Introduction to Groundwater Environmental Level Setting (Updated Feb 2019)

1.0 Introduction

As part of work towards a Rangitāiki Water Management Area (WMA) plan change process for water quality and quantity, we will consider whether we can set more specific groundwater allocation limits for hydrogeological units underlying Rangitāiki WMA than the current region-wide allocation threshold (in Proposed Plan Change 9).

While Council has commissioned detailed groundwater modelling, the results will not be available for some time. In the mean-time, the technical information available is the same as used for setting conservative region-wide interim groundwater allocation limits. Amendment to these interim limits would largely be dependent on willingness to accept some increase in the risk of effects on groundwater levels and stream flows in return for some additional water availability / less over-allocation. There is also a risk that when future information is available from detailed models, the allocation limit will have to be amended up or down again. The allocation zones may also change to better reflect hydrological units.

This paper introduces groundwater concepts and information (sections 2-5), then presents two options for community group feedback/advice (sections 6-7). Community group advice will assist Council to decide whether to progress consideration of Rangitāiki specific groundwater allocation limits at this stage or not.

2.0 Groundwater models now and in the future

The technical groundwater quantity information Council currently relies on for the Rangitāiki Water Management Area (WMA) is based on a **simple water balance model**. The simple water balance model is based on limited information and has greater uncertainty associated with it compared to more complex groundwater models that require more information.

A 'steady state' (magnitude and direction of flow is constant with time) MODFLOW groundwater model is being developed for Rangitāiki to help inform setting more robust groundwater quantity limits and results are expected in 2019. A 'transient' MODFLOW groundwater model (magnitude and direction of the flow changes with time) will then be developed. The transient model will provide a greater level of confidence than the steady state model. However, development of the transient model is dependent on the collection of seasonal groundwater level changes over a number of years and results will not be available for several years.

Options for setting groundwater limits based on the simple water balance model before either the steady state, or transient groundwater model results are completed, are discussed here.[1] Alternatively limits could be set based on the initial steady state MODFLOW groundwater model. This is likely to be more feasible in the Mid –Upper Rangitāiki than in the Lower Rangitāiki. This is because doing so in the Lower Rangitāiki will have implications on other adjacent WMA's that are not currently part of the community engagement process.

[1] Note: Any assessment of setting groundwater limits is based on effects on the groundwater and surface water bodies as a whole. Sufficient water may be available for allocation within groundwater limits to grant a consent. However, this does not necessarily mean there will not be any local effects on other water users or connected surface water bodies and these will continue to be assessed on a case by case (individual consent) basis.

3.0 Aquifer and Stream Types

There are generally two kinds of aquifers (or more accurately, two ends in the spectrum of types of aquifers): confined and unconfined as shown in Figure 1 below.

Unconfined aquifers are those into which water seeps from the ground surface directly above the aquifer. In an unconfined aquifer the water is not under pressure. A bore penetrating an unconfined aquifer will have a water level in it at the same level as the water table.

Confined aquifers are those in which an impermeable dirt/rock "capping" layer exists that prevents water from seeping into the aquifer from the ground surface located directly above. Water seeps into the aquifer from some distance away. In a confined aquifer the water is under pressure. A bore penetrating a confined aquifer will have a water level above the top of the aquifer.

Unconfined aquifers can interact with surface water bodies. **Gaining streams** are streams that receive water from these groundwater systems. **Losing streams** are streams that lose water to the groundwater system. Different parts of the same stream can be gaining and losing in different locations. The same part of a stream may be gaining or losing at different times. Streams may change between gaining and losing depending on the relative water levels between the stream and the groundwater system. Taking groundwater reduces the water level/pressure in the aquifer and may intercept groundwater discharging to a stream as base-flow, reducing the amount of water discharging to the stream, or even drawing water from the stream. The greater the amount of water taken from the ground, the greater the potential is for effects on base-flow to streams.

Figure 1 Groundwater movement in an aquifer (confined and unconfined parts of the aquifer are in blue)

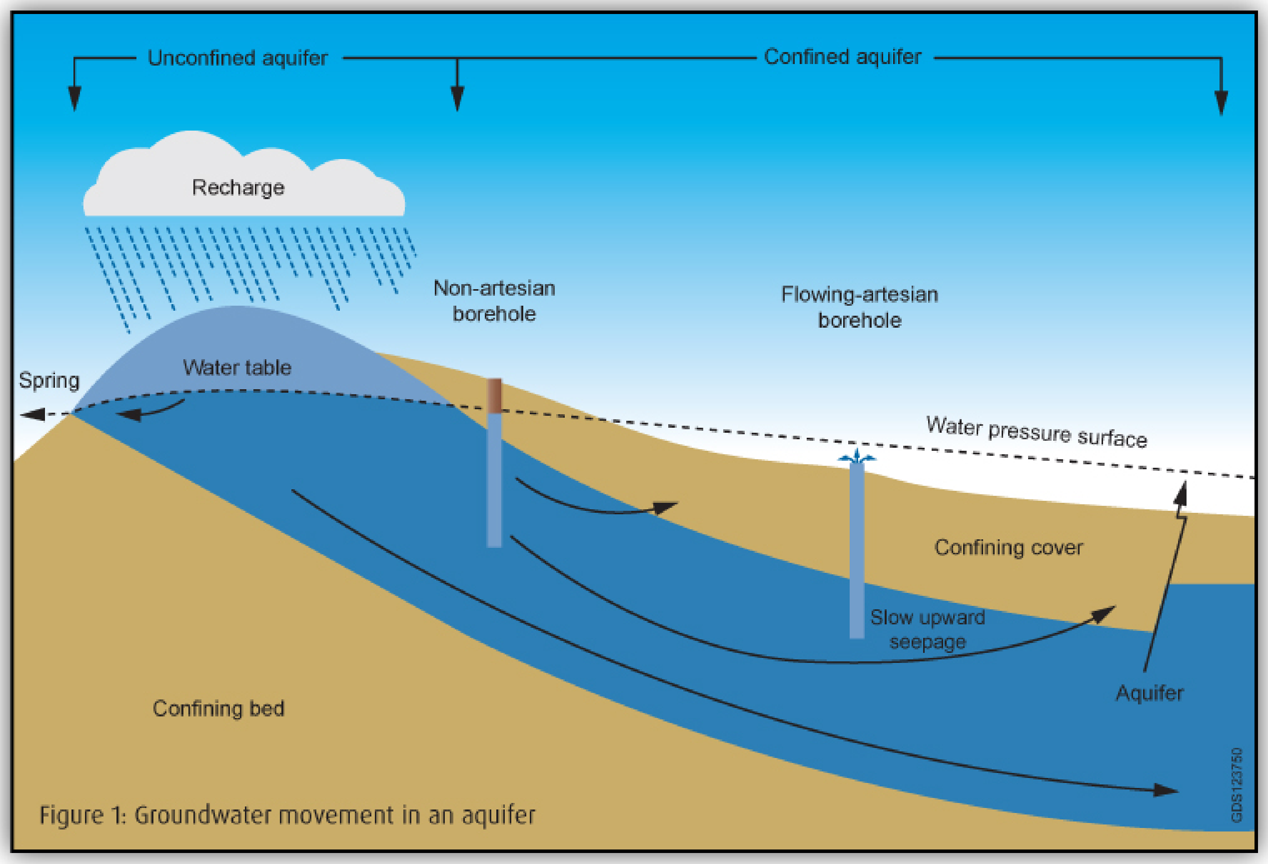


Figure 1: Groundwater movement in an aquifer

4.0 Geology and Allocation Zones

The Rangitāiki WMA is geologically complex. The Mid-Upper Rangitāiki groundwater area has the same boundary as the surface water catchment boundary above the Matahina Dam. The aquifers in the Rangitāiki Plains area extend across a number of different surface water catchments including: the Tawawera River catchment, part of the Rangitāiki River catchment and part of the Whakatāne River catchment. The MODFLOW groundwater model being developed includes the aquifers across the wider Rangitāiki Plains.

4.1 Mid-Upper Rangitāiki

The simplified surface geology and structure of the Mid-Upper Rangitāiki area is presented in Appendix 1. The area has greywacke basement in the Ikawhenua Ranges to the east. These rocks are separated by north-south trending faults from volcanic deposits to the west. The volcanic rocks to the west are predominantly ignimbrites (Whakamaru Group, Matahina Formation and Kāingaroa Formation) and more recent localised pumice deposits (Okataina volcanics and Taupō Group). There are Tauranga Group sediments on top within the Galatea, Waiohau and Minginui basins located along the north-south trending faults. The greywacke rocks are generally not productive aquifers, except where they are highly fractured. The ignimbrites, Tauranga Group and pumice are productive aquifers. The aquifers that groundwater is taken from are generally assumed to be unconfined.

Council's current simple water balance model establishes groundwater allocation zones for the purpose of managing groundwater allocation and use. These zones are based on surface water catchment boundaries and the simplified hydrogeological units. Some of the zones actually contain different hydrogeological units at greater depth that may not be unconfined. The groundwater allocation zones for the Mid-Upper Rangitāiki area are presented in Appendix 2.

4.2 Rangitāiki Plains

The simplified structure and geology of the Rangitāiki Plains is presented in Appendix 3. The greywacke basement in the area has been subjected to on-going block faulting that has formed the Whakatāne Graben. The graben is a basin like structure created by the block faulting. There are a number of major faults in the area. The Edgecumbe Fault has caused the major displacement of up to 2.3km vertically. The eight major geological units overlying the greywacke basement are:

- Q1 non-marine: recent terrestrial sediments (various)
- Q1 marine: recent marine sediments (pumiceous sand)
- Q2-Q4 non-marine: older terrestrial sediments (gravel)
- Q5 marine: Marine sands
- Q6-Q8 non-marine: older gravels
- Volcanics undifferentiated: Various volcanic material (in the south)
- Matahina Ignimbrite
- Greywacke basement (oldest)

The Matahina Ignimbrite is a productive aquifer. It becomes increasingly confined by the overlying Tauranga Group material toward the coast.

Groundwater allocation zones were established for the purpose of managing groundwater allocation and use based on surface water catchment boundaries and the groundwater flow direction. The groundwater allocation zones are not separate aquifers or aquifer boundaries. They are simply management areas. Within these zones below the ground surface there are a series of different geological layers that form different aquifers. Groundwater can move between groundwater allocation zones. The groundwater allocation zones for the wider Rangitāiki Plains and area within the Lower Rangitāiki WMA are presented in Appendix 4. The MODFLOW groundwater model will better represent hydrogeological units.

5.0 Water Balance

Simple water balance calculations were undertaken to estimate the amount of groundwater recharge in each of the zones. Groundwater recharge is the portion of the rainfall that infiltrates into the ground to replenish the aquifer. The calculations were generally based on rainfall minus actual evapotranspiration.[2]

Residual groundwater recharge in each allocation zone was then determined by calculating groundwater recharge minus groundwater outflow to surface water i.e. 'base-flow'. The aim was to maintain groundwater levels to preserve stream base-flow. Surface water base-flow estimates were based on stream flow information.

In summary, the simple calculations for each groundwater allocation zone were:

Rainfall – evapotranspiration = **groundwater recharge**

Groundwater recharge – base flow = **residual groundwater recharge**.

6.0 Alternative Options for Groundwater Allocation Limits

The interim allocation limits in the Region-wide Proposed Plan Change 9 (PPC9) are based on 35% of the **residual groundwater recharge** calculated in each allocation zone.

Two options are considered for setting Rangitāiki specific groundwater limits before the MODFLOW model results are available.

Option 1 is to stick with the PPC9 limits based on 35% of the calculated **residual groundwater recharge**. Option 2 is to set limits based on a greater percentage of the calculated **residual groundwater recharge**. 50% of **residual groundwater recharge** was selected here to illustrate option 2. Potentially this could range from 35% up to 100% depending on the level of risk of alteration in groundwater levels and surface water flow that is accepted.

The following risk guidance for water balance models has been broadly estimated by scientists:[3]

- Low (up to 10% of **recharge**)
- Medium (11% to 25% of **recharge**)
- High (over 25% of **recharge**)

Groundwater allocation limits for the two options were expressed in terms of % of **groundwater recharge** within each groundwater allocation zones in order to compare them with the guidance provided above. Results are presented in Table 1 below.

A comparison of consented allocation to limits based on the two options is presented in Appendix 5.

[2] The approach used to estimate the amount of groundwater recharge in the Mid-Upper Rangitāiki was slightly different. It also included surface water run-off inflows and outflows. Quick flow was not included in the Rangitāiki Plains because good estimates of surface water inflows and outflows were not available at points into and from the Rangitāiki Plains.

[3] The level of risk will be different for other models that are expected to have greater levels of confidence. The proposed National Environmental Standard on Ecological Flows and Water Levels, Discussion Document, suggested 15% and 35% of recharge depending on the type of aquifer. This was not specific to the method used to calculate recharge.

Table 1 Allocation limit options as % of groundwater recharge

Groundwater Management Zone		**Option 1 – PPC9** (35% of residual groundwater recharge) % of recharge	**Option 2 – alternative** (50% of residual groundwater recharge) % of recharge
Mid-upper Rangitāiki	Headwaters	12.0	17.2
	Kāingaroa South	12.2	17.4
	Galatea Plain	12.7	18.2
	Minginui	12.3	17.5
	Kāingaroa North	12.0	17.1
	Pokairoa	12.6	17.9
	Waiohau Basin	8.8	12.5
	Matahina	10.1	14.4
	Ikawhenua	12.5	17.8
Lower Rangitāiki	Edgecumbe Catchwater	14.3	20.5
	Mangamamako	0	0
	Ngakauroa Stream	29.8	42.6
	Nursery Drain	5.4	7.6
	Rangitāiki Dunes	0	0
	Reids Central Canal	30.8	44.0
	Waikowhewhe	0	0

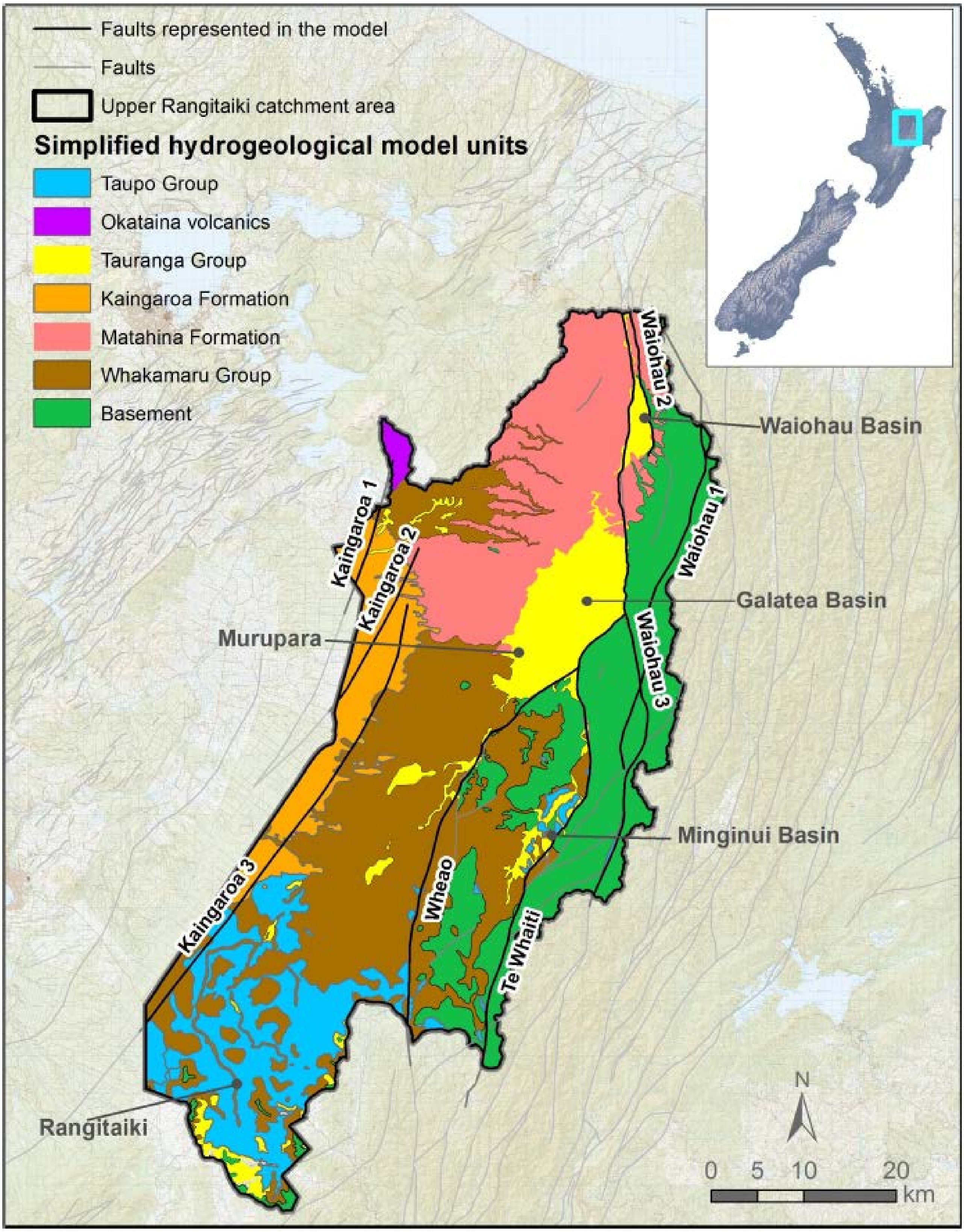
7.0 Options Assessment

Advantages and disadvantages of the two option considered are summarised in Table 2 below.

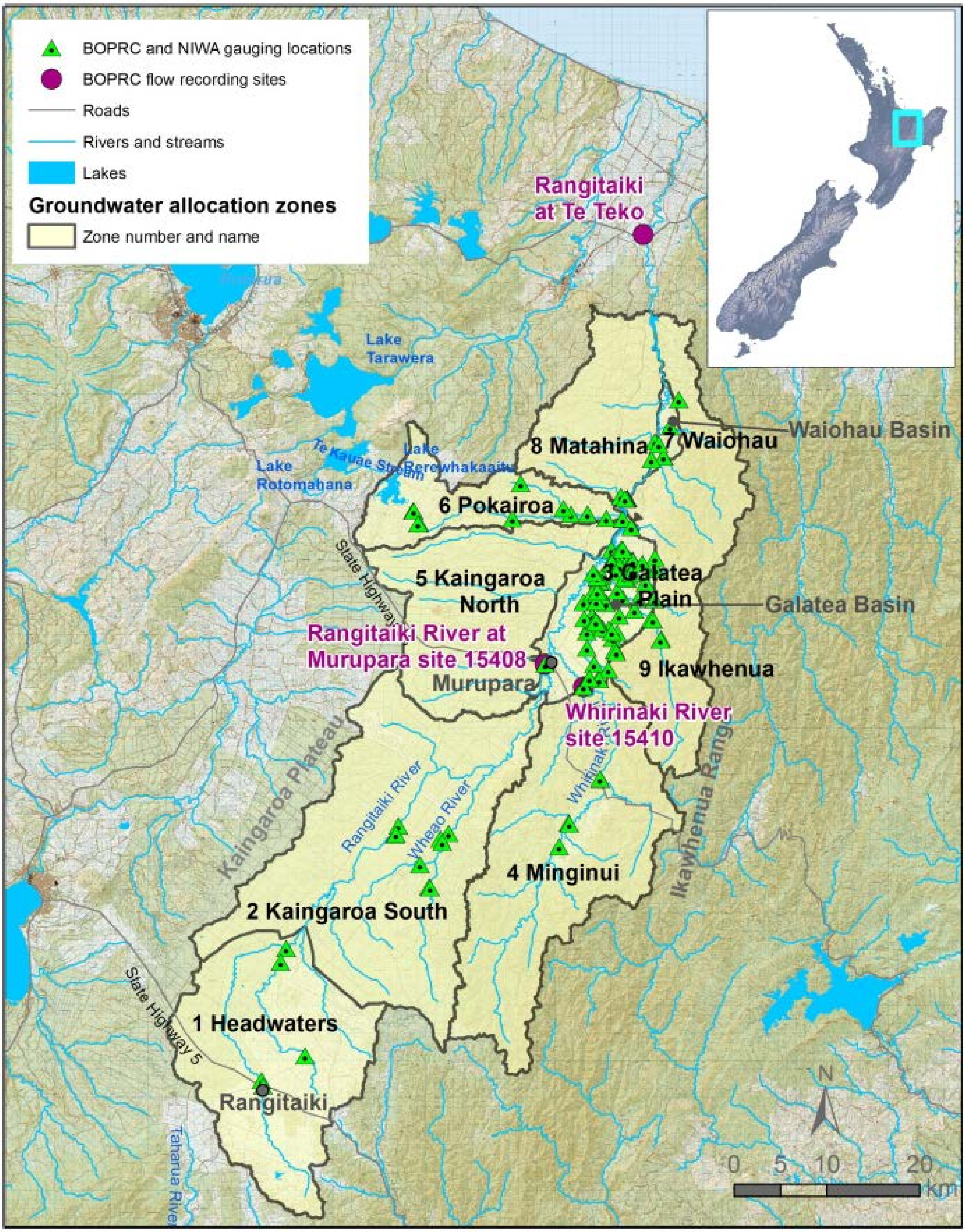
Table 2 Assessment of options

Option	PPC9	Alternative
Advantages	• Low/medium risk for Upper Rangitāiki • Low/medium risk for Rangitāiki Plains • Maintains status quo • Accommodates existing authorised takes except in 4 Rangitāiki Plains zones • Minimises allocation clawback potential in the future if MODFLOW modelling shows a need for more restrictive limits • No further change process required until more reliable/detailed modelling is available.	• Accommodates existing takes except in 4 Rangitāiki Plains zones • In some zones more water would be available; or the degree of over allocation would be reduced.
Disadvantages	• Does not accommodate existing authorised takes in 4 Rangitāiki Plains zones • Greater development constraint.	• Medium risk Upper Rangitāiki • Medium/high risk Rangitāiki Plains • Increase allocation clawback potential in the future if MODFLOW modelling shows a need for more restrictive limits • Relies on current simple water balance model and management zones.

Appendix 1


Faults represented in the model
Faults
Upper Rangitaiki catchment area
Simplified hydrogeological model units
Taupo Group
Okataina volcanics
Tauranga Group
Kaingaroa Formation
Matahina Formation
Whakamaru Group
Basement
Waiohau 2
Waiohau Basin
Waiohau 1
Kaingaroa 1
Kaingaroa 2
Galatea Basin
Murupara
Waiohau 3
Minginui Basin
Kaingaroa 3
Wheao
Te Whaiti
Rangitaiki
N
0 5 10 20
km

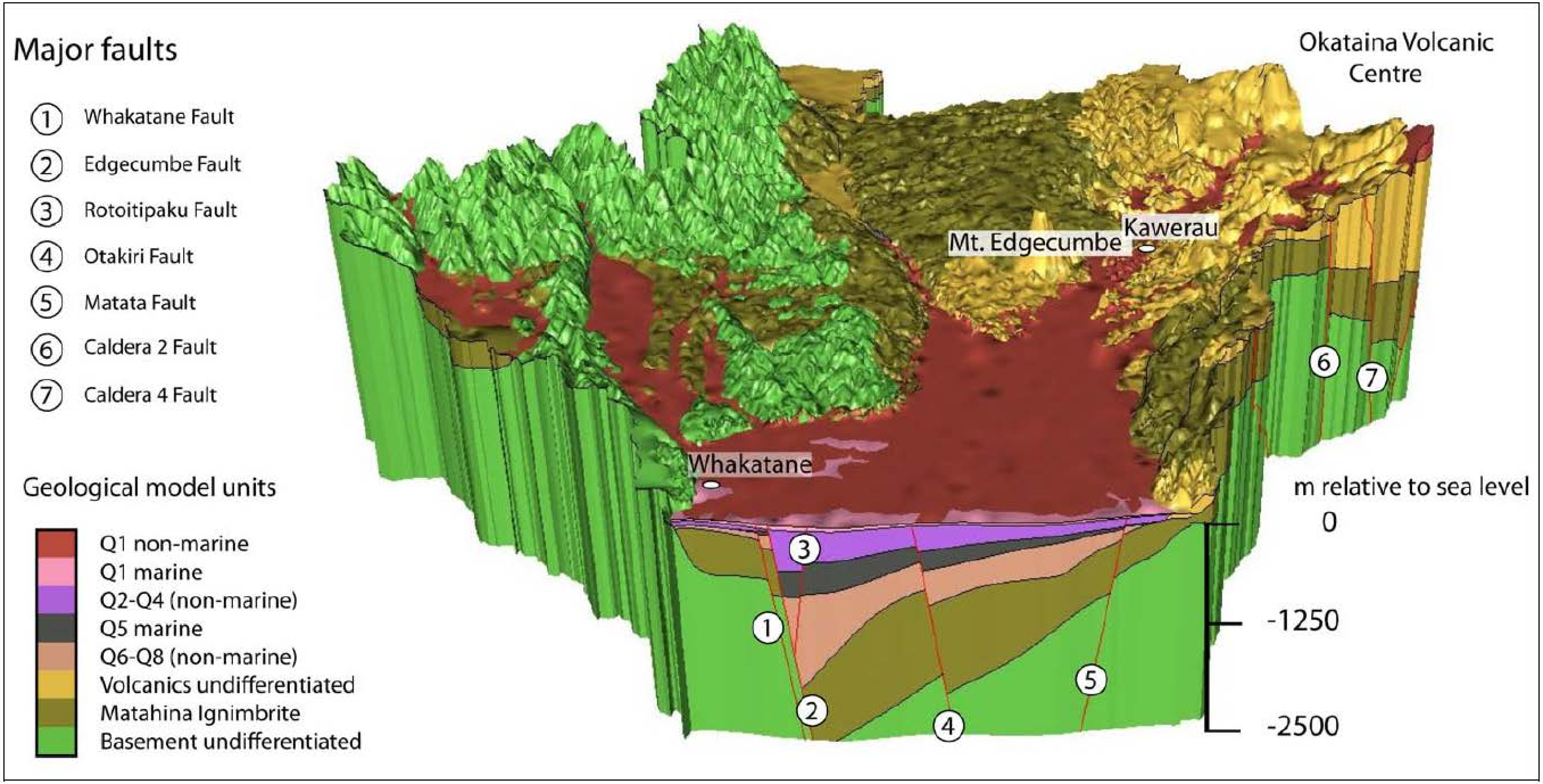
Appendix 2



BOPRC and NIWA gauging locations
BOPRC flow recording sites
Roads
Rivers and streams
Lakes
Groundwater allocation zones
Zone number and name
Rangitaiki at Te Teko
Lake Tarawera
Lake Rotomahana
Te Kauae Stream
Lake Rerewhakaaitu
8 Matahina
7 Waiohau
Waiohau Basin
6 Pokairoa
5 Kaingaroa North
3 Galatea Plain
Galatea Basin
Rangitaiki River at Murupara site 15408
Murupara
9 Ikawhenua
Whirinaki River site 15410
State Highway
Kaingaroa Plateau
Rangitaiki River
Wheao River
Whirinaki R
Ikawhenua Range
4 Minginui
2 Kaingaroa South
1 Headwaters
State Highway 5
Rangitaiki
Taharua River
N
0 5 10 20
km

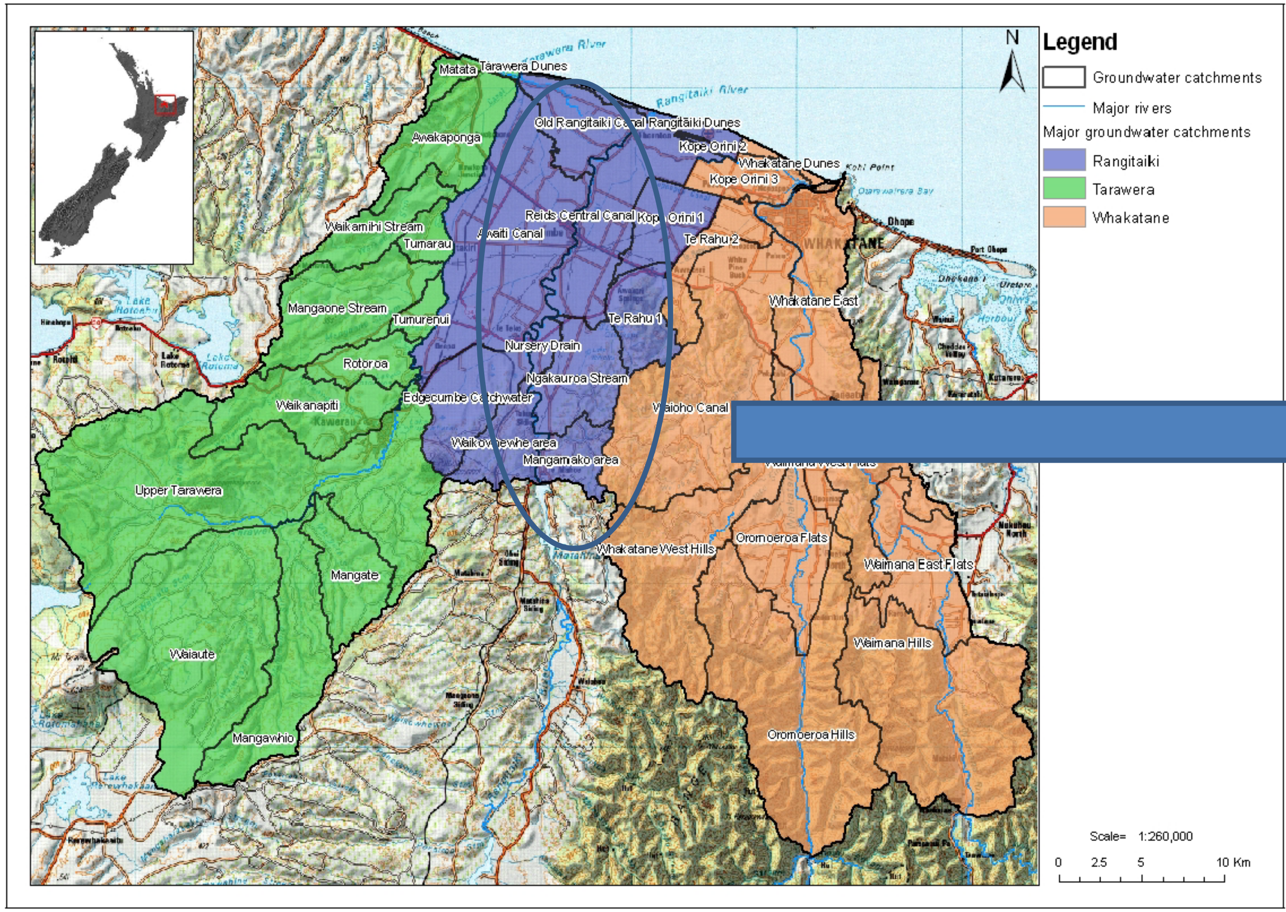
Appendix 3

Three dimensional model of the Rangitāiki Plains geological units and faults

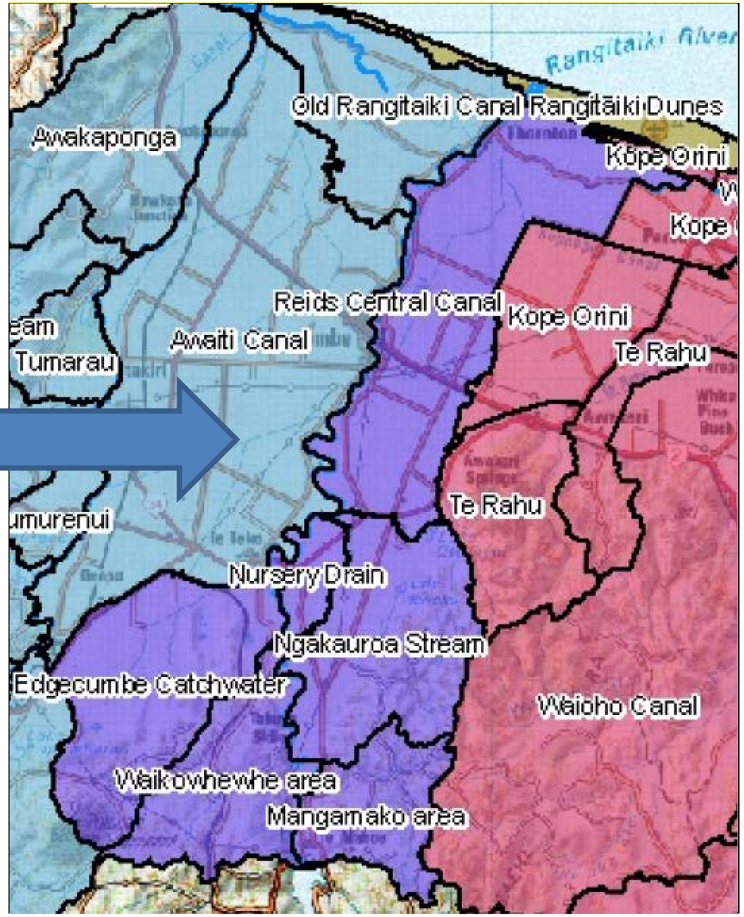


Appendix 4

Groundwater allocation zones for the wider Rangitāiki Plains



Groundwater allocation zones within the Lower Rangitāiki WMA (shown in purple)



Appendix 5

Comparison of consented allocation to limits based on the two options

Groundwater Management Zone		Consented Allocation[4] m^3/year	Option 1 – PPC9 (35% of residual groundwater recharge) m^3/year	Option 2 – alternative (50% of residual groundwater recharge) m^3/year
Mid-upper Rangitāiki	Headwaters	1460	35,320,320	49,406,400
	Kāingaroa South	0	44,150,400	61,758,000
	Galatea Plain	5,218,454	8,830,080	12,351,600
	Minginui	80,520	45,254,160	63,301,950
	Kāingaroa North	155,855	26,490,240	37,054,800
	Pokairoa	526,308	15,452,640	21,615,300
	Waiohau Basin	0	1,103,760	1,543,950
	Matahina	0	16,556,400	23,159,250
	Ikawhenua	0	23,178,960	32,422,950
Lower Rangitāiki	Edgecumbe Catchwater	1,402,914	3,355,430	4,793,472
	Mangamamako	18,250	0	0
	Ngakauroa Stream	4,754,449	4,845,506	6,922,152
	Nursery Drain	1,561,668	143,489	204,984
	Rangitāiki Dunes	116,250	0	0
	Reids Central Canal	1,881,966	5,750,590	8,215,128
	Waikowhewhe	702,720	0	0

[4] Based on the Bay of Plenty Regional Council Groundwater Allocation Map Tool, 1 February 2019
https://boprc.maps.arcgis.com/apps/MapSeries/index.html?appid=7a2ff1e0b0454bdb89498f0e019a23dd