Managing Groundwater Resources in New Zealand to Account for Environmental Change

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ABSTRACT: Water regulators in New Zealand have recognised the need to adapt water allocation regimes and water permit conditions to reflect the likelihood of lower catchment yield on the east coast from 2030 due to climate change. Water management mechanisms to protect the environment and maintain the reliability of other water users are currently being applied or assessed in Marlborough province. These include seasonal water quota based on spring aquifer status, linking water use to environmental triggers to avoid seawater intrusion or spring depletion; and redefining water permit entitlements to account for recharge variability.

1 INTRODUCTION

The east coast catchments of New Zealand's South Island currently experience the country's driest summers due to the rain shadow effect of the Southern Alps mountain range on the prevailing westerly weather systems, and they are predicted to become significantly drier due to climate change by 2080. Model simulations by the National Institute of Water and Atmospheric Research (NIWA), predict the risk of a severe drought such as a 1 in 20 year event is likely to double by 2080, meaning lower flows in rivers and less storage in underground aquifers (NIWA, 2005).

The province of Marlborough is situated at the top of the South Island. It includes a diversity of catchments types from mountain ranges extending to altitudes of 3,000 metres, to drowned river valleys and alluvial flood plains. The east coast currently experiences the highest annual potential evapotranspiration deficit (PED) of any province in New Zealand, at around 600 millimetres, and produces the majority of the country's valuable Sauvignon Blanc grape crop. Potential evapotranspiration deficit is an annual measure of drought representing the accumulated amount of water required to optimise crop yield.

Fig. 1 below shows a map of New Zealand with Marlborough marked by the circle at the top of the South Island. While future droughts are likely to become more intense, last for longer and occur more frequently; irrigation water demand continues to increase as vineyards expand into marginal areas in terms of water availability. One of two things can happen if the predicted rates of climate change eventuate, either consumptive uses of water become less reliable or water resources become degraded. While there always needs to be a balance between competing uses, legislation in the form of the Resource Management Act 1991, favours the protection of environmental minimum flow regimes as the fundamental priority.

Fig. 1. Location map

Mechanisms are being adopted by New Zealand water management authorities to account for changes in catchment yield. The aim is to maintain the intrinsic values of waterways linked to aquifers and provide certainty for water users.

Sharing rules and restriction thresholds ensure water is only used for consumptive purposes after environmental needs are satisfied. There is a raft of techniques, each suited to particular catchment circumstances, and this paper will deal with 4 methods in practice or being assessed in Marlborough province for managing variability in catchment yield. They include: allocation regimes for ephemeral rivers recharging aquifers, seasonal quota based on aquifer status, active management of coastal aquifers and maintaining low flows in aquifer fed freshwater springs.

2 CASE STUDIES

2.1 Allocation regimes for ephemeral rivers recharging aquifers

Some lowland catchments in the dry, eastern part of Marlborough are already exhibiting declining trends in river flow. For example the mean annual flow of the Omaka River since continuous records began in December 1993 is 1,013 litres/second, however Fig. 2 shows flows are declining over time and since 2001 mean annual flows have averaged 757 litres/second. It isn't clear yet whether this is due to less rainfall, re-vegetation reducing runoff; or a combination of both. The Omaka River is ephemeral and during most summers loses all channel flow to alluvial gravels in its lower reaches, where it recharges local aquifers.

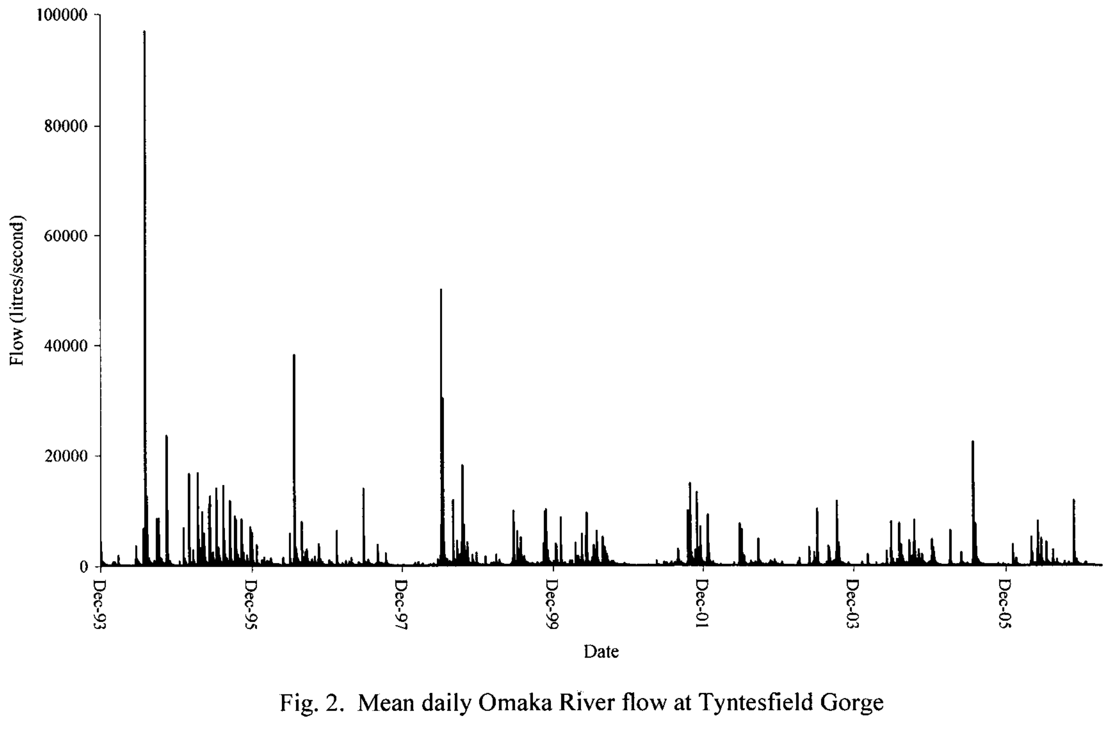

Fig. 2. Mean daily Omaka River flow at Tyntesfield Gorge

Three water allocation classes currently exist based on estimated Omaka River flow frequencies from 1993, prior to the installation of the recorder. An unrestricted A class totalling 170 litres/second was fully allocated by the 1990s, and equalled the estimated mean annual low flow plus a subsidiary volume of aquifer storage. Flow dependant B and C class channel water is still available to store in dams, but reliability is low and reduces with successive permits.

Regulators recognised the declining trend in river flow could impact on downstream wells, which include an industrial complex/municipal water supply. One option is to make the currently unrestricted A class permits flow dependant. Allocation definitions are being reviewed in light of the decade of flow record, so as to provide certainty to local domestic or irrigation water users, and downstream groundwater permit holders.

The critical months in terms of highest water demand by irrigators and lowest river flows are January, February and March; when all channel flow is lost to groundwater. One approach is to allocate 50% of the 80 percentile flow, meaning 65 litres/second would be available for allocation, with the remainder staying in the environment to meet downstream aquifer commitments. Water meter readings show historic actual use varies seasonally, but is of the same order. Eq. (1) describes the proposed formula.

$$\frac{\textit{80 percentile Omaka River flow for January-March}}{2} \quad (1)$$

2.2 Seasonal quota based on aquifer status

The Deep Southern Valleys Aquifer suite consists of 3 confined alluvial aquifers which are recharged by overlying catchments including the Omaka River. Irrigation wells range in depth from 30 to 245 metres below groundlevel and are very low yielding. This is reflected in typical aquifer storativity and transmissivities values of 1×10^{-4} and 100 m^3/day/metre respectively. Recharge occurs slowly due to their relative isolation from the surface and the low permeability of the alluvial host formation.

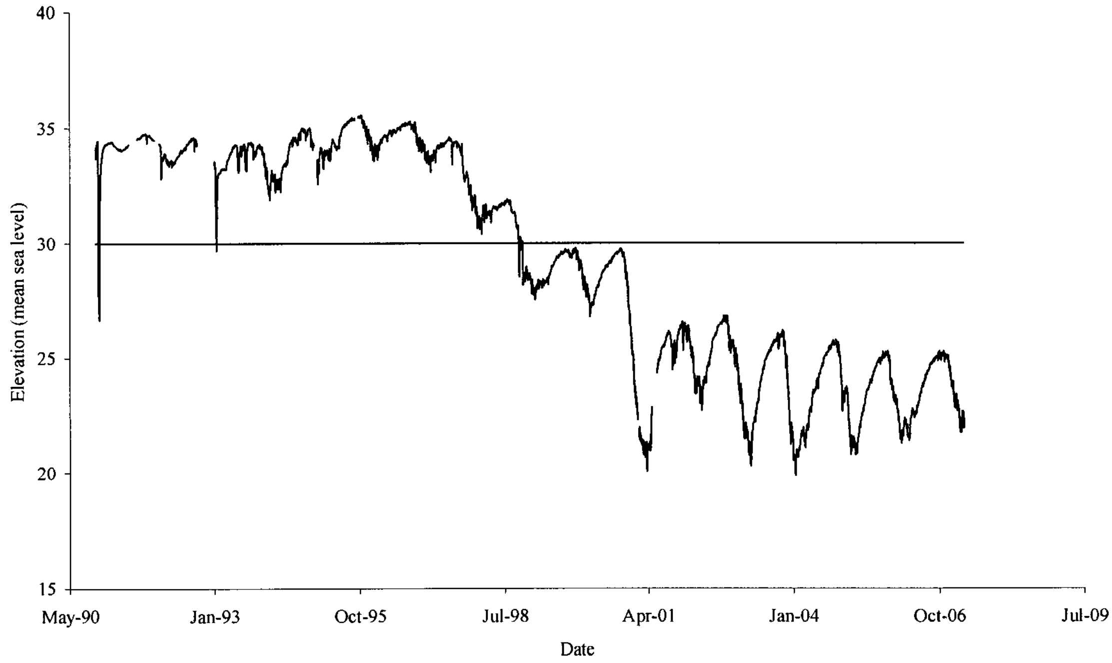

Fig. 3. Benmorven Aquifer level record 1990-2007

Fig. 3 shows aquifer levels in the worst affected Benmorven Aquifer have fallen by 10 metres since 1990 due to a combination of the 1997/98 and 2000/01 droughts, together with increased demand. The horizontal line represents groundlevel.

To stabilise aquifer levels at no lower than the 2000/01 drought minimum, a voluntary allocation regime for all irrigators was agreed to by the community based on a notional safe yield across all three aquifers of 600,000 m^3 of groundwater.

The proportion of this sustainable yield which can accessed by water permit holders depends on aquifer status on the 1st of October, prior to each summer irrigation season. If aquifer levels are low due to high demand during the previous summer or low spring recharge, the volume of groundwater available to permit holders is reduced.

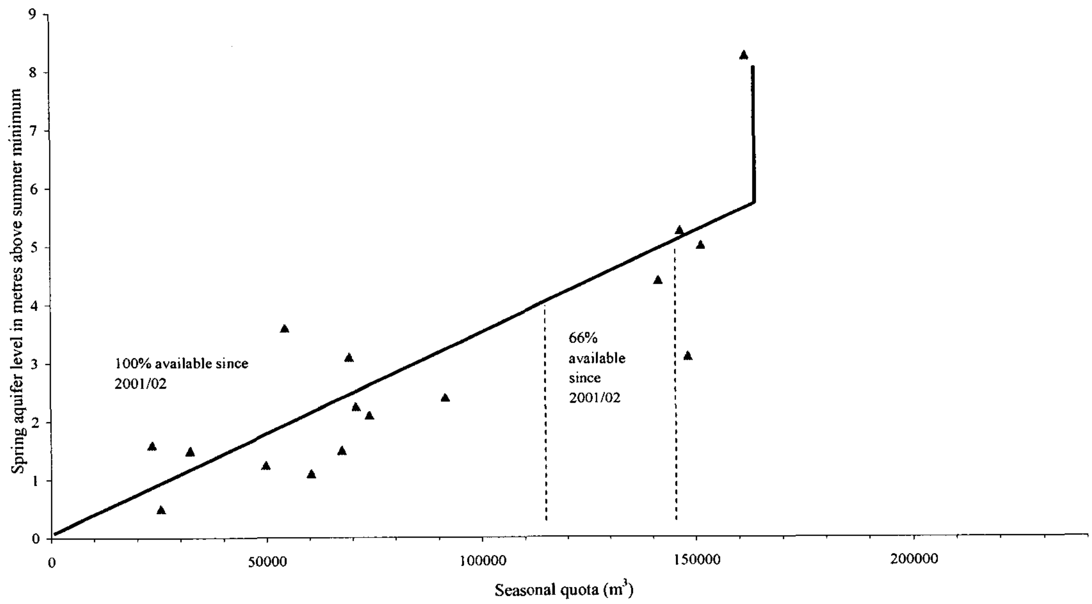

Fig. 4. Benmorven Aquifer yield versus drawdown

The relationship between yield and drawdown for each aquifer was derived using the observed fall in aquifer level versus the metered volume of water pumped from wells each summer. The method ignores rainfall or evapotranspiration.

Fig. 4 shows the simple linear relationship for the Benmorven Aquifer where the triangles represent an individual season dating back to the mid 1980's. If aquifer levels at the Benmorven monitoring well on the 1st of October were 5 metres above the designated minimum level, 144,000 $m^3$of water would be available for abstraction in the upcoming season. This catchment volume is then distributed amongst water permit holders based on their irrigated crop area and type.

This simple rule of thumb approach works well and provides an incentive for irrigators to actively manage their bulk water quota throughout the summer. Key parts of the management approach are flow meters, good records of aquifer behaviour, and a water user group to oversee the system.

2.3 Active management of coastal aquifers

Increasing demand from irrigators and the need to protect domestic water wells near the Pacific Ocean coast saw the establishment in 2000 of a network of seven sentinel wells to provide early warning of seawater intrusion. To date this is only a potential issue and no wells have been affected by the landward movement of the seawater interface.

Two aquifers exist at the coast. The unconfined Rarangi Shallow Aquifer occurs at a depth of 10 metres and overlies the confined Wairau Aquifer where wells are commonly screened at a depth of 50 metres below the surface. The shallow aquifer is more at risk from seawater intrusion because it lacks the confining layer isolating the Wairau aquifer from the Pacific Ocean. A pressure differential exists between the two systems with levels up to two metres higher in the Wairau Aquifer. Fig. 5 shows the variation in aquifer level at sentinel well 3667 from 2000 to 2007.

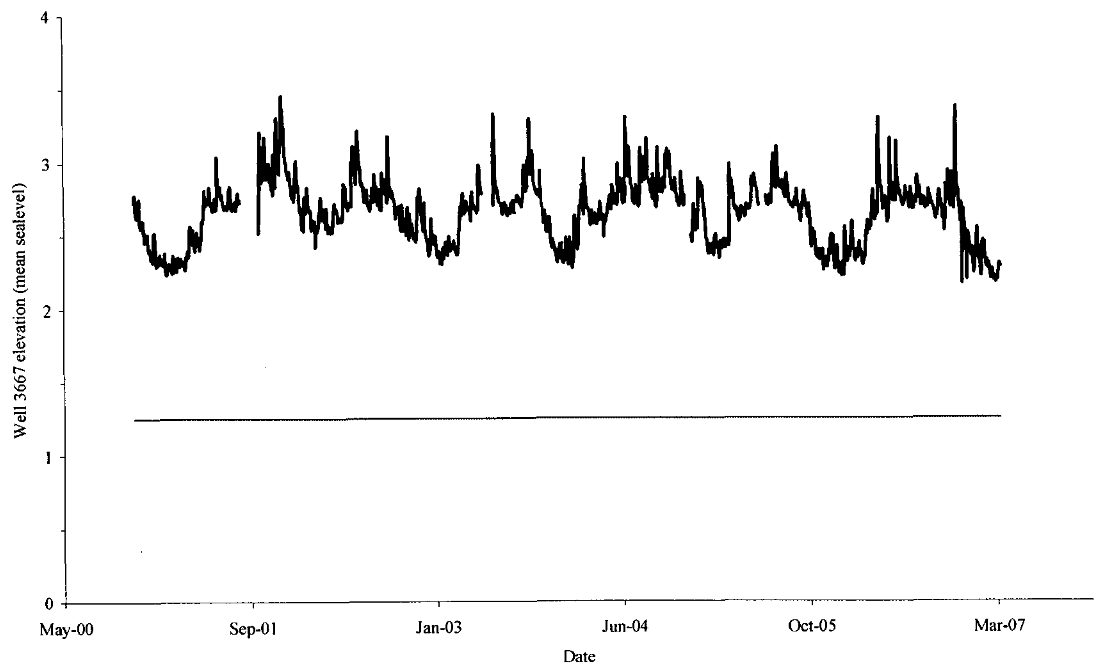

Fig. 5. Variation in Wairau Aquifer level at sentinel well 3667

All water permits within the proposed coastal management zone have conditions which control when they can pump, to maintain the seawater interface below water well screens. The conditions specify thresholds at the nearest sentinel well in terms of groundwater electrical conductance and aquifer level. These criteria are listed in Table 1.

Table 1. Groundwater level criteria

Aquifer	Depth to base of aquifer (metres below mean sea level)	Freshwater elevation at coast (metres above mean sea level)	Electrical conductance (mS/m)	Permit thresholds
Rarangi Shallow Aquifer	10	0.25	60	Reduce actual use by 33%
			80	Reduce actual use by 66%
			100	Cease pumping
Wairau Aquifer	50	1.25 (represented by line in Fig. 5)	60	Reduce actual use by 33%
			80	Reduce actual use by 66%
			100	Cease pumping

2.4 Maintaining low flows in aquifer fed freshwater springs

Many of New Zealand's economically important aquifers are hosted by alluvial gravel formations recharged by alpine rivers and they commonly have freshwater springs associated with them. These exist due to topographic or structural controls such as a flattening of the land surface, or the appearance of less permeable sediments.

Due to their groundwater origin these freshwater springs have characteristically stable flows all year round and their high quality water provides outstanding habitat for plants and fish life. Spring Creek is the largest freshwater spring in Marlborough with median and mean flows of 4,000 litres/second, and a standard deviation of only 540 litres/second. It is highly prized by the community for its continuous flows of clear water. A minimum flow of 3,000 litres/second at the gauging site in the middle reaches, represents when headwater recession becomes significant.

Spring Creek flow can potentially be depleted by pumping from nearby wells due to its hydraulic connection to the aquifer. To maintain low flows it may be necessary in the future to control local groundwater use during droughts. Fig. 6 shows the correlation between aquifer level at well 3009 and gauged Spring Creek flow from 1996 to 2007.

To maintain a minimum flow of 3,000 litres/second, wells close to the channel would need to stop pumping at an aquifer elevation of 12.5 metres above mean sea level. If this approach were adopted it would only occur very infrequently as flows of 3,000 litres/second are exceeded 99% of the time based on ten years of flow record.

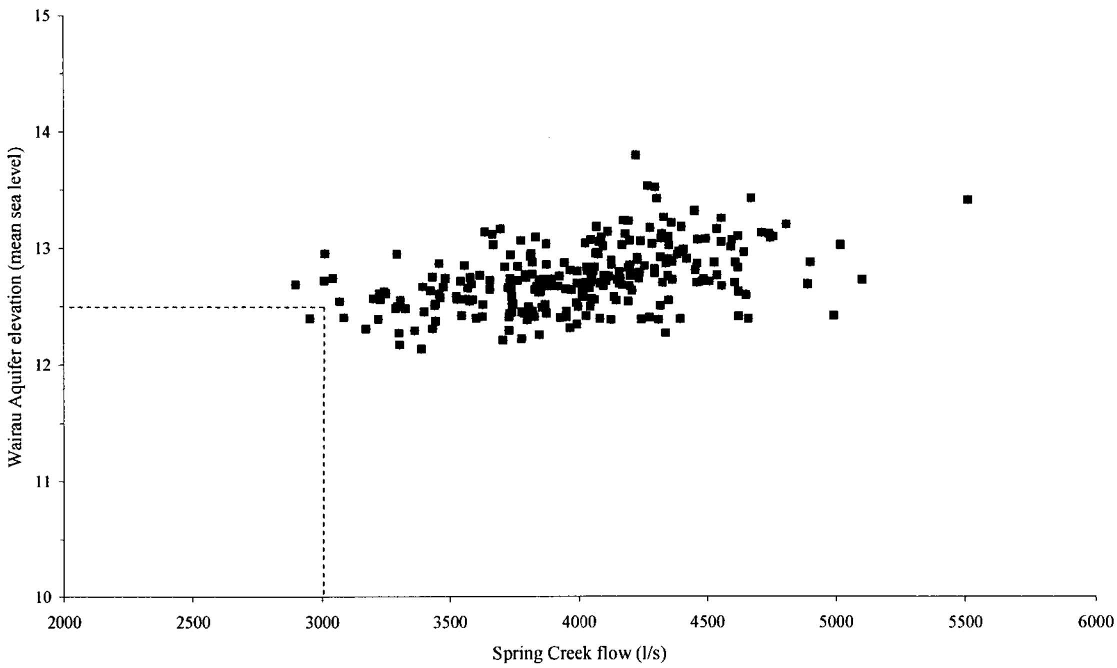

Fig. 6. Wairau Aquifer elevation versus Spring Creek flow 1996-2007

3 CONCLUSIONS

New Zealand groundwater regulators and policy makers will increasingly need to account for recharge variability in the twenty first century, if climate change predictions eventuate. The focus of aquifer management will be to maintain certainty for water users while providing for the environment. New approaches are needed including retrospective reviews of existing consents or policies, along with universal environmental thresholds on water permits. A systematic review process will rely on good hydrologic record to quantify temporal changes, and wherever possible measurements should be made on all important water resources. In lieu of these data a conservative approach to aquifer management is warranted.

4 REFERENCES

Mullan, B., Porteous, A., Wratt, D., and Hollis, M. (2005). "Changes in drought risk with climate change". NIWA Client report WLG2005-23 Prepared for the New Zealand Ministry for the Environment