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Report

River Scheme Sustainability Project

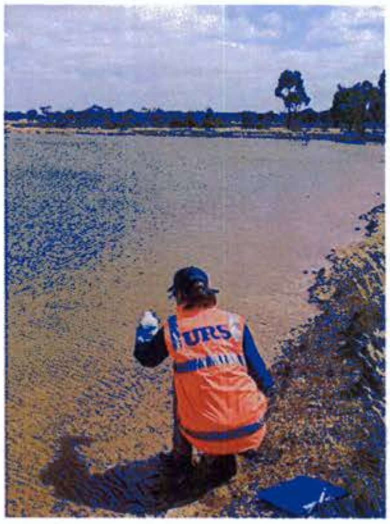
Rangitaiki Tarawera Flood Mitigations Optioneering

June 2014
42073888/01/B

Prepared for:
Bay of Plenty Regional Council

Prepared by URS New Zealand Limited

NEW ZEALAND



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DOCUMENT PRODUCTION / APPROVAL RECORD				
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Report Name:
River Scheme Sustainability Project

Sub Title:
Rangitaiki Tarawera Flood Mitigations Optioneering

Report No.
42073888/01/B

Status:
Final

DOCUMENT REVISION RECORD		
Issue No.	Date	Details of Revisions
1B	13/06/2014	Revision following workshop held at Bay of Plenty Regional Council on 28/05/2014

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1 INTRODUCTION AND OBJECTIVE OF THE REPORT

1.1 Introduction

Bay of Plenty Regional Council (BoPRC) is reviewing four river schemes and one drainage scheme to determine options for sustainable management and flood mitigation in each scheme as part of the River Scheme Sustainability (RSS) Project. This RSS project consists of four phases: vision, investigation, analysis and framework and aims to identify options over a 100 year planning horizon with the influence of climate change. The project is currently in phase 2 (2013-2014), the investigation phase.

URS has been commissioned to provide sustainable flood mitigation options for Rangitaiki-Tarawera catchment as a part of the RSS phase 2 Optioneering workstream.

1.2 Objective and structure

The objective of this report is to briefly outline current catchment characteristics, current flood mitigation infrastructure, to identify catchment issues and provide a list of potential future management options. It considers a 100year forward planning horizon and the implication of climate change. A high level analysis of management options is provided through the listing of the pros and cons of each option.

The report is structured as follows:

- Section 2 is a brief overview about the Rangitaiki Tarawera catchment which includes information on the land cover, geology, hydrology and current flood management infrastructure as well as potential catchment issues.
- Section 3 lists various flood mitigation options and their applicability to Rangitaiki-Tarawera catchment.
- Section 4 maps of the different options proposed in Section 3.
- Section 5 recommends a number of options for further analysis during Phase 3 of RSS project.

2 CATCHMENT DESCRIPTION

2.1 Catchment overview

The Rangitaiki Tarawera catchment covers an area of approximately 4000km^2, where the Rangitaiki catchment comprises of 3005km^2 and the Tarawera Catchment comprises of 990km^2 of the total area. **Appendix A** shows the catchment boundaries of the Rangitaiki-Tarawera catchments.

The headwaters of Rangitaiki River are located 32km east of Lake Taupo and 130km from the Bay of Plenty coast at an elevation of 800m above mean sea level. The Rangitaiki River flows across the Kaingaroa Plateau where it has been dammed at the northern end at Murupara. The River then passes through Ikawhenua Ranges, flows over the Galatea Plains and enters Lake Aniwhenua, where it is also dammed. It should be noted that several smaller tributaries which arise from Ikawhenua ranges, cross the Waiohau valley and contribute to the flows downstream of Aniwhenua. The river passes through a gorge and then out to the Waiohau Plains before entering Lake Matahina. The river then flows through through a well-defined valley before crossing the Rangitaiki Plains.

The upper parts of the Tarawera catchment include a number of lakes namely, Lakes Tarawera, Otaina, Okareka, Tikitapu, Rotokakahi and Rotomahana. The area has an elevation just below 300m. This is where the Tarawera River begins. The river drops 150m, 6.5km after leaving Lake Tarawera, then flows through to the settlement of Kawerau. The Tarawera catchment also includes part of of the drainage network on Rangitaiki plains.

2.2 Land cover

Rangitaiki -Tarawera catchment land uses are exotic forest, Indigenous forest and exotic grassland which account for 47%, 26% and 19% of the catchment area,respectively. Urban land use is minimal compared to the rural land uses.

The floodplain area in both catchments comprises mainly rural land use which is dominated by dairy pasture, and includes small areas of orchard cropping and indigenous and exotic scrub. **Appendix A** displays the land cover of Rangitaiki-Tarawera catchment.

2.3 Geology and Hydrology

The Rangitaiki Plains are part of the catchments of two main rivers: Tawarera River and Rangitaiki River, both the subject of this study.

The Rangitaiki Catchment is underlain by Rangitaiki Ignimbrite through the centre of the catchment, Mid Pleistocene deposits and Pumiceous Pyroclastics are located on the west and Holocene deposits and greywacke in the east. The Tarawera catchment comprises of Holocence deposits, Rhyolite Domes and Rotoiti pyroclastics.

The Tarawera River Catchment is dominated by large lakes in the upper catchment that control the flood peaks. The catchment is covered by volcanic deposits with high permeability, and covered mainly by exotic forest and grass lands. The Tarawera River plains are only divided from the Rangitaiki Catchment by the left stopbank of the most eastern river channel and its low lands are drained by a set of canals and pumping systems that discharge into the Tarawera River.

The Rangitaiki River has a long main channel and numerous contributing tributaries. The catchment has a time of concentration of over 48hrs and the western and eastern sides of the upper catchment generate approximately 45 % and 55% of the run off respectively . In this catchment a few areas with differing hydrology features can be identified as outlined below and the specific discharge quantities are shown in Table 2-2

- The western catchment upstream of Matahina Dam is defined by very permeable volcanic deposits and a flatter topography. This area produces a very low runoff, has long percolation time through soils and is mainly covered by exotic forests. This area makes a relatively small contribution to peak flows in large storm events.
- The eastern catchment upstream of Matahina Dam is defined also by permeable volcanic deposits, with more sand and silts, a more hilly topography and mainly covered by indigenous forests. The eastern side releases its runoff quickly as the soil is less permeable than the west, and slopes are steeper, producing higher peaks flows. This area produces the majority of the peak flow for the catchment (approximately 70%). Flood management options therefore need to focus on managing significant flows from this area during storm events.
- The lower catchment, defined downstream of the Matahina Dam, is mainly defined by low lands, flat plains covered by grass and lower permeability soil types. The runoff of this area is drained by a set of canals and pumps into the river. This part of the catchment has little influence over the river flow and levels but is subject to significant flooding and as a result river banks are fortified by stopbanks to help manage and contain flood volumes.

There are two reservoirs in the catchment with a major influence on the catchment hydrology: Aniwhenua and Matahina, the latter being by far the largest and most important. In both locations, other dams are used for hydroelectric power generation, and they are operated to maximise power production and the safety of the dam structure. The operation of the dam is not optimised for flood mitigation purposes.

The expected peak flows for the Rangitaiki and Tarawera catchments are shown in **Table 2-1**, and some general details of the catchments are presented in **Table 2-2**.

Table 2-1 Peak flows in the Rangitaiki Tarawera catchments

Peak Flow	Rangitaiki (m^3/s)	Tarawera (m^3/s)
5 yr	320	64
10 yr	410	72
20 yr	505	79
50 yr	650	88
100 yr	780	95

Table 2-1 depicts flows without climate change. An estimated mid-range warming in temperature of 2.1 °C is expected for the Bay of Plenty Region by 2090; that would increase the rainfall depth by over 10% in the catchment for storms for frequencies over 10yrs, and up to 16.8% for storms over 50yrs of recurrence. The potential increment in the respective runoff would have a similar percentage or even higher. The Probable Maximum Flow (PMF) event has a more than 100 year return period and a greater rainfall volume, this has not been

specifically considered for the purposes of this report, however, under the current regime PMF flows would be conveyed to the Rangitaiki Plains to put pressure on and in all likelihood breach the existing stopbank system.

Table 2-2 Hydrological parameters

Sub-catchment	Catchment Area (km²)	Approximated flow (m³/s)	Specific Discharge m³/s/km²
Rangitaiki at Te Teko	2952	824	0.27
Matahina lake	2852	840	0.29
Aniwhenua lake	2479	653	0.26
Whirinaki River	526	388	0.74
Rangitaiki River US Whirinaki junction	1225	73	0.06
Tarawera River	990.0	96	0.1

** based on calibrated model of the storm of July 2004, URS, 2011.*

As can be seen in **Table 2-1** the peak flows in the Rangitaiki are much greater than the Tarawera and more challenging in terms of flood management and flood risk. Given the upstream geology and river form, options will be focussed on managing flows in relation to the capacity of the main river channel. The smaller flows in the Tarawera lend themselves to the consideration of several smaller scale options to reduce or mitigate the flooding, though the Rangitaiki catchment requires major actions in order to obtain a noticeable benefit. There is potential to link the two catchments to assist with the management of peak flows and this is outlined further in the catchment options.

Table 2-2 shows that the highest discharge rates originate in the Galatea Catchment, upstream of the Matahina Dam. Management of runoff from this area is the key to flood risk management for the Rangitaiki.

2.4 Infrastructure

There are several reservoirs within the catchment which store water for various purposes including power generation. Of these, there are two major reservoirs of significance which can hold large volumes. The two reservoirs' details are summarised in the **Tables 2-3** and **2-4**.

Table 2-3 Matahina Reservoir volumes

Matahina Reservoir	Elevation (m)	Volume (Mm³)	Area (Km²)	Difference (Mm³)
Extreme min	71.60	45.13	2.12	45.13
Min	73.15	48.47	2.19	3.34
Max	76.2	55.33	2.31	6.86
Extreme Max	76.80	56.76	2.34	1.42

Table 2-4 Aniwhenua Reservoir volumes

Aniwhenua Reservoir	Elevation (m) *	Volume (Mm³)	Area (km²)	Difference (Mm³)
Normal Min	146.1	4.0	1.51	
Normal Max	146.8	5.1	1.76	1.2
Emergency Spillway	148.6	9.5	3.1	4.4

** Approximated levels for Min and Mx based on 2004 operational records. Spillway level based on estimated top of bank, actual level may vary.*

The live storage of the Matahina Dam is larger than that in Aniwhenua Lake. The former is over 11Mm³ and the latter in the operational range of 1.2 Mm³ to a potential spillway maximum of approximately 5.6 Mm³. The operation of both dams could be optimised for better flood control.

Whilst Matahina Dam can hold over 11Mm³, a storm like the July 2004 event generated a total volume close to 400Mm³ with a peak flow about 780m³/s. The live storage available in the Matahina Dam could hold all of the peak hydrograph volume of a storm like July 2004 whilst releasing flows under 625m²/s. If only half of it is capacity is used in such a storm, the maximum flows delivered to the downstream reaches could be reduced from 780m³/s to less than 680m³/s. Thus the presence and operation of Matahina Dam is a critical consideration for flood management on the Rangitaiki Plains.

The volumes of the remaining smaller reservoirs are not currently available to URS, but are thought to provide localised flood mitigation for recent developments or to provide storage for irrigation. Their relative capacities are thought to be minor compared with the large volumes produced in extreme large events.

Future irrigation schemes are being considered for the Rangitaiki Plains and Galetea area, again these projects if implemented are not expected to make a significant impact on flood flows and volumes as peak flow rates are estimated to be 6.7 m³/s and 5m³/s over areas of approximately 11,000 and 10,000 hectares and projected storage volumes are relatively small compared to Aniwhenua or Matahina for example.

River stopbanks in the lower Rangitaiki and Tarawera plains are also important infrastructure. They currently provide flood protection to the large low lying areas that were once wetlands. These stopbanks are sensitive structures that need close management and constant maintenance, but in recent years have been breached, causing widespread flooding over the lower catchment. Most of Rangitaiki river stopbanks aim to provide capacity for a 100yr storm event, though in numerous locations they have a lower capacity or they often fail before the maximum capacity is reached. The Rangitaiki River has an estimated capacity between its existing stopbanks of about 620m³/s.

The Rangitaiki plains drainage system is a complex infrastructure. It is composed of a large set of canals distributed over the low land of the plains which are protected by the stopbanks at the Rangitaiki and Tarawera rivers. The canals discharge at higher water levels by pumping the water into the Rangitaiki or Tarawera rivers. Currently these pump stations are small, located near the base of the catchment and hence will make little impact on flood peak flows or there effects on upstream properties.

Reids canal is also the path of a large overland flow path and flood storage that bypasses the Rangitaiki River to mitigate the impact of large flows in the Rangitaiki River. A spillway over the right bank of the Rangitaiki River conveys the excess of flood waters into the Reids canal and the allocated floodable areas. Flow bypasses a section of the river and is later discharged just before the river mouth. Improvements have been designed for the Reids Canal to increase its capacity to up to 190m³/s and ensure a better and safer operation. This capacity combined with the 620m³/s within the Rangitaiki River channel results in a capacity of up to 810m³/s from the entire catchment. This assumes that the stop bank system remains in place and is structurally sound, however the repeated breach of the stop banks, in practice, has led to consideration of other flood management options.

2.5 Catchment issues

The Rangitaiki River catchment is a very large catchment with relatively low runoff coefficients due of its volcanic geology. This makes it very sensitive to land use management and changes would potentially significantly increase the runoff volumes and peaks delivered to the lower catchment. Thus the Rangitaiki plains are then very sensitive to any change in the upper catchment. This is also a major issue as it constrains further developments in the upper catchment, limiting the economic potential. In fact, the current land use is dominated by dairy and horticulture, i.e. based on drained fertile soils of the reclaimed plains. In 100 years with sea level rise, these land uses may no longer be applicable within the catchment and new sources of income will need to be developed.

Prior to land drainage which began in the 1940s, the current Rangitaiki plains were covered by wetland, rich in sediments and without a clearly defined river path. Large floods would spread over the wetlands and would maintain a sustainable ecological and hydrological balance. Two major changes occurred in this area with important consequences:

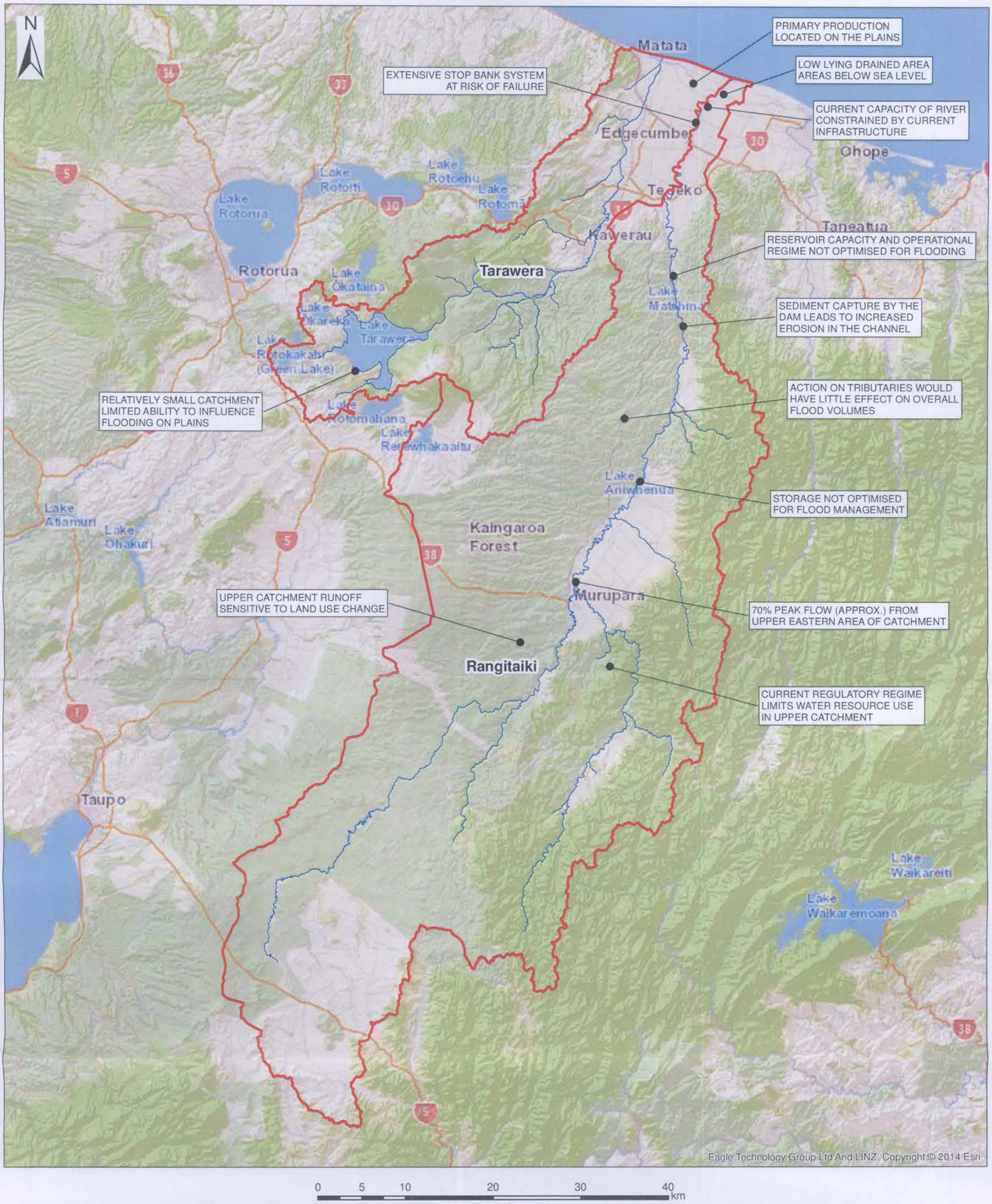
- The reclamation of the low land for farming required the construction of a complex drainage system powered mainly by pumps, and the construction of a large river stopbank along the Tarawera and Rangitaiki rivers to stop the river taking the land bank into wetland.
  - The flood mitigation methods to date have focused on the extensive use of stopbanks. The stopbanks confine the river channel and limit channel capacity in relation to their height. They also require constant maintenance and repair and may not be sustainable in the future, hence alternative solutions are to be considered.
  - Following the land reclamation, some areas located in Rangitaiki plains appear to be at or below sea level and therefore are more sensitive to flood events. This will be exacerbated in the future by climate change effects and in particular sea level rise. Future flood management options will need to account for this.
- The construction of two reservoirs in the Rangitaiki River to generate hydroelectricity.

Several pieces of international research on this matter (stated in **Section 6**) and local studies done in the area, especially in the Rangitaiki catchment, suggest:

- The construction of a dam has a large impact on the health of the downstream portion of rivers. It considerably reduces the amount of sediment transport which produces an imbalance in the downstream river that promotes erosion and weakens the ground by removing the fine sediment of the river bed thus increasing the risk for failure of the ground and undermining of stream bank structures. This also has negative implications for stream ecology and biodiversity.

- The reduced concentrations of sediment in the Rangitaiki River mouth were measured and recorded in the 1980s and thought to be attributable to the construction of the Matahina Dam, (NZJMFR, 1981)
- The Matahina Dam is located in a critical portion of the river, where the slopes are reduced quickly from a 2% to less than 0.05%. This means the full load of sediment and nutrients from the upper catchment is caught by the upper end of the reservoir and it is not delivered to the lower river where it is required to maintain the strength of the ground, to promote biodiversity in the river and to keep sediment balance between the river and the beaches.
- Dam operation also has the ability to adversely affect day to day river flow patterns and those which occur during a significant storm event. The river is very sensitive to the dam's flow regime, an intermittent flow being more damaging than a homogenous flow

Figure 2-1 provides a summary of the key catchment issues.



Bay of Plenty REGIONAL COUNCIL

RIVER SCHEME SUSTAINABILITY PROJECT

Final

RANGITAIKI-TARAWERA KEY CATCHMENT ISSUES

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Figure: 2-1

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3 IDENTIFICATION OF FLOOD MITIGATION OPTIONS

Flood mitigation options have been identified to address the issues previously listed in Section 2.5. Table 3-1 lists the type of options ("T"), their applicability, objectives as well as their pros and cons in terms of relative costs, environmental impacts and social/cultural factors. Mapping of the options numbered in **Table 3-1** is provided in **Section 4**.

Our approach has been to consider structural and non- structural options. Structural options can be categorised by detention, retention, containment or diversion or a combination of more than one of these elements. All options have been considered in light of the stakeholder consultation already carried out by BoPRC and within the constraints of the catchments which are outline below;

- The storage potential of Lake Tarawera but the limited catchment area and the short steep channel down the Rangitaiki Plains
- A large area of catchment that generates low flood runoff because of the high infiltration features of the soils and the exotic forest cover.
- The Rangitaiki catchment with its geology, numerous short tributaries on the plateau and a long main channel mean that flood management options along the main stem of the river are most effective.
- The high headwater plateau that lends itself to consideration of water diversion
- The flood attenuation capacity of the existing dams and limited additional locations for storage of significant volumes
- A currently restricted flow capacity in the channel below the Matahina dam across the Rangitaiki Plains where there is excess energy because of the sediment load trapped by the dam.
- The structural integrity and level of service of the current stop bank system
- Potential increase in capacity of the Reid's Canal system
- The extensive and drained flood plain that is close to sea level and below sea level in some locations.

Table 3-1 Rangitaiki Tarawera Flood mitigation options

Nb	T	Option	Applicability	Project Reference	Objective	Pros	Cons
0A		Do nothing apart from continuing maintaining the stopbanks	Do not apply any further structural options in the Rangitaiki-Tarawera catchments, just continue maintaining the stopbanks *Stopbanks discussed by BoPRC*		Status quo: maintain same or similar level of risk of flooding in the catchment	Costs well understood and will continue into the future Environmental effects continue as under status quo	Will not mitigate flooding Flood risk will continue to increase with climate change and increased need for stop bank integrity. Cost and issues will continue if BoPRC continues to maintain stopbank system
0B		Do nothing at all	Do not apply any mitigation option at all		Do absolutely nothing to mitigate flooding		Will not mitigate flooding Flood risk will continue to increase with climate change and increased need for stop bank integrity Level of service will deteriorate if no further maintenance is carried out
	Structural	**Drainage upgrade works**					
1A		Diversion of flood volumes or water from the river: channelling and control of diversion waters to provide a flooded area/ large wetland or offline storage	Use the Tarawera Lake to hold the runoff or even divert some other surrounding lower areas into it. If the spare capacity of the low Tarawera river is sufficient then it can be used to release pressure in others low areas.	US – Colorado (URS): Dry Creek Drainage Improvement Project US – Louisiana (URS): Mississippi River Diversion into Maurepas Swamp AU – various URS projects in River Murray, Chowilla, Pike, Katfish and Gunbower Forest floodplains US – Louisiana (URS): Install 15MW Power Generation for the Sewerage and Water Board of New Orleans, Carrollton Facility Cf. internal URS work related to Waikato- Irrigation/Hydro Potential – Transboundary option	To reduce the peak flow in the Tarawera and/or Rangitaiki rivers in large events Reduce the risk of flooding in the Rangitaiki plains To capture the excess of storm water for other uses (recreation, irrigation, hydroelectric, etc.) to provide an extra income to invest in the catchment	Reduce risk in low lands by controllably flooding others areas A canal or pond would provide an opportunity for recreation areas Sustainability (pond/lake creation) Can be used for irrigation / generates offset. With the use of controlled flooded areas, "sale " of stored water could be used to provide compensation to farmers (permanent / seasonal) Transboundary transferring could be profitable	Loss of farming land Will not enhance the stopbanks Relies on Third party agreement or use Potential Iwi issues Reduces some of the volume in the hydroelectric dams for power generation if water is to be diverted to neighbour catchments upstream of the hydroelectric dams Diverted flow unlikely to reduce flood peaks
1B			Offline storage in the lower Rangitaiki plains by using spillways and/or gates on the stop banks. Could be linked to Rangitaiki Community Irrigation Scheme				
1C			Diverting water from western upper catchment of the Rangitaiki river towards Reporoa Basin (Waikato) through a tunnel or channel to storage		Revenue Generation	Will produce an offset by income from selling water and/or hydroelectricity Selling water diverted from Rangitaiki river to elsewhere in catchment or Waikato region (Ohakuri subcatchment) as irrigation demand is high and water resources are not sufficient.	Will not enhance the stopbanks Relies on Third party agreement or use Potential Iwi concerns Reduces some of the volume in the hydroelectric dams for power generation if water is to be diverted to neighbouring catchments upstream of the hydroelectric dams Diverted flow unlikely to reduce flood peaks

Nb	T	Option	Applicability	Project Reference	Objective	Pros	Cons
1D			Diversion of flood flows between Rangitaiki and Tarawera Rivers		Manage flood peaks and reduce flood extent.	Potential to reduce pressure on stopbank system and flood risk.	Would require canal to be constructed that allows two way flow between the rivers to account for time differential of flood peaks. Stakeholder issues with transboundary diversion of waters.
1E			Use of water in the upper catchment for irrigation purposes as per proposed Galatea Community Irrigation Scheme		Increase primary production	Irrigation will increase production Some storage benefits within the 20km long irrigation canal Agreement alreadyreached with Trust power to use excess water when not required for irrigation. Increased production the Galatea could offset future reduced f production on the Plains should agricultural activity decrease over time.	Relatively small storage volume compared to peak flood flows. Stakeholder issues and reliant on third party agreements for location of canal.
		Drainage Facilities / Infrastructure					
2		Improved Dam Operation: Operational regime, SCADA system (and links to flood Forecasting - Early warning system, see option 10)	Apply the system to the existing dam schemes Changes to operational regime at Matahina and other dams to maximise storage capacity for predicted events	US – Colorado (URS): Dry Creek Drainage Improvement Project US – Louisiana (URS): Elmwood Pump Station and Fronting Protection	Synchronisation of the dams and any available resource in the catchment to manage capacity during a flood emergency.	Optimised flood storage Flood forecasting option Risk management	Need agreement with Dam operators to change regime and monitor Need ability to monitor and trigger alerts through Council Capital cost
3		Dam improvement / Management revision and optimisation	Reimplementation of the Matahina Dam diversion tunnel to be used as sediment corridor to establish a healthier balance in the lower Rangitaiki River.		Regularly let sediment pass	Sediment release to river, improve soil composition-structural integrity Sustainability Flood Control Optimisation	Ongoing maintenance cost to keep tunnel clear Requires agreement of power company
4		Construction of new dam (e.g. flood/dry dam)	Potential new dry dam downstream of Matahina dam. Two potential locations as shown in the map. Build a plant upstream or downstream to supply alternative energy using the excess volume of water in Matahina dam (and/ or applicable to a new dam)	UK – Scotland (URS): Galston Flood Prevention Scheme US – Colorado (URS): Dry Creek Drainage Improvement Project AU (URS) North Para Dam project US – Alabama: Taylorsville Dam (earthen structure: flood dam)	To provide online flood storage and management for flows over a certain threshold	Some Flood control dam can be "environmental friendly" (AU), i.e. having a smaller footprint area, reducing environmental effects and reducing resource demand / carbon footprint A dry dam allows a normal flow and river health when flows are under the defined threshold.	Stakeholder issues The volume available for storage is important but may be limited by the power house level at Matahina Dam The benefits and threshold flow will depend of the way Matahina dam operates
5		Construction of new power dam	Identification of new locations required. Potentially as part of Galetea Irrigation Scheme. *Discussed by BoPRC*		Creation of alternative energy sources: hydroelectricity, geothermal	Will mitigate floods through increased storage capacity	Environmental Effects Stakeholder issues

Nb	T	Option	Applicability	Project Reference	Objective	Pros	Cons
6		Remove the dam and replace with other facility	Remove Matahina Dam and replace with alternative such as a dry dam A dry dam or a series of small dams can be placed instead with a smaller storage and increased flood protection purposes		Remove the dam to re-establish the flow and sediment balance in the Rangitaiki River	More sustainable Sediment balance and ground stability in the lower Rangitaiki river Will enhance the river's health and biodiversity Will open opportunities for off-line storage for irrigation Uncountable opportunities in the recovered land, tourism, farming	Capital costs Cost of operation Power generation industry would need to be moved to other less sensitive environments
7		Tidal Gates closed to the river mouth	Improvement of existing tidal gates systems *Discussed by BoPRC*	AU – Melbourne (URS): City of port Philip Drainage upgrade program	Prevent tidal cycle affecting up stream environment and flow capacity	Attaching a tide gate to the outfall reduces sea water ingress/surcharge & allows additional capacity of the existing drains while river basin storage is filling Potential sediment erosion reduction It can be used to hold water in the river during Matahina Dam operation and reduce the amount of sediment flushed out	Not efficient as volume trapped has to be significant to hold the river flood No Storage in the River Daily operating regime would need to be developed
		River Options					
8		River restoration and improved integrity of stopbanks: - Erosion protection: rip rap, geotextile fabric, steel and vinyl sheet pile, deep soil mixing, wick drains, light weight aggregate - shape of floodwalls (e.g. T-walls, mitre gates) - improvement by increasing the height of stopbank - Selective river reach straightening	Localised application of straightening and widening the Rangitaiki river in some areas / widen the canal and reinforce the banks Another option is to rebuild a second line of stopbanks further out along the riverbanks and let the river naturally develop and widen in these areas. *River straightening discussed by BoPRC*	US – Colorado (URS): Dry Creek Drainage Improvement Project US – Virginia (URS): Potomac River Waterfront Flood Mitigation Study, city of Alexandria US – Louisiana (URS): Levee Improvement project US – Louisiana (URS): Task Force Guardian - Hurricane Katrina Storm Repairs to Levee System US – Louisiana (URS): Hurricane Protection Office (HPO) LPV 105-111 US – Louisiana (URS): Houma Navigation Canal Lock and Floodgate US – Louisiana (URS): Hurricane Storm Damage Risk Reduction System US – New Jersey (URS): Green Brook Flood Control Study UK – Scotland (URS): Galston Flood	Meet flood protection requirements Reduce the risk of breach in the stopbanks by providing an efficient erosion protection, or by increasing the capacity of the river to reduce velocity and levels. Reduce the head losses in some areas by straightening and widening the river. By reducing the flow velocity it reduces the erosion and promotes sedimentation in the river bed.	Cost effective Reduced Erosion Increased Stopbank structural integrity Potential improvement in biodiversity with reduced erosion but depends on methods and whether it creates habitat Flood mitigation ecological implications - a wider river could be closer to a natural state A proper design can control erosion if velocity is increased in some areas. A straighter river is subject to reduced erosion forces.	Capital cost Degree of sustainability is subject to the climate change predictions and the ecological state desired for the river Straightening increases velocity of flow that needs to be properly designed Implies further modification of river system Potential sediment issue in some areas

Nb	T	Option	Applicability	Project Reference	Objective	Pros	Cons
				Prevention Scheme Various projects in the Netherlands			
		Building based solutions					
9		Upgrade / Re-construction to increase conveyance capacities: bridge raising / canal crossing structures and roadway reconstruction	Localised structures can be identified. *Discussed by BoPRC (2008 report): new replacement bridge*	US – New Jersey (URS): Green Brook Flood Control Study US – Louisiana (URS): Miscellaneous Urban Drainage Design Projects US – (URS): Bridge Replacement on US 90, Program and Construction Management Services	To reduce head losses in the river due of undersized bridges or other crossing structures and thus reduce flooding upstream of structures	Localised solution to marginally increase the capacity of the river in areas where it is required.	Solution is not sustainable on its own. Localised benefit
10		Emergency response improvements (action, evacuation, SOP)	Link to Matahina and other storage and conveyance infrastructure to develop tiered emergency response	US – Virginia (URS): Potomac River Waterfront Flood Mitigation Study, city of Alexandria US – (URS): Worldwide Bridge and Dam inspections at US Military Installations	Monitor the flood event and link to an emergency procedure or tiered response. Prediction would give time for community in low areas to react and follow emergency actions.	Flood forecasting Optimisation of catchment storage based on real time information therefore opportunity to optimise flood response Risk management Community information and education	Need ability to monitor flows and trigger alerts through Council Capital cost
11		Public education programs on flood-proofing principles and alternatives	Educate community and engage in mitigation options as appropriate	US – Virginia (URS): Potomac River Waterfront Flood Mitigation Study, city of Alexandria US – New Jersey (URS): Green Brook Flood Control Study	Increase public awareness and engagement	Increased awareness and buy in Improved stakeholder input and relationships	Time intensive to implement
12	Non structural	Existing landuse management – could include changes in farming practices in response to flood risk	To allow dairy industry to grow, together with other activities in other areas of the catchment. Differential rating schemes – based on benefit. Changes to farming practices to adapt to flood risk. Land use management will protect the forestry areas in the upper catchment and focus on the plains development. Impose increased development controls *This option has been discussed by BoPRC: land use changes, upstream land use (e.g. forestry to keep to reduce flooding downstream)*	AU – Melbourne (URS): Gunbower Forest Hipwell Road US – Virginia (URS): Potomac River Waterfront Flood Mitigation Study, city of Alexandria NZ - Awanui (Northland region) and Taieri (Otago Regional Council) – implemented differential rating systems based on benefit derived from flood management schemes	Maintain sustainable primary production and manage development in flood prone areas Fund flood management schemes	Opportunities to increase production and lower associated water quality issues with practices such as herd homes. Opportunity to maintain dairy farming and have it adapt and respond to changes in flood management strategy Opportunity to develop differential rating system based on relative benefit derived from the flood management scheme. Thus potential for funding capital works and incentives for farmers to adaptive practices. Maintain and controlled the amount of flow drained to the lower catchment Maintain large forest areas protected	Does not prevent flooding Rely on 3rd parties agreement In terms of the health of the new environment, it does not solve the sediment imbalance produced by the Matahina dam

Nb	T	Option	Applicability	Project Reference	Objective	Pros	Cons
13		Future changes in landuse management to manage inundation effects eg: creation of emergency retention areas, land acquisition / farm areas to be allocated for other purposes. Change of the landuse into wetland or flood areas, etc. Elevated walkways, dry flood proofing for residences / businesses, inlet and roadway improvements	Relocate the agriculture activities in the upper catchment and creation of a wetland *Creation of floodable areas has been discussed by BoPRC*		To maintain levels of runoff controlled in the catchment in order to control floods in the lower Rangitaiki plains	Opportunity to create new landuse plan for the whole catchment Return to original ecological state in the Rangitaiki plains would be encouraged (waterbird breeding, healthy populations of resident native fish) Increase safety of population / stock Opportunities for new primary production in the lowlands – rice / Aquaculture Reduce the dependency of Matahina Dam operation rules	Limit development of the upper catchment and allow for development runoff implications with the flood management approach The restriction of the upper landuse is not a sustainable alternative for economic reasons
14		Define minimum building flood levels, raising building platforms for farm buildings & regulate new consents as they are in risk area	*Discussed by BoPRC*	NZ – numerous councils implement this approach.	To properly manage landuse on risk of flooding at a property level	Increase safety of population and stocks Relatively simple option and if stock and property is made safe then allowable flood areas may be developed If herd home approach is adopted then potential to increase productivity and reduce water quality effects.	Needs to be used as a complement of other options Localised but effective approach
15		Risk Management measures implementation: e.g. strategy, flood proofing facilities	Define a risk management strategy and dissemination of flood risk information to local residents Install flood proof power generation capabilities (applicable to facilities such as Dairy factories, Edgecumbe facilities, WWTP? etc.)	UK – Essex (URS) Essex Local Flood Risk Management Strategy US – Louisiana (URS): Install 15 MW Power Generator for the Sewerage and Water Board of New Orleans, Carrollton Facility	Implement a risk management strategy and measures to react more effectively in case of a flood event	Risk management Flood consequences will be mitigated in these flood proofing facilities Social Impact	Does not mitigate flood event in general Short term, localised response
16		Regional / District Plan changes	Changes to Policy, Objectives and Rules in Regional and District Plans		Better control land use and development and allow flexibility with respect to operation and storage in power generating dams	Increase storage in upland areas Avoid increases in runoff due to development Manage development to minimise flood risk Encourage new forms of landuse in lower catchment	Timeframe for plan changes Longer term solution so will not mitigate flood effects in shorter term Appeals process and submissions from stakeholders
		URBAN DEVELOPMENT OPTIONS					
17		LID catchment solutions in case of catchment development occurring: WSUD (Water-Sensitive Urban Design)	Not currently applicable in rural setting but will become relevant if new urban areas are created	AU – Melbourne (URS): City of port Philip Drainage upgrade program US – New Jersey (URS) Green Brook Flood Control Study US – Louisiana (URS): Miscellaneous Urban Drainage Design Projects US – Florida (URS): Comprehensive	Reduction of properties and buildings affected by flooding	Sustainable approach Will mitigate Flooding	Will not solve the flooding issue Small impact in large catchment

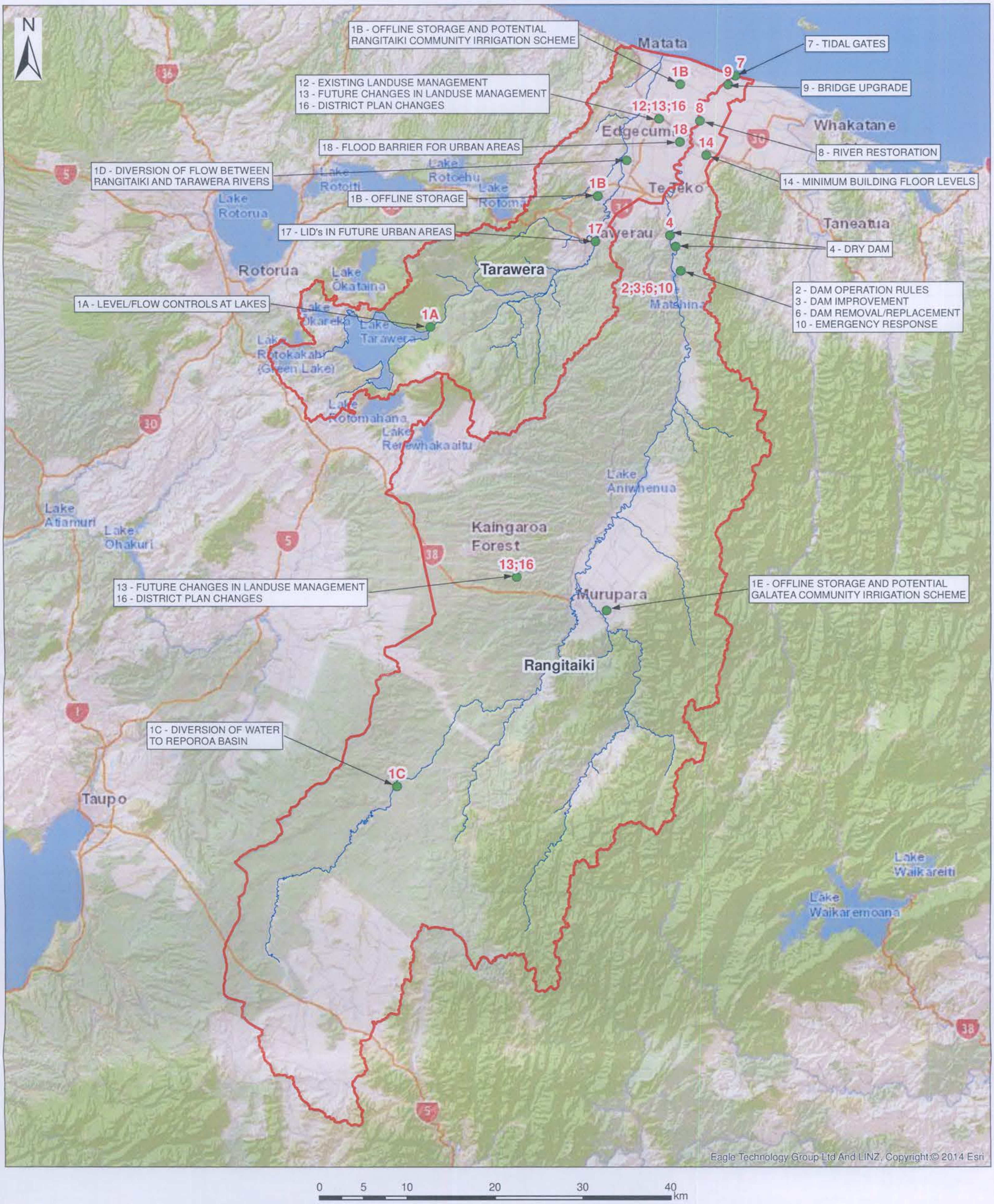
Nb	T	Option	Applicability	Project Reference	Objective	Pros	Cons
				Everglades Restoration Plan UK (URS): Developing Urban Blue Corridors			
18		Construction of a flood barrier encircling key infrastructure e.g. factories, townships, power stations Scour protection provided on protected sides of flood walls Reinforced turf provided on the protected side of earthen berms	Not directly applicable unless: Flood barrier encircling the townships (e.g. Edgecumbe?) / the farms	US – Louisiana (URS): Alliance Refinery Flood Barrier Project	Scour protection: to increase durability in the event that the wall is over stopped Reinforced turf: to prevent erosion improving the survivability of the system Alignment of earthen berms and sheet pile flood walls as well as the foundations for the flood gates: accommodate to raise the level of protection	Flood consequences will be mitigated inside the flood barrier	Only applicable to local areas Does not mitigate flood event in general

4 MAPPING

Mapping of the options numbered and listed in **Table 3-1** is provided in **Figure 4-1**.

Some of the options have not been mapped as:

- Options 0A and 0B do not apply any structural methods;
- Location of option 5 (potential construction of an additional power dam). A suitable location has not been identified yet;
- Options 11 and 15 are linked to general public education program and risk management therefore implementation areas need to be discussed if these solutions are chosen



Bay of Plenty REGIONAL COUNCIL

RIVER SCHEME SUSTAINABILITY PROJECT

Final

RANGITAIKI-TARAWERA FLOOD MITIGATION OPTIONS

URS

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Figure: 4-1

Rev. A | A3

5 CONCLUSION AND RECOMMENDED OPTIONS

The options listed in **Table 3-1** have been considered and combinations of those suggested through a workshop process. The most promising options are discussed below and are recommended for further investigation.

There are four major sustainable scenarios that would promote long term stability in the catchment.

1. **Replace Matahina Dam with Dry Detention Dam** - If the criterion is to protect the Rangitaiki plains by providing a healthy river and promote more sustainable opportunities then one solution is to replace Matahina dam with a dry dam, and move the hydraulic generation capabilities to other less sensitive environments. The dry dam would allow free flow in normal conditions and promote a healthy river and beaches. For high flows the peak can be controlled and stored in a smaller reservoir. This solution would promote long life prosperity for the Rangitaiki plains, with new opportunities for development in the upper and lower catchments.

2. **Downstream Structural Works** - If the Matahina Dam and its current mode of operation remain unchanged, then possible application of a dry dam downstream of Matahina and re-alignment of the river. It would involve straightening and widening the river and providing erosion protection. As there is no sediment balance to be provided in the river, then a river protected against erosion would ensure a long term management of the catchment and offers opportunities to increase flood conveyance whilst improving ecological outcomes. The degree of works in the river would depend also of the secondary options considered for the area, such a secondary dry dam downstream of Matahina, increased operational control of flood volumes by the Matahina Dam and allowance for controlled flooded areas in the plains. If the Matahina Dam allows some degree of flood control it could permit further development in the upper catchment.

3. **Plan Changes** - Changes to Regional and District Plan policy, Objectives and rules to control land use to better manage runoff generated by land use and development and to increase flexibility of water resource management in the upper catchment such that capacity and operation of the Matahina Dam can be better used for flood management.

4. **Land Use Change on the Plains** - If the Matahina Dam is to prevail and the maintenance of the low lands is no longer sustainable, then a radical but sustainable solution would be to move the dairy industry to the western side of the upper catchment. This would vacate large areas in the plains that could then be used as controlled flooding areas (for example the area between the Tarawera River and Rangitaiki River) and used for community, alternative primary production such as aquaculture and tourism purposes. An over design of the resulting Rangitaiki Plains system should allow room for significant development in the upper catchment and has the potential to bring prosperity to the catchment.

In addition to the above four main options the implementation of detailed early warning system without any major changes in infrastructure could, based on response to real time flow data, maximize and optimise utilisation of the resources available in the catchment to control flood flows. The warning system would consider all the storage resources in the catchment and to inform and mobilize the community for an efficient use of them. It would involve early prediction of flood flows based on a real time weather prediction and flow/level validation. This option could incorporate a new dry dam downstream of Matahina Dam, new controlled flooding areas, and trigger other secondary smaller storage options from which water could then be "sold" for irrigation purposes.

Funding of future flood management schemes could be generated through the development and implementation of differential rating approaches based on the benefit derived from the relevant flood management schemes as demonstrated by the Northland and Otago Regional Councils.

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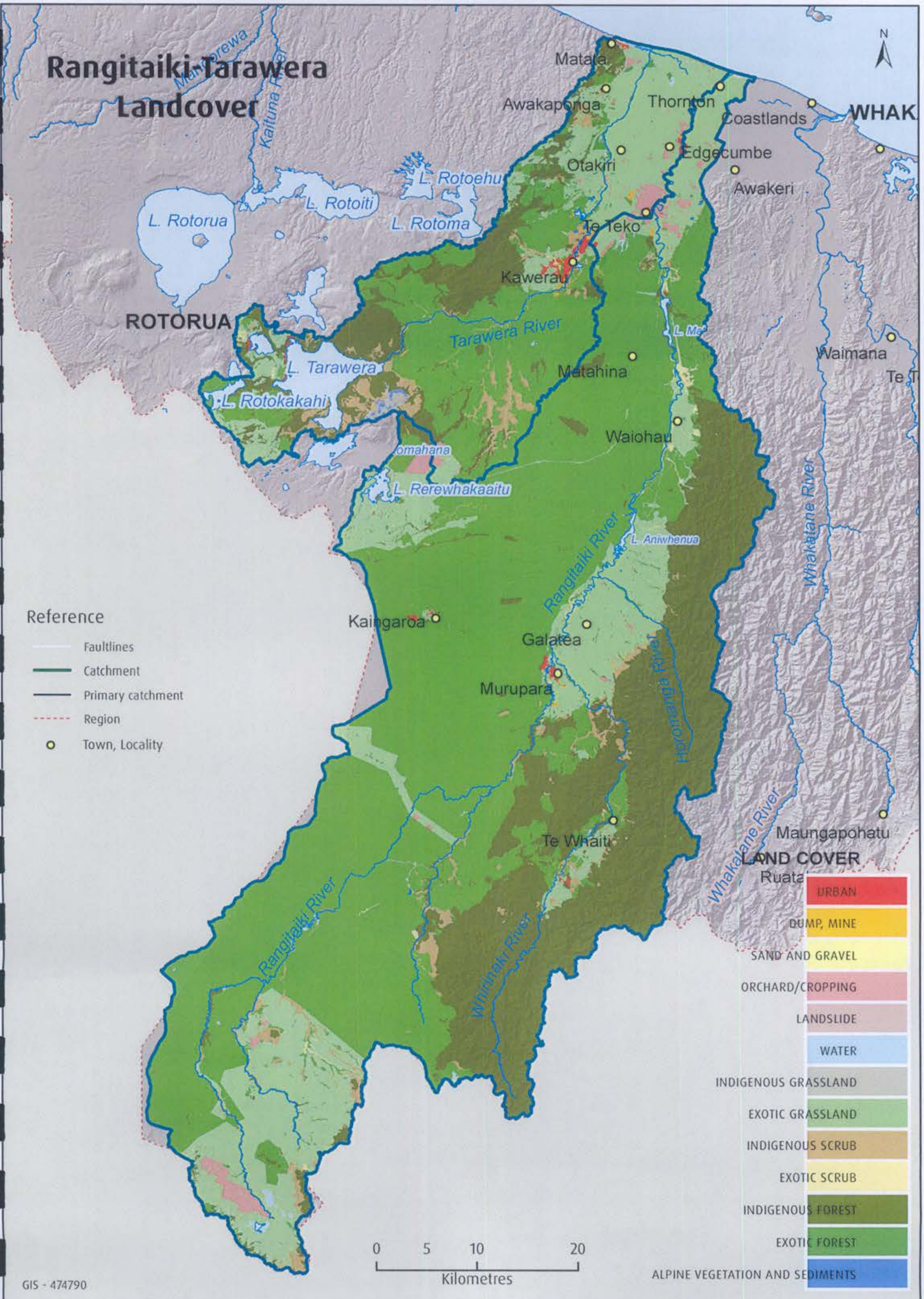
APPENDIX A RANGITAIKI TARAWERA CATCHMENT



Rangitaiki-Tarawera Landcover
Reference
Faultlines
Catchment
Primary catchment
Region
Town, Locality
LAND COVER
URBAN
DUMP, MINE
SAND AND GRAVEL
ORCHARD/CROPPING
LANDSLIDE
WATER
INDIGENOUS GRASSLAND
EXOTIC GRASSLAND
INDIGENOUS SCRUB
EXOTIC SCRUB
INDIGENOUS FOREST
EXOTIC FOREST
ALPINE VEGETATION AND SEDIMENTS
0 5 10 20
Kilometres
N
Matata
Awakaponga
Thornton
Coastlands
WHAK
Otakiri
Edgecumbe
Awakeri
L. Rotoehu
L. Rotoiti
L. Rotoma
L. Rotorua
Te Teko
Kawerau
ROTORUA
Tarawera River
L. Tarawera
L. Rotokakahi
Matahina
Waimana
Waiohau
L. Rerewhakaaitu
L. Aniwhenua
Rangitaiki River
Whakatane River
Kaingaroa
Galatea
Murupara
Horomanga River
Te Whaiti
Maungapohatu
Ruatahi
Whirinaki River
Kaituna River

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