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Rescaling knowledge and governance and enrolling the future in New Zealand: a co-production analysis of Canterbury's water management reforms to regulate diffuse pollution

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Addressing diffuse agricultural pollution to improve water quality is a socio-economic, political and policy challenge worldwide. In New Zealand, catchment load limits are being introduced to regulate nutrient losses from agricultural land. Focused on the South Island region of Canterbury, this paper presents an interpretive co-production policy analysis to examine the role of science through modeling in rescaling the knowledge and governance of diffuse pollution. The paper assembles a discourse of limits, scientific representations of catchment scale diffuse pollution, a 'fast-track' institutional pathway, and identities of scientists and government as knowledge broker and the community as decision-maker. The analysis identifies the paradoxical scripting of 'predictable nature' and 'uncertain nature' and the enrolment of the future as a governance space essential for resolving water resource conflict. The paper illustrates a role for modeling well beyond informing and facilitating environmental decision-making to constituting the identities, objects and spaces of governance.

1. Introduction

As water resources diminish in both quantity and quality, devising ways to address diffuse pollution while reconciling often-conflicting values, interests and uses for water is an ongoing and fraught endeavor for governments worldwide (see Bellamy et al., Eberhard et al. and Huang and Xu this issue). Under state-led hierarchical regimes, expert knowledge and the authority of science have been indispensable warrants for environmental regulation and government-supported developments (Jasanoff, 1987). However, on a range of environmental issues not limited to water, the science used by governments to authorize either development or tighter regulations can face debilitating challenge through environmental assessment processes, the media and the courts. In these arenas, uncertainties of science are routinely exploited to call decisions or project proposals into question or delay action (Bocking, 2004; Jasanoff, 1987; 1990). While litigation and controversy continue, for some time governments have been turning to community collaboration to address water resource conflict (Eberhard et al. and Förster et al. this issue). Scaling decision-making down and opening it up to a wide range of voices and knowledges is expected to address collective issues as well as deliver better outcomes on the basis dialogue fosters greater legitimacy for the science used in policy and policy implementation (Margerum, 2011; Sabatier et al. 2005; Scholz and Stiftel, 2005; Wesselink et al., 2011). In line with the international trend, community collaboration is being promoted by New Zealand’s central government to implement its National Policy Statement for Freshwater Management (NPSFM) (MfE, 2014) and collaborative approaches are being adopted by regional councils.

To contribute to calls for further understanding of the role of science in rescaling environmental governance (Cohen, 2012; Cohen and McCarthy, 2015; see also van Kerkoff and Lebel, 2015; Wyborn, 2015), this paper focuses on the use of modeling in regional planning in New Zealand. As the blueprint for central government's NPSFM reforms, collaborative water quality limit-setting has been proceeding across New Zealand's South Island region of Canterbury since 2010. Under its Canterbury Water Management Strategy (CWMS) (CMF, 2009) there has been a shift away from trying to manage the environmental effects of agriculture at the property scale with no overarching limits to managing them with catchment scale limits. This paper focuses on limit-setting in Canterbury, with reference to the sub-regions known as the Hurunui Waiau and Selwyn Waihora – the first two zones to have completed Canterbury's new hybrid regional planning process of collaboration and statutory force.

2. A co-production conceptual framework

Co-production is a conceptual framework well-suited to examining the role of science in rescaling environmental governance. As a mode of interpretive critical policy analysis, Jasanoff (2004, p. 3) describes co-production as a lens through which to trace "how knowledge-making is incorporated into practices of state-making, or of governance more broadly and, in reverse, how practices of governance influence the making and use of knowledge". Drawing insight from constructivist theories of knowledge and the field of science and technology studies (STS), the co-production framework used here stands in contrast to instrumental modes of co-production that aim to produce shared knowledge (van Kerkhoff and Lebel, 2015; Wyborn, 2015). Co-production as critique identifies discourses, representations, institutions and identities in-the-making to evaluate their interconnection and reveal “the social arrangements that prop up particular natural orders or in reverse, the epistemologies that help to sustain particular social orders” (Jasanoff, 2004, p. 278).

A foundational STS insight that underpins the Jasanoff (2004) articulation of co-production is that “nature alone” cannot be the sole determinant of the validity or otherwise of scientific knowledge claims (Knorr-Cetina and Mulkay, 1983, p. 4). Hence, although science is often invoked in official statements that account for how regulatory disputes, for example, have been brought to an end, scientific renditions of nature or environmental effects are not sufficient explanations of consensus or closure (Jasanoff, 1987, 1990; Engelhardt and Caplan, 1987). The full picture also requires understanding the social practices that contribute to the construction, mobilisation and validation of knowledge claims (Jasanoff, 2004; Latour, 1987; Shapin and Schaffer, 1985). In other words, what becomes accepted as ‘reality’ (even if temporary) is not revealed by science as a mere reflection of unmediated nature but nor is it socially determined; ‘reality’ derives from the mutual constitution of both nature and society (Jasanoff, 2004). This means that in evaluating the practices of “ordering knowledge”, analysis is to look also at practices of “ordering society” (Jasanoff, 2004, p. 13). Jasanoff explains:

> In this view of co-production, human beings seeking to ascertain facts about the natural world are confronted, necessarily and perpetually, by problems of social authority and credibility. … At times of significant change … it may not be possible to address questions of facticity and credibility of knowledge claims without, in effect, redrafting the rules of social order pertaining to the trustworthiness and authority of individuals and institutions …. Only by solving social problems in this way can satisfactory warrants be produced for radically new orderings of nature. Doing science merges, in other words, into doing politics (Jasanoff, 2004, p. 29).

Jasanoff (2004, p. 39) states that the instruments of co-production, i.e. discourses, representations, institutions and identities, "operate at the nexus of natural and social order" and "stabilize both what we know and how we know it." From this perspective, knowledge-making and state-making can be seen as a process of ordering rather than revealing, and modeling as an ordering device that has become indispensable in environmental policy (Egmond and Zeiss, 2010). Hence, tracing the social practices that bring order to our knowledge of nature and *vice versa* can bring into view "new objects and spaces of environmental governance", for example, understanding how global circulation models constitute global climate change (Cohen and McCarthy, 2015, p. 4).

3. Methodology

In requiring in-depth research and data triangulation, the qualitative case study (Yin, 2013) is useful for grappling with the complexity and fluidity of the 'real-life' context of collaborative limit-setting in Canterbury. The empirical resources have been analysed using discourse analysis, which Hajer and Versteeg (2005, p. 175) define as follows:

> an ensemble of ideas, concepts and categories through which meaning is given to social and physical phenomena, and which is produced and reproduced through an identifiable set of practices. The 'discussion' … is the object of analysis; discourse analysis sets out to trace a particular linguistic regularity that can be found in discussions or debates.

To apply the co-production conceptual framework using discourse analysis, my approach has been deductive and inductive (Merriam and Tisdell, 2015). In terms of the former, the instruments of co-production, i.e. discourses, representations, institutions and identities, were used to focus the analysis on how society and nature are being ordered and enacted in the establishment of water quality limits. This was accompanied by an iterative, inductive process, which involved interpreting and conceptualizing statements for their alignment with the instruments as well as connections between them.

The empirical resources are extensive and include publically available central government policy documents outlining water management reforms and regional council planning documents, hearings evidence and scientific reports related to formal water quality limit-setting processes that have been underway across Canterbury since 2010. I have supplemented these official accounts by following limit-setting in practice in the Hurunui Waiau and Selwyn Waihora zones. I have regularly attended monthly zone committee and public meetings in the Hurunui Waiau and participated in limit-setting focus groups in Selwyn Waihora. Through the focus groups and meetings, as well as attendance at regional plan public hearings and briefings for both zones, I have witnessed the different stages of Canterbury's collaborative limit setting process, from development through to the beginning of implementation. These attendances have been rich in opportunities to observe and record what has been said and done on-the-ground to verify the coding of the instruments of co-production from the documents. As such, the attendances and observations have been used in the process of interpreting meaning to draw findings focused on identifying new identities, objects and spaces of governance.

4. Background

In brief, under New Zealand's hierarchical *Resource Management Act, 1991* (RMA), environmental governance is devolved by central government to two tiers of local government: regional councils and territorial authorities. Through national environmental standards and national policy statements, central government direction on the management of natural and physical resources cascades down to local government. The concept of 'sustainable management' underpins this 'effects-based' legislation, which mandates the control of environmental effects rather than prescribe activities. Regional councils are required to develop regional policy statements to give effect to national standards and statements as well as identifying resource issues and strategies to address them. While not mandatory, regional councils can also develop regional plans to give effect to issues identified in regional policy statements. Regional councils issue consents that authorize resource use (e.g. water takes or discharges to water) under specified conditions. Territorial authorities manage land use and subdivision and develop district plans to give effect to the upper layers of statements and plans (Peart, 2007). Managing water resources on a first-in first-served basis, consent-by-consent, fails to recognize resource bounds and capacity. Hence, many have argued that the consent system under the RMA has: a) been unable to address cumulative effects; b) foreclosed integrated catchment-based water planning; and c) fostered too much time-consuming litigation in the Environment Court (CMF, 2009; Gunningham, 2011; Jenkins, 2011; Russell and Frame, 2011).

In this context, water quality has become a highly-charged political issue in New Zealand, in Canterbury especially. The agricultural industry, in particular the dairy sector, is routinely criticized as the cause of degraded water quality (see Foote et al., 2015). Over half New Zealand's land area is dedicated to pastoral and arable farming (Howard-Williams, 2010) and one-third is public conservation estate (DOC, 2015).

Across its varied terrain are 425,000 kilometres of rivers and streams, more than 4,000 lakes and over 200 aquifers that are replenished by an estimated 608 billion cubic metres of annual precipitation (MfE and MPI, 2014). In catchments dominated by agriculture, the legacy of past land use and management practices (e.g. excessive fertilizer, deforestation, grazing on erosive slopes) is converging with the more recent effects of water abstraction and nutrient losses from intensified land use (PCE, 2012). There is widespread concern that New Zealand's '100% Pure' brand that underpins both tourism and agriculture is under threat (Foote et al., 2015; LAWF, 2010; PCE, 2012). Clearly, not addressing water quality could have high ecological, social, cultural, economic and political costs.

Government has responded. Water quality is now on the political, policy and operational agendas of all levels of New Zealand government. For example, the key purpose of central government's NPSFM is to establish "enforceable quality and quantity limits" for all freshwater water bodies (MfE, 2014, p. 3). Yet, diffuse pollution is a challenging socio-economic, political and policy issue for governments the world over (Rabotyagov et al., 2014). Measuring nutrient losses and assigning responsibility at the property level for the purpose of enforcing compliance with regulations is very difficult when causes and effects can occur over distant spatial scales and long, often generational, temporal scales. While the highly visible effects of nutrients are ultimately evident through seasonal algal blooms, at their source or at the individual or property scale, nutrient losses of nitrogen and phosphorus from agriculture are easily unnoticed or deemed insignificant. Thus, notwithstanding provisions under the RMA to address cumulative effects, regulation is fraught given the practical impossibility of identifying who is responsible for what, where and when (Howard-Williams et al., 2010).

The region of Canterbury is where 70 per cent of the country's irrigated agriculture is situated. Its CWMS articulates a vision to "enable present and future generations to gain the greatest social, economic, recreational and cultural benefits from our water resources within an environmentally sustainable framework" (CMF, 2009, p. 6). The vision is to be achieved through long-term targets: ecosystem health/biodiversity, natural character of braided rivers, kaitiakitanga (i.e. Maori stewardship), drinking water, recreational and amenity opportunities, water-use efficiency, irrigated land area, energy security and efficiency, regional and national economies, and environmental limits (CMF, 2009, p. 8). While the targets are to be "advanced in parallel" (CMF, 2009, p. 9), they are to be guided by "environment, customary use, community supplies and stock water" as *first* order priorities and *second* order priorities of "irrigation, renewable electricity generation, recreation and amenity" (CMF, 2009, p. 8).

The CWMS is being implemented as a collaborative front end of Canterbury's new hybrid governance framework (see Gunningham, 2011). The process begins with the establishment of a sub-regional Zone Committee (ZC) created under New Zealand's *Local Government Act, 2002* by the Environment Canterbury Regional Council (ECRC) and the relevant territorial authority. In what would be described by Eberhard et al. (this issue) as a networked governance approach, the ZC works with the regional council and territorial authority in consultation with interest groups, the community, and industry to develop a Zone Implementation Programme (ZIP) to advance CWMS targets. Limit-setting has become a dedicated stage of the CWMS collaborative process after a ZC identifies its community's aspirations for freshwater catchments and priorities to give effect to the CWMS targets in the ZIP. Community-based decisions are then translated by planners into regional plan provisions and rules which are subsequently plugged into the statutory RMA process, which involves plan notification, public submissions and public hearings before independent commissioners and, eventually, an operative regional plan (see Duncan, 2013).

There are ten CWMS zones in Canterbury in which a number of waterbodies and their catchments are situated (CMF, 2009). In December 2013, the Hurunui Waiau zone was the first to complete the new process. Due to limited data, load limits were set only for the Hurunui River. Its catchment loads for nitrogen and phosphorus are a calculation of a six-year rolling average of monthly observations of in-river nutrient concentrations and river flow measurements from upper and lower catchment sites (ECRC, 2013). While based on in-river data, interpretation, credibility, lag time and allocation challenges have arisen (e.g. HDC & EC, 2015a; see also Duncan, 2014a). Selwyn Waihora, and all other zones, has adopted a modeled catchment load limit approach (ECRC, 2015b) which overcomes some of these issues (e.g. the lag time can be modeled in and an allocable load can be calculated) but opens many questions about linking numbers derived from predictive models to compliance and enforcement mechanisms (see Duncan, 2014b). For example, in all zones, including the Hurunui Waiau, farmers are required to use the government/fertiliser industry-sponsored property-scale nutrient management model, Overseer® (or equivalent approved by ECRC) to demonstrate nutrient loss compliance with regional plan rules. As an empirical model, Overseer® is regularly updated and is being developed to expand its capability for use in policy. While it produces numbers on both nitrogen and phosphorus, its use for compliance within Canterbury beyond the Hurunui Waiau Zone has been confined to nitrogen given the model's current lack of capability and the less direct pathways of phosphorus getting into water (e.g. via sediment). A shift in the use of Overseer® from decision-support for fertilizer application to regulatory tool has been controversial due to, for example, high margins of error and large shifts in output numbers as the science and data systems that operationalise the model are updated (Duncan, 2014b). Notwithstanding, Overseer® is central to limit-setting in Canterbury and in many regions across the country (Arbuckle, 2015).

5. A co-production analysis

5.1 *Making discourses: a discourse of limits*

Within the co-production framework, discourse is characterized as a persuasive way of talking about phenomena and constituting identities and representations that are routinely deployed by institutions. The empirical resources show a consensus across government, amongst scientists and the broad range of stakeholders, that the way to address the issues currently contributing to diminished water quality is by setting *enforceable* resource limits (CMF, 2009; LAWF, 2010, 2012a, 2012b, 2015; MfE, 2013). For example, central government's national collaborative advisory body, the Land and Water Forum (LAWF), states:

> A central difficulty is that as a nation we have found it hard to set or manage limits. Without limits it is hard to manage diffuse discharges – nutrients,

> microbes, sediment and other contaminants that wash into water from the land – and impossible to deal with the cumulative effects on water bodies of water takes on the one hand and diffuse and direct discharges to water on the other … It is in all our interests to maintain and improve the quality of freshwater in New Zealand, including instream values. For that we need limits, standards and targets in line with national needs, values and objectives which are applied taking account of the needs, values and objectives of communities. They must address contaminants and flows. (LAWF, 2010, pp. viii – ix)

Concerns about cumulative effects extend to the additional but unknown "load to come" (due to, for example, the time it takes for nitrogen to move through groundwater to surface water) (Howard-Williams et al., 2010, p. 134). The modeled load limit approach can incorporate the lag effect. In 2009, in a report commissioned by the ECRC as part of its Land Use and Water Quality Project (LU&WQP), it was argued:

> It would be more certain for environmental outcomes, fairer, less time-consuming and more cost effective, if appropriate water quality objectives and related nutrient load limits were established before the assimilative capacity of a lake (or a river system) is exceeded. This would make the ground rules for land developers clear before they make investment decisions. Measureable plan objectives and nutrient load caps would clearly quantify the sustainable capacity of the lakes in terms of catchment land use (Norton et al. 2009, pp. 4-5).

A way to operationalise this proposed limit-setting regime was subsequently offered. It involves a number of steps starting with community decisions on desired water quality objectives informed by community values. Through modeling, these objectives would be quantified by scientists into threshold levels of nutrient enrichment (or nutrient reduction) in waterbodies and ultimately translated into catchment nutrient loads. These catchment loads would be translated into property nutrient discharge allowances and used by planners to devise land use rules to be complied with by property owners (Norton et al., 2010; see also Duncan 2013, 2014b). Woven into the LU&WQP's *Preferred approach* *for managing the cumulative effects of land use on water quality in the Canterbury region* (ECRC, 2012), the catchment-based limit setting framework, with its sequence of community, science and planning phases, now underpins the Canterbury Land and Water Regional Plan (ECRC, 2015b) and has been adopted by central government to operationalise the NPSFM and its accounting regime that is envisaged to allow resource managers to know when "resource availability is available for current and potential resource users" (MfE, 2015, p. 17).

5.2 *Making representations: catchment-scale diffuse pollution*

Scientific representations are ordinarily conceived as reflections, or getting-closer-depictions, of reality revealed by science. From a co-production perspective, they are conceived as outcomes of social, political and technological practices and imperatives that engage with and constitute the material world (Jasanoff, 2004, p. 39). The CWMS states that a shift from "effects-based management of individual consents [i.e. property scale] to integrated management based on water management zones" is needed to enable the "[m]anagement of cumulative effects of water abstraction and land use intensification" (CMF, 2009, p. 7; see also MfE, 2015). This planning imperative frames the scale of water quality science and modeling commissioned by the ECRC, thus reconfiguring how environmental monitoring data are interpreted, translated and communicated into the planning process. Geographic information systems – in conjunction with a range of environmental databases that categorize soil characteristics and land use patterns – render maps, graphs and charts that depict potential present and possible future diffuse pollution as well as the extent to which it could be reduced through mitigation alongside modeled regional economic impacts.

In Selwyn Waihora, collaborative and scientific work was undertaken over several years to identify an agreeable catchment load limit. Hydrologic, environmental and economic models were used to predict and communicate the effects of current and future land use intensification and irrigation expansion under a range of scenarios alongside mitigation options to address environmental effects on the lower catchment's shallow coastal lake, Te Waihora/Lake Ellesmere (Robson, 2014). Validated through the collaborative and then the statutory planning process, the regional plan sets a catchment load limit for nitrogen for existing farms of 4,830 tonnes per annum. This load limit is to be achieved by 2037 with an overall 14% reduction in nitrogen by 2022. This will involve farms reducing nitrogen losses beyond what have been estimated to be good management practice loss rates, with different levels of responsibility, e.g. dairy 30%, irrigated sheep, beef or deer 5% (ECRC, 2015b, p. 197B; Robson 2014).

5.3 *Making institutions: a politically-expedient institutional pathway*

Within the co-production framework, institutions are characterized as playing a central role in the stabilization of natural and social orders (Jasanoff, 2004, p. 40). In other words, institutional arrangements (e.g. courts or advisory bodies) can bring closure (even if temporary) to scientific disputes. In Canterbury in 2010, a means of closure on resource limits was created when the democratically elected councillors of the ECRC (or ECan) were dismissed by central government under special legislation, the *Environment Canterbury (Temporary Commissioners and Improved Water Management) Act, 2010* (the ECan Act) (Rennie, 2010; Russell and Frame, 2011).[1] This legislation suspends regional council elections and creates a unique institutional pathway that allows the ECRC to temporarily step outside the RMA to establish water quality limits through a non-adversarial process. Specifically, as well as requiring central-government appointed commissioners (ECan commissioners) to take account of the vision and principles of the CWMS, a key provision is that appeal rights on regional plans are restricted to the High Court if a case can be mounted on points of law. This action disallows merit appeals to the Environment Court, which is an adversarial arena. RMA hearings, to which most regional planning in Canterbury is now confined, are inquisitorial. It has been argued by central government (MfE, 2013) and the LAWF (2012b) that disallowing merit appeals to the Environment Court is necessary to discourage litigation and to force parties to collaborate and abide by decisions, knowing such agreements cannot be overturned at a later time in court. In practice, this means that catchment-scale water quality limits can be put in place in Canterbury through a truncated process. This pathway is now emulated in a Resource Legislation Amendment Bill that seeks to amend the RMA to allow regional councils across the country to opt into a 'fast track' collaborative regional planning process similar to what has been imposed in Canterbury.

5.4 *Making identities: knowledge brokers and community decision-makers*

Within the co-production framework, it is important to consider how identities (human, non-human, individual or collective) are shaped, how they "restore sense out of

[1] In October 2016, regional council elections were held in Canterbury under central government's mixed model whereby seven councillors were elected to join six central government appointed commissioners on council. The ECan Act remains in place.

disorder", and how the roles they play sustain "social roles" and foster "power and meaning" (Jasanoff 2004, p. 39). The following statement that opens the ECRC 2015 CWMS progress report illustrates how the discourse of limits constitutes the ECRC and the community in particular ways:

> The CWMS is underpinned by collaboration; empowering communities to make their own decisions to meet agreed region wide and local targets. Through the CWMS, the process of setting Environmental Limits provides an opportunity for the community to take local ownership of water management and to work together through complex information to reach decisions on their priority outcomes and values. Zone committees and communities are working collaboratively through the Resource Management Act (RMA) plan development timetable. This intensive process supports Environment Canterbury to meet its statutory responsibilities, working with the people of Canterbury to achieve sustainable management of the region's water and land resources and align the planning framework to CWMS targets (ECRC, 2015a, p. 8).

Setting limits mobilizes a collaborative community that is local, empowered to take ownership, and works together. ZC and community tasks include working through complex information (i.e. the science and modeling) and making decisions. The community, through a ZC, is a collaborator, decision-maker (on science, priorities and values) and supporter of the ECRC, which is scripted as working with and at the behest of the community.

In this collaborative arena, a new identity has been cast for scientists. Invoking Roger Pielke's (2007) repertoire of the roles of scientists in policy, scientists constitute themselves (and the ECRC) as knowledge broker. ECRC's technical report in support of Selwyn Waihora zone's catchment load limit-setting process states:

> Setting outcomes and natural resource limits for catchments and deciding on

> the available capacity for resource use is not simply a technical question. These decisions are value judgements that involve weighing up, trading off, and balancing between conflicting outcomes and values. The key role for the technical team in these processes is one of informing those decisions, by making consequences transparent, rather than making the decisions themselves.
>
> This shifts the role of Environment Canterbury from knowledge 'arbiter' to one of knowledge 'broker', exploring the implications of different management options with the community. It also shifts the role of the science, away from trying to find the 'right' answer and defending that position in scientific terms to a role of supporting and informing (Robson, 2014, p. 16, emphasis in original).

Hence, the role of science is defined as follows:

> In order to help the Zone Committee and the wider community make informed value judgements recognising the uncertainty that exists in the technical work, the expectations of the technical team were to:
> • Describe the direction of change and likely magnitude of change under future scenarios
> • Predict the likelihood of outcomes being achieved for each of the future scenarios (Robson, 2014, p. 16).

Rather than claim comprehensiveness, accuracy, or rigor of method to invoke epistemic authority, scientists maintain they have been involved in the supply of information that is "sufficient, relevant and credible" that has been:

> legitimately gathered, analysed and presented to a community in a way for them to understand the connections and make recommendations in the knowledge of the likely consequences – i.e. to make an informed value judgment. This shift also means that an understanding of the inevitable uncertainty of the science or limited information is integral to the nature of the decisions being made, and is not used as a reason for not making them (Robson, 2014, p. 16).

These statements characterize uncertainty as inevitable rather than something to shy away from.

> There are many sources of uncertainty in a limit setting process such as the Selwyn Waihora. There is uncertainty both in the input sources of information and the numeric models and assessment techniques used to make

> predictions. Where possible the uncertainty associated with individual technical assessments has been discussed in the technical reports. However, no quantitative assessment of overall uncertainty of the scenario predictions has been attempted (Robson, 2014, p. 16).

Framing uncertainty as inevitable and everywhere but not a reason not to make a decision avoids miring ZC members in discussions over data, model assumptions and parameters, and stymies calls for more science.

Importantly, the value judgments of the community derive from a very small group of people. A ZC comprises representatives from the local territorial authority and local Maori (i.e. runanga), and between 4-6 community members who either live in or have a special interest in the zone. In the context of the ECan Act, an ECan Commissioner contributes to deliberations of each ZC. Each ZC has an ECRC facilitator. The ECRC commissions the science and the modeling used for setting limits and responds with further information, advice and presentations from experts or stakeholder groups deemed necessary or called for by the ZC. Appointment of community members involves expressions of interest sought by the ECRC from the wider community, and appointees being chosen by representatives of the ECRC, the territorial authority and local runanga on the basis of the "balance of interests required for the Zone" (ECRC, 2015c, np). A key criterion for appointment is a member's ability to "work in a collaborative, consensus-seeking manner" (ECRC, 2015c, np). Interest or stakeholder groups do not get a dedicated seat at the table. Members could have an affiliation with an environmental or industry organization, for example, or harbor particular interests or values. However, according to the ECRC ZC terms of reference, members are to "[w]ork in a collaborative and co-operative manner using best endeavours to reach solutions that take account of the interests of all sectors of the community" and "[c]ontribute their knowledge and perspective but not promote the views or positions of any particular interest and stakeholder group" (ECRC, 2015c, np).

While ZC meetings occur once a month, meeting preparation for decision-making and commitments beyond them, including stakeholder engagement and public consultation, are extensive and time-consuming. Indeed, it has been identified in a report commissioned by the ECRC that these roles have been taking an emotional and physical toll and that "the commitment required to be on a zone committee appears to have been underestimated by just about everyone including ECan" (Henley, 2014, p. 3). Community and local runanga representatives are remunerated with $4,000 per annum for committee members, $5,000 for deputy chair and $6,000 for chairperson (plus travel expenses). Community members cycle through the committees on a three-year basis (ECRC, 2015c). Hence, collaborating, decision-making and supporting the ECRC falls to a small sub-set of 'the community' who meet particular criteria, and who receive limited remuneration for their high-level workloads and responsibilities.

However, as the wider community has slowly become aware of the implications of the rules and regulations, community ZC members are finding themselves at the centre of community division. For example, in the Hurunui Waiau zone in September 2014 – nine months after its plan had been finalized – around 350 farmers descended upon the monthly ZC meeting to express their deep concern about how the rules favoured high nitrogen leaching farms over low-loss farms, and the loss of farm equity. A rule intended to limit further land use intensification that defines land use change as a 10% increase in nitrogen loss (as modelled by Overseer®) has caught the normal operations of dryland farmers in the regulatory net making their farm businesses technically illegal under the plan's rules (see HDC & EC, 2015b; Fulton, 2014). In Selwyn Waihora, the ZC is defending criticism that nothing is happening (ECRC, 2016; see also https://www.youtube.com/watch?v=3RBi3IlkX30).

6. Discussion

To address calls for further understanding of the role of science in rescaling environmental governance, I have focused on modeling used in regional planning in New Zealand's South Island region of Canterbury, where catchment nutrient load limits are being instituted to regulate diffuse agricultural pollution. Instigated by the CWMS, water governance in Canterbury has been rescaled from the region to sub-regional zones with considerable decision-making power devolved to ZCs. Deliberation and learning are occurring; decisions are being made; plans, limits and rules are being developed and passed through the statutory RMA process; and on-ground actions are gaining momentum (ECRC, 2015a; Henley, 2014). It is noted that notwithstanding the considerable decision-making power devolved to communities, the Canterbury case supports the conclusions of Eberhard et al. (this issue) who argue that the so-called shift from 'government to governance' is not appearing to result in a loss of state authority. Instead, networked governance is supplementing rather than replacing traditional hierarchical governance systems.

Pivotal to Canterbury's progress have been the quantitative, aggregative, standardizing, calculative and predictive capabilities of modeling, which usually escape critical attention. Given the challenges of capturing catchment-scale social-ecological interactions, surface and groundwater dynamics, lag times, the impossibility of knowing what nutrients are actually being leached from what property, and what good management practices have or have not been adopted and when, science's modeled catchment scale representations bring much order to the intractable indeterminacies, uncertainties and complexities of the real world.

A co-production analysis focuses on "how knowledge-making is incorporated into practices of state-making, or of governance more broadly and, in reverse, how practices of governance influence the making and use of knowledge" (Jasanoff, 2004, p. 3). This framework seeks to bring into view the mutually constitutive epistemological (i.e. how we know) and ontological (i.e. what we know) dimensions of what *becomes* shared knowledge (Jasanoff, 2004; Latour, 1987; van Kerkhoff and Lebel, 2015; Wyborn, 2015). It does so by examining "the social arrangements that prop up particular natural orders or in reverse, the epistemologies that help to sustain particular social orders" (Jasanoff, 2004, p. 278). In other words, as Cohen and McCarthy (2015, p. 11) argue "rescaling of environmental governance plays a significant role in constructing its own objects of governance". To examine closely the identities, objects and spaces that derive from the 'how' and 'what' of intertwined knowledge and governance practices, I have assembled a discourse of limits, catchment-scale representations of diffuse pollution, a politically-expedient institutional pathway under the ECan Act that limits appeal rights, and identities that constitute 'the community' as decision-maker and sees scientists and the regional council defining themselves as knowledge broker.

The discourse of limits that echoes through New Zealand's national and regional water policy and planning reforms has played a key role in rescaling knowledge and governance. As "an ensemble of ideas, concepts and categories through which meaning is given to social and physical phenomena" (Hajer and Versteeg (2005, p. 175), this discourse has mobilized a quantitative epistemology through the knowledge practices of science and modeling. Through these practices, diffuse pollution has been made visible, and tractable. The scale at which this visibility and tractability has been rendered and given meaning is interwoven with political goals (e.g. strategic resource use), management imperatives (e.g. to overcome a failing consent system) and institutional necessities (e.g. the ECan Act) to create a new object of governance – the catchment. In a Canterbury catchment, the identities of 'the community' as decision-maker, with scientists and the ECRC as knowledge broker, are scripted through the goals, imperatives and necessities that have instigated, facilitated and validated the process of rescaling and the resultant catchment load limits. Hence, the catchment is as social and political as it is physical.

Further conceptualisation through the lens of co-production identifies two further identities scripted through the discourse of limits. The first is 'predictable nature'. The quantitative epistemology renders the nation's water resources measurable, governable and, now, allocable at the scale of the catchment. Demonstrating how knowledge-making is bound up with state-making, 'predictable nature' underpins not only national and regional water policy and planning reforms but also central government's 'business growth agenda' with the goal to increase exports from 30 to 40 per cent through, for example, building infrastructure (e.g. large scale irrigation schemes) and gaining access to natural resources (e.g. water) – while recognizing the need to set limits (MBIE, 2015). Constituting a natural resource as predictable is essential for its measuring, accounting and (re)allocating (Porter, 1995; Scott, 1998).

Perhaps paradoxically, the second identity is 'uncertain nature'. With the exploitation of uncertainty and model deconstruction substantially averted under the ECan Act, scientists were free to disclose how the models can script only estimates of the current diffuse pollution problem and possible directions of impacts, change and potential outcomes in the future (Robson, 2014). 'Uncertain nature' embodies disclosures essential for scientists working in very close proximity to the ZC and the broader community. Through the knowledge practices of modeling and reconfigured institutional arrangements, the decision-making space was cast by scientists as filled with uncertainty, with resolution deemed to reside with 'the community'.

While they appear diametrically opposed, it is argued that 'predictable nature' and 'uncertain nature' are part of the "ensemble of ideas, concepts and categories" that bring meaning to the discourse of limits (Hajer and Versteeg, 2005, p. 175). Indeed, they constitute a discursive repertoire (Mulkay, 1980) that is invoked by actors at different stages of the planning process. For example, 'uncertain nature' influenced the role of scientists, i.e. knowledge broker not arbiter nor decision-maker. Arguably, it was concern about unleashing ‘uncertain nature’ into the adversarial arena of the Environment Court that contributed to central government’s unprecedented moves to limit appeal rights under the ECan Act. In contrast, ‘predictable nature’ is embedded in the precise numeric renditions of diffuse pollution that are circumscribed by the catchment – a load limit of 4,830 tonnes per annum and a 14% load reduction. Notably, it is ‘predictable nature’ not ‘uncertain nature’ that is invoked to construct the regional planning instruments and operationalise the NPSFM accounting regime.

Going further, following the focus of Cohen and McCarthy (2015) on objects and spaces of governance created through rescaling, it is argued that a new space of governance, one that extends spatial concepts of the catchment, has been created in Canterbury. In Selwyn Waihora, the catchment-scale models were used to not only quantify future environmental effects, they were used to negotiate and reconcile conflicts between values, interests and uses for water and to open opportunities to explore a range of mitigation options and potential water quality effects and outcomes. In this respect, the quantitative, aggregative, standardizing, calculating and predictive capabilities of the modeling are scripting a temporal scale onto what is ordinarily conceived as spatial. Opening up the future to negotiation on possible actions and mitigations, in response to the practical realities of advancing the CWMS targets in parallel, has involved an extension of the governance space beyond the ostensible spatial boundaries of a catchment to enrol the future.

The linchpin of this co-production is central government’s orchestration of a means of knowledge closure around the modeling that appears far more resistant (although not completely) to challenge than relying on the authority of science, with its high risk of deconstruction in the Environment Court (Jasanoff, 1987). Under the ECan Act, the indeterminacies and uncertainties that pervade the models and predictions are immune from exploitation and the models are relatively safe from those with the means to contest them in court. Arguably, this coproduction is a political, policy and planning triumph. So enamored is central government with what has been achieved, it has moved to amend the RMA to emulate the Canterbury experiment across the country with a 'fast track' collaborative pathway available to all regional councils. Hence, the social ordering and politics described by Jasanoff (2004) as necessary to order a new rendition of nature is becoming increasingly explicit in New Zealand.

7. Conclusion

The co-production analysis brings into view the institutional and political fortifications that have had to be built by central and regional government to create and protect new identities, objects and spaces of governance to establish limits that can be more swiftly and apparently less contentiously translated into land use rules that are, at least in theory, enforceable. Marked out by a discourse of limits that deploys a quantitative epistemology through science and modeling, water and its assimilative capacity are rendered governable and allocable at the catchment scale and environmental effects knowable far into the future. Their armory is availed by the ECan Act. It has been shown that the use of modeling in regional planning has moved well beyond informing or facilitating. Indeed, the analysis shows that in Canterbury, at least, the modeling is constituting new identities, objects and spaces of governance.

The implications of the apparent success of this political and institutional stronghold are important to consider. What has occurred in the Hurunui Waiau zone illustrates the risks of the 'fast track' when decisions are made quickly and the implications of innocent-looking numbers are not fully understood by ZC members or are impossible for even planners to think through given the complexity of the rules and the lack of understanding of the socio-economic context into which such precise limits and rules seek to intervene (HDC & EC, 2015b). Furthermore, ECRC's (and central government's) framing of 'the community' as homogenous, agreeable and working together sits in stark contrast to the broader highly diverse groups, communities and agricultural sectors that are now coming into conflict outside courts of law by virtue of setting resource limits which are creating winners and losers. This unfolding would appear to be the 'collateral damage' governments deem necessary to set limits to address the cumulative effects of diffuse pollution. The big question is: will the limits be enough? Extending the governance space beyond its spatial bounds far into the future means many of us are unlikely to ever know.

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