Technical and Scientific Considerations When Setting Measurable Objectives and Limits for Water Management

NIWA Client Report: CHC2010-060
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Technical and Scientific Considerations When Setting Measurable Objectives and Limits for Water Management

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Executive Summary

Introduction

The Ministry for the Environment (MfE) commissioned NIWA to provide a report containing: i) background on the technical and scientific aspects of setting measurable water management objectives and limits in resource management; and ii) technical discussion on concepts such as allocation and assimilative capacity in relation to water quality.

The purpose of this report is to assist, from a science perspective, with development of knowledge on the wider topic of setting limits in water management, which comes under the Water Quality Limits Project that is part of Government's New Start for Fresh Water Officials' Work Programme. The ideas in this report are from the authors' perspective as water resource scientists working in the resource management industry. This could form a basis for discussion on limit setting with people that have other perspectives, such as those working in law, policy, planning and other technical fields.

Background

The need for limits in water management has been widely discussed recently. For example the Government's Cabinet paper proposing a *New Start for Fresh Water* (Offices of the Minister for the Environment and Minister of Agriculture [ME & MA] 2009) stated: "… *New Zealand is approaching some water resource limits, which can be seen in areas with deteriorating water quality, water demand outstripping supply, and constrained economic opportunities.*" In particular the Cabinet paper identified that "*water resource limits*" were needed "*to shape actions on quantity and quality*" and also identified the importance of "*supplementary measures to address the impacts of land use intensification on water quality, and manage urban and rural demand*".

Terminology

Setting limits for water management requires multiple disciplines including various science fields (e.g., climatology, hydrology, hydrogeology, geomorphology, chemistry, ecology, earth and agricultural sciences, social and cultural sciences, and economics), as well as law, policy and planning expertise. Ideas for setting limits are evolving across these multiple disciplines, creating significant integration and communication challenges, and particularly problems with inconsistent use of terminology. We have defined and used consistent terminology in this report with the hope that our ideas may be more easily integrated with ideas from work in other disciplines (see Glossary at the end of this Executive Summary). Terms defined in the Glossary are underlined throughout the remainder of this report.

Integration of science, planning and law

There is a need to integrate expertise from the science, planning and legal disciplines. While bridging these disciplines has always been important in resource management, the approach suggested in this report places an even greater emphasis on interdisciplinary communication for regional planning. This is because the approach represents a shift in thinking from a reactive mode (i.e. concentrating on regulating the effects of new activities) to a pre-emptive planning mode (i.e. identifying the capacity for use of resources and setting limits). This requires greater use of scientific knowledge by planners, thinking at more expansive scales by scientists and more creative use of legal tools.

Structure of the main report

The purpose of the report and terminology are provided in Section 1. Section 2 contains an overview of the need for measurable objectives and why defining these allows a range of limits such as water quality standards to also be justifiably set. Section 3 describes how science can be used to help overcome a range of challenges and to set measurable objectives and limits. Section 4 describes how science can help implement measurable objectives and limits strategically under the Resource Management Act (RMA), and specifically through regional plans. Section 5 describes the benefits of setting measurable objectives and limits, and illustrates the benefits with examples. Section 6 summarises the challenges and refers back to solutions identified throughout previous sections. Section 7 contains our conclusions.

Conclusions - key messages

Limits for water management can potentially be set at any, or all levels of the resource management framework established under the RMA, that is; at the national level (i.e., in national policy statements and national environmental standards); regional level (i.e., in regional policy statements and regional plans); or the local operational level (i.e., individual resource consents with conditions). There are advantages and disadvantages of setting limits at each these levels, and there is a need for a national decision on the best approach. We suggest it is clear that setting limits *only* at the operational (i.e., individual consent) level is inadequate, and that limits need to be set at some higher strategic planning level(s). We suggest there are many good reasons for an approach that sets limits, *at least* at the regional plan or catchment plan level.

In this report we propose that it is possible to define measurable objectives in regional plans and that doing so will significantly improve water management. Measurable objectives allow a range of limits to be justifiably set using science, such as water quality standards, catchment contaminant load limits, maximum water take and discharge rates, minimum river flows and lake and groundwater levels, minimum standards of discharge quality, restrictions on dam operations and restrictions on land uses. We suggest that objectives must be sufficiently measurable (i.e., preferably numeric) that they allow limits to be justifiably set using science, and as such we suggest that measurable objectives are a fundamental pre-requisite in order to fully achieve the purpose of a regional plan, i.e. to assist a regional council with its functions under s30 RMA.

In order for regional councils to properly carry out their s30 RMA functions for managing and allocating water resources, particularly when demand for those resources approaches available supply, a regional plan must provide a basis for determining the capacity for use of the resource; i.e. the amount of resource use that can be made by people *while* sustaining all competing values at some identified acceptable level. We suggest that the capacity for use of the resource depends on value judgements that should establish, in an unambiguous manner, the level at which all competing values will be sustained, i.e., the environmental states or outcomes sought. We propose that the outcomes sought in the plan should be defined by measurable (preferably numeric and SMART[1]) objectives. The plan's policies and rules can then justifiably set limits to resource use, such as water quality standards, that are clearly linked to achieving the measurable objectives. Plans that contain measurable objectives *and* linked limits such as water quality standards, can achieve at least five important benefits for managing water resources. By way of summary these are:

(i) Increased clarity and therefore certainty for environmental outcomes;

(ii) a basis for managing cumulative effects;

(iii) clarity about future resource availability and the conditions likely to be imposed on resource users;

(iv) an ability to manage multiple types of activities that affect water quality in addition to managing point-source discharges, such as non-point discharges from land uses, water takes, diversions, dams and riverbed works (i.e., the integration of water quality, quantity and land management); and

(v) an ability to measure attainment of objectives and thus properly monitor the effectiveness of plan provisions through time.

We conclude that defining measurable objectives and setting limits such as water quality standards is challenging but achievable. We have identified numerous challenges and described five key components of an approach that uses science to help overcome the challenges. By way of summary these are:

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[1] SMART (Specific, Measurable, Achievable, Relevant, and Time-bound; after MfE 2003)

(a) Use science knowledge and the regional planning process to inform decision makers so that necessary value judgements can be made. The role of science in this process is to describe the effects of various management options, on environmental, social and economic values, so that informed choices between the options can be made by decision makers, not scientists;

(b) Use technical relationships from science research, including published national guidelines and research papers, as well as analysis of region-specific data, to develop options for measurable objectives, and limits such as water quality standards;

(c) Structure plan provisions according to a spatial framework that defines groups of water bodies that are sufficiently similar, both physically and in terms of their values, to be treated as management units;

(d) Acknowledge and manage scientific and other types of uncertainty in a risk-based manner;

(e) Combine science knowledge with effective use of planning tools provided under the RMA.

The most important aspect of the approach is the requirement for regional council decision-makers, via the regional planning process, to make the difficult value judgements concerning the balance between capacity for use of the resource by people and sustaining all competing values at some identified appropriate level. These value judgements are necessary to define measurable objectives, and limits such as water quality standards, in a regional plan. Ultimately if these value judgements are not made strategically in a regional plan, it will be necessary to make them on a case-by-case basis for every future consent application. This will result in poor ability to achieve the five benefits for water management listed above; i.e., there will be uncertainty for environmental outcomes and resource users, poor ability to manage the cumulative effects of multiple types of resource use activities, and limited ability to monitor plan effectiveness.

The approach faces numerous other challenges that we have identified in Section 6. Key among these is that setting measurable objectives and limits will probably lead to more complex (i.e., larger) planning documents than plans which rely on broad narrative provisions. Managing this complexity and educating plan users is a significant challenge. Setting measurable objectives and limits in regional plans may be costly, but not doing so will also have significant costs in the long run. Water resources are complex systems that are coming under increasing pressure from equally complex socio-economic activities. Larger, more complex plans are a likely consequence when the demand for use of water resources approaches the sustainable limits of supply. It is logical that, as demand for resources increases, the benefits of setting limits will at some point outweigh any disadvantages and therefore justify the costs.

In this report we have provided support for these conclusions from the science, planning and resource management literature, from legal commentators, from national policy and guidance documents, from the RMA itself, and using logical argument. The success or otherwise of the approach outlined here can only be determined by its application and the course of time. We acknowledge and invite discussion of these ideas with others involved in water management, and we hope the ideas set out here can improve clarity and lead to further discussion and refinement of the process of setting limits for water management.

GLOSSARY

(Key terms, approximately in the order that related concepts are addressed in this report)

Values

Humans value many things about water bodies. Values are the reasons why we manage the water resource, including uses by people (e.g., drinking water, irrigation, hydro-generation, recreation) and intrinsic values (e.g., ecology, cultural, aesthetic, natural character). NB. A comprehensive list of values is provided in the Report and Recommendations of the Board of Inquiry into the Proposed National Policy Statement for Freshwater Management (NPS) (MfE 2010).

In-stream values (and out-of-stream values)

We use in-steam values to describe values associated with water left in a river, lake or aquifer (e.g., ecology, recreation, cultural, aesthetic, natural character), as opposed to out-of-stream use values (e.g., drinking water, irrigation, hydro-generation). NB. The recommended NPS list of values is similarly sorted into two types based on whether they are values involving 'use' by people versus 'intrinsic' values.

Value judgement

The values "compete" with one another to a certain extent, particularly in-stream and out-of-stream values but also within these two types of values. The "value judgement" is the decision that determines the desired balance between the competing values. It sets the agreed level at which the individual values will be supported (i.e., it decides the desired environmental state - see definition below).

Capacity for use

The amount of resource use that can be made by people *while* sustaining all competing values at some agreed level. Because value judgements are required to determine the acceptable level for supporting all values, so too the capacity for resource use depends on these value judgements. Capacity for use varies widely between water bodies; some water bodies that support very sensitive and significant in-stream values may have zero capacity for use, while other water bodies may have significant capacity for use.

In the context of water quality, the capacity for use is the capacity of the water body to dilute and/or assimilate contaminants derived from human uses, while sustaining all other values at desired levels. In the context of water quantity, the capacity for use is the rate at which water can be removed from the water body (or be diverted or dammed) while sustaining all other values at the desired level.

We note that the term capacity for use (sometimes referred to just as resource capacity) has been used by legal commentators (e.g., Salmon 2007, Milne 2008). The RMA also recognises the "*capacity of water to assimilate a discharge of a contaminant*" (s30(1)(fa)) (see definition for assimilate below). We are not aware of any specific legal definitions for these terms and so the definition we provide in this report represents our use of these terms. Our definition appears to be consistent with the way these terms have been used by Salmon (2007), Milne (2008) and in the RMA (s30(1)(fa).

Assimilate, assimilative capacity

The RMA (s30(1)(fa) refers to the capacity of water to assimilate a discharge of a contaminant. In this sense we consider that the 'capacity to assimilate' or 'assimilative capacity' is virtually synonymous with our use of 'capacity for use'. However the latter term is broader and applicable to both water quantity and quality management, whereas the former term applies primarily to water quality. Note that in this sense 'assimilative capacity' does not necessarily mean that a particular contaminant is completely removed, absorbed or converted to other chemical forms (biochemistry use of the term), rather it means that the concentration or load of the contaminant remains within some chosen acceptable level.

Environmental state (description of)

Descriptions of aspects of environmental state may be made in a wide variety of ways from broad narrative terms (e.g., suitable for recreation) to quite specific numeric terms (e.g., water clarity of 1.6 metres visibility and riverbed slime cover less than 30% are often deemed as environmental states that are suitable for recreation). From a science perspective, it is most helpful for management (and in particular for setting limits) when environmental state is described by measurable (preferably numeric) variables. Many numeric variables have been scientifically developed to describe aspects of environmental state.

The environmental state is directly related to the suitability of the environment to support in-stream values. Selecting a desired environmental state sets the level at which individual values will be supported. The most useful numeric variables are those that describe an aspect of environmental state that is understood by the average New Zealander (e.g., water clarity, lake water colour, stream bottom slime (algae/periphyton) cover, amount of habitat for valued species, recreation grade).

NB: We note here that not all aspects of environmental state can currently be expressed in numeric terms and some values may never be expressed in this way (e.g., aspects of spiritual and cultural values).

Outcome, environmental outcome

An environmental outcome is the environmental state that eventuates after some management action (or inaction). For example, in the context of a regional plan, the environmental outcome is the environmental state that results from implementation of the regional plan. If the plan has been successful, the environmental outcomes will be equal to or better than the plan objectives.

Desired outcomes, like environmental states, may be expressed in a variety of ways from broad to specific (e.g., broad narrative objectives, tight narrative objectives and numeric objectives all express desired outcomes). In this report we consider it is most useful if desired outcomes are expressed as specifically as possible, certainly as measurable objectives, preferably as numeric objectives and even more desirably as SMART objectives whenever possible.

Objective

In this report we use objective to mean a regional plan objective, including the specific meaning and relationships with other plan provisions as prescribed under the RMA (e.g. s67).

However we note the word “objective” is used in several RMA instruments (national policy statements (NPS), national environmental standards (NES), regional policy statements (RPS) and regional plans (RP)) to describe the intended outcomes for each of those instruments.

Objectives may be expressed at different levels of detail or precision, and this determines the extent to which the intended outcome is left open to interpretation. Thus objectives can range from broad narrative objectives (defined below) to tight narrative objectives (defined below) to numeric objectives (defined below). We also refer to measurable objectives (defined below) and SMART objectives (defined below)

Narrative objective

Broad narrative objectives express the intended outcome (i.e. environmental state) in very abstract, non-quantified terms, for example: sustainable management; safeguard life supporting capacity; suitable for recreation. Broad narrative objectives are open to wide interpretation. They avoid making value judgements by declaring intentions in terms that few would disagree with. Broad narrative objectives are not clearly measurable. Broad narrative objectives might arguably be called goals.

Tight narrative objectives express the intended outcome (i.e. environmental state) more narrowly than broad narrative objectives but nevertheless in non-numeric terms, for example: achieve “good” ecological status; communities have access to safe drinking water; water bodies are swimmable; maintain high quality ecosystems. Tight narrative objectives are still open to flexible interpretation but do imply that the value judgements have been made with greater specificity than broad narrative objectives. As a result, not everyone can be expected to agree with a tight narrative objective. Tight narrative objectives are to some extent measurable, but are not as clearly measurable as numeric objectives.

Numeric objective

Numeric objectives express the intended outcome (i.e. environmental state) in numeric terms, for example: clarity = 1.6 metres; slime cover = 30% cover of bed; available habitat = two-thirds of habitat at Mean Annual Low Flow; suitability for recreation = “Good” recreation grade (associated numeric-based thresholds define the difference between “Good” and “Poor” categories). The nomination of an acceptable environmental state in numeric terms implies a value judgement was made and expressed specifically.

NB: As noted previously under the definition for environmental state, not all aspects of environmental state can currently be expressed in numeric terms and some values may never be expressed in this way (e.g., aspects of spiritual and cultural values). For this reason there will always be a need for narrative objectives in addition to numeric objectives. In this report we suggest numeric objectives be used wherever possible. Where narrative objectives are used, it is useful if they are as ‘tight’ (i.e., specific) as possible.

Measurable objective

An objective that is measurable. A numeric objective is obviously measurable but tight narrative objectives may also be measurable to some extent if carefully worded.

Note that we consider the term "quantitative objective" is virtually synonymous with measurable objective, but we prefer the latter term for a general audience. An objective must be sufficiently quantitative in order to be measurable. We don't use quantitative objective in this report but define it here because it is used in some literature on this topic.

SMART objective

Defined after MfE (2003). This is a particular type of measurable objective in a regional plan that is Specific, Measurable, Achievable, Relevant, and Time-bound.

Standard

We only use this term where the word has regulatory force, by virtue of being defined in a regulatory instrument. For example a guideline (defined below) is *not* a standard.

The word "standard" is used in several RMA instruments, for example:

- A National Environmental Standard (NES) is a national level instrument provided for as an option under the RMA. The RMA provides flexibility for what an NES should constitute.
- The RMA (Schedule 3) lists standards for eleven water quality classes (based on management purposes) that a regional council may (optionally) use in a regional plan (s69 RMA). If the regional council does use any of these eleven classes and includes rules about water quality in a regional plan, then the rules "*…shall require the observance of the standards specified in that schedule in respect of the appropriate class or classes unless, in the council's opinion, those standards are not adequate or appropriate in respect of those waters in which case the rules may state standards that are more stringent or specific.*" (s69 RMA).
- The (proposed) National Policy Statement (NPS) - As recommended by the Board of Inquiry (MfE 2010) refers to water quality standards used in regional plan rules.

In this report we are primarily concerned with standards as used in regional plan rules.

Water quality standard

We use the term water quality standard as used in a regional plan rule, including the specific meaning and relationships with other plan provisions as prescribed under the RMA (e.g. sections 68, 69 and 70). Moreover we use the term (as it is most commonly used in existing regional plans) to mean a *receiving* water quality standard (i.e. a standard to be achieved in the receiving water after reasonable mixing).

In existing regional plans, water quality standards have tended to be a mix of narrative and numeric statements, and tend to have been used to manage point source discharges, although attempts by regional councils to use them for managing non-point discharges are increasing.

[As a prelude to a central idea developed in this report, we note here our suggestion that a water quality standard is most useful for management when it is a technically derived number that describes how a particular measurable objective (see above including the NB) will be attained. Generally, variables that make good water quality standards are those that: i) are influenced by resource use; ii) can be managed; and iii) have direct causative relationships with the measurable objectives (e.g., suspended solids and turbidity for clarity, nutrient concentration for slime, flow for available habitat, E. coli concentration for recreation grade). We suggest that a water quality standard can only be technically determined once the acceptable environmental state (i.e. a measurable objective) is defined.

When a water quality standard is set in a regional plan rule on its own (i.e., without linking it to a measurable objective), this tends to hide the fact that its determination relied on a value judgement. The underlying information from which a water quality standard can be derived is the technical relationship between the contaminant concentration and some measure of the effect on a nominated value (e.g., relationships provided in guidelines). In setting the water quality standard then, the acceptable effect has to be nominated – and this is the value judgement. When a water quality standard is set in a regional plan rule without also clearly describing the objective, this means the value judgement has been made implicitly rather than explicitly.

The analogues of water quality standards in water quantity management are minimum flows and maximum allocation rates.]

Limit

The word limit is used with several meanings in resource management. Most commonly it is used either in the context of a "limit to resource use" or in the context of an "environmental limit". Examples of the former include maximum water take or discharge rates and contaminant loads, minimum discharge quality, restrictions on dam operations and restrictions on land uses. Examples of the latter include receiving water quality standards and minimum river environmental flows. In this report we use the term limit to encompass all of these controls as they all either directly or indirectly define the capacity for use of the resource.

[From the ideas developed in this report it will become clear that we draw a distinction between limits and objectives. Objectives establish, by way of value judgements, the intended outcomes for all values. Limits should be directly related to objectives and can only be technically derived once objectives are clearly defined.]

Rule

A rule in a regional plan, including the specific meaning and relationships with other plan provisions as prescribed under the RMA (e.g. sections 68, 69 and 70).

Policy

A policy in a regional plan, including the specific meaning and relationships with other plan provisions as prescribed under the RMA (e.g. section 67). Also a policy in a regional policy statement (regional policy) or national policy statement (national policy) including the specific meaning of those terms as prescribed under the RMA.

Spatial framework

A spatial framework is a way of grouping areas with similar characteristics for the purpose of defining 'management units' (i.e. water resources of different types, including lakes and rivers). The characteristics are similar among water resources belonging to a management unit and the management units are distinctive. The management units are spatially explicit, i.e. they are able to be mapped.

Guideline

A document that provides technical guidance that is non-mandatory. A guideline has no statutory meaning or relationship with plan provisions under the RMA. The word is not mentioned in the RMA.

[It is important, for understanding the ideas developed in this report, to appreciate that technical guideline documents usually provide options for criteria (defined below) and demonstrate links (i.e., relationships) between causes of effects (e.g. toxicant concentrations) and various levels of environmental state. There are many existing examples (e.g. ANZECC 2000, MfE 2000, MoH 2000, MoH & MfE 2003b, Davies-Colley 2000, Burns & Bryers 2000, Hickey & Martin 1999, MfE 1994, MfE 1992).]

Criteria, criterion

We use the term criteria to describe variables that provide technical indicators of the effects of resource use. Examples include concentrations of contaminants (e.g., nitrate) that cause identifiable effects. Guideline documents often provide relationships between criteria and environmental state. Criteria from guidelines have no statutory meaning but they can be selected and used as water quality standards in regional plans (which do carry statutory meaning) once they have been adopted (i.e., ratified) through the RMA planning process.

Permitted, controlled, discretionary, non-complying and prohibited activities

We use these terms exactly as provided in the RMA for use in rules in regional plans (s68, 77B and s104A-D RMA), and including the specific meaning and relationships these terms have with other with other plan provisions.

1. Introduction

The Ministry for the Environment (MfE) commissioned NIWA to provide a report containing:

i) Background on the technical/scientific aspects of setting measurable water management objectives and limits in resource management; and

ii) Technical discussion on concepts such as allocation and assimilative capacity in relation to water quality.

The purpose of this report is to assist with development of knowledge on the wider topic of setting limits in water management and comes under the Water Quality Limits Project as part of Government's New Start for Fresh Water Officials' Work Programme.

The ideas in this report are presented from the authors' perspective as water resource scientists working in the resource management industry. This perspective reflects work within the science community (with hydrologists, geomorphologists, ecologists, and chemists), with policy analysts, planners, lawyers and engineers in local government and industry. Our ideas have developed during our work integrating science and technical information for projects ranging from individual development proposals that require environmental assessments and hearing evidence, to catchment and regional planning assessments, as well as developing national level resource management tools and advice. It is intended this report could form a basis for discussion on limit setting with people that have other perspectives, such as those working in law, policy, planning and other technical fields

In our previous attempts to communicate some of these ideas to people of various professions and roles in resource management we have learned two important things that should be made clear from the outset. First, ideas for limit setting are evolving across multiple technical fields creating significant integration challenges. Second, and consequently, terminology is critical.

1.1. Setting limits requires multiple disciplines

Setting limits for water management requires multiple disciplines including various science disciplines (e.g., climatology, hydrology, hydrogeology, geomorphology, chemistry, ecology, earth and agricultural sciences, social and cultural sciences, and economics), as well as law, policy and planning expertise at national, regional and local levels. In New Zealand, technical considerations for limit setting are the subject of research and management effort in several science organisations, local government and industry, as well as several current and proposed government funded (FRST) research programmes.

1.2. Terminology is critical

We have used consistent terminology in this report with the hope that our ideas may be more easily integrated with the outcomes of work in other disciplines - see Glossary of terms after the Executive Summary. We have found that these terms can have different meanings for people with different backgrounds (e.g. planning, law, science). Lack of clarity about what is meant by terms can lead to an inability to convey important concepts and ideas. For example the meaning of ‘objective’, ‘limit’ and ‘standard’ differ according to individual’s varied professional backgrounds. Even within the Resource Management Act 1991 (RMA) the word ‘standard’ is used with more than one meaning. Terminology has the potential to become particularly confusing in the resource management field because of the range of disciplines and stakeholders involved. We suspect that there continues to be significant misunderstanding between professional disciplines, resource management stakeholders and the public. We recommend that the Glossary be read first, and then the remainder of the report considered with specific reference to terms in the Glossary. Defined terms are underlined throughout the report.

2. Report overview: measurable objectives and limits

The intention of this section is to give readers a high level introduction to the scope of material that will be covered in the report. This section sets the wider context for the topic of limit setting, confirms the need for limits, and previews the key messages of the report, in order to provide a mind map for the more detailed sections that follow.

2.1. Background

The need for limits in water management has been widely discussed recently. The Government’s recent Cabinet paper proposing a *New Start for Fresh Water* (Offices of the Minister for the Environment and Minister of Agriculture [ME & MA] 2009) stated: “… *New Zealand is approaching some water resource limits, which can be seen in areas with deteriorating water quality, water demand outstripping supply, and constrained economic opportunities.*” In particular the Cabinet paper identified that “*water resource limits*” were needed “*to shape actions on quantity and quality*” and also identified the importance of “*supplementary measures to address the impacts of land use intensification on water quality, and manage urban and rural demand*”.

Many commentators recognise that limits are needed in water resource management (e.g., Organisation for Economic Co-operation and Development (OECD) 1996 and 2007, Office of the Controller and Auditor General (OCAG) 2005, Salmon 2007, Milne 2008, Snelder and Hughey 2005, Norton and Snelder 2003 and 2009, Howard-Williams et al., 2010). Many commentators have also pointed out the deficiencies of existing regional water plans, including lack of specificity, consistency and justifiability of plan provisions and the inability to handle cumulative effects (e.g.., Frieder 1997; MfE 1998; Erickson et al. 2001; Oram 2007; Peart 2007; Crawford 2007). Some commentators have referred specifically to the importance of establishing clear, measurable management objectives in regional plans as a fundamental requirement for the process of setting limits (e.g., OECD 1996; OCAG 2005; Norton and Snelder 2003; 2009).

2.2. The need for measurable objectives

In this report we propose that it is possible to define measurable objectives in a regional plan and that doing so will significantly improve water management. We suggest that objectives must be sufficiently measurable (i.e., quantitative) that they allow limits to be justifiably defined. As such we suggest that measurable objectives are a fundamental pre-requisite in order to fully achieve the purpose of a regional plan, i.e. to assist a regional council to properly carry out its functions under section 30 of the Resource Management Act (RMA).

In order for regional councils to properly carry out their functions for managing water resources (s30(1)(a),(e), (f), (fa) of the RMA) and allocating resources (e.g. s30(4)), particularly when demand for those resources approaches available supply, a regional plan must provide a basis for determining the capacity for use of the resource, i.e. the amount of resource use that can be made *while* sustaining all competing values. We suggest that the capacity for use of the resource depends on value judgements that should establish, in an unambiguous manner, the level at which all competing values will be sustained, i.e., the environmental states or outcomes sought. Because of the need to remove ambiguity we propose that the desired environmental outcomes should be defined by measurable (preferably numeric and SMART[2]) plan objectives. The plan's policies and rules can then justifiably set limits to resource use, such as water quality standards, that are clearly linked to achieving those measurable objectives. Plans that contain measurable objectives *and* linked limits such as water quality standards can achieve a further five important benefits for managing regional water resources:

(i) Increased clarity and therefore certainty for environmental outcomes;

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[2] SMART (Specific, Measurable, Achievable, Relevant, and Time-bound; after MfE 2003a).

(ii) a basis for managing cumulative effects;

(iii) clarity about future resource availability and the conditions likely to be imposed on resource users;

(iv) ability to manage the multiple activities that affect water quality, in addition to managing point-source discharges; and

(v) ability to measure attainment of objectives and thus properly monitor the effectiveness of plan provisions through time.

In order to describe how setting measurable objectives and linked limits can achieve these five benefits it is necessary to clarify some terminology and develop an understanding of the role of science. For this reason we will leave the key benefits as summarised above for now. We will return to this list and describe these benefits in greater detail, and provide examples, in Section 5.

2.3. Defining measurable objectives is challenging but achievable

We acknowledge that defining measurable objectives is challenging for many reasons. The task is complicated by regional variation in water resources and various types of scientific uncertainty. However these problems can be dealt with by structuring plan provisions according to a spatial framework of 'management units', by using the planning tools provided under the RMA (e.g. particularly the RMA's activity category system), and using science knowledge provided by national guidelines and analysis of regionally or locally-specific data. We will describe the role of science in Sections 3 and 4 of this report.

The definition of measurable plan provisions requires that the regional council, through the regional plan, makes value judgements concerning the balance between use of resources and maintenance of environmental values. These value judgements are a major challenge, but if they are not made strategically in a regional plan, it will be necessary to make them on a case-by-case basis for every future consent application, resulting in uncertainty for resource users and for environmental outcomes, and restricted ability to achieve the five benefits listed above. In this report we have provided support for these assertions from the science, planning and resource management literature, from legal commentators, from national policy and guidance documents, from the RMA itself, and using logical argument.

2.4. Measurable objectives allow justifiable limits to be set

Establishing limits recognises that water resources are of finite size - that is water bodies have a capacity for use, beyond which further resource use will not maintain environmental values at an acceptable level and will thus be unsustainable. Because the capacity for use depends on value judgements concerning the environmental state or level of outcomes sought, the capacity for use varies between different water bodies. For example a pristine river or lake that has highly sensitive and significant in-stream values might have zero capacity for use - that is any abstraction or contamination would degrade in-stream values to an extent that is unacceptable to the community despite any social or economic benefits that such uses might bring. In contrast many water bodies have significant capacity for use - that is some amount of abstraction and/or other uses that produce contaminants can be allowed in the catchment while still sustaining in-stream values at a level that is, on weighing the beneficial and adverse effects, acceptable to the community.

The acceptable level for maintaining in-stream values (i.e. measurable objectives) needs to be established by the community through planning processes, in order for science to be used to help establish limits. Science can help to identify values and options for measurable objectives to give the community choices. Science can also help to describe the likely consequences of those choices - in practice there is a need for iteration within planning processes to allow fully informed choices to be made. Once measurable objectives are established, science can be used to set limits for a wide variety of resource uses, such as abstractions, diversions, dams, point and diffuse discharges, and other activities that affect the quantity and quality of water resources as outlined below.

2.4.1. How are limits expressed in water quantity management?

For water quantity, the capacity for use of a water body (i.e. river, lake or aquifer) is usually understood and expressed as a rate at which water can be removed from the water body while sustaining water quantity-related values at some level. The maximum rate is called the allocation rate (i.e., the maximum rate that water can be taken or diverted) and is usually expressed as a flow or an annual volume. It is also generally understood that this rate is not constant in time but is varied in order to protect the values of the water body. For rivers, abstraction or diversion is varied in order to retain a minimum residual flow (the minimum flow). In lakes and aquifers the abstraction or diversion is varied in order to maintain minimum levels. Because river flows and lake and aquifer levels vary naturally in response to climatic variation, the allowable take or diversion varies over time resulting in variation in water availability, which is often referred to as the 'reliability of supply'. The reliability of supply is dependent on the allocation rate, the minimum flow and the natural characteristics of the water body. For a given water body and minimum flow, the reliability of supply decreases as the allocation increases (i.e. as more water is abstracted or diverted). Conversely, there are differences in the reliability of supply among water bodies even if allocation rates and minimum flows and levels are equivalent, due to differences in the natural variation in flows and levels over time (as described in more detail later in Section 3.5). Thus, the combination of allocation rates and minimum flows or levels are the limits that quantify capacity for use of a water quantity resource. These limits may be understood by water users as the allocation and the reliability.

2.4.2. How are limits expressed in water quality management?

In the context of water quality, the capacity for use of a water body is understood as its capacity to dilute and assimilate[3] contaminants while sustaining water quality-related values at some level. This capacity for use is most often expressed as a water quality standard (a concentration in parts per million or similar units) or a contaminant load (e.g., annual load in tonnes/year). However, the limits implied by a water quality standard may be expressed in other ways depending on the type of activity as follows:

i) For a point discharge, the limit may be expressed as a maximum instantaneous effluent discharge rate, effluent contaminant concentration and seasonal or annual volume.

ii) For diffuse (non-point) discharges the limit may be expressed as a maximum total contaminant load (e.g., seasonal or annual load) that can be assimilated in a water body or, potentially even more specifically, the maximum area allowable within a given catchment for a particular land use with known contaminant-generating characteristics.

iii) For a water take or diversion, because of the relationship between water quantity and dilution of contaminants, the limit may be expressed as the allocation rate and the minimum flow or level, which establishes the quantity of water that can be removed from the river (or lake or aquifer) without unacceptably influencing the capacity of the water body to dilute the load of contaminants from its catchment.

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[3] Note that there is sometimes confusion over use of terms ‘assimilate’ and ‘assimilative capacity’. The RMA (s30(1)(fa) refers to the capacity of water to assimilate a discharge of a contaminant. In this sense we consider that the ‘capacity to assimilate’ is virtually synonymous with our use of ‘capacity-for-use’ – its just that the latter term is broader and applicable to both water quantity and quality management – the former term applies primarily to water quality. See terminology in Glossary for further clarification.

iv) For a dam, the limit may be expressed as a maximum dam size and lake level operating regime, in order to maintain the capacity of the water body to assimilate the load of contaminants from its catchment. For example the response of lakes and rivers to nutrient inputs is highly influenced by water residence time in lakes and the frequency of floods down rivers, both of which may be affected by dams.

2.5. Structure of this report

In Section 3 of this report we will discuss how science can be used to help define measurable objectives and set limits. In Section 4 we will describe how such measurable objectives and limits could be implemented within an RMA framework. In Section 5 we will return to the five key benefits for management summarised above and describe these in more detail, using terminology developed in Sections 3 and 4 and providing examples. In Section 6 we will summarise the challenges for setting limits and the solutions currently available. Section 7 contains our conclusions.

For the remainder of this report we will focus primarily on the case of defining measurable objectives and setting limits for managing water quality. We consider limits for water quality are more conceptually complex than for water quantity management because the latter generally involves more direct use of the resource. In general, similar challenges, solutions and benefits exist for water quantity management. From time to time in the report we refer to examples and key points of difference for water quantity management.

3. How science can be used to help set measurable objectives and limits

3.1. Introduction

We have often observed confusion about the role of science in resource management processes, primarily caused by lack of clear separation between the value judgement making process and the science-based process of describing the effects of resource use on the environment. The former process is the socio-political role of decision-makers making normative decisions (e.g., those with functions and delegated authority under the RMA and Local Government Act, i.e., central and local government, appointed commissioners and Environment Court). The latter process is a role for scientists. We have observed that lack of clarity about the role of science has caused multiple problems including misunderstandings and frustration for scientists, decision-makers, policy makers, managers and stakeholders, as well as increased tension during hearing processes.

In this section of the report we describe an approach to setting limits to water resource use that better utilises existing science knowledge by clarifying the discrete roles of information provider and decision-maker. The approach quantifies capacity for use of water bodies and therefore provides a basis for limiting resource use so that it is sustainable. The approach addresses other challenges that face managers, including the issue of spatial environmental variability and many types of uncertainty. The approach that we outline here is potentially able to provide the five desirable features of water resource management listed in Section 2.2. The approach has been developed in conjunction with our work for a number of regional councils including Otago Regional Council, Horizons, Environment Southland and Environment Canterbury.

We envisage that effective limit setting needs to incorporate five broad components as follows:

i) Use science to inform the value judgement-making process (but not make the value judgements)

ii) Use science to define objectives and standards

iii) Implement limits strategically

iv) Account for spatial variability of water bodies in setting objectives

Manage uncertainty.

None of these components has primacy and we do not imply any order of importance in listing them. They are interrelated and all are necessary as part of a ‘package’ for using science to help set limits. We have chosen a particular order to explain these five components (in Sections 3.2 to 3.6), but we have found that people from different disciplines with their different perspectives find it hard to appreciate the significance of each component until the whole package is explained. The reader will find similar themes being repeated in the following sections, and in some cases the same examples will be used to demonstrate subtly different benefits of the approach. We will now describe each of the five components in some detail.

3.2. Use science to inform the judgement-making process

Recognising that value judgements are required to define acceptable environmental states or outcomes is critical for making the most effective use of science for setting limits. An inter-departmental paper led by the Ministry for the Environment (MfE 2008) noted that “*New Zealand has struggled with difficult decisions requiring value* *judgements or potential trade-offs partly because we lack high-level national outcomes, strategies, bottom lines, standards or planning frameworks to inform those decisions*” and “*These factors also make it hard to manage cumulative effects on the environment.*” The paper concluded that: “*Decisions will be much better informed, and the inevitable value judgements will be much more transparent, when we have a process for setting clear outcomes, targets and standards*” (MfE 2008). We suggest that a cornerstone of such a process is recognising that biophysical science can assist the value judgement-making process by clearly articulating a spectrum of options for environmental states. Social scientists, economists and others can similarly articulate the social and economic consequences of (preferably) the same options so that informed choices can be made.

As a general principle, the use of a water body as a resource by people tends to degrade its environmental state and thus its ability to support in-stream values. We acknowledge that mitigation measures can reduce environmental effects. However at some level of resource use, mitigation will be unable to prevent unacceptable environmental effects. Therefore the nomination of an acceptable environmental state either implicitly or explicitly involves a value judgement that strikes a balance or trade off, between in-stream values and the capacity for use of a water body by people.

We have found it useful to portray the value judgement as a relationship between environmental state and resource use on an x/y plot (Figure 1). Scientists are able to objectively describe the consequences of various levels of resource use on a range of variables that describe environmental state. In the simple example shown in Figure 1, the environmental state (y-axis) decreases (degrades) as the amount of resource use (x-axis) increases.

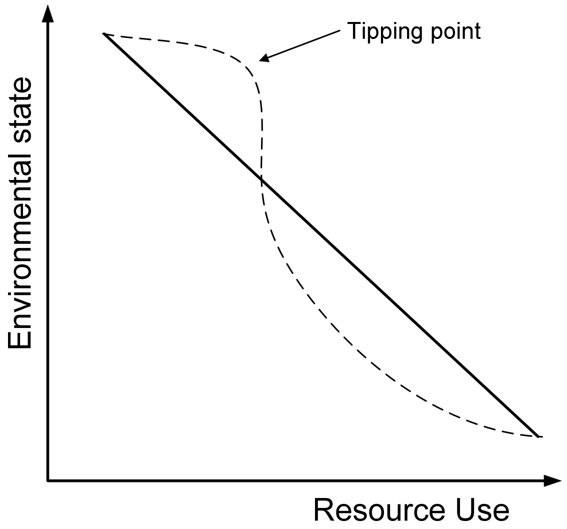

Figure 1: **Schematic representation of relationships between environmental state and resource use.**

Figure 1 clearly shows that the fundamental resource management decision involves a trade-off between environmental state (y-axis) and resource use (x-axis). We deliberately draw this simple example relationship as a smooth straight line (see solid line in Figure 1) to emphasise that the options are a continuum of possibilities. In reality there are many relationships for many different environmental state variables and resource use variables. These relationships are seldom linear and may be represented by many different types of curves (for example see dotted line in Figure 1). These relationships can sometimes have inflexions or 'tipping points' that may define expedient decision points, for example where a small increase in resource use suddenly results in rapid deterioration in environmental state (see Figure 1). However, often science does not show such obvious decision points and it is necessary to choose a point on the continuum in order to define the acceptable balance between environmental state and the capacity for use. This choice is a value judgement and it cannot be made objectively by science. In the next section we discuss how the trade-off can be expressed quantitatively so that choices can be presented to stakeholders and decision-makers as a range of options.

3.3. Use science to define objectives and standards

From a science perspective, in order to be clear and measurable, the desired environmental state should ideally be expressed by measurable (and preferably numeric) objectives that specify what we want to maintain or achieve. Ideally measurable objectives should quantify environmental states that are directly related to the suitability of the environment to support values. They should also be understood by non-specialist stakeholders in the resource management process i.e., the 'average New Zealander'. For example, visual clarity, periphyton (slime) cover and habitat (i.e. water depth and velocity) are examples of environmental state variables that the public can generally understand. These variables can be used to express the suitability of the environment for a range of values such as recreation, fisheries, aesthetic, natural character and cultural values. For example clarity of 1.6 meters, periphyton cover not greater than 30%, habitat equal to that available at 2/3rd mean annual low flow, all express the "level" at which values are intended to be supported.

The idea of numeric objectives is not new - for example a numeric objective for water clarity for Lake Taupo has been specified in Environment Waikato's Waikato Region Plan Variation 5 - Lake Taupo Catchment (known colloquially as "RPV5"). Selection of this particular numeric objective (i.e., 14.6 metres water clarity[4]) was a socio-political judgement that was made by choosing from a range of scientifically defined options. Other options included the possibility of selecting a more aspirational

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[4] This was determined as the existing lake water clarity as at 2001 - see http://www.ew.govt.nz/Policy-and-plans/Protecting-Lake-Taupo/.

numeric objective (i.e., water clarity greater than 14.6 metres) with consequential severe restrictions on land use, or to accept lesser water clarity with less restrictive implications for managing land use. Defining a numeric objective for clarity in RPV5 allowed justifiable limits (e.g., nutrient concentration and load limits) to be set (i.e., proposed in the planning process) for managing land use and other contaminant sources in the catchment. We will expand more on this example later.

When the desired environmental states are expressed as numeric objectives, scientific tools (e.g., guidelines and models) can often provide criteria (see Glossary) that can be used to justifiably set limits to resource use (e.g., water quality standards and minimum flows). In other words criteria, when adopted (i.e., ratified by the planning process), can become water quality standards and/or minimum flows set in a regional plan. The most useful criteria are variables that:

i) are technical indicators of resource use (i.e., they increase proportionally as resource use increases);

ii) have direct causative relationships with an environmental state variable; and

iii) can be managed (i.e., will respond to management interventions such as restrictions and mitigation measures).

Examples of relevant criteria and their related environmental state variables include: suspended solids concentration and turbidity which affect clarity; nutrient concentration which affects periphyton (slime) cover in the beds of rivers or trophic status in lakes; and flow which affects the area of available habitat for aquatic species. The relationship between measurable objectives (i.e., preferably numeric objectives) and criteria can be portrayed on the same type of x/y plot (Figure 1) already discussed. A measurable objective is simply a desired environmental state selected from the y-axis, while the related criteria that could be used as a water quality standard can be read from the x-axis (Figure 2). Figure 2 can also be thought of as a “cause and effect” or “dose and response” relationship.

An example of a relationship between a measurable objective and criteria is the relationship between the amount of algae and the nutrients nitrogen and phosphorus in lakes and rivers. As nutrient concentrations increase in lakes and rivers, algal biomass generally increases and may follow a curve such as shown schematically in Figure 3. In stony bottomed rivers algae appears as periphyton (slime) growing on the bed. In lakes algal biomass can appear as filaments adhering to plants and other surfaces or as phytoplankton (suspended algae). The environmental state defined by algae biomass has direct effects on environmental values such as aesthetics, recreation and aquatic ecology (e.g., invertebrate and fish communities). The New Zealand Periphyton Guidelines (MfE 2000) quantify the relationship between periphyton biomass and nutrient concentration using an empirical model. Similarly the relationship between nutrients and phytoplankton can be established for lakes (e.g., Burns and Bryers 2000). Figure 3 shows this relationship conceptually as an x/y plot that expresses the same idea as Figures 1 and 2. In Figure 3 the relationship increases in the opposite sense to Figures 1 and 2 because increasing algal biomass represents a *reduction* in environmental state. However the principle is the same; the relationship provides options for choosing a numeric objective (options A and B in Figure 3) and provides nutrient concentration criteria that could be used as water quality standards to achieve the chosen objective.

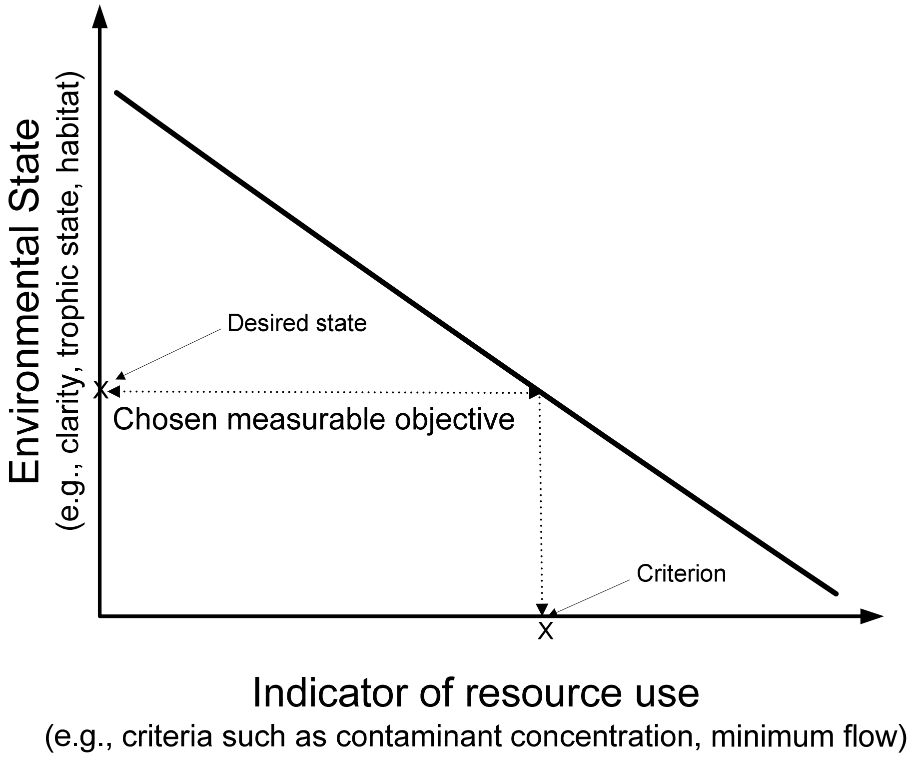

Figure 2: **Schematic representation of the relationship between a numeric objective (i.e., a chosen environmental state) and a criterion (i.e., an indicator of resource use).**

Freshwater science has described many relationships between environmental state variables and criteria. These relationships underlie many of the water quality guidelines that are in use including various national water quality guidelines published by MfE (e.g., MfE 1992, 1994, 1998, 2000, 2003b and others (e.g., Davies-Colley 2000, Hickey and Martin 1999) (Table 1). Guidelines generally provide options for environmental states and define the water quality guideline criteria that would achieve these. For example, the New Zealand Periphyton Guidelines offer options for a high level of environmental state (Option A in Figure 3) with an associated low quantity of streambed algae, and a medium level of environmental state (Option B in Figure 3) with a correspondingly greater quantity of streambed algae. The guidelines provide nutrient concentration criteria that are relevant to achieving these two environmental states (Figure 3). Guidelines also often provide methods so that users can generate customised relationships (i.e., more specifically defined) at smaller scales (e.g. regional and catchment) using locally derived information.

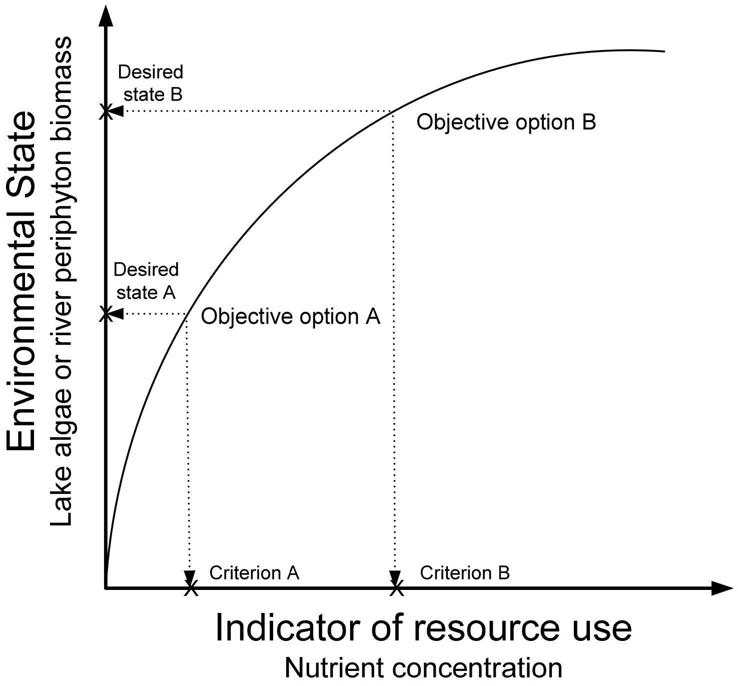

Figure 3: Schematic representation of the relationship between nutrient concentrations and lake algal biomass or periphyton (slime) growing on the bed of stony bottomed rivers.

Table 1: Examples of relationships between environmental objectives and criteria that are the basis of many national guidelines.

Environmental state (X-axis)	Criteria (Y-axis)	Guideline reference
Human response	Toxin concentration	MoH 2000
Aquatic organism response	Toxin concentration	ANZECC 2000
Periphyton biomass	Nutrient concentration	MfE 2000
Lake Trophic Level Index[5]	Nutrient concentration	Burns & Bryers 2000
Recreation grade	Microbial concentration	MoH & MfE 2003b

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[5] Trophic Level Index (TLI) is a function of nitrogen and phosphorus concentrations, Secchi depth [clarity] and chlorophyll *a* concentration (Burns and Bryers 2000).

Guidelines carry no statutory meaning under the RMA. Guideline criteria are usually only given statutory meaning when they are used to set conditions on resource consents or to define regional plan provisions, such as water quality standards. Sometimes when criteria from guidelines are used to set a consent condition or a regional plan water quality standard, the fact that they were derived from relationships and that a choice was made about the desired environmental state (e.g., as shown in Figure 3) is often obscured. In setting a water quality standard, the acceptable environmental state has to be nominated and this is the value judgement. When a water quality standard is defined in a regional plan without also defining the related numeric objective, this means the value judgement has been made implicitly rather than explicitly. Another example is the use of toxicity guideline criteria, which are generally based on experimentally derived relationships between the concentrations of toxic substances and the response of test organisms, often quantified as the proportion of the sample showing lethal or detectable effects. Toxicity criteria (e.g., concentration of a toxin, such as nitrate) are often selected for use as water quality standards in a plan or conditions on a consent, based on some pre-ordained or "accepted effects" level (e.g., 80% or 95% species protection). When a toxin water quality standard is expressed on its own without its related accepted effects level (i.e., a numeric objective), the value judgement is implicit rather than explicit. This can result in the water quality standard being misunderstood as a wholly scientifically determined quantity when in fact it is based on a value-judgement.

In our opinion, the best way for decision makers to conceptualise the limit setting process is to use the relationships between environmental states and criteria in order to respectively identify numeric objectives and related limits such as water quality standards. This approach makes the value judgements clear and clarifies that the objectives and limits set are ultimately a societal decision that reflects a trade off between the economic value of resource use and sustaining a range of other environmental, social and cultural values.

The complexity of the decision making process may require an iterative process before a decision can be made. This is especially the case when the environmental state or resource use options need to be further translated into consequences for other values, such as economic and social costs and benefits. Scientists (including physical and social scientists and economists) and other technical experts can assist stakeholders and decision makers to explore the social and economic consequences of choosing amongst different options for the environmental state by converting the technical indicators of resource use on the x-axis (e.g., nutrient concentration) into economic costs and benefits (Figure 4). For example, economists can assess the cost to agriculture of having to achieve a particular concentration or load of nitrogen into waterways. These costs can be linked back to the options for different levels of environmental state. In this way options can be weighed and choices transparently made. Consequences other than monetary cost can be quantified and presented in a similar way.

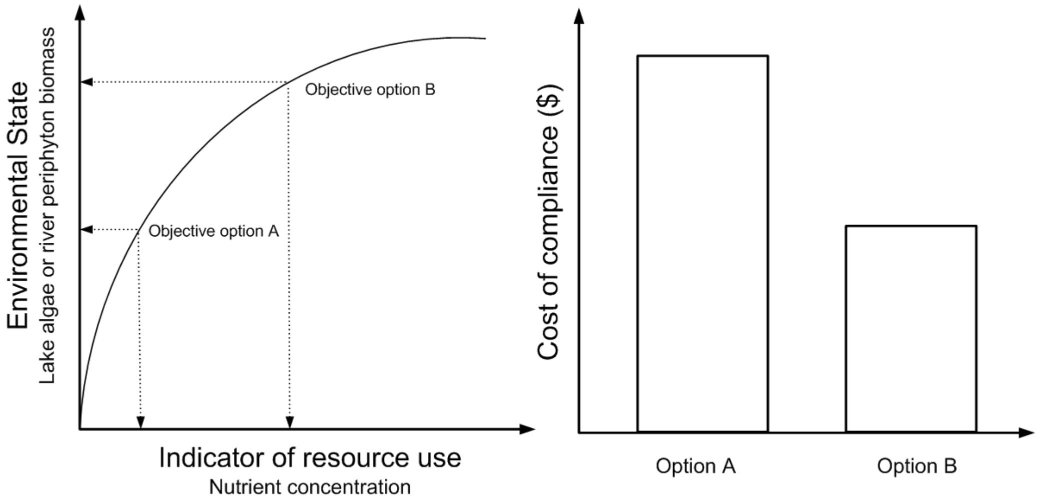

Figure 4: **Schematic showing options for numeric objectives and water quality standards, and the economic consequences of each option. The left-hand plot shows the relationship between options (i.e., A and B) for numeric objectives (algal biomass) and water quality standards (nutrient concentrations). The right-hand plot shows the cost to agriculture of having to comply with water quality standards A and B.**

3.4. Implement limits strategically

Measurable objectives and related limits such as water quality standards could be set at any level of the resource management framework hierarchy established under the RMA; i.e., at the national level (in national policy statements and/or national environmental standards), at the regional level (regional policy statements and regional plans), or at the local operational level (individual resource consents with attached conditions). If measurable objectives and related limits are not set in regional plans or higher policy levels, it is left to decision-makers on individual consents to set limits in resource consent conditions on a case-by-case basis. The problem with setting limits on a case-by-case basis is it creates uncertainty for environmental outcomes and for resource users, inefficiency and inconsistency in handling individual consent cases, and an inability to take into account cumulative effects. To address these problems we suggest it is necessary to set measurable objectives and related limits *strategically* at the level of *at least* regional water plans (including catchment plans and region-wide plans). We will elaborate further on this in Section 4 and describe how science could help define measurable objectives and related limits within the regional plan framework provided under the RMA. However before we do that it is necessary to consider two further challenges; managing spatial variability and managing uncertainty.

3.5. Manage spatial variability

There is considerable environmental variability in rivers and lakes in New Zealand and within most regions. Variability exists due to natural physical differences between rivers, differences in attributes valued by people, and differences in the current extent of human-induced change. Environmental variation across water bodies results in differing contexts for considering resource use. Environmental variation means water bodies; 1) support different values or the same values to differing levels, and 2) have differing sensitivities to resource use. An example illustrating the first point is that not all rivers are valued as trout fisheries or are valued to differing levels. This means that it may be appropriate that measurable objectives differ between water bodies. For example, numeric objectives for clarity would differ between lowland and high-country lakes and rivers. The second point can be explained as differences in the x/y relationships discussed earlier (Figures 2 and 3). For example, the relationship between nutrients and periphyton on a river bed varies as a function of a number of environmental factors. An important factor is the frequency of flood events of sufficient magnitude to detach and flush the periphyton. Even if they have the same nutrient concentrations, rivers that flood frequently may not reach the same periphyton biomass as rivers that flood less frequently, because the period for biomass to grow and accumulate is shorter. Thus, x/y relationships differ for rivers with different flood frequencies (Figure 5). This means that the criterion (e.g., nutrient concentration in Figure 5) differs between river types even when the numeric objective (e.g., periphyton biomass) is the same.

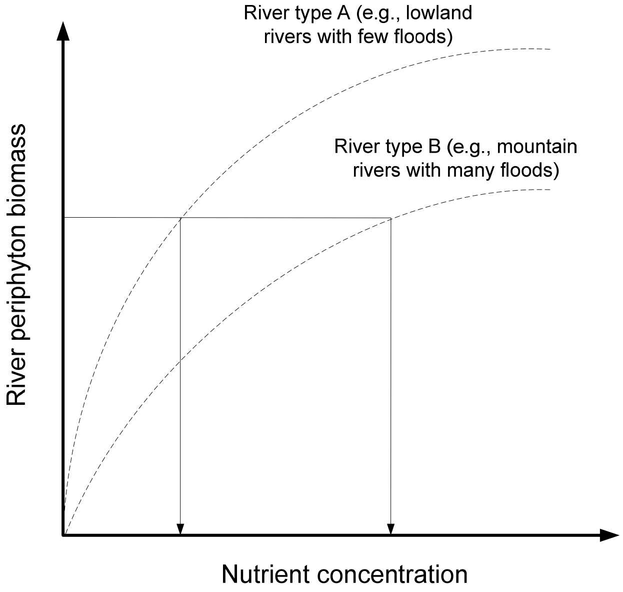

Figure 5: **Schematic representation of the relationship between nutrient concentrations and periphyton (slime) growing on the bed of two types of stony bottomed rivers. These types differ with respect to environmental factors such as the frequency of floods.**

The RMA allows for variability at the national scale by giving mostly narrative directions for water quality management, such as the water quality effects to be avoided (s107 and s70 RMA). In these sections, and also in Schedule 3 water quality classes, the RMA uses words such as "*conspicuous*", "*objectionable*", "*unsuitable*" and "*significant*" to allow flexibility for interpretation across the many different contexts nationally to which these sections are applied. Regional plans provide an opportunity to zoom in to the regional scale and thus reduce the scope of environmental variability to more manageable levels. Even so, variability within most regions is still considerable. We consider that this variability may have contributed to most so-called *first generation* regional plans being written with generic, usually entirely narrative objectives. This restricts the certainty, efficiency and consistency of those regional plans because unless objectives are defined in measurable terms they will be open to interpretation. In effect this means that *first generation* regional plans with narrative objectives have not clearly defined the capacity for use of water bodies.

One way of reducing environmental variability and establishing limits is to work at the level of the individual catchment. It is easier to define measurable objectives and associated policies, rules and water quality standards for catchment plans than region-wide plans. Perhaps the best known example nationally is for Lake Taupo, where numeric objectives were defined for visual water clarity and algae growth (i.e. a Trophic Level Index). The nutrient load limits (e.g. for nitrogen) necessary to achieve those objectives were determined specifically for the Taupo catchment using scientifically defined relationships. Environment Waikato incorporated the objectives and nitrogen limits into its RPV5. However, a draw-back with a catchment-based approach is that it requires a large effort in terms of science and planning resources. This is appropriate in catchments of high resource value, but such effort cannot be applied to all the catchments of a region, especially where a large number of catchments may be coming under pressure. While a long-term goal of catchment-specific planning and management may be appropriate, the immediate need is for a method of setting strategic limits that apply to all water bodies of entire regions with an appropriate and achievable level of effort.

A critical component of our approach to setting limits is the notion of subdividing regional water bodies into groups called "management units" that stratify the variation that exists among water bodies. These management units provide focussed contexts within which values can be identified and the relationships between environmental state and criteria are then developed. Management units allow the value judgements that are required to set measurable objectives and related limits (e.g., water quality standards) to vary. To be helpful, management units must be clearly defined and need to be able to be mapped so as to provide plan users with a high degree of certainty as to what management unit any particular water body has been assigned to. We refer to such mapped definition of management units as a spatial framework. A spatial framework provides a basis for defining relatively homogeneous groups of water bodies (i.e., groups that are similar from a management perspective) for which relationships between environmental state and criteria (i.e. x/y relationships; e.g., Figure 5) can be applied.

A simple example of a spatial framework is the distinction that can be drawn between streams draining lowlands, hill-country and mountainous areas in New Zealand. Typically streams draining lowland areas are narrow, deep, meandering with muddy bottoms. In contrast, streams draining hill-country tend to be wide, shallow and straight with stony bottoms. Rivers whose catchments are dominated by mountains are often very wide with braided channels. These three types of rivers exhibit strong differences in hydrological regimes. Mountain rivers have their highest flows in mid summer when snow and ice is melted and their lowest flows in winter when water tends to be locked up as ice. Lowland rivers have flow regimes with the opposite seasonality and hill rivers are often somewhere between because of a degree of spring snow melt and strong orographic effects means they can have high flows in any season. The combination of these morphological and hydrological factors as well as others, such as water chemistry, means this simple classification defines groups of rivers with fundamentally different values. The differences in environmental factors also produce differences in their sensitivities to resource use and therefore the relationship between environmental state and criteria. For example, the response of these three types of rivers to increased nutrients can be expected to be different. Even given the same degree of resource use, the environmental state that is achievable in rivers belonging to these groups will be different (see Figure 5).

Environmental classifications, such as the River Environment Classification (REC; Snelder and Biggs 2002) have been developed by MfE specifically for this purpose (www.mfe.govt.nz). The REC has assigned all rivers in New Zealand into classes according to environmental characteristics. The classification is hierarchical allowing rivers to be subdivided into a small number of groups containing broadly similar rivers and finer levels comprising a lower number of more similar rivers. The second level for the REC classification subdivides rivers into classes based on catchment topography and defines the lowland, hill-country and mountain rivers described above. We consider that environmental characteristics are fundamental to defining management units because physical factors are strongly associated with the values and sensitivity of water bodies, and therefore to the capacity for use of water bodies. However, we also acknowledge that cultural, social and economic factors are important and define another set of factors that may need to be included in defining management units. An example illustrating this point is that two environmentally similar rivers may be valued differently if one is close to a city and the other is remote. This could result in the adoption of different objectives for the two rivers and, ultimately, different limits.

We emphasise that our definition of a spatial framework should not be confused with the catchment as a spatial unit. Using (say) REC classes as the spatial framework (rather than individual catchments) would result in management units being widely dispersed across many individual catchments within a region. In addition, a catchment may contain sections of rivers that belong to a number of REC-defined management units. We consider that a classification such as the REC is a helpful tool for setting limits both within individual catchments and across many catchments. This can be understood by considering the simple example of the second level of the REC described above comprising lowlands, hill-country and mountain rivers. Many catchments in New Zealand (as defined from their mouth at the coast) will generally contain a main stem whose source is likely to be mountain or hill-country and many tributaries whose sources may be hill or lowland areas. As we describe above, from the point of view of values, setting measurable objectives and defining limits these three different management units are fundamentally different. However, while the REC-type classification may often be a logical framework for helping to define limits, we acknowledge the importance of catchments as a basis for management implementation of limits. An example of this is that if a main stem river has strict water quality standards applied, it will often be important to consider the appropriate water quality standards to be applied to its tributary streams, to ensure that this limit is achieved. Similarly it is necessary to consider appropriate limits in both tributary streams and main stem rivers in order to achieve objectives and limits in estuaries, harbours and other coastal waters. In these instances the detail of water quality standard setting requires that consideration is given to the whole catchment.

We suggest that unless the environmental context is more specifically defined and accounted for in regional plans in the manner described here, it is very difficult to formulate measurable objectives and justifiable limits. Furthermore, we suggest that the concept of subdividing regions into management units and developing plan provisions for each of these separately is so fundamental that it could result in structural differences in regional plans. Rather than organising plans around types of activities, as is the case for many first generation plans, we suggest that plans could be organised based on waterbody types (management units). For example ECan’s NRRP Chapter 4 Water Quality and Horizons’ One Plan are organised around spatial management units.

3.6. Manage uncertainty

Dealing with multiple types of uncertainty is a widely recognised challenge in resource management (e.g., MfE 2008; FRST 2007; PCE 2003). Rouse and Norton (2010) examined how scientific uncertainty has been dealt with in case studies of processes under the RMA at national, regional and local levels, and identified the general need to:

i) Identify sources of uncertainty

ii) Employ methods to reduce uncertainty where possible, and

iii) Acknowledge unavoidable uncertainty and manage this effectively.

The first two of these steps are generally well recognised and undertaken by scientists in all technical disciplines using a range of discipline-specific methods (e.g., Maier and Ascough 2006; Costanza and Cornwall 1992). Methods to reduce uncertainty include basic methods like obtaining sufficient field or experimental data to produce statistically significant results, as well as more sophisticated methods like statistical techniques to quantify error, and classification systems to reduce the amount of environmental variation within management units (see previous Section 3.5). The first two steps are usually carried out by scientists as comprehensively as time and funding allow. Generally though, it is inevitable that there will always be some unavoidable uncertainty that needs to be managed for policy development and decision making (Rouse and Norton 2010).

With respect to using science to define the capacity for use of water resources and set limits, the key area of scientific uncertainty is around definition of the relationships between resource use criteria and environmental states; i.e., the many x/y plots discussed in Section 3.2 and 3.3 that can be produced by science and that often appear in national guidelines. One obvious way of reducing this uncertainty is to apply more science funding to strengthen confidence in the relationships. This would probably be justified where the level of uncertainty prevents decisions being made and where it is likely that further research would help. This might be particularly fruitful for some of the less well defined but important relationships (for example the effects of sediment on aquatic ecosystems - there is currently no national guideline on this topic), and relationships where unforeseen new events may affect previously described relationships (for example the arrival of the invasive alga ‘didymo’ (*Didymosphenia geminata*) has implications for the MfE (2000) New Zealand Periphyton Guidelines).

We suggest that identifying areas where further basic science funding is justified for limit-setting purposes is very important and is a task that goes beyond the scope of the present report. We note that this need seems to be at least partly in hand as a result of input by end-users (e.g., regional councils, MfE, DoC and others) to the central government funded research bidding process, as well as MfE’s current project reviewing the ANZECC (2000) guidelines. However it might be useful for MfE to review the link between these two processes, specifically in terms of identifying research priorities to inform limit-setting in water management. The remainder of this section of the report will focus on managing uncertainty that remains despite science research effort up to any particular point in time, and specifically the present time.

Despite the best efforts of scientists to define relationships between common resource uses and environmental states, it is inevitable some uncertainty will always remain due to the complexity of these relationships. Reviews of international and national literature (e.g., Rouse and Norton 2010; PCE 2003) suggest at least five generic approaches are available for managing this residual, unavoidable uncertainty for policy development and decision making. These are: i) acknowledge the extent of knowledge and ignorance, ii) risk management approaches, iii) adaptive management approaches, iv) precautionary approaches, and v) monitor, evaluate and review systems. We suggest that each of these approaches can be used to help the process of setting limits for water management. In the following subsections we briefly describe ways this could be done. Further information on the five general approaches can be found in Rouse and Norton (2010) and PCE (2003).

3.6.1. Acknowledge the extent of knowledge and ignorance

Acknowledging uncertainties in scientific information is central to good decision making (PCE 2003; POST 2004). This means acknowledging that science defined relationships (e.g., the x/y plots described in Section 3.3) are not perfectly defined, but are best approximations that have bands of uncertainty (i.e., measures of error) around the numbers used for numeric objectives and water quality standards. Where possible the size of this uncertainty (i.e., error bands) should be quantified so that a judgement can be made about whether a particular relationship is well enough defined for use in setting a numeric objective and water quality standard in a policy or planning document.

One example from our work with ECan is that only some science-defined relationships were considered strong enough to justify inclusion of numeric objectives in the proposed (NRRP) regional plan. For example, after reviewing the available information, Hayward et al., (2009) proposed numeric objectives for: an invertebrate community health indicator = QMCI; a macrophyte indicator = % cover; a periphyton indicator = % cover; a sedimentation indicator = % cover; a visual quality indicator = clarity in metres; and suitability for recreation = SFRG Grade. Where science-defined relationships between environmental state and resource use were less well defined, ECan planning staff recommended more flexible narrative objectives to express desired outcomes, despite the disadvantages of this already discussed. This proposal was made by planning staff informed by science, using a risk-based approach where it was judged that the risk of using the wrong number was worse than using no number at all, while recognising that further work was needed. For example, it was decided to use only narrative objectives (but as tight narrative as possible) for: fish community health; toxic algae; and visual colour (e.g., Hayward et al., 2009). Ultimately it will be up to hearing commissioners to decide whether this proposed approach will be adopted in the NRRP. It is possible (and desirable) that science-defined relationships may improve sufficiently to justify inclusion of numeric objectives for these latter aspects in future.

3.6.2. Risk management approaches

Risk is the product of the ‘likelihood’ of occurrence of an event and the ‘consequence’ of that event. Environmental risk is obviously highest when both the likelihood and consequence of an activity on the environment are great. One way of managing risk is to give greater attention to situations that represent high environmental risk and less attention to situations that represent low environmental risk. To do this, it is necessary to identify which situations are higher risk and which are lower risk. There are similarities between the way science-based water quality guidelines and regional plans can be used to do this. We suggest that water quality guidelines could be used more effectively for setting numeric objectives and water quality standards if these similarities were better recognised. We elaborate on this below.

Water quality guidelines are currently the best approximation of a broadly applicable relationship between environmental state and resource use (see Section 3.3). In reality the exact nature of the relationship is dependent on many variables. Most water quality guideline documents acknowledge this uncertainty and define conservative (for the environment) criteria (i.e., there is high certainty that a given environmental state will be achieved if a criterion is met). Guidelines generally recommend that when a criterion is breached this should *trigger* closer inspection to determine the actual effects and whether further breaching of the criterion can be tolerated. Indeed the term “trigger level” is given to some criteria in some guideline documents (e.g., ANZECC 2000).

We have frequently encountered the argument that water quality guideline trigger criteria should not be used as water quality standards in regional plans because their applicability for all situations is uncertain – that is, the criteria may be too conservative (for the environment) and thus unnecessarily restrict resource use in some situations. Some commentators have stated that trigger criteria from guidelines should not become absolute or immovable “bottom line” standards (e.g., Fitzpatrick 2006). Our view is that the hierarchical system of activity categories provided for use in rules in regional plans (s68, 77B and s104A-D RMA) can be used to stratify uncertainty for management in a similar manner to the trigger system used in water quality guidelines. In other words a tiered approach to the treatment of activity categories (i.e. permitted, controlled, discretionary, non-complying and prohibited activities) can be used to reserve differing levels of discretion for each category based on the potential risk of adverse effects. In a sense, these two systems are complementary and provide an important, but little recognised link between approaches used by science and planning. We work through an example of how this system could work in a regional plan below.

A tiered approach to the treatment of activity categories means that water quality standards can be used in plan rules as a test for determining what category a particular activity will be assigned and therefore how it will be treated in the plan and decision-making process. Environmentally conservative water quality standards (e.g., those derived from trigger levels in guidelines) can be used as a threshold test for permitted and controlled activities, thus allowing activities that represent very low risk to the environment to be dealt with quickly, efficiently, and with a high degree of certainty for resource users (i.e., permitted activities do not require resource consent and controlled activities can usually be processed very efficiently). Somewhat less conservative water quality standards can be used as a threshold test for discretionary activities, thus providing a clear environmental expectation for consent applicants, but reserving discretion about whether consent will be granted so that case-specific factors can be given closer attention during a consent consideration process. An activity that does not meet the water quality standards set for a discretionary activity is considered a non-complying activity, thus providing a cautionary message to resource users (e.g., consent applicants) that careful consideration will be required, but the activity may still be granted consent after yet closer attention under the tests of s104D RMA. This is broadly the approach that has been used in ECan's NRRP.

Using the system described here, water quality standards in regional plan rules are not immovable bottom lines, but are used to stratify uncertainty, directing more attention to activities with high environmental risk and less attention when risk is low. Under such a system, one of the "bottom line" tests for non-complying activities (under s104D) is the plan objectives and policies. Therefore it is particularly important that plan objectives and policies provide clear direction to decision-makers for the s104D test. If the plan objectives and policies are vague, multiple non-complying activities may be granted that give rise to unacceptable cumulative effects. We consider this is one important reason for, and key benefit of, setting measurable objectives in a regional plan. In our view, it is appropriate that measurable objectives rather than water quality standards function as the "bottom line" test. This is because measurable objectives describe the actual desired environmental outcome in terms that most people can understand and readily debate. Once the debate has occurred and the necessary value judgements have been made in setting the objective (see Section 3.2), there is little scientific uncertainty associated with the measurable objectives. Most of the scientific uncertainty is associated with the relationship between the effects of resource uses and measurable objectives (i.e. the uncertainty is associated with how the objectives will be achieved). Scientific input is therefore able to be more focussed because the role of the science is clarified.

3.6.3. Adaptive management approaches

Adaptive management (e.g., Holling 1978) has been loosely defined as ‘management with a plan for learning’ (Wintle 2007). The adaptive management process allows for new information gathered after a decision-making point to be used in a feedback loop, so that new or improving knowledge (i.e., learning) can be incorporated in policy and decision making processes (Rouse and Norton 2010). With respect to using science to define the capacity for use of water resources and set limits, the key area of ongoing learning involves the definition of the relationships between resource uses and environmental states. There is no doubt that science knowledge will continue to increase. There will be improved descriptors of environmental states (e.g., metrics and indices) that will be useful for better articulating numeric objectives in the future. Relationships between resource uses, water quality standards and numeric objectives will be defined with greater certainty. It will be important that a process exists to enable updated science knowledge to be incorporated into the limit-setting parts of the water management framework. Such a process exists already with the periodic plan review process under the RMA (Rouse and Norton 2010).

Adaptive management usually involves proposing a model or hypothesis about how a system will respond to a management action (or a resource use). The model and the predicted outcome serve as a basis for structuring monitoring and remedial actions should the trajectory of the system (as detected from monitoring data) indicate that the desired outcome (i.e., the objective) will not be met. From this it is clear that adapative management pre-supposes that the objective of management is known, but that it is the details of how that should be *achieved* that is in doubt. Given this we suggest that the approach can only be effective when the objectives are expressed in measurable terms. We consider this is an important reason for, and key benefit of, setting measurable objectives in a regional plan.

We have encountered an alternate, more literal interpretation of adaptive management; one that suggests limits need not be set pre-emptively, but rather resource allocation could continue as long as environmental monitoring is in place to detect effects and signal when it is time to stop allocating. This is sometimes referred to as the “suck and see” approach. Our view is that this approach is unlikely to be successful for many reasons, in particular because many effects of water resource use on the environment take years or even decades to manifest (and therefore be detected by monitoring) and may be very costly or impossible to reverse. This approach is also likely to cause problems for resource users because, as the amount of resource use approaches limits of supply (albeit undefined), this can reduce water quality and the reliability of supply (i.e., water quantity) for existing users. By the time monitoring suggests it is necessary to stop allocating, the resource is likely to be already over-allocated, raising equity issues for existing users.

3.6.4. Precautionary approaches

When a potential adverse environmental effect (or potential risk) has been identified, but there is uncertainty about the extent of effect or risk, it may be appropriate to apply the precautionary principle in decision making (e.g., Myhr & Traavik 2002, EC 2000). A working definition of the precautionary principle is contained in the UN Rio Declaration arising from the 1992 United Nations Conference on Environment and Development, as follows:

> *In order to protect the environment, the precautionary approach shall be widely applied by the States according to their capabilities. Where there are threats of serious or irreversible damage, lack of full scientific certainty shall not be used as a reason for postponing cost-effective measures to prevent environmental degradation.*

Application of the precautionary principle can be complex due to differing interpretation of the words used to formulate it (Weiss 2003). One difficulty associated with the precautionary principle is that it does not specify the standard of proof (such as reasonable doubt) required before precautionary approaches should be adopted (Weiss 2003). There are also concerns that the precautionary principle may be inappropriately advocated by submitters opposing development in environmental cases to encourage inaction by decision makers (Weiss 2003), and that it may be a barrier to scientific progress (POST 2004). This has led some to argue that the precautionary principle needs to be balanced by a so called Principle of Reasonableness that would aim to ensure that "*new research and development work that promises major benefits would not be blocked until the detailed implications of this technology are well understood.*" (Weiss 2003, p158). An approach that has been suggested is that the precautionary principle should provide a fall-back position when scientific uncertainties are such that risks cannot be sufficiently assessed (POST 2004).

Rouse and Norton (2010) reviewed use of the precautionary principle in resource management case studies in New Zealand. They identified that there is no government-wide guidance on application of the precautionary principle in New Zealand. The New Zealand Treasury published a policy perspectives paper (Cameron 2006) discussing the need for a generic risk management framework in New Zealand, which would give a context for use of the precautionary principle in managing risk and uncertainty, in a similar manner to guidance used by the European Commission (EC 2000). The Treasury document concluded that New Zealand lacks guidelines for implementing the precautionary principle and risk management, and that such guidelines would ensure a more consistent approach to managing risk and uncertainty.

With respect to using science for setting limits in water management, we suggest that deciding on the appropriate extent of precautionary approach is an important part of the normative decision-making process necessary for defining numeric objectives (see Section 3.2). This is part of the planning process under the RMA. Scientists can help quantify the risk of various options for environmental state and thus numeric objectives and limits (i.e., the likelihood and consequence of environmental effects), thus informing decision-making, but it is not the role of science to decide what level of precaution is appropriate.

3.6.5. Monitor, evaluate and review systems

Any plan or decision making process should include a period for evaluation of whether the research, policies and methods have achieved the environmental outcomes sought. Time and resources must be given to evaluate progress and to readjust targets, research programmes, and policies and methods. We suggest that the 'monitor, evaluate and review' approach can only be effective when the environmental outcomes sought are expressed in measurable terms. We consider this is an important reason for, and key benefit of, setting numeric objectives in a regional plan. Where it is not possible to set numeric objectives, narrative objectives should be as tight (and therefore measurable) as possible.

4. How can science help implementation of limits under the RMA?

4.1. Mechanisms for strategic implementation

Objectives and limits could be set at any or all levels of the resource management framework established under the RMA (Figure 6). The RMA sets overarching goals (national level) in the Act itself (s5), provides for national policy statements (NPS) and national environmental standards (NES) which could set limits in a nationally strategic way, provides for regional policy statements (RPS) and regional plans (including region-wide or catchment plans) which could set limits in a regionally strategic way, and provides for individual resource consents with attached conditions that set limits in a locally operational way.

A key concept already introduced (see Glossary and Section 3.4) is that objectives and limits can be expressed in a range of ways with varying degrees of specificity. For example a broad narrative objective might be "maintain suitability for recreation". This could also be expressed in a tight narrative objective by "maintain suitability for swimming". This could be expressed even more specifically as a numeric objective by, for example, "maintain a 'Good' recreation grade". Note here that we are referring to a defined classification system (i.e. MfE 2003b) that defines exactly what 'Good' grade means in measurable terms. Finally a water quality standard could be expressed even more specifically by referring to the maximum concentration of indicator micro-organisms (i.e., the limit) required to achieve a 'Good' grade (e.g., maintain less than 260 E.Coli per 100ml water).

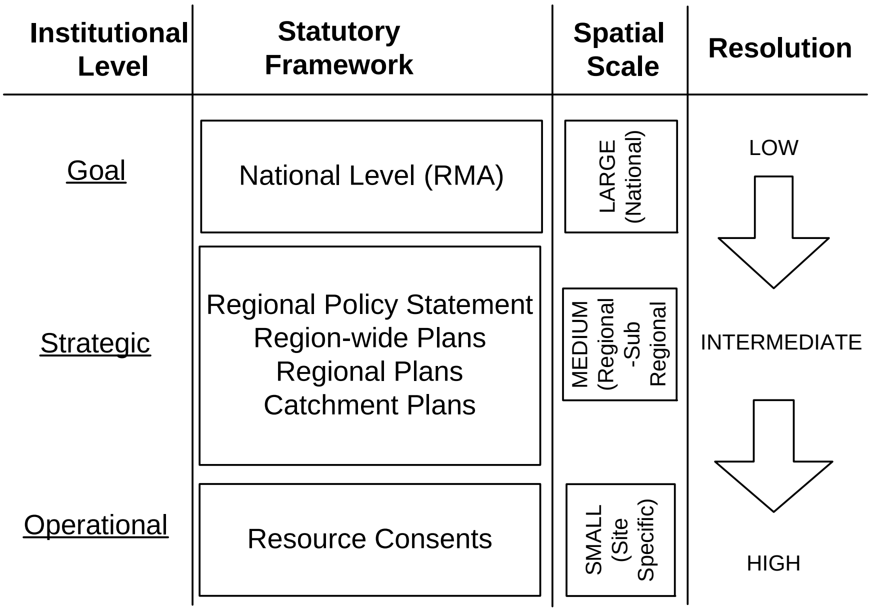

Figure 6: Schematic representation of a resource management hierarchy

A key question is; at what institutional level should objectives and limits be set, and at what level of specificity? We have recently explored this question in work for the Land and Water Forum (e.g., Howard-Williams et al 2010, Snelder and Norton 2010a, 2010b). We suggest that objectives and limits should be set with increasing level of specificity as we move from higher to lower levels in the institutional hierarchy (Figure 6). We suggest that there are good reasons to set measurable objectives, and limits such as water quality standards and minimum flows, *at least* at the regional plan or catchment plan level (Figure 6). Our main reasons for this are:

i) In order to realise the five benefits listed in Section 2.2, and therefore be able to properly carry out the functions of regional authorities for managing and allocating water resources (i.e., s30 RMA), it is necessary to make the value judgements to establish the capacity for use of the resource at a strategic level (i.e., catchment level or greater) rather than at the operational level of case-by-case resource consents. Numeric objectives and related limits such as water quality standards would clearly establish the capacity for use of the resource in a regional plan.

ii) If the value judgements necessary to set numeric objectives and water quality standards are not made strategically, it will be necessary to make them on a case-by-case basis for every future consent application (i.e., the historical situation), resulting in inconsistency and uncertainty for resource users and for environmental outcomes, and poor ability to achieve the five benefits listed in Section 2.2.

However, making the value judgements necessary to establish measurable objectives and water quality standards at the regional plan or higher levels is a major challenge. We believe this may have been a key reason why few first generation regional plans did this; it was much easier to avoid difficult or contentious decisions and devolve responsibility for these value judgements to case-by-case consent decisions. Making these value judgements at the regional or national level would need to take account of the considerable spatial variability in environmental characteristics and values of water bodies across regions and New Zealand respectively. While spatial frameworks can assist with this (see Section 3.5), it is still a major undertaking at the regional level and would require even greater effort (and produce a larger, more complex planning/policy document) at the national level. There are other advantages and disadvantages of setting measurable objectives and water quality standards at regional versus national levels. Doing this at the national level would produce more consistency across the country but may reduce the level of community involvement in the value judgement making process. The opposite would be the case at the regional level. There is a need for a national level decision on whether measurable objectives and water quality standards are to be set at regional versus national level. However we suggest it is clear that the operational level (i.e., case-by-case consents) is inappropriate and we reiterate there are good reasons for an approach that sets measurable objectives and limits such as water quality standards and minimum flows, *at least* at the regional plan or catchment plan level.

There is currently no compulsion for regional councils to make the value judgements necessary to set measurable objectives and water quality standards in regional plans, other than the broad functions listed under s30 RMA. Regional plans are not mandatory under the RMA (other than a regional coastal plan). The (proposed) NPS for Freshwater Management as recommended by the Board of Inquiry (MfE 2010) would, if it became operative, make regional plans mandatory and would require regional plans to set "*Freshwater Quality Standards and Environmental Flows and Levels*" but the proposed NPS does not specify what form these should take or require them to be measurable (www.mfe.govt.nz).

We will summarise later some of the benefits (Section 5) and challenges (Section 6) associated with this suggested approach, but first we offer in the next section our perspective on an approach that uses available science knowledge to set numeric objectives and water quality standards within an RMA regional plan framework.

4.2. An approach for implementation through the regional plan framework

A major challenge to defining limits in a regional plan is the requirement to work within, and make good use of, the planning framework defined by the RMA. This requires blending all of the concepts discussed so far in this report with planning architecture and legal requirements of the RMA. The perspective we provide in this section is based largely on our work with regional councils and particularly Environment Canterbury (ECan) (e.g., Norton and Snelder 2009, 2003; Snelder and Guest 2000). This section necessarily delves into the mechanics of a regional plan and sections of the RMA relating to water quality. We acknowledge that we are not planners, but this section reflects our experience with planning, consenting and hearing processes, and the content draws on previous input from planners, particularly from ECan (see Acknowledgements).

The RMA dictates the provisions a plan must or may contain, and how those provisions will relate to each-other. Plans *must* include objectives, policies and rules (s 67(1)) and *may* state issues, methods other than rules, environmental results expected and a number of other matters (s 67(2)). Rules *may* also contain water quality standards (s 68) and if so those standards must observe as a minimum the standards set out in Schedule 3, and must not reduce the quality of water at the time a plan is notified unless it is consistent with the purpose of the RMA (s 69). A discharge allowed by a regional rule or resource consent must not cause certain effects after reasonable mixing (s 70 and s 107). We suggest that key components of an approach that satisfies these requirements and makes good use of planning mechanics are:

- Measurable (preferably numeric and SMART) objectives wherever possible.

- Water quality standards used within rules.

- Water quality standards in the rules should be clearly linked to - but not the same as - the numeric objectives.

- Narrative statements will also be needed in both the objectives and in the rules, however these should be as specific as possible.

- Using water quality standards means that guidance must be provided in the plan on the definition of ‘reasonable mixing’.

In the five sub-sections that follow, we justify the use of this arrangement of plan provisions in the context of the requirements set out under the RMA.

4.2.1. Measurable (preferably numeric) objectives wherever possible

Objectives should be numeric objectives wherever possible in order to establish a clear basis for:

- Providing decision-makers with a test for non-complying activities (s 104D);
- Assessing cumulative effects of multiple and diffuse discharges;
- Assessing cumulative effects of activities other than discharges (e.g., land-use, water takes, dams, diversions and works in riverbeds); and
- Monitoring the effectiveness of plan provisions over time (s 35).

The reason measurable objectives are needed for effectively managing non-complying activities arises from the section 104D tests of the RMA[6]. The tests require that a consent authority may grant consent for a non-complying activity only if the effects of that activity are minor, *or* if the activity will not be contrary to objectives and policies of the relevant regional plan. Therefore to guide decision-makers on non-complying activities, strong objectives and policies that set measurable (i.e., preferably numeric) thresholds are necessary. As a matter of good planning practice (e.g. MfE 2003a) policies should describe what is going to be done to achieve an outcome (i.e. an objective) rather than describe what the intended outcome is. Thus, intended outcomes should be expressed in the objectives rather than the policies.

The reason measurable (preferably numeric) objectives are needed for effectively managing cumulative effects, and effects of activities other than discharges, is that the objectives establish the acceptable threshold for the sum total effects of multiple activities. As the intensity of effects of activities in a catchment increases, it generally becomes more difficult for dischargers to meet receiving water quality standards defined by rules. This is because the ambient (i.e. upstream) water quality declines due to increased contaminant loads and more water takes, and the waterbody then has less capacity to dilute new contaminants. A point is reached where new dischargers can no longer achieve receiving water quality standards - they become non-complying activities and the s104D test then applies. In the absence of strong direction from a threshold defined by measurable (preferably numeric) objectives (or policies),

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[6] As necessary under section 104D(1)(b) of the Act

numerous additional discharge consents (or consents for other activities) could be granted on the basis that the effects of each new activity on their own are minor[6]. Measurable objectives define the capacity of the resource, the point when ‘enough is enough’ to use Milne’s (2008) terminology or, as he also puts it “*when the accumulation of insignificant effects becomes significant*”.

Measurable (preferably numeric) objectives are also a useful component of monitoring the effectiveness of the plan provisions through time as required by the RMA[7]. It is logical to test the effectiveness of a plan by comparing monitoring results with numeric objectives (rather than policies), although we note that an objective does not necessarily have to be achieved in the lifetime of a plan. A regional plan may state the environmental results expected to be achieved by the policies and methods[8] at staged intervals (e.g. by the time the plan is subject to a formal review) and it may take several stages to achieve an objective.

4.2.2. Water quality standards used within rules

Water quality standards should appear within rules so that the plan is able to make use of the hierarchical activity category system (s 77B and s 104A-D) for managing uncertainty in a risk-based manner (as described in Section 3.6.2). This system of categories is useful for prioritising activities on the basis of risk of adverse effects, and thereby determining the level of attention given to different activities. Water quality standards must also appear within rules if existing discharge permits are to be reviewed under s 128(1)(b) to ensure they align with objectives set by a new regional plan.

4.2.3. Water quality standards in rules should be linked to the objectives

Water quality standards in the rules should be linked to (but not the same as) the measurable objectives. The objectives should state *what* environmental outcomes are desired; policies should provide the guidance for decision-making; receiving water quality standards in the rules should provide for *how* the objectives will be achieved for specific activities, such as discharges. This linkage between objectives, policies and rules is consistent with good planning practice (e.g., MfE 2003a).

This link is a way of separating the desired environmental outcomes (i.e. the objectives) from the controls (i.e. the rules and associated receiving water quality standards) to achieve those objectives. The objectives are based on community input

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[7] As required under section 35 of the Act
[8] As allowed for under section 67(2)(d) of the Act

and reflect value judgements concerning the costs and benefits of resource use. For example decision-makers, having heard submissions from the community, need to decide whether the objective for a particular waterway or group of waterways will be a recreation grade of ‘good’ or ‘fair’ (or some other grade), while science can determine what microbiological standard (e.g. concentration of *E.coli*) is necessary for rules to achieve that chosen objective.

The hierarchical structure of objectives and rules (containing standards) is logical and creates a consistent understandable approach. The hierarchy means that plan objectives drive policies which in turn drive rules.

4.2.4. Narrative statements will also be needed

Narrative statements will still be required in both the objectives and in the rules because scientific knowledge cannot currently provide numbers to describe all desired environmental outcomes or standards. Over time, some narrative objectives may be periodically replaced with numeric objectives at the time of plan review. However some environmental values (e.g., cultural and spiritual values) can not easily be described quantitatively and may always require narrative expression in the objectives and rules. Where narrative statements are necessary they should be as specific as possible (i.e., tight narrative objectives are more useful than broad narrative objectives - see Glossary).

4.2.5. Water quality standards require guidance on defining ‘reasonable mixing’

There is a national guideline on reasonable mixing (Rutherford et al., 1994) but guidelines carry no statutory meaning. For this and other reasons, when using rules that apply water quality standards to discharges, it will be necessary to provide specific guidance on how *reasonable mixing* (s 107) will be defined in the regional plan. This is an additional topic that we have explored in work for ECan (e.g., Norton and Snelder 2003) and is beyond the scope of the present report.

5. Benefits of setting measurable objectives and limits

In Section 2.2 we listed five key benefits of defining measurable objectives and setting limits such as water quality standards in regional plans:

i) Increased clarity and certainty for environmental outcomes

ii) A basis for managing cumulative effects

iii) Clarity about future resource availability and the likely conditions imposed on resource users

iv) Ability to manage multiple activities that affect water quality, in addition to managing point-source discharges

v) Ability to measure attainment of objectives and thus properly monitor plan effectiveness

Here, we return to these five benefits, providing more detail and examples.

5.1. Increased clarity and certainty for environmental outcomes

We have discussed the idea that objectives can express desired environmental outcomes in a range of ways from the broad to the very specific (see Glossary). In general, broad narrative objectives and tight narrative objectives lack clarity and therefore certainty for environmental outcomes. We have also discussed the idea that desired environmental outcomes must be expressed in measurable terms (preferably as numeric objectives) before scientific tools can be justifiably used to set limits such as water quality standards (see Section 3.3). Thus, if measurable objectives are established in regional plans this greatly increases the justifiability of the policies and rules, compared to the predominantly narrative objectives that are used in most currently operative regional plans.

An example we have already introduced is the numeric objective set for water clarity in Lake Taupo. It was shown that under current nutrient loadings Lake Taupo’s water quality would continue to decline, affecting ecosystem functions and causing a deterioration of lake values for some time into the future (Spigel et al. 2003). Environment Waikato’s (EW) response was to identify numeric objectives for Lake Taupo water quality including an objective to achieve 14.6 metres water clarity (+/- 2.7 m as measured by Secchi disk depth). This allowed the use of science tools (lake-specific models in this instance) to quantify nitrogen, phosphorus and chlorophyll *a* concentrations and ultimately the catchment nutrient load limits necessary to achieve the numeric objective. The water quality objectives, nutrient limits and associated land-use rules have been incorporated into the Waikato Region Plan RPV5. The RPV5 thus establishes limits and provides a measurable planning mechanism to regulate the contribution of nutrients from land-use activities in the Taupo catchment in order to achieve a clear measurable objective. (http://www.ew.govt.nz/Policy-and-plans/Protecting-Lake-Taupo/).

Environment Bay of Plenty (EBOP) has developed numeric objectives for the North Island lakes Rotorua, Rotoiti, Rotoehu, Okaro and Okareka, expressed in terms of a numeric lake Trophic Level Index (TLI) for each lake. EBOP has incorporated these objectives, along with several rules to manage nutrient loads from land-use within defined loading caps, into their Proposed Regional Water and Land Plan. The rules, collectively known as “Rule 11” effectively draw a “line in the sand” to cap existing nitrogen and phosphorus loss from land use activities in lakes (http://www.envbop.govt.nz/Water/Lakes/Rule-11.asp).

Environment Canterbury (ECan) has developed numeric objectives for all lake types (e.g., TLI) and river types (e.g., periphyton percent cover, macrophyte percent cover, clarity, fine sediment percent cover and the macroinvertebrate community index QMCI) and has incorporated these in the PNRRP (Hayward et al. 2009).

5.2. A basis for managing cumulative effects

Several legal commentators have pointed out there is no impediment under the RMA to setting quantitative limits on resources to manage cumulative effects. On the contrary, in response to the suggestion that the RMA is unable to handle cumulative effects, the Hon Peter Salmon QC pointed out:

“*If one looks at the definition of effects, at section 5 and its three ‘bottom lines’ and at the duties and responsibilities of regional councils set out in section 30, there is clear power to deal with cumulative effects. It is a question of identifying the resource, determining its capacity and then limiting its use so that the section 5 objectives can be met. Cumulative effects may be difficult to identify in some instances but I cannot see how a better system for dealing with them can be provided. Whatever the system devised, the same problems of identification and control will arise.*” [our emphasis] (Salmon 2007)

In a paper commissioned by MfE to inform debate about how the RMA handles cumulative effects, Milne (2008) noted that the fundamental issue is determining “*the point in time or space where the accumulation of insignificant effects becomes significant*” (Gargiulo v Christchurch City Council C137/2000). Or, he puts it another way, “*how should decision makers determine when is enough, enough?*” He emphasised the need for resource managers to:

(i) Identify the resource (where, what, how much?);

(ii) determine capacity for use (what are the sustainable limits of the resource?); and,

(iii) establish limits to use of the resource.

Milne (2008) also discussed the challenges and barriers facing resource managers, and suggested techniques for addressing cumulative effects, including a number that are consistent with the approach to regional planning that we have suggested in this report:

- Strong objectives and policies
- Minimum standards of receiving water quality
- Non-complying activities coupled with strong objectives and policies

From a science perspective the strongest objectives and policies are those expressed in measurable (i.e., preferably numeric) terms. Resources can only be clearly identified (i.e., where, what, how much?) and their capacity for use clearly determined (i.e., limits set) when objectives are expressed in measurable terms. Water quality standards can only be justifiably defined using science tools when measurable objectives are established (see Section 3.3). The use of non-complying activity status, defined by a test as to whether or not water quality standards are achieved, coupled with strong objectives (e.g., numeric objectives) and policies, becomes possible using the approach we outlined in Sections 3.6.2 and 4.2.1.

In summary, we consider that the approach described in this report provides a strong basis for managing cumulative effects using the existing framework provided under the RMA. When only narrative objectives and policies are used in regional plans, this weakens the basis for managing cumulative effects; in other words it is not clear when enough is enough.

5.3. Clarity about future resource availability and the likely conditions imposed on resource users

The benefits described in the two previous subsections lead to increased clarity about future resource availability and the likely conditions imposed on resource users. When there is clarity about the environmental outcomes sought (e.g., numeric objectives are defined) and there is a strong basis for managing cumulative effects, then the capacity for use of the resource is well established and this provides clarity for would-be resource developers considering investment decisions.

In a typical scenario, a would-be resource user should be able to determine whether a proposed activity will meet water quality standards (or minimum flows in the case of water quantity) in the plan rules, and therefore whether their activity will be treated as permitted, controlled or discretionary (see Section 3.6.2 for explanation) under the plan. If standards can be met, there is a reasonable degree of clarity about the likelihood that activity will be granted consent and, in the case of permitted and controlled activity status, there is absolute certainty for the would-be user provided conditions prescribed in the plan rules are met. If the activity does not meet standards in the plan rules, then it is a non-complying activity and the would-be resource user must then assess whether it is yet possible to achieve plan objectives and policies (i.e., pass the “higher hurdle” test of s104D RMA[9]).

For non-complying activities, there will be cases where it is possible to meet plan objectives and policies despite breaching standards in the rules, but this situation is clearly a riskier investment decision for would-be users and requires a correspondingly greater level of effort in terms of the consent application and associated assessment of effects. We have been involved in these types of cases where we have provided assessments for applicants (e.g., the proposed North Bank Tunnel hydro scheme on the Waitaki River; the Hunter Downs Irrigation Scheme in South Canterbury), and cases where we have provided assessments for decision-making authorities (e.g., Canterbury Central Plains Water Irrigation Scheme; multiple irrigation consent applications in the Mackenzie Basin).

Another important consideration is the timeliness of setting limits to provide clarity about future resource availability and conditions of use. The Lake Taupo and Rotorua Lakes examples discussed in Section 5.1 are examples that illustrate this point. Both RPV5 (Lake Taupo) and Rule 11 (Rotorua Lakes) were designed to manage a situation where lake water quality showed early signs of, or had already, declined. Both these planning instruments will restrict further land use development and it is possible that some areas of existing intensive land use will ultimately need to be retired in order to meet numeric objectives for water quality in some of these lakes. In other words, Rule 11 and RPV5 are playing “catch-up” for lakes whose capacity to assimilate nutrients without further deterioration in water quality has already been exceeded. This creates very complex challenges (e.g., equity issues) for management methods to “claw back” resource use (http://www.ew.govt.nz/Policy-and-plans/Protecting-Lake-Taupo/). Ideally it would be: more certain for environmental outcomes, fairer, less time-consuming and more cost effective, if numeric objectives and related limits such as water quality standards and nutrient load limits, were established *before* the assimilative capacity of a lake or a river system is exceeded. This would make the situation for resource developers clear *before* they make investment decisions. An example where this is being attempted is ECan’s current efforts to establish a numeric objective (TLI) and related nutrient load limits (in tonnes of nitrogen and phosphorus per year) for Lake Benmore, in order to manage the potential water quality effects of proposed large scale intensified land use in the Mackenzie Basin (e.g., Norton et al., 2009).

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[9] Strictly speaking the wording of the test in s104D RMA requires that the activity “… *not be contrary to the objectives and policies*…”

5.4. Ability to manage multiple types of activities that affect water quality in addition to point-source discharges, such as non-point discharges from land uses, water takes, diversions and dams

Point source discharges are the easiest of the activities that affect water quality to manage. Most point discharges around New Zealand are currently managed reasonably well (e.g., OECD 2007) by some combination of individual consents (with attached conditions) and regional plan rules containing water quality standards for permitted, controlled and discretionary activities. Far more challenging is the need to manage the cumulative effects of multiple non-point source discharges from land uses and other activities such as water takes, diversions, dams and riverbed works that all affect water quality and/or related values. The management of cumulative effects of multiple activities is one of the key challenges currently facing water managers both in New Zealand (e.g., MFE 2007, OECD 2007) and internationally (e.g., Herrit et al., et al., 2010).

Setting water quality standards in regional plan rules is unlikely, on its own, to provide effective management for all the different activities that affect water quality. This is because achieving water quality standards is generally only one of a number of inter-related factors that influence whether or not objectives can be met and thus values supported at the desired level. For example, the quantity of algae (periphyton) on a riverbed is affected by the concentration of nutrients (e.g., nitrogen and phosphorus) in the water, but is also affected by the frequency of flood events (which flush algae from the bed) and the extent of riverbank vegetation shading (which shades the bed and limits light for algae growth). If a numeric objective is established for the quantity of algae that is acceptable to support values (e.g., 30% cover; 120 mg/m^2 chlorophyll *a*), then science tools (e.g., guideline relationships) can be used to define the nitrogen and phosphorus concentrations and/or loads (i.e., water quality standards and/or load caps) necessary to achieve that numeric objective, given an *assumed* flood flow frequency and *assuming* no shading limitation by riverbank vegetation. There are two important implications of this:

- First, the river flow regime characteristics affect the calculation of the number used as a water quality standard (e.g., nutrient concentration). So if the flow regime were to be significantly altered by unforeseen takes, diversions and/or dams (i.e., unforeseen at plan development stage and therefore not accounted for in the calculation assumptions), then the water quality standards (and/or load caps) for nutrients would become obsolete and need to be altered. This demonstrates the weakness of relying on water quality standards in rules *alone*. Multiple activities affecting water quantity and quality *must be managed together* in regional plans - identifying common measurable objectives that apply to both is a key to achieving this integration. An example is the measurable objectives in Table WQL5 of ECan's PNRRP. In addition, ECan is investigating the merits of establishing nutrient load limits (related to achieving the Table WQL5 measurable objectives) for river catchments that are subject to potential future increases in intensive irrigated landuse (i.e., potentially involving increases in contaminants *and* in water takes and dams).

- Second, while restricting nutrient concentrations (i.e., by using water quality standards) is a sure way to prevent nuisance algae growth, it is not the only way to achieve this. For example in situations where nutrient management is very difficult (e.g., catchments already under intensive agriculture) it may still be possible to achieve an acceptable algae cover (i.e. achieve an objective) by reducing nutrients *and* ensuring adequate riverbank vegetation cover to limit growth by shading.

The key point is that measurable objectives are the ultimate destination for management, while the water quality standards for discharges and restrictions on other activities (i.e., takes, diversions, dams and land-use) are multiple inter-related ways of getting there. It is only possible to justifiably use science tools to establish policies and rules for managing all these different types of activities when the desired environmental state is expressed as a measurable objective.

5.5. Ability to monitor plan effectiveness

It is only possible to objectively monitor and assess whether plan provisions have been effective in achieving desired environmental outcomes when those desired outcomes are expressed in measurable terms (e.g., numeric objectives). It is very difficult to use science tools to directly measure attainment of broad narrative objectives or even tight narrative objectives because these are open to wide interpretation. Thus, monitoring and reviewing effectiveness of plans with only narrative objectives is likely to be subjective, inconsistent between reviewers and ultimately less than optimal for informing management.

Monitoring and assessing attainment of water quality standards in plan rules should be done with caution and should not be assumed to equate with plan effectiveness. This is because, as already discussed in the previous section, water quality standards are just one (albeit important) method of achieving the plan objectives. Water quality standards are not in themselves necessarily important environmental outcomes. For example we are not concerned about the concentration of nitrate in a water body *per se*, but we are concerned about whether nitrate is having a toxic effect on humans or aquatic life, and is causing nuisance algae growth (i.e., the outcomes of interest). It is possible to breach water quality standards and still achieve numeric objectives and vice versa. Monitoring programmes should include adequate sampling of all variables used as numeric objectives in regional plans, as well as variables used as water quality standards. Arguably, the greater effort should be on the former rather than the latter, but the opposite is generally currently the case around the country.

6. Summary of challenges with setting measurable objectives and limits

There are many challenges and potential solutions for setting measurable objectives and limits for water management in New Zealand (e.g., OECD 1996 and 2007; OCAG 2005; Salmon 2007; Milne 2008; Snelder and Hughey 2005; Norton and Snelder 2003 and 2009; Howard-Williams et al., 2010; Frieder 1997; MfE 1998 and 2008; Erickson et al. 2001; Oram 2007; Peart 2007; Crawford 2007; ME & MA 2009). We believe there are at least partial solutions for all of the challenges that we have encountered. Many of these solutions have already been described in previous sections of this report. Naturally the solutions require a degree of effort and cost. It will be a matter for decision-makers to weigh the effort and costs against the benefits for management we outlined in Section 5. However it is logical that, as demand for resources increases over time, the benefits of setting limits will at some point outweigh and therefore justify the costs. This is particularly true in water bodies where effects arise only after long lag times have elapsed because these are often extremely costly to remedy. The following is a summary list of key challenges and related solutions we have identified thus far:

1. Ideas for limit setting are evolving across multiple technical fields creating significant integration and communication challenges including problems with inconsistent use of terminology. See Section 1 and Glossary.

2. There is a need to integrate expertise from scientific, planning and legal disciplines. While bridging these disciplines has always been important in regional planning, the approach suggested in this report places an even greater emphasis on interdisciplinary communication. This is because the approach represents a shift in thinking from a reactive mode (i.e. concentrating on regulating the effects of new activities) to a strategic mode (i.e. identifying the capacity for use of resources and setting limits). This requires greater use of scientific knowledge by planners, thinking at more expansive scales by scientists and more creative use of the available legal tools in the RMA.

3. Making value judgements is difficult and is political. See Sections 3.1 and 3.2. Exercising the value judgements needed at a strategic level to define measurable objectives and thus justify setting limits is hard because it involves trade-offs i.e., some values will win and some values will lose. In some cases these judgements will foreclose resource use and in some cases they will allow resource use and accept some level of degradation of intrinsic values. Being explicit and transparent about these judgements at a strategic level can be politically unattractive. There is

a political tendency to want to retain discretion in the decision making process, by devolving responsibility for making the value judgements to case-by-case consent processes. This is probably at least part of the reason that first generation regional plans have tended not to set measurable objectives and limits for resource use.

4. Using science effectively requires clarification of the roles of science versus decision-making. These are described throughout this report, particularly in Sections 3 and 4. The role of science is to assist decision-makers faced with the challenge of making value judgements, by describing the effects of various management options, on environmental, social and economic values, so that informed choices between options can be made.

5. The process of setting limits relies heavily on science-defined relationships between measures of resource uses and environmental states (e.g., x-y plots as shown in Section 3.3). Many such relationships are available in the form of guidelines and other technical documents and research papers (see Section 3.3). However many aspects of environmental state and relationships with resource use are not well described and further research to extend existing guidelines and develop new relationships is required. Thus there is a need to acknowledge the extent of knowledge and ignorance, and provide flexibility for incorporating new information as it becomes available in future. Some priority areas where new science knowledge would assist are discussed in Section 3.6.1. It is recommended that an appraisal of research needs for limit setting be undertaken (see Section 3.6).

6. Science-defined relationships between measures of resource uses and environmental states are best estimates and simplifications of reality. Many such relationships are likely to involve multiple stressor interactions that are difficult to quantify. It is necessary to simplify science and make informed assumptions for management applications.

7. Some aspects of environmental state are not easily expressed in numeric terms (e.g., those relating to cultural and spiritual values) and may always require narrative expression. However, ongoing research is identifying methods to estimate quantitative measures of some of these less tangible values.

8. Managing scientific and other types of uncertainty (and associated risk). This is a widely recognised key challenge. Several potential approaches are described in Section 3.6. Science based arguments highlighting uncertainty are sometimes used as a basis to retreat from making a decision to adopt a numeric objective, and to instead adopt a narrative objective that is less arguable but also less helpful for defining the capacity for use of a resource.

9. Managing spatial variability. This is a widely recognised key challenge. An approach that makes use of spatial frameworks is described in Section 3.5.

10. There is the requirement to use science but to also work within, and make good use of, the planning framework defined in the RMA (e.g., existing RMA sections and existing instruments such as NPS, NES, RPS, RP's). This requires collaboration between many different technical people including scientists, planners and lawyers. An approach is described in Section 4.2.

11. Some detailed planning aspects cause challenges for legal interpretation. For example a problematic requirement is s69 RMA "*…a regional council shall not set standards in a plan which result, or may result, in a reduction of the quality of the water in any waters at the time of the public notification of the proposed plan unless it is consistent with the purpose of this Act to do so.*" In order for a regional council to form a value judgement that it is acceptable to allow some further resource use (e.g., point discharges or intensified land-use) in a particular catchment after the date of plan notification, and to set numeric objectives and water quality standards accordingly, it must transparently argue that reduction of water quality in the catchment is consistent with the purpose of the Act. This can be a politically awkward argument to make.

12. Existing environmental monitoring data covers some locations and variables very well but some locations and variables are poorly represented. This can make it difficult to justify using generic criteria from national guidelines for setting measurable objectives and limits, without being able to confirm their appropriateness with local data.

13. Regional plans that set measurable objectives and limits must undoubtedly be more complex documents than plans that rely on broad narrative provisions. This is a very significant challenge. However, water resources are complex systems that are coming under increasing pressure from equally complex socio-economic activities. A larger, more complex plan is to some extent unavoidable when the demand for use of water resources approaches the sustainable limit of supply. We argue that only by using measurable objectives, policies and rules, can regional plans quantify the capacity for use of the resource and provide for the five benefits described in Section 5. It is necessary for plans to be well written in order to help plan users navigate through the plan provisions that are relevant to their particular needs.

7. Conclusions

Limits for water management can potentially be set at any, or all levels of the resource management framework established under the RMA, that is; at the national level (i.e., in national policy statements and national environmental standards); regional level (i.e., in regional policy statements and regional plans); or the local operational level (i.e., individual resource consents with conditions). There are advantages and disadvantages of setting limits at each these levels, and there is a need for a national decision on the best approach. We suggest it is clear that setting limits *only* at the operational (i.e., individual consent) level is inadequate, and that limits need to be set at some higher strategic level(s). We suggest there are many good reasons for an approach that sets limits, *at least* at the regional plan or catchment plan level.

We propose that it is possible to define measurable objectives in regional plans and that doing so will significantly improve water management. Measurable objectives allow a range of limits to be justifiably set using science, such as water quality standards, catchment contaminant load limits, maximum water take and discharge rates, minimum river flows and lake and groundwater levels, minimum standards of discharge quality, restrictions on dam operations and restrictions on land uses. We suggest that objectives must be sufficiently measurable (i.e., preferably numeric) that they allow limits to be justifiably set using science, and as such we suggest that measurable objectives are a fundamental pre-requisite in order to fully achieve the purpose of a regional plan, i.e. to assist a regional council with its functions under s30 RMA.

In order for regional councils to properly carry out their s30 RMA functions for managing and allocating water resources, particularly when demand for those resources approaches available supply, a regional plan must provide a basis for determining the capacity for use of the resource; i.e. the amount of resource use that can be made by people *while* sustaining all competing values at some identified acceptable level. We suggest that the capacity for use of the resource depends on value judgements that should establish, in an unambiguous manner, the level at which all competing values will be sustained, i.e., the environmental states or outcomes sought. We propose that the outcomes sought in the plan should be defined by measurable (preferably numeric and SMART) objectives. The plan's policies and rules can then justifiably set limits to resource use, such as water quality standards, that are clearly linked to achieving the measurable objectives. Plans that contain measurable objectives *and* linked limits such as water quality standards, can achieve at least five important benefits for managing water resources. By way of summary these are:

(i) Increased clarity and therefore certainty for environmental outcomes;

(ii) a basis for managing cumulative effects;

(iii) clarity about future resource availability and the conditions likely to be imposed on resource users;

(iv) an ability to manage multiple types of activities that affect water quality in addition to managing point-source discharges, such as non-point discharges from land uses, water takes, diversions, dams and riverbed works (i.e., the integration of water quality, quantity and land management); and

(v) an ability to measure attainment of objectives and thus properly monitor the effectiveness of plan provisions through time.

Defining measurable objectives and setting limits such as water quality standards is very challenging but achievable. In particular there are five key components to an approach where science can help:

(a) Use science knowledge and the regional planning process to inform decision makers so that necessary value judgements can be made. The role of science in this process is to describe the effects of management options, on environmental, social and economic values, so that informed choices between options can be made;

(b) Use technical relationships from science research, including published national guidelines and research papers, as well as analysis of region-specific data, to develop measurable objectives and limits such as water quality standards;

(c) Structure plan provisions according to a spatial framework that defines groups of water bodies that are sufficiently similar, both physically and in terms of their values, to be treated as management units;

(d) Acknowledge and manage scientific and other types of uncertainty in a risk-based manner; and

(e) Combine science knowledge with effective use of planning tools provided under the RMA.

The most important aspect of the approach is the requirement for regional council decision-makers, via the regional planning process, to make the difficult value judgements concerning the balance between capacity for use of the resource by people and sustaining all competing values at some identified appropriate level. These value judgements are necessary to define numeric objectives and limits such as water quality standards in a regional plan. Ultimately if these value judgements are not made strategically in a regional plan, it will be necessary to make them on a case-by-case basis for every future consent application. This will result in poor ability to achieve the five benefits for water management listed above; i.e., there will be uncertainty for environmental outcomes and resource users, poor ability to manage the cumulative effects of multiple types of resource use activities, and limited ability to monitor plan effectiveness.

Setting measurable objectives and limits will probably lead to more complex planning documents than plans which rely on broad narrative provisions. Managing this complexity and educating plan users is likely to be a very significant challenge. Setting measurable objectives and limits in regional plans may be costly, but not doing so will also have significant costs in the long run. Water resources are complex systems that are coming under increasing pressure from equally complex socio-economic activities. Larger, more complex plans are a likely consequence when the demand for use of water resources approaches the sustainable limit of supply. It is logical that, as demand for resources increases, the benefits of setting limits will, at some point, outweigh and therefore justify the costs.

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