Combined Kaituna and Pongakawa-Waitahanui Freshwater Futures Community Group Workshop 11 Notes: Groundwater Quantity

Pongakawa Hall, Old Coach Road, Pongakawa

Wednesday, 20 November 2019 commencing at 10.00am

Members present:	*Kaituna Community Group* - Barry Roderick (Chair), Claudia Hellberg, Hohepa Maxwell, Jon Fields, Julian Fitter, Mary Dillon, Matthew Leighton, Murray Linton, Paul van Den Berg, Richard Fowler *Pongakawa-Waitahanui Community Group* - Andre Hickson, Colin McCarthy, Dennis Walker, Grant Rowe, Councillor Jane Nees, John Garwood, John Cameron, John Meikle, Julian Fitter, Mike Maassen
Apologies:	*Kaituna Community Group* – Brian Thomas, Cor Verwey, Hendrik Metz, Ian Schultz, Jeff Fletcher, Jessica Dean, John Fenwick, Manu Wihapi, Maria Horne, Morgyn Bramley, Nick Webb, Councillor Paula Thompson, Peter Ellery, Vivienne Robinson *Pongakawa-Waitahanui Community Group* - Bernie Hermann, Bev Nairn, Darryl Jensen, Geoff Rice, John Rapana, Kevin Marsh, Melv Anderson
BoPRC Staff present:	Stephanie Macdonald & Kerry Gosling (Facilitators), Andrew Millar, Nicki Green, Sue Simpson (Water Policy), Raoul Fernandes (Science), Julie Bevan (Policy and Planning Manager), George Wood, Niamh Priest, Ngahuia Muru (Summer Student)

Related documents previously circulated:

Briefing Note - Workshop 11: Groundwater Quantity
The briefing note and workshop presentation are available online here – Kaituna[1] and Pongakawa-Waitahanui[2].

1. Welcome/karakia/introductions

Members were welcomed by the Chair and thanked for attending. Hohepa opened the workshop with a karakia. Apologies were noted. Julie Bevan, BoPRC Policy and Planning Manager, introduced herself. The BoPRC students gave a background on themselves. Nicki informed the meeting that Warren Webber had resigned from the group as he was moving to Blenheim. John Rapana would be representing Ngāti Mākino at future workshops, in place of Kepa Morgan.

2. Purpose of the day

Members were reminded the purpose of the group is to help council implement the National Policy Statement for Freshwater Management (NPSFM), confirm values, express preferred objectives, provide feedback on water quality and quantity limits and provide input and advice to council on solutions to manage activities within the limits.

This freshwater puzzle has many pieces. This workshop focuses on:

[1] https://www.boprc.govt.nz/our-projects/kaituna-maketū-freshwater-community-group/
[2] https://www.boprc.govt.nz/our-projects/pongakawa-waitahanui-freshwater-community-group/

- understanding the groundwater system in Kaituna-Pongakawa-Waitahanui WMA
- confirming values and objectives
- exploring modelling scenarios, results and implications for setting limits
- getting feedback on management options.

3. National and regional updates (presentation slides 7-12)

3.1 Regional update

Central government wants major changes to freshwater management and to put new legislation in place quickly. The community group and its work continue to be very relevant. The work will be useful in other catchments.

Submissions on central government's *Actions for Healthy Waterways: A discussion document on national direction for our essential fresh water* closed at the end of October 2019. MfE are summarising the 17,000 submissions for the advisory panel. The five member panel (David Sheppard - retired principal Environment Court judge, Maree Baker-Galloway, Tracy Brown, Antoine Coffin and Andrew Fenemor) will make recommendations by April 2020. Draft regulations will be released in May 2020. Final Cabinet approval is expected at the end of June 2020. The regulations are expected to come into force in July 2020 before the general election.

3.2 Regional update

Floodway and drainage bylaw review

This Floodway and drainage bylaw review[3] is a review of the council's Floodway and Drainage Bylaw 2008. It will affect the whole region including the Kaituna area. The review is currently in the pre-consultation stage. Public drop-in sessions have been organised. Jo Heath can be contacted (Jo.Heath@boprc.govt.nz) if your organisations would like a presentation.

The bylaw applies to drains, pumping stations, defences against water (including stop banks, floodwalls, stoplogs), river edge protection works and floodways owned or under the control of council. It does not apply to privately owned and operated drainage schemes.

Proposed Plan Change 9 (PPC9): Region wide water quantity appeals

Court-assisted mediation will take place on 4 and 5 December 2019 to try and resolve outstanding matters. A court hearing will be scheduled if sufficient progress is not made in mediation on resolving the appeals.

PPC9 includes region-wide interim limits for surface and groundwater quantity. Plan Change 12 will replace these with Kaituna-Pongakawa-Waitahanui WMA specific water quantity limits. The sub-regional groundwater quantity limits for the Kaituna-Pongakawa-Waitahanui WMA will be informed by the results of the recently developed groundwater model for the area, which will be discussed today.

Kaituna-Pongakawa-Waitahanui - Plan Change 12 timeline

A surface water quantity community group workshop is proposed for early next year. Discussion documents for the wider public will be drafted next year and staff aim to discuss these with the groups as well. This is a period of uncertainty in terms of central government's proposed changes to freshwater management legislation. Council needs more certainty about changes to the legislation before deciding whether one region-wide plan change, rather than current progressive sub-regional WMA based changes, is an option to meet the potentially reduced NPSFM timeline.

[3] https://www.boprc.govt.nz/our-projects/floodway-and-drainage-bylaw-review/

4. Hydrogeology and groundwater (presentation slides 13-19)

Key concepts and information on how groundwater systems work, interaction with surface water and the Tauranga geothermal system was presented. Details and response to questions are in Appendix 1.

5. Modelling (presentation slides 20-40)

The current Geological and Nuclear Sciences Limited (GNS) mass balance model and MODFLOW three-dimensional numerical groundwater model design were explained. Details and response to questions are in Appendix 2.

6. Groundwater values and uses (presentation slides 41-49)

Groundwater values, uses and management objectives were presented. Details and response to questions are in Appendix 3.

Group members were asked 'Are your values provided for in the list on presentation slide 42? Are there any others?'

Feedback:

- The mauri of groundwater needs to be included in health.
- How are ecological values recognised? Ecological values in streams are covered by the groundwater value associated with providing for base-flow.
- The level of nitrate contamination and manganese concentration in groundwater can affect what it is used for. Water quality values need to be considered.
- Groundwater discharges to connected surface water bodies provides cold water discharges into rivers which is important for ecological health.
- Groundwater is an important source of domestic supply.
- Western Bay of Plenty District Council has a consented combined instantaneous take from five bores of 145 litres/second. In summer, there are only 10-12 days where it is close to using the maximum consented volume. Annual use is significantly less than the maximum instantaneous flow rate multiplied by 365 days.

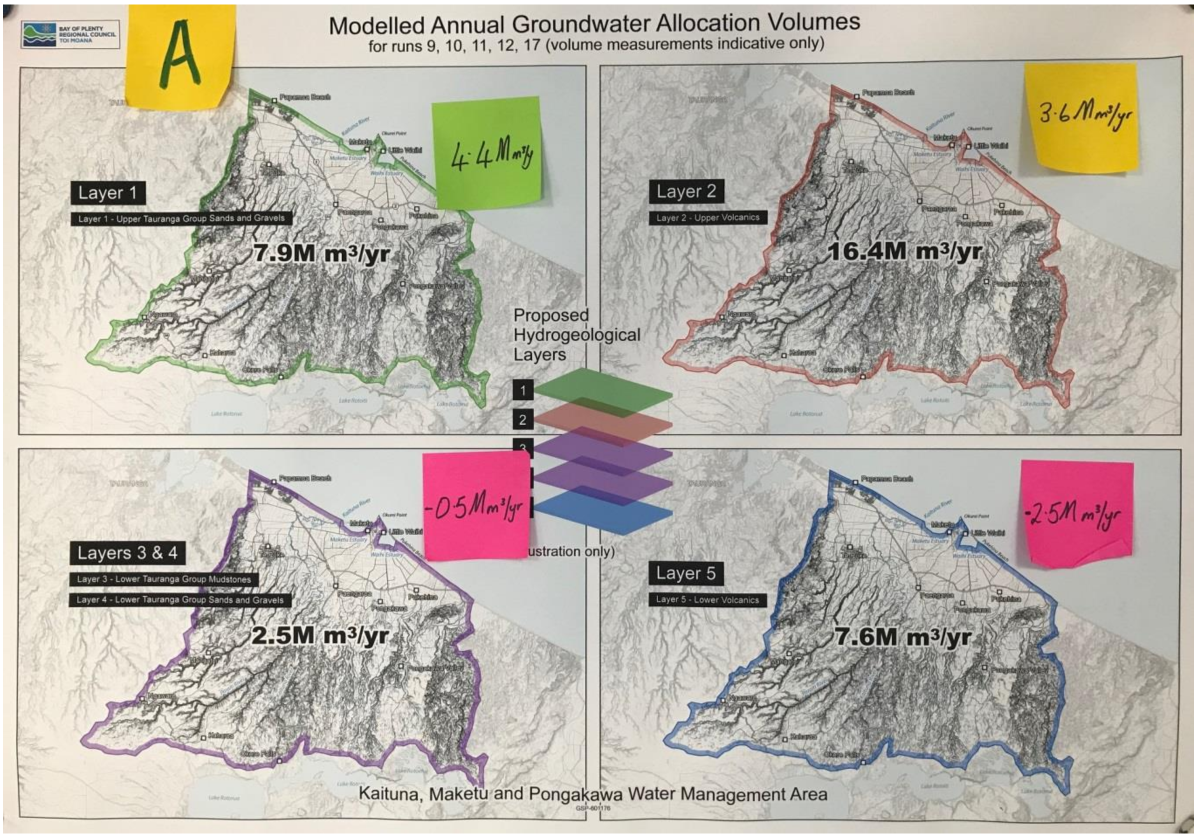
7. Scenarios and results (presentation slides 51-61)

Information was presented on modelling limitation concepts, the Kaituna-Pongakawa-Waitahanui MODFLOW model scenarios and results. Details and response to questions are in Appendix 4.

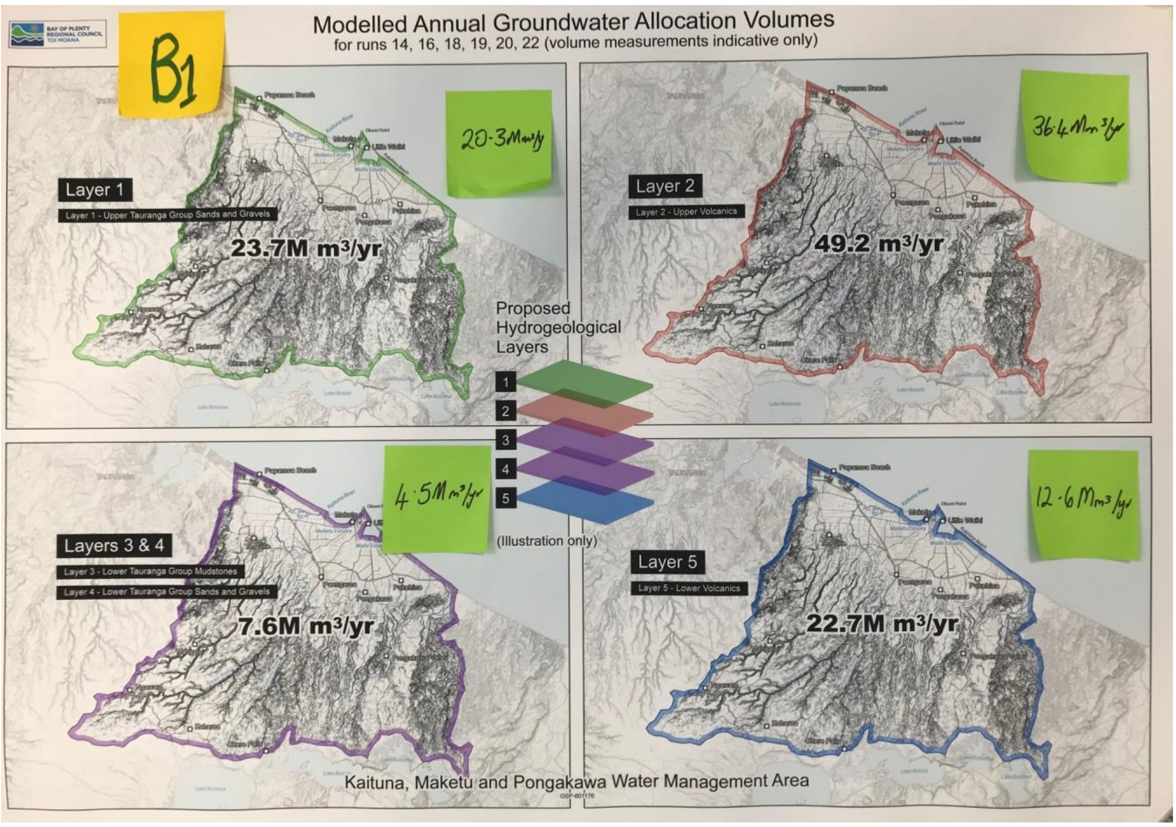
Separate possible allocation limits were determined using the model for each of the respective layers (and zones in the case of Options C1 and C2) shown in the maps shown below. Remaining allocation and over-allocation shown on the maps was calculated by subtracting the current allocation for each layer and management zone (where relevant) from the respective possible limits. Coloured 'post-it notes' on the maps indicate the following for each layer and management zone:

- Green = 0-50% allocated. The number expressed is the remaining allocation volume.
- Yellow = 50-90% allocated and the remaining allocation volume.
- Orange = 90-100% allocated and the remaining allocation volume.
- Pink = greater than 100% allocated. The number expressed is the over allocation volume.

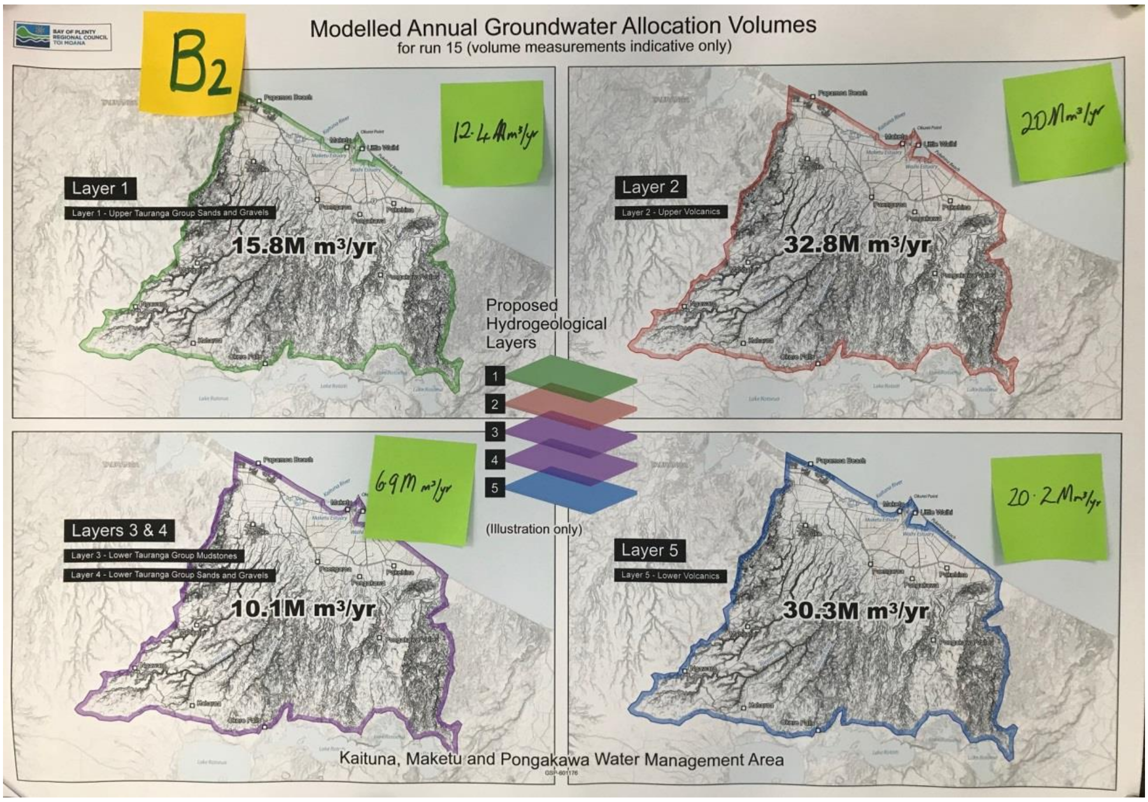
Option A results map



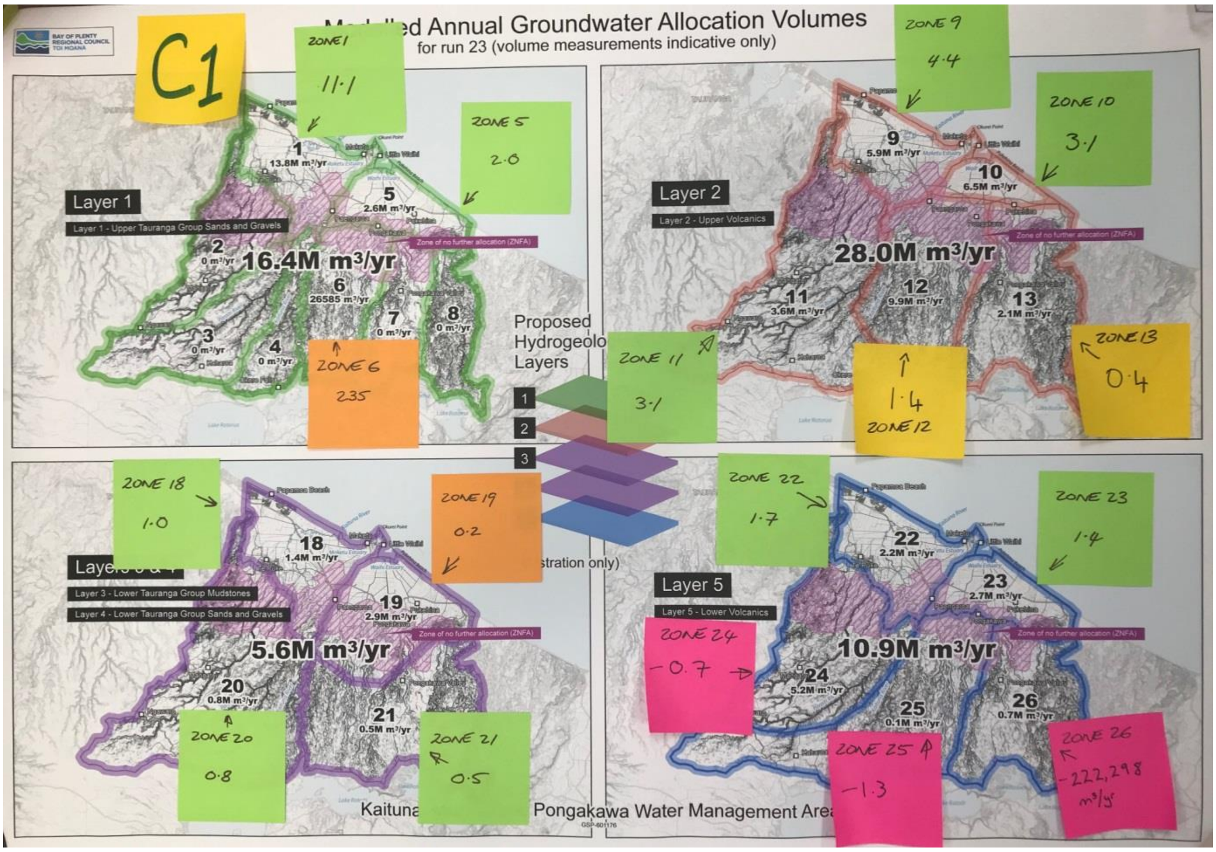
Option B1 results (maximum 5% base-flow reduction) map



Option B2 results (maximum 10% base-flow reduction) map

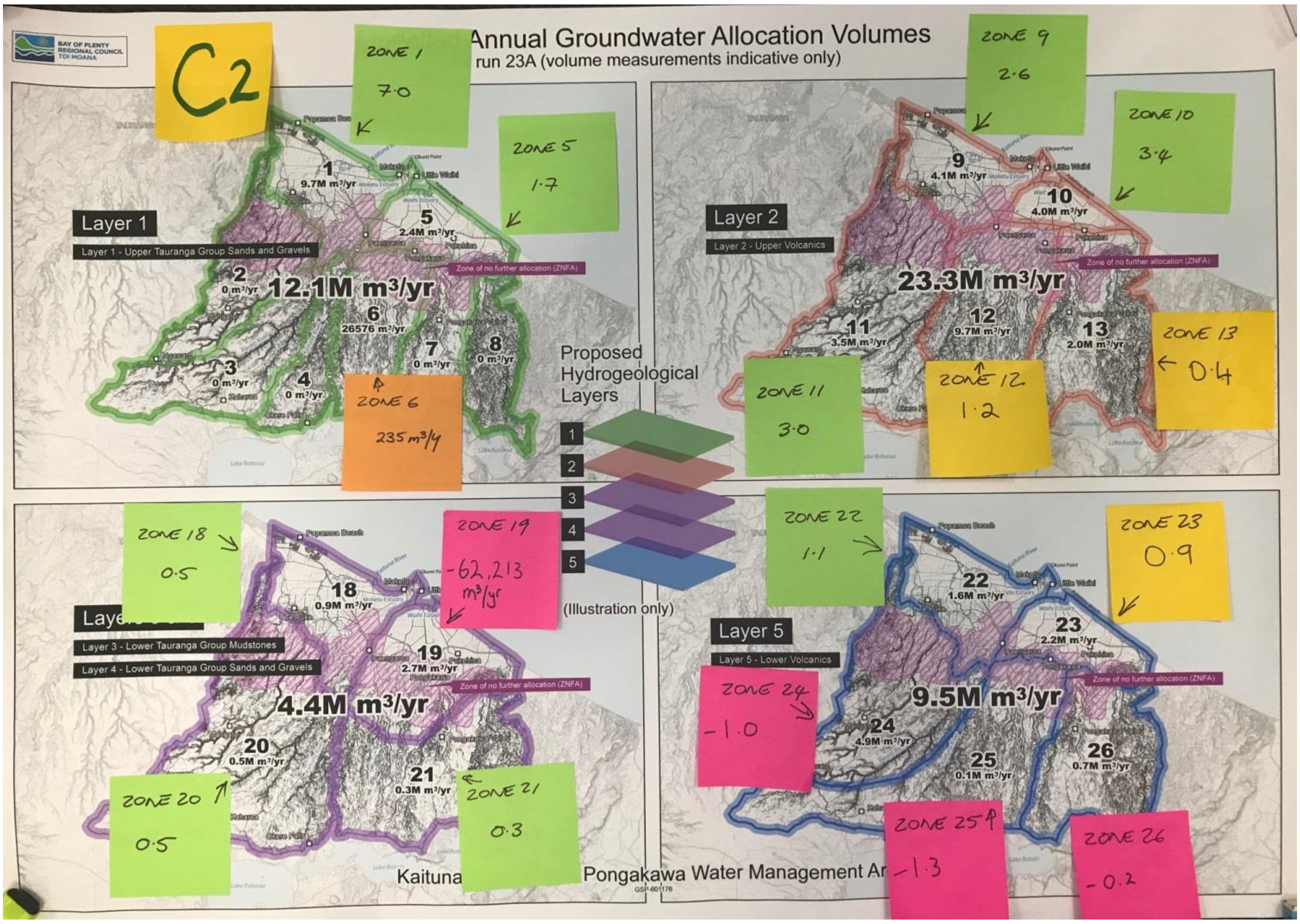


Option C1 results map



Note: These notes from the 20 November 2019 workshop are provided without prejudice. As part of the process, the content records key discussions points, which do not form the group's recommendation to Council, except where it is explicitly stated so.

Option C2 (conservative) results map



Community group members were asked to consider the results on the maps and provide feedback about the options presented on a worksheet. Collated feedback from community group members is in Appendix 5.

8. Summary comments from the community group

A clear understanding of the modelling scenario is required to select a preferred allocation option. The modelling is complex. The effect of seasonal water requirements for uses such as frost control should be considered in the model.[4]

The Waiari Stream currently has over-allocated surface and groundwater resources.

There needs to be some consideration of how difficult Option C would be to implement from an administrative point of view compared to Options A and B.

The model predictions provide useful information. They are a huge step forward in terms of providing an understanding the groundwater system and connected water bodies. Ecological effects of changes on base-flow in connected water bodies are an important consideration in determining the preferred groundwater allocation option.

Consideration needs to be given to reductions in consented allocation based on reasonable use.

[4] These can influence the model prediction results. This was considered in the design of the MODFLOW model and so is already reflected in the results.

If there are initiatives for sharing of water allocation these should be explored.

There are environmental and financial values to consider.

Further growth and economic development will result in increased population and demand for infrastructure. It is not easy to decide between the options.

9. Next Steps

BoPRC is currently considering opportunities to improve allocation efficiency including consideration of consented unused water. A workshop was held on 18th November 2019 with industry leaders and consent holder representatives from across the region to discuss identify collaborative opportunities and find solutions. A report discussing the key issues and recommendations from the workshop will be drafted. It will be publically available.

Any potential changes to allocation limits will be part of a notified regional plan change. Community group views on the potential allocation limit options will help inform those decisions. The local community group and iwi views are vitally important.

Members were thanked by the Chair for attending.

Appendix 1: Groundwater and hydrogeology – presentation notes and responses to questions

Key concepts and information:

An aquifer is an underground layer where the material contains or can transmit water. Aquifers are recharged primarily by rainfall infiltrating into the ground. Groundwater levels change in response to recharge and water use. Taking groundwater reduces groundwater levels in the aquifer. The larger the volume and the longer water is taken, generally the larger the groundwater level reduction. Groundwater levels usually recover to their pre-existing levels when the taking of water stops. Taking groundwater can affect connected surface water bodies and the potential for saline intrusion from coastal waters. The size of groundwater level drawdown and proximity to connected surface water bodies and the coast; influences the magnitude of effects on stream base-flow and groundwater level near the coast.

Unconfined aquifers are recharged by rainfall and surface waters directly above the aquifer making its way through permeable soil and rock. The natural groundwater level is at the top of an unconfined aquifer. Confined aquifers are covered by material that does not allow water to infiltrate from directly above the aquifer. Recharge in confined aquifers comes from water travelling from some distance away. The natural groundwater level in confined aquifers is under pressure and is above the top of the aquifer. Unconfined aquifers can be connected to surface water bodies. Streams can gain (base-flow) and lose water through the stream bed. Whether they gain or lose water depends on the difference between groundwater and stream water levels. Water flows from higher elevation to lower elevation under the force of gravity.

Saline water at the coast can intrude into aquifers containing fresh water if too much water is taken from the aquifer as a whole; or too much water is taken from one location close to the coast.

The Tauranga geothermal system is different to other geothermal systems in the region. The Tauranga system is fresh water heated by hot rocks beneath the ground that are slowly cooling. In comparison the geothermal water in Rotorua is heated by a different process, to greater temperatures and from much deeper within the earth. The water there has a higher mineral content than fresh water.

The effects of taking groundwater on connected surface water bodies are spread out in time and space. The effects of taking surface water directly from a stream are immediate and more localised.

Response to questions:

Streams can gain and lose water from connected groundwater systems in response to natural changes in seasonal water levels. The same stream can gain water in one location and lose water in another location. The same stream location can change from gaining to losing water at different times of the year. There is a continuum between confined and unconfined aquifers. Aquifers that are not completely confined can be connected to surface water bodies.

The potential for saline intrusion effects from an individual take depends on: the distance from the sea, volume taken, depth of the bore and aquifer characteristics. The closer to the sea, the larger the volume, and the deeper the bore the more potential there is for saline intrusion. Bores within 20-30 metres of the sea are expected to be at greater risk than those further away. Saline intrusion could occur in confined aquifers, but there is less risk than in unconfined aquifers.

In the Kaituna-Pongakawa-Waitahanui area it can take up to 250 years for rainfall recharge to move through the deep aquifer and 20-30 years in the shallow unconfined system.

Rainfall recharge and groundwater abstraction are taken into account in the design of the three-dimensional numerical groundwater model. This is covered in the discussion on modelling.

Appendix 2: Groundwater modelling – presentation notes and responses to questions

Key concepts and information:

Groundwater models simplify complex groundwater systems. There are different types of groundwater models. They are based on the information available at the time. The 2009 Geological and Nuclear Sciences Limited (GNS) mass balance model previously developed for council is used to inform current interim water allocation limits for PPC9. A water balance was calculated for each separate groundwater management zone established in the design of the model. These management zones are specific to the GNS model. The PPC9 approach was to allocate 35% of water balance calculated in each of the GNS mass balance model groundwater management zones. Groundwater limits are managed on an annual volume basis. The interim allocation limits based on the GNS mass balance model and PPC9 approach in the Kaituna-Pongakawa-Waitahanui area for all groundwater management zones is a total of 36.8 million m^3/year. The groundwater allocation as of November 2019 for all zones was 32.3 million m^3/year. Therefore, the total surplus for all groundwater management zones is 4.5 million m^3/year overall. However, the Lower Kaituna Hills, Lower Kaituna Plains, Mangorewa and WAI3 Ignimbrite management zones are over-allocated in terms of their individual interim limits. Lower Kaituna Hills and Mangorewa groundwater management zones have PPC9 interim water allocation limits of zero. Consents were granted prior to the introduction of the interim water allocation limits resulting in the over-allocated in terms of the interim limits.

The recently developed three-dimensional numerical groundwater model is based on the internationally recognised software MODFLOW. The model is made up of separate layers divided into cells. Calculations are done by the model in each cell and water is transfer between cells in the model. The conceptual model which it is based on is a representation of the underlying hydrogeology of the groundwater system and factors that may affect the groundwater system. A geological model was used to establish the thickness and aerial extent of geological layers used to help develop the conceptual model that was represented in the MODFLOW software. There are five hydrogeological layers represented in the model. They are based on hydrogeological properties of the geological units. Four of the layers contain usable volumes of water.

Various types of model boundaries are represented in the MODFLOW model design. The model boundaries represent different types of interaction between other parts of the wider groundwater system outside the area considered in the model; and, surface water bodies in various locations within the modelled area. The types of boundaries selected in the groundwater model take into account aquifers that cross the area considered in the model. A 'no flux' boundary is used where there is no flow. A 'flux' boundary is used for water coming across a model boundary.

Council monitors rainfall and groundwater infiltration (recharge). This information is considered in the model design. Surface water flow and groundwater levels are also monitored. The three-dimensional MODFLOW groundwater model is calibrated by comparing modelled and measured stream base-flow and groundwater levels. The calibrated model can consider changes in: allocation volume and spatial distribution of takes; stream base-flow in connected water bodies; groundwater levels; climate change; and, land use changes. It can consider 'what if' scenarios at a sub-regional scale, such as changes in allocation and consequent effects on stream base-flow and groundwater levels.

Response to questions:

The council's decision in PPC9 to allocate 35% of the water balance calculated in the GNS mass balance model was generally based on proposed interim limits for 'aquifers other than shallow, coastal (predominantly sand)' in the Proposed National Environmental Standard on

Ecological Flows and Water Levels (2008), MfE[5] (PNES Flows and Water Levels). For these aquifers the PNES Flows and Water Levels adopted an allocation limit of 35% of the Average Annual Aquifer Recharge as calculated by the regional council. However, the council approach in PPC9 is generally more conservative. The GNS mass balance model aims to establish a 'high level' of protection for surface water bodies connected to the groundwater system. Accordingly, it also subtracts estimates of stream base-flow from Average Annual Aquifer Recharge. This approach results in interim allocation limits that are not spatially uniform across the region between groundwater allocation zones in terms of percent of Average Annual Aquifer Recharge. It ranges from 0 to 35% of Average Annual Aquifer Recharge. In most groundwater allocation zones it is less than 25% of Average Annual Aquifer Recharge. Decisions on consent applications are currently based on PPC9 interim allocation limits until new plan allocation limits are notified and replace them. Council's decision in PPC9 to allocate 35% of water balance calculated in the GNS mass balance model does not have any influence on future groundwater allocation limits set using the recently developed three-dimensional numerical groundwater model.

Not all resource consents for consumptive freshwater takes currently require measuring and reporting. Under the Resource Management (Measurement and Reporting of Water Takes) Regulations 2010[6] introduced by central government, takes of 5 litres/second or more needed to be measured and reported from 10 November 2016. Many consent holders were already required by council to measure and report water use before November 2016. PPC9 requires that all new and replacement consents for consumptive freshwater takes, measure and report water use. Over time, as consents expire and are replaced, those that are not currently required to measure and report water use will be required to do so.

Under the Resource Management Act 1991 (RMA) water can generally be taken without a resource consent for an individual's domestic needs and a person's animals for drinking water. If water is only taken for these purposes, measuring and reporting of water use cannot required by council.

The GNS mass balance model only considers rainfall recharge, not potential recharge from irrigation. Recharge is approximately 20-40% of rainfall in the GNS mass balance model, depending on the part of the region. The proportion of the interim limit allocated that has been allocated is calculated based on the interim limit in the respective groundwater management zones and consented allocation located within them. The GNS mass balance model consists of two management zone layers in the Kaituna area and one layer in the Pongakawa-Waitahanui area.

Background information on current allocation and demand is relevant when considering decisions on potential future allocation limits. With continuing growth and development there is a growing demand for fresh water. The increase in demand results from various factors. These can include: municipal supply to provide for population changes; intensification of productive land and associated irrigation water requirements; and, commercial and industrial activity. These factors support growth in the region. If the demand for water can't be met the region's potential growth and economic well-being may be affected.

Council used the available water use data to estimate water use in the new three-dimensional groundwater model. Differences in seasonal water use for municipal, irrigation and frost protection takes were considered in the model design. There was sufficient water use data to develop a calibrated model suitable for informing decisions on setting groundwater allocation limits. The calibrated model has been peer reviewed by independent consultants. Once the

[5] https://www.mfe.govt.nz/fresh-water/freshwater-acts-and-regulations/national-environmental-standards/proposed-national

[6] https://www.mfe.govt.nz/fresh-water/freshwater-acts-and-regulations/regulations-measurement-and-reporting-of-water-takes

model based on available actual water use data was calibrated to observed groundwater level and stream flow data, it was then used to predict the effects of existing consented allocation and increased allocation in a range of different circumstances.

Not all the water allocated in resource consents is actually used. Actual water use is important to calibrate the model and to consider water use efficiency. Together with other information, actual water use data can help inform decisions on water requirements and future allocation.

Decisions on water allocation must take into account existing consented allocation in the wider groundwater resource / management zone. Council is required by the NPSFM to avoid further over-allocation and phase out existing over-allocation. Unused consented water cannot be re-allocated to new users if it results in over-allocation of the water resource. The existing unused consented allocations would first have to be reduced before it could be re-allocated to new consent holders, in order to avoid any over-allocation.

Information on the proportion of consents required to measure and report water use is shown in Table 1 below.

Table 1: Consented water meter and reported use information for 12 months to 1st November 2019

Location	% of all groundwater consents required to measure and report		% of annual volume reported to be used (for groundwater consents required to measure and report)
	By number of consents	By volume consented	All use types
Kaituna	64	87	19
Pongakawa-Waitahanui	76	96	12

The geological model was informed by geological mapping and bore log information obtained from drilling records. LiDAR (Light Detection and Ranging - remote sensing) and satellite mapping are not used to determine the geological model.

Model hydrogeological layer 1 (Tauranga Group alluvium) in the plains and model layer 2 (upper volcanics) in the hills are connected to surface water bodies. They are permeable and transmit water. Layer 3 (mudstone) has low permeability and does not transmit water easily. It is not laterally continuous over the area considered in the model. This is shown in the model cross-section on slide 32 of the presentation. Layer 4 (sand and gravels) and layer 5 (lower volcanics) become increasingly confined with depth.

Model boundaries are established in the design on the model. They include ‘river boundaries’ that simulate surface water and groundwater interaction. The degree of interaction depends on groundwater levels, river levels and stream bed conductance. ‘Drain boundaries’ in the model simulate the constructed drains removing shallow groundwater from the aquifer to facilitate agricultural development in the immediate area. Unlike the river boundaries, drain boundaries represent the pumped drainage network.

Two groundwater infiltration (recharge) monitoring sites were established by the council in 2018. Council considers data requirements on an on-going basis, subject to funding. Funding requirements will be considered in Annual Plan discussions in December. There is sufficient data to develop a calibrated model that is suitable for suitable for informing decisions on setting groundwater allocation limits. However, more groundwater infiltration data would be useful. It would help to further reduce model limitations and uncertainty. There are a number of rainfall monitoring sites located in the area. In addition, virtual rainfall data across the modelled area is available from the National Institute of Water and Atmospheric Research (NIWA). Measured and modelled rainfall data was used in the groundwater model to help estimate rainfall recharge to the groundwater system. The data reflects geographic and seasonal differences in rainfall. Accordingly, these differences are reflected in the groundwater model design. Rainfall outside of the modelled geographic area is not considered directly. However, rainfall recharge from outside the modelled area (such as in the Mamaku Plateau) would be considered indirectly. The 'general head boundaries' included in the model design allow groundwater flow across the model boundary from the surrounding area.

The groundwater model could be used to calculate water balances at a surface water local catchment scale. However, it has been designed as a sub-regional scale model. Model prediction results at a local scale would be less reliable. The groundwater model scenarios can, and do, assess the effects on stream base-flow in several different connected surface water bodies.

Groundwater modelling results for the current consented allocation scenario shows an area of long-term groundwater water level drawdown of up to about 2.5m in the Lower Kaituna area. This reflects relatively large current consented volumes including for municipal water supply in that location. Groundwater levels reduce over time when more water is taken out of the system at a rate faster than it can be replaced. The area of groundwater level drawdown influence (called the cone of depression) expands until it reaches a new equilibrium. The rate at which groundwater levels change reduces logarithmically over time for a constant discharge volume. A new equilibrium is reached when the rate of groundwater flowing into the area of influence, is the same as it is being taken out. At this point the cone of depression stops expanding. The model results represent the volume being taken continuously over a 30 year period. After this period of time there is not expected to be any significant changes in water level drawdown, or extent of the area of influence.

The MODFLOW model prediction results are not related, and do not depend in any way on the GNS mass balance model interim allocation limits. The MODFLOW model is more sophisticated. It is cable of assessing changes to the rate of groundwater extraction and impacts on groundwater levels and flows in connected surface water bodies. This helps to better inform decisions on sustainable groundwater abstraction limits.

Appendix 3: Groundwater values and uses – presentation notes and responses to questions

Key concepts and information:

Most groundwater is currently allocated to irrigation and municipal/domestic supply uses. Some is allocated for commercial/industrial and other uses. A small proportion of allocated water is geothermal (30 degrees Celsius or more).

Possible future land use scenarios were previously developed with the community groups and others, as part of the (water quality) catchment modelling. Possible future land use change 'Scenario C' was for urban growth, horticulture expansion, unconstrained sea level rise, new forestry and mānuka in the upper catchment. The impacts of these potential land use changes on the demand for water were considered in the report Freshwater Constraints to Economic Development, Aqualinc Research Ltd, 21 December 2018[7] (Freshwater Constraints Report). Assuming water supply was accessible; the current ratio of irrigated to non-irrigated area and possible future land use 'Scenario C', there is estimated to be:

- 684 hectares of potential irrigation expansion in Kaituna-Maketū and Waiari
- 2,275 hectares of potential irrigation expansion in Pongakawa-Waihī and Waitahanui.

The assumption is there would also be further horticultural development area that is not irrigated.

Effects on groundwater recharge (infiltration) from possible future land use change were considered in the MODFLOW model.

Groundwater values determine objectives for managing the groundwater system. Limits adopted reflect the maximum amount of groundwater resource use available, which allows the freshwater objectives to be met.

Response to questions:

'Heating' use in slide 42 relates to the use of energy in geothermal water. Taking geothermal groundwater (or non-geothermal groundwater nearby) can affect the degree and rate of geothermal water temperature change. Some of the geothermal water taken is discharged back into the ground and some is discharged to surface water bodies. The Tauranga geothermal system is centred on Tauranga City. Only a small part of the Tauranga geothermal system is located in the Kaituna-Pongakawa-Waitahanui WMA. The Tauranga geothermal field has been considered in the report, 'Update of the Tauranga Basin Geothermal Reservoir Model, GNS Science Consultancy Report 2018/102, July 2018'. The results of the geothermal modelling indicated current geothermal water allocation could cause some local water level decline and a small decrease temperature (less than 5 degrees Celsius). As part of the proposed Tauranga WMA process the TOUGH2 (Transport of Unsaturated Groundwater and Heat) and MODFLOW modelling are being considered for further modelling of the Tauranga geothermal field. TOUGH2 is designed for heat rather than flow, and MODFLOW is better for considering flow.

Land use change / practices and bore construction (rather than groundwater use) can have an influence the potential for contamination of groundwater. Taking groundwater can cause saline intrusion in some circumstances. There is information available on groundwater quality and suitability for different uses.

Taking groundwater can affect stream base-flow in connected surface water bodies. The MODFLOW model can predict the changes in stream base-flow in different surface water bodies spatially, for different groundwater management options. It does not predict the ecological effects of those base-flow changes. The ecological effects of changes in base-flow

[7] https://atlas.boprc.govt.nz/api/v1/edms/document/A3420983/content

will be discussed in a future workshop on surface water quantity and instream water requirements. Depending on the magnitude of changes, base-flow reduction is expected to have some ecological effect on surface water bodies. There is expected to be some natural variation in base-flow. Small reductions in base-flow such as less than 1% are difficult to measure and not expected to have a significant effect.

Based on possible future land use ‘Scenario C’, there would be significant reduction in the area of the following land uses:

- arable, dairy/dairy support and sheep/beef in Kaituna-Maketū and Waiari
- dairy/dairy support, high intensity beef/dairy grazing and sheep/beef in Pongakawa-Waihī and Waitahanui.

Possible future land use ‘Scenario C’ for Kaituna-Maketū and Waiari includes a 943 hectare increase in urban area. For Pongakawa-Waihī and Waitahanui there was no expected increase in urban area.

Possible future land use scenarios were not for a specified time period. Effects on groundwater recharge (infiltration) from possible future land use change were considered in the MODFLOW model by assuming the changes happened from day one and the model was run for a subsequent 30 year period. Actual changes in land use over time, such as five year periods could be modelled. However, based on the current model prediction results this type of change is not expected to have a significant effect on the results.

It has taken one and a half years to develop the calibrated MODFLOW model and another year to develop and run the various scenarios. It cost $150,000.

Based on the Freshwater Constraints Report the potential irrigation expansion of 684 hectares in Kaituna-Maketū and Waiari has the potential to increase:

- gross orchard or farm gate revenue by $142 million
- earnings and earnings before interest and tax (EBIT) by $53 million
- employment by 1,220 full time equivalent employees.

The potential irrigation expansion of 2,275 hectares in Pongakawa-Waihī and Waitahanui has the potential to increase:

- gross orchard or farm gate revenue by $398 million per year
- EBIT by $148 million per year
- employment by 3,390 full time equivalent employees.

Unconstrained sea level rise is likely to move the saline / freshwater interface further inland, but it may not be significant. The resulting loss of land would probably be more significant.

Appendix 4: Modelling scenarios and management options – presentation notes and responses to questions

Key concepts and information:

In giving effect to council's obligations under the NPSFM, much of the required decision-making will be made based on uncertain information. Models are important tools that can assist understanding complex physical process. All models have limitations and uncertainties, particularly where data is scarce. The groundwater model helps to make informed decisions about how much of the water in the ground that we can't see, or measure directly, can be allocated.

The MODFLOW model developed for the Kaituna-Pongakawa-Waitahanui WMA is based on a simplification of the groundwater system using all of the information and data that is currently available. A number of assumptions have to be made because there are always spatial information gaps related to the geology and hydrology, amongst other factors.

How well models are able to predict observed (measured) data gives some indication of the level of uncertainty in model results. The Kaituna-Pongakawa-Waitahanui MODFLOW model is built to Class 2 Confidence Level Australian Groundwater Modelling Guidelines. It is calibrated to a standard that is suitable for informing decisions on setting groundwater allocation limits. The calibrated MODFLOW model used to consider changes to the annual volume of groundwater extraction, impacts on groundwater levels and stream base-flow changes in connected surface water bodies.

Options A, B and C were explained in the Briefing Note. Options A and B have a single geographic management zone for each of the separate hydrogeological layers. Option C considers: a number of separate geographic management zones within each hydrological layer resulting in a different spatial allocation. The boundaries of the proposed zones for Option C were based on the mapped aerial extent of the geological layers within each of the hydrogeological layer in the model.

Response to questions:

Predicted stream base-flow reductions are the maximum reductions relative to the natural state (no groundwater or surface water being taken), resulting from the modelled groundwater volume being taken continuously over a 30 year period. The stream base-flow reductions are only calculated at several identified locations, where monitoring data is available. The predicted reductions demonstrate that the magnitude of effects is not uniform over the whole area considered by the model. The location and magnitude of the takes affects the results. The predicted base-flow reductions will not be uniform along the length of a stream. They will generally be greatest in the location of the greatest groundwater level drawdown.

The MODFLOW model considered the consented volume of groundwater allocated and its spatial distribution. It does not consider the effects of surface water takes on base-flow. These surface water take effects would be in addition to the effects from groundwater abstraction and will be discussed at a future workshop.

The calibrated MODFLOW model already reflects current actual water use, so there is no need to model this as a separate management option. The effects of this are reflected in measured actual groundwater levels and base-flow.

The MODFLOW model results estimate the effect of taking water from the separate hydrogeological layers represented in the model. Four out of five layers in the model are expected to contain usable volumes of water. The current consent allocation volumes were assigned to the correct model hydrogeological layer based on the respective bore depths and where relevant management zone based on bore location. Separate potential allocation limits were determined using the model, for each of the respective model hydrogeological layers; and, where relevant management zone. When drafted Plan Change 12 may include separate allocation limits for each of the four hydrogeological layer.

Consent applications would consider which of the four model hydrogeological layers they were taking from and the respective limit for that layer; and would also consider the zone, if the plan change includes management zones as included in Option C. This is similar to the current approach in PPC 9 where, in some parts of the region (including Kaituna area), there are two layers and various management zones within each layer, each with separate allocation limits. Consents are granted to take from a specific layer and groundwater management zone, reflecting the bore depth and location.

If the hydrogeological layer that groundwater was taken from changed, the consent would need to be changed accordingly. This situation may occur if a consent holder altered their existing bore, or drilled a replacement bore, which took groundwater from a different layer.

The climate change prediction of 2% less rainfall was based on NIWA climate change prediction models. The MODFLOW model was re-run using this rainfall climate change data. The reduction in rainfall results in slightly larger predicted stream base-flow reductions.

Potential allocation volumes were increased through a trial and error process until either the base-flow or saline intrusion criteria are first breached, at which point the maximum potential allocation was determined. The distribution and take volumes are not uniform over the modelled area. Nor are the predicted effects on: groundwater levels at the coast; or base-flow. For Option B1 (current land use and climate), the saline intrusion criteria was breached before the base-flow criteria. In that instance the maximum base-flow reduction was approximately 4% and potential allocation was three times current allocation.

The results of modelling management options were simplified in the presentation to make the overall results easier to understand. They were summarised in slide 64 as follows:

Option	**Potential Allocation Limit**
A	Current allocation
B	Three times current allocation
C	Up to two times current allocation

Why do the results of Option B1 and B2 show the same base flow reductions? The results in the presentation for Option B1 and B2 (current land use and climate change) are similar to each other, but different. The modelled base-flow reductions for both options were reported to be 'up to 5%' in the presentation. The percentage changes have been rounded off. Detailed results are presented in Table 1 below.

Table 2: Option B for current land use and climate change

Scenario	**Base-flow constraint**	**Results**		
		Groundwater level breach	**Base-flow reduction**	**Max available = x current allocation**
Climate change (-2% rainfall)	5%	No	2.2 - 4.8%	2x layers 1-3 4x layers 4-5
	10%	Yes	2.2 – 5.4%	3x

The results in the presentation for Option C were also simplified. The criterion for Option C included no further base-flow reduction relative to Option A - current consented allocation. The modelled base-flow reductions for both Options C1 and C2 were reported to be ‘up to 2%’ in the presentation. The percentage changes have been rounded off. Unrounded results for the same stream gauging (measurement) locations originally assessed in Option A were 0.5 – 1.5%. Detailed results of base-flow reductions were discussed in the Community group briefing note and are also presented in Table 2 below.

Table 3: Comparison of Option A and C1 base-flow reductions for current climate change and land use

Gauging Station	Modelled % Base-flow Reduction	
	Option A	Option C1
Kaituna	1.1	1.5
Mangorewa	0.2	0.5
Pongakawa	1.3	1.5

Three additional river gauging locations were subsequently assessed for Option C1. Predicted base-flow reduction for these additional rivers ranged from 0.5% (Waitahanui) to 5.6% (Puanene). Note some significantly exceed the original base-flow criterion of no base flow reduction (1%) as they were not part of the initial Option A assessment. The base-flow reduction for all rivers considered is 0.2% to 0.4% more than Option A scenario for consented maximum abstraction volume with current climate and land use.

The results for Option B1 and B2 (current climate and land use change) in the presentation should be the same. Option B1 in the presentation should have indicated that groundwater saline trigger level was breached. In this case there is no further base-flow reduction or increase in allocation possible for either Option B1 or B2 (current climate and land use change). Therefore, the results are the same for both options. For all B2 options, while the criterion was a maximum of 10% base-flow reduction, the results show that this criterion was never breached. That is because the groundwater saline trigger level was always breached first.

When a consent expires and a new application is lodged for the same activity the consented volume (and other consent conditions) can be reconsidered on its merits. The consent volume is based on the application supporting information and the prevailing provisions in the regional plan, including any allocation limits. In some circumstances consent conditions can also be reviewed before a consent expires.

Climate change was not considered in Option C because it did not make a significant difference to the model prediction results.

There are two existing groundwater level monitoring bores located at the coast. They have been established for approximately three to five years. The groundwater model prediction results consider groundwater levels at the coast. Additional virtual monitoring sites were considered in the model along the length of the coast to ensure appropriate coverage for assessing the potential for saline intrusion. The model results represent the volume being taken continuously over a 30 year period. The potential allocation limits were determined over that period with the water level criteria set at the coast which avoided saline intrusion. So no saline intrusion is anticipated for the modelled options.

Estimated reductions in consented allocation based on reasonable use were considered in the Freshwater Constraints report[8]. The report found there is potential to reduce current consented

[8] https://atlas.boprc.govt.nz/api/v1/edms/document/A3420983/content

allocation by applying 'reasonable use' methods to refine consented volumes. Only irrigation and frost protection were considered. There may be potential for further reductions in consented allocation based on reasonable use for other uses. These were not considered in the Freshwater Constraints Report.

Details of estimated reductions are as follows. 'Reasonable use allocation' is discussed in section 2.2.6 and 'Future Supply and Demand' in section 2.2.7 of the Freshwater Constraints report. The Kaituna-Pongakawa-Waitahanui WMA case study is presented in section 4.3 of the Freshwater Constraints report. For the Kaituna area, using the reasonable use figures, groundwater allocation for irrigation and frost protection was estimated to reduce from 6.5 million cubic metres to 2.8 million cubic metres (57% reduction). The total groundwater allocation was estimated to reduce from 14.8 million cubic metres to 11.1 million cubic metres (25% reduction). For the Pongakawa–Waitahanui area, using the reasonable use figures, groundwater allocation for irrigation and frost protection was estimated to reduce from 15.2 million cubic metres to 7.1 million cubic metres (53% reduction). The total groundwater allocation was estimated to reduce from 24.6 million cubic metres to 16.5 million cubic metres (33% reduction). MODFLOW prediction results for current allocation has little effects on groundwater levels. Estimated reductions in consented allocation would result in even less effect on groundwater levels and stream base-flows.

Appendix 5: Collated feedback from community group members on modelling options

Response	Option															Comments	
	A			B1			B2			C1			C2				
	A[1]	T[2]	U[3]	A	T	U	A	T	U	A	T	U	A	T	U		
1			✓	✓					(✓)	✓			✓			Identify unused water, (B2 miss-id saline intrusion concern)	
2		✓				✓			✓		✓	✓			✓	Claw back unused allocation, no base-flow reduction	
3			✓			✓	✓			✓				✓		B2 accept subject to ecological assessment, C2 has no merit over C1	
4			✓		✓			✓				✓	✓			B1 and B2 may cause over-allocation in zone of no further abstraction,C1 limits development	
5	✓					✓			✓		✓			✓		B1 and B2 contrary to objectives, C1 and C2 are more complicated to implement	
6		✓				✓			✓			✓			✓	Over-allocation is a concern	
7			✓	✓			✓	✓			✓	✓			✓	B1 and B2 limit risk and maximise allocation, option C1 and C2 restrict use were water is needed most	
8			✓	✓				✓			✓					A limits growth, C1 complicated, explore storage	
9			✓			(✓)						(✓)				(B1 miss-id no further allocation and C1 saline intrusion concern)	
10																Need more information on results to comment	
11	✓					✓			✓	✓				✓		A least environmental impact, meter all water and charge	
12		✓	✓		✓	✓			✓		✓		✓			Need to change to sustainable growth, concern Waiari over-allocated	
13			✓	✓					(✓)	✓			✓			(B2 miss-id saline intrusion concern), C1 and C2 preferred	
14		✓		✓					(✓)	✓			✓			(B2 miss-id saline intrusion concern), B1, C1 and C2 preferred	
15	✓				✓				✓		✓		✓			Claw back unused allocation, concern ✓Waiari over-allocated	
16																Prioritise environment over economy and groundwater over surface water	
Total	3	4	8	5	3	7	2	3	9	5	6	5	6	3	2	Lowest ranked option	Highest ranked option
	7		8	8		7	5		9	11		5	9		3	Lowest ranked option	Highest ranked option

[1] Acceptable
[2] Tolerable
[3] Intolerable

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