Science Preparedness for Limit-Setting

Technical Report

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Executive Summary

The National Policy Statement for Freshwater Management (NPSFM) directs regional councils, in consultation with their communities, to set objectives for the state of fresh water bodies in their regions and to set limits on resource use to meet these objectives. In preparation for this, Environment Southland embarked on a three year science programme to characterise natural systems. This programme is nearing completion and is transitioning to applying science for use by the council and the community.

The purpose of this report is to identify the types of scientific information and skills which have provided the greatest value to limit setting processes elsewhere in New Zealand, and to use this as a basis for assessing Environment Southland's preparedness (e.g. identifying current strengths, gaps and opportunities) for its next stage of limit-setting.

A considerable amount of useful science has been generated on Southland over decades, mostly in biophysical sciences. This information has been used in planning processes; however, this information is not yet organised in a way that fully meets the needs of limit setting. In order to prepare for the next stage of limit-setting, it is recommended that Environment Southland:

- distinguish and identifiably adopt clear scientist roles - preferably an impartial honest broker role for scientists inside the organisation;
- establish a group responsible for framing the questions needed to drive delivery of science information;
- increase transdisciplinary awareness and continually improve delivery of well-integrated, simplified information for non-technical audiences, including developing techniques for communication and handling uncertainty;
- test conceptual understandings of science using a diverse range of participants, early in the process; and,
- plan early for the process of packaging science information to inform the setting of objectives and limits.

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1. Introduction

In 2011, the government introduced New Zealand's National Policy Statement for Freshwater Management (NPSFM). The NPSFM directs regional councils, in consultation with their communities, to set objectives for the state of fresh water bodies in their regions and to set limits on resource use to meet these objectives. Since its introduction, the NPSFM has been amended twice (in 2014 and 2017) incorporating a national objectives framework (NOF) that sets out a compulsory but non-exhaustive list of values, a process for developing freshwater objectives, and a minimum acceptable state (i.e. a "national bottom line") for some objectives to support the compulsory values. Some key requirements of the NPSFM are to:

- consider and recognise Te Mana o te Wai in freshwater management;
- safeguard fresh water's life-supporting capacity, ecosystem processes and indigenous species;
- safeguard the health of people who come into contact with freshwater;
- maintain or improve the overall quality of fresh water within a freshwater management unit (FMU);
- follow a specific framework (NOF) for identifying the values that tāngata whenua and communities have for water, and using a specified compulsory but non-exhaustive set of water quality measures (called attributes) to set objectives in support of the identified values;
- set limits on resource use (e.g. how much water can be taken or how much of a contaminant can be discharged) to meet objectives over time and ensure they continue to be met;
- determine the appropriate set of methods to meet the objectives and limits; and,
- take an integrated approach to managing land use, freshwater and coastal water[1].

The NPSFM must be fully implemented no later than 31 December 2025 (or 31 December 2030 in certain circumstances). In Southland, as in other regions, NPSFM obligations sit within a wider policy context that includes other legal requirements e.g. water conservation orders and statutory acknowledgements.

In preparation for limit setting required by the NPSFM, Environment Southland embarked on a three year science programme with a number of research agencies and stakeholders. The programme began in late 2014 and focused on characterising the region's natural systems; specifically to understand land use contaminant inputs, how water and contaminants move through the landscape, what drives spatial and temporal variability in water quality, and ecosystem responses to pressures from contaminants. The programme was designed to provide a base of scientific understanding to inform community consultation processes, broad resource management conversations and has informed the current proposed Southland Water and Land Plan (pSWLP) process.

With the three year programme near completion and having produced a large volume of useful information for the pSWLP process, the science programme is now shifting its focus from characterising natural systems to applying science for use by the council and the community in the next stage of regional plan limit-setting required by the NPSFM.

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[1] This list is not exhaustive and has been adapted from http://www.mfe.govt.nz/fresh-water/national-policy-statement/about-nps

1.1 Purpose, structure and scope

The purpose of this report is to identify the types of scientific[2] information and skills which have provided the greatest value to the limit setting processes elsewhere in New Zealand, and use this as a basis for assessing Environment Southland's preparedness (e.g. identifying current strengths, gaps and opportunities) for its next stage of limit-setting. The structure of the report is:

- Section 2 draws on our experience in limit-setting processes in several regions around the country[3] to identify at a generic level the types of science information and skills that are useful for limit-setting.
- Section 3 builds on this to examine Environment Southland's preparedness for its next stage of limit-setting, and develops some recommendations for the science programme.
- Section 4 summarises our conclusions and recommendations.

It is not within the scope of this report to assess or compare scientific tools and methodologies used in limit setting but rather, to identify the most valuable *types* of information and skills based on our experiences in limit setting processes.

It is intended this report will inform Council's *People, Water and Land* programme (which includes limit setting) and will inform Southland's science and monitoring strategy by helping to prioritise future research and target specific scientific skill-sets.

[2] We use science broadly in this report to include all knowledge providers, including of biophysical environment, cultural, social and economic information.

[3] Including involvement in Canterbury, Greater Wellington, Bay of Plenty, Hawkes Bay and Gisborne, some observation of parts of Horizons, Waikato, Northland and Otago, and some familiarity with the Southland context.

2. The role of science in limit-setting

In this section we identify, at a generic level and independent of the Southland context, the types of science information and skills that are useful for limit-setting. Some material is drawn and summarised from a national guide (MfE 2016) and two recent publications that have explored this topic in greater detail (Rouse and Norton 2017; Rouse et al., 2016). We then use this in section 3 as the basis to examine Environment Southland's preparedness for its next stage of limit-setting.

2.1 Using science to inform decisions

When considering what types of science information and skills provide greatest value to limit setting processes, it is important to first understand the role science and scientists have, and how that can vary at different stages in the limit setting process (shown in Figure 1).

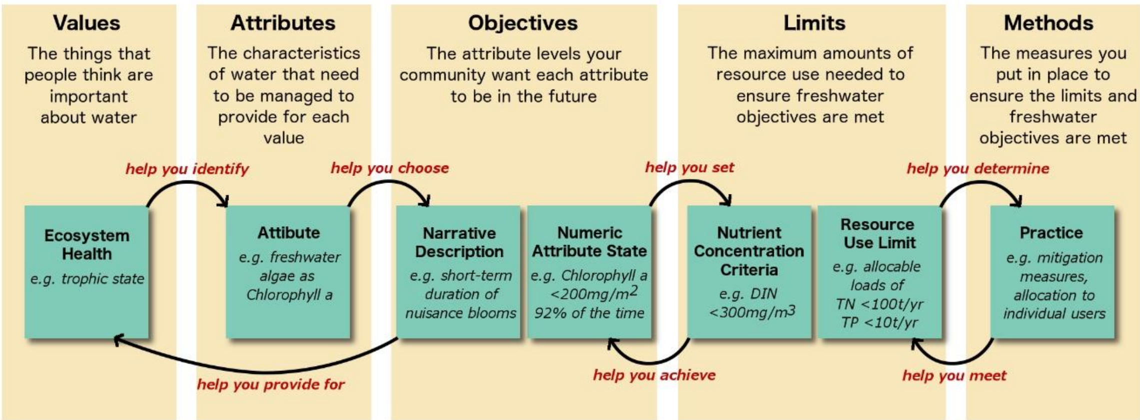

Figure 1: The limit setting process (adapted from MfE, 2017).

In our experience with other limit setting processes to date, it is important to be clear, both within the Council team and in community interactions, that the primary role of science in a limit-setting process is to build understanding of a system and then objectively inform choices around objectives and highlight their implications for limits, rather than instruct or make value-laden decisions on the level at which objectives and limits are set. In our experience this apparently simple role definition is not consistently understood within council science teams and the community. This leads to misunderstandings and breakdown of trust within council teams, and with the community, causing numerous subsequent process difficulties. Clearly establishing roles and a positive team-work culture is useful from the outset.

The rationale for the primary science informing role in limit-setting is laid out in Rouse and Norton (2017) and includes justification from New Zealand's Chief Science Advisor who puts it "*the preferred position for the professional researcher embedded within the policy process is as an honest broker explaining what is known, what is not known, and thus the implications of the options that emerge*" (Gluckman 2013). Our experience helping councils with limit-setting processes over the last ten years is that it greatly assists if the council's science team identifiably plays the honest broker role. This is not to deny that some stakeholders may choose to use science to advocate for their values. However it is useful to create a culture that clearly distinguishes this use of science to advocate from the objective role of the council's science team. It requires all stakeholder scientists operating in the process to be transparent about whichever role they decide to play for the duration of the process. Chopping and changing roles during a process will create unacceptable confusion.

To illustrate by hypothetical example, imagine the case where a council planner unwittingly asks a council biophysical scientist what exactly the limit should be for a given parameter; the scientist equally unwittingly responds by offering an environmentally conservative number, because that precaution reflects the scientist's personal values, rather than offering a range of number options and a description of the level of environmental risk that goes with each. The planner gladly accepts that apparently efficient response and inserts that number into the process. Suppose that later in the process social, cultural and economic analysis predicts significant implications will arise from the conservative limit, and another biophysical stakeholder scientist shows that the environmental risk is only slightly higher, and much less socially damaging, with a less conservative limit.

This example could equally be reversed, i.e. the initial limit offered is shown later to be biased towards resource use rather than being environmentally precautionary. In either case, several potential problems now exist, and these are likely to propagate new problems down the track:

i) There is tension in the council team because the planner distrusts their scientist's ability to give the "right" answer, even though that scientist knew nothing about the social, cultural and economic implications of their original answer at the time;
ii) the council scientist distrusts the planner for asking an unreasonable question initially, and for the blame that eventuated, and/or for an eventual decision away from the scientist's personal values;
iii) the stakeholder is publicly critical of the science, transparency and fairness of the council's process; and
iv) others in the community don't know who to believe so they start taking sides based on their differently held values, and the underlying science becomes further muddied.

A better process would have been all scientists agreeing on the risk profiles of the range of options for the objective and associated limit, with community debate on the merits between values supported by the different options then informing a transparent decision between the options.

2.2 Science context in limit-setting

Science contributes to at least five broad areas of limit-setting for freshwater quantity and quality:

i) Conceptual understanding of the system (including causal linkages and feedback loops);
ii) Informing the setting of objectives and limits on resource use, to support values;
iii) Informing allocation, and other methods to achieve limits and objectives; and,
iv) Monitoring attainment of limits and objectives through time.
v) Differing requirements in over- versus under-allocated catchments.

2.2.1 Conceptual understanding of the system

It is important to develop a conceptual understanding of the catchment under consideration as a system, including the biophysical, social, cultural and economic components, and their causal linkages and feedback loops. Conceptual diagrams are a useful tool to help discuss and refine the conceptual understanding of the system and its parts. They help to frame key technical questions in limit-setting projects, such as:

- How do water and contaminants move through the landscape?
- What are the main land and water resource use pressures and their effects on attributes and values?
- What types of limits to resource use are therefore required?
- What possible alternative futures (i.e. scenarios) should be explored and what would be the consequences of each for environmental, social, cultural and economic values?[4] This requires decisions on how scenarios should be framed and how aspirational they should be.

Conceptual diagrams also help identify technical and other knowledge providers that will be needed as part of the team. It is then possible for the team to begin to address the key project questions, for each part and for the system as a whole. When developing a conceptual understanding of the system it is useful to seek alternative views, which may be based on local experience not known to technical experts and/or alternative knowledge systems, and discuss these. Consulting widely at this stage helps identify alternative views and uncertainties that need attention early, saving difficulties later in a project if the conceptual understanding proves to be incorrect or contested. Therefore collaborative and strong stakeholder engagement skills are important in the science team.

2.2.2 Informing the setting of objectives and limits

Limit-setting under the NPSFM has changed the fundamental questions from policy-makers to scientists. The main question used to be "*What are the effects of this particular individual water take or discharge of contaminants?*" for decisions on individual proposed case-by-case activities (e.g. consent processes). Under the NPSFM the need to set objectives and limits in regional plans means the key question has instead become "*How many of these water takes and/or discharges of contaminants in combination could this catchment accommodate, and where within the catchment, while either maintaining or achieving a desired environmental state; i.e. a freshwater objective?*" In other words "*What is the maximum amount of resource use available (i.e. the limits), which allow desired or acceptable freshwater objectives to be met, where will they be met, and over what timeframe?*"[5] This is the key high-level question facing scientists in limit setting processes - it of course can be usefully broken down into a series of more tractable questions as we shall discuss later.

Bearing in mind the honest broker role, it is clear the high-level question involving identification of both objectives and limits can't be answered by scientists alone because the answers for limits depend on the level at which freshwater objectives are set, and these involve value judgements to balance capacity for resource use on one hand while sustaining all competing values at some identified appropriate level. We suggest based on our experience helping other councils that scientists can best inform this process objectively by describing consequences for

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[4] These examples are all important technical questions in addressing Part CA2 of the NPS-FM

[5] This is the definition of a "limit" in the NPSFM, but framed as a question.

values of different combinations of freshwater objective and limit pairings, often as part of exploring future scenarios. Scientists can use models or analytical inference to predict what the future could look like under various resource management scenarios that allow trade-offs and choices between present and future generations to be transparently explored.

Freshwater objectives and associated limits are related such that the choice of the level at which an objective is set determines what limit is needed, and changing the limit requires also changing the level at which the objective is set. Our observation is that some regional plans in the past have followed a linear process of setting aspirational environmental objectives first, followed by setting seemingly acceptable but un-related and inadequate provisions that enable more resource use than is likely to achieve the stated objectives. This disconnected approach is less contentious because it avoids making tough decisions (i.e. it avoids either setting tougher limits that could achieve the aspirational objectives, or setting less aspirational objectives that are achievable under more resource use enabling limits). Such an approach tries to “have its cake and eat it too”. However, the approach is likely to disappoint in future when stated objectives aren’t achieved, leading to over-allocation and a more difficult claw-back problem. A more robust approach is to allow for iteration during the process of deciding what objectives and limits to set. In such an iterative process the initially drafted freshwater objectives might be adjusted (or the time taken to achieve them might be lengthened if deemed appropriate) if the implications of associated limits are predicted during scenario testing to be unacceptable. Exploring well-thought out scenarios can inform such iterative adjustment as long as there is a good feedback loop between science predictions, community evaluation and feedback, and then policy making.

2.2.3 Informing allocation and other methods to achieve limits and objectives

Once the freshwater objectives and associated limits are set (i.e. the size of the resource and agreed state of environmental attributes are set) there remains the significant question of whether to allocate the resource and if so how. Our experience with other councils is that in some situations (e.g. when a catchment is at or over-allocated) this can be at least as contentious as setting the freshwater objectives and limits, because it involves value judgements around questions of fairness and equity. Science (including biophysical, social science and economics) can usefully inform this in the same way – by describing the consequences of different allocation options to inform debate and decision-making by others (i.e. again the science team acts as honest brokers rather than picking winners and losers). Systems-thinking (e.g. considering the biophysical, social, cultural and economic components) is a useful approach for determining effective levers to use to achieve limits and objectives.

2.2.4 Monitoring on the attainment of limits and objectives through time

Science also has a long-term role in monitoring the attainment of freshwater objectives (i.e. by monitoring attributes) and limits through time to inform plan effectiveness and future plan reviews. We have found that an important subsidiary role within this is to help articulate the priority long-term importance of meeting the freshwater objectives over and above the importance of the limits. The limits are one of several means to achieving outcomes (i.e. the freshwater objectives) but limits are not the intended outcomes in themselves. For example managing nuisance periphyton at an acceptable level is often an outcome we are interested in, and is a compulsory attribute to use for setting freshwater objectives under the NPSFM. Nutrient limits (nitrogen and phosphorus) are one of several means to achieve periphyton objectives; other means include flow limits and riparian management controls for example. However, concentrations or loads of nitrogen and phosphorus are not outcomes that we care about directly in themselves, as long as periphyton objectives are being achieved. We have found that this is not consistently understood by participants in resource management processes around the country and is a significant obstacle to effective limit-setting processes. Given the scientific uncertainty in predicting the limits necessary to achieve objectives (discussed further later) it is likely that refinement of limits will be necessary in future plan reviews and this can be guided by long-term monitoring and analysis of both objectives and limits.

2.2.5 Requirements of over- versus under-allocated catchments

Different approaches may be justified in over- versus under-allocated catchments if these types of catchments can be identified in round terms early in the process. Over-allocated catchments are likely to need more process iteration (of the type described in section 0) to explore whether aspired-to freshwater objectives will need adjusting (and/or the timeframes to achieve them lengthened) once the environmental, social, cultural and economic implications are understood from technical prediction work and have been socialised with the community. These cases are likely to require some form of resource use claw-back and associated allocation discussions are therefore likely to be more intense and time-consuming. These cases may also justify choosing stronger, more allocable types of limits even though these are more complex to implement. All these things will affect the way a process is set up in these over-allocated catchments.

Under-allocated catchments may need less process iteration as it may be largely a matter of maintaining a currently acceptable environmental state (i.e. the freshwater objectives will be clearer and firmer from current state monitoring data) and capping resource use at some level with minimal negative effect on existing resource users. Alternatively some improvement on current state may be desired but identified as achievable using mitigations without any claw-back of resource use. These cases may justify choosing less sophisticated types of limits that are less complex to implement. Catchments where there are significant prospective future resource users may be a sub-category that requires some intermediate level of effort to assess the implications of the future prospective use. It is generally less contentious capping or foreclosing on a future prospective use before investment has been made by the user, than clawing back on resource use by a user who has already committed their investment.

2.3 Harnessing many types of knowledge

2.3.1 The ‘pyramid’ of information and importance of well-framed questions

Effectively harnessing the large amount of knowledge available across the many science disciplines and other community knowledge providers is a substantial challenge for science in limit setting. We have found that the breadth and amount of science knowledge can be overwhelming even for people who work day to day in resource management. We’ve also found it can help to think of the science knowledge resource as being a deep well or the broad base of a “pyramid” (see Figure 2), into which we need to dip to extract what we need for tackling particular questions at a point in time, not trying to answer everything at once. That said, the whole pyramid is important; the mid and upper levels of the pyramid cannot exist without the base. The process of clearly framing the detailed questions for efficiently harnessing the knowledge available, and for identifying gaps, is therefore very important.

We've already identified that scientists cannot tackle the high-level question face on and alone. A series of more detailed subsidiary questions (that assume community values are already well established) include: 1) "*What types of freshwater objectives (i.e. which attributes)?*", 2) "*What types of resource uses?*", 3) "*What types of limits for those resource uses?*", 4) "*How do the answers to all these vary spatially across the region?*", and of course for each given catchment 5) "*What level of each limit is necessary to achieve each given optional level of freshwater objective attribute?*". A key step for the council team is to frame these and other more detailed subsidiary questions in a way that allows the available science knowledge to be effectively harnessed. An example is offered for the value of 'human health for recreation' (i.e. swimmability) in text Box 1.

BOX 1: Example of mid-level question-framing for the value of 'swimmability' (i.e. human health for recreation)

1) ***What types of freshwater objectives (i.e. which attributes)?***

The NPSFM makes this value compulsory and makes it compulsory to at least use the attribute *E.coli*, but other attributes may also be relevant in some catchments (e.g. clarity, colour, nuisance or toxic algae, depth etc). Answering this question involves science and other knowledge providers offering what measures are available (i.e. with existing data for a reasonable period), and community consultation identifying which are important where.

2) ***What types of resource uses?***

The answers here include water takes and point and diffuse discharges (and the land-uses causing the latter), as well as activities in or near waterways such as riverbed and flood control works and riparian activities. Science informs which of these are key drivers of state (i.e. of changes in attribute state) in different catchments.

3) ***What types of limits for those resource uses?***

From among the identified key resource uses (e.g. takes, discharges, land use etc) affecting identified attributes (e.g. *E.coli*, clarity, nuisance algae), what kinds of limits could be used to constrain those resource uses in some manner to meet desired attribute states. These may include both numeric and non-numeric types of constraints (e.g. numeric limits on *E.coli* concentrations/loads and clarity and colour from point discharges, restrictions on stock access to waterways, farm plans with requirements to identify and manage critical source pathways, riparian setbacks or other management, soil and bank erosion controls, urban storm-water and other run-off controls, and nutrient and flow conditions that affect nuisance algae growth).

4) ***How do the answers to all these vary spatially across the region?***

The answers here require a mix of science and other knowledge input (e.g. physiographics and other work), community-derived identification of areas valued for swimming and other contact recreation, and planning analysis to assist in judging a pragmatic and implementable spatial scale for regional plan-writing.

5) ***What level of each limit is necessary to achieve each given optional level of freshwater objective attribute?***

This is the difficult question that science needs to inform by using 'cause-effect' relationships to predict consequences of options. These relationships may be explicitly and quantitatively described by scientific studies or may need to draw on semi-quantitative or even qualitative expert inference. The existence of uncertainty in these relationships is inevitable and a given; process tools and guidance are available to help technical teams handle uncertainty while maintaining credibility.

For the *E.coli* example the NPSFM provides some nominal options for different levels of infection risk associated with swimmability, corresponding to different in-stream (i.e. receiving water) concentrations of *E.coli*. The task for science is to predict what amount and level of each type of limit identified at Question 3 will be needed to achieve each of these optional levels of in-stream *E.coli* concentration, and thus associated optional levels of infection risk. Economic and social analysis will predict the implications (for people) of implementing and complying with the various options for limits. Debate and ultimately decisions are then based on weighing those implications against the level of swimmability attained (in this case the decided acceptable level of risk of infection), and probably also the time allowed to get there. A similar options-informing science role based on cause-effect relationships is needed for other identified attributes such as clarity and nuisance algae.

2.3.2 Multiple disciplines for limit-setting

Multiple technical disciplines are required to predict consequences of options (e.g. scenarios) for multiple values, including multiple biophysical disciplines, social and cultural sciences, economics, and including indigenous Maori knowledge (mātauranga Māori) and community information as illustrated in the base of the pyramid in Figure 2. These need to be able to inform on all the relevant implications of resource use for land, groundwater, rivers, lakes, estuaries, the coast, and all associated ecosystems and communities.

2.3.3 Key types of knowledge used in limit setting

The types of knowledge that are most relevant and useful for limit setting include:

- a fundamental understanding of environmental systems (including socio-economic and cultural) and their processes that are relevant to the catchments in question. Transdisciplinary awareness is important in the council team;

- descriptions of current environmental state and trends (including rates of change and ecological thresholds based on monitoring of attributes and other indicators, and by extrapolation using models and classification systems to areas where data don't exist. These help communities to identify and describe their values, and provide options for scientifically measurable ways of expressing those values in terms of attributes that can be used as freshwater objectives under the NPSFM;

- identification of major drivers of current environmental state and observed past change (e.g. geographic situation, specific land and water resource uses, climate variability and change), as well as predictions of potential future change scenarios. This helps identify key resource management issues that need to be managed and informs what future scenarios are relevant to test;

- cause-effect relationships; including those observed at a generally high level (e.g. correlated patterns of land use and water quality change) and, most usefully where possible, at the level of demonstrated science relationships between identified attribute states (to use for freshwater objectives) and relevant indicators of resource use (to use for setting limits). These help to describe the consequences of various options for limits (i.e. amounts of resource use) in terms of the effect on freshwater objectives (i.e. attributes). These are crucial for informing limit-setting by scenario testing;

- spatial pattern and specificity for the above three bullet points across the region (e.g. Environment Southland's physiographics work). This helps illustrate and manage spatial variability (i.e. define freshwater management units in NPSFM terms) and helps prioritise what resource management effort should be spent where.

2.3.4 Predictive models

To describe consequences of options and scenarios to inform choices about objectives and limits it is necessary to attempt to predict the future (*i.e. what will happen if we do this?*). This inevitably requires some form of modelling or other analytical inference based on knowledge and observations from the past. The choice of which models to use is a key step in the process for the council team and this may need to be iteratively revisited as the process progresses. Being somewhat agile in the use and choice of these models (e.g. starting simple, and having a 'plan B' assessment approach) is useful.

In general, a mix of numerous models/assessments will be needed to cover the various types of freshwater objective attributes and limits, physical environments, values and technical disciplines described above. Our experience with other councils shows that even highly sophisticated and complex models can only ever cover a subset of these relevant aspects. There is no one "do everything" model and not all are computer models; simple predictive relationships are a form of model. Multidisciplinary interpretative analyses, often in narrative qualitative or semi-quantitative terms, are always needed after the models have produced results. Our observation is that complex models are time and resource hungry; careful judgement of "fit-for-purpose" is needed. In general, models for predicting consequences of scenarios need to be agile and able to predict direction of change and approximate magnitude of effects; models for defining a short-list of numeric objectives and implementing limits may need to be more sophisticated depending on the choice of what type of limits are to be set.

2.3.5 Complexity, uncertainty and associated risk

We have already touched on the challenges of complexity and uncertainty. It is useful to explicitly recognise the need to manage both of these things in order to avoid "paralysis by analysis" and make forward progress with limit setting. This will mean accepting conscious decisions to simplify, manage and live with a level of uncertainty. We have observed in other council processes that people will always want more information when facing tough value-judgement decisions; delaying the tough calls by requesting further information is a usual, natural human response. Our observation is that there comes a point where further information is unlikely to alter the decision; picking this point is a key challenge for the council team. Particular skills and some resource management tools are useful to handle these aspects as described in the next section. Part of this challenge is ensuring that decision-makers include deliberations on a broad range of factors; i.e. including biophysical, socio-economic and cultural information, what is practicable, achievable and acceptable risk management.

2.4 Skills needed

2.4.1 Knowledge and technical skills from many disciplines

There is an ongoing need for the traditional expert knowledge providers in each of the required technical discipline areas (see base of pyramid in Figure 2). These scientists and other knowledge providers need to be effective members of multidisciplinary teams working alongside communities and council planners (second row of pyramid in Figure 2).

2.4.2 Dedicated integrators

From experience with other councils we have also found it crucial to specifically identify the role of integrating, translating and communicating multidisciplinary information for both the public and decision-makers (third row of pyramid in Figure 2). People with all these skills and an ability and desire to work within community processes and planning frameworks are not common. However, once the role and skills are explicitly identified it is possible to train people with the right experience and inclination into the role. The skills required of these "Integrators" have been detailed in the attached papers and guideline, and are briefly summarised below.

2.4.3 Integration

While all discipline experts in the team will need to broaden their interdisciplinary appreciation, the integrator(s) will need to take on the responsibility of being across all relevant fields in the project, to help move beyond discipline-specific approaches – the notion of transdisciplinary science - which necessarily comes at the expense of depth of attention given to any one traditional technical specialist field. Where this integration role in the past has largely been performed by planners, the technical complexity of limit-setting today justifies specialist integrators to perform this role. It is a demanding and potentially stressful role. The integrator(s) provide a conduit to the wider team of technical experts and work alongside planners and community process facilitators.

2.4.4 Communication

Our experience with other councils shows that communicating complex technical information credibly and accessibly for a wide audience is crucial in limit-setting processes. This includes translating information to a simplified level using more plain language, a task that is uncomfortable for some technical experts more familiar with operating in traditional science fora. Numerous communication tools can assist, and some are described in the paper and guide mentioned previously (e.g. Rouse and Norton 2017; MfE 2016). Understanding the big questions and those things that will really make a difference to communities is essential when communicating science.

2.4.5 Uncertainty

Handling uncertainty has been such a feature of other councils' limit-setting processes to date that it prompted the Ministry for the Environment to prepare a draft guide outlining useful skills and tools on the subject (MfE 2016). In short, the guide advocates a three-stage approach that involves assessing and reducing uncertainty where practical, communicating the remaining uncertainty and risk with the community and decision-makers, and thereby incorporating uncertainty into decision-making.

2.5 Summary

- The primary role of science in NPSFM limit-setting processes is to objectively inform choices around objectives, their consequences, and the limits (to resource use) required to achieve them, rather than instruct or make value-laden decisions on the level at which objectives and limits are set.

- It greatly assists the process if all scientists in the council's team understand, and identifiably play, the 'honest broker' role. It is important that all scientists at least understand this role.
- Several science-related roles are needed in the team, including the traditional information providers of many knowledge disciplines and, critically for limit-setting today, the trans-disciplinary "Integrator" role.
- Science helps limit-setting in three main areas by:
  i) Informing the setting of objectives and limits;
  ii) informing allocation of those limits and other methods to achieve objectives; and then
  iii) monitoring and assessing attainment of limits and objectives through time.
- Science informs the setting of objectives and limits by assessing and then describing the effects of different options, such as through testing future scenarios.
- Many types of knowledge, models and tools are needed, as illustrated across the base of the pyramid in Figure 2.
- Handling complexity, uncertainty and associated risk are key challenges that require distinct skills.
- Effective communication of science and other knowledge is crucial and also requires distinct skills.
- Over-allocated catchments may require different approaches (e.g. more iterative exploration of objectives, limits and timeframes) than under-allocated catchments, but the key knowledge-informing elements of the process are the same for both.

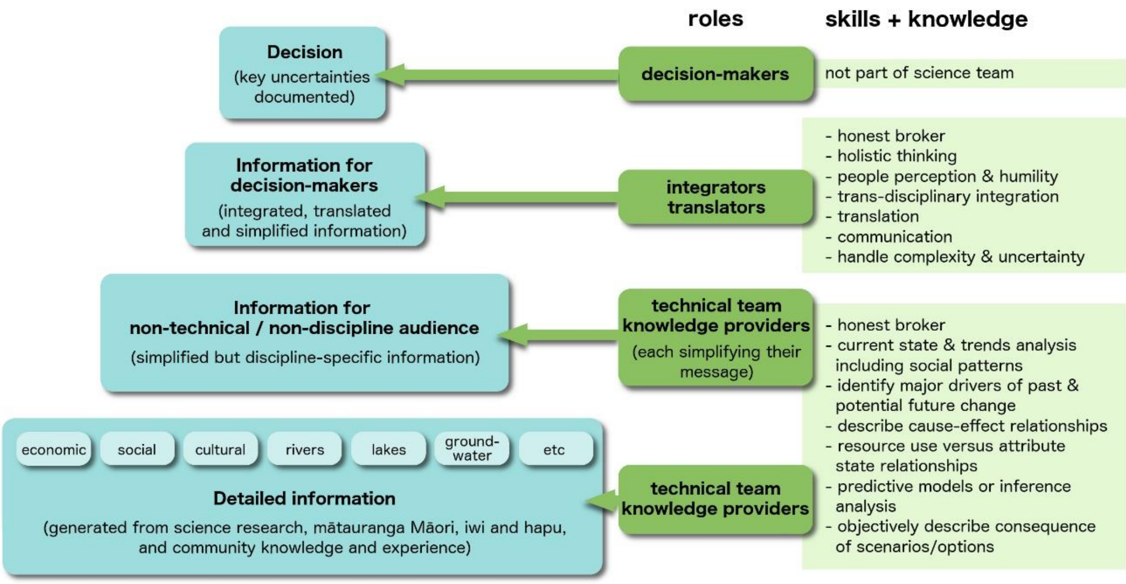

Figure 2: Illustration of the 'pyramid' of information, roles, skills and knowledge types typically needed in NPSFM processes (adapted from MfE 2016).

3. Science preparedness for the next stage of limit-setting in Southland

In this section we examine Environment Southland's preparedness for its next phase of limit-setting, based on the necessary science roles, information and skills identified in section 2.

3.1 Science roles and skills

Environment Southland has a well-established team of scientists who provide knowledge skills in many of the individual disciplines that will be required for limit setting (e.g. aquatic ecology, hydrogeology, hydrology, hydrochemistry, limnology, pedology and economics). However, science roles are defined in terms of level and type of technical expertise and have not yet been explicitly identified or defined for the purposes of a limit setting project within Environment Southland.

Experience in integrated catchment management and limit setting projects from across the country shows that as a minimum, a 'tight 3' is required for leading these projects; a technical (integrator) lead, a lead planner and a community (engagement and facilitation) lead. The technical lead needs to have an aptitude for harnessing the capability of many discipline experts, stakeholder and other community expertise, and for managing consultants and scientists.

The tight 3, along with the project manager (who may be one of the tight 3), should be responsible for exploring the questions that frame up science information needs. These three can, and likely need to be, supported by other individuals. Based on our experience, these roles are fully immersive and we note that few people undertake this role for more than one limit setting process. Ideally, the tight 3 are local and "on the ground", however they can be (and are often) supported and mentored remotely.

We recommend that Environment Southland:

- undertake steps to ensure the council's science team has a culture that distinguishes and identifiably adopts clear scientist roles - preferably an impartial honest broker role;
- recognise the importance of greater transdisciplinary awareness in the team and design team building and capacity development in this area into the programme (i.e. build capacity for continually improving technical staff delivery at the second level of the "pyramid");
- recognise the importance of continuous improvement in skills and techniques for communication and handling uncertainty; and,
- a tight 3 is established within council to lead any limit setting approach. This group should be responsible for framing the questions needed to drive delivery of science information.

3.2 Science knowledge

3.2.1 Conceptual understanding of the system

Since 2014, Environment Southland's science programme has focused on characterising the region's natural systems and supporting development of a robust understanding of the regional economy (i.e. the Southland Economic Project). The outputs of this work will provide a useful basis for describing how Southland's natural systems function, their state and trends and drivers of change. Much of this information has been co-developed with multiple research partners.

The majority of the characterisation research has been weighted to biophysical sciences with limited research in cultural and social sciences. All forms of science, including mātauranga Maori, need to be brought together for consideration by the community as part of the limit setting process.

An example, Environment Canterbury (ECan) teams involved in limit setting projects have evolved from previously presenting themselves as 'the experts' to emphasising co-generation of information. In the Hurunui process for example, all key science assessments and assumptions are tested against a science stakeholder group (SSG) who also have a responsibility to help collaboratively solve technical and knowledge issues as they arise in order to best inform the community process. The SSG thus helps the council's science team inform the community and decision-makers but specifically does not make any value decisions.

In our experience, it can be challenging to mesh conventional science with mātauranga Maori and other knowledge systems; however, it is important all types of knowledge are able to equally inform the conceptual understanding of the system. Agreement or overlap should be encouraged but where consensus is not able to be reached, it is important to respect the value of all perspectives and represent these equitably.

We recommend that Environment Southland:

- consider a step early in its next limit-setting stage whereby the conceptual understandings generated by the science programme are tested using a diverse range of participants. This will establish buy-in to science findings and will allow other knowledge sources to be incorporated into the conceptual understanding of the system. Involving a wide range of participants early will help avoid a lengthier and more costly process arising from debate on key concepts; and
- establish an SSG or equivalent whose role is to help solve technical and knowledge issues as they arise[6]. The work of the SSG and the content they are asked to tackle will need to be steered by the tight 3 leadership group mentioned previously and will need active facilitation.

3.2.2 Informing the setting of objectives and limits by describing options

The high level question facing scientists in limit setting processes is *"what is the maximum amount of resource use available (i.e. limits), that will allow freshwater objectives to be met and when, with an acceptable level of uncertainty?"* Science can be used to help answer this question only if given a clearly quantified objective (i.e. if the value judgements on the level at which to set an objective have already been made). If the objective has not been fully decided then science can be used to objectively describe the consequences of several options for freshwater objective and limit pairings, to inform a subsequent value judgment decision on which option to adopt. Exploring the consequences of options requires science to make predictions, typically in the form of future scenarios. Environment Southland's science programme has useful information to inform scenario testing but it is not yet packaged in a manner that allows predictions to be made.

[6] The purpose of a SSG or equivalent group would differ to the Technical Advisory Group (TAG) established to support the characterisation research programme. The TAG provided science direction and technical advice while the SGG would be more actively involved in co-generating science knowledge.

We think there are two approaches Environment Southland could consider:

- A 'clean slate' approach would mean freshwater values, attributes and options for objectives would need to be established before considering options on limits and methods. With this approach, science is required to help inform all phases of the limit setting process (see Figure 1).

- Alternatively the proposed Southland Water and Land Plan (pSWLP) could be used both explicitly and implicitly, to build a first principles framework. For example, using the values, objectives and water quality standards in the pSWLP to establish and relate values with attributes and freshwater objectives. With this approach, the key question for science (and planning) is: *what are the options for limits and methods that would allow the pSWLP objectives and water quality standards to be met?* This approach may or may not exclude the potential for iterative consideration of alternative options for objectives to those already in the pSWLP.

We recommend that Environment Southland consider early how it will undertake the process of packing science information to inform the setting of objectives and limits. This is a significant process decision that should be planned into the work programme early. The process adopted may vary depending on the approach taken (e.g. using identified values, objectives and water quality standards in the pSWLP, starting fresh, or something in between these options).

BOX 2: Example of Southland science preparedness for the value of 'swimmability'

The NPSFM requires regional councils to develop regional targets to contribute to a national target of making 90% of New Zealand's large rivers and lakes swimmable by 2040 (with an interim target of 80% swimmable by 2030). Draft regional targets must be available to the public by March 2018 with final regional targets public by the end of 2018. Because these dates are imminent, swimmability has been selected as an example to demonstrate Environment Southland's science preparedness for limit setting.

1) *What types of freshwater objectives (i.e. which attributes)?*

The NPSFM makes it compulsory to at least use the attribute *E.coli* and this attribute is also used in the proposed Southland Water and Land Plan (pSWLP) for bathing sites. However, other attributes may also be relevant for some communities or catchments when considering swimmability. Table 1 lists some attributes that communities may decide are important in assessing swimmability and identifies whether Environment Southland has data available to assess these attributes. For some attributes, numeric pSWLP objectives (or water quality standards) may already exist to protect either or both human and ecological health values (as indicated by "A" or "B" respectively). Table 1 shows that there is sufficient data available to assess most water quality variables with more limited data available for other types of attributes (e.g. site access).

Table 1: Example of possible swimmability attributes for Southland

Possible Attributes	Data Available?	Existing standards A=For human health B=For ecological health			Comment
		NPSFM[1]	RWPS/pSWLP[2]	Recreational Guidelines[3]	
Access					Limited data available
Clarity	✓		B		

E.coli	✓	A	A	A	
Colour			B		Not measured
Nuisance algae	✓	B	B		
Toxic algae					Limited data available
Temperature	✓		B		Limited temporal data
Water depth					Limited data available

[1]National Policy Statement for Freshwater Management 2014 (amended 2017) (NZ Government, 2017).
[2] Regional Water Plan for Southland and proposed Southland Water and Land Plan (ES, 2010 and 2016)
[3]Microbiological water quality guidelines for marine and freshwater recreational areas (MfE, 2003)

2) *What types of resource uses?*

Science can help identify key drivers that influence changes in attribute state in different catchments. For instance, faecal source tracking surveys that have been undertaken in the region can be used to identify sources of microbial pollution. This combined with information on land use and contaminant transport pathways (e.g. physiographics) could provide a basis for which key drivers influence changes in microbial state across different catchments. Table 2 provides an example of the types of information available for identifying key drivers of swimmability for differing attributes. The amount of information available to identify types of resource users varies depending on the attribute.

Table 2: Example of data available to help identify resource users influencing swimmability. N/A means that for that attribute, it is not an appropriate data source.

Possible Attributes	**Possible data sources**					
	Source tracking data*	**Consents(takes/discharges)**	**Land use data**	**Satellite imagery**	**Contaminant pathways**	**In-stream monitoring data**
Access	N/A	N/A		✓	N/A	N/A
Clarity	✓	✓				✓
E.coli	✓	✓	✓		✓	✓
Colour						
Nuisance algae	✓		✓		✓	✓
Toxic algae	✓					✓
Temperature		✓				✓
Water depth	N/A	✓			N/A	✓

*Can include indirect tracking of pollutant sources. For example, using nitrogen source tracking methods to identify resource users contributing to nuisance algae.

3) *What types of limits for those resource uses?*

There are a range of limits that could be used to constrain resource uses in some manner to meet desired attribute states. Science (and including whole systems thinking) can help with identifying what types of constraints could be used and the attributes those constraints will influence. An example of this is shown in Table 3.

Table 3: Example of limit types to constrain resource uses that influence swimmability and the attributes they would influence.

Possible Attributes	Possible limit types						
	Stock access to water ways	**Farm management plans**	**Riparian management**	**Soil and bank erosion prevention**	**Storm water/runoff controls**	**Water takes**	**Numeric limits on discharges**
Access	✓		✓	✓		✓	
Clarity	✓	✓	✓	✓	✓	✓	✓
E.coli	✓	✓	✓	✓	✓		✓
Colour	✓	✓	✓	✓	✓		✓
Nuisance algae	✓	✓	✓	✓	✓		
Toxic algae	✓	✓	✓	✓	✓		
Temperature		✓	✓		✓	✓	✓
Water depth		✓		✓	✓	✓	

4) ***How do the answers to all these vary spatially across the region?***

This requires a mix of science and other knowledge input including an understanding of how and where swimming values vary across communities and catchments. Environment Southland's characterisation programme provides a good basis for informing understanding of spatial variability (e.g. physiographics, CLUES modelling).

5) ***What level of each limit is necessary to achieve each given optional level of freshwater objective attribute?***

Science informs this question by using 'cause-effect' relationships to predict consequences of options. For *E.coli*, the NPSFM provides some options for different levels of infection risk associated with swimmability. NIWA have undertaken some *E.coli* modelling at the farm scale for a catchment in Southland which could be used to help predict what amount and level of each type of limit identified at Question 3 will be needed to achieve each of these optional levels of *E.coli* concentration, and thus associated levels of infection risk. Socio-economic analysis can be undertaken using the Southland Economic Model to predict the transition pathways of various options for limits. Less information is available to relate other attributes to infection or aesthetic risk for swimmability.

4. Conclusions and recommendations

This report set out to identify the types of scientific information and skills which have provided the greatest value to the limit setting processes elsewhere in New Zealand, and to use this as a basis for assessing Environment Southland's preparedness for its next stage of limit-setting.

Environment Southland and research partners have generated considerable amounts of useful science over decades, mostly in biophysical sciences. This information has been used in planning processes including the pSWLP; however, this information is not yet organised in a way that fully meets the needs of limit setting.

In order to prepare for the next stage of limit-setting, we have recommended that Environment Southland:

- undertake steps to ensure the council's science team has a culture that distinguishes and identifiably adopts clear scientist roles - preferably an impartial honest broker role;
- recognise the importance of greater transdisciplinary awareness in the team and design team building and capacity development in this area into the programme (i.e. build capacity for continually improving technical staff delivery at the second level of the "pyramid" shown in Figure 2);
- recognise the importance of continuous improvement in skills and techniques for communication and handling uncertainty;
- establish a minimum tight 3 within council to lead any limit setting approach. This group should be responsible for framing the questions needed to drive delivery of science information;
- consider a step early in its next limit-setting stage whereby the conceptual understandings generated by the science programme are tested using a diverse range of participants. This will establish buy-in to science findings and will allow other knowledge sources to be incorporated into the conceptual understanding of the system. Involving a wide range of participants early will help avoid a lengthier and more costly process arising from debate on key concepts;
- establish a Science Stakeholder Group or equivalent whose role is to help collaboratively solve technical and knowledge issues as they arise; and
- consider early how it will undertake the process of packaging science information to inform the setting of objectives and limits. This is a significant process decision that should be planned into the work programme early. The process adopted may vary depending on the approach taken (e.g. using identified values, objectives and water quality standards in the pSWLP, starting fresh, or something in between these options).

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