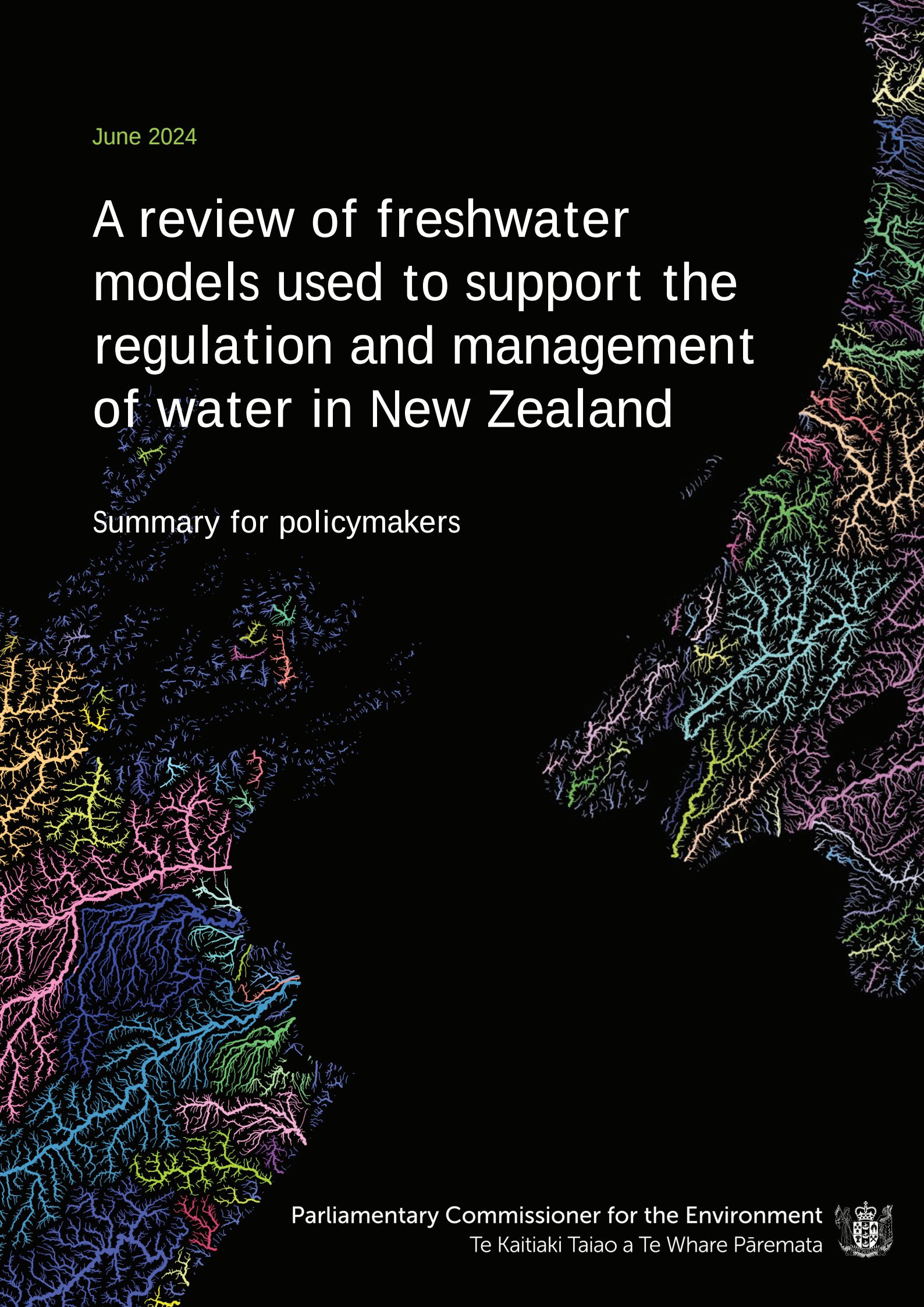
June 2024

A review of freshwater models used to support the regulation and management of water in New Zealand

Summary for policymakers



Parliamentary Commissioner for the Environment
Te Kaitiaki Taiao a Te Whare Pāremata

June 2024

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Cover images: Catchments in the top of the South Island, bottom of the North Island. Source data: MfE Data Service (data.mfe.govt.nz) and LINZ Data Service (data.linz.govt.nz). Analysis and visualisation: Toitū Te Whenua Land Information New Zealand. This page: Lake Taupō, photo by Dougal Townsend, GNS Science.

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Why this ‘dry’, technical report matters

Freshwater is critical to every human being. In Aotearoa it also has an immense cultural significance to Māori and non-Māori alike. It is essential for our economy, from agriculture to power generation. Clean scenic rivers and lakes are backdrops to our tourism industry.

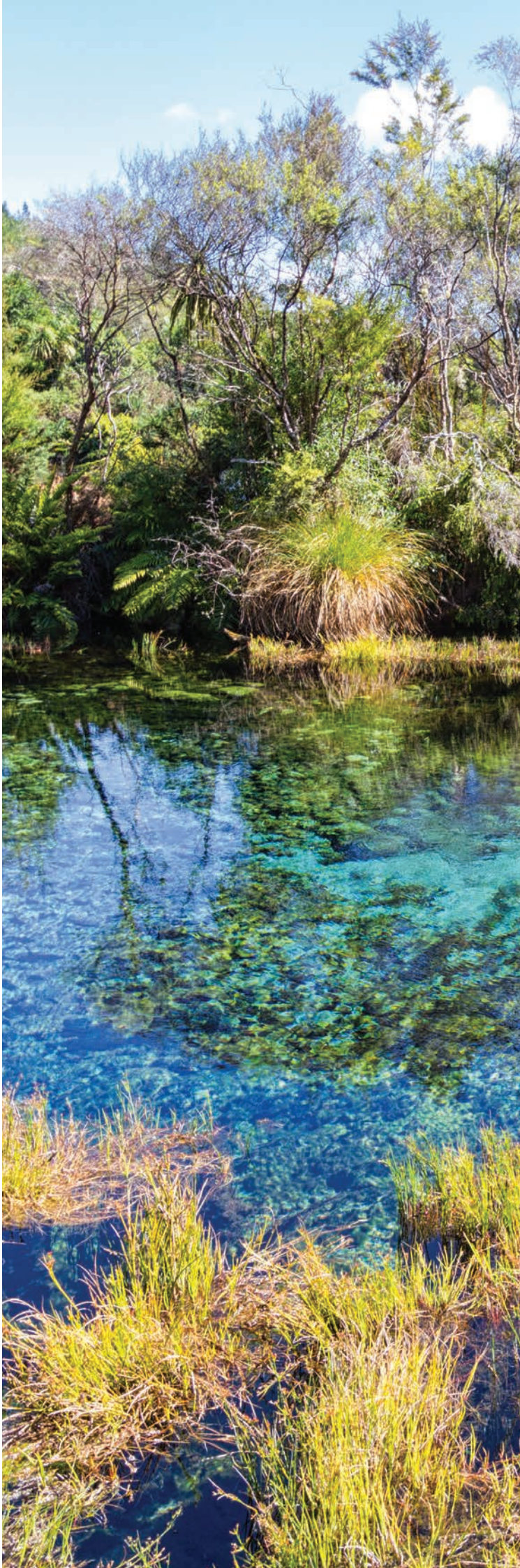
Yet the state of our freshwater resource is fragile – both in quality and quantity.

In our devolved environmental management system, regional councils are tasked with managing freshwater. For the most part they are left to their own devices for how to do that, although they need to comply with sometimes prescriptive central government requirements.

Modelling is an important tool that regional councils use to support their freshwater management responsibilities. This review of how councils use freshwater models to support their regulatory responsibilities found that there were inefficiencies, overlaps, gaps and inconsistencies across the sixteen different regional councils and unitary authorities. The challenges also included fragmentation, reinvention of the wheel and thinly spread modelling expertise.

We have a highly devolved – but inadequately supported – approach to environmental regulation. Thirty years ago, central government devolved responsibility for water and prescribed parts of those responsibilities, but it has not supported councils with the tools they need to manage their obligations. There is a need to strengthen central government’s capacity to support regional councils in their endeavours.

This summary for policymakers reviews the issues, diagnoses several problems and proposes some solutions. If councils are to turn around the declining state of New Zealand’s freshwater, they need all the help we can give them.



Te Waikoropupū Springs. Photo: Sebastian We, Flickr

Why review freshwater modelling?

While New Zealand has plenty of freshwater, we are heavy users of the resource. Many regions in Aotearoa have overallocated freshwater or are close to doing so. Less water means more pressure on freshwater species and higher concentrations of contaminants. Additionally, changing the flow and quality of water affects the mauri of the water and the health of the ecosystems it supports. Climate change is also re-dealing the cards and will have complex feedback effects on existing pressures, driving land use change and further impacting the quantity and quality of freshwater.

Water resource models that help predict freshwater quantity and quality are important tools to support robust, evidence-based freshwater management. A range of water quality and quantity models are currently used across New Zealand to support regulatory tasks such as managing contaminant discharges and water takes. Most models are used by regional councils and unitary authorities. Others have been, and are being, developed by mana whenua, industry and community groups for their own roles in water management.

Those who use models, or are affected by their use, need to know how much confidence can be placed in their outputs. Regulators must be able to defend their decisions to hapū, iwi, the community and ultimately in the courts, so they need to be sure that models used to reach those decisions are robust and reliable.

This investigation reviewed the suitability, strengths and limitations of water resource models that predict freshwater quantity and quality, and the way they are being used to support the regulation and management of water in New Zealand.

The investigation also involved an extensive literature review, wide-ranging stakeholder engagement, a survey of regional councils and unitary authorities on their use of freshwater models, and the commissioning of a report on freshwater models developed by, or in close collaboration with, mana whenua. The literature review included a model stocktake and a technical evaluation of the most commonly used biophysical freshwater models.

Te Waikoropupū Springs. Photo: Sebastian We, Flickr

What do models do?

Models provide insights about things that may be hard or impossible to measure. Models can fill gaps in monitoring data, identify trends, gain insights into processes within a system and provide predictions.

In the freshwater resource management context, models can help by:

- assessing trends
- estimating current water body health
- estimating required contaminant reductions
- establishing cause–effect relationships between resource use and the health of water bodies
- estimating the effect of freshwater improvement actions
- estimating the effect of climate change on water quantity and quality
- exploring scenarios and future outlooks.

Models come in many shapes and forms and range from very simple to very complex. While using a simple model detailed on a spreadsheet is sometimes sufficient, models used to imitate complex hydrological systems often involve mathematical equations to simulate the physical and chemical properties of that system.

Modelling and monitoring (i.e. field data and assessments) are interdependent. It is essential to have monitoring data to build, calibrate and use environmental models.

Used carefully, modelling can play a central role in improving environmental research. Observations help build a model, the model then deepens understanding of a process, which incentivises better and more detailed data collection, and in turn enables further model improvement.

In many instances models can also provide robust information to support the management and regulation of water, for example, in setting or meeting specific regulatory requirements.

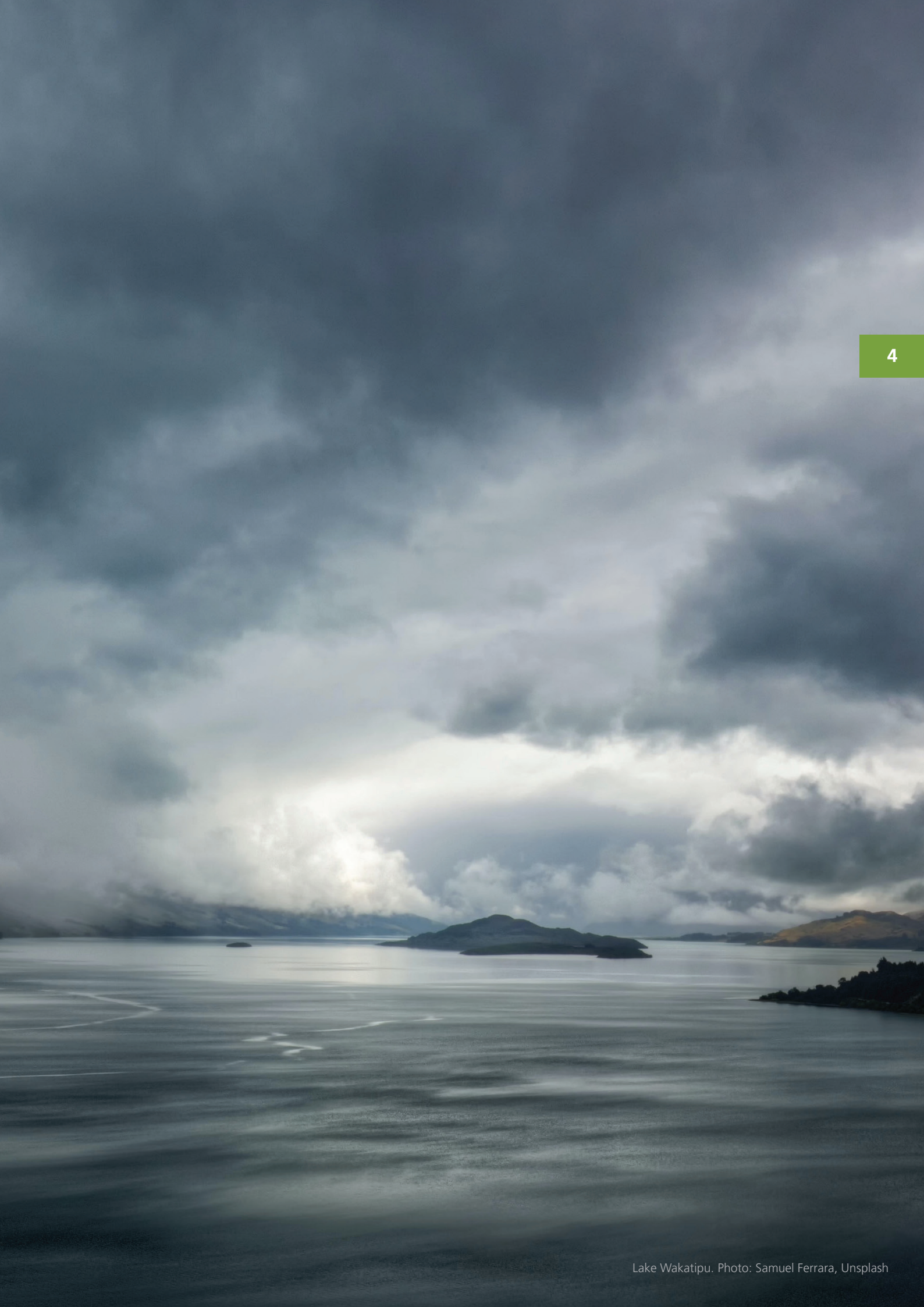
The current policy framework for managing water in New Zealand forms an intricate web of policies and rules that interact with each other. While the Government has signalled changes to the current framework, the models themselves will remain relevant, as robust models and data will be needed to manage freshwater in almost any policy framework.

Māori models

Models developed within a te ao Māori view encapsulate social, cultural, economic and relational parameters; the physical and the spiritual realms; as well as biophysical. Whakapapa is the basis for te ao Māori models, as it makes sense of the connections between all things and how they interact, allowing experts to predict an outcome based on the understanding of those interactions.

Although founded on the same principles, Māori models can vary significantly. Hapū and iwi have noted that biophysical models are unable to incorporate all of what is known of the world from a te ao Māori perspective. All-encompassing models have been developed to illustrate the holistic way te ao Māori is viewed. Hapū and iwi are reclaiming tools lost to colonisation that can be used to respond to new pressures and regulatory requirements.[1]

[1] For a review of freshwater models developed by, or in close collaboration with, mana whenua, see Taylor, L., 2023. *Te Mana o te Wai, Te Oranga o ngā Tāngata*. Prepared for the Parliamentary Commissioner for the Environment. Auckland: E Oho! Awakening Aotearoa. https://pce.parliament.nz/publications/a-review-of-freshwater-models-used-to-support-the-regulation-and-management-of-water.



Lake Wakatipu. Photo: Samuel Ferrara, Unsplash

Key findings

A large number of models exist, and many have overlapping functions

A large number of water models exist. At least 75 biophysical freshwater models are used by regional councils and unitary authorities in a regulatory context to assist with water resource management. These models are used to support a variety of tasks, including managing contaminant discharges and water takes.

A further 34 freshwater models developed by, or in close collaboration with, mana whenua were identified.

Many of these models have overlapping functions, meaning they are used in the same environmental domain, sometimes for the same purpose. For example,

- 12 models are designed to model groundwater, covering groundwater quantity, quality or both
- 47 models are designed to model rivers and streams, covering river water quantity, quality or both
- 19 river water quality models are used to estimate nutrient loads in rivers and streams
- 13 models are used to assess sediment in rivers and streams.

As different models use different assumptions, principles and data sources, when multiple models are used for the same purpose within the same domain, they can produce different results. For example, recent predictions of total nitrogen loads based on two different but widely used models diverged at both national and regional scales. Divergent results can lead to very different management decisions.

Rather than adding value, the proliferation of models confronts regulators with the quandary of having to choose the 'best' model and then defend that choice, which is not an easy task. This choice is made harder when models lack transparency, are not systematically evaluated and there is a lack of guidance.

Model development is siloed and fragmented

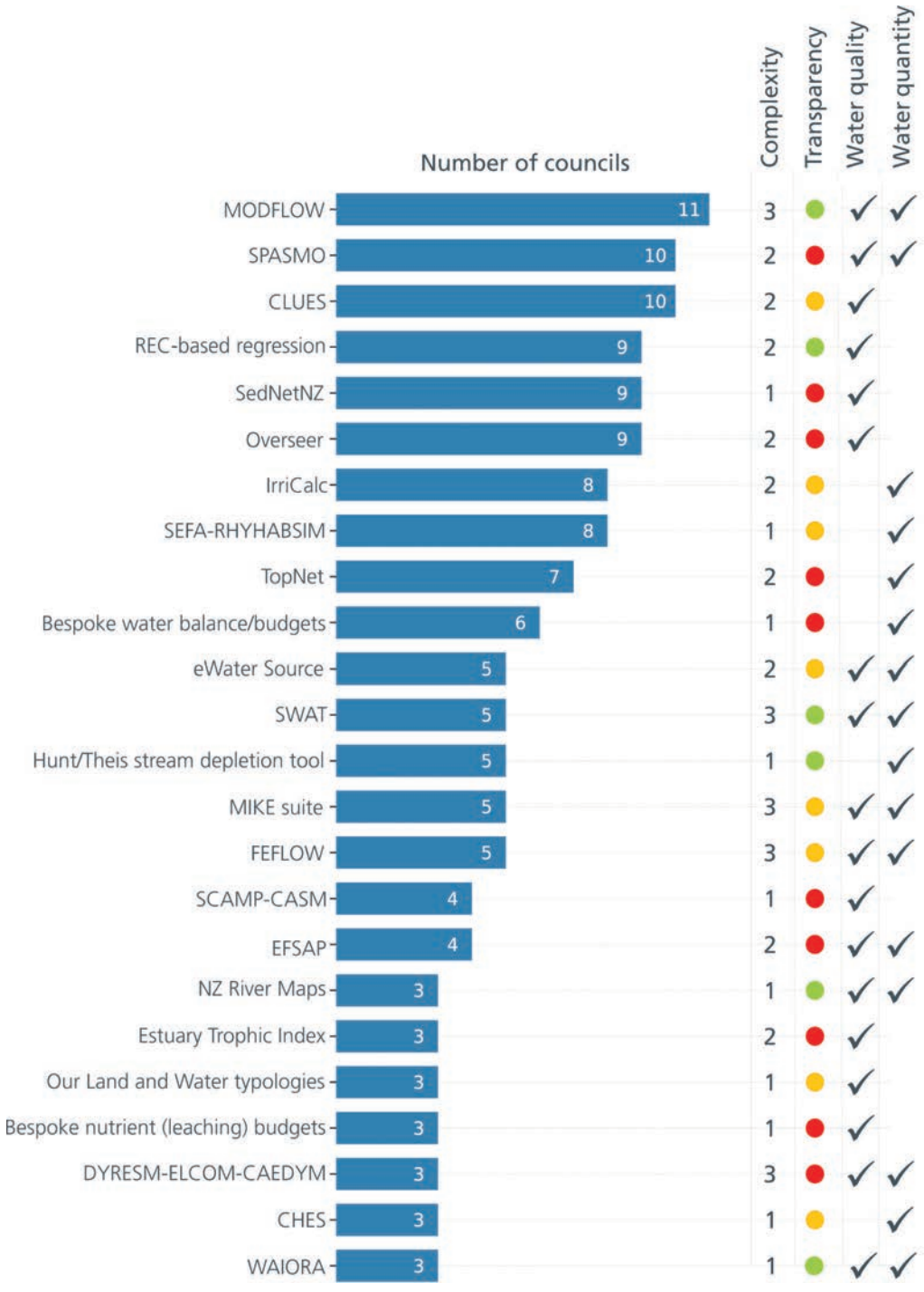
Model development is siloed and fragmented hindering collaboration efforts. Development often takes place in isolation within different institutions, and there is often a strong reluctance to share. Collaboration has suffered at the hands of a competitive desire to 'own' the model and underlying data. The result has been the development of competitive models (for example, sediment models developed by the National Institute of Water and Atmospheric Research (NIWA) and Manaaki Whenua – Landcare Research). That approach does not lead to well-supported, collaborative modelling work or more transparent models.

A lack of model evaluation

Models are not systematically evaluated, even though criteria for evaluation exist. This makes it hard to judge which models are best for particular circumstances, or if models are fit for their intended purpose.

As part of this report, a technical evaluation of the 24 most widely used biophysical freshwater models (in use by three or more councils) was undertaken. The evaluation found that most models have a good scientific basis (model structure, algorithms, peer review and validation). However, it also found many shortcomings with respect to transparency (Figure 1).

Many models are opaque and the data underpinning models are frequently non-transparent or inaccessible. This makes it difficult to link models or evaluate and verify them and their outputs. Additional shortcomings were found with regards to uncertainty and computational infrastructure. Combined, each of the weaknesses stands in the way of the comparability and interoperability of models, including the potential to reuse them.



Source: PCE

Figure 1: Technical assessment of the 24 most widely used models. The number in the bar denotes the number of councils that have reported the use of any specific model. Complexity is categorised as 1 = simple; 2 = moderately complex; 3 = very complex. Transparency is categorised as: fully transparent (green); moderately transparent (amber); not transparent (red). In addition, models are categorised as those that are focused on water quantity, water quality, or both.

Guidance on model use falls short

Guidance on model use – including judging if a model is fit for purpose – falls short of what is useful.

The National Policy Statement for Freshwater Management (NPS-FM) 2020 requires that the best available information is used. It places a higher information requirement on science than its predecessors, and integration of other sources of information (such as mātauranga Māori) is needed to support its successful implementation.

This means there is a need for better data, better models and better integration of models than currently exist. However, the NPS-FM 2020 does not prescribe specific models or modelling requirements for use. As a result, there is uncertainty about how to meet the requirements.

While the Ministry for the Environment released guidance in June 2023 for councils on developing and using models in the regulatory context, this document fell short in several ways. It is not well-known among modellers, and it is only one of several documents that contains model guidance.

Importantly, it does not provide specific guidance on freshwater models or technical assessments of existing models, so it is unclear if models currently in use actually meet the evaluation criteria and good practice process described in the guidance.

Practical implementation support is also lacking, and council staff are looking for help to support on-the-ground freshwater management.

Models are not used to their full potential

Lack of guidance, experimentation in model use, and poor collaboration, sharing and reuse of models have led to councils often opting to develop their own models. The investigation found that 60% (45 of 75) of the models used by councils were 'single use', meaning they had been developed for use by a specific council, often for a specific application in a specific location. These models were not used by other councils and were rarely reused within the original council for tasks such as evaluating relevant progress and plan effectiveness.

While specificity of local conditions may, in some cases, indicate the need for single-use model development, most of the more widely used models are sophisticated and sufficiently flexible to be used in a wide variety of settings and most catchments. However, only three models MODFLOW, SPASMO and CLUES – have been used by ten councils or more, indicating that many models are not being used to their full potential.

As a small country, New Zealand cannot afford to waste scarce modelling resources on forays into multiple, expensive and often ineffective model developments and applications, especially when suitable tools already exist.

Variable use of models in a regulatory context

The use of models to support the regulation and management of water in New Zealand is variable across the regional councils. The choice of models – and whether to use them at all – is determined by a range of factors, including resourcing and expertise, confidence in using models, previous experience and the specific task or regulatory requirement at hand.

While Bay of Plenty Regional Council, Environment Canterbury, Hawke's Bay Regional Council, Horizons Regional Council and Waikato Regional Council often use models in a regulatory context, West Coast Regional Council is only using a very limited number of models and Nelson City Council has not used any freshwater models at all.

The majority of the councils are using, or have recently used, models to support water quantity management (i.e. to set environmental flows and levels or identify limits on water takes). Likewise, most councils are using models to quantify catchment contaminant loads and any required reductions to meet desired outcomes. Models are used to establish cause–effect relationships, assess trends and explore options and scenarios.

While models play a useful role at many stages of the planning process, they have predominantly been used to inform the development of regional plans and other planning instruments. Only six councils have reported using models as part of a compliance package. No councils have reported using models for direct enforcement such as breaches of resource consent conditions or to formally assess plan effectiveness. The latter is a missed opportunity as reusing models in this way could help determine if the desired outcomes have been (or will be) achieved.

Further examination revealed that multiple models (often with overlapping functions) are used by regional councils to address the same regulatory requirement. For example, as part of determining baseline water quality states for a range of attributes listed in the NPS-FM 2020, at least 15 models are being used to predict nitrogen losses and movement from soil to water. Similarly, in identifying water take limits, at least eight different models are being used to estimate the soil water balance, i.e. to estimate how much water evaporates and how much drains down to recharge groundwater.

The variety of models used by councils range from very simple spreadsheets to highly advanced numerical solutions. In principle, this is good: councils need to make use of a range of models that cover different levels of complexity. However, many councils reported that they are yet to find the ideal level of model complexity for their needs. While most of the models in use were considered too simple by many, complex models presented challenges for staff and in some cases were abandoned for simpler alternatives. For example, in Canterbury, early attempts to use an advanced integrated Mike-SHE model for plan change 2 (Hinds) proved difficult to complete in the required timeframes and simpler bespoke models were resorted to for the plan change recommendations.

Thin resourcing

Resourcing is thin and there is a shortage of model developers and model users. When surveyed, staff from all councils signalled a shortage of freshwater scientists and a significant lack of inhouse technical modelling skills. Faced with a lack of inhouse skills, councils are often forced to subcontract much of their modelling work to external providers. Councils without the financial resources to subcontract, tend to make decisions based on the available observations and data. If these data are limited, and they often are, the resulting decisions may be inadequate.

An overall shortage of skills means that model development, application or maintenance is often left to one person, which is risky for the future use of that model.

Data shortcomings affect models

Models are an extension of data, so any shortcomings with data are carried over into models. Without robust data there will not be robust models.

Known data shortcomings include data paucity and data accessibility. Experts within councils generally agree that there is a shortage of data needed for freshwater policy and planning purposes. The general view is that, despite some recent improvements, databases within councils are still piecemeal and disconnected.

Another known shortcoming is limited data accessibility, as much of New Zealand's environmental data are not openly accessible or have limited accessibility. Much data on estimates of nutrient loss to our water are owned by the farming industry or Crown Research Institutes.

Data on soil, flow and climate are often not shared with regional councils. With limited access to data, modellers have to work with whatever they can access. As a result, there is a real risk that data from different time periods with different degrees of uncertainty are scrambled together. If the data being used are incongruent there is an increased risk of model incongruence.

Lack of commitment to mana whenua developed models

There is a lack of commitment to, and investment in, mana whenua developed models and associated processes to involve mana whenua in the development and application of freshwater models.

The report on Māori models commissioned for this investigation found that many whānau, hapū, iwi and Māori groups are already using a combination of traditional and contemporary tools and models to assist them with water management in their rohe. The stocktake identified 34 models that had either been developed by Māori or in collaboration with Māori. These models were assessed on whether they could be used as part of NPS-FM 2020 implementation.

While Māori freshwater models exist, the use of Māori models in a regulatory context is virtually non-existent. While some are in pilot stages, none of the 34 freshwater models identified in this investigation are in use by councils to support the full implementation of the national policy statement for freshwater management. To decide which models to use, more consultation needs to take place between councils and tangata whenua to identify what other information sources or models are needed.

The NPS-FM 2020 requires councils to engage with tangata whenua and facilitate their active engagement. This requirement is designed to overcome the historical experience of tangata whenua who have either been involved too late in the decision-making process or completely left out. Councils will need to help empower tangata whenua and be responsive to how tangata whenua would like to be involved in freshwater management.

Summary of issues

The shortcomings identified in this review are in no small part a consequence of New Zealand's highly devolved approach to environmental regulation, where each council has responsibility for managing freshwater in its regions and using models to do that. This has come at the price of an inefficient and siloed modelling environment. Despite their best efforts, council staff have been unsuccessful in establishing a more joined-up modelling environment.

The large number of models used by regional councils and unitary authorities to support the regulation and management of water poses further challenges. Rather than adding value, the proliferation of models confronts regulators with the dilemma of having to choose the 'best' model and defend that choice, which is not an easy task if you are not an expert in modelling or model development. It is a choice made harder when models lack transparency, are not systematically evaluated, and there is a lack of guidance. Nationally, New Zealand's modelling resource is dispersed and unevenly spread among regional councils, publicly funded research institutions and some businesses.

Another consequence of the large number of models, combined with inadequate guidance on their selection and use and a lack of systematic model evaluation, is an elevated risk of legal challenge to council decisions based on modelling outputs. Councils are looking to central government for help, but the guidance currently available is generalised and not specific to the challenges of freshwater models. Further, there is a lack of practical implementation support to turn any guidance into practice and ensure a much more robust and confident use of fit-for-purpose models. On a national scale, freshwater modelling is not organised in a way that can best support the regulation and management of freshwater in New Zealand.

Dart River Te Awa Whakatipu. Photo: Samuel Ferrara, Unsplash

Recommendations

Better national-level coordination and support for freshwater modelling is needed if models are to be used effectively and robustly to support evidence-based water regulation and management.

The first four recommendations focus on solutions that could be implemented in the short-term. While they can be progressed immediately, they would benefit from the establishment of a national freshwater modelling support centre, which is the most effective and efficient way of carrying the desired improvements into the future – the fifth recommendation.

1. The Ministry for the Environment (MfE) should further develop national guidance on the use of models in a regulatory context to support freshwater management across the country.

2. MfE should establish a rōpū of experts to support the development and implementation of Māori freshwater models.

3. MfE should ensure an evaluation of existing freshwater models against guidance on the use of models in a regulatory context is undertaken.

4. MfE should lead the selection or development of a preferred suite of models adaptable to local circumstances.

5. The Minister for the Environment should establish a national freshwater modelling support centre with a mandate to support regional councils, unitary authorities and mana whenua. The Secretary for the Environment should prepare a report advising the Minister for the Environment on where and how such a centre could fit into existing institutional arrangements.

Simon Upton

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Huka Falls. Photo: Coen Versluis, Flickr

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