ARTICLE CASE

The challenges of regulating diffuse agricultural pollution to improve water quality

A science policy perspective on approaches to setting enforceable catchment load limits in New Zealand

RONLYN DUNCAN

Department of Environmental Management, Lincoln University, Lincoln, Christchurch, New Zealand
Email: Ronlyn.Duncan@lincoln.ac.nz

ABSTRACT Worldwide, the cumulative effects of diffuse pollution arising from a range of human activities are diminishing the quality and ecosystem capacity of lakes, rivers, estuaries, and oceans. Devising effective ways to regulate the causes and effects of diffuse pollution is a fraught legal, political, policy, and management challenge given the difficulties in identifying and measuring who is responsible for what, where, and when. In 2011, under its *Resource Management Act, 1991*, the South Pacific nation of New Zealand introduced national policy to arrest diffuse pollution with a requirement for local government to institute enforceable water quality and quantity limits on all freshwater bodies. The blueprint for these national freshwater policy reforms comes from its South Island region of Canterbury. Canterbury's regional council has adopted a catchment load approach whereby an overarching limit on nutrient losses from agricultural land is calculated and linked to land use rules to control property-scale agricultural activities. With a focus on the Canterbury region, this case study examines two approaches to establishing a catchment load for diffuse nutrient pollution to link to legal provisions in its regional plan. One is based on a river's nutrient concentrations and the other relies on predictive modelling. The case study opens important questions about measuring and regulating diffuse pollution and the difficulties faced by policy-makers and regulators in linking numbers to legally binding compliance and enforcement mechanisms, e.g. how to account for lag effects when establishing 'in-stream' limits and how to address changes in software when relying on 'modelled' limits?

LEARNING OUTCOMES

- An in-depth understanding of the characteristics of diffuse pollution that relate to the difficulties in identifying and measuring links between causes and cumulative effects and the implications for regulation and management.
- A comparison of the strengths and weaknesses of two approaches to the regulation of diffuse pollution: 'in-stream' versus a 'modelled' catchment load limit approach.
- The ability to critique the legal, policy, and management framework for regulating diffuse pollution and propose options for future action.

CLASSROOM TESTED? YES

INTRODUCTION

For some time, governments across the world have been devising ways to impose limits and thresholds on the use, take, and contamination of natural resources and ecosystem services to prevent or reverse over-exploitation. For example, sustainable yield mechanisms are used to manage marine and forest resources; licensing is used to regulate pollutants into freshwater, oceans, and the atmosphere, and trading schemes are used to regulate a range of pollutants [1, 2, 3]. Some of these regulatory approaches rely on measuring the extent or capability of a resource from which to calculate a yield. Others rely on measuring end-of-pipe losses. While these modes of regulation can work for point sources of pollution, and are often resolvable by technological and engineering solutions, regulating diffuse

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pollution presents a number of challenges, which are the focus of this case study.

CASE EXAMINATION: CHARACTERISING DIFFUSE POLLUTION

Regulating the causes and effects of diffuse pollution is a fraught legal, political, policy, and management endeavour the world over given the difficulties in identifying who is responsible for what, where, and when [4, 5, 6, 7, 8, 9]. From agricultural land, nutrients can move into waterways through groundwater and via sediments moving with surface run-off in rainfall events. The movement of nitrogen arising from fertiliser and cow urine through or over soil can vary significantly from place to place and is influenced by a range of factors, for example: farm type, land use practices, distance from waterways, soil properties and structure as well as microbial activity that can catalyse denitrification in soils [10, 11]. Measuring nutrient losses and assigning responsibility is very difficult when causes in one place can have effects long distances away and across long, sometimes generational, time scales. Hence, when policy-makers and regulators consider the cumulative effects of diffuse pollution, they have to also consider the additional but unknown "load to come" with the myriad uncertainties of when and where it might arrive and its impact [6, p.134].

NEW ZEALAND'S RESOURCE MANAGEMENT LEGISLATIVE AND INSTITUTIONAL CONTEXT

New Zealand's 'effects-based' *Resource Management Act, 1991* (RMA) establishes the legal, institutional, policy, and planning framework for the integrated management of the nation's natural and physical resources. While the Act has been able to regulate point sources of pollution (with varying degrees of success), it has struggled to deal with diffuse pollution notwithstanding its provision to address cumulative effects. Guided by the objective of 'sustainable management', the RMA requires the *effects* of activities to be managed rather than prescribe where and how activities should occur [12].

On-the-ground implementation of the RMA is delegated to local government, which consists of 11 regional councils (that largely align with water management catchments) as well as 11 city councils and 50 district councils (collectively known as territorial authorities) [12, 13]. The RMA establishes a framework that is hierarchical. This means that central government can provide national policy direction and consistency to local government through national policy statements and national environmental standards. The RMA requires the provisions of higher level policy statements and standards to cascade down to regional policy statements and then to regional and district or city plans, which can be quite specific in terms of rules that establish with what environmental effects consents to use or gain access to a resource can be granted or not.

MANAGING EFFECTS

The meaning of 'effect' in the RMA is comprehensive and includes: "any positive or adverse effect; any temporary or permanent effect; any past, present, or future effect; any cumulative effect which arises over time or in combination with other effects". These are "regardless of the scale, intensity, duration, or frequency of the effect, and also includes any potential effect of high probability and any potential effect of low probability which has a high potential impact" (RMA Part 3). The 'effects-based' RMA has been criticised for how it has been implemented to operate on a consent-by-consent basis that cannot account for the overall capacity of a resource. Hence, notwithstanding the wide-ranging definition of 'effect', many have argued that the consent system under the RMA has been unable to effectively address cumulative effects [14, 15]. Important for this case study is the assumption that underpins the RMA which is that environmental effects are measurable. While amenable for regulating point sources, the RMA runs into difficulties when faced with diffuse pollution. Assuming measurability has implications for how water policy in New Zealand has been developed and written and for policy implementation [16].

POLICY REFORMS TO ADDRESS DIFFUSE POLLUTION

In 2011, two decades after the introduction of the RMA, New Zealand's central government moved to provide national guidance for the regional planning and management of the nation's water resources under a National Policy Statement for Freshwater Management (NPSFM) [17]. The NPSFM establishes a limits-based approach across the existing effects-based system by requiring regional councils to set enforceable water quality and quantity limits for all freshwater management units in accordance with national values and community objectives. Hence, the NPSFM seeks to bolster the RMA's regulatory reach to diffuse pollution.

MEASURING EFFECTS AND SETTING LIMITS

Prior to the introduction of the NPSFM in 2011, and drawing inspiration from the United States Environment Protection Agency's Total Maximum Daily Load regime [18, 19], local government in the South Island region of Canterbury was already heading down the path of setting limits under its Canterbury Water Management Strategy (CWMS) [14] (see www.ecan.govt.nz). Canterbury's limit setting approach, which has become the blueprint for national reforms under the NPSFM, involves a number of steps: it starts with community decisions on desired water quality objectives informed by community values. These objectives are then quantified by scientists into threshold levels of nutrient enrichment (or nutrient reduction) in waterbodies and ultimately translated into catchment nutrient loads. These catchment loads are used by planners to devise land use rules that link to property-scale nutrient discharge allowances [16, 19, 20, 21, 22]. This approach is expected to make diffuse pollution governable and allocable and water management precautionary as well as proactive rather than reactive. The vision is as follows:

> 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 [23, pp.4–5].

This is an accounting vision that is now embedded in regional planning in Canterbury and is a provision of the NPSFM that is expected to allow resource managers to know when "resource availability is available for current and potential resource users" [17, 24, p. 17]. Achieving the vision and implementing the policy is still a work in progress and is facing challenges that relate to measuring diffuse pollution and tightly linking numbers derived from models to regulation and compliance mechanisms [20, 22].

MEASURING NUTRIENT LOSSES FROM AGRICULTURAL LAND

Pivotal to setting limits in New Zealand is a mathematical model known as Overseer® (www.overseer.org.nz). It is a farm-scale nutrient budgeting tool that was developed by government and industry long ago to help fertiliser sales representatives and farmers to work out how much fertiliser to apply on farm. It quantifies nutrient pathways, e.g. nitrogen through the farm system into production or as excess into the atmosphere or water (i.e. through drainage arising from irrigation). While initially used as a decision-support tool, regional councils across New Zealand are now requiring farmers to demonstrate compliance with regional plan rules and conformity with good management practices with outputs from the model [20, 25].

The use of Overseer® in regulation has been, and remains, highly controversial. It has created many challenges for farmers and policy-makers alike [16, 22]. Controversy arises from the model's well-known levels of inaccuracy of between plus or minus 20–30% in predicting nutrient losses, unavoidable variability in how data is interpreted for use in the model, the low resolution of rainfall and soil type data embedded in the model, the tendency for regulators to use the numbers in absolute rather than relative terms, and the continued release of new versions of the model to update the science that predicts the effects of agricultural land use and quantifies mitigation measures [20, 22, 25, 26, 27].

CANTERBURY'S CATCHMENT LOAD APPROACH

The following cases illustrate two ways that have been used by the Canterbury regional council to establish catchment load limits for regulating diffuse agricultural pollution to address water quality. One is identified as an 'in-stream' approach and the other is a 'modelled' approach. Both have strengths and weaknesses to which I now turn.

Hurunui Waiau Zone: an 'in-stream' approach

Current implementation of the CWMS requires communities to collaborate to make decisions to address social, environmental, cultural, and economic targets in the management of water resources [14]. To this end, in 2011, North Canterbury's Hurunui Waiau Zone Committee determined that a significant expansion of irrigation could occur only if water quality in the zone's two major rivers (the Hurunui and Waiau) remained the same or saw an improvement into the future. To be plugged into the 'effects-based' RMA, and made enforceable under a regional plan, this decision had to be translated by scientists and planners into numbers and rules that could capture and control particular activities that could affect river water quality. Land use change was defined in the plan as a 10% or greater increase in nutrient loss from land, as calculated by Overseer®. A number of provisions, including the 10% rule, were linked to nutrient concentrations in both rivers and 'in-stream' catchment loads for nitrogen and phosphorus in the Hurunui River [28]. These load limits were calculated using an average of six years of monthly water quality monitoring observations and flow records taken in the upper and lower catchment.

As long as the Hurunui River catchment loads were not exceeded at the lower catchment monitoring site (i.e. State Highway 1), all farms could operate as a permitted activity. However, by the time the regional plan was fully operative in December 2013, the phosphorus load in the river had been exceeded. This meant that any land use change above State Highway 1 would be deemed a non-complying activity. These rules were intended to ensure there was a way for the regional council to pull land use intensification into the regulatory system to disallow it or impose conditions. However, there have been unintended consequences. For example, dryland farmers (i.e. those without irrigation), whose farms have very low nutrient losses, have found themselves facing the prospect of farming illegally by virtue of 10% of their low nutrient loss numbers derived from Overseer® triggering the land use rule through normal farming operations. At a zone committee meeting attended by around 350 unhappy farmers in September 2014, questions were being asked about how the rules could possibly be about addressing water quality when they allowed dairy farms to generate far greater losses than them under the plan (e.g. 10% of 60 kg/ha/pa for a dairy farm = 6 kg/ha/pa before invoking the rules whereas for them 10% of 5 kg/ha/pa = 0.5 kg/ha/pa triggers the rules).

A strength of this 'in-stream' approach is that it links the rules to the actual state of the Hurunui River. It also makes everyone in the catchment above the State Highway 1 monitoring site responsible for land use practices that contribute nutrients to the river. These aspects are also a weakness because the nutrients detected in the river at a particular point in time reflect *past* land use practices. This means that the environmental effects of what is currently occurring on the land are yet to show up.

Existing dairy farmers maintain that water quality is likely to improve in the future given their adoption over several years of what are now classed as good management practices (GMP), for example, the conversion from flood to spray irrigation. They have also expressed concern that the effects of further large-scale irrigation would not be seen for some time and could ultimately jeopardise everyone's consent to farm. Indeed, they argue that 'nutrient headroom' they expect will be coming through the groundwater system should belong to them, given the investment they have made to create it, not new irrigators [16, 29, 30].

It would appear that making everyone equally responsible has caused friction across agricultural sectors that contribute different levels of nutrients to the cumulative effects problem. And those calculated to have the highest levels of nutrient losses, the dairy farmers, are reluctant to create 'nutrient headroom' to allow new irrigation as it would impose mitigation costs they maintain could over-burden their businesses given that they have already invested in more efficient irrigation systems. From their perspective, this would be a subsidy from them to new irrigators. Dairy farmers maintain that while they are willing to adopt industry-agreed GMP they are not prepared to go any further [29]. In the process, dryland farmers are losing equity in their properties as the potential for converting to currently-lucrative dairy farming has been lost with the setting of limits.

Selwyn Waihora zone: a 'modelled' approach

In North Canterbury's Selwyn Waihora zone, collaborative and scientific work was undertaken over several years to identify an agreeable catchment load limit. Importantly, this limit had to include an allocation for a large-scale irrigation scheme that had already been approved in the zone. Hydrologic, environmental, and economic models were used to predict and communicate the effects of current and potential 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 [31]. These models include Overseer® and the catchment model CLUES (Catchment Land Use for Environmental Sustainability—see www.niwa.co.nz) which contains a suite of models, including Overseer®, to assess the effects of land use change on water quality [32].

This region's plan provisions set a catchment load limit for nitrogen for existing farms of 4,830 tonnes per annum and provide an allocation for the approved irrigation scheme known as Central Plains Water. The catchment load limit is to be achieved by 2037 with an overall 14% catchment reduction by 2022. To achieve this load limit, rules have been written, underpinned by catchment modelling, to require existing farms to reduce their nitrogen losses beyond what have been estimated to be GMP loss rates. Hence, the modelled approach allows different levels of responsibility to be calculated and reflected in the rules, e.g. dairy 30% beyond GMP and irrigated sheep, beef, or deer are required to go 5% beyond GMP [31]. It also means that existing farmers are forced through regulations (and the process of dividing up the modelled future catchment load) to go beyond GMP to create headroom for the new irrigation scheme.

As well as differentiated responsibility, a strength of the modelled approach is the lag effect can be accounted for and a range of future scenarios with different land use and mitigation configurations can be tested. From the scenarios and modelling outputs, an ultimate level of contamination and protection can be agreed upon, which occurred through a community process to set the limits set out above [31].

However, a number of challenges arise. First, it is not possible to know if the difference between actual water quality and predicted water quality arising from predicted nutrient losses is due to the lag effect (which would mean nutrients are still on their way to a waterbody) or attenuation (i.e. the processing of nutrients underground before they get to water). To overcome this uncertainty, an attenuation assumption is included in the modelling that half of what is calculated to be leaching from land makes its way to water [31]. Second, while the modelled approach provides an allocation (i.e. a number) for each farmer to work to, once the load is set and allocated it is very difficult to claw-back what has been given. Third, highly contingent numbers derived from a string of models are being used to establish legally binding rules, which raises important questions about the credibility and enforceability of the numbers and the public accountability of compliance mechanisms [16, 22, 33].

Compounding these challenges is that Overseer® is regularly updated. This has meant that the numbers from the same on-farm activities keep changing as new versions of Overseer® are released to reflect, for example, improvements in the science and finer resolution of embedded environmental data systems. Updates also include calculations for on-farm mitigation actions to be deducted from nutrient contributions [20, 22, 26]. Because the science has been showing greater effects arising from irrigation on particular soil types, in Selwyn Waihora far more farmers have been caught in the regulatory net than was expected when the plan was written [22]. This means additional administrative burdens for the regional council and many more farmers are having to apply for a consent to continue to farm. Those wanting tighter regulations would argue this is the appropriate outcome while farmers are concerned about unexpected costs that can run into the thousands of dollars to obtain a consent to continue farming and the continued costs of demonstrating compliance.

These issues have prompted a small shift away from Overseer® in Canterbury to setting thresholds for consents for permitted activities in regional plans based on the area of high nutrient loss land uses (e.g. winter grazing of dairy cows and fodder crops). Notwithstanding the challenges and the adjustments, Overseer® remains central to limit-setting in New Zealand and Canterbury for a range of compelling reasons related to consistency and quantification that bring visibility and tractability to nutrient losses to manage cumulative effects [34]. Hence, government funding is now focused on efforts to value the benefits of Overseer® [34], expand the model's capability and applicability and provide guidance on how planners and regional council staff should use the model in regulation [20, 25].

This case study presents how New Zealand is grappling with setting resource limits and opens many important questions about measuring, predicting, and regulating diffuse agricultural nutrient pollution and the challenges of linking numbers to legally binding compliance and enforcement mechanisms.

CASE STUDY QUESTIONS

1. How does the management of diffuse pollution differ from point-source pollution and how should regulations differ?
2. What are the advantages and limitations of an 'effects-based' approach?
3. What are the challenges of implementing the 'limits-based' regime?
4. What other strengths and weaknesses of each limit-setting approach can be identified?
5. What strategies, beyond regulation with catchment limits, could be used to address diffuse agricultural pollution?

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