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NATIONAL POLICY STATEMENT FOR FRESHWATER MANAGEMENT 2014

A Guide to Freshwater Accounting under the National Policy Statement for Freshwater Management 2014

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1 Introduction

The [National Policy Statement for Freshwater Management \(NPS-FM\)](#) requires regional councils and unitary authorities to establish freshwater accounting systems for both water quantity and quality. This document provides guidance on how to establish freshwater accounting systems to meet the requirements of the NPS-FM. Its primary audience is people working in regional councils and unitary authorities (hereafter referred to as 'councils'). However, other stakeholders, such as those involved in collaborative decision-making processes with councils, may also find it of value.

1.1 Document structure

There is no single correct or preferred way to establish a freshwater accounting system to meet the requirements of the NPS-FM. Rather each system needs to reflect the issues of the freshwater management unit for which the accounts are being generated. Therefore, to allow councils flexibility to establish a freshwater accounting system that suits their unique needs, the Ministry for the Environment has avoided providing prescriptive guidance on 'how to account for fresh water'. Instead, this document provides advice on the principles and key components that make up a successful accounting system, along with general guidance and explanations. Case studies are used to illustrate key points raised in the text and/or to show how the concepts may work in practice. Note that, while care has been taken to provide high-quality case studies, inclusion of a case study in this guidance should not be taken as an indication of endorsement of the approach by the Ministry for the Environment.

The outline of the remainder of this document is as follows:

Section 2 – explains what freshwater accounting is and the relationship between the NPS-FM accounting requirements and other regulatory instruments used to manage fresh water.

Section 3 – outlines nine principles for freshwater accounting that encapsulate the fundamentals of good accounting practice.

Section 4 – provides general advice on matters such as the importance of scale and significance, spatial and temporal resolution of accounting, using models, and dealing with uncertainties.

Section 5 – outlines the key components and main steps involved in establishing freshwater quantity accounting systems.

Section 6 – outlines the key components and main steps involved in establishing freshwater quality accounting systems.

A high-level overview of the NPS-FM, including the freshwater accounting guidance requirements, is in [A Guide to the National Policy Statement for Freshwater Management 2014](#). This provides background and context information, as well as policy interpretation of the NPS-FM. It also explains much of the terminology from the NPS-FM that is used in this guidance on freshwater accounting.

1.2 Development of this guidance

In 2014, the Ministry for the Environment engaged a project team led by the National Institute of Water and Atmospheric Research (NIWA) to help develop freshwater accounting guidance. The team's report forms the basis of this guidance.

Staff from six councils were also involved and provided valuable input throughout its development.

All contributors are listed in the Acknowledgements on page 80 of this document.

1.3 Other National Policy Statement for Freshwater Management guidance

This is one in a series of guidance documents being developed to support the implementation of the NPS-FM. Note that some of these guidance documents will provide more detail on topics that are touched on in this guidance, including:

- setting freshwater management units (FMUs)
- freshwater objective-setting process (values, attributes and freshwater objectives)
- limits and management methods
- using models.

For a full list of the guidance that is already available or under development, see www.mfe.govt.nz/fresh-water/tools-and-guidelines/implementing-national-policy-statement-freshwater-management.

2 Background

This section explains what freshwater accounting is and the relationship between the NPS-FM accounting requirement and other freshwater management instruments.

2.1 What is freshwater accounting?

The term ‘freshwater accounting’ refers to collecting information about the existing water use and the pressures on the freshwater resources being managed in a particular area. To do this, freshwater accounting must be carried out for both water **quality** and **quantity**.

The NPS-FM defines freshwater accounting systems as follows:

“Freshwater **quality** accounting system” means a system that, for each freshwater management unit, records, aggregates and keeps regularly updated, information on the measured, modelled or estimated:

- a) loads and/or concentrations of relevant contaminants;
- b) sources of relevant contaminants;
- c) amount of each contaminant attributable to each source; and
- d) where limits have been set, proportion of the limit that is being used.

“Freshwater **quantity** accounting system” means a system that, for each freshwater management unit, records, aggregates and keeps regularly updated, information on the measured, modelled or estimated:

- a) total freshwater take;
- b) proportion of freshwater taken by each major category of use; and
- c) where limits have been set, the proportion of the limit that has been taken.

Within a freshwater **quantity** accounting system, all water taken from the freshwater management unit must be quantified. This includes water taken under resource consent (both the total amount allocated within the consent and the amount of water that is actually taken), as well as any (estimated or modelled) takes that are permitted or do not require a resource consent, such as stock water. This includes both consumptive and non-consumptive takes of water.

Similarly, a freshwater **quality** accounting system requires all relevant contaminants that are being discharged to fresh water to be quantified. This includes both point sources and diffuse sources of contaminants.

2.2 Why do we need accounting for fresh water?

It is essential to have good information on how we use fresh water, to make effective decisions on freshwater objectives and limits for resource use, as well as managing within those limits once set. Freshwater accounting is one part of this information. The NPS-FM requires councils to establish freshwater accounting systems (Part CC) for FMUs, where decisions on freshwater management are being made. The aim is to deliver an improved ability to set effective freshwater objectives and limits across the region.

The four main reasons councils need to account for fresh water are to:

- inform decisions on the setting and reviewing of freshwater objectives and limits
- inform decisions on the granting of resource consents and managing within limits, once these are set, to determine where reductions in discharges are needed, or where quantity is over-allocated
- provide feedback to communities on progress against set freshwater objectives and to act as a trigger for any needed changes in management practices
- provide information for investors about catchments where there are freshwater resources available, where constraints exist for further development (ie, where storage may be necessary).

Note that this guidance only covers the development of freshwater accounting systems. It does not cover the future use of the freshwater accounts in the setting of freshwater objectives and limits.

2.3 Relationship between freshwater accounting and other provisions of the NPS-FM

As indicated in Section 2.2, freshwater accounting is intended to help inform the setting of freshwater objectives and limits. The requirement for freshwater accounting is therefore closely related to Policy A1, Policy B1 and Policies CA1–CA4, which direct councils to set these freshwater objectives and limits using the National Objectives Framework. Other sections that relate to freshwater accounting include Part CB and Part D.

Part CB of the NPS-FM directs councils to establish a monitoring plan to monitor the progress against freshwater objectives (once these are set), using representative sites and long-term trends. Freshwater accounting information could comprise part of this monitoring data, in which case the monitoring plan would include details of the freshwater accounting system. Part D of the NPS-FM requires councils to take reasonable steps to engage with iwi and hapū in the management of fresh water. As freshwater accounting is one of the foundations for making decisions about the management of fresh water, it is suggested that councils engage with iwi and hapū about the intended approach to freshwater accounting.

For a comprehensive discussion of how the various parts of the NPS-FM relate to one another, please refer to [*A Guide to the National Policy Statement for Freshwater Management 2014*](#).

2.4 Relationship with other freshwater management instruments

While this guide covers the need for accounting as required by the NPS-FM, it is important that councils are also aware of other developments that may result in more prescriptive future requirements to collate regional records and report at the national level. The data used to inform freshwater accounting systems may overlap with other data requirements.

[*A Guide to the National Policy Statement for Freshwater Management 2014*](#) provides a summary of how the NPS-FM relates to national environmental standards (NES), national policy statements (NPS), the [*Resource Management \(Measurement and Reporting of Water Takes\) Regulations 2010*](#), water conservation orders, the Resource Management Act 1991 (RMA), Treaty of Waitangi settlement legislation and the Hauraki Gulf Marine Park Act 2000. When establishing accounting systems, consideration must be given to ensure that all obligations under these legislative instruments are adequately met.

Of particular relevance to freshwater accounting is the Resource Management (Measurement and Reporting of Water Takes) Regulations 2010 (commonly referred to as the ‘water metering regulations’). The water metering regulations require holders of consents for water takes greater than 5 litres per second to collect records of their water use and provide annual records to their council (unless the use of the water is non-consumptive, as set out in regulation 4(2)). The information generated under these regulations will be a substantial component of freshwater accounting, particularly for quantity. The regulations include staged implementation of reporting based on take size. Work is under way to collate this information at the national level.

To help facilitate and support national reporting, regional councils and the Ministry for the Environment have partnered, through Environmental Monitoring and Reporting (EMaR), to develop and operate regional and national data collection networks and reporting platforms. This includes standard monitoring protocols, methods, robust quality assurance and a federated national data management system. There may be benefit in councils considering the data collection and reporting advice from EMaR when establishing freshwater accounting systems, so that data management processes are complementary.

Case study 2.1 describes a previous national-level project to collate and analyse water quantity accounting information.

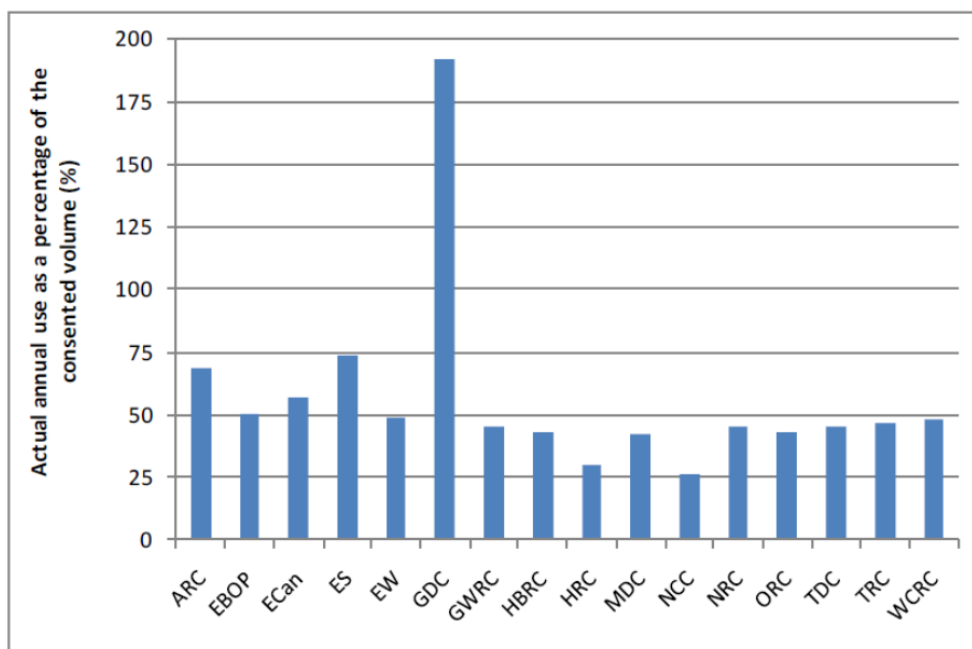
CASE STUDY 2.1 – WATER ALLOCATION SNAPSHOT

As part of its national environmental reporting programme, the Ministry for the Environment has, in the past, commissioned several reports to help measure a national water quantity indicator: *the volume of water allocated (via resource consent) to consumptive uses*. (See www.mfe.govt.nz/environmental-reporting/fresh-water/freshwater-demand-indicator/freshwater-demand-allocation.html.)

The most recent report (Aqualinc Research Ltd, 2010) presents a summary of the approach and results of the 2010 survey of freshwater take consents for both consumptive and non-consumptive uses, and also includes estimates of actual abstraction volumes of the consented takes.

Figure 2.1 shows that, for most regions (with the exception of Gisborne), total water use is likely well below (65 per cent of) allocation levels. Freshwater accounting information will help councils determine the difference between allocation and use, and identify potential situations where paper allocations can be better aligned with actual use. This will enable councils to better provide for Objective B3, which requires councils to improve and maximise the efficient allocation and use of water. Note that there may also be situations where matching paper allocations with actual use may not be desirable. For example, a certain industrial use (such as frost spraying in horticulture) may often not use its allocation but still needs that potential water for use.

Figure 2.1: Estimated annual water use by regions



Source: Aqualinc Research Ltd, 2010.

The report is available at: www.mfe.govt.nz/publications/water/water-allocation-2009-10/.

3 Principles of freshwater accounting

This section outlines nine high-level principles of freshwater accounting that encapsulate the fundamentals of accounting practice. The principles reflect a general philosophy of how freshwater accounting should ideally contribute to councils' freshwater management 'toolbox'.

The nine principles are based on:

- the six criteria used to evaluate accounting systems in the stocktake reported in Rouse et al, 2013 (see www.mfe.govt.nz/publications/fresh-water/regional-council-freshwater-management-methodologies-accounting-systems-and)
- general features outlined in the Australian standard for water accounting (see www.bom.gov.au/water/standards/wasb/wasbawas.shtml)
- principles and protocols for Tier 1 statistics (see www.mfe.govt.nz/environmental-reporting/about-environmental-reporting/national-environmental-indicators/environmental-indicator-criteria/index.html)
- principles suggested by council representatives.

Table 3.1: Principles of freshwater accounting

Principles	Descriptors
Risk-based	Accounting systems should allow for accounts to be generated using methods appropriate to the scale and significance of issues in a freshwater management unit (FMU). Identification of relevant contaminant sources should be linked to risks faced in an FMU.
Transparent	The purpose of the accounting system should be clearly stated. Accounting information should be easily accessible by water users, iwi and the community. All methods used for accounting should be clearly documented, so that calculations are repeatable.
Technically robust	Accounting systems should use good practice methods based on relevant science. Accounting systems should allow comparison between years (or reporting periods) and with other FMUs. Any errors and uncertainties of methods used should be clearly documented. Quality assurance steps should be documented, and methods for handling any data issues that may come to light outlined.
Practical	Accounting systems should allow for councils to collate information from various existing systems or models (eg, consents databases, monitoring databases). The systems should allow reports to be generated and displayed for water users, iwi and the community. Accounting systems should be future-proofed, so they remain practical, capable of being replicated, understood and upgraded over time.

Principles	Descriptors
Effective and relevant	<p>Accounting systems should be fit for purpose – that is, they should allow for the four potential uses of accounting information (see section 2.2) for regional freshwater management.</p> <p>Accounting systems should produce meaningful information (accurate, appropriate to the spatial scale of the issues and useful to the intended end users), noting that this may vary with the purpose of the accounts being produced.</p> <p>Accounting systems should be cost-effective.</p>
Timely	<p>Accounting systems should allow a council to produce regular accounts in a suitable form for water quantity and water quality for the FMUs, where freshwater objectives and limits are being set or reviewed.</p> <p>Accounting systems should allow councils to collect and analyse information at frequencies that are relevant to the intended management use (eg, seasonally, to be relevant to ecological systems and variability in flows; daily, if data will be used for operational water take and/or restriction management).</p>
Partnership	<p>Accounting systems should be developed and information collected in partnership with stakeholders, iwi and the community. This will help to ensure that the accounts produced are well understood and accepted. It will also help to minimise duplication of resources and ensure that appropriate aggregation is used to protect individual and commercial privacy.</p>
Adaptable	<p>Accounting systems should allow for flexibility to accommodate different methods appropriate to the scale and significance of the issues in different FMUs.</p> <p>The systems should allow for improvements in methods and the accuracy of measurements, estimates and/or modelling results over time.</p> <p>Accounting systems should allow for the integrated and iterative nature of freshwater management.</p> <p>Where considered appropriate or necessary, systems should allow for reporting that is scalable from FMUs (or water management zones, if this is different) to the regional level.</p>
Integrated	<p>Where appropriate, the system should allow for the consideration and combined reporting of, for example, surface water and groundwater interactions or discharges to different receiving waters, such as estuaries.</p>

4 General guidance

This section provides general guidance on applying the principles in table 3.1. A box at the beginning of each topic highlights which principle(s) are relevant. Guidance is provided on the following topics:

- the importance of scale and significance ([4.1](#))
- setting freshwater management units ([4.2](#))
- spatial resolution of accounting ([4.3](#))
- frequency of accounting ([4.4](#))
- the need for flexibility ([4.5](#))
- comments on using models ([4.6](#))
- estimating accuracy and uncertainties ([4.7](#))
- presenting information to communities ([4.8](#)).

4.1 The importance of scale and significance

The following advice is aligned with the principles: Risk-based, Practical.

While in global terms New Zealand has abundant water (Statistics New Zealand, 2011), our island weather and topography mean this water is unevenly distributed, both spatially and temporally (Salinger et al, 2004). While there is an abundance of water overall, there may be high demand (and thus potential scarcity) for suitable water for particular uses. The resulting variability in water supply, demand, run off, discharges and receiving environments means each region has very specific water quantity and quality issues to manage.

The NPS-FM, through Policy CC1(b), expects that accounting happens “at levels of detail that are commensurate with the significance of the freshwater quality and freshwater quantity issues, respectively, in each freshwater management unit”. This policy direction is a fundamental starting point for much of the guidance that follows – that is, that FMUs (or waterbodies, catchments, aquifers, regions, or parts thereof) do not all have the same water resource management needs. Methods for accounting for all water takes and all relevant sources of contaminants can therefore vary between FMUs.

One way to decide which methods may be appropriate to use is a risk-management approach. Understanding risk normally requires an understanding of the *likelihood* and *consequences* of an event or action. Freshwater management under the RMA is implicitly risk based (Rouse and Norton, 2010). Case study 4.1 provides an example of a risk-based approach.

CASE STUDY 4.1 – USING A RISK-BASED APPROACH TO SELECT TECHNICAL METHODS

The *Draft Guidelines for the Selection of Methods to Determine Ecological Flows and Water Levels* (Beca Infrastructure, 2008) outline a risk-based approach for selecting methods to be used to set minimum flows to protect ecological instream values (as part of setting environmental flows or limits, in NPS-FM terminology).

The system looks at the degree of hydrological alteration (how much water is to be taken from the water body) to help assess the *likelihood* aspect of the risk and ranks this against the significance of values identified for that water body to better understand the *consequence* aspect of that risk. For example, for rivers, a low degree of alteration and low significance of values would mean that a simple method (or estimate) could be used to assess potential ecological flow requirements, such as a hydrological statistic or expert panel. At the opposite end of the spectrum, a high degree of alteration and high instream values would suggest a need to use detailed knowledge and models to predict ecological flow requirements.

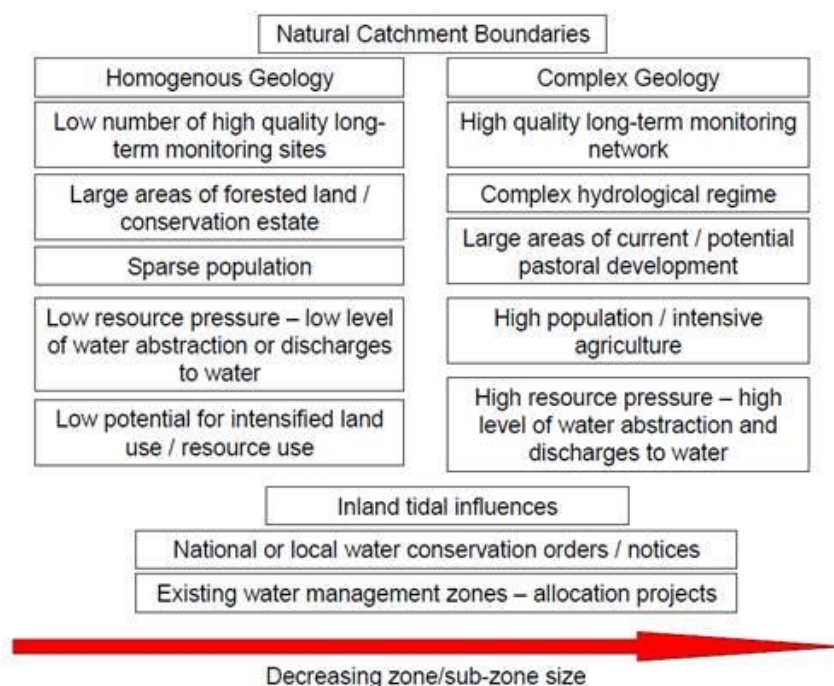
A risk-based approach similar to case study 4.1 could be used to select methods for freshwater accounting, using an understanding of the pressures on water quantity and quality in an FMU on one hand, and the values of that FMU to its community on the other. A scoping exercise could be undertaken first to identify priority or high-risk FMUs. For example, *A Guide to the National Policy Statement for Freshwater Management 2014* suggests that, for water quality accounting, a preliminary assessment of likely values and objectives could be carried out. Along with this, an initial low cost accounting process could be completed to identify the most relevant contaminant(s). Once the range of possible freshwater objectives is narrowed, more accurate accounting may be needed. This is likely in cases where, for example, significant reductions in discharges of relevant contaminants are needed to achieve the freshwater objectives being considered.

This risk-based approach is discussed further in 4.5, and case study 4.2 describes the risk-based approach used by Horizons Regional Council for setting FMUs.

CASE STUDY 4.2 – HORIZONS REGIONAL COUNCIL'S RISK-BASED SETTING OF FRESHWATER MANAGEMENT UNITS

Horizons Regional Council used a risk-based approach to set its water management zones (WMZs). In the Whanganui catchment, where the pressures on water are relatively low, Horizons selected relatively large WMZs. In contrast, for the Manawatū catchment, where pressures are high, much smaller WMZs were set, enabling more detailed information to be collected. Figure 4.1 illustrates the criteria used to select WMZ size.

Figure 4.1: Using resource pressure and other influences in a risk-based approach to selecting the size of water management zones in the Horizons region



More information can be found at

www.horizons.govt.nz/assets/horizons/Images/Development%20of%20Water%20Management%20Zones%20in%20the%20MW%20Reg.pdf.

4.2 Setting freshwater management units

The following advice is aligned with four principles: Technically robust, Effective and relevant, Adaptable, Integrated.

FMUs are the fundamental units of a freshwater quantity and quality accounting system. The NPS-FM defines an FMU as:

...the water body, multiple water bodies or part of a water body determined by the regional council as the appropriate spatial scale for setting freshwater objectives and limits and for freshwater accounting and management purposes.

Additionally, accounts for FMUs could enable comparisons to be made between them, or aggregation to explore regional issues.

The main point to note is that the number and scale of FMUs in a region will have an impact on plan development and workability. FMUs will contain common freshwater objectives for the water body or bodies within it, so that representative monitoring sites can be readily established. This means FMUs should be not just hydrologically coherent (of similar hydrology) but also similar from a social perspective, so that communities and iwi with common interests and values are contributing to common objectives.

Many councils had already set water management zones or units before the introduction of the NPS-FM. These zones may or may not be the same as an FMU. For instance, they may need scaling up or down for particular issues to be addressed, in order to contribute to a common objective being set for an FMU. These zones may have been set for water quantity management purposes and may need to be reviewed to assess whether they are also appropriately scaled for meeting the needs of the NPS-FM.

4.3 Spatial resolution of accounting

The following advice is aligned with five principles: Technically robust, Effective and relevant, Adaptable, Integrated, Practical.

As explained in 4.2, the fundamental unit for freshwater accounting is the FMU. The most suitable spatial resolution used for an accounting system will be dictated by the issues and concerns needing to be managed within the FMU, and the availability of information.

A freshwater accounting system could operate at a regional, FMU, catchment or sub-catchment level, or even at an activity (individual take or point source) level, depending on the needs of the council and the information available. Flexibility in the accounting system to allow accounts to be produced at the most relevant scale, and be aggregated to FMU or regional levels, may be desirable. Some councils are already able to produce accounts for regional and catchment scales, as highlighted in case studies 4.4 and 4.5.

CASE STUDY 4.4 – REGIONAL WATER ACCOUNTS

Some councils already have systems that enable them to produce accounts at a regional level. For example, table 4.1 shows water quantity accounts for the Auckland region for the years 2004/05 and 2005/06.

Table 4.1: Key water use and allocation statistics for Auckland region

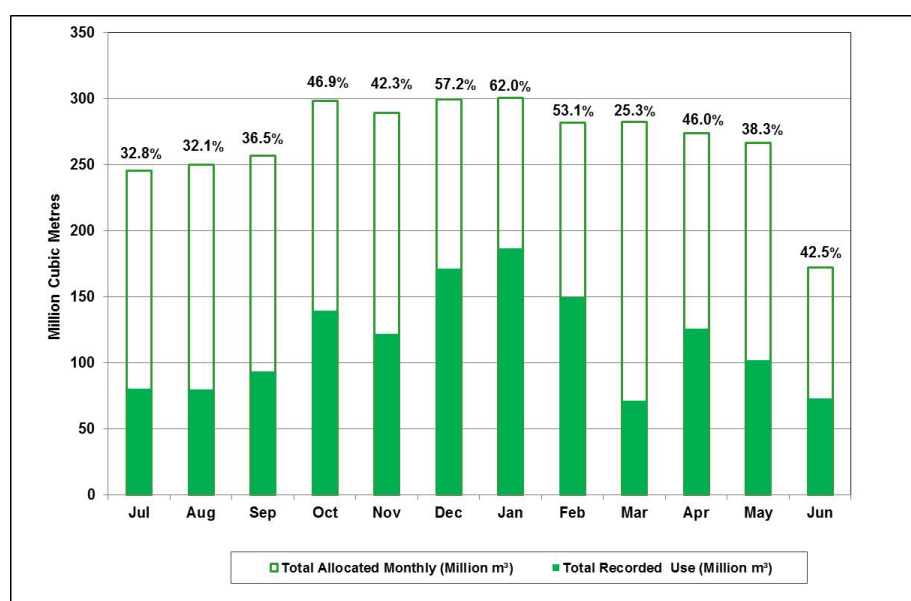
Key water statistics	2004/05	2005/06
Number of consents	1,499	1,439
Groundwater take consents	1,172	1,132
Surface water take consents	327	307
Water allocated	152 Mm ³	138 Mm ³
Water used	118 Mm ³	104 Mm ³
Inactive consents	22%	21%
Quarterly meter returns	90%	91%
Failed quarterly returns	4%	9%
Consents with use exceeding water allocation	12%	14.50%

Note: Mm³ = million cubic metres.

Source: Auckland Council, in Rouse et al, 2013

Figure 4.2 shows surface water use data collected for the 2011/12 water year in the Canterbury region as a monthly allocation. The allocated volume for each month is shown by the green outlined portion of the bar, and the actual water use volumes are shown by the solid green portion. The percentage of allocation used is shown at the top of each bar.

Figure 4.2: Allocated versus used surface water volumes in the Canterbury region (2011/12 water year)

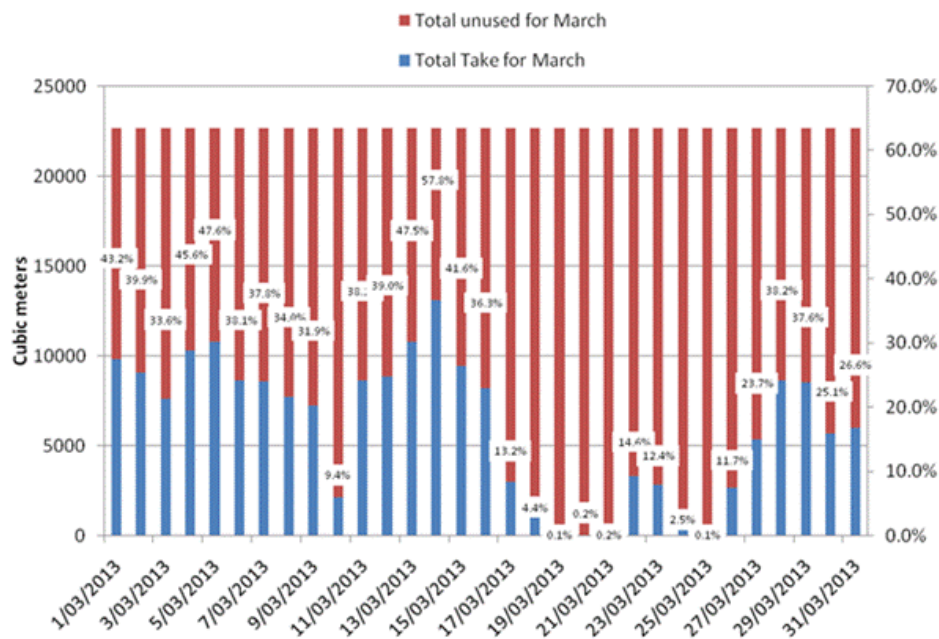


Source: Environment Canterbury, in Rouse et al, 2013

CASE STUDY 4.5 – CATCHMENT WATER ACCOUNTS

Waikato Regional Council has a system that enables it to produce accounts at catchment or sub-catchment level. For example, figure 4.3 shows allocated and actual takes from the Waihou catchment.

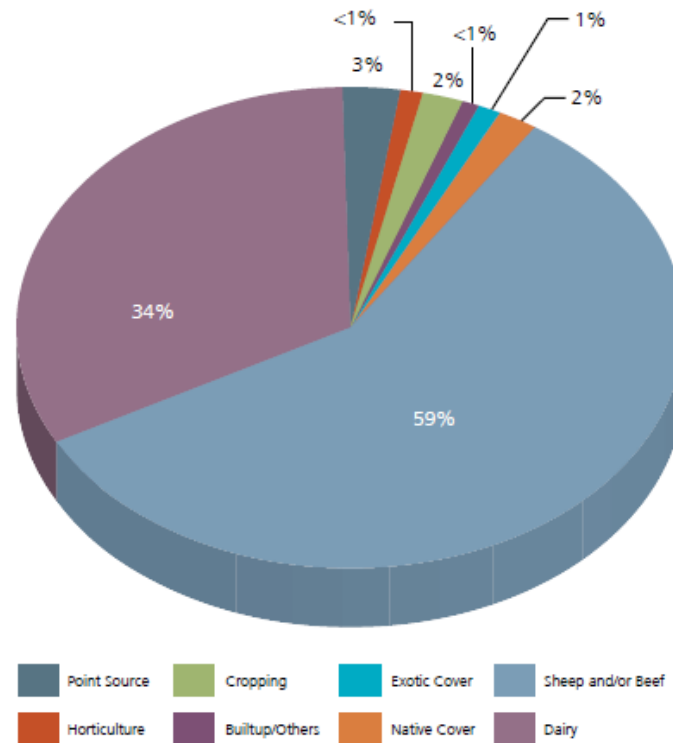
Figure 4.3: Allocated and actual daily use in part of Waihou catchment, March 2013



Source: Waikato Regional Council, in Rouse et al, 2013

Figure 4.4 shows sources of nitrogen in the upper Manawatū catchment.

Figure 4.4: Percentage contribution from different land uses to nitrogen load in upper Manawatū River



Source: Horizons Regional Council State of the Environment 2013 report, in Rouse et al, 2013

4.4 Frequency of accounting

The following advice is aligned with four principles: Technically robust, Effective and relevant, Timely, Adaptable.

One of the important things to define when producing freshwater accounts is the frequency of reporting. Frequency of reporting is different from the frequency of measurement. For example, the water metering regulations require records to be produced from continuous measurement, recording a volume of water taken each day (or week in certain circumstances). However, these records of measurements taken over the duration of a water year (1 July through to 30 June) have to be reported annually, within a month of the end of the water year.

The NPS-FM (Policy CC2) says that accounting information should be available 'regularly' and for FMUs where councils are setting or reviewing freshwater objectives and limits. The frequency with which councils choose to produce and report accounts depends on their management needs. It is likely that very few management questions will be answered with annual accounts. Seasonal

information reflecting ecological processes and drivers, such as flow conditions, may be more important. For example, high loads of contaminants during flood flows may not be such a problem as at low flows, and so rather than annual loads, councils may choose to 'bin' flows to better understand how loads vary with flow (see case study 6.4). Again, a risk-based approach would suggest that frequency of accounting should relate to the risks and/or issues being managed in an FMU, and at a frequency that allows detection of change.

The frequency with which accounts are accessed and reported will also depend on the system being used. Most councils are likely to have (at least initially) a hybrid physical 'system' whereby some data is managed through information technology (IT) systems (databases, perhaps telemetered water quantity data) and some manually (through paper returns from consent holders). Where IT systems are used, thought needs to be given to ensuring any existing protocols (eg, quality assurance (QA) and quality control (QC)) would still be appropriate for use in an accounting sense. For manual systems (and possibly also for IT-based systems), councils may need to consider whether there may be some benefit in increasing the frequency of QA and QC processes. This applies particularly to water quality data where routine QA measures may not be as prevalent as those for water quantity.

It is important that data is quality assured in advance of generating accounting reports. More detail on QA and QC is provided in 4.7. Further detail on national initiatives on the standardisation of data is in case study 4.11.

There may be advantages in developing accounting systems that allow for more automated production of accounting reports. Such automation is useful for managing issues where more frequent accounting information (such as weekly, monthly or seasonal) could make decision-making easier in cases where more intensive management is required. Managing water takes within water quantity limits, by establishing restrictions to keep instream flows above a minimum, is an example of where automation may be useful.

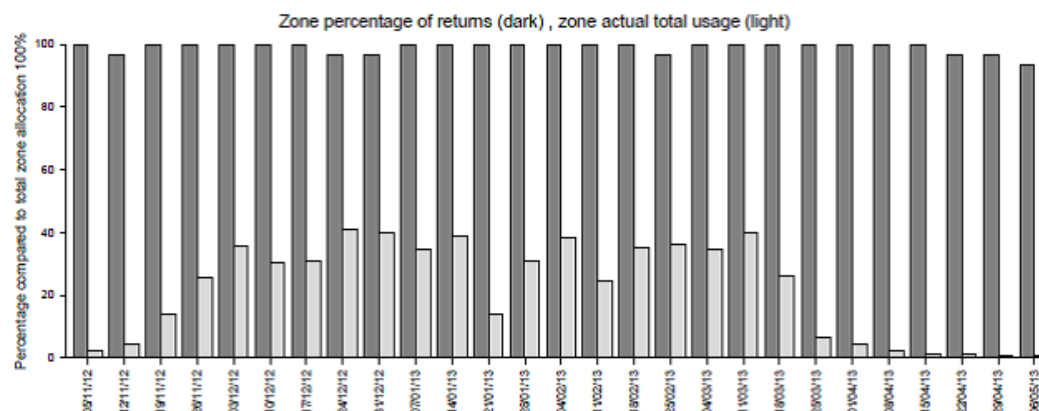
Case study 4.6 outlines examples of freshwater quantity accounting systems from Tasman District Council and Horizons Regional Council that use weekly and daily intervals respectively.

CASE STUDY 4.6 – FREQUENCY OF ACCOUNTING

Councils have existing accounting systems that are fit for purpose for their freshwater management needs. Two contrasting systems, summarised in Rouse et al (2013), are discussed here.

Tasman District Council's water quantity accounting system uses manual returns from consent holders in some catchments. Levels of returns are generally high and enable the Council to produce accounts, such as figure 4.5, which shows the percentage of returns received and the weekly actual use for the Moutere Eastern Groundwater Zone, between November 2012 and May 2013.

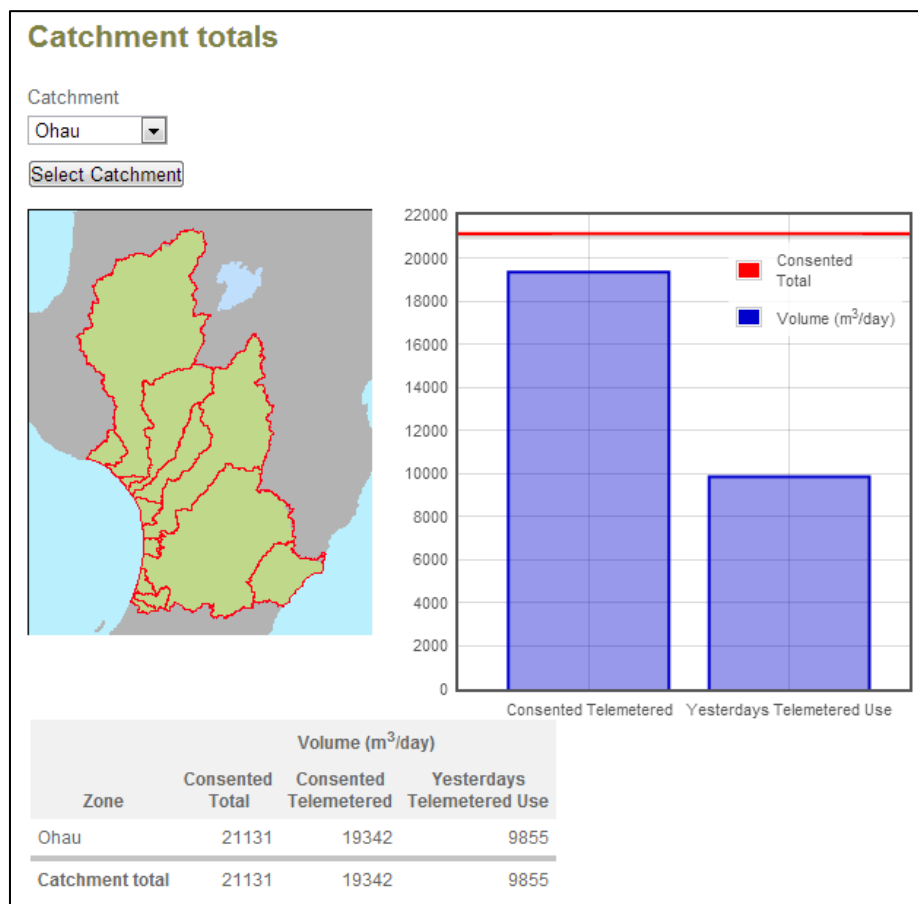
Figure 4.5: Returns received and actual weekly use for the Moutere Eastern Groundwater Zone, November 2012 to May 2013



Source: Tasman District Council, in Rouse et al, 2013

Horizons Regional Council has developed a system called WaterMatters that enables it to use telemetry from metered water takes to produce daily accounts (as shown in figure 4.6). This information is used to assist with operational water take compliance and restrictions management.

Figure 4.6: Allocated and actual daily use on the two days preceding 21 June 213, for the Ohau catchment



Source: Horizons Regional Council, in Rouse et al, 2013

For more on WaterMatters, see Roygard (2009) at www.horizons.govt.nz/assets/horizons/images/One%20Plan%20officers%20reports/Dr%20Jon%20Roygard.pdf.

4.5 The need for flexibility

The following advice is aligned with five principles: Risk based, Transparent, Technically robust, Adaptable, Integrated.

The NPS-FM allows for councils to develop accounting systems and accounts at a level of detail “commensurate with the significance” of the issues being managed in an FMU (see also discussion in 4.1). That means the systems and methods used can be flexible to allow for spatial and temporal variability in management issues.

It is not easy to develop a robust accounting system for a complex real-world system. The level of importance of pressures or values (for water quantity or quality) varies between regions and catchments. The multiple individual pressures of a natural system may also interact in complex ways in a natural system, so an accounting system that allows an integrated approach may be desirable. Therefore, it is important for councils to apportion appropriate resources depending on the significance of their issues, to optimise the cost-benefit of any accounting exercises. For example, while high-frequency water sampling may be needed to assess nitrate concentration in a highly developed agricultural catchment to manage water quality, such an intense monitoring system may be unnecessary for a catchment that is near its natural state, unless the pressures are identified as increasing.

A sensible approach may be to begin with a simple system for accounting, allowing for methods and the system itself to improve with time. A good example is the approach taken by Horizons Regional Council (see case study 4.7), which developed a simple accounting system to identify the catchments, rivers and aquifers that required more accurate estimates. Detailed scientific and technical studies were then conducted on these 'hotspots' to improve understanding of the water quality.

More information about using a flexible, risk-based approach to select methods appropriate for different types of water takes (eg, permitted or consented) and different sources of contaminants is provided in 5.2 and 5.3.

CASE STUDY 4.7 – APPROACHES TO ENVIRONMENTAL FLOW SETTING

Horizons Regional Council used an explicitly risk-based approach for selecting methods to set minimum flows and core allocation limits for its water management zones and sub-zones. It has developed a decision support framework and identified six 'scenarios' that may require the use of different techniques. These range from robust techniques, such as physical habitat modelling, to default methods using percentages of a river's mean annual low flow (MALF). For more on Horizons' approach to flow setting, see Roygard (2009) at www.horizons.govt.nz/assets/horizons/Images/One%20Plan%20officers%20reports/Dr%20Jon%20Roygard.pdf.

Otago Regional Council uses physical habitat modelling as one of the key science components to setting minimum flow requirements for main stem rivers in its catchments. At present, IFIM (physical habitat modelling) is the approach used, mostly because there are few alternatives at a similar cost. Habitat modelling is both data and time intensive, which means these studies can be relatively expensive. However, Otago rivers are either heavily relied on for water abstraction or contain high fisheries value (both sports fish and native fish), which means the risks are high and more detailed methods are justified.

To set allocation limits, hydrological alteration, surety of supply and actual take information are considered as part of the minimum flow process. Actual takes are accounted for through summing the water use data collected under the national water metering regulations or consent conditions.

Technical reports supporting Otago Regional Council's approach can be found on its website www.orc.govt.nz/Utils/Search/?whole=true&query=aquatic+ecosystems.

In summary, allowing for flexibility is important when determining what accounting method to use. The method should be able to change as circumstances change. As discussed in 4.1, it may be appropriate to use a risk-based approach; first carry out a scoping exercise and then devise an appropriate approach for the region. The general approach might then be:

- measure at an appropriate intensity in high-priority areas
- estimate where order of magnitude is sufficient
- model (with validation) where measurements are not possible and/or detailed predictions are needed.

In practice, methods for measuring consented water takes may differ from methods used to estimate certain permitted uses. Whatever methods are used, it is important to ensure they can produce water accounts in a manner consistent with the freshwater objectives set for the FMU. Furthermore, accounting information for an FMU or catchment may need to feed into regional accounting systems to allow comparisons between FMUs and may, in the future, be useful for national reporting.

CASE STUDY 4.8 – BEING PRECAUTIONARY WHEN USING ESTIMATES

If robust measurements are unavailable, it may make sense to be conservative in producing estimates. Waikato Regional Council used this approach in determining allocable surface water flows (ie, a type of limit). It developed a default approach to setting the allocable flow component of water quantity limits, using a statistic (10 per cent of Q_5)¹ as the allocable flow for streams when minimum flows were not set using a more detailed scientific study of instream flow requirements. As the Council learns more about stream hydrology through scientific studies of similar streams, it has allowed for flexibility to increase the percentage of allocable flow for some streams (J Smith, Waikato Regional Council, pers. comm., 8 July 2014). Statistical methods are useful in migrating information from different scales, such as the size of a catchment.

4.6 Comments on using models

The following advice is aligned with four principles: Technically robust, Effective and relevant, Adaptable, Integrated.

The well-known adage “you can’t manage what you don’t measure” is largely true. But, as outlined in 4.5, for the sake of practicality, it is unfeasible to measure everything, at least not all the time. For example, some measurements, particularly water quality concentration measurements, are

¹ Q_5 – the seven-day low flow, which has a 20 per cent probability of occurring in any one year (one-in-five year return period). A seven-day annual flow minima is the lowest average flow over seven consecutive 24-hour periods for each complete year of flow record.

expensive to collect or analyse, and can cost hundreds of dollars per sample. It is therefore common practice to use models to obtain information that it is not feasible to measure. For example, models may be used to estimate contaminant loads or to extrapolate from limited existing data in order to inform decision-making on limits.

For the purpose of freshwater accounting, modelling may need to be carried out at different scales in order to provide sufficient information for the setting of freshwater objectives and limits.

As stated by George Box, “All models are wrong, but some are useful” (quoted in Motu, 2013). It is important to remember that models are abstract representations of reality and that they necessarily contain important assumptions and limitations. Furthermore, the amount of data and information available to construct a robust model can also be limited. It is therefore important to be open about the design and inherent assumptions used in a model, because if its structure and input data are inaccurate or uncertain, this will be directly reflected in the model’s outputs. Being transparent and expressing the assumptions, limitations, error and uncertainty associated with predictions is an essential part of using models. It is important to understand these limitations, particularly when they are to be used to communicate with communities involved in freshwater management decisions for an FMU (see 4.8).

The NPS-FM requires that freshwater quality accounts identify the source and attribute the amount of each relevant contaminant to their sources. Modelling may therefore need to be carried out at the activity scale, particularly for contaminants that are discharged to the environment in a diffuse manner such as nutrients from farming activities. The model OVERSEER® (discussed further in 6.5) is commonly used for this purpose. Similarly, freshwater quantity accounts are required to identify the proportion of water taken by each major category of use. For unmetered water takes (for example, permitted takes such as stock water), it may be necessary to develop models to estimate the water being taken for these uses (see case study 5.5).

However, modelling at the activity scale alone does not provide enough information to understand the impact of all the activities together on the receiving freshwater bodies. Integrated catchment models are therefore necessary to determine the cumulative impacts of all the activities together. Catchment models can also allow other factors that influence the impact of contaminants and water takes, such as lag and attenuation, to be considered as well. See Motu (2013) for further discussion on farm scale and catchment scale nutrient models. Case study 6.9 also provides examples of the use of nutrient models from around New Zealand.

Models can also be used as a predictive tool, especially for exploring scenarios for different possible futures. For example, an integrated groundwater–surface water model can be used to predict the future effects of water quality in a river (say in 50 years’ time) due to different scenarios of land-use change. A third use of models is to better understand complex systems, such as when there are significant surface water–groundwater interactions with lag times that we need to better understand in order to set limits. As summarised by Motu (2013), the processes that determine nutrient loss, transportation and concentration are complex. This complexity arises from spatial variability of soil, topography and land use; and temporal variability of climate, land management practices and nutrient transport beneath the ground.

There are two broad categories of models (Motu, 2013). Theoretical or conceptual models emphasise the key components of a system and their interactions without seeking to quantify the magnitude of any component or interaction (they are not quantitative). Numerical or computer models provide representations of reality that both describe how the different parts of the model interact and quantify the magnitude of the different interactions. In practical modelling systems, data is essential for testing and validating models.

Some key aspects that should be considered when selecting a model for use in freshwater accounting are provided below in case study 4.9.

CASE STUDY 4.9 – TEN TIPS FOR SELECTING MODELS

The following tips are taken from Wyatt et al (2014) and are based on advice from the Envirolink Tools decision support system (DSS) website <http://tools.envirolink.govt.nz/>.

1. Clearly define the questions you need the model, tool or DSS to help answer.
2. Define the requirements of the decision-making process you intend to follow (timeframes, resources, community participation).
3. Understand how the information provided by a tool, model or DSS will need to be presented to be useful for the community engagement and decision-making process you intend to follow.
4. Understand the underlying assumptions and limitations of the tool, model or DSS – can you live with these when explaining results and trying to create consensus in decision-making?
5. Understand what data and technical expertise is required to run the tool, model or DSS – can you provide or source these?
6. Check if there are additional costs involved in using the tool, model or DSS, such as software or licencing.
7. See how easy the tool, model or DSS is to use – can it be readily included into an existing decision-making process?
8. Check to see if there is support for learning about, setting up and using the tool, model or DSS (documentation, case studies, New Zealand examples and/or users).
9. Understand the ‘maturity’ of the tool, model or DSS – new and emerging DSSs may require more resourcing to learn and implement.
10. Do more homework – take time to explore options and to understand the merits of using different approaches and DSSs.

4.7 Estimating accuracy and uncertainties

The following advice is aligned with four principles: Transparent, Technically robust, Effective and relevant, Adaptable.

As freshwater accounting is used to inform the setting of freshwater objectives and limits, uncertainties associated with the accounting data must be considered in the subsequent decision-making. Measurements and estimates are inherently associated with errors in that they are

inaccurate (they vary from the 'true' value) and contain uncertainty (there is some level of confidence in how well the estimate reflects the 'true' value). This uncertainty arises due to many factors such as limited or missing data, poor quality data, conceptual and structural errors of a model, and boundary condition errors. The expression of uncertainty for an estimate represents the compounding errors of data and the model itself (Maier and Ascough, 2006; Shepherd et al, 2013). Uncertainties will therefore exist whether a model is at the activity or catchment scale.

It is also important to recognise that *modelling uncertainty* and *predictive uncertainty* are not the same thing. *Modelling uncertainty* can be quantified and represents the imperfect fit of the estimates or predictions to reality. *Predictive uncertainty* arises from extrapolation errors. Future predictions made using a model often have high uncertainty as the future typically does not look like the past – for example, future flow predictions may be uncertain due to the effects of climate change.

It is vital to express an uncertainty for all estimated values because decision-makers and stakeholders need to understand it when considering the information. In other words, the uncertainty signals the level of confidence that they can place on the information. To this end, an estimate produced by a model or similar methodology is only complete if it is accompanied by a statement of the uncertainty. This uncertainty is often expressed as a statistical measure (for example, a standard error). It is also important to understand the impact that these uncertainties can have on the decision-making process. For instance, in high priority FMUs with issues of over allocation, it may be necessary to reduce the uncertainties in order to provide the necessary confidence in the outcomes of decisions.

In situations where decisions have to be made despite high levels of uncertainty, additional processes should be put in place to manage the associated risk. For instance, it may be appropriate for a programme of work to be outlined where, over time, uncertainties can be reduced and estimates refined (for example, through improved input data as a result of better monitoring practices) to allow decisions to be reviewed in the future. Similarly, using the precautionary principle may be appropriate when making decisions where uncertainties are high. For a high-level overview and additional resources on dealing with uncertainties when making decisions, see *A guide to section 32 of the Resource Management Act: Incorporating changes as a result of the Resource Management Amendment Act 2013* (Ministry for the Environment, 2014).

Examples of how councils are managing uncertainties and accuracy issues through QA and QC practices are summarised in case study 4.10. Case study 4.11 outlines some of the national initiatives under way to help standardise environmental data, to help increase consistency in data collection, thereby also creating consistency in accuracy and managing uncertainty.

CASE STUDY 4.10 – QUALITY ASSURANCE FOR HYDROLOGICAL DATA

Agencies that collect hydrometric data generally operate under a quality management system – that is, a set of rules to direct and control an organisation with regard to quality. It may include a policy or strategy, but more than anything, quality management is a process. Water data collection and archiving can be managed in a number of ways to assure the quality of the end product. For example, staff training, technical competence, good measurement practices, standard operating procedures and methods, proper facilities and equipment, calibration and maintenance of equipment, data checking (such as correcting gaps or spikes in a data series), system improvements and, finally, internal and external audits. There are standards such as ISO 9000 that exist to help ensure quality levels. All councils operate quality assurance (QA) and quality control (QC) systems, which are being formalised through the National Environmental Monitoring Standards (NEMS) initiative (see case study 4.11).

Environment Canterbury and Otago Regional Council are in the early stages of developing QA and QC systems for telemetered water metering data (under the water metering regulations). The checks are currently limited to assessing spikes and gaps in data. Environment Canterbury has developed a detailed approach that needs the water meters and associated telemetry equipment to be installed by accredited organisations, which ensures that the ± 5 per cent accuracy requirement of the water metering regulations is signed off by an industry-certified water meter installer (M Ettema, Environment Canterbury, pers. comm., 8 July 2014).

Horizons Regional Council has also developed requirements for water meter installation. Further details can be found at www.horizons.govt.nz/assets/publications/managing-our-environment/publications-consents/HRC-Watermeter-Brochure-12pg-FIN.pdf.

CASE STUDY 4.11 – NATIONAL INITIATIVES TO HELP STANDARDISE ENVIRONMENTAL DATA

Several initiatives currently being developed will continue to improve and standardise environmental data collection.

As described in 2.4, both the water metering regulations and Environmental Monitoring and Reporting (EMaR) are soon likely to require information fundamental to regional water accounting to also be reported at national level.

Land, Air, Water Aotearoa (LAWA) has expanded from being a collaboration between New Zealand's 17 regional and unitary councils, and is now a partnership between the councils, Cawthron Institute, Ministry for the Environment and Massey University, and has been supported by the Tindall Foundation. The website hosts environmental data from across the country, which is quality assured and archived. A user-friendly interface allows simple graphing and exploration of the data, and fact sheets offer more information on key topics (see case study 4.12).

The National Environmental Monitoring Standards (NEMS) steering group has prepared a series of environmental monitoring standards, with support from the Regional Chief Executive Officers and the Ministry for the Environment. The development of these standards was led by regional and unitary councils from across New Zealand, in partnership with the electricity generation industry and the National Institute of Water and Atmospheric Research (NIWA). These documents prescribe technical standards, methods and other requirements associated with the continuous monitoring of a number of environmental parameters. Drafts are currently under development for several topics, including water level recording, open channel flow measurement, water temperature, turbidity and dissolved oxygen.

See www.lawa.org.nz/ for more on LAWA and NEMS
www.mfe.govt.nz/more/environmental-reporting/about-environmental-reporting-nz/our-environmental-reporting-programm-0.

4.8 Presenting information to communities

The following advice is aligned with four principles: Transparent, Effective and relevant, Partnership, Adaptable.

Under the framework established by the NPS-FM, freshwater management may be approached in a collaborative way, and many councils are already exploring how to do this. If freshwater objectives and limits are to be set as part of a collaborative process, then any accounts produced need to be understandable to a non-technical audience. While the NPS-FM does not require collaborative processes to be used in this way, Policy CC2 requires councils to take, "... reasonable steps to ensure that information gathered ... is available to the public, regularly and in a suitable form". Furthermore, there are likely to be groups in each community and iwi who see value in freshwater accounts as a general source of information on fresh water, independent from any formal council-led decision-making processes. Some tips to help address this requirement are listed below.

- Make sure the purpose of the accounts is clear – which of the four key reasons for accounting outlined in 2.2 are you currently addressing? What are the main issues driving your need to account?
- Identify the audience that the accounts are intended for. This will help determine the best way for presenting the information.
- Be clear what FMU and which time period the accounts refer to.
- Avoid jargon and acronyms as far as possible.
- If frequently used technical terms cannot be avoided, introduce and explain each one and use them consistently.
- Use every-day analogies if these help communicate complex ideas.

- Use visuals (for example, bar or pie charts), as well as tables of figures. Consider using other formats, such as videos, where appropriate.
- Provide clear explanatory notes on methods and assumptions used, uncertainties and limitations associated with data such as gaps.
- Provide sources for further information for those who might be interested in finding out more.

Case study 4.12 provides examples of how environmental science information has been presented to communities to date, including the use of report cards and the LAWA website.

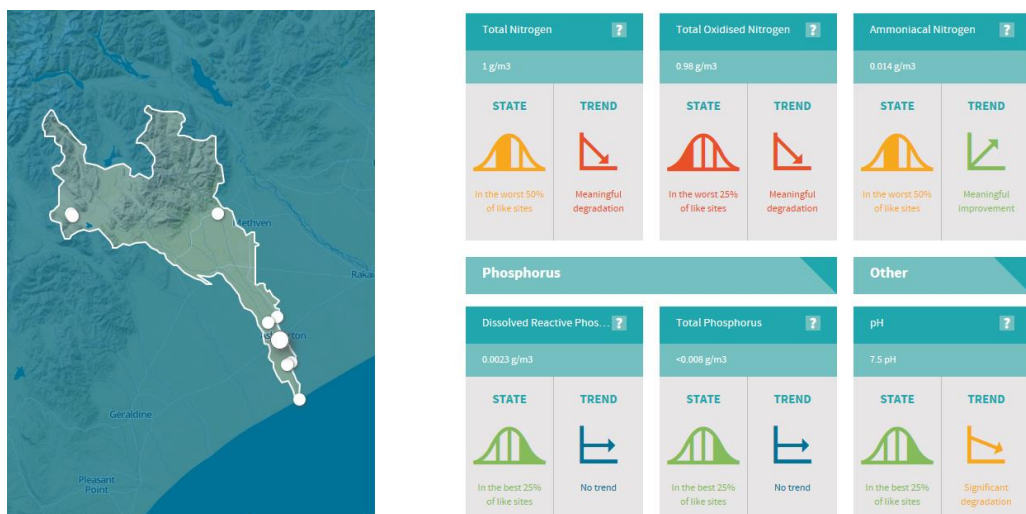
CASE STUDY 4.12 – COMMUNICATING IN COLLABORATIVE LIMIT-SETTING PROCESSES

In a broader freshwater management context, different councils and researchers are exploring different ways to communicate complex science information to communities as part of collaborative limit-setting processes. Examples include ‘traffic light’ tables or wheels, which use colours to indicate the extent to which different (often conflicting) freshwater objectives are being met. See section 5.6.1 of Wyatt et al (2014) for more information.

Two other examples of communicating environmental data to the community are state of the environment (SoE) report cards and the Land, Air, Water Aotearoa (LAWA) website. Councils have been reporting SoE results to their communities for many years, and have developed many types of ‘report cards’ to simplify this complex information. For example, Auckland Council produces report cards for its SoE monitoring, including fresh water, for different reporting areas. An overall grade is given to the area, based on water quality, flow patterns, nutrient cycling, habitat quality and biodiversity. A catchment map, photo and quick facts are given, as well as the overall grade and grades for the five indicators. The report cards are available online and downloadable as a PDF. For more information, see: <http://stateofauckland.aucklandcouncil.govt.nz/report-type/freshwater-report-card/>.

One of the key aims of LAWA (introduced in case study 4.11) is to help local communities find out more about their fresh water. The LAWA website allows someone to explore data, selecting a region and then a catchment area. Figure 4.8 is taken from the Ashburton River at a State Highway 1 site and shows the median *state* of a number of environmental indicators, compared with other sites, and *trend* information based on nine-year data. See: www.lawa.org.nz/explore-data/canterbury-region/ashburton-river/ashburton-river-at-sh1/.

Figure 4.7: Snapshot of water quality data for the Ashburton catchment, from the Land, Air, Water Aotearoa website

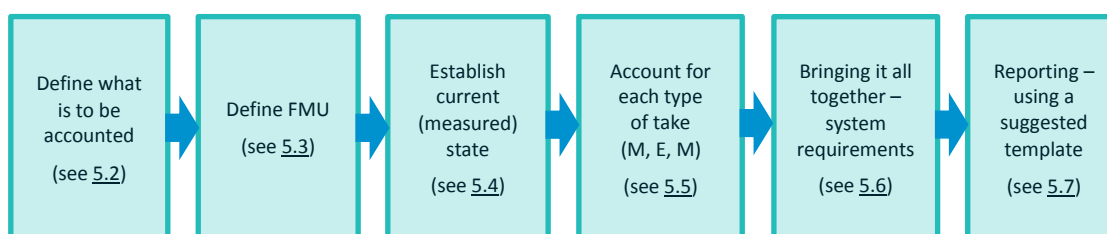


5 Key components of freshwater quantity accounting systems

5.1 The key components of freshwater quantity accounting

Figure 5.1 outlines the key components of freshwater quantity accounting.

Figure 5.1: Key components of freshwater accounting for water quantity



Note: M, E, M = measure, estimate or model.

Note that, in reality, this process is likely to be iterative. For instance, although the FMU defines the scale at which accounting must be carried out, some knowledge of the current state (ie, the hydrological regime, how much water is available and what contaminants are present) is necessary in order to ensure the scale of the defined FMU is appropriate.

The NPS-FM requires councils to use the National Objectives Framework to set freshwater objectives and limits for an FMU. There is a degree of overlap with methods that help with accounting and the methods (such as the use of models) used to set freshwater objectives and limits. This section focuses on accounting and, where possible, refers readers to other sources of information about limit setting and collaborative planning approaches.

5.2 Define what you are accounting for

The first step in establishing a freshwater accounting system (as indicated in figure 5.1) is to define what is being accounted for and the units to be used.

Identifying all water takes

The first stage of freshwater quantity accounting is to define and establish what is being accounted for. There are many different types of water takes, and the NPS-FM requires councils to account for them all. One useful approach is to separate the types of take based on their characteristics.

Because councils have managed different types of water take as business-as-usual before the NPS-FM required accounting, they are likely to have a thorough understanding of the topic. However, this section outlines the different types of take to ensure this guidance offers a complete package, and to reflect the important role they play in the later stages of water quantity accounting.

Water takes can be broadly defined in three ways:

- consumptive and non-consumptive
- consented
- unconsented.

Consumptive or non-consumptive use

Consumptive water use is when water is removed from a water body for a purpose and is not returned to the water resource system, such as water used for irrigation and domestic supply. Therefore, once removed from a water body, consumed water is not available for reuse. In areas with high connectivity between groundwater and surface water bodies, consumptive takes from one can affect the other. In this case, there may be benefit in considering both groundwater and surface water together in freshwater accounts.

Non-consumptive water use (such as that defined in regulation 4(2) of the water metering regulations) includes water withdrawn for use but returned directly back to the source without significant delay. For example, water withdrawn for purposes such as hydropower generation is generally non-consumptive. It is important to account for both consumptive and non-consumptive takes for informing the setting of objectives and limits. For example, any consumptive takes located upstream of a non-consumptive take (such as a hydro-generation dam) may affect the ability for the dam to operate effectively. In some cases, non-consumptive takes may also result in a change in water quality. For example, water taken for cooling purposes may be returned to the water body at an increased temperature. In such cases, the change in quality may be relevant for freshwater quality accounting.

As consumptive water takes result in water being removed from a water body and a reduction in available water volume (over a reasonable timeframe), it is important that water accounting systems clearly differentiate between consumptive and non-consumptive takes. Where only a portion of the take is returned to the source, a freshwater quantity accounting system should clearly identify the volume available for reuse in a non-consumptive take, to help ensure water resources are managed efficiently.

Consented takes

The RMA stipulates that a resource consent is needed for the take and use of water, although there are specific circumstances where this can occur without consent (these are discussed under 'unconsented takes' below). Consent can be required for both consumptive and non-consumptive takes. Consented takes are likely to represent the highest proportion of water use in many FMUs. Therefore, accurate and appropriate information about consented takes is critical for water accounting. Information stored in a consent database is essential for many facets of water management and reporting where it may be used to avoid over allocation, improve water use efficiency, protect wetlands, check for compliance with consent conditions and provide input to state of the environment reporting, as well as for freshwater accounting purposes.

It may be appropriate and pragmatic to use consistent fields in a consent database, noting that regional flexibility to allow fit-for-purpose management is also important. The accounting requirements in the NPS-FM may mean there is a need to review and improve the current consent information collected. The suggested list of fields below is for guidance only – councils may use only those they determine as necessary or add more fields, as required, to meet FMU or regional circumstances. A certain level of standardisation is important to enable computer-based systems of data storage and retrieval.

The potential fields for a consent database are:

- Consent identifier (number)
- FMU
- Consumptive or non-consumptive
- Primary source (eg, groundwater or surface water)
- Source type (eg, river, storage)
- Source catchment (eg, Hurunui River catchment)
- Source name (eg, Waikato River, Kaawa aquifer)
- Primary use
- Secondary use (eg, stock water when the primary use is irrigation)
- Use type (eg, pasture irrigation, vegetable irrigation, cooling)
- Description of use
- Instantaneous rate of take (ℓ/s)
- Daily volume (m³/d)
- Weekly volume (m³/week)
- Seasonal volume (m³/season) (eg, for irrigation, if specified)
- Annual rate (m³/year)
- Take months (eg, October to April for irrigation)
- Irrigated area (hectares) and irrigation method (ie, k-line, border-dyke)
- Discharge/return volume (may need to use more fields, if necessary, to account for accurate net use – ie, ℓ/s, m³/d and m³/year may be required as separate fields)
- Transfer volume (may need to use more fields, if necessary, to account for accurate transfer – ie, ℓ/s, m³/d, m³/year period of the transfer, transfer location, etc, may be required as separate fields)
- Surface water/groundwater interaction apportion (eg, assign 20 per cent of a groundwater take to a nearby stream – may need more fields and association with other FMUs, if interaction is high)

- Map reference² (ie, Easting and Northing)
- Consent commencement date
- Consent expiry date
- Water meter installed (eg, yes or no)
- Water meter telemetered (eg, yes or no)
- Commencement date of water meter reading.
- Link/reference to water quality accounting system where applicable

The fields listed here range across different timeframes. As noted in section 4.4, the reporting frequency of accounts may vary significantly from the time periods at which data is captured. Time periods should be used in the accounts that reflect how the accounts are intended to be used.

Unconsented takes

The common unconsented water take types are:

- permitted takes under RMA s14(3)(b)
- permitted takes under regional/district plans
- unauthorised takes.

Section 14(3)(b) of the RMA permits the take and use of water for certain activities without the need to obtain a resource consent. These are known as ‘permitted takes’. These permitted takes allow for water to be taken for an individual’s reasonable domestic needs and stock water, provided that the use does not, or is not likely to, have an adverse effect on the environment.

To implement the RMA statutory requirements, councils often specify in a regional plan a quantity of water that can be taken without a resource consent. Case law has confirmed that this is a legitimate practice.

There are also potentially unauthorised takes, which are not permitted under the RMA or a regional/district plan, that exceed the consented volume or permitted activity rule, or are where an old consent has expired. It is important that the source (groundwater or surface water) of the unconsented take is identified and classified and assigned against the appropriate FMU.

Units of measure for water quantity accounting

It is important that appropriate and meaningful units are used for water accounting. The characteristics of surface water and groundwater differ in their availability over a timeframe following abstractions, and different units may need to be used. Excessive surface water takes, even over a short period of time, can detrimentally affect instream values (such as life-supporting capacity). So it is crucial to use the instantaneous rate as the fundamental mechanism to manage surface water (litres per second or cumecs). In most situations, it is also important to specify the maximum daily take (cubic metres per day) and maximum annual or seasonal volume as consent

² Remember to check that the grid reference matches the position of the actual take, if this is not the same as consented.

conditions, to achieve efficient water management and water accounting. In FMUs that include a lake (including hydro storage), units such as lake levels will need to be used.

For groundwater takes, the instantaneous rate is not the most important factor. Rather, the determinants of daily and annual volumes are more appropriate to ensure that sustainable aquifer levels are maintained. However, instantaneous rates (litres per second) may also need to be stipulated for consented groundwater takes, as the water metering regulations use 'litres per second' as the unit.

5.3 Define the freshwater management unit

The next step in figure 5.1 above is to define the FMU in which you are to set or review limits and therefore produce accounts. Some initial comments on defining FMUs are covered in 4.2.

5.4 Establish the current (measured) state

If accounting information is being used to inform limits, information on the available water resource (river flows or groundwater levels) will also be required.

The NPS-FM requires that all takes from an FMU be accounted for via freshwater quantity accounting (see definition in 2.1). Establishing the current state also involves determining the hydrological regime of the water body. This baseline information will help to determine the natural variations that are unrelated to the identified pressures.

Understanding water resource availability

For accounting where limits have been set, the types of takes outlined above are likely to be the only things that need to be accounted for. However, for accounting where limits have not yet been set, councils may also need to know more about the water resource itself. For surface water bodies, such as rivers, to set limits for resource use as required by the NPS-FM, a key step is to determine minimum flow requirements (the flows required to maintain instream values). These could include ecological values, recreational values, amenity and natural character values and *tāngata whenua* values (Beca Infrastructure, 2008). Councils have been undertaking such analyses for some time, and advice already exists on these topics. However, until recently, not all councils had taken the next step to establish allocation limits (Rouse et al, 2013; Rouse and Norton, 2013). Naturalised flow series (ie, assuming no abstraction, damming, diversion or discharge) are generally used for establishing minimum flow requirements and allocation limits.

Case studies 5.1–5.3 highlight some useful resources for setting environmental flows. These have been included in this guidance to provide context around the sorts of decisions that freshwater accounting systems will inform.

CASE STUDY 5.1 – GUIDANCE ON METHODS FOR SETTING ENVIRONMENTAL FLOWS

Two main documents can help councils set environmental flows:

- *Flow Guidelines for Instream Values* (Ministry for the Environment, 1998a and 1998b).
- *Draft Guidelines for the Selection of Methods to Determine Ecological Flows and Water Levels* (Beca Infrastructure, 2008).

Case study 4.1 (section 4) discusses how a risk-based approach can be used to guide the selection of these methods. The *Draft guidelines* (Beca Infrastructure, 2008) focus on methods to address ecological values. The *Flow guidelines for instream values* also discuss these values, along with methods to address recreational, amenity and natural character, and tāngata whenua values.

For groundwater, a common and appropriate method for determining sustainable aquifer yields is to develop an integrated groundwater–surface water model. Developing a sufficiently accurate groundwater model requires a large amount of data and information, and it may be appropriate to first develop a basic (conceptual) groundwater model to identify where data gaps exist. The development process may therefore require a reasonable period of time. Basic approaches, such as percentage of average annual rainfall as an annual sustainable yield, can be used in the absence of an accurate modelling approach. However, a cautious approach should be used to arrive at conservative estimates when using simple methods, as it may take centuries to recharge a groundwater system that has been over extracted. The *Draft guidelines* (Beca Infrastructure, 2008) describe methods for deciding appropriate groundwater minimum levels. Case study 5.2 provides a brief summary of how Tasman District Council has set limits for managing groundwater.

CASE STUDY 5.2 – SETTING GROUNDWATER LIMITS

Tasman District Council uses an integrated groundwater–surface water model for managing the water of the coastal Motueka–Riwaka Plains. The primary purpose of the model is to ascertain the sustainable yield from the aquifer system while ensuring depletions of the nearby Motueka River and springs do not exceed allowable limits (as stipulated in the Resource Management Plan) and preventing saltwater intrusion (Aqualinc Research Ltd, 2008).

In determining the water resource extent and setting limits, the NPS-FM also requires councils to think about the reasonably foreseeable impacts of climate change. Some councils are already undertaking such assessments as part of their freshwater objective and limit-setting processes, as illustrated in the case study below (5.3).

CASE STUDY 5.3 – EXPLORING CLIMATE CHANGE EFFECTS ON WATER RESOURCES

A number of regional councils and unitary authorities are undertaking or commissioning assessments of the potential implications of climate change for water resources in their regions. For example, a summary of the potential implications of climate change for water resources and hazards for Gisborne District Council was provided by Collins (2012). This included projections of mean seasonal river flow and mean annual low flow (MALF) for the region's Waipaoa River under middle-of-the-road climate change scenarios for 2040 and 2090. Flows across all seasons were projected to decrease, particularly those in winter and spring, while the slight decline in MALF was comparable to measurement error.

See the Council's website: www.gdc.govt.nz/freshwater-quantity/.

Environment Canterbury has also commissioned a number of climate change impact studies focusing on water supply from several of the region's rivers. Discharge along the Alps-fed Waimakariri River, for example, is projected to increase substantially, particularly during winter, due to increased winter precipitation in its headwaters (Zammit and Woods, 2011b). In contrast, discharge along the foothills-fed Ashley River, which reaches the coast only 13 kilometres further north, is projected to experience only a marginal increase in annual flows, with a notable decline in spring (Zammit and Woods, 2011a).

5.5 Account for each type of take

The fourth step in figure 5.1 is to account for all water takes. The NPS-FM requires accounting for all water takes, including:

- consented (including both consumptive and non-consumptive)
- permitted
- unauthorised takes.

At present, it is more likely that accurate information will be available for consented consumptive takes, both what is allocated and what is used (at least for takes greater than 20 litres per second due to the current water metering regulations). It may therefore be appropriate for consented takes to be accounted for separately from unconsented (permitted and unauthorised) takes. Accounting for the total water use from unconsented and non-consumptive takes will most likely require the use of estimates or models, as it is unusual for water measurements to be available for these takes. One-off measurements of unconsented takes may be useful to improve or validate the assumptions used in any estimates or models.

Consented takes

Some comments on allocation

As stated in 5.2, consented takes are likely to represent the highest proportion of water use within an FMU. Accurate checks and balances for consented takes are therefore essential for water accounting and to ensure resources are not over-allocated.

Surface water availability at a given location may not be solely determined by the availability within the (sub) catchment containing that location. This is because allocation of water in an upstream sub-catchment will reduce the availability within lower catchments. For example, in the upper Waikato catchment, the catchment is fully allocated at the Karapiro Dam. Although there is allocable water within a number of upper sub-catchments when assessed in isolation, this water cannot be allocated because the water resource for the lower catchment at Karapiro Dam is fully allocated. Thus, accounting systems need to be able to help councils understand how takes from one location in an FMU may impact on takes in other parts, including tributaries and smaller waterways. This is necessary for considering limits to avoid over-allocation (see case studies 5.1 and 5.2 for more information). Where possible, this issue should be considered when FMU boundaries are being defined.

The allocation to non-consumptive takes can also determine the availability for consumptive use, rather than instream minimum flow requirements (eg, for ecological values). This is the case in the upper Waikato catchment, where water availability for consumptive takes within the catchment is primarily established based on non-consumptive takes for hydropower generation for the eight power stations located on the river.

Water quantity accounting can become complex when non-consumptive takes are partly consumptive. For example, Huntly Power Station takes 40 cumecs for cooling and returns 38 cumecs. Furthermore, non-consumptive takes may be returned to a different water body from where they were abstracted. Therefore, councils need to understand the initial take and the return, and thus the net take in their accounting.

Actual use

The water metering regulations require all water consents that authorise water takes at a rate of 5 litres per second or more (with the exception of non-consumptive takes as defined by the regulations) to record their actual water abstraction and report this data annually to the council. These regulations initially only applied to takes of 20 litres per second or more. From 10 November 2014, they have applied to takes of between 10 and 20 litres per second. From 10 November 2016, they will apply to takes of between 5 and 10 litres per second. If appropriate consent conditions, recording, reporting, storing and compliance systems are in place, councils should be able to produce accurate annual water accounts for the consented takes of 5 litres per second or more with relative ease. Case study 5.4 outlines how Horizons Regional Council is using a web-based system to manage telemetered water meter data.

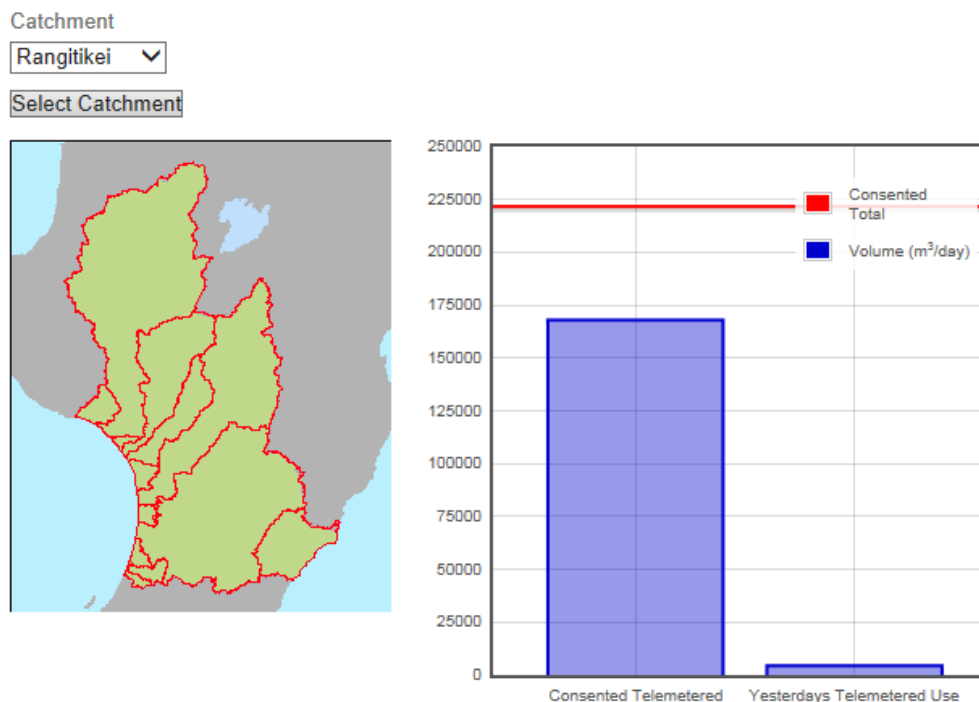
CASE STUDY 5.4 – USE AND DISPLAY OF TELEMETERED WATER USE DATA

Horizons Regional Council has installed telemetry systems on water meters in its region and captures close to real-time data. The data is displayed through its WaterMatters website, which is:

...a web-based information system for individual consent holders and those organisations in the region interested in water management. It allows individual consent holders to monitor their water use from their computer at home, and it allows whole water management zone monitoring against predetermined water allocation limits.

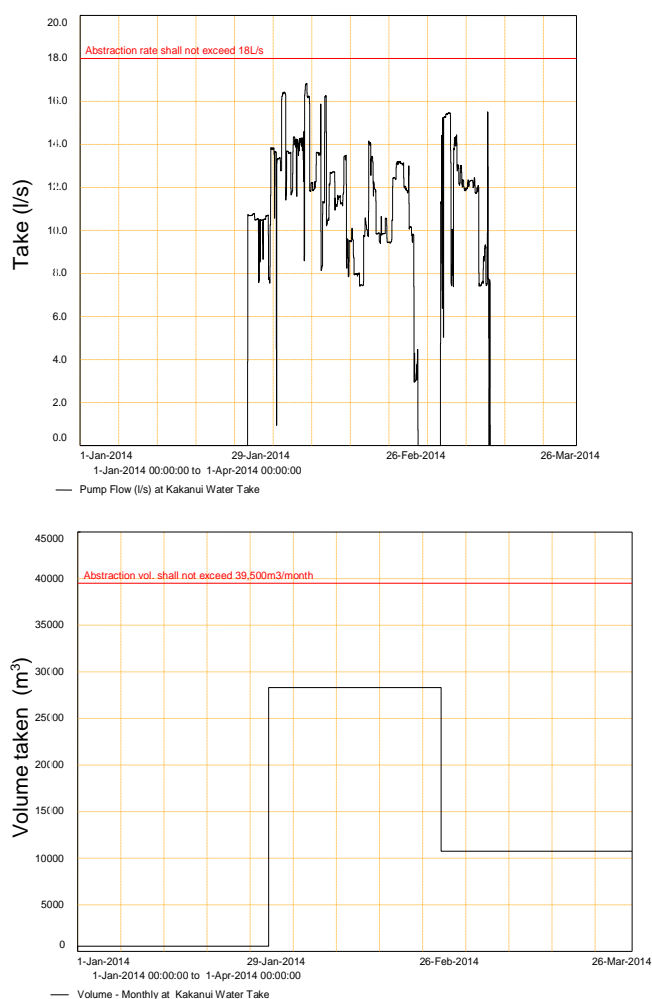
An example screenshot is shown in figure 5.2, and more information can be found at www.horizons.govt.nz/managing-environment/resource-management/water/watermatters/watermatters-overview/.

Figure 5.2: Screenshot from WaterMatters from the Rangitikei catchment, July 2014



Through consent conditions, Otago Regional Council has had telemetry systems installed on all water takes from the Kakanui River that are greater than 5 litres per second, to allow real-time water management for the catchment's water users during times of low flow. The data is displayed through an independent provider's website where individuals can view their own water use on their home computer while the catchment's water allocation committee can view all water users' data, allowing it to make real-time decisions during times when sharing is necessary to meet minimum flow expectations. The screenshot in figure 5.3 shows the rate of take and monthly volume used for a water take in the Kakanui River.

Figure 5.3: Screenshot of the rate of take and monthly volume used for a water take in the Kakanui River



As discussed in section 4, while the water metering regulations require consent holders to provide annual returns, some councils are requiring more frequent data collection. Real-time data collection (for example, using telemetry) may be helpful for larger takes and within catchments and streams that are highly allocated. Councils could consider including appropriate consent conditions to gather water use data at meaningful frequencies and in useful formats (such as electronic) to assist them in effective water management. Where net takes need to be accounted for, both take and discharge (returned water) should be measured at the same frequency.

Some regional/district plans require all consented water takes to be measured, such as in the Waikato region. Consented takes that are not currently measured need to be estimated for water quantity accounts. One approach that can be used to account for unmeasured takes is to use pro rata estimates based on measured takes for similar water uses. For example, an estimate for an unmeasured consented pastoral irrigation water take could be based on a measured pastoral irrigation take in an area with a similar microclimate. It is also important to use data from similar soil types (where the soils' plant-available water is similar) and where irrigation management practices are similar. However, it may be difficult to find exact matching conditions between takes for all

purposes, and a number of assumptions may need to be made. Another possible way for estimating water use from groundwater takes is by using the power consumption of pumps as a proxy measure for the water abstracted. For all such estimates, uncertainties can be high and it is important that the accounts clearly express these.

Permitted takes

As permitted activities (either under RMA s14(3)(b) or under regional/district plans) do not require resource consents, councils generally do not have detailed information about actual permitted use, such as the location of the take, water source and purpose of the take. However, under the NPS-FM, councils are required to estimate the amount of this permitted water use in their accounts. It may be helpful to do this by source (ie, groundwater or surface water).

To manage water resources sustainably, councils need a reasonably accurate understanding of the water used under permitted takes and its significance in comparison with the total resource available. This is not as important for some areas – for example, on Banks Peninsula in Canterbury, permitted takes are considered to be minor compared with the consented takes (T Davie, Environment Canterbury, pers. comm., 6 July 2014). However, Waikato Regional Council has found that the cumulative permitted water use is significant in some catchments, to the extent that it is placing stress on environmental bottom lines (Waikato Regional Council, 2007). This reinforces the importance of councils using approaches that are appropriate for the significance of the issue in their FMUs.

It is unlikely that all properties (or their owners) use the maximum authorised amount under the regional/district plan all the time. For example, the Waikato Regional Plan authorises use of up to 15 cubic metres a day per property. Therefore, estimates need to be made using reasonably accurate demands within an FMU, such as domestic (using population figures), stock water (using stock numbers), and associated demands (including dairy shed demands that do not require a consent), and small irrigation activities (in rural residential areas).

It is important that councils develop a pragmatic and defensible approach for estimating permitted water use that can be updated with relative ease. For example, Waikato Regional Council has developed a method for estimating water use under permitted takes, as summarised in case study 5.5.

CASE STUDY 5.5 – ESTIMATING PERMITTED TAKES

Waikato Regional Council has developed a model for estimating takes permitted by its regional plan and RMA s14(3)(b) using a geographic information system. The method uses population (census), livestock (AgriBase), property information (Land Information New Zealand) and river and groundwater bore databases to estimate reasonable water demands for certain uses and their potential source (ie, groundwater or surface water). The model's accuracy has been tested using water measurements from seven rural water supply schemes (Waikato Regional Council, 2007).

The report can be found at: www.waikatoregion.govt.nz/Services/Publications/Technical-Reports/A-Model-for-Assessing-the-Magnitude-of-Unconsented-Surface-Water-Use-in-the-Waikato-Region/.

Unauthorised water use

There may be unauthorised water takes in a region – for instance, where a water user mistakenly believes their water use is authorised under the RMA/regional plan/district plan. One potential unauthorised water use can be for dairy shed wash down and milk cooling, as this can be a permitted activity if the take does not exceed the maximum amount authorised under the regional/district plan. However, with recent intensification and increased stocking rates, the water demands for dairy shed wash down and milk cooling have increased on many dairy farms. Similar water use increases may have occurred in small orchards, nurseries and market gardens, where the users are unaware of the regional/district rules. Therefore, councils need to assess such potential takes and account for unauthorised water takes. Councils should also have a strategy to address such unauthorised takes – such as requiring resource consent or reduction of takes to fall within permitted take rules.

Assessing databases, such as AgriBase (ie, stock numbers), against consented data for both water takes and discharges, and examining aerial maps and visits to potential water use properties (that do not have resource consents) are some approaches councils can use to estimate unauthorised water use.

Avoiding double counting

Double counting, as the name implies, is where the same portion of water is accounted for more than once. For example, water taken for a water scheme may be quantified once as the total abstraction and then again as it is supplied amongst the end users. Double counting often arises as a result of using existing databases that were established for a different purpose (such as resource consent databases) to supply information for freshwater accounting. When developing freshwater quantity accounts, care should be taken to avoid double counting, particularly for consumptive takes. However, double counting of non-consumptive takes (for example, when the same water is used twice as it passes through two dams) is fine provided that it is adequately clear in the account that this is the case.

5.6 Bringing it all together

System needs

The ultimate objective of the NPS-FM is to provide accounts using all of the components discussed above. The next stage (step five, the second-to-last step in figure 5.1) is to bring the different threads of information together to achieve the four intended purposes of accounting, as outlined in 2.2.

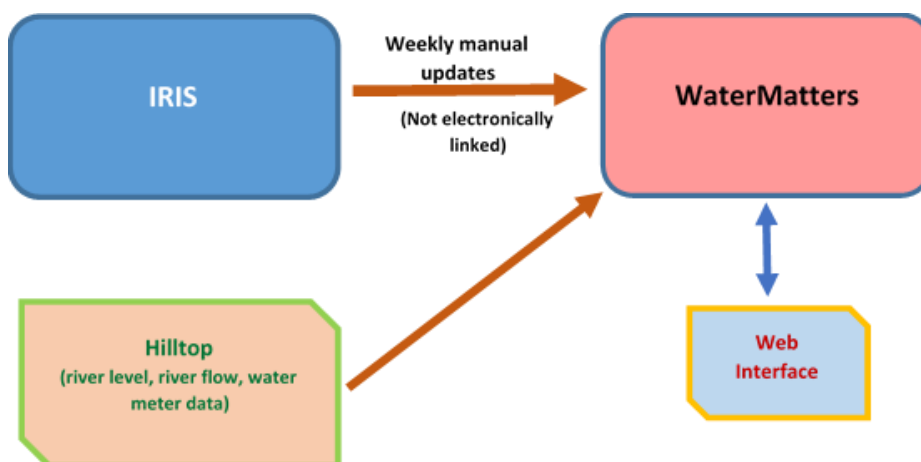
A freshwater quantity accounting system may be a hybrid system with many components, as outlined in 5.1. The data and information on the available resource (where limits have been set), consented amounts (consent database), actual measured water use (water meter) and estimates of unmeasured water use (unmetered consented takes, permitted takes and unauthorised takes) may sit in different locations and formats within the council. Some are likely to be in electronic form, and others, at least at this stage, may be in paper format. The accounting system should enable these varied information sources to be readily collated.

Some examples of existing water quantity accounting systems are provided in case study 5.6 below.

CASE STUDY 5.6 – EXAMPLE WATER QUANTITY ACCOUNTING SYSTEMS

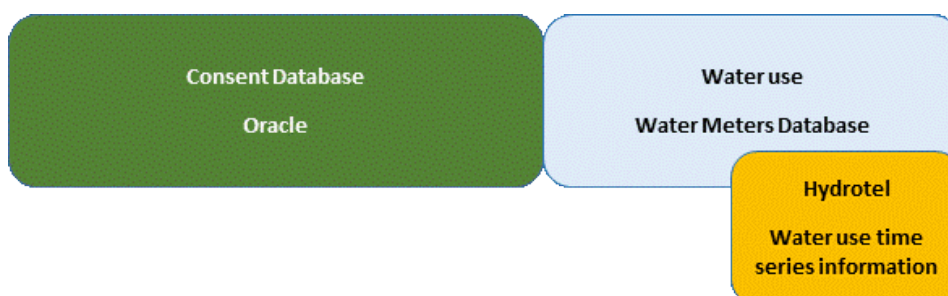
Figures 5.4 and 5.5 are two schematics of water accounting systems taken from Rouse et al (2013). These systems comprise various consent, state of the environment monitoring or water metering databases, linked manually or automatically to a system that enables the council to generate and display water quantity accounts.

Figure 5.4: Horizons Regional Council's water quantity accounting system



Note: IRIS = Integrated Regional Information System.

Figure 5.5: Auckland Council's water quantity accounting system



Councils will need to produce accounts as necessary for FMUs where freshwater objectives and limits are being set or reviewed. As this process will be repeated across multiple FMUs, it is worth developing a robust accounting system. The investment needed will depend on regional circumstances, as some councils currently have more advanced systems than others. As almost all councils have some form of current system in place (at least to address a part of the accounting system; see Rouse et al, 2013), councils can and should consider modifying the current system (if required) or developing a new system.

The most efficient system would be completely electronic, linking water availability and different uses, which can be updated at regular intervals. This type of system requires significant investment in metering, telemetry and automatic systems for QA, store and display of the data, and may not be necessary for all regions or FMUs. Where paper-based data is unable to be linked directly to an

electronic system, manual input of data and QA is likely to require significant resources. This type of system may be appropriate for some FMUs, such as those at near-natural state or with few development pressures.

An example of an integrated electronic system used for freshwater quantity accounting by the Waikato Regional Council is provided in case study 5.7.

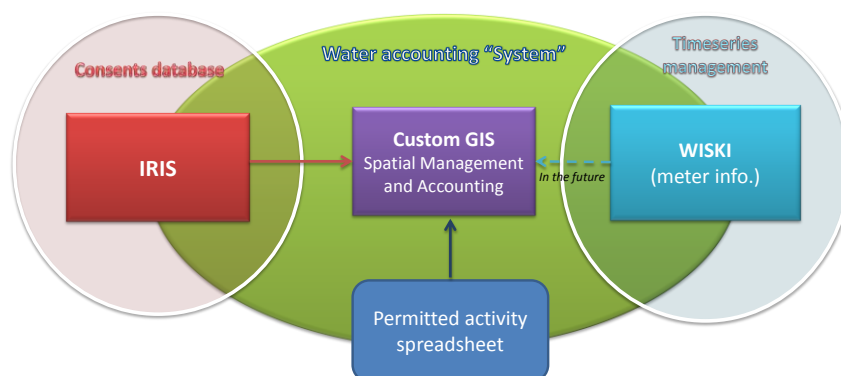
CASE STUDY 5.7 – EXAMPLE OF A WATER QUANTITY ACCOUNTING SYSTEM

Waikato Regional Council has developed a Water Allocation Calculator (WAC) for overall water management as shown in figure 5.6. The WAC is an integrated electronic system consisting of many components. These include:

- Catchment – created using minimum flow ecological studies, the National Institute of Water and Atmospheric Research’s River Environment Classification (REC) and a purpose-built ‘tracer tool’. This provides information on total resource availability by stream and catchment. The database is linked to all water use types (consented and permitted) to tally total water use against the availability at any given time. The ‘tracer tool’ enables managing all the sub-catchments within a large catchment because allocation or use in one part of the catchment has an impact on other parts (see 5.5).
- Aquifer – similar to ‘catchment’, but contains information on sustainable yield, groundwater recharge and rainfall recharge.
- Consents – all consented takes, including non-consumptive takes. This also includes information about net use (ie, take – return) and percentage use of surface water and groundwater for a consent (determined based on knowledge of the resource interaction).
- Permitted takes – estimated permitted takes for human and stock use (see 5.2).

The WAC is a dynamic system – one part automatically updates every two hours and other parts update daily. The resulting calculations help consent officers understand water availability within any particular catchment or aquifer when assessing new water take applications. The tool also helps science and policy staff understand the overall water allocation status across the region.

Figure 5.6: Waikato Regional Council’s water quantity accounting system



Note: IRIS = Integrated Regional Information System; GIS = geographic information system; WISKI = time series database

5.7 Preparing a report

The final step (the sixth in figure 5.1) in the accounting process is to prepare a report to communicate the accounting information to those involved in the setting or reviewing of freshwater objectives and limits.

While the main driver for freshwater accounting is to provide better information for councils to implement the NPS-FM requirements for limit setting, a nationally consistent reporting template could also deliver benefits, including:

- allowing communities and regulators to assess the status of their water use against other regions and FMUs
- the ability to compare water accounts between regions. This may allow stakeholders (eg, irrigators, industries, investors) to identify the potential regions and FMUs suitable for future growth, between, as well as within, regions
- the ability for central government to more easily compile national accounts, if required in the future (while noting there is currently no prescription for this).

We include a suggested template in table 5.1, which could be used for regular water quantity accounting reporting by FMUs. For example, water exports out of an FMU, which require a consent to take water (eg, taking water from the Waikato River for the Auckland City reticulated supply), and discharges (eg, Tongariro Power Scheme discharges water into the Lake Taupō catchment in the Waikato region after taking water from the Whanganui River catchment in the Horizons region). Water diversions such as these that occur between regions (or FMUs) should be considered in the accounts for both the exporting and importing region. If limits (minimum flows and allocation rates) have been set, these could be inserted into this table and reported against as well. Where limits have been set and are to be reported against, there may be benefit in describing or linking to a description of the process used to set a limit.

Case studies 2.1, 5.4, 5.5 and 5.6 provide other examples of catchment, regional and national accounts that could guide councils in what to include in a freshwater quantity account.

Table 5.1: Suggested template for water quantity accounting

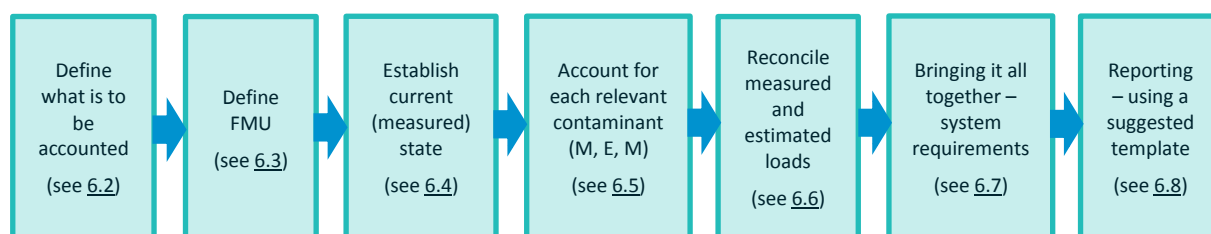
FMU	Name of catchment or sub-catchment, or aquifer			
Period	Date range (eg, 1 July–30 June Year)			
Location	Grid ref (eg, centroid of catchment polygon, or most downstream point)			
FMU includes	Both SW and GW takes ✓ SW takes only GW takes only			
Units	eg, Million cubic metres per year (Mm ³ /year)			
Total volume of FMU (surface water flow/groundwater quantity)				A
Total sustainable yield available for consumptive use				B
Non-consumptive takes				
Number of consented takes	x			
	Authorised volume (Mm ³ /year)	Volume used (Mm ³ /year)	Error estimates (%)	Methods used
Consented				Measured and/or estimated
Transferred				Measured and/or estimated
Consumptive takes				
Number of consented takes	xx			
	Authorised volume (Mm ³ /year)	Volume used (Mm ³ /year)	Error estimates (%)	Methods used
Consented takes	C	F		Measured and/or estimated
Consented discharge	D	G		Measured and/or estimated
Net consented take	E (C-D)	H (F-G)		Measured and/or estimated
Permitted		I		Estimated
Unauthorised		J		Estimated
Transferred				Measured and/or estimated
Summary				
	Volume (Mm ³ /year)		Percentage use (%)	
Total net use	K (H+I+J)		K/B x100	
Made available to the environment	L (A-K)		L/A x100	

6 Key components of freshwater quality accounting systems

6.1 The key components of freshwater quality accounting

Figure 6.1 outlines the key components of freshwater quality accounting.

Figure 6.1: Key components of freshwater accounting for water quality



Note: M, E, M = measure, estimate or model.

6.2 Define what you are accounting for

As shown in figure 6.1, and as with freshwater quantity accounting, the first step in setting up a freshwater quality accounting system is to determine what is to be accounted for. This includes identifying the relevant contaminants to be accounted for and the appropriate units to be used.

Identifying relevant contaminants

As with water quantity accounting (see previous section), the first stage of water quality accounting is to define and establish what you are accounting for. The NPS-FM requires water quality accounting to address all relevant sources of contaminants. Careful consideration needs to be given when identifying which contaminants are relevant, as there could be major cost implications if irrelevant contaminants are selected. As a first step, it may help to understand whether the contaminants of concern are conservative or non-conservative. Non-conservative contaminants are those that are transformed in the environment. Understanding this will help to determine how the contaminants should be accounted for.

The NPS-FM requires councils to use the National Objectives Framework to set freshwater objectives and limits for an FMU. Because freshwater accounting is required for FMUs where freshwater objectives and limits are being set or reviewed, we briefly look at how some of the National Objectives Framework features help select relevant contaminants.

Compulsory values

Appendix 1 of the NPS-FM includes two compulsory national values – ecosystem health and human health for recreation – for which attributes are listed in its Appendix 2. The attributes relate to quantifiable aspects of the freshwater environment that councils must monitor and manage in order to meet the compulsory national values. Table 6.1 lists the attributes relating to these two compulsory values for both rivers and lakes. For example, to manage ecosystem health, the National Objectives Framework requires the management of total nitrogen (TN) and total phosphorus (TP), which would need accounting for in an FMU that contains lakes. Note that Appendix 2 of the NPS-FM is not fully populated and that additional attributes will continue to be added over time.

Table 6.1: Attributes to be managed under the National Objectives Framework

Compulsory value	Rivers	Lakes
Ecosystem health	Periphyton	Phytoplankton (chlorophyll <i>a</i>)
	Nitrate (as N)	Total nitrogen
	Ammonia (as N)	Total phosphorus
	Dissolved oxygen (below point sources only)	
Human health for recreation	<i>E. coli</i>	<i>E. coli</i>
	Planktonic cyanobacteria (lake-fed rivers only)	Planktonic cyanobacteria

Additional national values

As well as the compulsory values for each FMU, Appendix 1 of the NPS-FM contains additional national values that councils must also consider. There will be cases where an attribute listed in Appendix 2 for a compulsory value is also relevant to one of the additional national values. For example, *E. coli* could also be a relevant attribute for mahinga kai, mahi māra (cultivation), wai tapu (sacred waters) and wai Māori (water supply). It is also likely that other attributes, not currently listed in Appendix 2, may also be required to achieve these values. For example, an FMU that is deemed nationally significant with respect to mahinga kai might lie within a catchment used for coal mining. In this case, it may also be necessary to set freshwater objectives and limits for suspended sediment and heavy metals, and to include these contaminants in the freshwater accounts for that FMU.

Regional values

The NPS-FM also allows councils to set objectives and limits to protect other values that are not included among the additional national values in Appendix 1 (Policy CA2(b)(ii)). The setting of such freshwater objectives, and limits to achieve those objectives, will require accounting for the contaminants that impact on the values chosen.

One instance where the use of regional values (and unique attributes) will likely arise is in urban FMUs. For example, in the Auckland region, suspended sediment concentrations and heavy metals (copper and zinc) have been shown to be important, particularly in estuarine environments. While at first glance this may appear outside the remit of the NPS-FM, Policies A1, B1 and Appendix 1 specifically instruct councils to take into account the connections between water bodies, and connections between freshwater and coastal waters, in particular. Although the majority of the effect of these contaminants is on coastal ecosystems, the delivery mechanism is freshwater streams and creeks. This relationship is discussed further in case study 6.1.

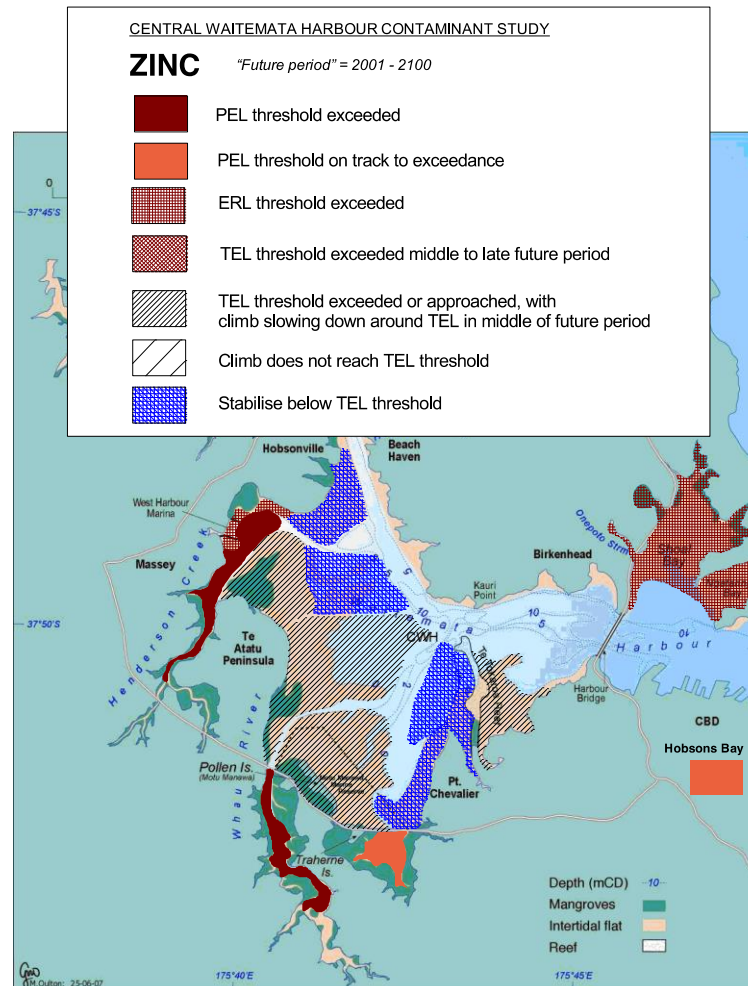
CASE STUDY 6.1 – IDENTIFYING ATTRIBUTES IN AUCKLAND STREAMS RELEVANT TO REGIONAL VALUES OF AQUATIC ECOSYSTEMS

A series of major studies by Auckland Regional Council (the predecessor of Auckland Council) found that stormwater from urban catchments could have serious long-term impacts on the health of receiving waters (see Mills and Williamson (2008) for a review of information up to 2005). Heavy metals, particularly copper and zinc, were investigated.

Also in 2008, a series of reports was published on the effects of urban stormwater on the ecosystem health of the Central Waitemata Harbour. One of the outputs of the study was an assessment of long-term accumulation of sediment, copper and zinc in large-scale harbour depositional zones. The potential for adverse ecological effects from copper and zinc in the harbour sediments was assessed against sediment quality guidelines for chemical contaminants. Other tools assessed the effects of different stormwater management interventions on sediment and stormwater chemical contaminant accumulation in the central harbour over a 100-year period.

The results of the Central Waitemata Harbour study (see Green (2008a) and Green (2008b) for the results of scenario testing) could provide justification for selecting sediment, copper and zinc as relevant contaminants to be accounted for (see figure 6.2).

Figure 6.2: Schematic summary of zinc sediment quality guideline exceedance in the Central Waitemata Harbour, based on modelling zinc inputs from the catchment



Source: Auckland Regional Council Technical Report, TR2008/043 (Green, 2008a)

Auckland Regional Council also developed a Benthic Health Model for use in classifying intertidal sites according to categories of relative ecosystem health, based on its community composition and predicted responses to stormwater contamination. For more information about this tool, see Hewitt and Ellis (2010).

The NPS-FM requires councils to set a freshwater objective for periphyton. Councils will manage periphyton biomass in streams and rivers through the use of limits on nitrogen and/or phosphorus from point and diffuse source discharges. To manage the periphyton attribute, dissolved inorganic nitrogen (DIN) and dissolved reactive phosphorus (DRP) should be included in water quality accounts. The frequency of accounting for these contaminants may need to reflect seasonal variabilities in water temperature or flows (as discussed in 4.4). Similarly, although suspended solids and water clarity are not yet included as compulsory attributes for ecosystem health in the NPS-FM, there are numerous examples, particularly in lowland streams, rivers and estuaries, where they are significant

factors impacting ecosystem health. Where regional freshwater objectives and limits are developed to manage sediment inputs to streams and rivers, then suspended sediment should be included in water quality accounts.

Another example of identifying relevant contaminants relates to fish species and their variable propensity to bioaccumulate contaminants. Bioaccumulation of contaminants may be an issue in some FMUs considered as nationally (or regionally) significant fisheries. The Rotorua lakes are one such example, where trout have been shown to bioaccumulate mercury, which potentially poses a health risk to people who consume more than a certain amount of trout. However, the source of the mercury is geothermal water, which the Bay of Plenty Regional Council can do nothing about. This is an example of 'natural' sources of contaminants, which are discussed further in 6.5. A council may choose not to set freshwater objectives and limits for mercury in such an FMU for this reason, but it is still important to account for this natural source of mercury. The inclusion of mercury (or other heavy metals) accounting may be justified in FMUs deemed significant fisheries where there are significant human-induced sources of the contaminant, where, although source control is not possible, other management actions such as health advisories could be used.

Tāngata whenua values

As with the compulsory values, additional values and regional values, measureable attributes that relate to any identified tāngata whenua values should also be included in freshwater quality accounts.

Units of freshwater accounting

The primary unit of water quality accounting is likely to be the load of contaminant (eg, kilograms or tonnes of nitrogen per year). This will be the means by which the amount of contaminant at a particular point in a stream network is compared with the amount attributable to different point and diffuse sources upstream of that point.

However, note that ecosystem response to contaminants is usually a function of the concentration of the contaminant in the water column. For example, the amount of phytoplankton in a lake is related to the concentration of nitrogen and phosphorous in the water column (as well as other factors, such as clarity). Concentration is the primary unit of any water quality analysis so there will likely be benefit in recording concentrations as well as load in a water quality accounting system. As flow will also be recorded for water quantity accounting purposes, instantaneous loads (concentration × flow) could be computed. However, whether concentrations are recorded inside or outside, the accounting system will depend on the method(s) used to compute loads and the temporal unit of accounting (ie, is it per day, week, month or year).

In most cases (at least initially), there may need to be paper-based calculations to compute point and diffuse source loads in those units. Where this is necessary, it may be more cost-effective to use existing databases to record concentration measurements (which are likely to be instantaneous measurements made at monthly intervals, for instance), computing loads and/or median concentrations, and then transfer the outputs to the water quality accounting 'system' (see 6.7). This can be done automatically within the accounting system, such as in case study 6.2.

CASE STUDY 6.2 – ESTIMATING DIFFUSE SOURCES OF NUTRIENTS IN THE HORIZONS REGION

Roygard et al (2012) provide a good summary of work carried out by Horizons Regional Council to determine relative contributions from point and diffuse sources at a range of flows. To do this, they developed and applied a calculation framework, which took data inputs (monthly water quality concentrations and flow time series) and employed a composite load calculation and flow stratification (discussed in case study 6.3).

6.3 Define the freshwater management unit

As with water quantity, the next step is to define the FMU that you are producing accounts for. Initial comments on this topic are in 4.2.

6.4 Establish the current (measured) state

The suggested next step (step three in figure 6.1) for water quality accounting is to establish the current state – that is, the loads and/or concentrations of contaminants in the FMU that you are accounting for. Determining the loads and concentrations already in the receiving water provides the comparison point (or reference) to which the sources and sinks (such as attenuation) are compared. The NPS-FM allows for the loads, concentrations and sources of relevant contaminants to be measured, modelled or estimated. However, because what is in the receiving waters provides a comparison point, they should be measured where possible.

In some cases, it is not possible or practical to measure water quality continuously, and it may be necessary to calculate loads and concentrations using some form of estimation. Thus, these loads and concentrations will have some levels of uncertainty associated with them. With a robust monitoring programme designed with the method of estimating loads (or concentrations) in mind, any bias and extraneous sources of error can be minimised, and the errors themselves known with a certain confidence.

Measurement and estimation is not always possible because of resourcing issues, in which case modelling is the only real alternative. While good modelling practice also deals with uncertainty, the difficulty of using modelling for estimating receiving water loads and concentrations in an accounting sense is that it is:

- difficult for stakeholders to understand
- likely that diffuse source loads and concentrations will also be modelled.

There is a risk that councils may end up comparing a modelled reference load/concentration (the load/concentration already in the receiving water) with modelled sources, possibly using the same model.

The use of measurement and modelling in establishing the current state is discussed in more detail below.

Measurement

All councils measure water quality to some extent, and have done so for extended periods. Some councils report on the state and trends in their water quality data through state of the environment reporting.³ Others, such as Waikato Regional Council, provide similar information through regular updates of their websites.⁴ Guidelines for setting up water quality monitoring networks are given by Davies-Colley et al (2011).

An existing water quality monitoring system should be able to meet the needs of water quality accounting. If setting up a system specifically for water quality accounting, the prime considerations would be:

- Relevant contaminants – these are what is required to be accounted for (see 6.2).
- Frequency – the frequency of sampling has implications for the precision of the estimate of load/concentration over the interval in question. There are good statistical texts (eg, McBride, 2005) and papers (Robertson and Roehrich, 1999) that will assist. A long record (more than 2 years) of monthly sampling is generally adequate for calculating annual medians and/or annual maximums (as stated in Appendix 2 of the NPS-FM) and is the duration recommended to councils for Environmental Monitoring and Reporting (EMaR) (Davies-Colley et al, 2012).
- Sampling strategy – deciding on a sampling strategy will involve considering the objectives of the programme and the flow distribution of the streams in question. Small ‘flashy’ streams will export most of their contaminants (especially particulate contaminants) during storms, which means estimating the load/concentration with high precision requires ‘storm chasing’ or use of flow-triggered automatic samplers. Such exercises may not be practical for routine monitoring. Some councils get around this problem by defining loads/concentrations that reflect river conditions ‘most of the time’, which is appropriate for most of the national values listed in the NPS-FM. For example, Horizons Regional Council uses flow-binning (case study 6.4) whereby loads are calculated according to particular flow ranges. Other councils use the fixed-interval approach (eg, sampling on the same day each month), which, providing the record is long enough, will theoretically sample the range of flow conditions in proportion to their flow distribution.
- Flows – measured or estimated? To calculate a load or concentration, you need a corresponding measurement or estimate of flow. Measured is desirable and, for existing water quality monitoring networks, councils may have a corresponding flow recorder. However, flow recorders can be expensive to install and maintain, and to get adequate spatial coverage for contaminant accounting it may be necessary to estimate flows from adjacent catchments. There are standard methods for making such estimates (see case study 6.3), but care needs to be taken to ensure the precision of the flow estimate is compatible with that of the load estimate.
- Estimation methods – there are a multiplicity of methods for load estimation and no ‘one size fits all’ method. For example, Diffuse Sources and NIWA (2013) reviewed estimation methods relevant to calculating nutrient loads to Waituna lagoon from diffuse sources. They recommended a range of regression approaches (‘rating curves’) for estimating contaminant loads. These regressions are based on concentrations varying significantly with flow rate and so the regressions employ a rating curve for load calculations.

³ For example, www.horizons.govt.nz/managing-environment/state-of-the-environment-2013/, and www.es.govt.nz/environment/monitoring-and-reporting/state-of-the-environment/water-2010/.

⁴ See www.waikatoregion.govt.nz/Environment/Natural-resources/Water/Fresh-water-quality-monitoring/.

Case studies 6.3–6.6 provide examples of methods that can be used to estimate contaminant loads.

CASE STUDY 6.3 – ESTIMATING FLOWS FOR LOAD CALCULATIONS

One method of establishing flow records for streams with no flow recorder is the concurrent gauging technique. Griffiths and Horrell (2012) recently undertook a review for Environment Southland of the appropriateness of the use of the concurrent gauging technique to estimate flows at ungauged sites. A literature review was carried out and a set of guidelines for the technique distilled. These guidelines address the use of natural flows, tertiary site location, concurrent gauging runs, concurrent gauging range, flood flows, regression, errors and normalisation.

There are also other techniques for estimating flows in ungauged catchments. Woods et al (2006) describe the testing and development of a model that can be used to predict mean flows across New Zealand. Other models have been developed that can be used to optimise the 'next best data' by searching for the nearest flow recorder to the site of interest (see also Booker and Woods, 2014). There are often great uncertainties with using such methods.

CASE STUDY 6.4 – FLOW STRATIFICATION METHODS

Horizons Regional Council uses flow stratification to address the issue of 'what proportion of the total load of contaminants arises from each flow band?'.

Stratification includes defining 10 flow 'bins' based on subdivision of the flow frequency distribution (the flow duration curve). The component of the load associated with each flow bin is estimated as the product of the mean concentration and the flow associated with the bin. These loads are then summed to find the total load. An advantage of the method is that it automatically produces the proportion of the load associated with different parts of the flow hydrograph (eg, high flows). The flow-stratified averaging approach was found to be effective in reducing bias associated with monthly sampling that does not generally consist of either very high or low flows. However, loads at low flows (ie, below the 20th percentile) were calculated by removing the loads assigned to highest two flow bins.

See Roygard et al (2012) or Roygard and McArthur (2008), available from www.horizons.govt.nz/about-us/publications/about-us-publications/one-plan/technical-reports/.

CASE STUDY 6.5 – A TOOL FOR ESTIMATING SEDIMENT AND OTHER CONTAMINANT LOADS

SedRate is a tool developed more than 10 years ago to help address issues with predicting sediment loads and, specifically, for fitting rating curves and calculating time-averaged loads (ie, yields). It enables a sediment rating to be established for a particular site by means of one of four automated methods, or by user-fit with mouse-clicks on the rating plot. This sediment rating is then applied to the site flow distribution to obtain the annual average sediment yield, along with many other useful statistics. Flow and sediment information is obtained from an MSAccess database. Although originally designed just for suspended sediment, SedRate has been expanded to fit ratings to and calculate yields for any flow constituent – for example, nitrogen and phosphorous.

A feature of the tool is that results displayed enable the user to explore the sensitivity of the results to the way the rating is fitted and understand the uncertainties associated with the estimates produced.

SedRate was used to provide sediment yield data for Hicks et al's (2011) national modelling of suspended sediment yields from New Zealand rivers and has also been used by Waikato Regional Council.

CASE STUDY 6.6 – REVIEW OF METHODS FOR CALCULATING LOADS

Recently, Aqualinc Research Ltd (2014) reviewed eight methods for calculating loads (including the regression methods discussed above) in an Envirolink-funded report prepared for Environment Southland. The purpose of the project was to provide advice on developing a nationally consistent approach to contaminant load calculation and software to calculate loads, by:

- identifying current methods and tools used
- assessing the accuracy and uncertainty of contaminant load estimates produced by these methods and tools.

Based on its review, Aqualinc found:

1. Expertise, professional knowledge and judgement are required to evaluate contaminant loads produced. As such, a single load calculation method, or a simple rule-based procedure for selection of methods, may not be appropriate and is not promoted.
2. There are existing appropriate tools to calculate loads (eg, SedRate tool and the Horizons Regional Council flow-stratified approach of Roygard et al, 2012), and further significant investment in load calculation software is not warranted.
3. Training and support for council staff involved in load calculation should be provided, based on the databases (eg, Hilltop, Tideda) and existing tools (eg, SedRate and Excel) that analysts use.

4. Further research into uncertainty of load calculations, its causes and implications should be carried out to provide improved future guidance associated with implementing the NPS-FM, and to provide guidance for future data collection for the purpose of load estimation, particularly for nutrients. (Note that Massey University is currently carrying out some research in this area with Horizons Regional Council.)

Modelling

As discussed above, we recommend that, for accounting purposes, measurement and estimation of loads and concentrations should be used as references against which sources and sinks can be compared. This should provide a robust measure against which other modelled and measured sources of contaminants contributing to that reference load or concentration can be compared. However, if measurement and estimation is not possible for whatever reason, then there are a range of models available to estimate loads and concentrations at both an activity scale and on a catchment basis.

Motu (2013) provides a review of the range of both activity scale and catchment scale models used in New Zealand for modelling nutrient losses from rural land and the concentrations and loads in receiving water bodies. Figure 6.3 outlines the catchment scale models currently used in terms of the areas that they cover and whether they include surface water or groundwater as well. In practice, it is likely that both activity scale models and catchment scale models will need to be used, with the activity scale outputs potentially feeding into the catchment scale model.

Figure 6.3: Classification of catchment scale water quality models in New Zealand

		Area covered		
		Catchment	Region	National
Model detail	Surface, groundwater & root zone	<div>MIKE SHE</div> <div>SWAT</div>		
	Surface & groundwater	<div>ROTAN</div> <div>TRIM</div> <div>FEFLOW</div> <div>MODFLOW</div>	<div>AquiferSim</div> <div>SPARROW</div> <div>FEFLOW</div> <div>MODFLOW</div>	
	Surface water flow only	<div>CLUES</div>	<div>CLUES</div>	<div>CLUES</div>
		<div>Model estimates loads on a daily basis</div> <div>Model estimates loads on an annual basis</div>		

Source: Motu, 2013

Motu (2013) made the point that there is no perfect model. All have their place and limitations, and the choice of one particular model over another will depend on the application and the skill of the modeller. None of the models in figure 6.3 were developed specifically with water contaminant accounting in mind, however, CLUES (Catchment Land Use for Environmental Sustainability) has been developed specifically to model nutrient, sediment and *E. coli* loads across the country. Recently, the source model developed by eWater⁵ in Australia has been used in New Zealand by Horticulture New Zealand, which notes that, unlike CLUES, it is an open source model and able to be readily adapted for specific purposes (C Keenan, Horticulture New Zealand, pers. comm., 9 July 2014).

6.5 Account for relevant contaminants

The fourth step in freshwater quality accounting as shown in figure 6.1 is accounting for the relevant contaminants, including attributing them to their sources. At this stage, consideration is also given to lag effects in groundwater and attenuation of contaminants.

Accounting for all sources of contaminants

As with understanding current FMU loads and concentrations as a whole (6.4), a variety of methods are available to measure, estimate or model sources of contaminants, each of which is applicable to certain situations. The following sources of contaminants are covered in this section:

- natural sources
- point sources
- diffuse sources.

Natural sources

It is important to estimate the proportion of current loads coming from natural sources. Natural sources of contaminants may result from the geology, soils or hydrology (eg, geothermal waters) of an area. In many cases, it may be difficult to manage contaminants that occur naturally in given FMUs (eg, the Rotorua lakes mercury example in 6.2), but it is very important to account for these sources as well as human-induced sources (point and diffuse sources discussed below). Understanding natural sources of contaminants is also important for establishing the background levels when setting limits for contaminants that have both natural sources and sources resulting from human activities.

Point sources

Point sources of contaminants are the easiest to measure. They are generally visible, covered by resource consents or permitted activities (eg, septic tank discharges), and the contaminants of interest are often subject to consent monitoring conditions. A specific discharge consent (with associated monitoring conditions) can also provide the basis for a definition of a point source versus diffuse sources and thereby determine whether the contaminant load is measured, modelled or estimated. For example, there are approximately 11,400 dairy farms in New Zealand, the majority

⁵ See www.ewater.com.au/.

(approximately 90 per cent in Waikato) of which irrigate their shed effluent directly to pasture. However, even if there are only 1000 direct discharges to waterways, this is a big number to track. The discharges directly linked with farming activities (eg, discharges of dairy shed effluent, dairy herd crossings) are therefore often excluded from the definition of point source discharges and included within the definition of diffuse sources (discussed later in this section). The main reason for this is that solutions proposed to better manage agricultural contaminants revolve around the development and implementation of whole of farm plans.⁶ It may therefore be more effective to consider agricultural discharges as part of the whole farming system (Ledein et al, 2007).

Therefore, point sources are usually defined as ‘large’ industrial or municipal discharges that have monitoring conditions – that is, data on discharge quality and quantity is available, allowing a good characterisation of the nutrient loadings in the discharge.

Monitoring of point sources

With point sources defined as above, it should usually be possible to determine the annual load of contaminants attributable to each point source using data collected by the consent holder. These data are returned to the council and held in council records under consent conditions. However, it is almost certain that the frequency with which point sources are monitored, and the quality of the data collected, will be highly variable. In determining sources of phosphorus and nitrogen in the Waikato and Waipa catchments, Vant (2014) commented on these aspects (see case study 6.7).

The lesson that can be learned from Vant (2014) is that expert judgement and experience is required to determine the best strategy for calculating point source contaminant loads. While some generalised guidance is possible (such as the method outlined by Vant (2014)) for ensuring unbiased estimates, the selection of the most appropriate calculation method and factors, such as determining the most appropriate ‘average’, will depend upon the period of record in question and the quality and quantity of data available.

CASE STUDY 6.7 – DETERMINING POINT SOURCE LOADS (VANT, 2014)

Consent monitoring information was used to determine the average mass flows of nitrogen and phosphorus that were discharged from each major point source in the catchment.

Comprehensive records were available for some sites, with daily wastewater flow rates available for more than half of the sites. Nutrient results were generally available at no less than monthly intervals, with weekly results being available for about one-third of the sites.

Unbiased estimates of nutrient mass flow were obtained by averaging the products of effluent flow and nutrient concentration that were determined at regular intervals – typically daily, weekly or monthly. That is, mass flows were calculated as the ‘average of the products’, rather than as the ‘product of the averages’.

For some point sources, changes to the respective sampling intervals during the period analysed meant that the raw data had to first be summarised as monthly means, with the average then being calculated from these.

⁶ See www.horizons.govt.nz/assets/horizons/Images/one_plan/point%20source%20non%20point%20source.pdf.

Estimation of point sources

As noted above, in most cases, it will be possible to calculate point source contaminant loads from consent monitoring data and it is usually more useful to consider small farm or industrial discharges as part of the diffuse source landscape. However, there may be instances where the consent monitoring has not been carried out and estimation is required instead. Or it may be desirable to estimate the total load arising from, for example, all dairy shed effluents discharging directly to receiving waters. In this case, it would be necessary to obtain statistics on stock numbers from the farms that discharge directly to receiving waters, some representative contaminant loads relating to farm discharges in the catchment (from consent monitoring, if available, otherwise from research papers), derive a 'per stock unit' load and calculate a load based on the total number of stock units for which there is direct discharge. If certain farmers have more sophisticated treatment than the standard facultative ponds and/or significantly different water use, then it may be necessary to account for these discharges separately. Estimation may also be required for other permitted activity point source discharges, such as septic tanks, depending on regional/district plan rules and conditions.

Diffuse sources

The past 5 to 10 years have seen a huge effort to estimate/model loads (particularly of nutrients) from diffuse sources.

Unlike point sources, it is impractical to measure diffuse loads routinely. Moreover, modelling also enables testing of land management scenarios, which provides a more effective management response than is possible by measurement.

It is important to point out that, in this section, we are discussing techniques that estimate/model diffuse sources of pollution only. From a contaminant management perspective, it is often more effective to couple models estimating diffuse pollution, such as OVERSEER®, with other models that incorporate routing and attenuation through a river network. These models (CLUES is an example) were discussed in section 6.4.

There are also distinctions to be made in the types of models that address rural and urban contaminants. These are discussed below.

Estimating diffuse contaminants from rural activities

Diffuse loads originating from rural activities can be estimated in two ways:

- directly, through catchment load coefficients (which usually include background loads) based on land use
- indirectly, from the equation:

$$\text{Diffuse anthropogenic load} = \text{Total river load} - \sum \text{Point Source load} - \text{Background load (Equation 1)}.$$

Perversely, the indirect estimation method is more accurate provided that total river load, \sum point source loads and background loads are based on measurement.

The direct method is based on published catchment coefficients attributable to single land uses. Usually, these are based on measured loads from small 'single land-use' catchment studies, which may or may not have been done within the region, or they have been based on modelled outputs for detailed pastoral land use (eg, Lilburne et al, 2010). Lysimeter studies are generally used in determining direct diffuse loads.

Vant (2014) provides a recent case study of the indirect method (case study 6.8).

CASE STUDY 6.8 – ESTIMATING DIFFUSE LOADS OF NITROGEN AND PHOSPHORUS IN WAIKATO

Vant (2014) compared the mass flows of nitrogen and phosphorus discharged from point sources, with the total mass flows of these nutrients that were carried by the Waikato and Waipa rivers during 2003–2012 (see table 6.2). Vant also estimated the contributions from background – that is, the mass flows that would have been carried by the rivers before development of their catchments. The pre-development or background mass flows were calculated from the respective catchment areas using methods described in Jenkins and Vant (2007). The background loads (3 kg N/ha/y and 0.3 kg P/ha/y) were based on actual measured loads on small undeveloped catchments within the region (B Vant, pers. comm., 8 July 2014).

Applying Equation 1, Vant (2014) derived the following ‘accounts’ in which human-induced diffuse loads from developed land are dubbed ‘land use’.

The combined mass flows from the various consented moderate-to-large point source discharges are shown, as are estimates of the pre-development or background mass flows, and the mass flows resulting from catchment land use.

Table 6.2: Mass flows of nitrogen and phosphorus in the Waikato River catchment during 2003–2012

	Upper Waikato		Lower Waikato* (excl Waipa)		Waipa		Combined	
Nitrogen (t/yr)								
Overall	3,623		3,501		4,069		11,193	
L Taupō outflow	339	(9%)					339	(3%)
Point sources	227	(6%)	437	(12%)	66	(1%)	730	(7%)
Background	1,314	(36%)	904	(26%)	928	(23%)	3,146	(28%)
Land use	1,743	(48%)	2,160	(62%)	3,076	(76%)	6,979	(62%)
Phosphorus (t/yr)								
Overall	271		408		273		951	
L Taupō outflow	23	(9%)					23	(3%)
Point sources	26	(9%)	127	(31%)	18	(7%)	171	(18%)
Background	131	(49%)	90	(22%)	93	(34%)	315	(33%)
Land use	90	(33%)	190	(47%)	162	(59%)	443	(47%)

* Results are for Karapiro-to-Tuakau rather than Karapiro-to-Port Waikato.

Source: Vant, 2014

Modelling diffuse contaminants from rural activities

Modelling diffuse loads of nutrients, particularly nitrogen, using OVERSEER® has become the industry standard. It is also useful for attributing contaminants to their sources. While not the only model available (see Motu, 2013), its acceptance by the Environment Court as a policy tool, by industry

support as a development path, and by farmers, has seen it widely taken up by councils looking at adopting nitrogen and phosphorus limits. Among other tools, Environment Canterbury has used OVERSEER® in its technical work to support the limit-setting process (eg, Scott, 2013;⁷ Robson, 2014; Environment Canterbury, 2012) and will require some form of nutrient accounting to monitor progress towards meeting limits. It is worth noting that OVERSEER® assumes best practice in its estimates of farm discharges (eg, it assumes effluent ponds are lined and/or do not leak), so if farms are not using best practice techniques, OVERSEER® will underestimate these discharges. Conversely, if farms are applying innovative farming practices (eg, precision farming) that have not yet been adopted within the model, OVERSEER® will overestimate these discharges. Furthermore, discrepancies have been known to arise within the modelled outputs of different versions of OVERSEER®. As with any model, it is important that transparency about the assumptions and limitations of OVERSEER® is maintained.

Case study 6.9 outlines the approaches used in Canterbury, Bay of Plenty and Otago for the modelling of nutrients. The example of using the model SedNet to model sediment loads in the Manawatū is then provided in case study 6.10.

CASE STUDY 6.9 – RURAL MODELLING CASE STUDIES

Three case studies from different regions and catchments are provided as examples of rural modelling.

Canterbury: The Selwyn Waihora catchment is a case study about modelling and accounting for nutrients to support a limit-setting process.

This catchment is relatively complex, so a series of models was ‘bolted’ together and used to predict the effects of changes in land use on groundwater, surface water and Te Waihora/Lake Ellesmere, as well as for evaluating economic, social and cultural impacts. The biophysical modelling chain can be broken down into four stages:

- land and climate
- groundwater
- surface water
- the lake.

Information on land and climate was derived from a variety of sources, with drainage and nitrate losses based on ‘Lookup Tables’ (Lilburne et al, 2010; Lilburne et al, 2013). These Lookup Tables estimated nitrate-N leaching losses from a range of land uses across the Canterbury Plains, covering multiple climate zones and soil types, and used a suite of models for estimating the leaching losses, including OVERSEER®, for pastoral farm types. The land and climate data enabled a series of geographic information system (GIS) layers to be created capturing soil type, rainfall, land use, irrigation, drainage and nitrate losses. These formed the basis of the subsequent modelling.

The groundwater quality model used the estimated nitrate-N losses (as concentrations) from the GIS layers to predict the groundwater quality in the shallow aquifers (Hanson, 2014). No denitrification, dilution or other attenuation was modelled in the unsaturated

⁷ See <http://ecan.govt.nz/publications/Reports/hinds-plains-water-quality-modelling-report-r13-93.pdf>.

zone and through the groundwater system on the plains, therefore, the nitrate-N concentrations in the shallow groundwater were assumed to be the same concentration as the drainage from the soil.

To predict nitrate-N concentrations in the streams, an empirical attenuation factor was established for each of the modelled streams and rivers, by comparing measured surface water concentrations and nearby shallow groundwater concentrations. This factor would include dilution, denitrification and other attenuation processes. This factor was applied to modelled groundwater concentrations for each scenario to give predicted surface water nitrate-N concentrations (Hanson, 2014).

Estimates of nitrate-N losses from non-agricultural land uses that were captured in the Lookup Tables (Lilburne et al, 2010; Lilburne et al, 2013) (eg, forestry, golf courses, lifestyle blocks) were modelled in the same way as agricultural losses. Losses from land-based treatment of municipal sewage were not explicitly modelled in the groundwater quality model; instead, typical losses under the land use to which the effluent was applied were used (Hanson, 2014). Estimates of point source losses were included in the overall catchment load calculations and were estimated by Loe (2013).

The lake quality model used quality and quantity information preceding modelling stages to predict the ecological response of the lake. The model predicted effects on a suite of indicators, including nutrient concentrations, risk of algal blooms, likely impact on biodiversity and Trophic Level Index.

The Zone Committee and community groups explored a spectrum of potential scenarios, understanding the consequences of each scenario across a range of indicators covering the four well-beings. Once a package of recommendations was agreed upon, the same modelling chain was used to produce the catchment limits as a loss from the rootzone, loss from community sewage schemes and loss from industrial processes, thus setting the limits that farmers and the community would need to collectively comply with, and also the limits passing through the receiving environment to support the agreed outcome. Table 6.3 shows the proposed catchment loss limits.

Table 6.3 Catchment target and limits for nitrogen losses from farming activities, community sewage systems and industrial or trade processes

Catchment	Activity	Nitrogen load t/yr	Target or limit
Selwyn Waihora	Farming	4,830	Target to be met by no later than 2037
	Community systems	62	Limit
	Industrial or trade processes	106	Limit

Bay of Plenty: Objectives, policies and rules have been set in the Bay of Plenty Regional Water and Land Plan to achieve a clearly stated Trophic Level Index for Lake Rotorua, and to control nutrient exports in the catchment. Bay of Plenty Regional Council used the ROtorua and TAupo Nitrogen (ROTAN) model to make predictions of nitrogen load to Lake Rotorua, to explore scenarios for future land use and nitrogen export in the catchment (Rutherford et al, 2011). A key aim of this work was to identify potential strategies to allow a reduction in nitrogen loads in the lake and enable the attainment of the target of 435 tN/yr, and to

estimate how quickly the load in the lake was likely to respond to such reductions. The ROTAN modelling concluded that, at current nitrogen export levels, the lake load would be 725 tN/yr by about 2080. If exports were reduced to 320 tN/yr from 2015, the lake load would decrease fairly quickly, allowing an adjusted target of 405 tN/yr to be achieved within about 35 years. See Rutherford et al (2011) for more details.

Otago: Otago Regional Council recognised that many of New Zealand's lakes with agricultural catchments have suffered significant declines in water quality, particularly with intensification of land use. Lakes Wakatipu, Wānaka and Hawea are considered iconic for the Otago region. The risk of the existing water quality and iconic values being degraded by increased contaminant loads to these lakes was considered significant. As a result, the Council has adopted an instream concentration approach to managing water quality through plan change 6A (Otago's water quality limits plan). Through the mediation process for plan change 6A, the landholders in the catchment acknowledged and endorsed the approach taken by the Council, but presented information showing the proposed 10 kg/N/ha/yr threshold was too tough to meet under existing practices. They asked for it to be lifted to 15 kg/N/ha/yr, while committing to some OVERSEER® validation work in the lakes' extremely high rainfall catchments (up to 3 metres per annum). The 15 kg/N/ha/yr threshold now stands for areas zoned as large lake catchments, as plan change 6A became operative on 1 May 2014. Otago Regional Council expects that the landholders will have OVERSEER® budgets carried out by an accredited person, based on the national protocol. The 15 kg/N/ha/yr threshold is applied as a whole-of-farm average to provide flexibility to manage the property as a whole. The Council reserves the right to ask for OVERSEER® budgets to ensure compliance or do catchment accounting. Plan change 6A also includes load limits of 20 kg/N/ha/yr for sensitive aquifer zones and 30 kg/N/ha/yr for the rest of the region.

CASE STUDY 6.10 – USING SEDNET TO MANAGE SEDIMENT LOADS

Horizons Regional Council's Sustainable Land Use Initiative (SLUI) is a voluntary programme that aims to reduce hill country erosion in target catchments within the Manawatū–Whanganui region. It has four goals, to reduce:

- erosion
- the impact of erosion on water quality
- the impact of erosion on flood protection
- the impact of erosion on infrastructure.

Horizons contracted Landcare Research (Dymond et al, 2014) to undertake an analysis of the effect of SLUI in reducing erosion rates and sediment yield using a model, SedNet. This model was recently applied in the Manawatū catchment as a case study.

The modelling used continuous sediment monitoring data and explored different scenarios to manage erosion. It found that a reduction of between 17 per cent and 40 per cent in overall sediment loads is possible if various parts of the SLUI initiative are implemented.

Estimating contaminants from urban stormwater

While urban stormwater issues affect a relatively small proportion of New Zealand's receiving waters, they have been intensively studied. Williamson (1993) published a summary of data collected around the country, which made it possible for managers to obtain load estimates of different contaminants according to urban land use (eg, commercial, light industrial, residential). Recently, NIWA has taken this concept and made it into a web-based tool called Urban Runoff Quality Information System (URQIS).⁸ While still under development, URQIS enables users to get reports on particular contaminants summarised by combinations of land-use type, region, water type or flow condition. An example of output from URQIS for ammoniacal-N, summarised by region, is shown in figure 6.4.

Figure 6.4: Example of output from the Urban Runoff Quality Information System for ammoniacal-N summarised by region

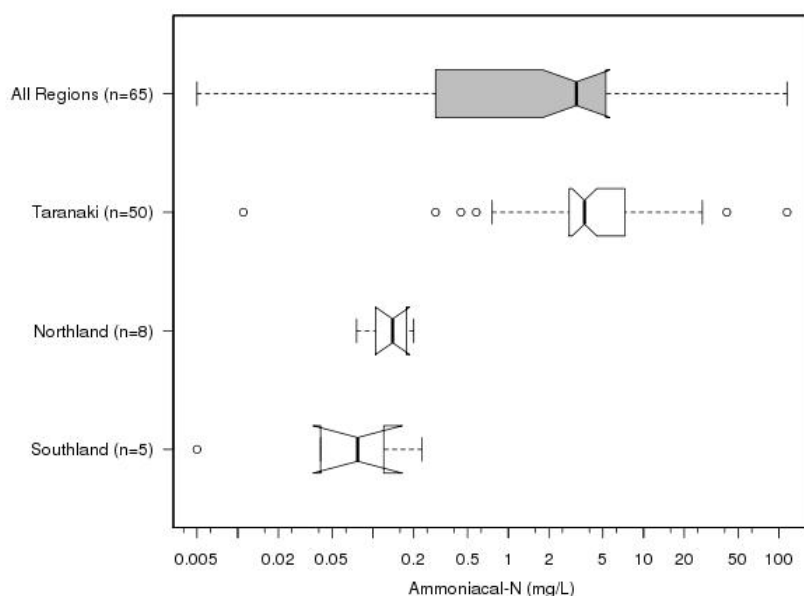


Figure produced by NIWA's Urban Runoff Quality Information System, 15-07-2014 09:42

Modelling contaminants from urban stormwater

The Catchment Load Model (CLM) developed by Auckland Regional Council (2010) is an extension of the estimation method described above. It is a spreadsheet-based model, developed to enable estimation of stormwater contaminant loads on an annual basis. The model is very simple in principle – the area of a particular land use (source) within the area being studied (the catchment) is multiplied by the quantity of contaminants discharged from that land use (source yield) to provide an annual load from that source. The loads from each source within the catchment are then added together to provide an annual contaminant load for the catchment of interest. The model estimates total suspended solids (TSS), copper (Cu) and zinc (Zn) loads from roofs, roads, motorways, pavements, parks, construction sites, stream channels and rural areas. The model can be used for hindcasting loads and is available for public use. However, it has been specifically developed for Auckland using Auckland data. While used in other parts of New Zealand, this is with limited success, mainly because the yields for TSS are unlikely to be correct for rainfall, and the soils different from

⁸ See <http://urqis.niwa.co.nz/>.

those in Auckland. However, the generation of chemical contaminants predicted in the CLM should be reasonably applicable to most urban areas of New Zealand.

An extension to the CLM model (C-CALM), which is based on a geographic information system (GIS) platform, will be released by NIWA shortly.⁹ It uses the same yield algorithms as the CLM but allows geo-visualisation of contaminant sources, which can aid communication between stakeholders. It will be freely available for non-commercial use and is discussed in further detail in case study 6.11.

CASE STUDY 6.11 – URBAN CONTAMINANT MODELLING

The Catchment Contaminants Load Model or C-CALM is a spatial decision support system (DSS) for stormwater planning activities. It estimates annual contaminant loads at the neighbourhood to stormwater management unit (sub-catchment) scale, from diffuse sources, for total suspended solids (TSS) and particulate and dissolved zinc and copper. The estimated load is then adjusted for stormwater treatment.

C-CALM was used by Moores et al (2013) as part of a trial of a new DSS developed under the Urban Planning that Sustains Waterbodies (UPSW) research project. The DSS uses C-CALM as one of several linked models that enabled the testing of urban development scenarios for effects (changes in environmental, social and economic indicators) on parts of the South-eastern Manukau Harbour and adjoining tidal creeks.

Groundwater lag considerations

Where groundwater makes up a significant proportion of a catchment's total flow, it is important to account for the contaminant contribution it delivers. However, travel time of groundwater in New Zealand can be very long (relative to the distance travelled) and models need to account for this lag. This is particularly important to manage expectations where limits have been set and management actions put in place to stay within those limits.

The nitrogen nutrient cap in the Lake Taupō catchment is a good example. The nitrogen limit was calculated with a knowledge of groundwater lag times (mean residence times 20–75 years). Higher nitrogen concentrations occur in groundwater with a greater fraction of water recharged since farm development some 40 years ago. Numerical groundwater modelling predicts nitrogen mass loading to the lake from current land use will continue to increase for a substantial period of time (more than 100 years). This lag is important because it relates to the considerable time required to replace old, pristine groundwater with nitrogen-enriched water from farming. The lags in the Lake Taupō area are discussed further in case study 6.12, and the use of water age assessment in assessing lags is outlined in case study 6.13.

⁹ Email c-calm@niwa.co.nz for the release date and more information.

CASE STUDY 6.12 – CONSIDERING LAGS IN LAKE TAUPŌ

The work done by Waikato Regional Council to set objectives and limits to manage water quality in Lake Taupō has been used as a case study in Rouse et al (2013). In setting limits, they undertook scientific studies to develop a nutrient budget for the lake and established a current load (eg, of nitrogen 1360 tonnes/year) and ‘baseline’ or pre-development load (650 tonnes/year). From this, they derived a ‘manageable load’ (710 tonnes/year) that can be attributed to human sources. The studies confirmed a time lag between the land and the lake, which means that current nitrogen leaching on the land and nitrogen loads entering the lake are not in equilibrium. As a result, it is necessary to do more than hold nitrogen discharges on the land at current levels to maintain current water quality. The amount of nitrogen ‘still to come’ before equilibrium is reached with current land use has been estimated at between 30 per cent and 41 per cent of the annual manageable load attributed to human generation.

CASE STUDY 6.13 – WATER AGEING IN THE HORIZONS REGION

To better understand how contaminants are transported, especially through groundwater systems, GNS Science and Horizons Regional Council have undertaken a project to age water at various river and stream sampling sites at base flow conditions (Morgenstern et al, 2014). This data helps to determine travel times, and thus lag time, between land-use change and impact, which will help determine the efficiency of policies in place to manage nutrients in the region.

The dating results from 29 sites across three catchments showed that the mean residence times were between 0 and 11 years:

- 6–7 years in the Whanganui River
- 3–3.5 years in the Rangitikei River
- 9–11 years in the Manawatū River.

These ages give an insight into lag times that need to be considered in models predicting the effects of land-use change on river water quality.

Attenuation

Nutrients, *E. coli* and even sediment are subject to various physical, chemical and biological processes during the time it takes to leach or run off an area of land, and travel through groundwater or in the river, before it is measured at a catchment outlet. The sum of these processes is known as ‘attenuation’. When modelling catchment loads, it is important to factor in attenuation. Specific processes making up attenuation (eg, denitrification through the riparian zone) can be incorporated into models or, alternatively, bulk attenuation factors can be estimated. For accounting purposes, estimation is probably adequate, providing there is a reasonable basis for making the estimate and this is made clear in the accounts.

Clothier¹⁰ estimated an attenuation factor of 0.5 for nitrogen in the upper Manawātū catchment. This was consistent with other estimates made for Waikato catchments (Alexander et al, 2002). More recently, in Hawke’s Bay, Rutherford (2012)¹¹ ran a series of sensitivity analyses for attenuation using %drainage as the variable parameter. Rutherford made the distinction between groundwater attenuation and stream attenuation.

Attenuation can be estimated by comparison of the sum of exports from each land use within a catchment using known source coefficients (load generated per unit area (see 6.4) with measured actual load at the catchment outlet. Using this method requires awareness that some published export coefficients include attenuation while others do not. The method also does not take into account the physical characteristics of the catchment in question.

There do not appear to be simple guidelines on determining attenuation suitable for contaminant accounts. ‘Rules of thumb’ prevail, with most authors opting for a factor of 0.5. However, given the large gap between catchment input loads and the load measured at the downstream catchment node, the lack of defensible guidelines appears to be a significant omission. Without a robust estimate of attenuation there is likely to be considerable argument about the significance of sources and their impacts on limits. There may therefore be benefit in investing in more accurate assessments of attenuation factors in those catchments where management actions are to be focused, as in the example provided in case study 6.14.

CASE STUDY 6.14 – CONSIDERING LAGS AND ATTENUATION IN THE UPPER WAIKATO RIVER

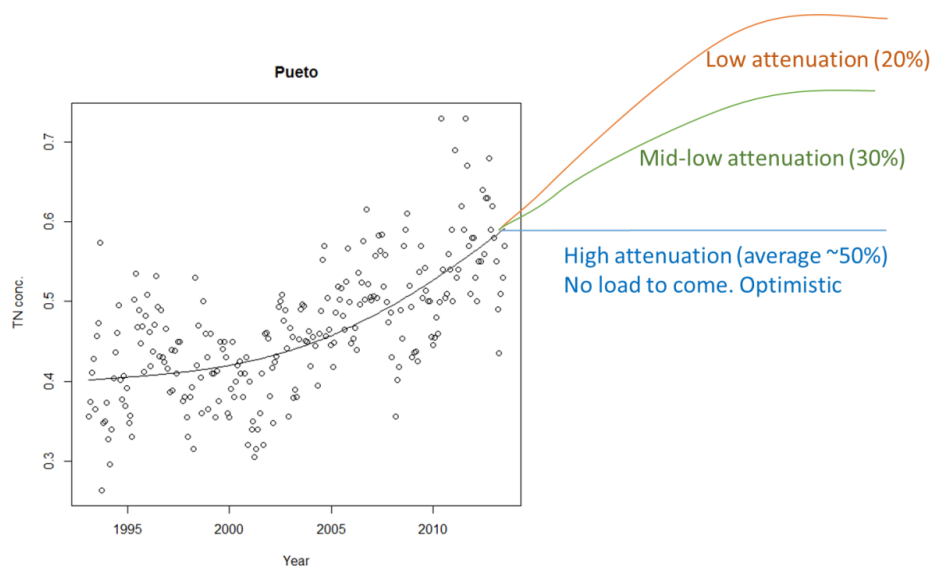
In a recent study by Elliott et al (2014), simplified catchment models were used to make water quality predictions for total nitrogen (TN), total phosphorus (TP) and chlorophyll *a* in the upper Waikato River (Pueto catchment shown below). Because there is significant uncertainty about the degree of attenuation, three different scenarios were used:

- a maximum value, which allowed matching of current concentrations
- a low value
- a mid-low value (see figure 6.5).

¹⁰ See www.horizons.govt.nz/assets/one-plan-publications-and-reports/Officers-reports-water-hearing/Dr-Brent-Euan-Clothier.pdf.

¹¹ See www.hbrc.govt.nz/HBRC-Documents/HBRC%20Document%20Library/20120829%20FINAL%20NIWA%20Modelling%20report.pdf.

Figure 6.5: Predicting total nitrogen (TN) concentrations in the Pueto catchment using three different attenuation factors



The model predictions (for future years along the horizontal axis) were sensitive to attenuation. In the most extreme case, concentrations in one catchment were predicted to increase by 147 per cent as a result of delayed responses (groundwater lags) to past land-use change.

For further detail on the methodology used in this study and its limitations, see Elliot et al (2014), available at www.mfe.govt.nz/sites/default/files/media/Fresh%20water/niwa-catchment-models-jul14.pdf.

6.6 Reconcile measured and estimated loads

The fifth step as described in figure 6.1 simply allows the comparison of the current measured state (loads) with the estimated loads from the various sources (natural, point sources, diffuse sources) for each contaminant. This calibration is an important step in the process.

Because each number (measured, estimated or modelled) will come with an associated estimate of uncertainty, comparisons of these will enable refinement of estimates and clarification of assumptions with regard to attenuation, lags and storage of contaminants.

6.7 Bringing it all together

System needs

Sections 6.3 and 6.4 describe how to measure the current state and account for all sources of relevant contaminants by FMUs. The ultimate objective, in terms of the NPS-FM's intended purpose for accounting, is to provide accounts using all of these components. That means the next stage (step

six in figure 6.1) is to bring the different threads of information together. Collating this information into water quality accounts will help with the four intended purposes of accounting, outlined in 2.2.

Rouse et al (2013) found that, generally, the systems councils use for water quality accounting are not as established as those for water quantity. Most examples of water quality accounting at that time were one-off source analyses rather than systems that allowed for regular accounting. However, if these one-off source analyses are carried out for all relevant contaminants where freshwater objectives and limits are being set or reviewed, this is water quality accounting. As accounting systems become more sophisticated, it may be possible for water quantity and quality accounts to be developed using a single system because there are many common components between the two, as outlined in case study 6.15 below.

CASE STUDY 6.15 – EXAMPLE WATER QUALITY ACCOUNTING SYSTEMS

Whereas Rouse et al (2013) were able to develop schematics for water quantity accounting systems, this was not possible for the water quality systems reviewed.

However, common components of the water quality systems were:

- consents databases for allocations and compliance data (actual discharges for some consented point-source discharges)
- state of the environment monitoring data (background contaminant levels in surface water bodies, in particular)
- regional plan objectives, policies and methods (including rules) and associated Schedules for permitted activities and numeric outcomes for water bodies
- databases of other information – soils, climate, topography, land use
- Lookup Tables, purpose-built calculators
- inventories of nitrogen and phosphorous.

From discussions with councils as part of the Rouse et al (2013) evaluation of accounting systems and limit setting, it was apparent there are a number of barriers to producing contaminant accounts. These barriers, and the approaches to overcome them, are council-specific – that is, the need for systems improvements and the method whereby these improvements are made, is specific to each council. While contaminant accounts can be produced using methods discussed above, currently, it would involve a lot of manual work to link outputs from all the various components to produce accounts – in the medium to long term, these could be automated. These issues are further explored below.

Consistent plan provisions and consent conditions

Where contaminants are identified in an FMU as being relevant and therefore featuring in contaminant accounts, those contaminants need to be identified in the appropriate plan and all relevant discharge consents need to have conditions set to reflect the limits set in the plan. While this may appear obvious, historic consents are not likely to include conditions reflecting the contaminant of interest (this is especially the case with nutrients), and care will be needed to ensure these consents do not simply ‘roll over’. Some thought will also need to be given to how discharge consent conditions are drafted to ensure that monitoring information is received in a form suitable for accounts.

Accessing consent information

Currently, council officers producing accounts (eg, Vant, 2014) need to manually extract consent monitoring information from the relevant database, calculate loads and/or concentrations in common units and compare the results with river loads and/or concentrations (which also need to be calculated). It should be possible to develop automated IT systems that calculate monitored loads and/or concentrations and output them directly to a contaminant accounting 'system' or display interface. Similarly, IT systems should be able to automatically and regularly calculate river loads and/or concentrations from audited flow and concentration data.

Systems to facilitate contaminant accounts

If systems are developed to automate consent monitoring, load calculation and river load calculations, it should also be possible to automate the generation of accounts. A missing link for some is the calculation of diffuse anthropogenic loads (diffuse loads-background). This calculation could be done using the method described by Vant (2014) or, alternatively, using OVERSEER® output reports (at least for nutrients) to generate those loads. Comparison between OVERSEER®-generated diffuse loads and loads generated by difference (Equation 1) would also be useful in providing catchment-specific attenuation coefficients. During the discussions with councils that were part of the Integrated Regional Information System (IRIS) consortium (Rouse et al, 2013), it looked hopeful that this would all be possible using that system. However, it appears that such features are not currently part of IRIS.

Communicating accounts with different audiences

It is likely that, as contaminant accounts are implemented, there will be increasing demand from stakeholders for councils to produce them. Thought needs to be given as to how often and in what form accounts are produced and the QA procedures that will need to be run before they are produced. Different forms of accounts may suit different audiences. For example, accounts produced to discuss limit setting among stakeholders may be more effective in graphical format. Such a format may also be suitable for a state of the environment report but should be supplemented with tabular format accounts as an appendix (rather like the presentation of accounts in a company report). The explanatory notes that accompany the report are important for those who want to find out more, such as methods used and assessments of uncertainties.

Dealing with uncertainty

All methods of estimating loads, whether using measured or modelled data, have some uncertainty about them – that is, the load is estimated as $x \pm y$ kg/d (or whatever the unit where x is the load and y is the uncertainty). The amount of uncertainty will vary between methods and between contaminants and may even vary spatially or temporally for the same contaminant using the same method (because of differences in the quality of flow information). It is important that stakeholders understand the uncertainty associated with load estimates, particularly in setting limits. This uncertainty should be explicitly stated on contaminant accounts.

6.8 Preparing a report

As previously discussed (6.2) the main driver for freshwater accounting is to provide better information for councils to implement the NPS-FM requirements for freshwater objective and limit setting, and therefore the accounting system will be unique to each FMU and region. However, potential benefits could arise from a nationally consistent template for reporting on water quality accounting.

Case studies 4.5 and 6.9 have examples of catchment and regional accounts that could provide guidance on what to include in a freshwater quality account. More examples can be found in Rouse et al (2013).

A template suggestion is included in table 6.4 that could be used for water quality accounting reporting for FMUs (per contaminant). The template is intentionally simple. It assumes permitted activities, such as septic tanks, could be estimated with diffuse sources, but equally a line could be added for permitted point sources. For estimates of loads from non-point sources, lines could be added to specify loads from different land-use types (eg, native bush, dairy, sheep and beef, horticulture, cropping, forestry, urban) using a 'hectare * loss rate' estimate for each contaminant type. If limits (FMU loads per contaminant) have been set, these could be inserted into this table and reported against.

Table 6.4: Suggested template for water quality accounting (per contaminant)

FMU	Name			
Period	Date range – eg, 1 July–30 June Year			
Location	Grid ref (eg, centroid of catchment polygon, or most downstream point)			
Contaminant	eg, Nitrogen			
Units	eg, Tonnes per year (T/year)			
Reference loads				
	Load (T/year)		Error estimates (%)	Methods used
Inflows to FMU (if any)	A			Measured and/or estimated
Background/ natural sources	B			Measured and/or estimated
Total leaving FMU	C			Measured and/or estimated
Point sources				
Number of consented discharges	xx			
	Consented load (T/year)	Actual load (T/year)	Error estimates (%)	Methods used
Sewage discharges	D	G		Measured and/or estimated
Industrial discharges	E	H		Measured and/or estimated
Total point source discharges	F (D+E)	I (G+H)		Measured and/or estimated

Non-point sources			
	Load (T/year)	Error estimates (%)	Methods used
Authorised non-point discharges	J		<i>Estimated and/or modelled</i>
Summary			
Total in			$K (A+B+I+J)$
Total out			C
Difference (lags, attenuation factors, storages, etc)			$K-C$

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