessed.

### 3.2.2 ECONOMIC ANALYSIS

The long term costs and benefits for each river scheme were analysed within the economics workstream. This is described within section 4.0.

### 3.2.3 FLOOD RISK GAP ANALYSIS

The RSS project incorporates a whole-of-catchment philosophy to managing floods. This philosophy was not in place when original Floodplain Management Strategy (FMS) documents were produced. The historic focus was on using hard engineering or structural solutions to manage floods. Future FMS work will incorporate this whole-of-catchment philosophy.

The existing FMS and supporting documents were reviewed and recommended actions discussed with both internal staff and relevant external organisations to confirm the status of the action.

### 3.2.4 OWNERSHIP AND GOVERNANCE (O&G)

This review considered BOPRC's existing O&G model, assessed relevant legislation and investigated alternative models. The existing in-house model was considered appropriate for Council's assets and provides flexibility to respond to future changes. The conclusion was to retain the existing in-house O&G service delivery model but continue to explore and develop regional collaboration.

### 3.2.5 CLIMATE EFFECTS

The climate change workstream investigated the past climate variability and trends for the Bay of Plenty region. It also presents scenarios for future climate change over the next 50 to 100 years. Specific climate change scenarios for the Bay of Plenty were incorporated into a report to guide the RSS project.

### 3.2.6 OPTIONEERING WORKSTREAM

As part of the optioneering workstream, catchment wide high-level soft and hard engineering solutions have been developed for the five major river and drainage catchments in the Bay of Plenty. To develop these options BoPRC engaged four consultancies with international expertise, and involved internal staff members, Councillors and River Scheme Liaison Group (representatives of the targeted ratepayer groups).

## 3.3 PHASE 3 - ANALYSIS

The project plan for the RSS project analysis phase proposes interrogation of two of the investigatory workstreams to provide a higher level of confidence. This includes the Optioneering and Economic Analysis workstreams.

## 3.4 PHASE 4 - FRAMEWORK DEVELOPMENT

Developing a framework of actions is proposed, including processes and links between the Regional Water and Land Plan, spatial planning, District Plans, and the Regional Policy Statement. The framework will guide the management of river schemes, feeding into the Rivers and Drainage Schemes Asset Management Plan, Long Term Plan, annual works programmes and management programmes. It will help to identify the trigger points leading to change in direction to keep the schemes sustainable.

# 4 ECONOMIC ANALYSIS[1]

The aim of the economic analysis was to examine the river scheme costs against the local and regional benefits for each scheme. The analysis was a total assessment of benefits and costs of existing stopbanks, bank edge protection, and drainage channels where applicable. The time-frame for analysis is the long term (>50 years).

The principal difference between a 'total analysis' and a 'marginal analysis' is what is assumed by the 'without stopbanks' scenario. In a total analysis, the economic value of a project or asset is ascertained by looking at a scenario where the asset does not exist at all. In contrast, a marginal analysis would have looked at the difference in economic value from small incremental changes to the asset.

The analysis was comprehensive with all costs and benefits associated with the river schemes being considered. Costs and benefits included:

- All affected parties in the Bay of Plenty region regardless of whether they are directly or indirectly affected.
- Financial (e.g. damage related costs) and social (e.g. peace of mind to people).
- The analysis did rely on an assessment of the risk of stopbank overtopping.

[1] *Section 4 & 6 - Excerpt from Benefits and Costs of Bay of Plenty Flood Protection Schemes report, Sapere Research Group (2014)*

## 4.1 METHODOLOGY

The methodology involved comparing the annualised regional benefits of the scheme with its annualised costs. Benefits and costs are annualised because this allows for the entire range of flooding possibilities (from 2 to 500-year events) to be aggregated into readily understood long term 'expected values'.

The methodology is shown schematically on Figure 3 below.

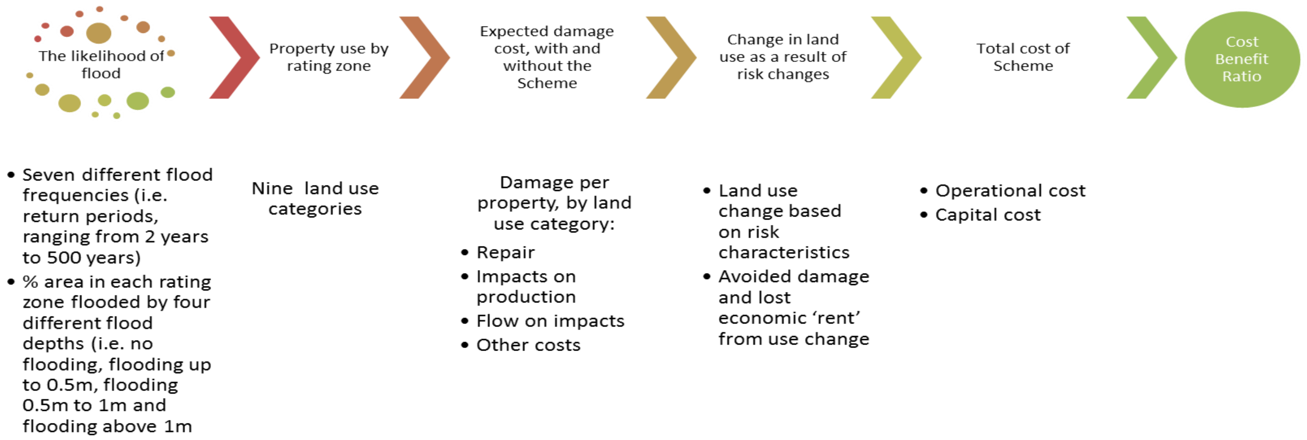


**Figure 3:** Diagram of Economic Analysis Methodology

The costs of the scheme are the financial costs of managing the scheme, including the opportunity cost of capital tied up in the schemes. The benefits of the scheme relate to the prevention of damage caused by floods.

Flood damage costs include losses to the property owner and knock-on impacts to the broader community. The effects of flooding can be devastating to the community in which it occurs in terms of the physical destruction of property and possessions, financial losses generated and the social stress, anxiety and misery created.

The damage caused by floods includes the costs relating to the replacement and repair of assets as well as the temporary loss of use of the assets damaged. The loss-of-use costs include direct costs to the property owner in addition to indirect (flow-on) impacts to the broader community.

The annual expected damage caused by a flood (including the repair/replacement, the loss of use and the flow-on impacts) depends on the likelihood of a flood, the severity of the flood and the type of property affected. Quantification of the benefits of flood protection therefore requires estimates of the flood risk by severity of flood for each property.

# 5 FLOOD RISK ANALYSIS

The flood risk analysis was undertaken as part of the Economic Analysis workstream to provide the required flood depth data to determine scheme benefits.

## 5.1 MODELLING METHODOLOGY

BOPRC required an assessment of the flood risk with and without stopbanks as part of the RSS Economics workstream. The methodology was jointly developed to efficiently categorise flood depth ranges within existing rating zones. The analysis considered with and without existing stopbanks for floods ranging from 2 to 500-year return periods.

A fully integrated one and two-dimensional (1D/2D) model was developed within InfoWorks ICM software utilising the latest LIDAR data.

For this work, analysis was summarised with property use by rating zone. Rating zones were used as a way to categorise land because BOPRC assumes these to be areas within which the flood risk is relatively uniform. This analysis estimated the flood risk with and without the stopbanks for each rating zone. This involved analysing seven different flood frequencies (i.e. return periods) ranging from 2 to 500-years. Estimates of the percentage area flooded to four different flood depth ranges (being no flooding, flooding up to 0.5m, flooding 0.5m to 1m and flooding above 1m) were required within each rating zone.

This data was then used in combination with information on damage by property type and flood depth to estimate the expected (i.e. the long-term average) damage cost by property type within each rating zone with and without a flood scheme.

## 5.2 MODEL INPUTS

The 1D and 2D model was developed with the following model inputs:-

- Surveyed river cross-sections for the Waioeka and Otara Rivers
- River hydrographs for 2 to 500-years (Figure 4)
- Tide level data for 2 to 100-years (Figure 5)
- Topographical data (2011 LIDAR)
- Existing rating zones & property points geospatially

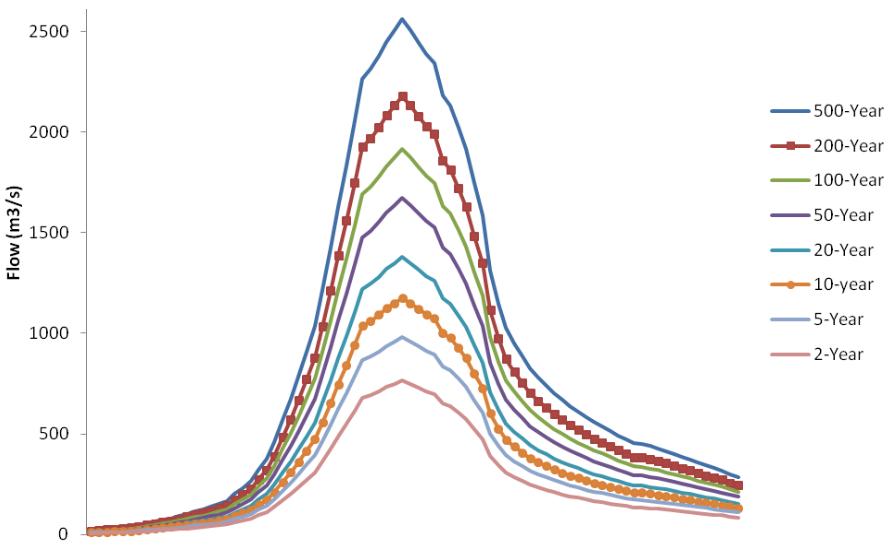


**Figure 4** – Waioeka River Inflows (2 to 500-Year)

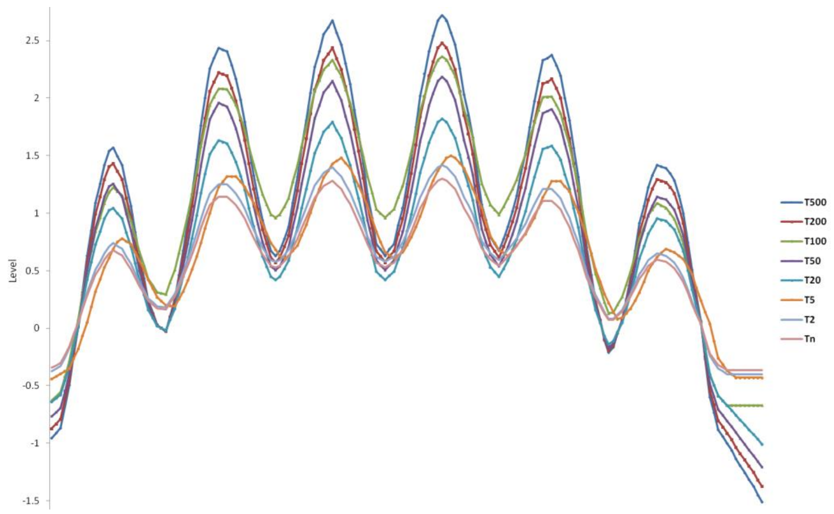


**Figure 5**– Sea Level Boundary Condition (2 to 500-Year)

## 5.3 MODEL ASSUMPTIONS

The model was built utilising the following key assumptions:

- Mannings roughness of 0.03 was applied to all river channels. This was calibrated to ensure no urban flooding within a 100-year event.
- The stopbanks were removed to reflect the floodplain estimated level (Figure 6).

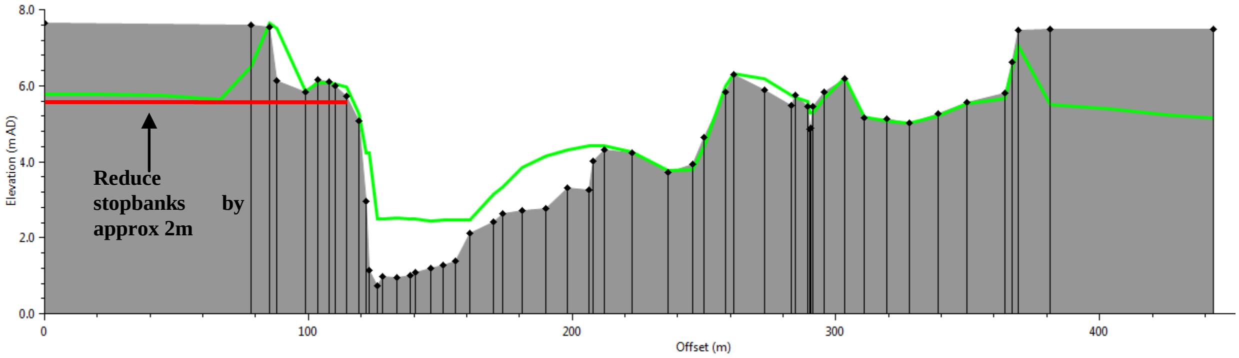


**Figure 6** – Typical surveyed river cross section with LIDAR in green

## 5.4 MODEL OUTPUTS

An example of the model outputs for a 500-year flood is shown in Figure 7 below. This data categorised the flood depths within each rating zone and demonstrated the benefit provided by the river scheme stopbanks.

| Likelihood of property in rate code having No Flooding | | | Likelihood of property in rate code of some flooding <0.5m | | | Likelihood of property in rate code of receiving flooding >0.5 and <1.0 | | | Likelihood of property in rate code of some flooding >1 | | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| Rating Category | Current | Without stopbanks | Rating Category | Current | Without stopbanks | Rating Category | Current | Without stopbanks | Rating Category | Current | Without stopbanks |
| **A1A** | 83% | 0% | **A1A** | 17% | 33% | **A1A** | 0% | 0% | **A1A** | 0% | 67% |
| **A2** | 33% | 0% | **A2** | 30% | 45% | **A2** | 10% | 13% | **A2** | 28% | 43% |
| **A2A** | 55% | 0% | **A2A** | 45% | 70% | **A2A** | 0% | 30% | **A2A** | 0% | 0% |
| **A3** | 31% | 7% | **A3** | 32% | 31% | **A3** | 31% | 39% | **A3** | 7% | 23% |
| **A3A** | 100% | 65% | **A3A** | 0% | 35% | **A3A** | 0% | 0% | **A3A** | 0% | 0% |
| **A4** | 65% | 15% | **A4** | 23% | 49% | **A4** | 5% | 28% | **A4** | 7% | 8% |
| **A4A** | 100% | 58% | **A4A** | 0% | 32% | **A4A** | 0% | 11% | **A4A** | 0% | 0% |

**Figure 7** –River scheme flood risk probability with/without stopbanks output example

The flood maps in Figure 8 below demonstrate the relative flood depths with and without stopbanks where the red zones have greater than one metre flood depth.

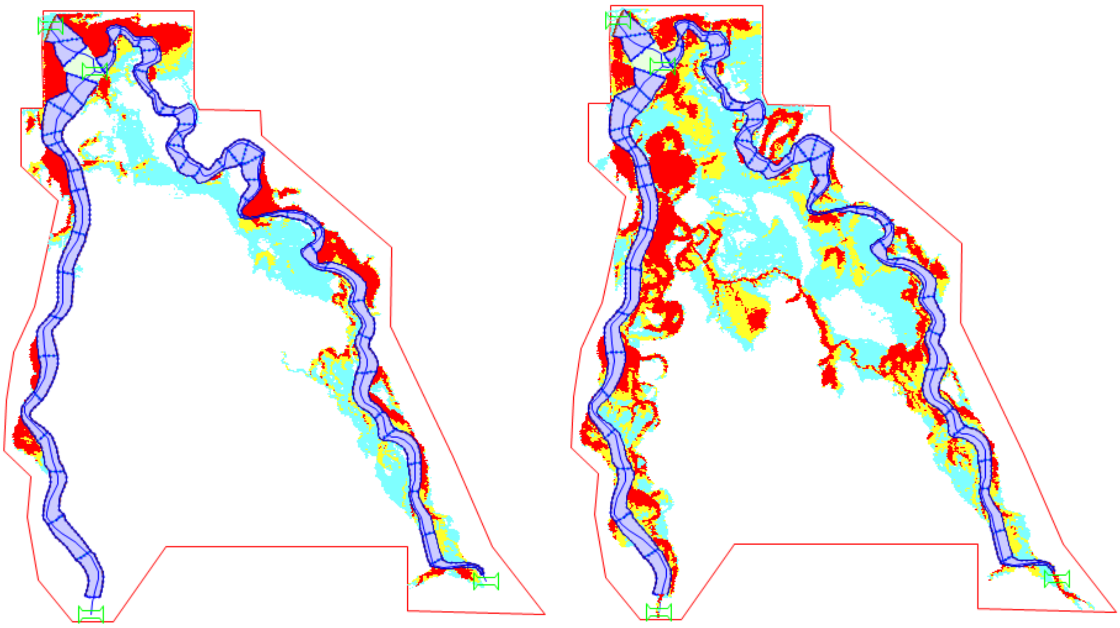

Figure 8: Waioeka-Otara 500-Year Flood Maps with & without stopbanks

# 6 RESULTS[1]

The main finding from the economic analysis workstream is that the benefits from each River Scheme outweigh the costs by multiple times. The analysis suggests as follows:

(a) The benefits of stopbank protection greatly outweigh the costs. The ratios between benefits and costs vary between the Schemes ranging from 7:1 to 34:1. This ratio is the avoided damage as a result of having flood protection in place relative to the total cost of the Scheme.

(b) Long term land use change as a result of higher flood risk can consist of full retreat, partial retreat or adaptation. Allowing for these changes in the economic modelling significantly modifies benefit/cost ratios. For example, under a modelled scenario in which half of the properties that experience deep (>0.5m) flooding regularly are abandoned, the ratios reduce to a range from 6:1 to 32:1.

(c) The direct costs of a flood include physical damage to homes, farms, schools and road and network infrastructure, plus clean–up costs. There are additional indirect and intangible costs too. These costs include impacts on local and regional production, human impacts and impacts on injury and health. The analysis shows that after a flood, the direct costs and indirect/intangible costs will be of a similar order of magnitude.

In the long-term, people respond to changes in flood risk. For example, if the level of protection decreases it can be expected that farms at high risk of flooding would return to their natural state or would reduce their production on that land, as property owners decrease investment in that property. In urban areas, we might expect that landowners begin to abandon properties which have become uninsurable as a result of high flood risk. Alternatively, we might expect to see a higher proportion of homes built to have a higher floor level as homeowners and councils seek to minimise flood risk. These responses can be termed under total retreat, partial retreat and adaptation.

# 7 CONCLUSIONS

Local Government is often constrained within their planning cycle timeframes. Best guidance on potential effects of climate change has predictions with a 100-year outlook.

It is rewarding to be involved in a project that has a longer-term vision. Despite limited direction on this subject nationally, Councils need to be proactive in working together and educating their communities on flood risk.

The work completed to-date has demonstrated the significant benefits of the river schemes. BOPRC now plans modelling without stopbanks within their regular floodplain modelling forward work programme.

**ACKNOWLEDGEMENTS**

Bay of Plenty Regional Council should be acknowledged for their vision into the future.

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