Water management in New Zealand

A road map for understanding water value

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Authorship

Each year NZIER devotes resources to undertake and make freely available economic research and thinking aimed at promoting a better understanding of New Zealand's important economic challenges. This paper was funded as part of this public good research programme.

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Executive summary

Good water management is hampered by uncertainty

Increased competition for water, concerns about water quality, and major irrigation investments being considered all point to the need for better information on how society uses and values water and better institutions to manage the use of water.

Durable water policy to support the sensible use of water requires an in-depth understanding of the characteristics of the water system within New Zealand and the policy challenges it presents. The main problem with New Zealand water policy is uncertainty. The uncertainty is driven by increased competition for water, a lack of understanding of society's preferences about how we use and value water, a lack of scientific information about water and inertia on the part of users and institutions.

This paper has been prepared as part of NZIER's public good programme to provide independent advice on water policy. We explore the current and expected future challenges facing water management, and review the history of water policy in New Zealand. We note that there is a broad consensus that the current approach under the RMA is flawed, and there is momentum to develop a multi-faceted framework that examines those challenges to assist stakeholders in thinking about what needs to be done for freshwater policy.

Our findings will not come as a surprise to policy makers, scientists and economists working in this field. But as we conclude, durable solutions require broad public and political support. With this paper we seek to provide a broader group of people access to the types of trade-offs that need to be considered.

Current challenges point to the need for change

The challenges facing water management in New Zealand are nuanced:

- there is significant variation of water quantity issues by catchments – scarcity and quality are not an issue across all of New Zealand all of the time, but
- most regions have at least one river (surface water) or aquifer (groundwater) that is either fully or over-allocated, or likely to become so in the next one to five years
- 39% of groundwater sites and 44% of lakes have nutrient levels above natural levels. However, they are not bad by international standards
- the full impacts of past and present water uses on water quality have yet to fully materialise
- the growth of agricultural (mainly dairying) and urbanisation are the main sources of water quantity and quality problems, and they are expected to continue.

The main consequence of falling water availability is increasing competition for water between different users and deteriorating water quality in some catchments.

We also recognise that there are challenges arising from the Treaty of Waitangi, but have not explored them in this report.

New Zealand water management has been characterised by inconsistency

New Zealand has had little consistent water policy over time. The ad-hoc responses of the 1840 – 1930s were replaced with an interventionist approach for the period from 1941 – 1989. Since then, the Resource Management Act (RMA) has given regional councils the responsibility of managing the complex trade-offs associated with water management.

The weaknesses of the current RMA system are well known, and have become clearer as water scarcity and quality issues have become more prevalent. The first-in, first-served mechanism is inefficient for allocating water; the lack of flexibility restricts improvements to water allocation, and there are large gaps in information and data.

There is scope to craft better policy, informed by overseas lessons

The lack of consistency in New Zealand's historical water management is a two-edged sword. It makes planning and investing around water use and infrastructure uncertain, which reduces investment in solutions. However, it also means that there is little historical precedent that must be respected; New Zealand has considerable scope to craft new and appropriate policy.

What we can learn from history however, is that without a clear understanding of problems we face and how New Zealanders value water (both from a market and non-market perspective), and without engagement of those affected by regulation, then decisions are likely to be ad hoc, short term and require constant revision.

Overseas experience points to some potential solutions: focusing on achieving the most value from water, using science to inform decision-making, developing water markets, being careful with allocations and using policy design to achieve social and environmental goals.

Frameworks help us to identify the trade-offs inherent in water policy

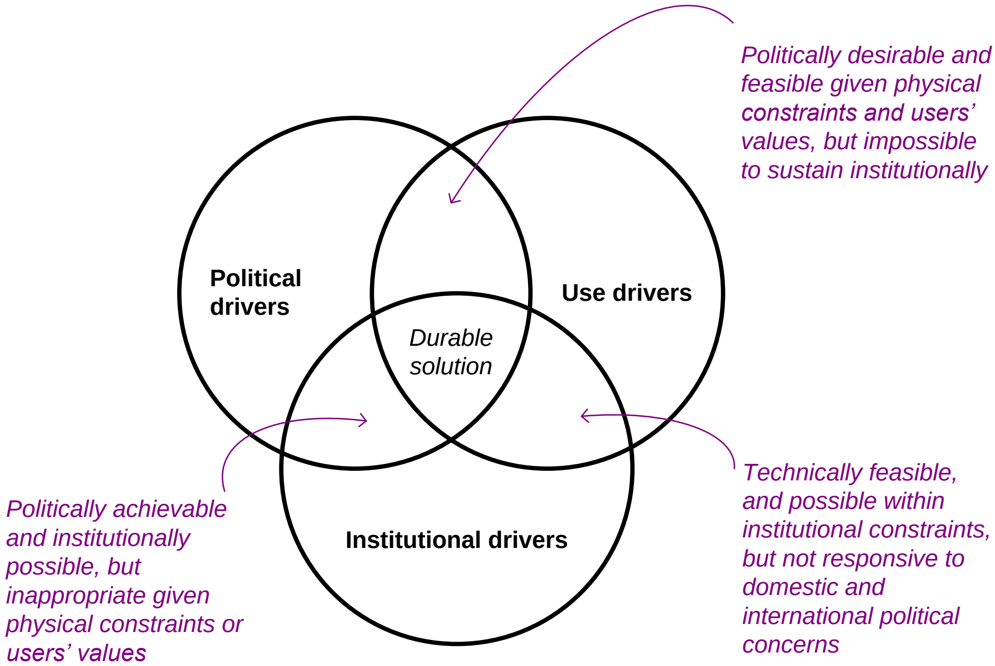
We present several different frameworks for thinking about water. A framework is a representation of reality that identifies the important elements and describes the structure of their relationships. Frameworks are often drawn as diagrams or flowcharts in reports, but they are truly useful when people can carry them around in their heads as mental models to aid their thinking.

The **multiple drivers framework** recognises that decisions about water use must take place in a specific political and institutional context, without forgetting the physical constraints or the values of water users. This provides a platform to understand water use within the catchment context.

Water management relies on:

- use drivers, recognising water use is a combination of physical, technological, social, and economic drivers
- institutional drivers that reflect the existing legislative framework that manages water
- political drivers such as concerns about perceived community values or timing of policies. Also, international pressures or conforming to international standards.

Multiple drivers framework



Source: NZIER

The use drivers (associated with the multiple drivers framework) can be considered in a general equilibrium context, which combines the physical descriptions of the possibilities and limits of water with the multiple ways that people can derive value from water, and gives us a way to talk about limits, feasibility, values and trade-offs.

The **ecosystem services framework** allows us to understand the physical and environmental limits of water use, as well as the multiple services that water performs for society and the environment.

Total economic value is a way to discuss the many different ways that water users derive value from water, both the marketed values and the non-market values.

Taken together, along with consideration of New Zealand's history and overseas experiences, these frameworks provide the tools for thinking about water issues, a way of triangulating results, and working towards durable water management solutions.

Practical application of these frameworks highlights potential solutions

Practical application of water management solutions is required for the best use of water. Applying the frameworks to key issues illustrates how New Zealand might work towards solutions:

- water trading can offer possible improvements in allocation so that water is put to its best use. However, giving the opportunity to trade does not mean that trading will necessarily take place in a catchment. Encouraging water allocations to be traded also requires institutional and political support
- water pricing overseas shows that it offers possible improvements and flexibility for achieving water management aims (i.e. the water is put to its best use), but water pricing is only one of the factors that can lead to better

use of water. To be useful, water pricing also requires institutional and political support to achieved desired aims

- ensuring that there is public support for public irrigation schemes is a crucial step in their development. This requires transparency so that the public understand why schemes have been undertaken and who benefits from the scheme and how
- environmental set-asides appear to be a useful and appropriate tool in a well-functioning water management system. They can be tailored to meet the needs of specific catchments and the needs of New Zealanders and allow for flexibility in the water management system
- a water management system relies on policy-related research. Without performance metrics, decision makers rely on their own experience and instincts that may or may not lead to good water management policy. This 'hit or miss' approach to such an important issue is unlikely to lead to good outcomes. Policy makers need to understand the strengths and weaknesses of the research and be active in challenging researchers to answer the pertinent policy questions.

The road ahead: our recommendations

Good use of water requires an understanding of the value of water to the various water users. With the right information and framework for understanding water, there is a potential to create durable management of water resources over time by developing regulation that allocates water in a way that reflects how stakeholders value it and responds to changes in users' preferences, technology and emerging environmental outcomes. The work and reforms in this space, such as the Land and Water Forum and the National Objectives Framework for freshwater, are on the right track but more needs to be done.

Our key recommendations are:

1. **Reform the allocation and reallocation mechanisms**. Allow water rights to be traded to ensure water flows to its best use. The current first-in, first-served approach is not an appropriate allocation mechanism
2. **Impose environmental externality limits based on case-specific evaluation.** Don't use one-size-fits-all limits but design the mechanisms that can achieve the largest 'bang-for-your-buck' in environmental terms
3. **Invest in coordinated research**. The difficulty with water policy is that it requires information from a range of disciplines (e.g. agricultural science, natural resource and environmental economics, hydrology etc.) across a range of geographical scales (e.g. farm, catchment, region). Greater coordination of research would allow New Zealand to get the greatest improvement in water policy from the research investment
4. **Centralise key water management decisions**. Our frameworks have emphasised the importance of political and institutional support. We believe the central Government and its agencies must provide the overarching water management principles and frameworks. This would provide consistency in key areas such as the design of allocation and compensation mechanisms, and environmental policies. It would also allow regional councils to focus on the regional specifics rather than designing water management systems from the ground up.

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1. Introduction

Better water management will benefit all New Zealanders. The focus on water policy has been driven by poorer water quality, shortages, and unease at the costs with poor water allocation. This paper examines the characteristics of the water situation in New Zealand and the policy challenges it presents. We develop a multi-faceted framework for examining those challenges, with a view to helping stakeholders think about what needs to be done for freshwater policy to more accurately reflect society's preferences. It has been prepared as part of the NZIER's public good programme to provide an independent and succinct review of what we know and do not know about the topic.

In preparing this report, we found that a lot has already been written. We did not want to repeat it – we refer to various publications that the reader may seek out. Instead, we wanted to produce a way of thinking about water, water policy, water management and water allocation that would allow us to reflect on current problems and work towards solutions. The goal is to use water wisely for the benefit of New Zealanders. How we do that depends on a wide range of factors, as this report describes. Most importantly, it depends on how we think about water resources. Thus, we focus on producing some mental models that we hope others will find helpful.

This report does not consider any issues arising from the Treaty of Waitangi. We recognise that those issues are important, but we are not experts on them. In addition, the focus of the report is on better water management to improve the well-beings of all New Zealanders, including tangata whenua.

Water policy in New Zealand has been in a state of flux for quite some time. The uncertainty is driven by increased competition for water, a lack of understanding of society's preferences, a lack of scientific information about water quality and inertia on the part of some users and institutions. It is clear that this situation is changing. We hope this report contributes something positive to that change.

2. Getting the most from water

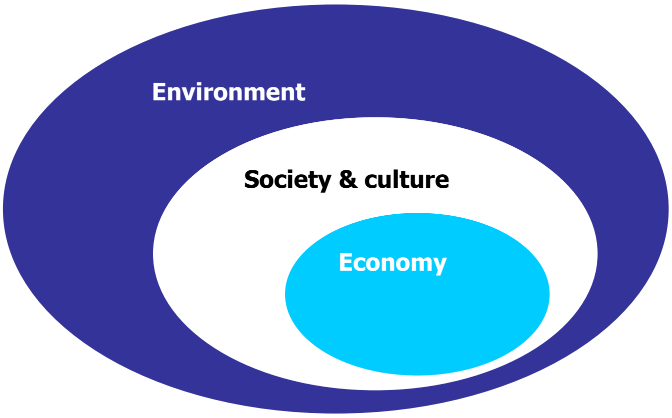
2.1. The goal of good water management

The goal of water management is to use water wisely across our whole society. Water resource limits are being reached. New Zealand has declining water quality, and in some areas and at sometimes there are water shortages. Water needs to be managed and used to provide for the economic, environmental, social and cultural well-being of New Zealanders:

- economic – to create income and wealth, both efficiently and equitably
- environmental – to support the country's ecosystems and its services
- social and cultural – to respect the social and cultural meanings and uses of water for all New Zealanders.

When it comes to water, these well-beings do not stand apart. Environmental well-being is necessary to support cultural values and economic production. Social well-being contributes to a well-functioning economy. Economic activity gives people the means to enjoy the environment and the social and cultural values it supports. The different well-beings are produced by a set of embedded systems, as shown in Figure 1.

Figure 1 Embedded systems – environment, society, economy



Source: NZIER

Finally, a central aspect of this goal is to provide for these uses today without harming the ability of people to meet their needs in the future.[1]

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[1] This concept is from the Brundtland Commission: 'Sustainable development is development that meets the needs of the present without compromising the ability of future generations to meet their own needs.'

2.2. Challenges with New Zealand's management of water

There is wide agreement about the main issues with water in New Zealand. The two key problems are:

1) water is becoming scarce in certain catchments as demand for irrigation and urban water increases
2) water quality is deteriorating as water flows reduce and nitrate leaching in particular increases.

There is also a surprisingly broad consensus across New Zealand that the current water management regime is ill-equipped to mitigate these problems. The consensus spans:

- cooperatives (e.g. Land and Water Forum, 2012)
- lawyers implementing the RMA (e.g. McGregor, 2007)
- industry and industry representatives (e.g. New Zealand Business Council for Sustainable Development, 2008)
- stakeholder groups (e.g. Deans, 2008)
- regional councils (e.g. Bay of Plenty Regional Council, 2013)
- national agencies (e.g. Hawke, 2006)
- academics, universities and research institutes (e.g. Makgill, 2010; NZIER, 2009).

A number of other issues are also described in the available papers and reports. An issue unique to New Zealand is the role of the Treaty of Waitangi in water management. Another issue is the impact of major projects like dams and flood control works on downstream erosion and ecology. There are difficulties between upstream and downstream water users, too, with regard to water quality and quantity. Finally, changes in land uses result in changes to the way water moves across and through the soil, further affecting surface water and groundwater.

The main weaknesses with the current management regime are summarised below. None of these problems are new to the stakeholders in water management in New Zealand. For example, these problems were signalled by the 2008 Cabinet Paper: New Start for Fresh Water.

First-in, first-served is an inefficient mechanism for allocating water

The Resource Management Act (RMA) process essentially allocates water on a first-in, first-served basis (New Zealand Business Council for Sustainable Development, 2008). When water is already fully allocated, new applications are rejected, even if they offer better economic and environmental outcomes than those already granted. When water is available, applications are accepted if the minimum sustainable management is satisfied, with no regard for the value generated by the use of water.

In a case of competing applications in Marlborough, the Court of Appeal noted (Makgill, 2010):

> *…there is nothing in the Act to warrant refusing an application on the ground that another applicant would or might meet a higher standard than the Act specifies…*

This leads to sub-optimal outcomes where water is not allocated to its best use (Counsell & Evans, 2005). The case of Hale v Marlborough District Council is an example. Hale sought consent to irrigate an eight-hectare vineyard, at a rate of just over one litre per vine per day. This rate was significantly lower than the typical rate of 12 litres per vine per day discussed in the Council's regional plan, yet the Council declined the application because the water source was already fully allocated. The Council's decision was upheld by the court (McGregor, 2007).

Lack of flexibility restricts improvements to the allocation of water

Initial allocation inefficiencies can be improved if there is some flexibility: essentially, mechanisms to change the allocation. However, the RMA process imposes high transaction costs and limits the ability and incentives for water to be traded or transferred. This has many problems. First, the high application costs under the RMA mean that improvements need to be large to make an application worthwhile. In addition, the high application costs create incentives for large transfers, which spread the fixed costs over a larger base, rather than smaller, potentially more innovative applications. Finally, people holding more water entitlements than they need do not face extra costs from doing so. In 2010, it was estimated that 35% of allocation holdings were not used (Aqualinc, 2010). As a result, water is being hoarded rather than being put to valuable use.

By contrast, water efficiency relies on flexibility, on being able to shift water from one use to another. Productive efficiency (or scale) depends on not wasting water, which is relatively costless when water is over-allocated to a specific user. Allocative efficiency (or matching) depends on the ability to move water resources to their most valuable use. Finally, dynamic efficiency (or innovation) relies on the ability to make changes or invest in innovation, which is not possible when allocations are completely fixed. Dynamic efficiency is possibly the most important when considering the contribution of water resources to well-being over time.

Information and data

There are large gaps in our knowledge of water resources and water uses. Much water use is not monitored or regulated, so it is difficult to get a complete picture of water use. Three major uncertainties with information or data make water management difficult. First, the value obtained by competing water users is often difficult to ascertain. This information is critical for determining efficient allocation of water between competing uses. The lack of clear information on the value of water uses often results in costly, ad-hoc and time-consuming legal proceedings to rule on water allocation.

Secondly, the future level of water availability is a result of complex climatic conditions. While this is true regardless of management system, the extent of fully or over-allocated catchments suggests that the RMA process has struggled to manage within this uncertainty. For example, a water allocation status report by the Bay of Plenty Regional Council (2013) highlighted that 62% of surface water bodies in the region were over-allocated.

Thirdly, there is rarely a complete picture of local water resources. An important area of uncertainty is the interconnectedness of surface water and groundwater, and the interactions of different groundwater resources or aquifers. It is also important to consider the impacts of freshwater on inshore fisheries.

The lack of monitoring, feedback loops, and capability also contributes to the problem. The RMA struggles in part because there are no transparent feedback paths for reacting to changing conditions, or frameworks for systematically collating and evaluating information about values from water users. Regional councils are left to make technically and politically difficult decisions about water management, often with limited capability and support from central Government (Cabinet Office, 2008).

2.3. Dealing with the challenges

As stated above, the goal is to get the best use from water, which is a shared resource with multiple and potentially competing uses. We can identify two general principles for dealing with the challenges:

- a first general principle is to allocate the resource until the marginal value from each use is the same across all uses. At that point, allocating more water to one user will reduce the country's well-being: what that user gains will be less valuable than what other users have to give up
- a second general principle is to improve the supply of water – its quantity, quality, timing, spatial allocation and certainty – while the benefits of making those improvements are greater than the costs.

Those are general principles. To put the principles into practice, New Zealand needs to make improvements in a number of areas:

- **information** – as we learn more about the requirements across the environment, society and the economy, we can be better at using water efficiently to achieve better well-being for New Zealanders. This information will be both technical – for example, 'what level of nitrates causes harm?' – and socio-economic – 'how important is it to people to be able to swim in this lake?'
- **technology** – changes in technology will allow us to overcome some of the challenges. Micro-irrigation or drip irrigation, for example, is more efficient with water than flood irrigation. Technologies for mitigating water pollution or cleaning polluted water will continue to be developed. Water storage and distribution can also help re-allocate water across time and space
- **decisions** – on the best use of water based on consultative processes and understanding values and constraints can help balance the competing water uses and provide greater certainty
- **institutions** – durable or resilient institutions that represent negotiated resolutions to water challenges can provide greater certainty for all water uses and users, manage quantity and quality issues across time and space, and provide a mechanism to respond to new information and challenges.

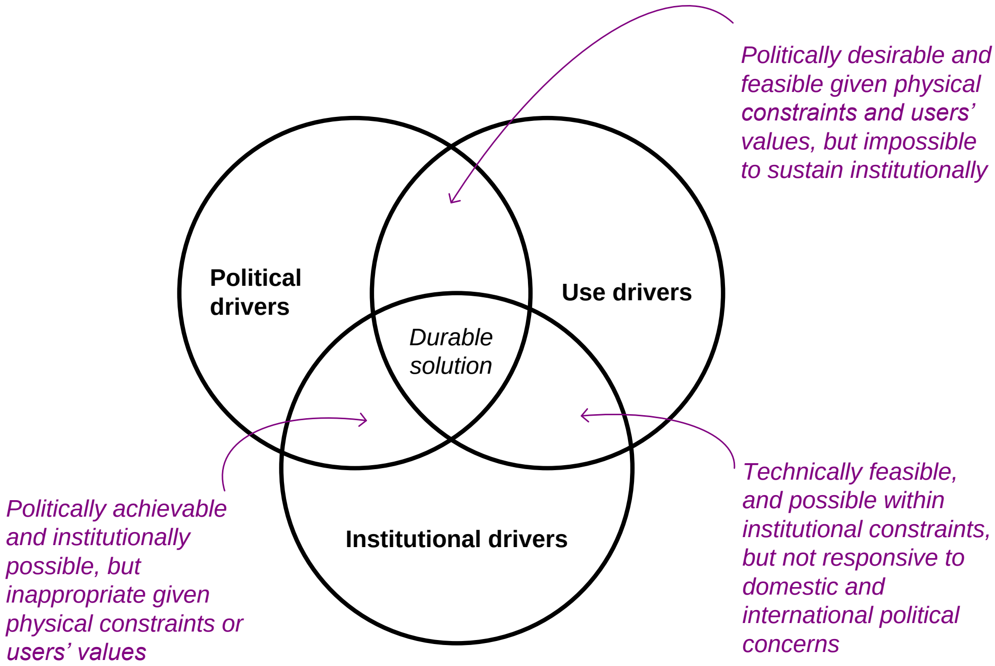
We do not pretend that it will be easy to meet the challenges posed by water. However, we believe that the ad hoc, contested approach (Christensen & Baker-Galloway, 2013) New Zealand has pursued should give way to better policy.

2.4. Multiple drivers framework

In the rest of this report, we provide frameworks for understanding water management, based on the history of water in New Zealand, overseas experience with water management, and solid economic frameworks. The central framework for the report focuses on the multiple drivers affecting water management decisions. The multiple drivers framework is shown in Figure 2 as a set of three overlapping circles:

- **Use drivers** are one circle. Water use is the result of a combination of physical, technological, social and economic drivers. These drivers are described in more detail in Section 3. In addition, ecological and economic models for understanding these drivers are explored in Section 6
- **Institutional drivers** are a second circle. Any water management solution will need to account for existing institutional structures – the framework of rights, the devolution of natural resources management to local bodies, the availability of mechanisms for transfer of water rights, etc. There may be possibilities for institutional development – creations of new rights or new mechanisms – but these may be required before some solutions are feasible. Institutional drivers both in New Zealand and overseas are reviewed in Sections 4 and 5
- **Political drivers** are a third circle. These may be domestic drivers, such as concerns about the election cycle or perceived fit with civic values. They may also be international drivers, such as pressure for New Zealand to achieve according to environmental standards set by international bodies, regardless of their fit with local conditions. We do not focus on Political drivers in this report, although we recognise their importance.

Figure 2 Multiple drivers framework



Source: NZIER

3. Water uses: challenges in New Zealand

3.1. Competition across several dimensions

The Land and Water Forum explored the difficulties of the competition amongst water users and the different dimensions of water. At some times and places, there may be competition for water both across the different well-beings – social and cultural uses competing with economic uses, for example – and between users within a single well-being – such as hydro-power generators competing with farmers. There may also be competing demands for quality and quantity, driven by the requirements of the users.

Table 1 sets out the diverse uses and functions of water, how they compete for water (what type of water use, i.e. extractive or non-extractive) and the importance of water quality to them.

Table 1 Quantity and quality impacts on water uses/functions

<table>
<tr><th>Use/Function</th><th colspan="2">Quantity</th><th>Importance of Quality</th></tr>
<tr><td>Irrigation use</td><td rowspan="2">Consumptive uses[2]</td><td rowspan="3">Extractive uses[3]</td><td>Medium</td></tr>
<tr><td>Residential use</td><td>High</td></tr>
<tr><td>Hydro-generation use</td><td>Non-consumptive uses[4]</td><td>Low</td></tr>
<tr><td>Ecological function</td><td rowspan="3">Other uses</td><td rowspan="3">Non-extractive uses</td><td>High</td></tr>
<tr><td>Recreation function</td><td>High</td></tr>
<tr><td>Cultural function</td><td>High</td></tr>
</table>

Source: NZIER, Land and Water Forum

As Table 1 suggests, competition for water resources occurs across several dimensions of water at once:

- quantity – for most uses, the amount of water is critical. Users will want to have access to enough water for their activities. In addition, some activities 'use up' the water and make it unavailable for others, while other activities do not
- quality – the quality of the water, defined by physical parameters such as dissolved oxygen and quantity of nitrates, is another crucial dimension. Different uses are more or less sensitive to water quality

2 Consumptive uses of water refer to water uses in which water is not returned to its original stream.

3 Extractive and non-extractive uses refer to respectively the out-of-stream and in-stream use of water.

4 Non-consumptive uses of water (such as hydro) means that water is returned to its original stream.

- time and place – for water to be available for use, it must be present at a specific time and place. The possibility of shifting water use across different times and places depends on the use; for some uses, the possibility is quite limited
- certainty – water uses and water users may need some level of certainty that they will have the amount and quality of water they want at the right time and place. For environmental uses, this certainty may be a function of an organism's life-cycle. For economic uses, certainty may be required in order to make investments viable.

3.2. Water quantity

Freshwater is plentiful in New Zealand by international standards. Among OECD countries, New Zealand has the fourth highest per capita water availability after Canada, Iceland and Norway. The high availability of water in New Zealand is due to our relatively small population and the abundance of water resources at the national level. Nevertheless, 'most regions have at least one river (surface water) or aquifer (groundwater) that is either fully or over allocated, or likely to become so' (New Zealand Business Council for Sustainable Development, 2008, p.4).

Pressure on surface water increasing

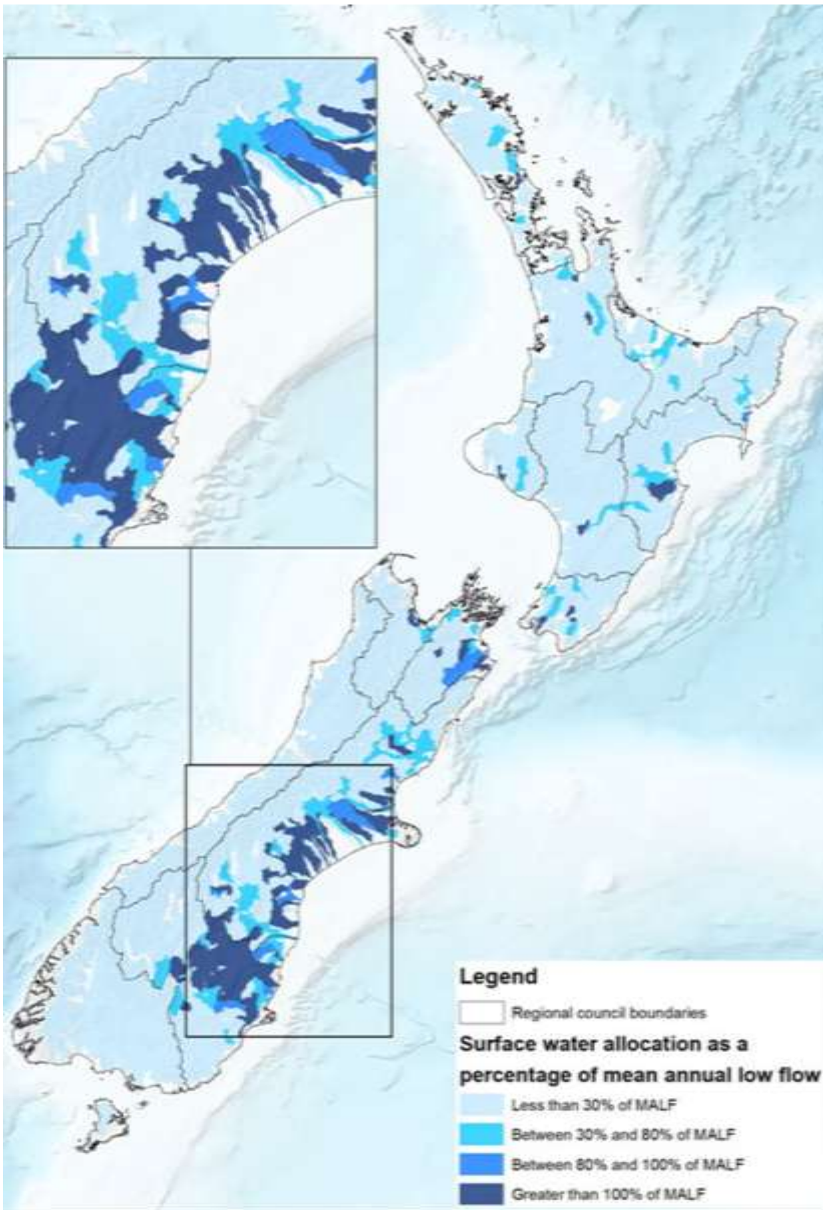
While there is an abundance of water at the national level, water scarcity is increasing in some parts of the country. Regions where surface water is under pressure are Canterbury, Otago, Marlborough, Wellington, Hawke's Bay, Waikato, Northland and Bay of Plenty.

The Land and Water Forum recognised that the problems of water in New Zealand are at the catchment level within regions (Land and Water Forum, 2010, p.1). Figure 3 shows where water might be over-allocated during the driest part of the year by catchments. These are areas where there is pressure on freshwater resources.

A number of catchments have allocated extractions that exceed the total available water; others are fully allocated or approaching full allocation, particularly in the regions of Canterbury and Otago. However, for other regions there is less pressure on catchments. For example, less than 1% of catchments on the West Coast have the potential to come under pressure during dry periods (Ministry for the Environment, 2010d).

Figure 3 Catchment variation in surface water availability

Allocation as a percentage of mean annual flow (MALF) of rivers in driest part of the year



Source: Ministry for the Environment, 2013a

For catchments experiencing water shortages, there is insufficient water to meet all uses. Table 2 sets out the volume of water allocated as a proportion of the mean annual low flow (MALF) for all Canterbury catchments. About half of the river streams in Canterbury are either over, fully or near full allocation.[5] In 2010, over-allocated catchments supplied 20% of the total allocated water in Canterbury (Ministry for the Environment, 2010d).

5 Catchments that are over, fully or near full allocation refer respectively to catchments with more than 100%, equal to 100% and between 80% and 100% surface water allocation as a percentage of MALF.

Table 2 Relative pressure on Canterbury river systems

All catchments, allocations as a proportion of mean annual low flow (MALF), 2002

Catchments over, fully or near full allocation	Allocation proportion	Other catchments	Allocation proportion
Waipara	1282%	Rangitata	78%
Maerewhenua	198%	Orari	67%
Ashburton	173%	Waihao	63%
Opihi	172%	Ahuriri	56%
Hakataramea	99%	Hurunui	47%
Pareora	97%	Waiau	45%
Selwyn	88%	Waimakariri	36%
		Rakaia	35%
		Ashley	34%
		Waitaki	26%

Source: Morgan et al., 2002
Note: The latest available statistics on surface water allocation as a percentage of MALF in Canterbury are from 2002. The allocated share by catchments is likely to be higher in 2013.

There are also significant water shortages in Otago, where half of the catchments have surface water that is either fully or over-allocated (Figure 4). The remaining catchments are likely to face water shortage issues in the near future. In 2010, over-allocated catchments supplied nearly three-quarters of the total allocated water for Otago (Ministry for the Environment, 2010d).

Figure 4 Otago surface water allocation

All catchments, allocations as a proportion of mean annual low flow (MALF), 2006

Source: Otago Regional Council, 2006

Groundwater sources also under pressure

In some parts of the country, groundwater sources are also under pressure. This is particularly true for the Canterbury region. Environment Canterbury has reported that 10 of the 29 zones[6] in the region are fully allocated and six are 'yellow zones' where effective allocation exceeds 80% of the allocation limit (Environment Canterbury, 2011). Similarly, in the Wellington region out of 38 aquifers, four groundwater aquifers are over-allocated, five are fully allocated and six are near full allocation (Keenan, Thompson, & Mzila, 2012).

In problematic regions such as Canterbury and Otago, half or more of all catchments are either over, fully or near full allocation. A smaller number of catchments are facing similar water shortages in Northland, Marlborough, Wellington, Waikato and Bay of Plenty.

[6] Zones can include more than one catchment.

3.3. Water quality

By international standards, New Zealand's water quality is generally good but declining(Parliamentary Commission for the Environment, 2013). The demands from agriculture and urbanisation have led to increasing nutrient concentrations and sedimentation that are adversely affecting water quality.

The Ministry for the Environment uses the quality of groundwater, river water and lake water as indicators of the overall water quality in New Zealand. Groundwater, lake water and river water quality depend largely on the nutrient level in the water, as well as the amount of sedimentation. Table 3 gives the three water quality indicators and their respective trends.

Table 3 Water quality and trend by indicator

Indicator	Quality	Trend
Groundwater	39% of groundwater sites have nitrate levels above natural levels (Ministry for the Environment, 2010b)	20% of all monitored sites have increasing nitrate levels (1995-2008) (Ministry for the Environment, 2010b)
River water (Surface water)	Compared to areas of native forest, median levels of total nitrogen are: - 5 times worse in pasture areas - 9 times worse in urban areas. (Ministry for the Environment, 2010c)	25% of all monitored sites have increasing nitrate levels (2003-2013) (Ministry for the Environment, 2013c)
Lake water (Surface water)	44% of lakes have high to very high nutrient levels (Ministry for the Environment, 2013d)	28% of all monitored sites have increasing nutrient levels (2005-2009) (Ministry for the Environment, 2013d)

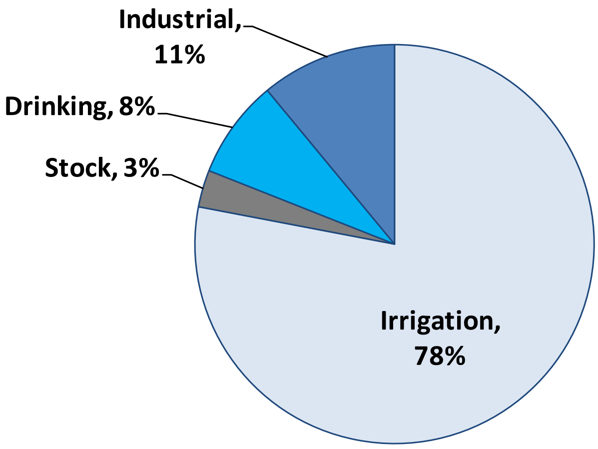
The impacts of past and present water uses on water quality have yet to manifest fully. In some instances, depending on the type of nutrient and on the geography of the catchment, it can take years for the nutrients to affect water quality. The lag between the initial water pollution and water quality deterioration means that the current situation is only a partial representation of the real water quality problem (Land and Water Forum, 2010, p.15).

3.4. Sources of pressure on water

Irrigation use

Irrigation is the largest water use in New Zealand by total water allocated, followed by industrial and drinking use (Figure 5).

Figure 5 Distribution of water allocation by use



Source: Aqualinc Research Limited, 2010
Note: Figures exclude hydroelectric water use.

The use of water for irrigation has grown rapidly since 1999. Between 1999 and 2005, the total consented irrigated land increased by 70% in Canterbury and doubled in Otago. In 2010, the total consented irrigated land of Canterbury and Otago represented close to 80% of national consents. The total consented irrigated land nationally has nearly doubled since 1999.

The growth in irrigation is associated with the decline in water quality. The OECD shows that between 1990 and 2005, New Zealand had the highest percentage increase (>800%) in nitrogen fertiliser and the second highest increase (>100%) in phosphate fertiliser use in the OECD (Land and Water Forum, 2010, p.15).

Table 4 Consented irrigated land by councils 1999-2010

In hectares, change in % between 1999 and 2010 (***in levels change if no consented irrigation land in 1999***), share of total in 2010

Regional councils	Change	Share
Northland Regional Council	-10%	1.3%
Auckland Regional Council	-8%	0.6%
Waikato Regional Council	213%	1.3%
Bay of Plenty Regional Council	72%	1.5%
Gisborne District Council	-48%	0.4%
Taranaki Regional Council	53%	0.3%
Hawke's Bay Regional Council	103%	4.4%
Horizons Regional Council	198%	1.9%
Greater Wellington Regional Council	79%	1.5%
Marlborough District Council	777%	5.1%
Nelson City Council	***28***	**0.0%**
Tasman District Council	48%	1.6%
West Coast Regional Council	***4,143***	**0.4%**
Canterbury Regional Council	70%	63.2%
Otago Regional Council	98%	15.6%
Southland Regional Council	145%	0.9%
New Zealand	**82%**	**100%**

Source: Aqualinc Research Limited, 2010, NZIER

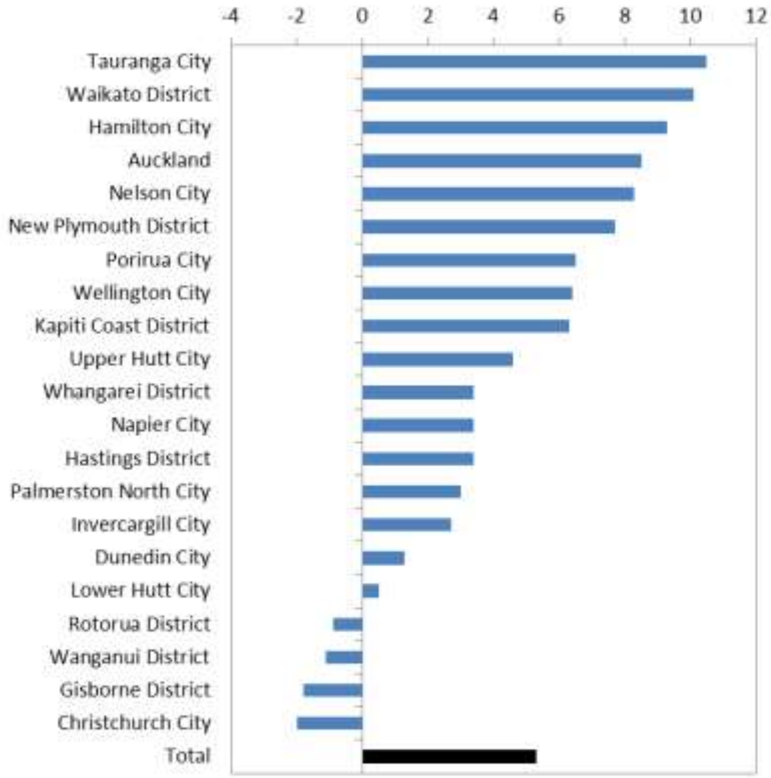
Note: Northland Regional Council's 1999 area could be a significant overestimate as it was entirely determined using estimates due to the unavailability of data on the actual area. (Ministry for the Environment, 2010a)

Urban use

There is an increasing demand for water in urban areas. The increase in residential water consumption is driven by population growth and migration to large urban areas mainly in Auckland and Wellington. Figure 6 sets out the urban population change for the major urban areas between the 2006 Census and the 2013 Census by Statistics New Zealand (Statistics New Zealand, 2013).

Figure 6 Population change 2006 - 2013

In percentage



Source: Statistics New Zealand, 2013

Urban growth related water issues are mainly from sewage leaking from pipes, storm water run-offs and discharges from processing facilities (Land and Water Forum, 2010). These have a significant impact on water quality.

3.5. Summary

Using water wisely for all New Zealanders requires an understanding of the value of water to the various water users. With the right information and framework for understanding water, there is a potential to create durable management of water resources over time by developing regulation that:

- allocates water in a way that reflects how stakeholders value it
- responds to changes in users' preferences, technology and emerging environmental outcomes.

The status of the water problem in New Zealand is that:

- there is significant variation of water quantity issues by catchments
- most regions have at least one river (surface water) or aquifer (groundwater) that is either fully or over-allocated, or likely to become so in the next one to five years

- 39% of groundwater sites and 44% of lakes have nutrient levels above natural levels. However, these are not bad by international standards
- the full impacts of past and present water uses on water quality have yet to fully materialise
- the growth of agricultural and urbanisation are the main sources of water quantity and quality problems, and these are expected to continue.

The main consequence of falling water availability is increasing competition for water between different users and deteriorating water quality in some catchments.

4. Water institutions: a history of New Zealand water

To place the views of current water management into context, this section traces the historical awareness of water issues and the policy responses which emerged to deal with them. The aim is to demonstrate the length of time that water has been considered an issue, and the multiple ways that New Zealand society and politics have responded.

4.1. Ad hoc responses 1840s-1930s

Problems with water became apparent not long after European settlement. They can be grouped under the following headings:

- loss of life due to flooding. Early European settlers located their communities close to rivers to take advantage of the fertile soils and transport links. As these communities developed, the risk of flooding increased. The main reason for this was the short time between rain falling and flood peaks, so much so that in the 19th century drowning became known as 'the New Zealand disease'[7]
- damage to farmland and assets caused by erosion in headwater catchments and flooding and siltation on the river flats downstream. Development in the form of deforestation and the drainage of wetlands accentuated flooding, erosion and sedimentation
- water borne diseases such as typhoid and sanitation issues. Sewage problems grew as towns expanded e.g. one out every three people living in the gold mining town of Cromwell was infected with typhoid.[8]

The government response to these issues included:

- the Public Health Act 1872 and the Municipal Corporations Act 1876 which assisted in creating the town sewage and water supply systems.[9] The ad hoc nature of responses was typified by human waste collection in 1890s Auckland being sited just above Western Springs, the city's drinking water source.[10] However, as waste water and drinking water were gradually separated, the incidents of water borne illness have diminished
- Forests Acts starting from 1874 which eventually led to the creation of the Forestry Service and the reservations of land as either production or protection forest
- various Drainage Acts and Empowering Acts establishing local boards for drainage and flood control

7 See for example http://freepages.genealogy.rootsweb.ancestry.com/~sooty/wanganuiriver.html, http://www.rootsweb.ancestry.com/~nzlscant/deaths.htm, and http://www.localweather.net.nz/smf/historical/today-in-new-zealand-*disasters*-history-10th-april/

8 http://www.pce.parliament.nz/assets/Uploads/PCE-Water-Quality-in-New-Zealand.pdf, p14

9 Ibid p14.

10 Ibid p14.

- the beginning of flood protection schemes in response to specific government directives.

Responses by government were relatively successful when it came to public health issues. The main focus of authorities, as cities started to grow, was on sewage and drainage issues around metropolitan centres. The Christchurch Drainage Board (1875) and the Auckland Metropolitan Drainage Board (1908) were institutional vehicles used to coordinate drainage approaches where in the past there had been fractured attempts among a number of local bodies as to how to approach the sewage problem.

Erosion problems were less well understood and therefore the responses were often piecemeal and ineffective. This is despite many reports, inspections by officials, and commissions of enquiry which attempted to address the erosion issues. This problem was exacerbated by the widespread deforestation in the North Island for mining, logging, and increased land clearance for pasture.

4.2. Interventionist approach 1941-1989

Economic progress between the two world wars and after World War II brought new pressures as town and country developed. Factories and town sewage systems emptied large amounts of pollutants into rivers and lakes. Farms also became more industrialised adding superphosphate and later urea to increase grass growth. With erosion, even more sediment was drained into rivers.

Since the 1940s a number of regulatory actions have been designed to mitigate against the worst aspects of water quality problems. The 1941 Soil Conservation and Rivers Control Act introduced an interventionist approach that lasted for four decades. The Soil Conservation and Rivers Control Council (SCRCC) was established to provide policy and advice to central Government. Further the Soil and Water Conservation Act of 1967 set up a parallel Water Resources Council (WRC), to oversee administration of rights to dam, divert, take or discharge water. Both functions were under the umbrella of the National Water and Soil Conservation Authority (NWASCA), which received technical and administrative support from the Ministry of Works and Development (MWD).

The SCRCC process set up Catchment Boards (forerunners of Regional Councils). These were empowered to levy rates for soil conservation and river control, however most funding came from central Government. SCRCC formulated policies on the rates at which government funding should subsidise different categories of river control and soil conservation; made representations about overall government expenditure on these activities prior to each budget; evaluated specific proposals put to it by Catchment Boards or MWD; and allocated subsidies to schemes that were assessed as necessary, technically adequate and economically worthwhile.

The 1941 Act gave the SCRCC and the Catchment Boards extensive powers to compulsorily acquire land; require landowners to undertake destocking and re-vegetation; enter land, carry out conservation measures, and recover the cost from the landowner; and pass regulations or by-laws controlling the use of land. These powers were rarely used.

Instead the SCRCC and the Catchment Boards attempted to reach their goals by encouraging voluntary compliance from landowners. From 1948 onwards, substantial financial assistance was made available to farmers who were prepared to install conservation measures on their properties in accordance with plans prepared by Catchment Board staff. Much time and effort was also invested in demonstration farms, extension and publicity.

The Waters Pollution Act (1953) set up a Pollution Advisory Council to regulate point source discharges into water. While deemed a success, the inability to systematically monitor and review water standards over time has led to some anomalies and inconsistent actions by regional councils and their predecessors.

As erosion and sediment problems persisted, the Town and Country Planning Acts of 1953 and 1977 gave local bodies extensive powers to regulate land use, by means of planning schemes, in order to ensure ‘wise use’ of land for communities' economic and social benefit. With the exception of zones designed to protect prime agricultural land from urban encroachment, and zones where development was restricted because of natural hazards such as inundation, slope instability or coastal erosion, there were few instances of local bodies using these powers to control land degradation.

Such controls were unpopular with landowners and were frequently subject to applications for specified departures from the district scheme, followed by appeals to the Planning Tribunal if the applications were declined. In rural areas conflict arose between private owners and councils who attempted to use zoning to exclude what they deemed to be ‘unwise’ use, particularly forestry and residential smallholdings.

4.3. The Resource Management Act 1991 – present

As environmental issues became more important during the 1970s and 80s, concern about mitigating adverse effects of land use on water bodies grew. Far-reaching reform was proposed in the form of:

- abolishing the NWASCA (in 1988) and coincidentally the MWD at the same time
- the creation of the Ministry for the Environment (MfE)
- the ending of grants and subsidies for land development
- incorporation of Catchment Boards into regional councils as part of local government reforms
- subsuming water policies into wider issues of environmental management by the replacement of the 1941 and 1967 Acts and also the Town and Country Planning Acts, with the Resource Management Act 1991 (RMA).

Prominent amongst these reforms was the development of the RMA. The executive functions under the Act fall mostly on local government with oversight from MfE. Regional councils are responsible for achieving integrated management of the natural and physical resource base including the maintenance and enhancement of water quality.

The impact of the RMA has been mixed since national values for water have not been defined. There has therefore been little guidance on how to proceed and decisions seem to lack consistency.[11] A key question with implementing the RMA relates to value, both market and non-market. While market values can be observed for property, goods, and services that are bought and sold, other non-market values are difficult to observe or measure. These non-market values include things that are important to New Zealanders: recreation, preserving water resources for the future and maintaining clean waterways irrespective of any expectation of future use. We are still unsure how New Zealanders value water resources or whether some water ways are valued more than others.

In this vacuum, campaigns such as 'dirty dairy' were launched by Fish and Game in 2002, the Clean Streams Accord has been launched and large amounts of public money have been committed to clean up Lake Taupo, the Rotorua lakes, the Waikato river, and Te Waihora/Lake Ellesmere. Without guidance on values for water (and other natural resources), it is not clear how to integrate them into RMA decisions.

To begin to tackle water quality issues the Land and Water Forum (LAWF) began discussions with stakeholders to find a way to bring people together collaboratively. This process and the three reports produced has been the necessary first step in constructive engagement between stakeholders. This process has produced goodwill between participants who previously were protagonists. However, for further progress, resolving the market and non-market value issue(s) is required so that stakeholders have a better appreciation of how much mitigation is required.

The Ministry for the Environment and the Ministry for Primary Industries have taken the lead with the establishment of a Water Directorate. The Water Directorate has coordinated research and provided regional councils with detailed social, environmental and cultural information to inform regional choices in Southland and Canterbury.[12]

This is a significant step forward. It has filled some of the gaps in New Zealanders' knowledge of the social, cultural, environmental and economic information required for regional councils to make effective and efficient water management decisions. However, this is only a start of the process since all regional councils require this type information to make good water management choices. Assisting regional councils to make good water management decisions requires good communication between central and regional government, building capability, and providing research that directly answers the policy questions in each catchment.

4.4. Summary

Apart from the individual agreements to clean up rivers and lakes, history shows that there has been little consistent water policy over time. The lack of consistency is a two-edged sword. It makes planning and investing around water use and infrastructure uncertain, which reduces investment in solutions. However, it also means that there is little historical precedent that must be respected; New Zealand has considerable scope to craft new and appropriate policy. The lack of action to date

[11] See for example, Harrison Grierson & NZIER (2011) Freshwater Management National Policy Statement Section 32 Evaluation P31. Report prepared for the Ministry for the Environment.

[12] http://www.mfe.govt.nz/issues/water/freshwater/supporting-papers/index.html

has an upside: there is a chance for the parties to sit down and make a fresh start on water management options. The RMA and the LAWF process provide a solid base from which to start the negotiations.

What history does show, however is that without a clear understanding of the problems we face, how New Zealanders value the problem (both from a market and non-market perspective) and engagement of those affected by regulation, then decisions are likely to be ad hoc, short term and require constant revision.

5. Water institutions: international experiences

Our review of New Zealand reports and papers on water issues revealed that there has been widespread consensus on the problems of water management in New Zealand, and indeed on many solutions, for much of the last decade. However, little has changed. This suggests there may be transitional issues that need to be considered. In this section we briefly review the Australian and Chilean experiences with water management, and document some lessons learned for New Zealand.

5.1. Australia

5.1.1. A brief history of Australian water management

Australian water management has evolved over time. Initially water rights (or entitlements) were bundled with land. As early as 1984, water rights in some regions were unbundled, allowing entitlements of water to change hands independently of sales of land. However, such steps towards water trading were typically tentative, beginning with just temporary seasonal allocation trading, and limited to defined irrigation zones (National Water Commission, 2011).

The Council of Australian Governments (COAG) reforms in 1994 increased the pace of water reform. More and more regions unbundled water rights from land rights, and trading of entitlements between irrigation zones was allowed.

In unbundling water rights, entitlement norms were set for each use category, based on consensus from intensive public participation. Those users with a history of using above the norm were typically granted either a grandfathered allocation that could not be passed on, or progressive reduction factors to ensure the user's right moved toward the norm over a reasonable time period (Haisman, 2005).

In the Murray-Darling Basin (MDB), Australia's largest irrigation zone, the initialisation of the market with tradable water rights led to an over-allocation of water. This was largely driven by the activation of 'sleepers' and 'dozers', terms for previously unused or underused allocations.

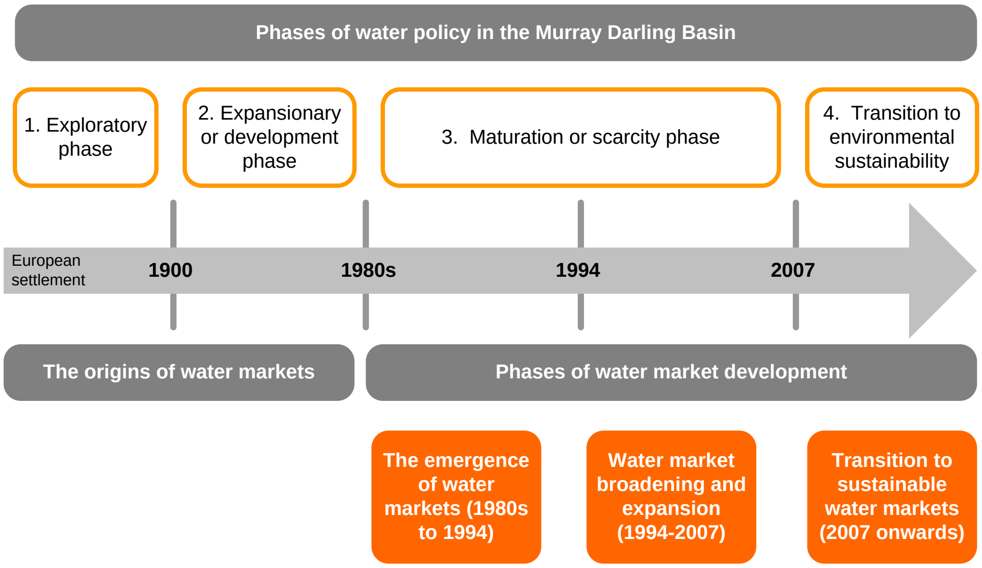
In 1995, the MDB cap was introduced as a policy measure to limit over-allocation and associated environmental issues (Quiggin, 2007). The cap ensured that any expansion or new use of water had to be purchased from an existing user. This meant the cap was effective in limiting any further over-allocation of water in the MDB, but it did nothing to reduce the over-allocation. Furthermore, the cap was not based on scientific assessment of environmental needs but simply on historical 1993-94 allocation levels. This meant debate still continued about the 'right' level of entitlements.

With the millennium drought, environmental conditions in over-allocated systems deteriorated. Initial government mechanisms focused on restricting or claiming back water entitlements to sustain minimum environmental flows. However, this process was politically difficult as the environmental science was less than certain, while the local economic impacts appeared to be high. The National Water Commission (2011) notes:

> *At the heart of the debate were the question of whether compensation should be paid when pre-existing entitlements to water are reduced, and the level of such compensation.*

Continued environmental deterioration ultimately led to the development of the government's buyback program in 2007. The program committed $3.1 billion over 10 years to buy water entitlements in the MDB for environmental purposes.

Figure 7 The evolution of Australian water markets



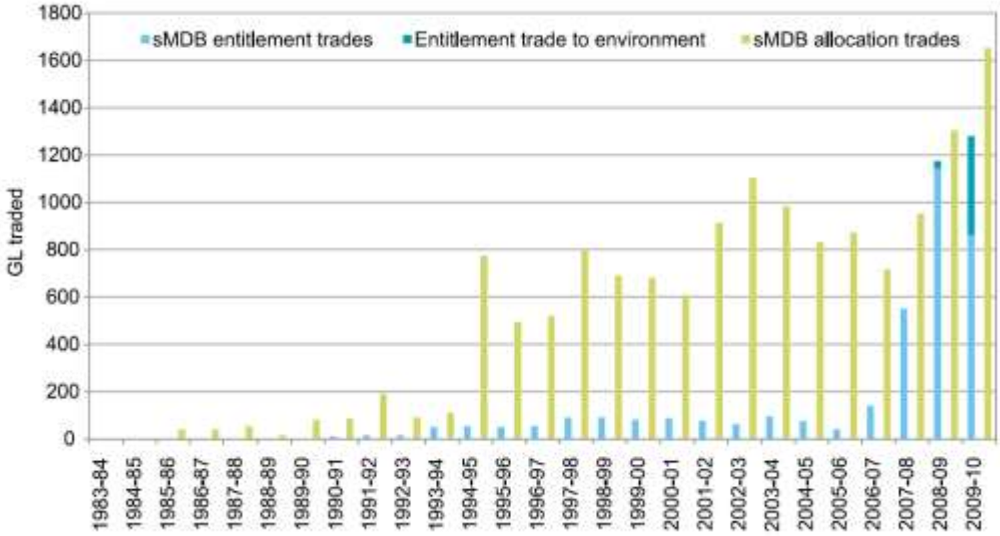
Source: National Water Commission (2011), adapted from Musgrave (2008) and Watson and Cummins (2010)

5.1.2. Australian water policy today

Australia's current water management makes strong use of markets and water trading to allocate water to its highest value use.[13] Trading can be either short term (annual allocations) or long term (permanent entitlements). Over 90% of trading in Australia occurs in the MDB (National Water Commission, 2011). Figure 8 shows that the volume of water traded in the MDB has increased dramatically over the last 30 years. Today around a quarter of total water available for consumptive use is traded (Varghese, 2013).

[13] The main non market values used in both Australia and Chile were those associated with environmental impacts (particularly minimum flows). Other recreational values have been built into the minimum flow requirements (Grafton et al, 2011 explores this in more detail).

Figure 8 Water trading in the MDB



Source: National Water Commission (2011)

There are a range of conditions and additions to trading that attempt to include environmental values into the market. These include:

- management of salinity to ensure the trade does not have adverse impacts. In Victoria this is achieved by defining zones according to salinity. Extra charges are imposed on trades to create disincentives for water movement that increases salinity concentrations (National Water Commission, 2011)
- restrictions on trade to reduce socio-economic concerns for towns and regions. For example, a limit restricts the volume of trade out of an irrigation zone to a maximum of 4% of total zone entitlements, although this limit is being phased out by 2014
- buyback of water entitlements to sustain minimum environment flows and to reduce over-allocation.

5.1.3. Evaluation of Australia's water policy

The development of water markets and the increase in water trading has led to an improvement in the allocation of water between consumptive users. A range of quantitative assessments have found that water trading has allowed water to flow to higher value uses, and shown that it reduces the negative impact of droughts or lower water availability (ABARE–BRS Water Economics Section, 2010; Grafton, Libecap, Edwards, O'Brien, & Landry, 2011; KPMG, 2011; National Water Commission, 2011; Productivity Commission, 2003).

However, trading and water markets in general also have a range of detractors. A first criticism covers the initial over-allocation of entitlements, and in particular the activation of sleeper and dozer rights. A second criticism of the water market is the ill consideration of the environmental system as a whole. Assigning entitlements and developing a market for surface water covers only a part of the hydrological system. Thus, while surface water extraction is now priced, water can be captured at other points in the cycle at no cost. For example, groundwater can be extracted from bores; surface water can be collected in on-farm dams, and rainfall can be captured before it enters into the common waterways (Quiggin, 2007).

Collectively then, critics suggest development of the water markets has increased the demand for water and reduced the water flowing back into the system; that the market mechanism which was introduced to allocate the resource efficiently in times of scarcity has contributed to the scarcity (Crase, 2008).

5.2. Chile

5.2.1. A brief history of Chilean water management

The 1981 Water Code clearly established legal rights for water that were subject to the same rules as other property rights. Under the Code, water could be traded as per real estate, and the State had very limited powers to intervene in the management of the resource (Bitran, Rivera, & Villena, 2011).

Initial allocations were granted free of charge to essentially all who wanted them. Once granted, the Code gave right holders freedom over their use of the water (Madden, 2010).

Initially, trading was intermittent at best under the new Code. Bauer suggests that owners were retaining surplus rights rather than selling them (Bauer 1995, in Madden, 2010). With free allocation continuing when water was available, the lack of scarcity no doubt also played a significant role by keeping the value of any water permit low.

Transaction costs and geography also were important. A study by Hearne & Easter (1995) found that trading was significant in only one of four river valleys where water markets were thought to be active.

In 2005 a major reform of the Code was implemented. The reforms established a fee for unused rights to promote more active water trading. The reforms also established a water flow restriction based on environmental minimum flows. This allowed the State to reject granting rights to preserve environmental flows (Bitran et al., 2011).

5.2.2. Chilean water policy today

As in Australia, Chile's water management makes strong use of water markets, supplemented with minimum flows established on environmental grounds. However, while some catchments have high levels of trade, many others have experienced little or no trade and a resultant low price of water.

The government has focused on improvements to the administration of trading, such as providing better information and transparency, to help trade to grow (Global Water Intelligence, 2010).

Maria Victoria Rojas, the chief technical officer at Leau, Chile's first water trading company, notes of the 2005 changes (Global Water Intelligence, 2010):

> *The reform introduced the fee for non-use, strengthened the role of auctions as a mechanism to reallocate rights, and introduced*

the obligation to justify requests for water rights. As a result, people's perception that water is free of charge is starting to change. The market has recently become somewhat more sophisticated, which has translated into more rights holders asking for our services.

However, with the continued increase in demand for water, some catchments are experiencing environmental degradation. New hydro-geological models are being developed to help inform the required minimum flows (Bitran et al., 2011).

5.2.3. Evaluation of Chile's water policy

As in Australia, the development of water markets and the increase in water trading has led to an improvement in the allocation of water between consumptive users. A review of Chilean water trading has found that it allowed water to flow to higher value uses, although issues with minimum flows (ecological uses) and efficiency promotion have not been resolved (Solanes & Jouravlev, 2006).

However, there are also regions where trading has been minimal and the price of water low, which saw the unprecedented policy response of incentivising use of rights by charging a fee on unused rights. The lack of trade suggests there was little water scarcity or that costs to trade were high (Madden, 2010; Solanes & Jouravlev, 2006). Such costs include a lack of information about the market and confidence in the regulatory framework (Harris, 2011). Geographical or physical barriers are also a strong deterrent to trade (Madden 2010).

During the development of the water market, environmental outcomes suffered with a deterioration of aquatic ecosystems in semiarid and arid regions (Harris, 2011). The reforms to the Code in 2005, including minimum environmental flows, appear to be improving the situation (Harris, 2011), however the management system needs to be flexible at dealing with new evidence as the science develops.

5.3. What we can learn from Australia and Chile

Australia's water policy has evolved over time, and reacted to problems as they have arisen. New Zealand is in a much better position to design water policy that actively seeks to manage trade-offs and potential issues up front.

Chile's water policy is probably the world's most free-market approach. Its climate and hydrological conditions are more similar to New Zealand than Australia.

There are a number of lessons we can take from both the Australian and Chilean experience in water policy, which parallel lessons from other countries (Greenhalgh & Selman, 2012):

- focus on achieving the most value from water
- use science to determine minimum flows to sustain healthy water ways, and be flexible and adaptive in the management of the environment as scientific knowledge improves

- use markets to allocate water between competing uses when conditions allow, but be aware that markets will not solve all problems, and may cause some if not managed: a market will incentivise under-used permits to be used or sold. If left unchecked, this could dramatically increase New Zealand's water use as about 35% of current New Zealand allocations aren't used (Aqualinc Research Limited, 2010)
- don't over-allocate permits. Australia suffered significant environmental issues due to the over-allocation of water during the initial phases of the water markets. This meant reactive, costly and politically difficult policies such as buybacks were required
- trading will not be an effective allocation mechanism if there exists significant physical, regulatory or information barriers. An efficient trading scheme needs to lower these barriers where possible
- add to or constrain the market to incorporate further externalities. Australia faces specific environmental issues that trading can exacerbate, such as salinity. These issues can be incorporated into the market framework
- use a consistent framework across all regions. State parochialism was a significant inhibitor to fully-functioning water markets in Australia
- where possible include urban areas within the same framework.

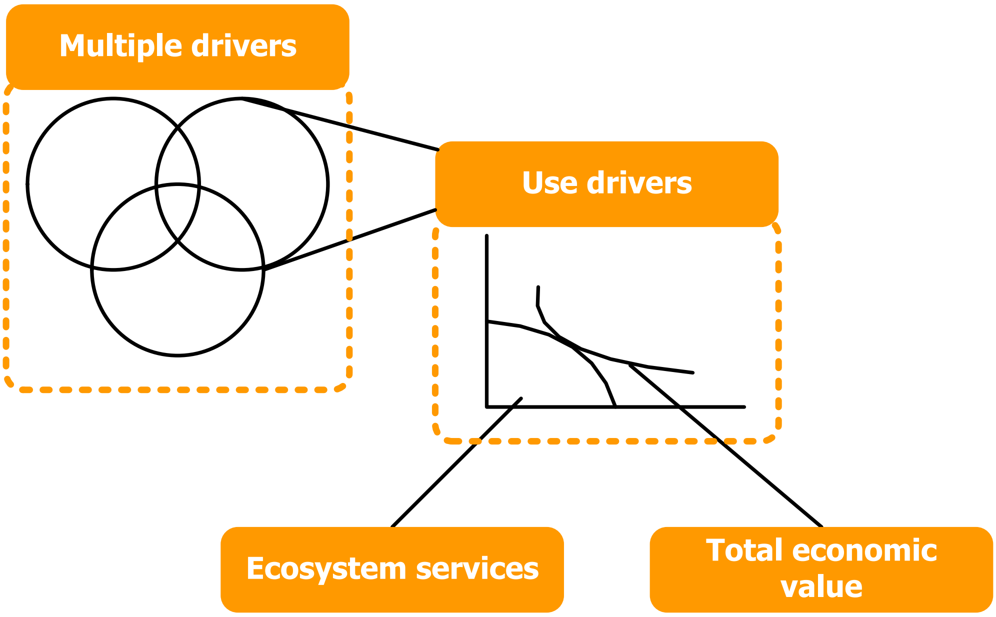
6. Thinking about solutions

We present several different frameworks for thinking about water. A framework is a representation of reality that identifies the important elements and describes the structure of their relationships. Frameworks are often drawn as diagrams or flowcharts in reports, but they are truly useful when people can carry them around in their heads as mental models to aid their thinking. The frameworks described here are simple on purpose, so that they can be such mental models.

We decided that a set of related frameworks was needed. No single framework captured all the necessary elements; each one provided insight into some aspects of water management. Figure 9 shows the frameworks and their relationships to each other. The multiple drivers framework provides an overview of issues surrounding water management and policy. One set of drivers are use drivers – how water could be used. These use drivers can be divided into ecosystem services – the supply side – and total economic value – the demand side.

Figure 9 Water frameworks

Interrelated frameworks for thinking about water management in New Zealand



Source: NZIER

Together, these frameworks provide a full picture of economic concerns, and then place those concerns into the wider context. Each of the four frameworks is described in the sections below. Further on, we will apply the frameworks to a few New Zealand-relevant questions and issues around water to show how these mental models can be helpful.

6.1. Multiple drivers framework

Our overarching framework for understanding water policy is the multiple drivers framework. We introduced the framework in Section 2.4 and it is shown in Figure 2 as a set of overlapping circles with three elements:

- Use drivers
- Institutional drivers
- Political drivers.

As we have already suggested, where the three circles overlap is a space representing durable water management solutions. They account for the physical constraints and the values of water users; they are responsive to political concerns; and they fit with the institutional structure that either exist or can be created. Outside this space, any attempt at assembling a water management solution will not be resilient to pressures. It may be overwhelmed by political pressures, it may not have the institutional backing required, or it may not represent the values of New Zealanders or the physical limits of ecosystems. To use water wisely for the well-being of New Zealanders, the challenge is to work our way towards a durable solution that balances the multiple drivers.

To understand the current shape of water issues in New Zealand requires us to examine the interplay of the political, economic and institutional drivers. Furthermore, it is how these three sets of drivers reinforce each other that determines and informs approaches to water management. They also determine the extent of the efficiency, effectiveness, innovation and durability of the regime.

As Figure 9 indicates, the bulk of this section will explore the use drivers further. Before moving on to that discussion, we briefly discuss institutional drivers.

Institutional drivers

The institutions around the provision and use of freshwater are key to any water management regime. The institutions must be able and willing to support whatever plan is developed. The literature on water management regimes and the history of New Zealand suggests that there are a number of important institutional issues, which we summarise here.

Administrative costs: It is important to understand how costs associated with water regulation will fall on users and non-users. These include compliance costs imposed by regulatory bodies on participants, administrative costs incurred by the regulatory bodies, and wider costs on society. The extent to which a proposed approach imposes such costs should be considered as relevant since they are likely to be significant.

Information availability: To perform in an efficient and durable manner any water management regulation will require information and data. The key requirements are that information is sufficiently complete, is available to the parties that need it, and provided in a way that can be understood by the parties.

In evaluating options it is important to determine the extent to which the proposed approach ensures high quality accurate information is available to participants in a timely manner. For example, if stakeholders are required to enter a contract of some sort they will need to know whether conditions are subject to change at short notice, particularly if it changes their position in their market; whether they face more transaction costs; and other relevant information that has a bearing on the contract and was not known when the contract was signed.

Regulatory certainty and discretion: Decision makers will also need to understand and take into account the extent to which future, unknown changes in regulatory policy or approaches could limit the returns to a particular regulatory decision. With a longer investment, a higher probability of regulatory change will increase the risk premium on the investment. The investor will need higher returns in the short to medium term in order to be persuaded to take on the investment associated with the risk. Therefore, the successful design of water management policies depends on how adaptable they are to changes in science, targets or environmental circumstances (e.g. droughts).

Practicality and robustness: Identifying whether a proposal can be practically implemented is also an important factor to be considered. That is, is the proposal compatible with the New Zealand economy and culture? Is there any international experience that can be drawn on?

Other issues that need to be considered include:

- What are the likely timeframes for implementation?
- What are the risks that the implementation will not be completed or will be imperfectly implemented (perhaps because only elements of the proposal are achieved)?
- How robust is the proposal given changes in the environment? Is flexibility required (related to regulatory certainty and discretion)?
- Can or should a market-based institution grow as water is used more efficiently? Will a larger market increase the complications associated with implementation?
- How will the regulations accommodate different geographical and climatic conditions?

Competitive effects: Consideration of the competitive effects and the extent to which regulatory design features encourage competition for water take/discharge (input market) and final product markets (output) needs to be further understood. Competition can improve efficiency, drive down mitigation costs, and lower the overall economic cost. The more open the market, the more likely it is that stakeholders will find different ways to reduce discharges or use water more efficiently. In output markets, it will become more important to consider how water management policies will impact on the competitiveness of firms e.g. the initial allocation of resource rights may impact on a firm's costs as well as impact on the ability of new competitors to enter the market.

Implications: Incomplete institutional frameworks create uncertainty. The gaps in the institutional structure mean that New Zealand policy makers do not have the full capability to make the best use of water. This allows other stakeholders (industry, community and political) to take stances that could potentially mitigate against a durable water management solution.

6.2. Use drivers

Use drivers are one of the three circles in Figure 2 and include the economic considerations around water use. The economic concept of a general equilibrium analysis provides a framework to think further about the drivers of water use. It recognises that there is both a supply side and a demand side.

On the supply side, technologies and resources provide a range of potential ways to use water. These are represented by a **production possibility frontier**, which indicates the possibilities for using water – all the ways that the total supply of water in New Zealand could be allocated across all its uses.

On the demand side, preferences and technologies combine in different ways to reflect the things that New Zealanders value. These values can be shown graphically with **indifference curves**. They can be used to depict the demand of things from water. Combining production possibility frontiers and indifference curves produces a general equilibrium analysis.

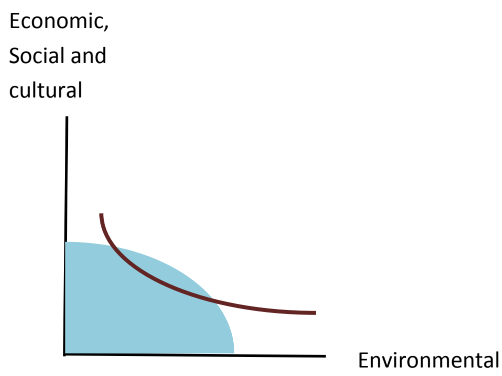
The basic framework is shown in Figure 10. As we have been discussing throughout this paper, water has many dimensions and there are many well-beings to consider. In the interests of presentation, we have reduced them to two dimensions. We recognise that this presentation simplifies the situation, but it does allow it to be represented graphically. The blue shape in Figure 10 represents the feasible space of possibilities, or the production possibility frontier. It depicts the possible uses of water, given available information and technologies. The shape recognises that some uses will contribute across more than one dimension, but also that limits will be reached. In a total sense, there is a finite amount of water. In a relative sense, more water allocated to one use may mean less allocated to another. This shape describes the physical possibilities of using water.

Figure 10 also shows the values that people place on the different uses of water, using an indifference curve (the red curve). The curved line describes the trade-offs that people are willing to make across the different uses, or the relative values that people place on the uses. People value more of both dimensions shown: more and better environmental functioning, more and better uses of water for economic and social and cultural benefits. They are also attuned to relative scarcity: for example, as less of the environment is available to them, they value it more highly.[14]

[14] There are many different ways to represent indifference curves to represent different trade-offs, such as perfect substitutability, minimum thresholds, and more. The indifference curve used here is based a number of assumptions about preferences for water, including transitivity and completeness (Deaton & Muellbauer, 1980).

Figure 10 Use drivers – general equilibrium framework

A general framework for water use and management



Source: NZIER

Figure 10 includes or accounts for the following aspects of water uses and management:

- there is a range of the technical possibilities for water uses that contribute to all the well-beings – this is the blue space
- people place value on different combinations of economic, environmental and social and cultural uses of water – this is the red curve
- some of these combinations of desired uses are feasible – the red curve is sometimes inside the blue space
- some of the desired combinations are not possible – the red curve is sometimes outside the blue space
- some desired uses may not use all the available water, so there may be some left over for other uses – the red curve is sometimes inside the blue space.

This use drivers framework has some important lessons for managing water:

- some combinations of demands on the water supply will be technologically impossible to satisfy
- there will be range of combinations that are feasible, rather than a single solution
- there may even be combinations that free up more water for additional uses.

In the next two sections, we dig further into both the supply and demand sides, using the ecosystem services framework and the total economic value framework. Ecosystem services are a way of describing the possibilities for using water to provide services that people value. Total economic value captures how much those goods and services are worth to people, across all the different types of value.

Ecosystem services and total economic value are often discussed with regard to the environment and natural resources. For example, research for the new Natural

Resources Framework (Ministry for the Environment, 2013b) considered both of these frameworks, but considered them in isolation rather than in combination with each other. Each one is incomplete. By bringing the two together – production and consumption, supply and demand – we create a framework that helps us think better about water management.

6.3. Ecosystem services framework

The ecosystem services framework is a way to describe what water can provide to New Zealanders. It provides a framework to understand the relationship between natural resources like water and human well-being (Figure 11).

Figure 11 Definition of ecosystem services[15]

Source: NZIER

Ecosystem services are defined as the benefits people obtain from ecosystems. Ecosystem services are divided into four categories of services (Millennium Ecosystem Assessment, 2005).

- provisioning services
- regulating services
- cultural services
- supporting services.

Provisioning services of ecosystems provide resources that humans use; they are the products obtained from ecosystems. Examples include food production, fibre production and freshwater for commercial, industrial and domestic use. Provisioning services represent the bulk of natural resources that support economic well-being.

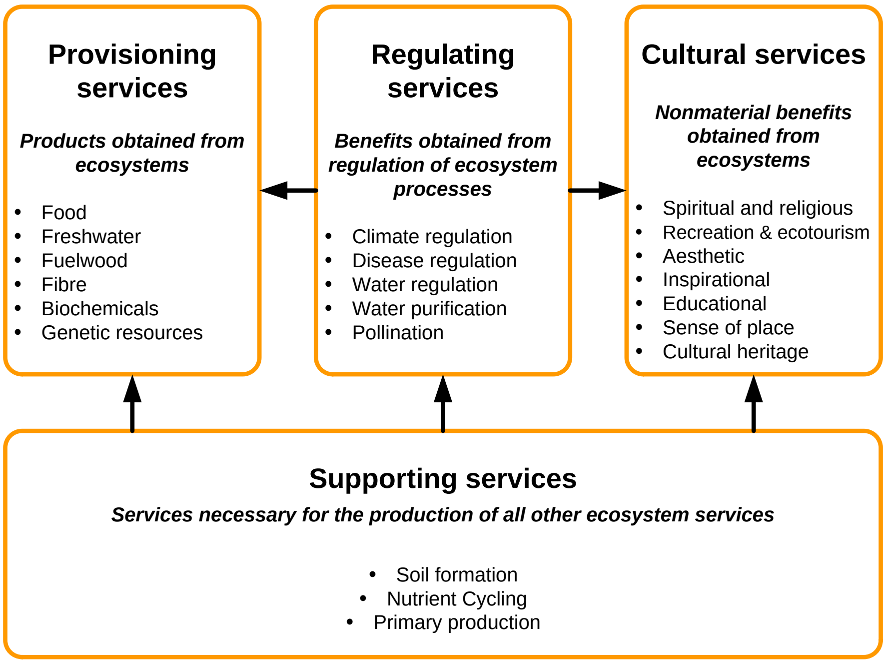
Regulating services are the ecosystems' capacity to auto-regulate themselves, to absorb human emissions and still remain stable. One of the most important regulating services may be the regulation of global climate. The treatment and detoxification of waste products is another major one.

Cultural services are the capacity of ecosystems to 'inspire people and produce non-material goods' (Dominati, Patterson, & Mackay, 2009). These are also non-material benefits people obtain through spiritual enrichment, cognitive development, reflection, recreation and aesthetic experiences. Cultural services are tightly bound to human values and behaviour. Perceptions of cultural services are likely to differ among individuals and communities.

Supporting services are those that are necessary for the production of all other ecosystem services. Their impacts on humans are either indirect or occur over a very long time. For example, people do not directly use soil formation services. However, changes in this service would indirectly affect people through the impact of provisioning services, such as food production. Changes in the other ecosystem services have direct or short-term impacts on people.

15 The ecosystem structure refers to biological, physical and chemical components.

Figure 12 Ecosystem services framework



Source: Adapted from Millennium Ecosystem Assessment, 2005

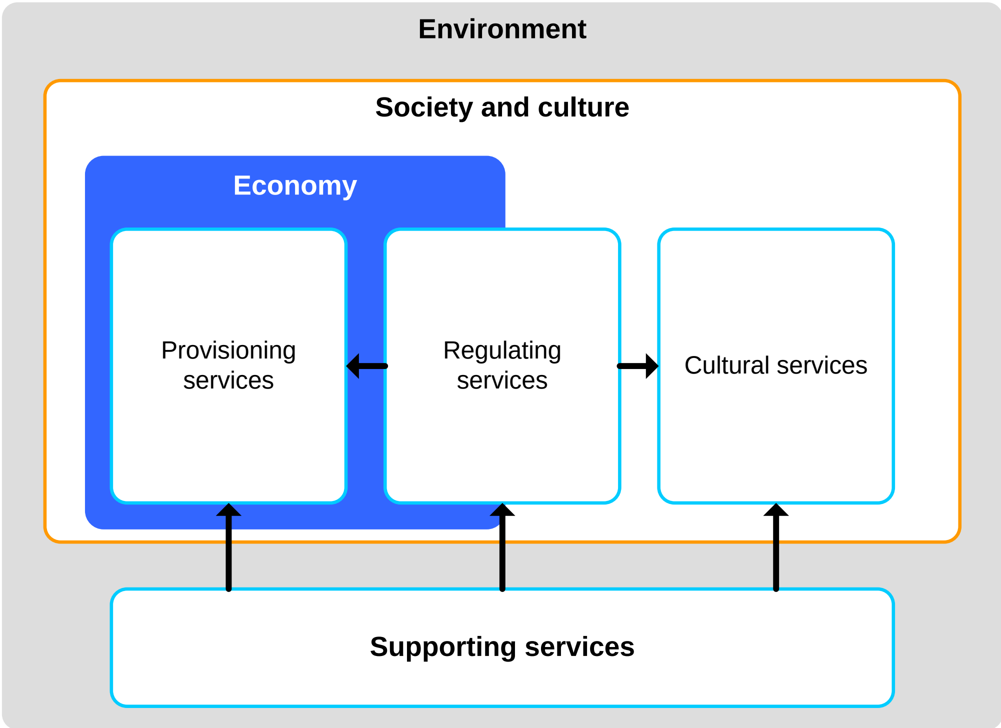
The different ecosystem services are interdependent. The distinctions amongst them rely on the kind of well-being they generally provide (Millennium Ecosystem Assessment, 2005). The four ecosystem services tend to relate to a certain type of well-being.

Provisioning services tend to relate mainly to the economic well-being (Figure 13). They are products obtained from ecosystems. Provisioning services depend on regulating services, thus so does economic well-being. Food production from agriculture, for instance, relies strongly on climate and waste regulation.

Economic well-being is embedded in the social and cultural well-being. Regulating and cultural ecosystem services tend to relate to the social and cultural well-being. This well-being includes spiritual and religious values, aesthetic values, educational values and recreation (including ecotourism).

Supporting services contribute to all the well-beings. In a direct way, they contribute to environmental well-being. In indirect ways, they contribute to all well-beings. An example might be the production of oxygen gas, categorised as a supporting service. Oxygen contributes directly to people's environmental well-being. In addition, oxygen supports the existence of people as well as animals for food production, thereby making a contribution to all the well-beings (Figure 13).

Figure 13 Relationship between ecosystem services and human well-being



Source: NZIER

There are significant connections between the different ecosystem services. Showing the linkages of the ecosystem services with the different well-beings allows us to understand these connections.

The ecosystem services approach allows us to understand that:

- ecosystems provide a range of ecosystem services that are interdependent
- the well-beings depend on the four different ecosystem services for support
- the well-beings are supported directly and indirectly by the different ecosystem services.

6.4. Total economic value framework

The single indifference curve shown in the use drivers framework (Figure 10) summarises a lot of information about relative values. We can now explore those values further, using the total economic value framework. This framework is a standard economic tool for categorising and exploring the different sources of value. It provides a way to capture all the ways that people value natural resources. The framework is set out in Figure 14.

One way that people derive value from natural resources is by using them. Use values are relatively easily defined into direct uses – mainly commercial uses that are reflected in the economy – and indirect use values such as water sports. People derive value from using water. They may use the water for irrigation, and then sell the resulting produce. They may enjoy swimming in a lake or fishing in a river – the water contributes to the value people derive from those activities.

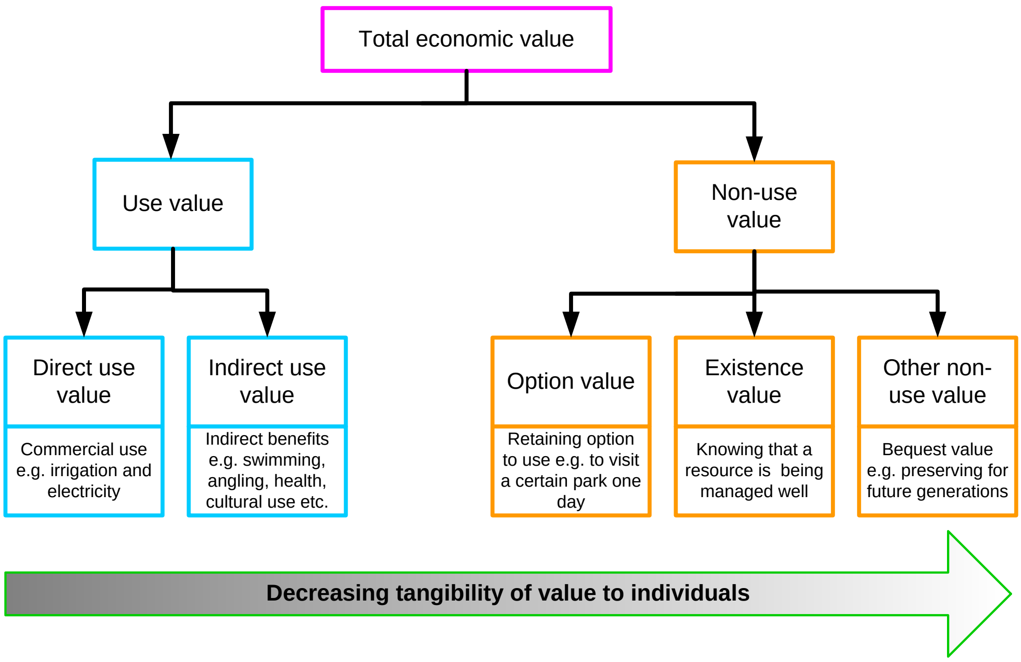
Water also provides what is called non-use value. Non-use value is something that people derive from water without actually using it, either directly or indirectly. A non-use value can be an option value (preserving the ability to use it later, such as when commodity prices improve), the existence value (preserving and improving what we have) and other non-use values (preserving something for future generations).

As we move from commercial, direct use of water to non-use values, particularly things like preserving rivers for future generations, we move from more tangible values to less tangible. More tangible values tend to be easier to quantify, and are often observed in markets. For example, it is possible to find out the price of milk powder and relate the price to the amount of water used to produce the milk powder (this is the 'embodied water' concept). This exercise would produce a quantitative, tangible estimate of the value of water. By contrast, non-use values are harder to observe. They often require targeted research to uncover.

Under the RMA, the benefits from use and non-use values are all equally important and as far as possible the assessment considers not only the more easily obtainable costs but the more intangible benefits. Many of the non-use values are not priced in markets; however, this does not mean they are not valuable. In fact, the RMA expressly points to:

> *managing the use, development, and protection of natural and physical resources in a way, or at a rate, which enables people and communities to provide for their social, economic, and cultural well-being (Section 5(2)).*

Figure 14 Total economic value framework



Source: Serageldin, 1999

6.5. Summary of frameworks

The section has reviewed several frameworks, which are nothing more than mental models that can help us make sense of water management. We have reviewed four frameworks that are essential for understanding water:

1. the multiple drivers framework recognises that decisions about water use must take place in a specific political and institutional context, without forgetting the physical constraints or the values of water users
2. the use drivers can be considered in a general equilibrium context, which combines the physical descriptions of the possibilities and limits of water with the multiple ways that people can derive value from water, and gives us a way to talk about limits, feasibility, values and trade-offs
3. the ecosystem services framework allows us to understand the physical and environmental limits of water use, as well as the multiple services that water performs for society and the environment
4. total economic value is a way to discuss the many different ways that water users derive value from water, both the marketed values and the non-market values.

Taken together, along with consideration of New Zealand's history and overseas experiences, these frameworks provide the tools for thinking about water issues and working towards durable water management solutions.

7. Applications

The test of these sorts of frameworks is their application. In the following sections, we review a selection of key issues. We link each issue to the historical information and international experience, and demonstrate how the frameworks help us think about the problems. We also show how the information and frameworks can help us work towards solutions.

7.1. Trading

Water trading is an important issue. Trading in water quality permits (nitrogen permits) already exists in New Zealand, and water quantity and quality trading exists in several places around the world. Thinking about trading using our frameworks, we find the following:

- trading may not be sufficient to solve the problems facing individual catchments (water challenges in New Zealand)
- it has been tried elsewhere (international experience)
- it fits with New Zealand history of water (New Zealand history)
- initial allocations are important particularly if over-allocation occurs (international experience, technical and political drivers)
- institutional design matters (international experience). New Zealand is too small for regional councils to design 'bottom-up' water management schemes for each catchment, therefore a centralised management system with specific catchment characteristics and data incorporated into the design is required (institutional and political drivers)
- there may be concerns about the 'fair price' of water, and pressure to ensure that the public and iwi receive value from private use of water (institutional and political drivers)
- trading requires good and appropriate design; it may be too difficult in specific areas or situations (institutional drivers)
- it may not be politically feasible (political drivers)
- technology can move water to times and places where it is more valuable or useful (ecosystem services, production possibility frontier)
- trading can move water from low value uses to high value uses (total economic value, indifference curve).

The lessons from trading suggest that water trading can offer possible improvement. It would benefit from central Government leadership and design, because of the resources required to do it well. It also requires catchment characteristics and data, to account for local variation. However, providing the opportunity to trade does not mean that trading will take actually place in a catchment. Initial allocation of water can be crucially important, and people may retain their allocations to manage risk. Encouraging the trading of water allocations so that water is put to best use requires institutional and political support.

7.2. Water pricing

From an economic perspective, an important consideration is that water users do not face prices that account for the true cost of water. As a result, some sort of water pricing mechanism is often suggested as a solution. Using our frameworks, we suggest:

- water pricing will likely require different pricing in different areas/catchments (water challenges in New Zealand)
- water pricing has been tried elsewhere (international experience)
- it fits with New Zealand history of water – pricing has occurred in some times and places (New Zealand history)
- it requires ways to meter water and pay for it (institutional drivers)
- pricing may not be popular with rate-payers (political drivers)
- pricing can either conserve water for use when and where it is more valuable, or provides funds for expanding infrastructure to improve water supply (ecosystem services, production possibility frontier)
- pricing encourages users to determine whether they are using water efficiently (total economic value, indifference curve).

Successful pricing schemes in the New Zealand context require central Government institutional and political support to be useful. The lessons from water pricing overseas shows that it offers possible improvements and flexibility for achieving water management aims (i.e. the water is put to its best use), but water pricing is only one of the factors that can lead to better use of water.

7.3. Public investment in irrigation

Prior NZIER research has demonstrated the wider economic benefits of irrigation, which tends to suggest a role for public investment in irrigation. The Irrigation Acceleration Fund and Crown Irrigation Investment are providing potential support for irrigation investment. We can review public investment through the frameworks in this report:

- the institutional design of the Irrigation Acceleration Fund and Crown Irrigation Investment is encouraging applications from areas where water storage has the potential for the biggest impact (water challenges in New Zealand, institutional drivers)
- public support is a feature of water infrastructure elsewhere (international experience)
- it fits with New Zealand history of water (New Zealand history)
- the approach being used by Crown Irrigation Investment is putting the onus on individual schemes to create the institutional capacity to manage the schemes – it is creating institutional capability (institutional drivers)
- the approach recognises the importance of the RMA, and is sensitive to appearing to be strict subsidies for producers (political drivers)

- it can expand the availability of water across most or all dimensions, although it can have environmental consequences (ecosystem services, production possibility frontier).

Ensuring that public support is practical and achievable is a crucial step in the development of public irrigation schemes. This requires transparency so that the public understand why schemes have been undertaken and who benefits from the scheme and how.

7.4. Set-asides for environmental purposes

One concern with increased irrigation, with or without increased water storage, is the impact on environmental outcomes. A way to deal with this concern is to set aside water for environmental purposes. Thinking about this issue using our frameworks:

- these set-asides can be tailored to the catchment (water challenges in New Zealand)
- environmental impacts are a concern with overseas water management schemes (international experience)
- they have also been a concern in New Zealand (New Zealand history)
- set-asides recognise that environmental, tourism and recreational users may not be sufficiently organised or directly affected enough to have their values included in water management solutions (institutional drivers)
- these water users, though, may express their preferences in the political arena rather than directly in a water management scheme (political drivers)
- the aim is to avoid solutions that are unacceptable – that do not provide sufficient quantities and water quality at the right times in the right places (ecosystem services, production possibility frontier)
- set-asides are a way to provide for the indirect value and non-use value that New Zealanders derive from water (total economic value, indifference curve).

Environmental set-asides appear to be a useful and an appropriate tool in a well-functioning water management system. They can be tailored to meet the needs of specific catchments and the needs of New Zealanders and allow for flexibility in the water management system.

7.5. Water policy research

Water policy is in a state of flux in New Zealand. Not only are changes to the RMA in progress, but individual regions are reviewing their water management regimes to put in place new rules to accord with the National Objectives Framework. Looking at water policy research using our set of frameworks indicates that:

- water policy research does not have to be done all at once, but can start where it can have the most impact (challenges in New Zealand)

- other management regimes, for example, in the Murray-Darling Basin, have suffered from lack of information and have had to regroup after the fact (international experience)
- the several water management regimes in New Zealand suggest that there is more to be done here, too (New Zealand history)
- part of doing the research is involving stakeholders, including regional and national government, industry groups, and others (institutional drivers)
- the research also needs to be sympathetic to the political forces and timetables involved (political drivers)
- current research is under way in New Zealand to describe the space of possibilities, of what can be done with the current supply of water (ecosystem services, production possibility frontier)
- the research has investigated potential commercial impacts, but has done much less with non-market values (total economic value, indifference curve).

A water management system relies on policy related research. Without performance metrics decision makers rely on their own experience and instincts that may or may not lead to good water management policy. This 'hit or miss' approach to such an important issue is unlikely to lead to good outcomes. Policy makers need to understand the strengths and weaknesses of the research and be active in challenging researchers to answer the pertinent policy questions.

7.6. National Objectives Framework

The Government has released its National Objectives Framework (NOF) on water (Ministry for the Environment, 2013a). The framework 'emphasises the iterative process needed when communities, iwi/Māori and councils are setting freshwater objectives and limits, with full consideration of the impacts of their decisions'. Applying our frameworks to the NOF suggests that:

- the NOF focuses on key indicators of water quality and provides guidance for regional councils to improve those indicators over time (challenges in New Zealand)
- the NOF is the first step in the development of a centralised institutional approach that provide water management certainty along with the flexibility of incorporated catchment characteristics and data (technical and institutional drivers)
- the policy envisages using overseas good practices to inform local decisions (international experience)
- the NOF references the Land and Water Forum, which explored the history of New Zealand water use and policy (New Zealand history)
- the NOF includes provisions for strengthening the institutions that manage water use and quality (institutional drivers)
- central to the NOF is a process of community and stakeholder participation to set water quality limits and develop policies (political drivers)

- part of the process is local and national information-gathering to understand the uses and limits of available water resources (ecosystem services, production possibility frontier)
- values – economic, environmental, social and cultural – are central to the NOF (total economic value, indifference curve).

The NOF provides a solid framework for achieving a durable solution to water management issues. Its implementation is an important building block in the development of a well-functioning flexible water management system.

8. Final thoughts and recommendations

There are problems with water use and quality in New Zealand. A few places in New Zealand have over-allocated water resources, and some water bodies have poor water quality. There are also worrying trends: some water quality indicators are trending downward, and the goal is to improve the trends before we actually have a water quality problem. New Zealanders are concerned about water resources, and are interested in establishing institutional and political solutions to deal with those concerns.

The multiple drivers need to be aligned before water management improves for a wider group of water users. Returning to the multiple drivers framework, we find:

- uses – there is a need to understand the limits of water, and also understand how technology can help us expand the limits and work better within them, all the while keeping in mind how people value water
- institutions – water management should be based on process, policies, and organisations with the scope and information to support the smart use of water
- political – political drivers need to support the wider interests of New Zealanders rather than narrow interest groups, but should also ensure that these interest groups have more to gain by being part of a solution rather than preventing one.

In light of these observations, we make the following recommendations:

RECOMMENDATION 1: REFORM THE INITIAL WATER ALLOCATION MECHANISM AND ALLOW FLEXIBLE REALLOCATION OF WATER

In researching this report, we were surprised by the consensus on the problems. Across many reports, over many years, from many sources, we learned that water is misallocated in ways that promote inefficient use. One culprit often pointed out was the first-in, first-served approach to allocating water. This approach has two main drawbacks. First, it allocates water on the basis of who gets in first, rather than who can make the best use of water. Secondly, it is inflexible, because it does not provide a mechanism to reallocate water, either through administrative transfer or market transaction. A poor initial allocation with no flexibility leads to inefficient use of a scarce resource, and that is where New Zealand has ended up. Thus, the current institutions are not working.

Our recommendation is to reform the initial water allocation mechanism and allow flexible reallocation of water once initially allocated. The first part of this recommendation – reforming the initial allocation mechanism – deals with equity or fairness. It is unfair that there are such high compliance costs to obtaining access to water. We recommend that the government review the process for the remaining allocation of water.

Regardless of the initial allocation, the Coase theorem in economics tells us that an efficient outcome is possible where costless trade is available. The second part of this recommendation promotes flexible reallocation of water through trading. We recommend that the government facilitate trading by implementing regulatory frameworks and national guidelines for the development of water markets. The focus should be on maximising the transparency and minimising the transaction costs of trade.

RECOMMENDATION 2: IMPOSE ENVIRONMENTAL EXTERNALITY LIMITS BASED ON CASE-SPECIFIC EVALUATION

New Zealanders are concerned about water quality, and are interested in establishing institutional and political solutions to deal with those concerns. The general relationships between land-use intensification and water quality are well-known: increased dairying leads to increased nitrate and phosphate rates in the waterways. However, the relationships are extremely complex, change significantly by region and even by farm, type of waterways, and are also impacted by range of external factors such as the climate.

Our recommendation is that environmental externality limits be based on case-specific modelling that incorporates these issues into the policy development. In work commissioned for the Ministry for the Environment, Kaye-Blake et al. (2013) found that it is still possible to achieve environmental improvements with intensification, and that one-size-fits-all limits will not achieve the largest 'bang-for-your-buck' in environmental terms.

RECOMMENDATION 3: INVEST IN COORDINATED RESEARCH

The Ministry for the Environment has created the National Objectives Framework and described a process for 'Managing fresh water in New Zealand' (Ministry for the Environment, 2013a). This framework can include a collaborative process in which community members discuss their values around fresh water. It also includes a process for investigating the current conditions – water quality, ecosystem health, etc. The values and the conditions are brought together to determine whether the community's values are being met, in much the same way as we describe a general equilibrium use drivers framework.

We believe water research needs to be well coordinated in order to implement the NOF or similar policy. Water policy requires information from several diverse disciplines including agricultural science, hydrology and economics. It is applied across a range of geographical scales, from farm-level up to nation-wide. With better coordination, researchers can bring their specific disciplinary skills to bear on the same issues on the same time and geographical scales, allowing a joined-up understanding of water issues. The Water Reform Directorate, formed in 2012 inside the Ministry for the Environment (Smellie, 2012), is an example of such coordinated policy research.

RECOMMENDATION 4: CENTRALISE KEY WATER MANAGEMENT DECISIONS

Our frameworks have emphasised the importance of political and institutional support. We believe the central Government and its agencies should provide the overarching water management principles and implementation guidelines for all regions in New Zealand. This would provide national consistency in the key areas such as the design of allocation, compensation and trading mechanisms, and environmental policies. We believe that the NOF has great potential for getting us closer to the goal of using water wisely across our whole society, but good implementation will be critical in achieving that potential. The central Government should provide definitive implementation guidelines that provide certainty for all stakeholders.

Regional councils could then focus on the key regional specifics around catchments, waterways and land and water-use within their region, rather than designing entire water management systems from the ground up.

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