NZLCM Centre Working Paper 02/11

Technical Workshop on Water Footprinting

18 August 2010

NZLCM Centre Working Paper Series:
Paper 02/11

Technical Workshop on Water Footprinting

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Series Editor: Dr Sarah McLaren
ISSN (Online): 2230-4282

This Working Paper Series is published by the New Zealand Life Cycle Management Centre. The Working Papers are produced periodically on topical issues related to activities of the Centre and its partners. Each working Paper is peer-reviewed by at least two reviewers.

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Workshop Summary

On Wednesday 18th August 2010, the NZLCM Centre hosted a Technical Workshop on Water Footprinting at the Ministry of Agriculture and Forestry, Wellington. The workshop was well attended by a range of people from industry, regional and national government as well as researchers in water management.

The workshop began with a range of presentations:

- Brent Clothier (Plant and Food Research): an overview of Water Footprinting issues
- Ranvir Singh (Massey University): an overview of the Water Footprinting Network' approach to define and calculate the water footprint, and its geographical-based applications
- Anthony Hume (Landcare Research): an overview of the LCA approach to water footprinting and further discussion about how the information could be related to consumers
- Steve Green (Plant and Food Research): water footprinting from a hydrological perspective illustrated with a case study of kiwifruit production in New Zealand
- Indika Herath (PhD student, Massey University): freshwater scarcity in New Zealand and the weaknesses and strengths of some of the indexes used to determine water usage and availability
- Lian Potter and Jason Holland (Ministry for the Environment): data on water usage for New Zealand.

Following on from the presentations, a series of group sessions were held on:

- How water-based metrics can support decision-making from a country/government, product or organisation perspective
- The elements that practitioners consider important in a water footprint indicator to support decision - making
- What kind of water footprint indicator or model is most useful and what kind of data are required.

It was agreed that water footprinting would only be useful if used appropriately i.e. alongside other environmental indicators and as a "big picture" tool. It was also agreed that it is important to ensure consumers and growers have an understanding of what is meant by a water footprint. However, it is also important to remember that "you cannot manage what you do not measure."

The next steps for New Zealand will be to get ready for when the ISO committee agrees on some water footprint standards. This will involve collecting data (on water usage, water wastage and leakage), and considering an implementation plan.

These Proceedings comprise the five papers presented in the morning session.

Paper 1

Water Footprinting: Emerging Issues

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The Imperative

Recently, ***The Economist*** (18 September, 2008) asserted that "… the world is facing not so much a food crisis as a water crisis". Farming, primarily for the creation of food products, uses 70% of the world's water. In New Zealand, 77% of allocated water is used for irrigation and 3% for stock water (MfE, 2006). So there is a pressing need to develop knowledge and tools to minimise agricultural water use and reduce impacts. ***The Economist*** concluded that "… farming tends to offer the best potential for thrift". Robert Glennon in his most recent book "Unquenchable – America's Water Crisis" concluded optimistically for the case of agriculture, as '… farmers are responding nimbly to these [thrifty] challenges by engaging in vanguard agriculture [through] identifying new ways of growing and marketing produce" (Glennon, 2009).

The concept of virtual water (Allan, 1998) and the water footprinting of primary products from vanguard agriculture seek to achieve such water thriftiness. Virtual water, or the water footprint of a product, is the net volume of water used in the supply chain to make that product. It is the net sum of the water use in the various stages of the production chain. The water footprint consists of three water colours. Green water is rainwater stored in soil that is either transpired by the plant, or by drainage serves to recharge receiving water-bodies. Blue water is the water drawn from these surface and groundwater reservoirs and which is irrigated onto soil to maintain transpiration, with any excess draining to recharge the blue water resource. Grey water is the drainage whose quality is degraded by leachates.

There is a drive for primary production systems to move to practices that mitigate environmental impacts, and which minimise the use of natural resources such as water and carbon. Whereas the general issue with carbon is the global atmosphere, the critical concern with water is the local hydrology. Reducing the water footprint of agricultural products will increase the eco-efficiency of food-production systems locally, and eco-verification of the water footprint should enable the premium pricing of primary products to the world's increasingly discerning retailers and consumers.

This thrifty imperative for the products from vanguard agriculture will be ever more challenging and will require nimble responses if we are to meet the demands of climate change (Clothier et al., 2010). Water footprinting will highlight the exigencies and lead to local solutions whereby the water footprints of products can be reduced to alleviate pressure on the natural capital stocks of water resources, and the ecosystem services provided by these water resources.

Various methods for determining water use and supply in the production of products have been mooted to define water footprints and impact assessments. Footprinting is about 'systems thinking' and in relation to water footprinting there is a need to acknowledge the complexity and connectedness of water inputs, transfers, and outputs through the hydrological cycle. To ensure believable footprint determinations it is critical that their quantification protocols draw on the research results that have already been hard-won by hydrologists and agricultural scientists. Scientists within the large and renowned discipline of hydrology have worked assiduously since the time of Leonardo da Vinci [1452-1519] to understand scientifically the complexity and connectedness of the hydrological cycle. It is crucial that the 'systems thinking' for water footprinting follows what is extant knowledge of 'hydrological systems'.

Water Footprint Labelling and Challenges

On August 20 2008, *The Guardian* newspaper cited the World Wildlife Fund report by Chapagain and Orr (2008) which "… revealed the massive scale of UK's water consumption". Whereas household water use is about 150 litres per person per day, Britons consume nearly 30 times as much in the 'virtual water' that is used in the production of imported food and textiles. Chapagain and Orr (2008) estimated that each Briton consumes 4,645 litres per day. Of that, only 38% of the water comes from Britain's own resources, and the rest depends on the water systems of other countries. No doubt responding to public concerns about such resource footprints, in July 2009 the giant American-based, retail-chain of Walmart announced plans to develop a worldwide sustainable product index. Walmart will now issue its 100,000 global suppliers with a survey of 15 questions. Two of the questions are: what is the amount of water used, and what is the water-use reduction target?

Hoekstra (2010) considered that "… global water-use efficiency can be increased by including water scarcity into trade decisions". Yet he lamented that projections for international trade patterns do not heed the role of freshwater in conferring comparative advantage, and he advocated that "… to better ensure trade and water use go hand in hand, product transparency through a water label" should be considered.

On behalf of the Food Ethics Council of the United Kingdom, Segal and MacMillan (2009) discussed the merits of water labels on food. They suggested that water footprints were potentially confusing and provided only a partial scrutiny which stopped short of the real issues. Indeed, they compared water footprint labels with the erroneous 'food miles' metric in the early days of the carbon debate.

Wichelns (2010) in a report from the OECD on '*An economic assessment of the virtual water concept in relation to the agri-food sector'* noted that "… water footprints consider water required only in consumption activities or those that examine all the water required in production". He concluded that water footprints calculated in that consumptive way "… do not contain sufficient information to evaluate the net benefits generated through the use of water resources … they are inadequate for evaluating the incremental costs, benefits, or environmental impacts of water use". He concluded that…"…water footprints and the blue-green [& grey] metaphor will be helpful in starting policy discussions but they will not be sufficient for determining optimal outcomes".

Frontier Economics (2008) in a report for the Victorian Department of Primary Industries concluded that virtual water would be "… especially burdensome on business, of no benefit in the pursuit of environmental policy, or for the development of virtual water labelling standards on food". They suggested the footprinting concept for water is threefold wrong by considering all water 'colours' to be the same, by suggesting implicitly that water would be released from a water-intensive use to produce products that are less water-intensive, and by failing as an indicator of whether water resources are being used sustainably.

The SABMiller-WFF (2009) report on the water footprint of beer ended with a chapter on the future of water footprints. They concluded that water footprint methods are evolving rapidly and many studies are pushing the methods towards agreed and harmonised accounting. They called for issues around the grey and green water footprints "… to be decided within technical discussions with partners and the WFN" (Water Footprint Network). This is to be welcomed.

Conclusions

Water footprinting must therefore take advantage of what has already been confirmed by hydrologists, and what is already hydrologically well understood. Quantification of water footprints is challenging and yet provides a means to discuss how we can better manage our local water resources and meet at the same time the growing need to feed the world. This could provide consumers with ethical options for food choices, and highlight the need for water conservation measures. It should also stress the exigency for the development of equitable allocation policies by regulatory agencies. Appropriate water footprinting will enable businesses to seek improvements in eco-efficient measures for labelling purposes, so that consumers are well informed and can follow sustainable and ethical patterns of consumption. However the water-footprinting protocols must be hydrologically meaningful. Otherwise they will lack credibility with the stakeholder communities of agriculturalists, policy agencies, supply-chain agents, and consumers. The value of water footprints would thus be diluted. We must find and use robust, reliable, and relevant water footprinting rules.

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Paper 2

Methods in Water Footprinting: the Water Footprint Network's Approach and Geographically-Based Applications

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Introduction

Freshwater is a vital resource that underpins the growth and development of human society. Its use around the globe is taking on new meanings in the face of increasing global demand for food production, economic growth and to combat the uncertainties of climate change. Scientists and water managers are warning of a 'perfect storm' of food shortages and water scarcity (The Economist – September 18, 2008; The Guardian – 18 March, 2009; BBC NEWS – 18 August, 2009). Business organisations are feeling the risks of increasing freshwater scarcity and pollution (JP Morgan, 2008). Market access and international protocols will necessitate the business organisations and countries to assess and report freshwater consumption and its environmental impacts (Segal and MacMillan, 2009; Hoekstra, 2010). Meeting the growing demands of food, water and material goods, while protecting freshwater ecosystems, is one of the key challenges of the 21st century (Postel, 2000). With this challenge ahead, traditional approaches are being replaced by a suite of new concepts and tools to assess freshwater use and its environmental, economical, social and cultural impacts. Included in these powerful tools is the concept of water footprinting.

The Concept of Water Footprint

The concept of water footprint was first introduced in 2002 by Professor Arjen Hoekstra to assess and compare the total amount of water used to support human activity in different regions of the world. "The water footprint, equal to the sum of the domestic water use and net virtual water import, is proposed here as a measure of a nation's actual appropriation of the global water resources (Hoekstra and Hung, 2002)". It was primarily introduced to illustrate the hidden links between human consumption and water use and between global trade and water resources management (Hoekstra, 2009).

Water Footprint Network's Approach

Since introduction of the concept of water footprint in 2002, there has been an overwhelming interest in applying and advancing the water footprinting methodology to assess water footprints from a process to a product level, from an individual to national level, and even on a global level (Hoekstra and Chapagain, 2007, 2008). Recognising the need and a gap, a number of world leading institutions established the Water Footprint Network (WFN) in 2008 to coordinate efforts to further develop and disseminate knowledge on water footprint concepts, methods and tools (http://www.waterfootprint.org/?page=files/WFN-mission).

In 2009, the WFN put together a manual to outline a complete, consistent and up-to-date overview of the water footprinting methodology (Hoekstra et al., 2009). In this manual, the water footprint is defined as an indicator of freshwater use, which accounts for both direct as well as indirect freshwater consumed and/or polluted. It has three main components: *the green water footprint* (the consumption of rainwater stored in the soil profile), the *blue water footprint* (the consumption of freshwater harvested from surface and groundwater stores), and the *grey water footprint* (the amount of freshwater required to assimilate the load of pollutants to an acceptable standard). The 'consumption' refers to the loss of water, through either evaporation or incorporation into a product, from a catchment. The water footprint, therefore, does not include the non-consumptive part of freshwater withdrawals (return flow) within the catchment. It is expressed in terms of the volume of freshwater, and includes a temporal and spatial dimension, i.e. when and where water is used. The water footprint can be calculated of a process, product, individual, business, community, region and a nation. The water footprint of a process is the basic building block of all other water footprint accounts. The water footprint of a product is the aggregate of the water footprints of the various process steps relevant in the production of a product. The water footprint of an individual is the aggregate of the water footprints of all products consumed by the individual. The water footprint of a nation is defined as the total volume of freshwater that is used to produce the goods and services consumed by the inhabitants of the nation (Hoekstra and Chapagain, 2007, 2008).

Water “footprint” or “shoesize”

The volumetric water footprint calculated by the WFN’s approach is criticized as a poor indicator of its environmental impact, and may lead to a potential for misinterpretation and confusion when comparing different products produced in different regions (Pfister and Hellweg, 2009; Ridoutt et al., 2009). Pfister and Hellweg (2009) emphasized that “.. a distinction between the various origins of water use is useful, because the resulting environmental impacts vary largely from region to region.” The same amount of water used for a product in a water-scarce catchment/ region will have a different impact than in a water-rich catchment/ region. Pfister and Hellweg (2009) suggested to weight the water consumption “shoesize” by the water stress index (the ratio of freshwater withdrawals to freshwater availability) to calculate a stress-weighted water footprint. Ridoutt and Pfister (2010) suggested the stress-weighted water footprinting approach as “..a simple, yet meaningful way of make quantitative comparisons between products, production systems and services in terms of their potential contribute to water scarcity”. In this approach, they suggested to ignore the green water use (the rainfall water stored in the soil profile) arguing that the consumption of green water *per se* does not contribute to water scarcity or environmental flows, and it is only accessible through access and occupation of land. Pfister and Hellweg (2009) point out that this omission is only valid if the consumption is comparable to the consumption of green water by natural vegetation at the same site.

Hoekstra et al. (2009b) argued that “..that redefining the water footprints does not make sense from a water management perspective, which requires spatially and temporally explicit information on water footprints in real volumes and impacts in real terms”. To inform freshwater management, it is highly relevant to know the size and colour of freshwater use, who is using it, when and where it occurs and in which context (degree of water scarcity and/or water pollution level) (Hoekstra et al., 2009). A distinction and proper accounting of the blue and green water footprints is also very important because the hydrological, environmental and social impacts and the economic “opportunity costs” of surface and groundwater (blue water) use for production differ distinctively from the impacts and costs of rainwater (green water) use (Hoekstra and Chapagain, 2008). The volumetric water footprints are very important when it comes to the discussion of freshwater appropriation and allocation issues, and then they provide necessary spatially and temporally-explicit data to assess environmental, economical, social and cultural impacts at local and catchment level. Hoekstra et al. (2009) has proposed three relevant water footprint impact indices to assess the local environmental impacts of a product or process by putting the water footprints in the context of the water scarcity and water pollution in a catchment at a time as follows:

Green Water Footprint Impact Index,

$$WFII_{green} = \sum_{x} \sum_{t} (WF_{green}[x, t] * WS_{green}[x, t])$$

Blue Water Footprint Impact Index,

$$WFII_{blue} = \sum_{x} \sum_{t} (WF_{blue}[x, t] * WS_{blue}[x, t])$$

Grey Water Footprint Impact Index,

$$WFII_{grey} = \sum_{x} \sum_{t} (WF_{grey}[x, t] * WPL[x, t])$$

where, WF_{green}, WF_{blue} and WF_{grey} are the green, blue and grey water footprints, respectively; Ws_{green}, WS_{blue} and WPL are the green water scarcity, blue water scarcity, and water pollution level, respectively in a catchment (x) in a period (t) (Hoekstra et al., 2009).

Geographically-Based Applications

The concept of water footprinting seems to provide an excellent framework for the planning and management of freshwater resources to address sensitive issues around efficient and equitable water allocation and use, water availability, water quality and pollution, and to form an information base for effective evaluation of competing water users (Figure 1). Degrading freshwater quality is of great concern in New Zealand, particularly in the areas dominated by intensive landuse (MfE, 2007). A grey water footprint analysis can help in identification of critical pollutants, to establish pollutant caps and then allocate the caps among the existing and future water users to protect freshwater quality.

In essence, the green and blue water footprints measure the "water quantity use", and the grey water footprint measures the "water quality use". The water footprint, therefore, provides a consolidated indicator of both water quantity and quality aspects of freshwater use over space and time in a catchment or region. The spatial and temporal information on water footprints and their impact on freshwater resources identify the "hotspots" of freshwater use in a catchment or region (Hoekstra et al., 2009). The identification of 'hot spots' is very useful when formulating the response measures, especially with limited resources to improve the freshwater management.

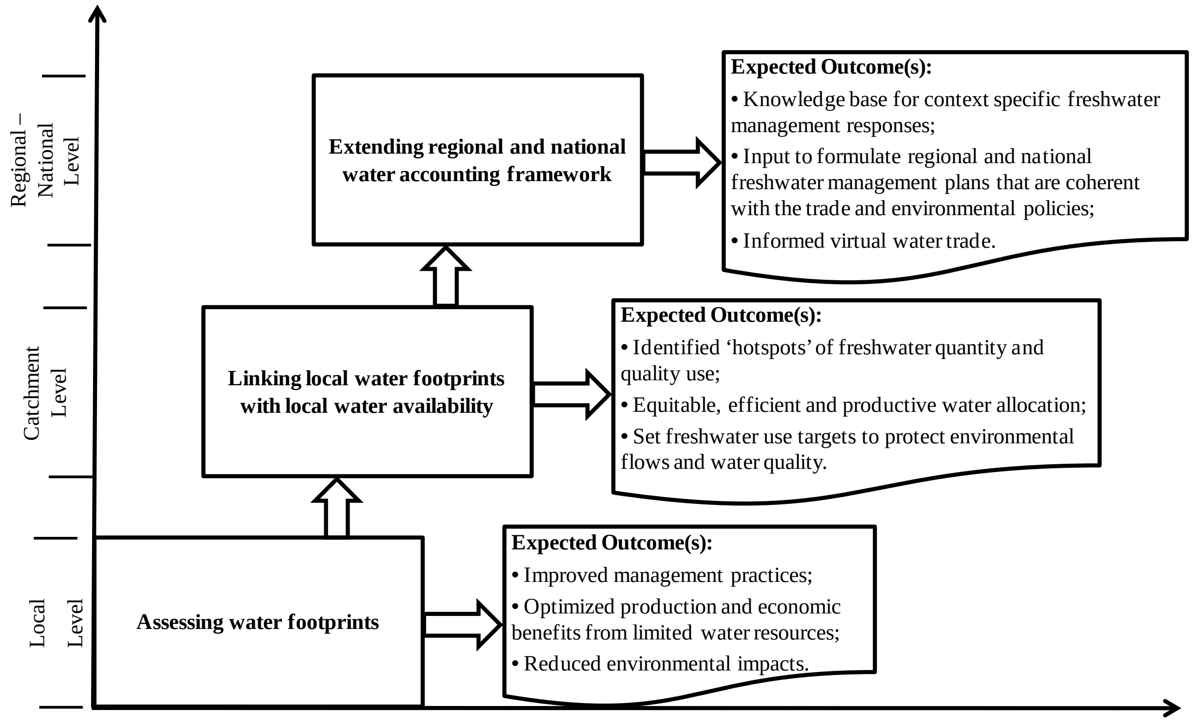

Figure 1: Expected outcomes from a geographical-based water footprinting analysis.

Traditional statistics on freshwater use – water allocations and abstractions – ignore green and grey water use, and pay little attention to the indirect water use associated with the goods and services consumed by the inhabitants of a nation. For instance, nearly 62% of the water associated with the agricultural and industrial products consumed in the United Kingdom is outsourced from other countries (Chapagain and Orr, 2008). *This highlights the fact that only looking at water allocations and abstractions within a nation does not provide a clear picture of national water use and its sustainability*. Volumetric water footprinting does allow the construction of a new water footprint accounting scheme including both internal and external water footprints associated with the good and services consumed by the inhabitants of a nation (Hoekstra and Chapagain, 2007). Such a national water footprint accounting scheme can provide clarity on how much freshwater abstraction within a country is used for domestic consumption and how much for 'virtual-water' export. Extending the regional and national freshwater use statistics by incorporating national and regional water footprint accounts, therefore, would certainly provide useful information to formulate national and regional water plans that are coherent with the trade and environmental policies, and better inform our understanding of the virtual water trade with other countries.

Concluding Remarks

The concept of water footprint has been primarily rooted in the search to illustrate the hidden links between human consumption and freshwater use, and between global trade and water resources management. Since its introduction in 2002, there has been an overwhelming interest in applying and advancing water footprinting to assess water footprints of different products, production systems and services, and also on geographical scales to inform production and trade decisions (Aldaya et al., 2009; Dabrowski et al., 2009).
The science of water footprinting is an emerging rather than a mature subject, and methodologies are proposed, debated and revised to define water footprints and their impact assessments (Hoekstra et al., 2009; Ridoutt and Pfister, 2010; Bayart et al., 2010 and Milà i Canals et al., 2010). However, this innovative concept provides an opportunity to visualise and integrate all components of freshwater use (blue, green and grey water) to inform the decision making to address difficult issues around efficient and equitable water allocation and use and protection of water quality. The green and blue water footprints indicate “water dependency”, and the grey water footprint indicates the “water care” aspect of freshwater use.

The idea of water footprints appears to be a very powerful communication tool to help build public awareness and provide an information base for consumers to make choices and develop a water-saving culture. It can provide a common language to engage different stakeholders in developing policies, strategies and practices for sustainable, equitable and efficient water use and its management. Water footprinting does broaden the scope of water management by introducing new, consumption- and global trade-related dimensions of water scarcity and pollution, and offer a potential analytical technique to benchmark our water use, set reduction targets and identify hotspots and priority areas for action. Water footprinting becomes a mechanism for business organisations to assess their water-related risks and opportunities, demonstrate their environmental stewardship and gain access to premium markets.

The challenge is the quantification of water footprints, given the high spatial and temporal variation in water use and its availability. Another challenge is the limited information on water use and it availability in catchments and regions. The experts and researchers have a challenging job ahead to develop a robust, reliable and relevant methodology to quantify and communicate water footprints in a meaningful way to enable consumers and producers to make their choices to reduce their water footprints.

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Paper 3

Measuring and Modelling the Water Footprint of New Zealand Kiwifruit

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Water Footprint of New Zealand Kiwifruit

The water footprint of a product is the volume of water used in the supply chain to make that product (Hoekstra et al. 2009). It is the net sum of the water used in the various stages of the production chain. For the purpose of the present discussion our 'production chain' will consider Class I export kiwifruit produced within the orchard gate.

Simply stated, the Water Footprint Network (WFN) definition of a water footprint consists of three water colours:

- the **green water** refers to rainwater stored in soil that is either transpired by the plant, or by drainage serves to recharge ground or surface waters;
- the **blue water** refers to water that is drawn from these surface and groundwater reservoirs and irrigated onto soil to maintain transpiration; and
- the **grey water** refers to drainage water that becomes polluted by leached nutrients and pesticides.

The most recent guidelines of the WFN fail to provide a purely mathematical definition of how the green, blue, and grey water footprints should be calculated (Hoekstra et al. 2009). Rather, many of the terms are represented by words, and this leads to ambiguity. Therefore, we have chosen to formulate a consistent set of equations to interpret the WFN guidelines. Our interpretation is based on two criteria: the equations must represent the entire hydrological system and they should, as much as possible, represent the environmental impact of production on the quantity and quality of the water resources. A schematic of the modelling framework is shown in Figs 1 and 2.

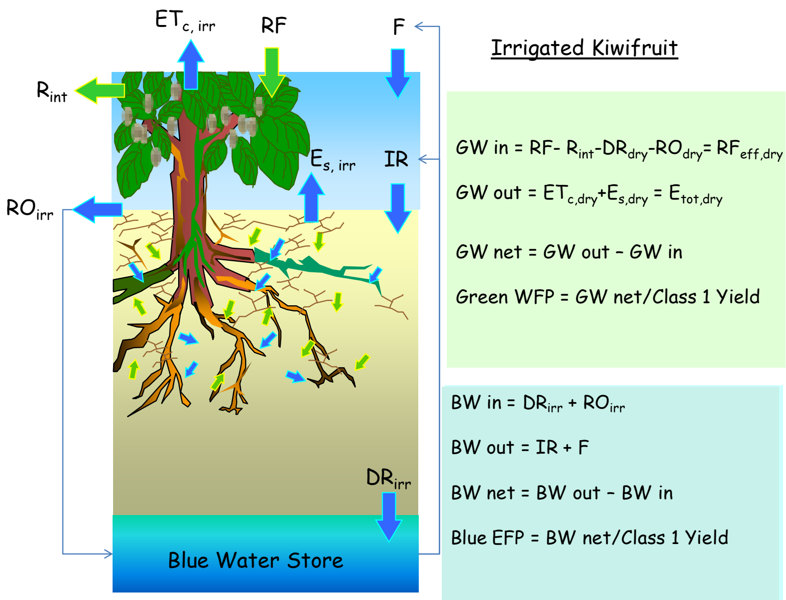
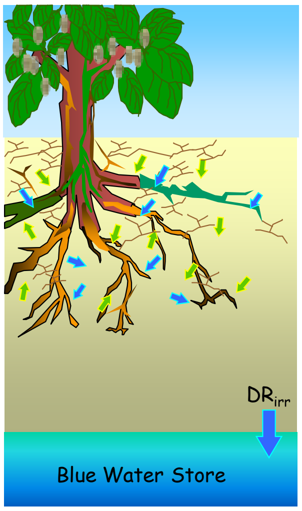


Figure 1: The calculation of the green (GW), and the blue (BW) water footprint (WFP) for irrigated kiwifruit. The notation is as follows: ET_c is crop water use, RF_{eff} is effective rainfall, R_{int} is intercepted rainfall, E_S is soil evaporation, *RO* is runoff, *DR* is drainage, *IR* is irrigation and *F* is water for frost protection. The subscripts 'dry' and 'irr' refer to rain-fed and irrigated orchards.



Dryland Kiwifruit

$GrW = DR_{dry} * (CP - CP_{nat}) / (DWS\_CP - CP_{nat})$

Grey WFP = GrW/Class 1 Yield

Irrigated Kiwifruit

$GrW = DR_{irr} * (CP - CP_{nat}) / (DWS\_CP - CP_{nat})$

Grey WFP = GrW/Class 1 Yield

Figure 2: The calculation of the grey water footprint (Grey WFP) for irrigated kiwifruit. The notation is as follows: *CP* is the solution concentration for the pollutant of interest, *DWS* is a drinking water standard, the subscript 'nat' is the freshwater concentration in the natural state, and the other variables are defined in Figure 1 [Equations from Hoekstra et al, 2009, p. 23]

The **green water** and **blue water** components are relatively easy to measure, or model, for most productive land uses (Fig 3). One only needs to evaluate the soil water balance, and to quantify the metric for production (i.e. yield). For example, in the case of kiwifruit production, the metric might be the volume of water (litres) used to produce a tray of Class I GREEN kiwifruit (assumed to be 3.6 kg of fresh fruit).

The **grey water** component, on the other hand, is more challenging to measure, for it requires one to quantify how much water is needed to dilute the load of the pollutant with the highest risk of polluting the groundwater when leaving the root zone. Typically, for the case of productive lands in New Zealand, the pollutant of most concern is NO_3-N and the risk associated with this is eutrophication. In order to assess the grey WFP, we need devices or models to determine the yearly averaged concentration of NO_3-N in the drainage water leaving the root zone soil.

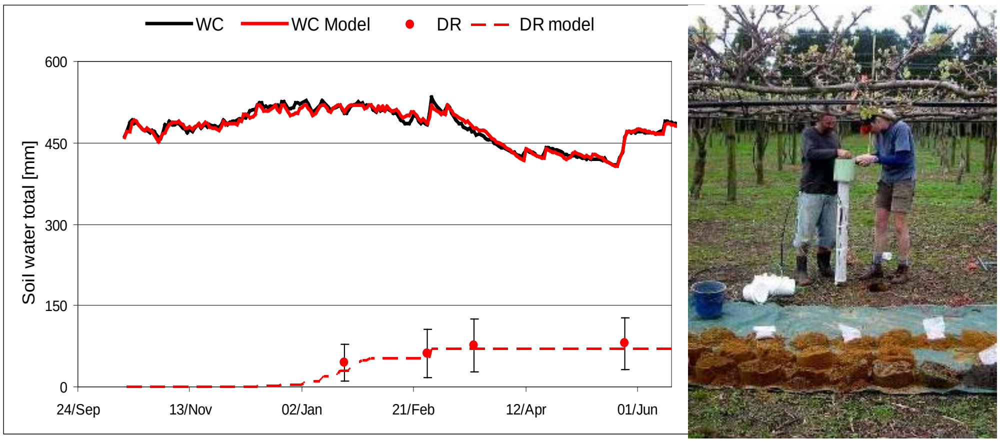


Figure 3. Drainage flux meters (DFM) being installed in a kiwifruit orchard near Te Puke. The graph shows the time series of soil water content (WC) and drainage flux (DR) as measured with TDR probes and DFMs, and as modelled using our SPASMO model (Green et al 2006).

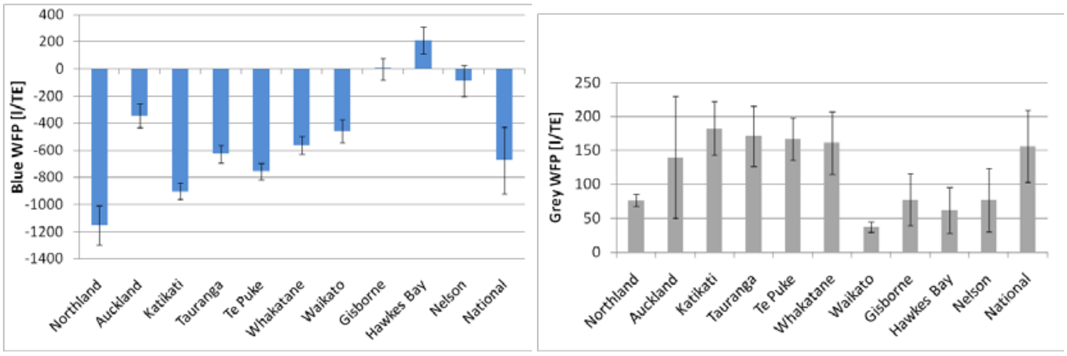


Figure 4: The blue (left panel) and grey (right panel) WFP of class 1 ZESPRI® GREEN kiwifruit at the regional and national scale as a function of the orchard water management. The bars show one standard deviation due to the variability of 5 regional soils.

The **total water footprint**, according to the WFN, is represented by the sum of the blue, green and grey water footprint. This footprint is supposed to serve as an overall indicator of impact on local water resources of the production of a product. However, we see no scientific justification for adding the grey water footprint to the blue and green water footprints. For example, in the case of kiwifruit for many regions we have a negative blue water footprint signalling there is no concern with freshwater depletion - indeed the reverse, as there is recharge. But there is a positive grey water footprint which at the same time indicates that there is a potential risk of pollution to the ground and surface water bodies (Figure 4). After summation, the total water footprint could be positive, negative or zero. However, this does not mean there is no environmental impact, but rather that the impact on the freshwater ecosystem by eutrophication remains, even if there is no depletion of the freshwater resource.

Data need to verify the blue and grey water footprints

To verify footprints, in our opinion there are two possibilities. The first possibility is that each orchard reports the yearly total of irrigation water, for example, in conjunction with submitting a spray diary to their respective industries. Next, the growers should also report the type and amount of N-fertilizer. With this information a water footprint calculator, such as that powered by Plant & Food Research's SPASMO engine (Green et al. 2006), could be used to predict the blue and grey water footprints and this could be compared with the baseline for the particular orchard, or industry.

The second possibility is to directly measure the drainage and the nitrate and possibly the concentrations of other contaminants using flux meters (Deurer *et al.* 2007). These new devices are now available, and can offer a cost-effective and reliable way of obtaining such measurements. Reliable measurement techniques are needed to improve our understanding, to quantify those footprints, and to test our models. Model-measurement comparisons, along with fine tuning, are very important to provide growers, industry and regulators with confidence in the quality of the data and appropriateness of the models used to determine footprints.

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Paper 4

Assessing Freshwater Scarcity in New Zealand

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Introduction

"Freshwater problems" are among today's most acute and complex scientific and technical issues. They increasingly reach beyond regional and national borders and are becoming global in nature. Dwindling water supplies, deteriorating water quality and increasing water demands are creating significant challenges to businesses and investors who have taken clean reliable and inexpensive water for granted. Although water is apparently plentiful according to some average global and national figures, there are enormous disparities between regions. Due to high spatial and temporal variability of freshwater availability and demand, regional assessment of water scarcity, that is demand in relation to availability, is of utmost importance for understanding the impacts of water use and conservation. This study aims to assess the freshwater status in New Zealand on a regional scale using three key indicators: the Falkenmark Index (Falkenmark et al., 1989), the Water Scarcity Index (Hoekstra and Hung, 2002; Alcamo et al., 2003), and the Water Stress Indicator (Smakhtin et al. 2004).

Data and Methodology

The above identified three key water status indicators were estimated based on water use and availability information across different regions of New Zealand. Water resource availability estimations and population were obtained from the physical stock account of water (average of 11 year period of 1995-2005), as published by the Statistics New Zealand (StatisticsNZ, 2010). Data on water use and allocations for 2002-2005 were extracted from the snapshot of water allocation in New Zealand by the Ministry for the Environment (MfE, 2006). In this assessment we found, however, that actual water-use data are not available for most of the regions. Therefore, when water-use data were not available, it was assumed that 70% of the allocated water was being used.

Falkenmark Index

The Falkenmark Index is an indicator of water resource availability per capita per year in a country, or a given region. A value of 1,700 m^3 per capita per year has been proposed as a threshold values, and countries where renewable water supplies cannot meet this value are said to experience water stress(Falkenmark et al., 1989). This is also known as the water resource per capita –WRPC (Canals et al., 2009). This concept is used here to assess apparent water stress for different regions in New Zealand (Table 1).

Water Scarcity Index (WSI^1)

The Water Scarcity Index has been widely used to assess water status as the ratio of total water use to total water available (Hoekstra and Hung, 2002; Alcamo et al., 2003). According to this index, the severity of water scarcity has been ranked as follows: $WSI^1<0.1$ - no water stress; $0.1 \leq WSI^1<0.2$ - low water stress; $0.2 \leq WSI^1<0.4$ - moderate water stress; $WSI^1 \geq 0.4$ - high water stress; and $WSI^1>0.8$ - very high water stress (Smakhtin et al., 2004). A similar concept is known as the water use per resource -WUPR (Canals et al., 2009). Table 1 shows the estimated Water Scarcity Index (WSI^1) for different regions in New Zealand.

Water Stress Indicator (WSI^2)

Smakhtin et al. (2004) proposed an alternative indicator for environmental water stress, defined as the ratio of actual water use (WU) to the actual water resources available for human use. This is derived by subtracting the environmental water requirements (EWR) from the total available water resources (WR): $WSI^2 = WU/(WR-EWR)$. This indicator is considered as a more accurate indication of the water resources available for further human use by 'reserving' the necessary resources for ecosystem functioning (Canals et al., 2009). According to the Water Stress Indicator, environmental water scarcity is categorised as follows: $WSI^2 > 1$ – over exploited; $0.6 \leq WSI^2<1$ - heavily exploited; $0.3 \leq WSI^2<0.6$ - moderately exploited; and $WSI^2<0.3$ - slightly exploited. Recently this index has used to assess the impact of the external water footprint of the UK on the water resources of other countries (Chapagain and Orr, 2008). In that study, 30% of the total available water resources were considered as the EWR. Nonetheless, the quantification of EWR is location and time specific and is often highly debated. According to Smakhtin et al. (2004), the EWR to maintain a fair condition of freshwater ecosystems ranges globally from 20-50% of the mean annual river flow in a basin. We have used 30% of total inflow to a region as the EWR, and then estimated the Water Stress Indicator for different regions in New Zealand (Table 1)

Results and Discussion

Assessment of freshwater scarcity for different regions in New Zealand according to the above three indices is given in Table 1.

Falkenmark Index

All the regions in New Zealand are well above the threshold index value of 1700 m^3 per capita per year (Table 1). The Auckland region has the lowest value of 5160 m^3 per capita per year, but this is still well above the threshold value. This indicator has been adopted as the standard indicator of water scarcity, being quite easy to estimate and understand. However, it does have limitations of not taking into account the role of infrastructure determining the usable water availability and water demand, or actual use in a country or region. The simple threshold does not reflect variations in the water demands in different countries or regions due to differences in consumption patterns or economic factors. Even though New Zealand is well endowed with fresh water according to this indicator, some reported studies show high levels of water use; for instance, New Zealanders use 653 litres of water per capita a day for domestic purposes. This usage has been rated as “excess use” compared to the other countries around the world(Lawrence et al., 2002).

Water Scarcity Index (WSI^1)

According to the WSI^1 in Table 1, none of the regions in New Zealand is water stressed. This indicator is more meaningful than the Falkenmark index as it takes into account for the actual water use, relative to water availability. The Southland region has the lowest value of 0.001, while Canterbury and Wellington have the highest values of 0.041. All the regions fall into the category of ‘no water stress’.

Water Stress Indicator (WSI^2)

All the regions of New Zealand have a WSI^2 of less than 0.3 (Table 1), and therefore they fall into the ‘slightly exploited’ category. The regional values range from 0.002 (Southland) to 0.059 (Wellington). This indicator captures hydrological aspects other than just availability, as it can be related to ecosystem health. Therefore it is more meaningful in terms of understanding the impacts of water use.

Table 1 The base information and water scarcity indicators for different regions in New Zealand (based on data from 1995 to 2005).

Region	Rainfall (Mm^3/y)*	Inflow from other regions (Mm^3/y)*	Total Inflow (Mm^3/y)*	Water use (Mm^3/y)	Available water for human use (Mm^3/y)	Population	**Falkenmark Index** (thousand m^3 per capita)	**Water Scarcity Index (WSI^1)**	**Water Stress Indicator (WSI^2)**
Northland	20227	0	20227	79.8	14158.9	148600	**136.12**	**0.004**	**0.006**
Auckland	6901	0	6901	127.93	4830.7	1337000	**5.16**	**0.019**	**0.026**
Waikato	42054	1088	43143	467.60	30200.1	384700	**112.15**	**0.011**	**0.015**
Bay of Plenty	24293	2074	26366	307.09	18456.2	260300	**101.29**	**0.012**	**0.017**
Gisborne	15966	1273	17239	207.48	12067.3	44700	**385.66**	**0.012**	**0.017**
Hawke's Bay	21548	1692	23240	310.17	16268	149400	**155.56**	**0.013**	**0.019**
Taranaki	14774	0	14774	73.92	10341.8	105000	**140.70**	**0.005**	**0.007**
Manawatu-Wanganui	37495	21	37516	138.60	26261.2	226100	**165.93**	**0.004**	**0.005**
Wellington	13962	40	14003	581.07	9802.1	460300	**30.42**	**0.041**	**0.059**
Tasman	26194	1294	27488	104.23	19241.6	46600	**589.87**	**0.004**	**0.005**
Nelson	693	0	693	20.44	485.1	45700	**15.16**	**0.029**	**0.042**
Marlborough	15631	1112	16743	130.34	11720.1	42700	**392.11**	**0.008**	**0.011**
West Coast	127531	7160	134691	191.03	94283.7	30500	**4416.1**	**0.001**	**0.002**
Cantebury	67011	2082	69093	2811.06	48365.1	526300	**131.28**	**0.041**	**0.058**
Otago	37000	85	37086	1224.93	25960.2	196600	**188.64**	**0.033**	**0.047**
Southland	86830	160	86991	116.55	60893.7	93000	**935.39**	**0.001**	**0.002**

*****Data were extracted from the Statistics of New Zealand: Mm^3-million cubic meters

Limitations and future research needs

One of the main issues in the assessment of water scarcity is the limited information available on the volumes of water actually used by different users. Furthermore, water scarcity estimations based on annual water availability do not indicate the seasonal water stress due to temporal differences in water availability within a year. Most importantly, none of the commonly used water scarcity indicators takes into account the quality of water, which frequently governs its utility. The water quality is an important aspect yet to be considered in water scarcity indicators, so there is a need to develop protocols which take water quality information into account when assessing water scarcity.

Conclusions

New Zealand is apparently well endowed with freshwater according to the estimated water scarcity indicators, although it does have very high levels of usage. Among the three indicators considered, the Water Stress Indicator (WSI^2) gives a better estimation of freshwater scarcity as it considers environmental water requirements by 'reserving' some of the necessary resources for ecosystem functioning. The water quality is however an important aspect yet to be included in water scarcity indicators.

If New Zealand wisely allocates its water resources and parsimoniously uses its plentiful water, without compromising its quality, then New Zealand has enormous opportunities to achieve competitive marketing advantage through ecoverification of the water footprint of its products.

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Paper 5

Water Use data for New Zealand: Current Availability, Gaps and Future Work

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New Zealand's water use compared internationally

Intensity of water use in New Zealand is still low at the national scale and by international standards. Compared internationally, New Zealand has an abundance of fresh water. In 2007, NZ had the 6th lowest water withdrawals as a share of total water available out of 30 OECD (Organisation for Economic Co-operation and Development) countries (OECD, 2010).

However, not all of the renewable resource is actually available for use – much of it needs to be retained in the rivers, lakes and aquifers to maintain the various values of these water bodies (such as ecological, recreational and cultural values). Furthermore, water is not always in the right place at the right time for users. A large proportion of New Zealand's annual rainfall occurs in winter when demand is relatively low.

Current availability

As in other countries New Zealand's environmental reporting programme makes use of core environmental indicators to provide key information. The Ministry for the Environment's (MfE) core set of national indicators comprises 66 variables which report on 22 indicators across ten key environmental domains.

One of these domains is fresh water which has five indicators: river water quality, lake water quality, groundwater quality, recreational water quality and **fresh water demand.** In order to report on fresh water demand the volumes of water allocated to human uses are recorded – also known as total consumptive (water not returned to source) water allocation.

Regional councils are responsible for granting resource consents in New Zealand. These consents are generally required before surface or groundwater may be removed for irrigation, drinking water supply, industrial and manufacturing works etc. Smaller volumes of water, such as low-level home supply, can also be allocated through permitted activity rules under councils' regional plans.

The consent process, or 'allocation of fresh water' can determine both the maximum volume of water that may be taken, and the maximum rate at which water may be taken.

Allocation is usually granted as a maximum daily and or weekly/rate or as a maximum annual volume. Weekly allocation rates are useful for understanding pressures on water demand that are related to seasonal activities (such as irrigation). Annual volumes are useful for understanding how much water is potentially used each year – irrespective of seasonal fluctuations in demand.

Total allocated volumes can be disaggregated by:

- Regional council jurisdiction
- Source (surface water, groundwater, storage, geothermal)
- Use (irrigation, industrial, public, stock)
- By day/week or by year for each of the above

MfE has a compiled national aggregated dataset for 1999, 2006 and 2010, using the data provided by the regional councils. A report prepared for MfE by Aqualinc Research Ltd. (Aqualinc, 2010) presents the most recent consent data available and discusses the current state of consented allocation and trends since 1999. It also presents findings on estimated actual usage compared to consented usage.

Gaps and limitations

Although these data and reports are useful for gaining a national picture across New Zealand, there are some gaps and limitations, in particular with the national indicator of total consumptive allocation.

Allocated volumes can only be seen as a proxy for volumes of water actually abstracted. Allocated volumes are a maximum and tend to overestimate the amount of water actually abstracted.

At present the degree to which actual abstraction is monitored varies greatly between regional councils and there is insufficient coverage for complete compilations of nationally aggregated data.

In addition although there are currently around 20,000 fresh water resource consents in New Zealand, around 200 of these are non-consumptive (for example hydro-electric), and although they may return the water to source, impacts can occur in the reaches downstream of abstractions before the point at which the water is returned (known as depleted reaches).

Small permitted activities may also have an 'in-combination' impact on the water resources within the waterways. Some councils do monitor these permitted activities but this is not standard.

Retrieving and aggregating council data

The councils generally store the consent information on databases following the authorisation of a resource consent.

The databases supplied and council comments show that consent data management significantly differs between regions. Most of the councils have identified the importance of maintaining a single database that contains all details related to allocation data, and some councils are planning to install better data management systems.

The ease of information retrieval from electronic consent databases varies depending on what is stored. Aqualinc Research Ltd. requested data for the *Updated Allocation Report, 2009* and experienced various errors, anomalies and inconsistencies in consent datasets. There were also gaps in data completeness. This makes data aggregation into national datasets difficult and reduces the robustness of the information the data provides. The New Start for Freshwater – project 8, hopes to address some of these gaps and inconsistencies – see below. MfE and the councils will continue to work together to improve the data on water allocation.

Ongoing and Future Work

New Start for Fresh water

In 2009 Cabinet agreed to a new strategic direction for managing fresh water, *A New Start for Fresh Water*. The programme has a 10 projects scoped to target areas where tangible progress can be made. There are some projects of particular importance to the future of water allocation in New Zealand, these include:

Project 1 – environmental **flow limits** and water measuring

- Establish methods for setting and enforcing quantity limits that reflect ecological bottom lines, Māori and broader community values
- Implement standards for measurement and reporting of takes
- Recommend ways of streamlining water conservation order processes

Project 4 – **allocation of water** to maximise value

- Identify barriers to more efficient allocation of abstracted water
- Identify options, and the associated information requirements for effective allocation framework (water takes and assimilative capacity)
- Explore incentives for councils to implement efficient allocation methods

Project 5 – **over-allocation** and possible interim interventions

- Identify pressure points and interim actions to address existing, and prevent future, over-allocation

Project 8 – water monitoring and reporting

- Identify and begin to correct gaps and inconsistencies in fresh water monitoring
- Define options to support councils and monitoring agencies, including national guidance, legislation, funding and incentives
- Prioritise actions and resourcing, with priority on reporting

Water stock accounts

The water stocks information produced by Statistics New Zealand (2005) will be updated in mid 2011. This is useful information on quantities of water in the inland hydrological system.

Tier 1 statistics

Tier 1 statistics are a portfolio of key official statistics which departments use to advise and inform ministers, and which are of broad public interest. They are performance measures of New Zealand and are essential to central government decision making, as well of high public interest, and provide international comparability. There is a possibility that Tier 1 statistics may include indicator information on water quantity in the near future.

Regulations for Measuring Water Takes

The Resource Management (Measurement and Reporting of Water Takes) Regulations 2010 have been developed in partnership with MAF, sector organisations, and councils.

One of the policy objectives of these regulations is to ensure consistent measuring and reporting of actual water taken at national, regional and catchment levels. More accurate and extensive information will also enable New Zealand to fulfil OECD reporting expectations, and will provide invaluable information on allocation usage in New Zealand in the future.

The regulations will apply to all resource consents allowed to take water at a rate of 5 litres/second or more, except for non-consumptive takes (as described in the regulations), and takes of geothermal or coastal water. The regulations will include transitional provisions so that existing consent holders will have between 2-6 years to comply.

For applicable consents, the regulations will impose minimum requirements relating to:

- the keeping of records of water use, and
- the provision of those records to regional councils on an annual basis.

Minimum requirements for the keeping of records will include minimum accuracy requirements, and a requirement to have water measuring devices regularly verified for accuracy. Measurements of water use will need to be continuous, but the actual records themselves will be comprised of daily or weekly totals.

Annual records will therefore be a further aggregation of those daily or weekly totals.

Summary

- New Zealand has a plentiful supply of freshwater, but in-stream values need to be maintained, which can limit the availability in some areas.
- MfE reports on a number of key environmental indicators to provide key information on the state of the environment.
- The indicator for freshwater demand is total consumptive water allocation.
- MfE holds aggregated consent data for the years 1999, 2006 and 2010. This data is obtained from regional councils who have the responsibility of allocating water in New Zealand.
- Retrieving and aggregating council consent data is time consuming and costly and is associated with errors, anomalies and inconsistencies.
- The freshwater demand indicator has some limitations because allocated volumes can only be seen as a proxy for volumes of water actually abstracted.
- Ongoing and future work hopes to address many of the gaps and limitations with the national data on allocation. This includes some of the projects within the New Start for Freshwater and regulations on measuring water takes. These initiatives should assist with the management of water allocation and the production of a more robust dataset on abstracted water in New Zealand.

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