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Emerging Scarcity and Emerging Commons: Water Management Groups and Groundwater Governance in Aotearoa New Zealand

Sarah Boone

Ministry for the Environment, Wellington, New Zealand; sarah.boone@mfe.govt.nz

Stephen Fragaszy

Ministry for the Environment, Wellington, New Zealand; stephen.fragaszy@mfe.govt.nz

ABSTRACT: In New Zealand, intensifying agricultural production, particularly in the Canterbury and Heretaunga Plains, has led to groundwater overabstraction. Aquifer connectivity to lowland streams results in decreased streamflow with concomitant impacts on nutrient concentrations and other relevant factors for indigenous flora and fauna. Recent legislative reforms including the 2017 amendments to the National Policy Statement – Freshwater Management have increased local government responsibility and authority to address cumulative effects of diffuse resource use and have increased pressure on agricultural communities to farm within environmental constraints. Numerous water management groups (WMGs) have emerged across New Zealand in the past decade to deal with these reforms and ensure reliability of irrigation water supply. Regional governments view WMGs as helpful in dealing with water allocation challenges and integrated environmental management approaches. This paper uses two case study WMGs from Hawke's Bay and Canterbury to illustrate aspects of common property management and explore the viability of this type of localised resource governance. The study highlights how these WMGs have navigated groundwater, local government, and environmental management issues and how their local context and constraints shaped their development. It also illustrates how WMGs can engage with water quality and broader environmental challenges while ensuring members' economic viability.

KEYWORDS: Water user groups, common property resource institutions, surface water–groundwater interactions, local governance, groundwater quality, New Zealand

INTRODUCTION

Despite Aotearoa New Zealand[1] having an enviable water endowment of an estimated 485 billion cubic metres (Bm^3) of renewable water supply per annum – over 100,000 m^3 per capita (OECD, 2017) – groundwater overabstraction is increasingly common in hot-spot areas across the country. This pressure on groundwater resources is most notable in the Canterbury Plains and the Heretaunga and Ruataniwha Basins in Hawke's Bay. New Zealand's agro-economy has undergone a large-scale transition from predominantly sheep and beef pastoralism in the 1980s to groundwater-dependent dairy and horticultural production. Agricultural intensification has led to increasing groundwater abstraction and declining groundwater quality trends, especially nitrogen pollution (MFE and Statistics NZ, 2017). These problems reflect an emerging common-property management challenge for the country.

Recent changes in water management regulation such as the National Policy Statement – Freshwater Management (NPS-FM, 2017) reflect increasing public concern over the cumulative impacts

[1] *Aotearoa* is the Māori name for New Zealand. The full title 'Aotearoa New Zealand' is increasingly used in official discourses.

of intensified agriculture on long-term environmental sustainability. The links between broader environmental sustainability and groundwater abstraction in New Zealand stem from the connection between groundwater's role in sustaining baseflows, nutrient levels in groundwater and hydrologically connected streams, and the inherent vulnerability of New Zealand's freshwater and estuarine flora and fauna (Joy and Death, 2013).

Absolute quantity of groundwater abstraction and fears of aquifer depletion are not the primary driving factor behind reforms in water allocation regimes, although the theme of managing groundwater scarcity is increasingly prominent in New Zealand discourse (Water NZ, 2017). Rather, more immediate concerns that are driving change in groundwater abstraction regimes are issues of wider ecosystem degradation and maintenance of ecosystem health. This is culturally and economically relevant for New Zealand through impacts on native *taonga*[2] species and national identity as well as the lucrative '100% Pure New Zealand' campaign promoted by Tourism New Zealand. New Zealand relies on agricultural exports and tourism for foreign exchange and these sectors rely on positive global perceptions of New Zealand's environment for competitive advantage (Tourism NZ, 2009). In addition to economic importance, maintenance of ecosystem health is a fundamental tenet of primary national legislation including the Resource Management Act 1991 (RMA, 1991) and linked national direction such as the NPS-FM (2017).

These emerging challenges to water security have prompted water users and primarily irrigators, to finance and form new types of grassroots resource management institutions. In this context, these new Water Management Groups (WMGs)[3] are a catchment or sub-catchment-scale organisation that collectively manages defined allocations of water and/or pollutant and nutrient discharge allowances across multiple properties, and in some cases are responsible for realising linked environmental outcomes.

This research examines how WMGs have self-organised to meet farmers' needs in response to recent legislative changes in national and regional water management regimes and increased groundwater resource constraints. It also explores whether there is evidence to suggest that these groups can practically provide improved common property management, and whether this matches expectations based on common property theory.

The analysis here focuses on two WMG case studies: the Twyford Cooperative Company Ltd in Hawke's Bay and Central Plains Water Ltd (CPW when referring to the overall irrigation scheme and CPWL when referring specifically to the company) in Canterbury. These case studies illustrate clearly how the WMGs have worked with local government to improve water supply reliability, address groundwater constraints, and contribute to improved environmental outcomes.

The study draws on an analysis of national and regional policy and technical documents, corporate reports, information collected between 2015 and 2017 from two national workshops for WMG representatives, five site visits to WMG areas, and 22 interviews with WMG representatives. With the exception of specific interviews with the Chairman of the Twyford cooperative, which are cited separately due to their specific content, we have cited the interviews, workshops and site visits collectively. The paper describes the over-arching legislative, policy, and political environment in which WMGs have emerged and act, and how these groups have interacted with local government and groundwater resource constraints to try and meet economic and environmental objectives. The sections of the paper examine successively:

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[2] *Taonga*: National treasures.

[3] We use the term Water Management Groups to signal that these groups are not only responsible for water-quantity abstraction allocations but are also increasingly used to manage associated water-quality issues. However, these groups bear large similarities to other types of Common Property Resource Institutions around the world, which are commonly referred to in academia as 'Water User Associations' or 'Catchment Management Groups'.

- how WMGs in New Zealand reflect theory on common property resource management
- the regulatory context that has contributed to WMG formation
- the hydrological context of the case study regions
- the two case studies
- the case study findings and discussion of their relevance to common property management theory and practical implementation

THEORETICAL FRAMING

Exploring the emergence of WMGs through common property theory

Common Property Resource Institutions (CPRIs) – including WMGs in various forms – have existed for millennia and were the dominant institutions for water management around the world prior to the rise of centralised nation states. Typically, these institutions developed in regions that experienced significant resource scarcity, with many examples around the world where these groups sustainably managed resources for hundreds of years. Research into the successes and failures of these institutions gained particular momentum in the 1990s, producing a rich corpus of academic literature.[4]

For much of New Zealand's history since European colonisation, collaborative management at a catchment scale has been the exception rather than the rule. This may be partly because during the 19th and 20th centuries, water resource users – and groundwater resource users in particular – did not face overt restrictions on water abstraction. Over the last few decades, however, new hydrological and regulatory contexts have put new pressures on individuals, and some resource users have responded by embracing collective catchment management and creating WMGs instead of simply seeking to bolster their own individual allocations.

This communally initiated movement toward collective management of a commons raises a number of questions, including why individuals have moved to form WMGs and whether these new groups have the characteristics that are likely to support them in successfully managing the common-pool resource they utilise – surface water and groundwater.

To identify the specific conditions and contexts that have supported the rise of WMGs in New Zealand, and assess their likely long-term effectiveness, it is useful to refer to Elinor Ostrom's classic theoretical framework for evaluating CPRIs. At a broad level, Ostrom identifies several 'design principles' that are common among successful CPRIs (Ostrom, 1993). These principles – adapted and interpreted within the New Zealand resource management context – are shown in Table 1.

We use this framework to analyse how the case studies of emergent WMGs in New Zealand reflect these design principles, which will provide an indication of their theoretical capability to manage groundwater effectively as a common property resource.

Water Management Groups in the New Zealand context

While some catchment groups began to emerge in New Zealand as early as the 1930s (McCaskill, 1973), WMGs in New Zealand today are fundamentally different in that they have explicitly formed in response to water quantity and quality challenges as well as policy changes (Interviews, 2017). The activities of these groups are regulated by regional councils, the local government bodies which authorise and monitor resource use (also simply referred to as 'councils' in this paper). The

[4] See the following references for context: Bruns, 1988; Ostrom, 1990; Ostrom, 1993; Ostrom et al., 1999; Borrini-Feyerabend et al., 2004; Kerr, 2007; Benkler, 2013.

relationships between councils and WMGs vary. In some cases, WMGs manage 'global' or shared water take and/or nutrient discharge consents (permits) related to agricultural activities and the group must self-monitor and report on consented themes such as water abstraction volumes or nutrient application and leaching using model outputs. In other cases, individual group members from a WMG retain their own consents and related liabilities to regional councils (HBRC, 2015).

Table 1. Adapted CPRI design principles.

Ostrom's design principles	Interpretation in the New Zealand context
1. Clearly defined boundaries	This refers to clear understanding of the resource available to be used. Essentially, it is understanding the size of the pool that is available for use, or the 'allocable quantum' that regional councils specify for given waterbodies, including aquifers, in their policy plans to meet national legislative requirements.
2. Congruence between appropriation and provision rules and local conditions	Local government-granted permits or 'consents' to take and use the resource are effectively limited to what is available; water take consent volumes/other conditions need to be flexible to adapt to changing resource availability.
3. Collective-choice arrangements	The WMG has a structure for collaborative decision making that involves individual members.
4. Monitoring	Local government can hold individuals and the WMG accountable for their resource use. This can incorporate self-monitoring methods if appropriate.
5. Graduated sanctions	The WMG has the authority to apply varying degrees of penalty for infractions by WMG members against agreed institutional arrangements or improper use of the resource.
6. Conflict resolution mechanisms	Structures for managing conflict are built into the WMG and into the WMG's relationship with local government represented by regional councils.
7. Minimal recognition of rights to organise	Central and local government acknowledge the right of the WMG to exist, to manage a resource allocation within a defined limit, and provide legitimacy to the WMG.
8. Nested enterprises	The institution has clearly defined relationships with overarching governance institutions, including *tangata whenua*[5] groups. This includes expectations or agreements around two-way communication.

It is difficult to derive absolute numbers of WMGs operating in New Zealand because the definition of a WMG is somewhat fluid. It is challenging also because WMGs are largely a new phenomenon in New Zealand and therefore surveys of them rely on social networks to identify participants (Interviews, 2017; Irrigation NZ, 2014). However, as of late 2016, Irrigation NZ – a not-for-profit membership organisation that advances sectoral interests and uptake of best farm management practices including promoting WMGs – identified 23 user groups spread across New Zealand as shown in the map below (Curtis, 2017). When considering an expansive definition of WMGs that includes, among other varieties

[5] *Tangata whenua:* in relation to a particular area, means the *iwi* (tribe), or *hapū* (sub-tribe), that holds *mana whenua* (customary authority) over that area (RMA, 2017).

of CPRIs, irrigation cooperative companies such as CPWL that self-regulate water allocation within a reticulated scheme, the total figure likely increases to approximately 30-40 WMGs nationwide (Interviews, 2017).

WMGs in New Zealand range dramatically in their purpose, structure, formality, and modes of operation. They also go by many names: water user groups/associations, river basin committees, catchment clubs, etc. WMGs come in many forms – from informal institutions constituted by agreements among neighbours to formal corporate entities. Irrigation NZ has identified the most typical institutional structures as being Limited Liability Companies, Cooperative Companies, Incorporated Societies, Informal Committees or Societies, Trusts and, Limited Partnerships (Irrigation NZ, 2015). While informal groups can be just as successful and easier to establish, more formal user groups have several advantages, chiefly in having the ability to penalise members who do not comply with their established rules.

Figure 1. WMGs in New Zealand with case studies highlighted (Curtis, 2017).

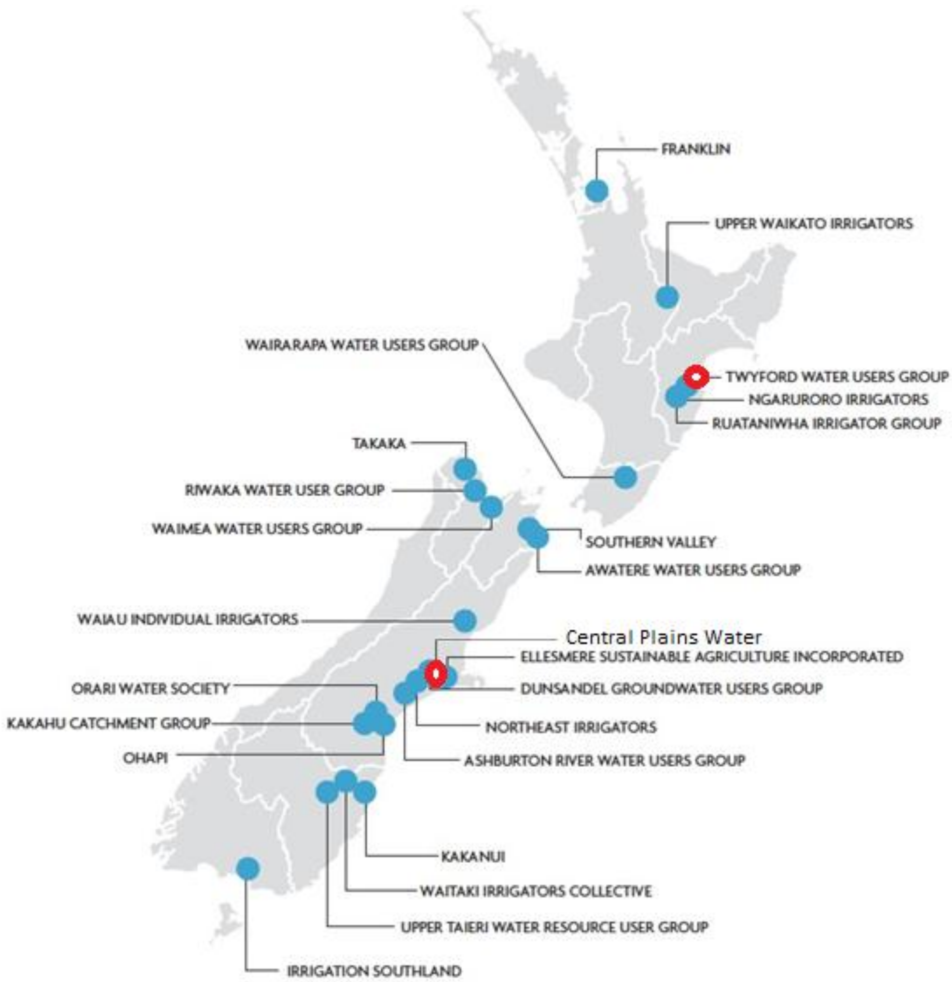


Table 2 establishes a basic classification system that describes the defining features of the most common types of WMGs in New Zealand.

Table 2. Features of common Water Management Group (WMG) types in New Zealand (Interviews, 2017).

Informal group	Membership group or club	Co-op/Collaborative group	Collective management group	Common Property Resource Institution (CPRI)
1. Group membership is not formal, allowing residents to attend meetings and be involved at will. **2.** Individuals have no automatic responsibility. **3.** Group members have 'normal' individual water take consents. **4.** For instance, Awatere User Group. **5.** Roughly a quarter of groups surveyed across New Zealand fall in this category.	**1.** Membership is formal. **2.** Group members may have some minor responsibilities and privileges, though not legally binding. **3**. Group members have 'normal' individual water take consents. **4.** Group structure, purpose etc. is easily changeable, though in practice it is often static. **5.** For instance, the Hinds Catchment Clubs. **6**. While it is difficult to assess due to their sometimes informal legal status, we estimate that less than a quarter of WMGs fall into this category.	**1.** In addition to formal membership. **2.** These groups are intentionally designed to have active participation and collective decision making. **3.** Many groups have legally binding constitutions and contracts with individual members, usually as incorporated societies. **4.** Can be more democratic and dynamic. **5.** Individuals hold their own resource consents. **6.** For instance, some irrigation companies such as Ellesmere Sustainable Agriculture. **7**. This is likely the dominant type of WMG, estimated to account for approximately half of all WMGs.	**1.** In addition to co-op characteristics. **2.** Individuals hold individual resource consents, but they are occasionally pooled together for reallocation or otherwise managed as though they are a single, global consent. **3.** Group members are considerably more active and regularly adjust allocations amongst themselves. **4.** For instance, Central Plains Water and some larger irrigation companies. **5.** A small but growing number of WMGs fall in this category.	**1.** Group has a global consent (members of the group do not have any individual consents, negotiating short-term allocations instead). **2.** The successful establishment of these institutions often reflects Ostrom's design principles. **3.** For instance, Twyford User Group (though it should be noted that even in this case individuals can return to their historic individual consent if they so choose). **4**. Only one group of those surveyed meets these criteria.

There are advantages and disadvantages to the degree of formality adopted by a WMG. For informal groups, there can be benefits in being open, inclusive and relatively free of administrative costs. These groups can function perfectly well when their objective is simply to create a shared community vision for catchment management and strengthen the rural social fabric. Emerging groups also may employ the informal or club models for a time as they build the necessary organisational groundwork and sense of community needed to establish a more formal group. For the more formal groups, however, the heightened level of self-organisation allows for more practical resource management decisions to be taken and a greater degree of assurance that group members will comply with them. Co-ops, collaborative management groups and CPRIs are each increasingly capable of requiring members to manage within shared resource abstraction and discharge limits, and can provide significant benefits to members in improving the reliability of resource supply and reducing individual administrative costs.

As shown, New Zealand WMGs predominantly fall towards the informal end of the spectrum at present. However, the number of formal institutions is increasing as central government, sector bodies, councils, and farmers increasingly promote and realise the benefits of functional WMGs. Ultimately, the degree of formality and form of the group should follow its intended function, as required by the hydrological and political realities in any particular catchment.

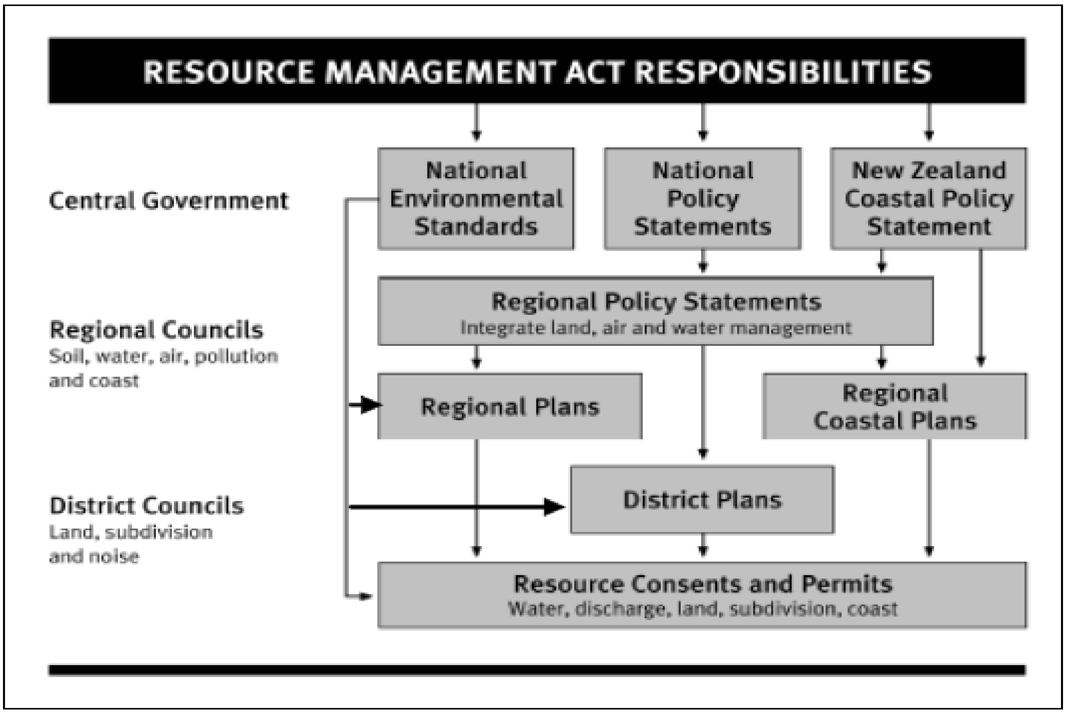
REGULATORY CONTEXT

The emergence of WMGs also relates to recent regulatory changes. Water management in New Zealand falls under the legislative purview of the RMA, which also empowers and provides direction to local government entities including regional councils. In addition to the primary legislation, national policy documents like the NPS-FM (2017) provide further overarching direction for water management regimes. Regional councils, in their policy statements and plans, set water allocation frameworks and rules for water takes through resource use 'consent' processes.

Consents are legal permits to undertake specific activities and use resources. Relevant types of consents for this paper include 'water take' consents that permit withdrawals or abstraction from surface water or groundwater bodies. At times a separate 'water use' consent is required for specific activities such as irrigation. Likewise, nutrient discharge consents are required in some regions to manage effluent and fertiliser leaching.

Water take consents vary significantly depending on local circumstances, but they almost always stipulate maximum instantaneous volumetric water takes as well as cumulative allowable takes within a period, and in most cases there are specific dispensations for low-flow situations. Figure 2 shows the hierarchical relationship of these policy instruments.

Figure 2. Hierarchy of water management legislation and policy instruments.



NPS-FM – Values-based water management framework

The NPS-FM (2017) prescribes portions of the regional plan-making process councils must use to set water management regimes including consenting rules. For the purposes of this paper, this process can be summarised and abbreviated as follows:

1. Councils must delineate freshwater management units (FMU) that include all freshwater bodies (including aquifers).
2. Councils must – through consultation with local communities including *tangata whenua* – identify values for each FMU, including at least the two national values – ecosystem health and human health for recreation.
3. Councils must formulate policy objectives – including describable freshwater attributes – to provide for the identified community values.
4. Councils must set rules on land-use activities as well as freshwater abstraction allocation regimes – including rules on abstraction timing and water use characteristics – to ensure the objectives are met to provide for the identified values.

Therefore, in theory, councils design water allocation and quality regimes – and govern water take and land use activities that affect them – to ensure the provision of nationally mandated and community-defined values. Doing this requires councils to account for takes and monitor hydrological regimes and water quality to examine the extent to which they are providing for these values (Measurement and Reporting of Water Takes Regulations, 2010). Council staff set up these environmental monitoring systems and undertake the relevant monitoring. District Health Boards – local entities governed by appointees and elected members, and largely funded by the Ministry of Health – have a role in environmental monitoring as it relates to public health and water supply provision and treatment.

Unrelated to the rise of WMGs, recent legislative reforms have also strengthened councils' ability to use collaborative and participatory processes (Part 4 of the RMA, 2017). This trend towards collaborative policy development indicates a broader shift in the national culture and overall direction of water management towards more consensus-oriented decision making amongst a range of water users at the grassroots level. This culture of governance has created a window of opportunity for WMGs to emerge, engage with regional councils, and take on increased responsibility.

WMGs and Regional Government

Regional councils have varied policies for and approaches to dealing with WMGs. We reviewed operative (fully in force) and proposed (still in development, but for which some sections can be operative) council plans and policy statements for WMG-relevant material based on initial targeted word searches in the NVIVO software environment. The list of council documents searched, and specific search terms, is shown in Appendix 1. Summary results and analysis are shown in Table 3. This review is supplemented and contextualised by interviews and workshops conducted by Ministry for the Environment and Ministry for Primary Industries staff (Interviews, 2017) and survey data from Irrigation NZ (2014).

The initial search contained 70 references to WMGs (as defined by the search terms) from 12 of 16 regional councils. We coded references to WMGs according to their thematic content based on textual analysis and iterative reflection on the categories to arrive at the framework shown in Table 1 below (Saldana, 2015).

Proposed plans, which in general are more recently amended than operative plans, explicitly mention WMGs more frequently than operative plans (8 of 13). This highlights the relatively recent surge of WMG growth and the fact that councils see opportunities inherent in being able to deal with groups of resource users collectively (Interviews, 2017).

Mentions of WMGs in council policy documents primarily fall within the 'policies' and 'methods' sections rather than 'rules' sections. Within the legislative hierarchy, this means that councils largely do not have regulatory oversight of WMGs as institutions except insofar as their activities and resource consents fall under council purview. At present, councils do not regulate the existence of WMGs in and of themselves – just their activities. Of course, where WMGs are established as corporations or non-profit entities they are subject to relevant rules of incorporation.

Interestingly, some councils have begun to promulgate criteria for what defines a formal WMG with which they can have substantively different relationships than individuals or other types of institutions. For example, the Otago Regional Council Plan (Appendix 2a; 2016) stipulates that groups must identify all consents that will be managed by the group, that it has an appropriate form and rules, that it seeks authority to manage the consents, and that the group is able to provide documented evidence that the members, including the consent-holders, agree to be bound by the group. Such plan provisions ensure that WMGs incorporate the monitoring, graduated sanctions and conflict-resolution design principles shown in Table 1.

The findings show that councils intend to support the development of WMGs primarily to help address the following themes related to surface water and groundwater management:

1. Water allocation during periods of low surface water flow and restricted takes
2. General issues of resource use efficiency and implementation of best farm management practices
3. Self-regulation and collective management of water usage
4. Reducing overall allocable water takes within an FMU, often called 'clawback' of water allocations.
5. Catalysing resource user participation in council-led collaborative governance mechanisms

Six councils have also enacted legal rules to carve out specific roles, exemptions, and perks for WMGs in relation to the following themes:

1. Water take consent terms and conditions, especially ability to transfer consents
2. Management of low flow reduced takes and allocation
3. Overall water take consent allocation limits
4. Nutrient allocation consents (only Canterbury)
5. Consent favourability (e.g. favourable consenting status for activity if initiated by WMG)

Even in the absence of such explicit rules, a method or policy promoted in the council plan can influence consent decision making. This is the case in Hawke's Bay where the plan does not have an explicit rule stating that being part of a WMG can mediate water restrictions in low-flow situations, but the Twyford Cooperative's consent conditions describe how precisely that can occur (HBRC, 2006; 2015). In contrast, Canterbury has the most explicit regulatory framework empowering WMGs (ECan, 2017). Ultimately, how WMGs and the activities they undertake are incorporated in planning documents is relevant as they directly relate to the ability of the WMG to act and negotiate water resource management challenges.

Irrigation NZ's (2014) survey shows that council staff overall believe that WMGs will be vital partners in resource management going forward because of their potential to increase efficiency of communication and engagement by condensing numbers of consent holders into a common institution. This naturally reduces the administrative burden on the council that, as a result, only has to regulate one entity. Also, councils hope that WMGs will ultimately become capable in self-management of water resources. This is a long-term goal, but they stress that economic, political, and social pressures are pushing farmers to organise and, as such, WMGs are likely to become increasingly widespread and play important roles managing these challenges (ibid).

Finally, through observation of emerging WMGs, regional councils have identified critical elements of functioning and accountable WMGs. Surveys of councils (Interviews, 2017; Irrigation NZ, 2014) illustrate that the most important elements supporting existing groups are robust and credible governance structures that provide auditability (related to design principles 4-6) and strong working relationships between the councils and WMGs (related to design principles 7 and 8) (Irrigation NZ, 2014). In further interviews, Fraser (2011) notes similar reasons for the success of groups in New Zealand, discussing the importance of community-based leadership, reliable up-to-date information on collective impacts and good relationships with regulators among several other factors. All these observations align closely with Ostrom's theoretical design principles, strengthening the case that these institutions may benefit from building on the theory surrounding successful CPRIs.

CASE STUDY HYDROLOGICAL CONTEXT

The case study WMGs draw groundwater resources in two intensively irrigated areas of New Zealand: the lowland plains of the Canterbury and Hawke's Bay regions. Rough estimates show that of the total groundwater storage of over 700 Bm^3 in New Zealand, over 500 Bm^3 are in Canterbury (Moreau and Bekele, 2015). Hawke's Bay is the second largest groundwater-dependent irrigation area in the country. Nationally, there are currently about 10,860 consents for groundwater takes, which altogether total 2.564 Bm^3 per annum (Booker et al., 2016). Of these, 3937 consents are in Canterbury and 1529 are in Hawke's Bay (MFE, 2015), and groundwater supplies 40% and 74% of allocated water volumes in those regions, respectively (Aqualinc, 2010).

In recent years, overall groundwater allocation volumes in these two regions have increased significantly, primarily due to agricultural intensification: from 1999-2010, Canterbury's and Hawke's Bay's allocated volumes have increased 165% and 152%, respectively (Aqualinc, 2010). In terms of the case study locations, the Heretaunga Aquifer in Hawke's Bay is the source for most groundwater take consents in the region – 1272 in all – and the Selwyn Waihora zone has 934, which is about a quarter of Canterbury's total (MFE, 2014). The allocated volume of groundwater take consents in the Heretaunga Plains and in Selwyn Waihora are approximately 191 and 520 Mm^3/year, respectively (ibid). Unfortunately, there is no record of actual abstraction volume, and so in both cases it is unknown what proportions of the allocated volume in groundwater take consents is actually used and when. However, consent conditions have maximum instantaneous abstraction rates and maximum daily, weekly or monthly volumetric takes so that the proportion of consented takes to actual use is not likely to reach 100%.

Groundwater in the Central Plains area

The Selwyn Waihora area consists of a wide alluvial fan that stretches from the foothills of the Southern Alps in the north and west to the coast in the southeast. The unconfined aquifer geology is dominated by alluvial gravels deposited and affected by braided river systems within glacial and inter-glacial climate systems. It is in this context that CPW has established a WMG to provide irrigation via surface water, in part to reduce pressure on groundwater resources. Inland of the coastal margin and within the CPW irrigation area, the aquifer system is a heterogeneous mix of alluvial sequences with variable proportions of coarse, well-sorted gravels and less permeable clay and silt materials. The area has moderate connectivity between vertical units along the groundwater flow path towards the sea, and as a result it can be considered as a single groundwater system (Williams and Lough, 2009). Groundwater flow follows topographic gradients towards the coast except where major river systems contribute to groundwater recharge (Liquid Earth, 2014).

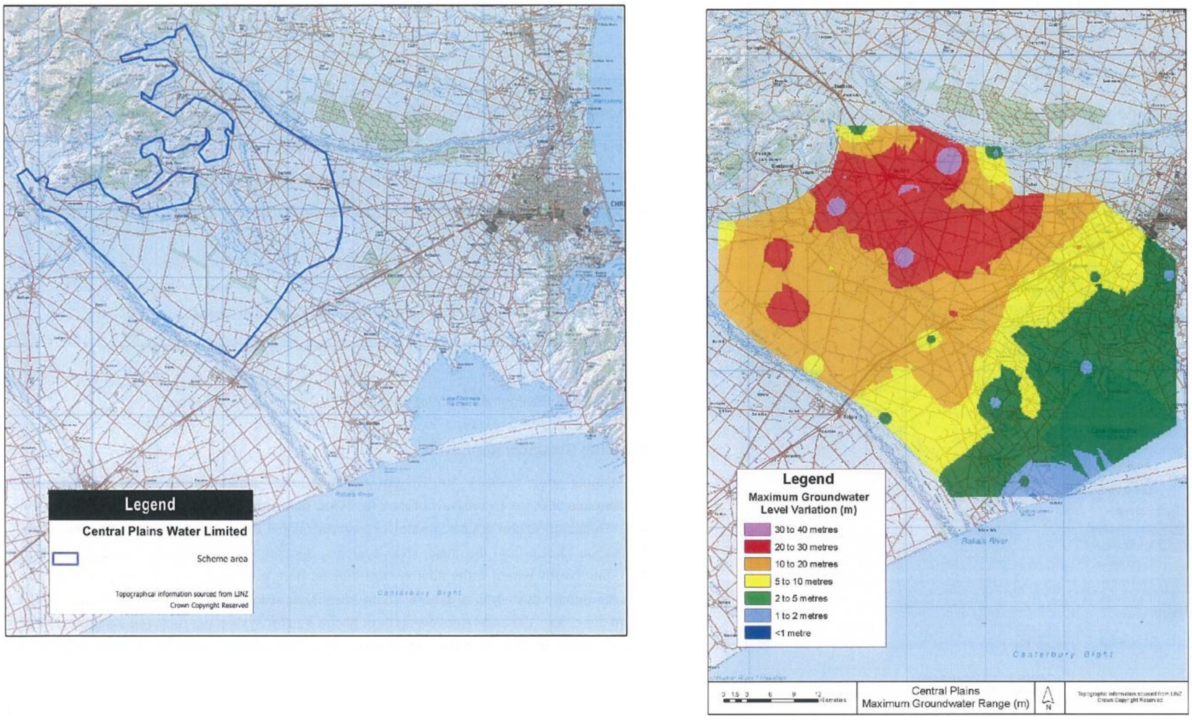
Table 3. Regional Council approach with WMGs – Case study regions in bold.

	Auckland (Op.)	Bay of Plenty (Pr.)	**Canter-bury (Op.)**	Gisborne (Pr.)	**Hawke's Bay (Op.)**	Nelson (Pr.)	Otago (Op.)	Marl-borough (Pr.)	South-land (Pr.)	Tasman (Op.)	Wai-kato (Pr.)	Welling-ton (Pr.)	Total
Policies/methods													
Council support development	**x**	**x**	**x**		**x**	**x**	**x**	**x**			**x**	**x**	**9**
Low flow allocation (drought)	**x**	**x**	**x**			**x**	**x**	**x**			**x**	**x**	**8**
General efficiency (water use and/or general BMP)		**x**		**x**	**x**		**x**	**x**		**x**	**x**	**x**	**8**
Self-regulation/ collective management (consents)		**x**			**x**	**x**	**x**		**x**		**x**		**6**
Clawback		**x**	**x**								**x**		**3**
General participatory governance						**x**	**x**			**x**			**3**
Rules													
Water transfer consent change		**x**	**x**		**x**		**x**				**x**		**5**
Low flow allocation			**x**				**x**				**x**	**x**	**4**
Water allocation limits			**x**				**x**				**x**		**3**
Nutrient limit allocation			**x**										**1**
Consent favourability			**x**										**1**
WMG official status													
Recognition			**x**		**x**		**x**						**3**
Definition			**x**				**x**						**2**

Aquifer recharge consists of relatively stable levels of alpine river infiltration and a more variable component dependent on climatic conditions that include direct land surface recharge, ephemeral foothill river inputs, and seepage from on-farm storage and channels (Williams and Lough, 2009). The middle reaches of the rivers contribute significant direct recharge estimated at up to 15 m^3/s from the Rakaia River, which forms the western border of the CPW scheme as shown in Figure 3 (left) (Scott and Thorley, 2009).

In the CPW area, groundwater abstraction does not exceed long-term inter-annual recharge volumes of approximately 700 Mm^3/year (Scott and Thorley, 2009). However, the fact that groundwater abstraction is concentrated in the summer – a period of low natural recharge – means that seasonal fluctuations in groundwater tables are very significant. Maximum seasonal groundwater table variation in the CPW area has reached 30-40 m as seen in Figure 3 (right) in an area where depth to groundwater typically ranges from 10 to 50 m (Liquid Earth, 2014). Seasonal fluxes have increased markedly in the last decade as overall allocated abstraction consents from both surface water and groundwater sources has quadrupled from monthly maximums of under 50 Mm^3 in 1990 to over 200 Mm^3 by 2010 (ibid; Scott and Thorley, 2010).

Figure 3. Left: CPW irrigation area; Right: Maximum seasonal variation in groundwater levels in CPW area.



Source: Liquid Earth, 2014.

Because of the connectivity of shallow aquifers to lowland streams and lakes, and the direct river recharge component, groundwater pumping can induce increased river recharge leading to decreased surface water flows and lowland stream discharges (Liquid Earth, 2014). These points are critical to the discussion in the section on groundwater-dependent ecosystems and groundwater quality, and the section that discusses how CPW manages surface water-groundwater interactions to aim for improved environmental outcomes.

Groundwater in the Heretaunga Aquifer, Hawke's Bay

The Heretaunga Plains consist of a wide alluvial system made up of riverine sediments from the Ngaruroro, Clive, Tutaekuri, and Tukituki rivers, of which the first three presently meet at the coast. The Ngaruroro alluvial fan area, within which the Twyford WMG is situated (see Figure 2), has between five and seven distinct water-bearing units separated by confining aquitards. The shallow aquifer in this fan consists of deposited gravel and sand that can reach 30 m in depth and is typically overlain by pumice-rich alluvium including some silts and clays less than 10 m thick (Lee et al., 2014). Groundwater flow in the shallow aquifer generally follows topographic gradients towards the coast (Dravid and Brown, 1997).

Shallow aquifer recharge in the Heretaunga Plains is dominated by direct losses from the Ngaruroro River on the order of approximately 430,000 m^3/day (~157 Mm^3/year) during low-flow periods and likely more during high-flow periods (ibid). Overall rainfall recharge in the area estimated over a 34-year period ranges between 1.6 and 2.7 m^3/s, and up to ~85 Mm^3/year (White et al., 2014). However, this volumetric recharge is distributed unevenly in space and time due to climate and soil differences. Over-irrigation likely contributes to groundwater recharge in certain areas and catalyses nutrient transport in local groundwater systems. Depth to well screens in the Twyford area is typically 20-50 m (HBRC, 2009) (ibid).

Monitoring and analysis of groundwater tables in the 1994-2014 period across the Heretaunga and Ruataniwha basins show primarily intra-annual fluctuation in groundwater levels driven by recharge and abstraction timing. Overall, longer-term trends show few areas with statistically significant changes in groundwater level, but some wells, including one monitoring well (well 10371 in Figure 2) near the Twyford District, have experienced long-term declines in groundwater table levels up to 3 cm/year, likely indicating local decreases in aquifer storage (HBRC, 2015a). Intra-annual variation in groundwater levels was also noted by HBRC (2009) for the Twyford area itself. Using LOESS decomposition, HBRC (2015a) show that the amplitude of seasonal changes in groundwater table levels has increased approximately 50% (from under 1 to about 1.5 m) between 1994 and 2013.

While the slowly decreasing trend in groundwater levels in some areas of the Heretaunga Basin is not currently a major policy concern, the effect of long-term and seasonal groundwater drawdown on lowland streamflow rates is important because of their ecological significance. Groundwater abstraction in the region does not approach recharge rates overall. However, relatively minor changes in groundwater levels affect lowland streamflow such as that of the Raupare Stream, which is hydrologically connected to the shallow aquifer from which the Twyford Cooperative and non-WMG irrigators abstract groundwater. HBRC (2009) showed that between 1991 and 2009 Raupare Stream outflows decreased by approximately 40 l/s on average due to local groundwater drawdown, and that variations within seasonal streamflow and groundwater table have also increased.

Groundwater quantity, quality and ecosystem health

Canterbury and Hawke's Bay lowland streams fit into the cool-dry/lowland climate class of New Zealand's River Environment Classification system. This means that their flow regimes are strongly linked to overland rainfall runoff, evapotranspiration, and groundwater discharge regimes (Snelder et al., 2002). Lowland streams of all classes across New Zealand have statistically significant decreasing trends in flow volumes and increasing trends in nitrogen and phosphorus concentrations as well as temperature (Larned et al., 2004). Recent state of the environment research shows that cool-dry/lowland streams as a class have the highest median total nitrogen and nitrate concentrations and are among the highest median total dissolved reactive phosphorus and *E. coli* concentrations (Larned et al., 2015).

Figure 4. Twyford consent areas showing surface water bodies and wells with surface water interaction (some but not all of these wells belong to current WMG members; HBRC, 2009).

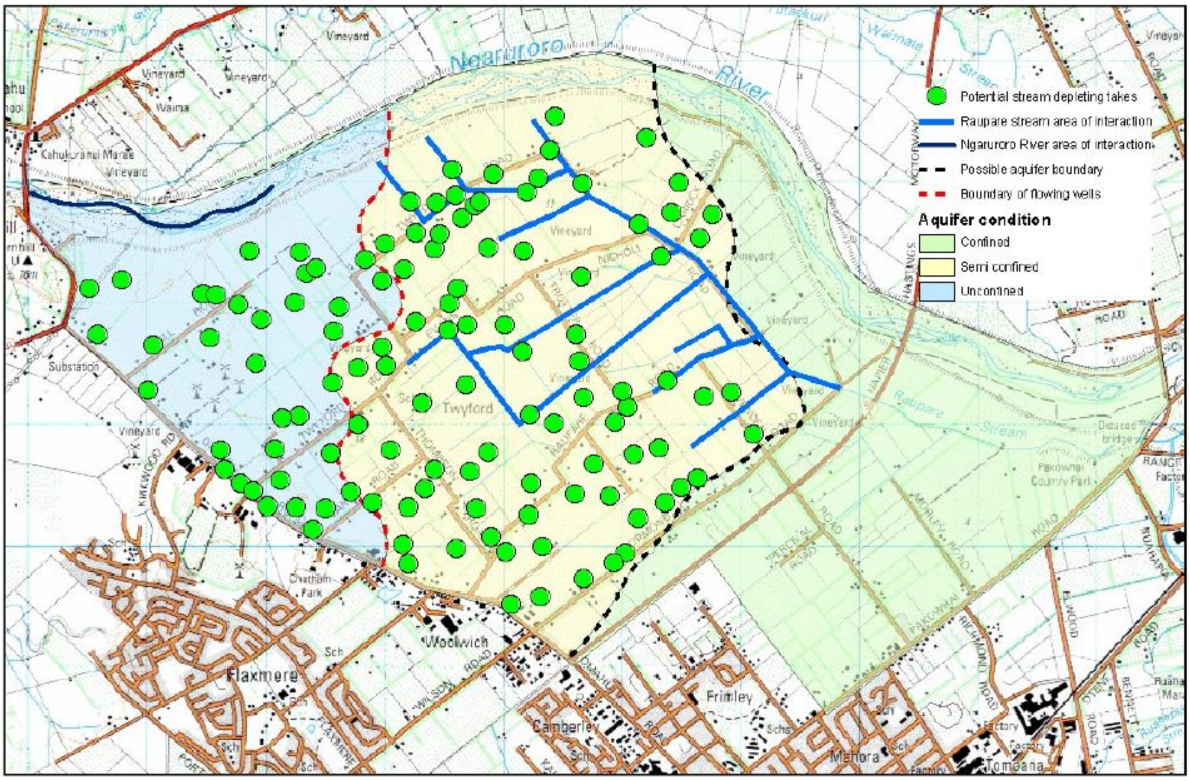
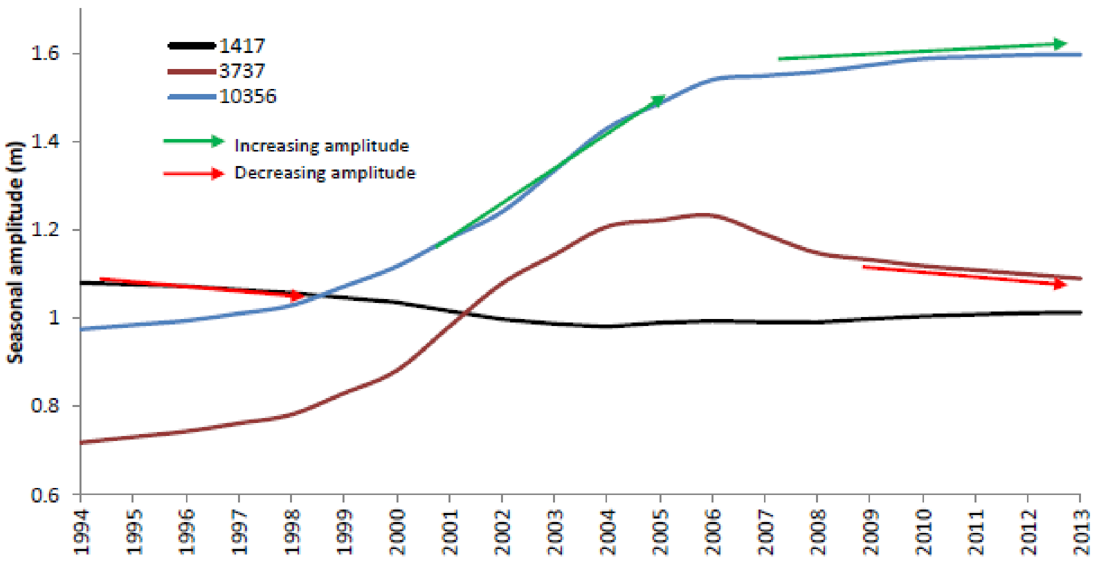


Figure 5. Amplitude of seasonal changes in groundwater level over time from three wells near Twyford area (HBRC, 2015a).



These streams have great importance for the indigenous biodiversity comprising flora and fauna, especially fish species currently under threat (Schallenburg et al., 2011; Townsend et al., 2008; Goodman et al., 2013). Given that surface water-groundwater interactions are very significant for water flow and quality characteristics in this class of stream, groundwater management connects directly to multiple components of ecosystem health as defined as a compulsory national value[6] (NPS-FM, 2017) and in widely used definitions of ecosystem integrity (Schallenburg et al., 2011). As a result, the cumulative impacts of groundwater management on wider environmental systems and ecological indicators has become a major focus of policy and regulatory concern that WMGs must navigate.

The evidence is clear that lowland streams of the type linked to the case study areas are under increasing anthropogenic pressure, and this is attributable to the higher proportions of intensive agricultural and urban development in these parts of New Zealand (Larned et al., 2004; Schallenberg et al., 2011). In Hawke's Bay, recent state of the environment reporting identified lowland streams as having particularly degraded ecosystem integrity and health (HBRC, 2016a). Similar reporting from Canterbury has spurred restoration efforts to focus on lowland streams (ECan, 2017). However, in both regions, even in a relatively small geographic area, the pressures on specific small streams in the sub-catchments vary significantly (ibid; HBRC, 2016). As a result, groundwater management is one major component of addressing these larger water quantity and quality challenges facing native ecosystems.

CASE STUDY ANALYSIS

Central Plains

This case study focuses on the conditions that prompted the development of CPW and how, as an institution, it must integrate surface water and groundwater management to meet collective groundwater abstraction reduction and ecological outcome objectives.

Background

CPW occupies part of the approximately 200,000 hectares of Canterbury bounded by the Rakaia (West) and Waimakariri (East) rivers. Since the early 1900s, development of agriculture has been groundwater-dependent. Through the 1980s, groundwater take consents were inconsistent in time and specification, had 35-year time frames, and there was not an overall aquifer-wide abstraction limit; individual abstraction was limited by pump capacity and energy costs. Until the 1980s, regulatory frameworks were largely adequate to avoid negative effects, primarily because of the overall low intensity of agricultural practices and low demand for groundwater relative to recharge.

The advent of export-driven dairy production from the early 1990s quickly raised irrigation demand, and a series of very dry winters from the late 1990s to the mid-2000s reduced recharge below normal levels. For production and scale reasons, dairy farmers in the area applied for numerous groundwater take consents. These were granted although they became increasingly contentious in public discourse and increasingly subject to legal challenges as the cumulative impacts of increasing groundwater abstraction, and nitrogen contamination, became apparent. The inability, or unwillingness, of councils

[6] Macroinvertebrate community structure is the most widely used proxy for assessing overarching ecosystem health in New Zealand. In particular, the Macroinvertebrate Community Index (MCI) is a widely used indicator of macroinvertebrate community composition that links to land-use pressures and water-quality characteristics among other factors (e.g. Quinn et al. 1997; Young and Collier, 2009). Cool-dry/lowland streams have, among the lowest median scores for the MCI, although the specific pressures driving MCI score reductions are variegated and diverse (Larned et al., 2015). MCI scores are strongly and negatively affected by low streamflow, which groundwater over-abstraction exacerbates, due to connections with two primary stressors: physiological stress from increased temperatures and reduced dissolved oxygen levels, and habitat stress from increased plant growth (Collier et al., 2014).

to control rapid intensification directly contributed to the political need for overarching national direction on water management that the NPS-FM provided. Recognising that continuous expansion of abstraction was not feasible, farmers renewed interest in an irrigation scheme to replace some portion of groundwater use in the area with surface water irrigation (Doak, 2018).

Groundwater consent review and contention

In the 1990s, Canterbury Regional Council began a process to review all groundwater consents in the Selwyn Waihora Zone in response to concerns about groundwater over-allocation. While it is uncertain whether unsustainable groundwater abstraction was actually occurring, Morgan et al. (2002) note that the long-term decreases in lowland streamflow and degradation of the quality of surface water and groundwater – especially nitrogen concentrations – were increasingly prominent issues.

Ultimately this review process failed to stop further groundwater allocation in the Te Pirita area in the Selwyn Waihora Zone, as did a later Environment Court appeal, due to the absence of sufficient information on actual abstraction (Environment Court, 2005). At the time, in the absence of the NPS-FM or other national direction providing added weight to consideration of cumulative downstream ecological effects of groundwater abstraction, there was little legal weight to support the application of precautionary principles to ecological values in groundwater take consenting processes.

Developing CPW

This context frames development of the CPW scheme, which came to fruition slowly from 1999 onwards. Groundwater irrigators in the area put forward the general CPW plan to increase reliability and volume of irrigation water supply, and the development and implementation of the Canterbury Water Management Strategy provided new frameworks for collaboration (ECan, 2010). The Selwyn Water Management Zone committee (now Selwyn-Waihora) supported by the regional council recognised that reducing pressure on groundwater resources was essential for meeting environmental goals and that surface water irrigation, if managed wisely, could help in this transition and permit further economic growth (ECan, 2017).

To put this into effect, local government bodies formed a committee and funded feasibility studies of the CPW scheme, which the central government also supported through the Irrigation Acceleration Fund (MPI, n.d.). In 2003, local government bodies established the CPW Trust, which then established CPW Limited (CPWL) to raise share capital to fund consent application processes for the development, implementation, and operation of the scheme. Interestingly, the consents are owned and administered by the Trust with water allocated to CPWL, which was entirely subscribed to by farmers in the scheme area (CPWL, 2011).

While the consenting process was long, expensive and arduous (CPWL, 2017), the collaborative consenting process brought a wide range of stakeholders to the table. The resulting plan and consent conditions have policies that incentivise farmers to join CPW rather than continue to abstract groundwater. For example, Policy 11.4.25 prohibits the transfer of groundwater consents to prevent unused 'sleeper allocations' being activated by trading, which would have undermined support for CPW and contributed to increased groundwater abstraction (ECan, 2017; Interviews, 2017). Aside from rules incentivising participation in the scheme, CPW consent conditions also require stringent self-monitoring regimes and reductions in nutrient losses over the whole area (Ecan, 2016a).

CPWL water users are entitled to volumetric allocations based on their company shareholdings and they are allowed to transfer water within the scheme area on a seasonal basis and shorter time frames (Section 3 – CPWL, 2015). Likewise, shareholders have a range of obligations that include meeting the overarching consent conditions held by CPW Trust, environmental risk management mechanisms, and information provision requirements to permit auditing (Section 6 – ibid). Currently, all consented water takes greater than 5 l/s, including groundwater abstraction, must be metered, and consent holders are required to provide regional councils water use information on an annual basis. As of 2016, about 4900 of 5400 consents for takes greater than 10 l/s had meters installed as required before the council began to implement compliance and enforcement programmes (ECan, 2016b).

Likewise, any new well-drilling and groundwater abstraction for agricultural purposes face significant barriers because the Selwyn Waihora Zone is overallocated (consents are granted to take more groundwater than recharge volumes). As a result, consenting processes severely limit the situations in which new abstractions can occur and require a high burden of proof that new abstractions would have minimal negative impacts on groundwater and surface water resources (s11.5.33-11.5.37 ECan, 2017). Because of these collective accountability measures and formal structure, CPWL can be considered a collective management group, but because of its individual shareholding structure and its non-democratic decision-making structures, it is not considered a CPRI institution per Table 2 above.

To date, CPWL farmers have invested approximately NZD350 million off farm and significant amounts on-farm, and CPWL Stage 1 has started operation across 23,000 ha leading to reduced abstraction of 20 Mm^3/year with more likely in the future as the scheme's reliability and cost-offsets are proven over time (CPW Trust, 2017). Stage 2 is under construction and was planned to open in September 2018. This will replace groundwater irrigation on a further 5000 ha with surface water irrigation sourced from an upstream river offtake to support surface water irrigation on a total of 21,000 ha. The 2017 annual report (ibid) shows Stage 1 water supply reliability near 100% (aided by a wetter than average summer period) and increasing uptake in the region, further decreasing groundwater demand in the catchment. Reduced abstractions are anticipated to raise local groundwater tables and increase lowland streamflow. Also, replacing groundwater irrigation with surface water irrigation is anticipated to dilute nutrient contamination in shallow groundwater lenses, those which most directly contribute to lowland stream baseflow (Central Plains Water Trust, 2017).

The Twyford Cooperative Company in Hawke's Bay

This case study focuses on the collaborative groundwater management of the Twyford Cooperative company. This group is unique in New Zealand as it manages both surface water and groundwater takes through a global consent – water allocations that are shared and managed by the entire group membership. Because of this, this group bears the closest relationship to a theoretical CPRI of any WMG in New Zealand today.

Twyford and the Ngaruroro Catchment

Twyford is a district on the Heretaunga Plains, north-west of Hastings City. It is an agricultural area with orchards, vineyards and mixed cropping as the main source of income (HBRC, 2016). The area is bordered by the Ngaruroro River, comprising a small portion of its total catchment.

The Twyford Cooperative Company is a group of approximately 196 irrigators that share a large portion of the district's land, albeit in non-contiguous properties. Of these users, 166 rely on groundwater bores generally between a depth of 20-60 m on the Raupare semi-confined aquifer – connected to the Ngaruroro catchment – with an additional 30 relying on a confined aquifer (van Beek, 2016). Several of these properties also have surface water takes on the Raupare Stream and its tributaries (ibid).

Since the early 2000s, the Hawke's Bay Region has experienced record-setting droughts, including for three consecutive years from 2006-2009 (Chappell, 2013). As a result, restrictions on water takes to protect ecological flows and ecosystem health have become increasingly commonplace, creating significant challenges for communities that rely on irrigation.

Irrigation restrictions, a policy change and the need for cooperation

During the 2006-2009 drought, Hawke's Bay Regional Council (HBRC) put in place severe restrictions on irrigation, prompting agricultural water users to lodge an appeal (van Beek, 2016). This coincided with the consultation period for a regional plan change (Plan Change 6), and a group of users in the Twyford district began to self-organise in order to represent their interests on both fronts (van Beek, 2016; Interviews, 2017).

A serious conflict emerged when the council implemented an outright irrigation ban. Twyford horticulturalists – who collectively relied on a minimum of only 37 l/s to ensure the survival of their rootstock – were upset by the blanket ban. They considered this minimum required volume insignificant in relation to the ecological flow of the Ngaruroro, and they argued that to continue this rate of take would not materially impact the river's ecosystem (van Beek, 2016). They were frustrated that the council had not considered substitutes for an outright ban and pressured the council to let them manage water takes amongst themselves (ibid).

Their argument hinged on the fact that the council's ban was driven by 'on paper over-allocation', the theoretical aggregated instantaneous take of all users, much like the Environment Court decision in relation to Canterbury mentioned above (Environment Court, 2005). Also like in Canterbury, there was inadequate abstraction data to evaluate actual water takes versus consented water takes.

However, there were a wide variety of different crops grown in the district, and this diversity meant that not all water users necessarily had to draw on the groundwater resources at the same time (van Beek, 2016). Because of the different crop cycles, this created the potential for flexible reallocation of resources between seasons and even at a weekly or daily scale. The group argued that collective management would permit takes adequate to ensure the survival of their crops without impacting on ecological flows (ibid).

HBRC ultimately encouraged the group to take this approach and so the group worked to establish a 'global consent' effectively pooling their individual consents together and managing them collectively. The Twyford Cooperative Company Ltd. was formally established and it received its global consent in January 2015 (HBRC, 2015).

Common property management under the Twyford Cooperative Company

The global consent granted by HBRC allows the growers to manage the available allocation between them providing that the overall limits for the group are not breached. To do this, the group has a fairly formal decision making and internal reallocation structure.

The group follows a traditional incorporated society structure and has an executive board that undertakes its leadership functions. The executive board – and in particular the Chair, Jerf van Beek – provides enthusiastic leadership. This strength may also become a weakness for the group in the future if succession is not carefully considered (Interviews, 2017).

Individual WMG members have a binding legal contract with the group that specifies their allocation (both instantaneous take in l/s and volumetric limit over a period of time.) The group retains the right to exclude individuals who do not comply with the terms of their allocation, and it charges dues to pay for an administrator (van Beek, 2016). Global consent compliance monitoring is made possible by individual members' own telemetered well data; as well as continuous streamflow gauges upstream and downstream of the irrigated area.

Any new members wishing to join the WMG or expand the scope of the global consent would need to work with both the group and council to amend the current global consent because it is currently site-specific (HBRC, 2015). When HBRC issued the global consent, it subsumed approximately 50 previously individual groundwater take consents within the delimited, non-contiguous area. The council would only allow for expanding the areal extent of the global consent if new entrants were WMG members and if it was sensible from a catchment management perspective to do so. The applicant would then have to confirm his/her contract with the WMG itself, agreeing to its terms and conditions.

The executive board is responsible for managing the global groundwater consents on behalf of the group, and the group's global consents are monitored and enforced by the regional council. Because of the hydrological links between surface water and groundwater, the group's groundwater takes have to be managed carefully in order to maintain the minimum streamflows for ecosystem health set by HBRC. The board plans for and implements a rotation process during times of scarcity in order to maintain these minimum flows (van Beek, 2016). Occasionally, the board also makes the decision to augment streamflow using some of the group's groundwater allocation.

Procedurally, because of the WMG's surface water takes and the strong hydrological connectivity between the groundwater takes and the Ruapare Stream, if the stream is nearing minimum flow levels HBRC informs the group that irrigation needs to stop for a period (e.g. for 12 hours or until flows return above a particular threshold rate). The executive board has also established various 'trigger points' at which it will prompt or require the group to take collective action. For example, when the group's collective monitoring shows that they are using more than 75% of their total allocation, the board informs members that they are getting close to limits and will have to start planning irrigation times collaboratively. When they reach 85% of allowable take, the group starts putting restrictions on irrigation – for example, rotating takes to reduce the instantaneous take by 50%. The board has the responsibility and right to put these restrictions in place (van Beek, 2016; Interviews, 2017).

Individual users have a strong incentive to comply with these restrictions as the rotation system effectively increases the reliability of their water take by averting blanket irrigation bans that the council might otherwise impose. Also, individuals within the group have a 1 l/s emergency allocation which they can use even under the most extreme restrictions. This is vitally important for orchardists who have significant investments in rootstock and who need this small but guaranteed allocation to keep their trees and vines alive during severe drought conditions. Without involvement in the WMG, farmers in the region have no such guarantee, leaving individuals to take the risk that the council might seek a blanket irrigation ban when minimum stream levels are breached (Interviews, 2017).

Aside from concerns directly related to irrigation water availability, the Twyford Cooperative has been financially beneficial for members in other ways. Members' land values have increased because of the improved reliability of water supply, which in turn helps them raise capital. Likewise, members have avoided much of the financial and administrative costs that would have been required to obtain and maintain individual resource use consents (van Beek, 2016).

Twyford's success in managing periods of water restrictions

In recent years, there have been several times when the group successfully managed rotations during periods of scarcity. In 2012-2014, rotations were put in place and the biggest irrigators were required to coordinate their takes (van Beek, 2016). Since the operation of the global consent in 2015, the group has not breached its consent conditions. The group has also established a process to augment the Raupare streamflow using their groundwater allocations, and also hold a side agreement with a local Māori tribe for stream restoration activities (van Beek, 2016).

Finally, since its inception, the group has dramatically improved its relationship with the council, which has allowed it to serve a greater self-management role. HBRC, and other councils, have reported that monitoring resource consent compliance from one entity that agglomerates resource users is far more efficient than monitoring individual users (Interviews, 2017). HBRC has continued to support this approach, signalling greater need to "allow users greater control of re-allocation and use decisions" as part of the region's water strategy (HBRC, 2016, 2011).

Ultimately, this case study illustrates how environmental and regulatory changes have put increased pressure on growers in the Heretaunga Plains, which has led them to build new institutions for sub-catchment governance. Because the user community has knowledge of its collective impact on the sub-catchment, and the council has provided support for experimentation, the Twyford group has been able to create an institution that reflects many of Ostrom's design principles.

DISCUSSION

Groundwater is a typical example of a common pool resource with attendant 'wicked problems' in its management (Rittel and Webber, 1973). The existence of this special issue of *Water Alternatives* is testament to the global nature of the challenge in sustainable groundwater management. In New Zealand, recent legislative reforms aim to help councils manage dispersed resource use, including groundwater abstraction, and their cumulative effects on the environment at the catchment and sub-catchment scales. Historically, the fact that consents are provided to individuals has made management of cumulative effects difficult for councils. Because WMGs operate at a sub-catchment scale and they also agglomerate numerous resource users into one institution, they provide opportunities for councils to integrate resource management objectives and to realise economic and environmental outcomes simultaneously.

Ostrom's design principles in action

These case studies indicate that in certain conditions, WMGs can provide better outcomes than allocation regimes that operate at the individual property level alone. Some aspects of these emergent institutions in New Zealand also corroborate foundational theory as these examples have organically developed in a way that is largely consistent with the design principles for effective commons management espoused by Ostrom. This finding should give some level of confidence that these emerging institutions can be robust enough to be trusted with taking on some sub-catchment scale decision-making functions. Table 4 summarises how the case studies reflect Ostrom's design principles.

When implemented effectively, council allocation regimes required under the RMA and NPS-FM provide clarity around in-stream flow requirements and permissible water takes. These clearly defined boundaries are further strengthened with good understanding and high visibility of groundwater-surface water interactions. Where this occurs, the impacts of groundwater takes are rapidly evident, allowing communities to understand and flexibly manage their impacts.

For consenting purposes, both HBRC and ECan have required institutional formality in their own relationships with WMGs and also in WMGs' own collective choice arrangements. ECan and HBRC have largely required graduated sanctions for non-compliant individuals and conflict resolution mechanisms to be written into WMG constitutions prior to issuing resource consents. These processes have strengthened the WMGs as institutions since they have established formal cooperation agreements for collaborative management.

The supportive nested-governance environment has permitted and facilitated the development of these groups. Increasingly, councils provide enabling policy architecture before the arrival of formal groups reflecting findings that council officials believe the importance of developing WMGs is growing rapidly (Irrigation NZ, 2015). Governance structures recognising WMGs' right to organise – at least in these cases – has been central in legitimising these institutions and promoting their success in managing cumulative effects.

The success in these case studies indicates a potential opportunity to replicate these good governance outcomes elsewhere in New Zealand and other areas with similar hydrological and regulatory traits.

Table 4. Case study reflections of Ostrom's CPRI design principles.

Design principles	Central Plains Water	Twyford Co-operative
1. Clearly defined boundaries	Due to recent regulatory changes, clear sub-catchment limits for groundwater abstraction and nutrient discharges are set. Hydrological connectivity data supports WMG to understand and manage their collective impacts. Individual takes are clearly defined by shares purchased in the scheme	Due to recent regulatory changes, catchment-scale limits associated with stream minimum flows and global consent take conditions clearly established. Terms of individual takes are clearly established within the WMG
2. Congruence between appropriation and provision rules and local conditions	Unclear how CPW allocations to individuals are adapted to dynamic resource availability, though presumably through informal cap and trade market for shares in the irrigation scheme, where cap fluctuates with availability. Individuals can continue to take according to their shares unless council imposes further restrictions	Group take and individual allocations regularly readjusted or rotated temporally to reflect changes in resource availability. This is an administrative versus market driven allocation system. Individuals can take up to their full allocation unless group executive has agreed that reductions are required. Even under worst restrictions, members are always allowed a 1 l/s emergency take
3. Collective-choice arrangements	Corporate structure (payment for service) reduces ability of individual users to influence decisions, though flexibility exists through buying and selling allocations within limits	Co-operative structure allows for group members to actively participate in re-allocation and irrigation rotation decisions and other democratic decisions if they wish to take an active role
4. Monitoring	Members' individual monitoring, group monitoring, and council oversight ensure the group manages within limits	Members' individual monitoring, group oversight, and council oversight ensures group manages within limits
5. Graduated sanctions	Group has internal regime for penalising non-compliance (e.g. using more than shares purchased). Group has ability to sanction or exclude members in extreme cases. Council has ultimate authority and can sanction individual members or the whole group	Group has internal regime for penalising non-compliance (e.g. using more than agreed individual allocation). Group primarily uses soft approaches/social pressure but has ability to sanction or exclude members in extreme cases. Council has ultimate authority and can sanction individual members or whole group
6. Conflict resolution mechanisms	Group has option for recourse to conventional legal proceedings	Minimally outlined in formal documents, but anecdotal evidence of managing conflict through interpersonal relationships. Conventional legal proceedings an option in extreme cases
7. Minimal recognition of rights to organise	Strong support from regional council, including through plan provisions (see Table 3)	Strong support from regional council, including through plan provisions (see Table 3)
8. Nested enterprises	Clearly defined roles and responsibilities between the council and WMG (see Table 3)	Clearly defined roles and responsibilities between the council and WMG (see Table 3)

Potential benefits of WMGs

As we have seen from these cases, councils increasingly incentivise the formation of WMGs because they have the potential to facilitate several core council objectives: improve and ease resource consent monitoring and compliance burdens, tackle environmental problems in an integrated way at a catchment/sub-catchment scale, and to promote efficient use of resources. Also, WMGs may provide unique opportunities for Māori development.

Improved consent monitoring and compliance

Both CPW and Twyford follow 'audited self-management' principles in resource consent monitoring whereby the WMG itself monitors and is responsible for the behaviour of individual members, and the council monitors and audits the environmental performance of the overarching entity. WMG members benefit in the form of favourable resource consents and reduced administrative burden related to maintaining individual relationships with council.

Integrated environmental management

Councils use a range of methods to implement integrated environmental management, and WMGs are increasingly part of the picture. In both cases, the councils' policy statements and planning documents highlight the impact of intensive land use on ecosystem health and outline future approaches to avoid, mitigate and remedy impacts of historical and current impacts (ECan, 2017; HBRC, 2006). Improved groundwater management – including changes in abstraction timing, volume, and end-use – is one of these avenues, and cooperating with WMGs provides the social, institutional, and financial capacity to approach these 'wicked problems' in an integrated fashion.

Individual resource users can receive significant advantages by participating in WMGs, which incentivises their creation. These advantages can include preferable consent conditions, improved resource reliability through cooperation to mitigate risks of blanket bans, and reduced costs and administrative burdens related to securing individual consents from the council. For individuals operating outside of a WMG, these costs and risks can be considerable.

Promoting resource use efficiency

Regional councils and water users report that WMGs are forming because consents to individuals are not a flexible enough mechanism (for example, not temporarily moveable or tradeable) to allow communities to reallocate and share resources efficiently or in a way that maximises reliability (Interviews, 2017). Also, typical processes for managing allocations during periods of low-flow restrictions are inflexible and create perverse incentives for individuals to use more water than they need (Interviews, 2017). Collective management such as in the Twyford case provides opportunities to surmount these obstacles and to meet environmental performance and resource efficiency/reliability outcomes simultaneously.

WMGs and Māori development

Development of WMGs may also provide chances for councils to enhance relations with and present improved opportunities for *iwi/hapū* to exercise their rights to *rangatiratanga,*[7] *mana whenua,* and *kaitiakitanga*[8] (Kahui and Richards, 2014; Memon and Kirk, 2012; Miller, Tait, and Saunders, 2015). While exploring the cultural dimension of this topic is beyond the scope of the paper, Kahui and

[7] *Rangatiratanga*: The expression of one's chieftainship.

[8] *Kaitiakitanga:* Guardianship or stewardship.

Richards (2014) provide a lucid discussion of the commonalities of Aotearoa's inter-cultural paradigms of resource management. Some types of WMGs such as collective management groups or CPRIs may align well with historical Māori resource management practices that communities may wish to revive. Indeed, multiple post-settlement governance entities and *iwi* (tribal) trusts have begun to explore the development of WMG variants to meet their economic development and *kaitiakitanga* objectives (Interviews, 2017).

Challenges

All this considered, we should note that WMGs are by no means a panacea. According to group leaders (Interviews, 2017), issues of institutional sustainability and longevity are the most pressing concerns. In New Zealand this connects to challenges for group leadership succession and funding for consistent and effective WMG administration. Also, group leaders stress that self-regulation is an ever-present challenge and without clear constitutional rules group leaders face difficulties dealing with group members' bad behaviour or non-compliance. More formal user groups typically have internal institutional mechanisms for issuing warnings and taking further action, including legal steps, before excluding members or engaging with the legal system. However, less-formal groups would likely be powerless in such situations. Thus, institutional capacity and liability are especially prominent issues for councils to consider and address when evaluating the appropriateness of dealing with WMGs formally or providing them the opportunity for audited self-management.

CONCLUSION

In the New Zealand context, WMGs are emerging nationwide and starting to fill important co-governance functions related to groundwater. WMGs in some cases collectively manage allocations for a defined resource pool using a variety of types of agreements ranging from informal to legally binding. WMGs provide opportunities for devolving resource management to users themselves while regional councils still maintain regulatory accountability and oversight. To date, WMGs have proven to be flexible and useful for managing groundwater, surface water, and linked agricultural pollution and for facilitating the uptake of best management practices in farming communities. WMGs are uniquely permitted in several regions to manage short-term resource trades to promote dynamic efficiency, and in some cases, they have unique responsibilities in terms of environmental monitoring and management.

The New Zealand examples presented in this study are particularly relevant for the literature on CPRIs where the following characteristics are prominent:

- where management of cumulative environmental outcomes are a critical component of the groups' authorising framework;
- where defined catchment/sub-catchment scale limits are clearly identified;
- where surface water-groundwater interactions provide a clear and timely feedback loop to support groundwater resource decision making and allocation.

The last point in particular is relevant because of the connectivity these case study aquifers have with nearby lowland streams. In these cases, groundwater abstraction can affect surface water bodies' discharge almost immediately whereas water-quality impacts can be inter-generational in nature. Indeed, the presence of these three overarching characteristics in the case studies examined has likely made collective action by the WMGs easier and more responsive to public and regulatory pressures to meet more stringent resource management requirements and wider environmental outcomes.

The case studies presented have each achieved some improvements in environmental outcomes, so when examined against some of the foundational theory on CPRIs, these case studies provide some confirmation that groups that exhibit certain organisational traits can provide more effective commons management than a system that relies entirely on individual allocations.

Some councils are developing forward-thinking policy frameworks to accommodate, regulate and incentivise these institutions given that they can facilitate councils' overall planning objectives. However, these regional policy frameworks are being developed in an ad-hoc fashion given the absence of consensus and national direction on the issue. For many councils, it remains unclear how CPRIs can fit within an overarching framework designed explicitly for allocation of resources to individual users. While WMGs are not appropriate in all cases, the evidence presented here supports the conclusion that at least in cases where common CPRI design principles can be met, WMGs can improve resource users' outcomes while facilitating and expediting the achievement of governmental resource management objectives.

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APPENDIX 1. REGIONAL COUNCIL PLAN DOCUMENTS SEARCHED

NVIVO Search terms:

Catchment management group/s

Catchment management club/s

Water management group/s

User group/s

Council	Document(s)	Plan link (in some cases, plans consist of multiple documents, all of which are available at the site provided as of 13 March 2017)
Auckland	Auckland Unitary Plan	http://unitaryplan.aucklandcouncil.govt.nz/pages/plan/Book.aspx?exhibit=AucklandUnitaryPlan_Print
Bay of Plenty	Regional Natural Resource Plan	www.boprc.govt.nz/plans-policies-and-resources/plans/regional-natural-resources-plan/
Canterbury	Canterbury Regional Policy Statement	www.ecan.govt.nz/document/download/?uri=3122545
	Canterbury Land and Water Plan	www.ecan.govt.nz/document/download?uri=3249652
Gisborne	Tairāwhiti Resource Management Plan	www.gdc.govt.nz/the-tairawhiti-plan/
Hawke's Bay	Regional Resource Management Plan	www.hbrc.govt.nz/our-council/policies-plans-strategies/rrmp/
Horizons	Horizons One Plan	www.horizons.govt.nz/CMSPages/GetFile.aspx?guid=b2f1afb2-a09e-4822-b89d-6645bd6d4d33
Marlborough	Marlborough Environment Plan	www.marlborough.govt.nz/your-council/resource-management-policy-and-plans/proposed-marlborough-environment-plan/volume-1-issues-objectives-policies-and-methods ; www.marlborough.govt.nz/your-council/resource-management-policy-and-plans/proposed-marlborough-environment-plan/volume-2-rules
	Marlborough Regional Policy Statement	www.marlborough.govt.nz/your-council/resource-management-policy-and-plans/regional-policy-statement
Nelson	Regional Policy Statement	http://nelson.govt.nz/assets/Our-council/Downloads/regional-policy-statement-1997.pdf
	Nelson Resource Management Plan	http://nelson.govt.nz/assets/Environment/Downloads/RMP-PDFs/most-recent-RMP-documents/Combined-

		chapters/NRMP-Volume-1-combined-Jun2016.pdf
Northland	Proposed Regional Plan for Northland	www.nrc.govt.nz/contentassets/506f48db06744ab782c65e56acd19dde/proposed-regional-plan-september-2017-final-7-sept-2017.pdf
Otago	Regional Policy Statement for Otago	www.orc.govt.nz/media/4084/regional-policy-statement-for-otago.pdf
	Regional Plan for Otago	www.orc.govt.nz/media/1207/regional-plan-water.pdf
Southland	Proposed Land and Water Plan	www.es.govt.nz/document-library/plans-policies-and-strategies/regional-plans/proposed-southland-water-and-land-plan/Pages/default.aspx
Taranaki	Regional Policy Statement for Taranaki	www.trc.govt.nz/assets/Documents/Plans-policies/RPS/rps-full-web.pdf
	Regional Fresh Water Plan for Taranaki	www.trc.govt.nz/assets/Documents/Plans-policies/FreshwaterPlan/RFWP2001-web.pdf
Tasman	Tasman Resource Management Plan	www.tasman.govt.nz/document/serve/Total%20Text%20Volume%20-%20U58-2017.10.14%20-%20optimized.pdf?path=/EDMS/Public/Other/Policy/Plans/ResourceManagementPlan/TRMPText/000000231411
Waikato	Waikato Regional Policy Statement	www.waikatoregion.govt.nz/assets/PageFiles/6777/2016/WaikatoRegionalPolicyStatement2016.pdf
	Waikato Regional Plan	www.waikatoregion.govt.nz/Council/Policy-and-plans/Rules-and-regulation/Regional-Plan/Waikato-Regional-Plan/
Wellington	Proposed Natural Resources Plan for the Wellington Region	www.gw.govt.nz/assets/Plans--Publications/Regional-Plan-Review/Proposed-Plan/Proposed-Natural-Resources-Plan-for-the-Wellington-Region-July-2015.pdf
West Coast	Regional Land and Water Plan	www.wcrc.govt.nz/our-services/resource-management-planning/Pages/Land-and-Water-Plan.aspx
	Proposed Regional Policy Statement	www.wcrc.govt.nz/Documents/Resource%20Management%20Plans/RPS/Proposed%20Regional%20Policy%20Statement.pdf