Physical Stock Accounts for Water[1]

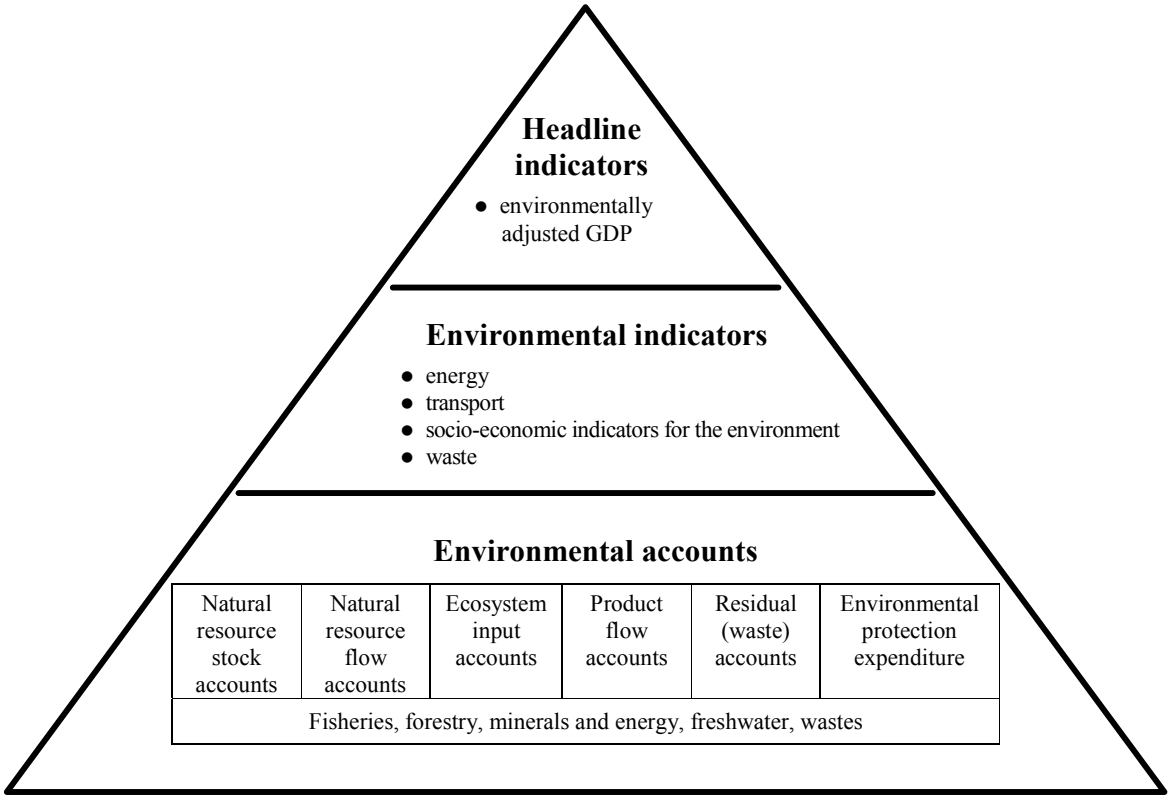
Environmental accounting

Statistics New Zealand is working with a number of government and other agencies to produce a range of statistical measures regarding the natural environment and the impact of economic and social activities on the environment. Among the statistical measures, Statistics New Zealand is developing environmental accounts for several natural resources: fisheries, forestry, minerals and energy, and freshwater.

Environmental accounts consist of physical and monetary stock and flow accounts. The physical stock and flow accounts are referred to as natural resource accounts. They measure the physical stocks (assets) and flows of natural resources in units such as tonnes and cubic metres. These quantities are then valued, resulting in monetary figures that will form the environmental accounts and be linked to economic statistics such as the Gross Domestic Product (GDP). Refer to figure 1 below.

Figure 1

Statistics New Zealand's Environment Statistics Framework



Further information on the environment statistics framework and strategy is available on the Statistics New Zealand website.[2]

The physical stock accounts are the first accounts to be developed for freshwater. They describe how the stocks of freshwater are affected by water flows within the hydrological system during accounting periods. The general structure of the accounts is defined by the United Nations handbook *Integrated Environmental and Economic Accounting* (commonly referred

1. This article was prepared by John Gudgeon, of the Regional and Environmental Statistics Group, Statistics New Zealand. It is extracted from the inaugural report *WATER: Physical Stock Accounts for the June years 1995 to 2001,* Statistics New Zealand (2004).
2. http://www.stats.govt.nz/domino/external/web/prod_serv.nsf/htmldocs/Environment+Statistics+Strategy.

to as SEEA).[3] In the SEEA, stock accounts are called asset accounts. They deal with opening and closing stocks of water resources and the flows that affect these stocks. In the New Zealand stock accounts, total opening and closing stocks are not quantified. Instead, the accounts are presented in terms of inflows, outflows and changes in stock levels. There are gaps in the New Zealand stock accounts concerning water use (abstraction and discharge) by people and livestock. These gaps will be filled when comprehensive data becomes available or suitable estimation methods are developed.

The water and energy physical stock accounts are currently the only New Zealand resource accounts developed at the regional level. Monetary stock accounts for water will follow if suitable valuation methods are developed. There is insufficient data on industry usage at this time to develop flow accounts for water. Stock accounts deal with components of the hydrological cycle relating to freshwater supplies in New Zealand. Flow accounts, if produced, would show exchanges of water between the environment and the economy (at an industry level).

The physical stock accounts for water cover the June years 1995 to 2001. Each accounting period represents the 12 months from 1 July to 30 June inclusive. The 1995 June year, for example, ends on 30 June 1995. The unit of measurement is millions of cubic metres (billions of litres).

Broad perspective

Most of the world's water is seawater. Only about 2.5 percent of water is freshwater. Ice-caps and glaciers account for about 70 to 80 percent of freshwater, depending on the source of information, while groundwater accounts for about 20 to 30 percent. Lakes, soil moisture, atmospheric water vapour, rivers, and water within living organisms account for the remainder, which is about one percent.

"Over the last 50 years, global water withdrawal has quadrupled while world population doubled."[4] The heaviest water user globally is agriculture, which is responsible for about 69 percent of total freshwater abstraction. Industry accounts for 23 percent and households for 8 percent. While per capita water consumption has decreased since 1980 in OECD countries, the net population growth has meant that water consumption overall has increased. Industrial use in OECD countries, with the exception of New Zealand, is now higher than agricultural use.

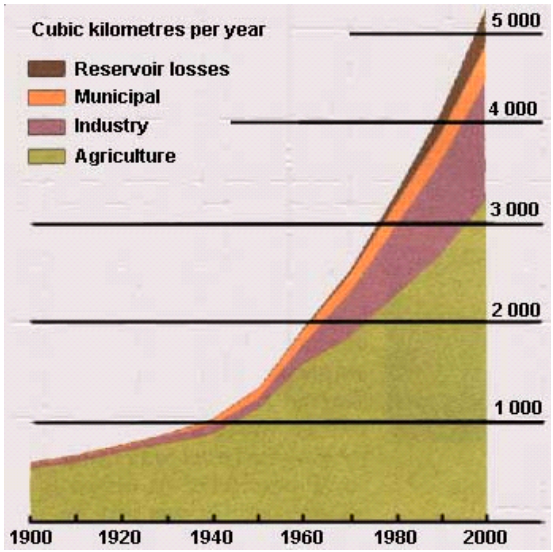
Figure 2

World Water Distribution[5]

	Water volume km^3 (million)	Percent of total water	Percent of fresh water
Total water	1,386	100.00	…
Saline water	1,351	97.47	…
Freshwater	35	2.53	100.0
- ice-caps and glaciers	24.4	1.76	69.7
- groundwater	10.5	0.76	30.0
- lakes, rivers, atmosphere	0.1	0.01	0.3

Figure 3

Estimated Annual World Water Use[6]



Relative to most other countries, New Zealand has abundant freshwater. The total annual amount of precipitation in New Zealand varies between 300,000 million and 600,000 million cubic metres. However, the availability of New Zealand's freshwater varies significantly between regions, with the amount of annual rainfall generally decreasing as one moves east.[7]

3. The handbook can be downloaded from the website http://unstats.un.org/unsd/environment/seea2003.htm.
4. *Water Crisis?* Rory Clarke, OECD Observer (19 March 2003).
5. *World water resources,* Food and Agriculture Organization of the United Nations (FAO).
6. *Water: a finite resource,* Food and Agriculture Organization of the United Nations (FAO), http://www.fao.org/docrep/U8480E/U8480E0c.htm [5 July 2004].
7. *Waters of New Zealand,* M P Mosley [editor] (1992). The New Zealand Hydrological Society. ISBN 0-473-01667-2 (out of print).

This is largely due to New Zealand's mountainous topography where one-third of the land area is above 1,000 metres. The mountains largely control the distribution of rainfall due to their orientation to the predominant west-southwest wind flows. Rainfall in most areas is higher during winter and spring than during summer and autumn.

The availability of water also varies between the rural and urban environments. The sustainable management of water in urban environments is becomingly increasingly important as the urban population increases, particularly with the added pressures of higher drinking-water standards and stricter discharge conditions. New Zealand's rainfall also varies markedly over periods of time. "Shifts in rainfall patterns indicate greater variability of supply in the future, and our per capita demands tend to still be rising, stressing supply and delivery systems, and taxing treatment capacity."[8]

"New Zealand's rivers and lakes provide about 60 percent of the water we consume (the other 40 percent comes from underground). They also provide 75 percent of our electric power."[9]

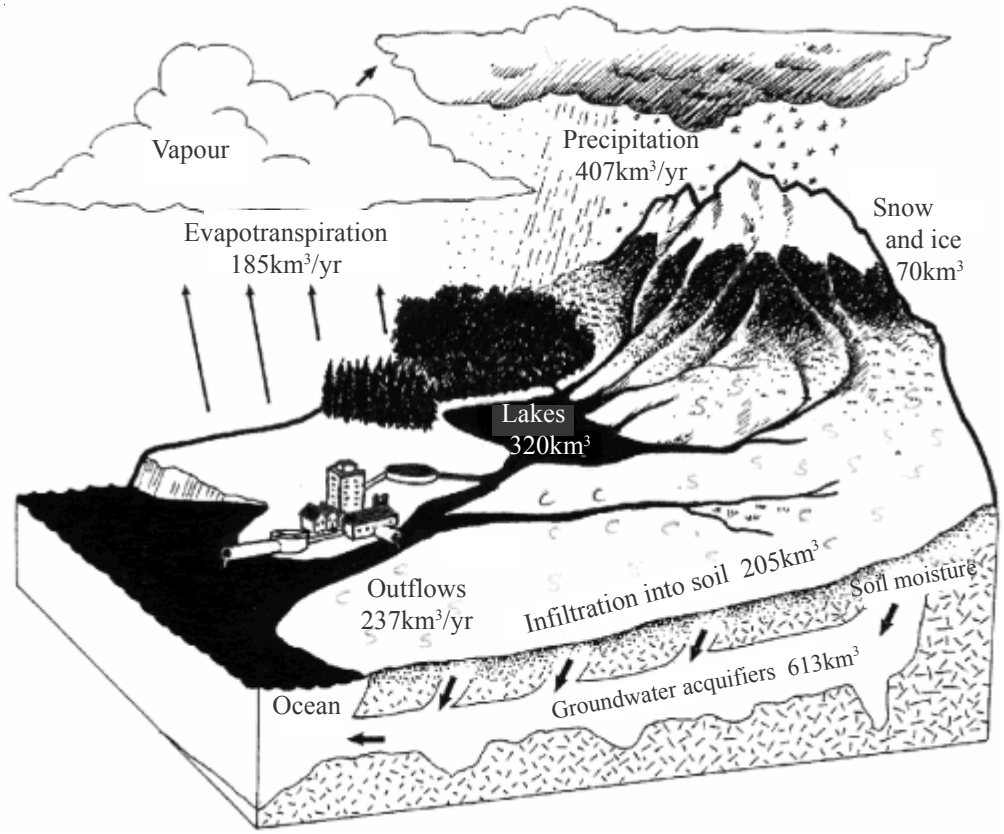
The hydrological cycle

Water has a number of properties that set it apart from other natural resources. Water is constantly moving and transforming into different states over time. Water is also constantly being renewed, but its availability fluctuates over time for different regions, depending on the hydrological cycle, human use of water, and other factors.

In figure 4, one cubic kilometre (km^3) equals 1,000 million cubic metres. Annual flows (km^3/yr) are for the June year 2001. Storage volumes (km^3) for snow and ice and groundwater aquifers are estimates as at 30 June 2001.

Figure 4

New Zealand Water Cycle

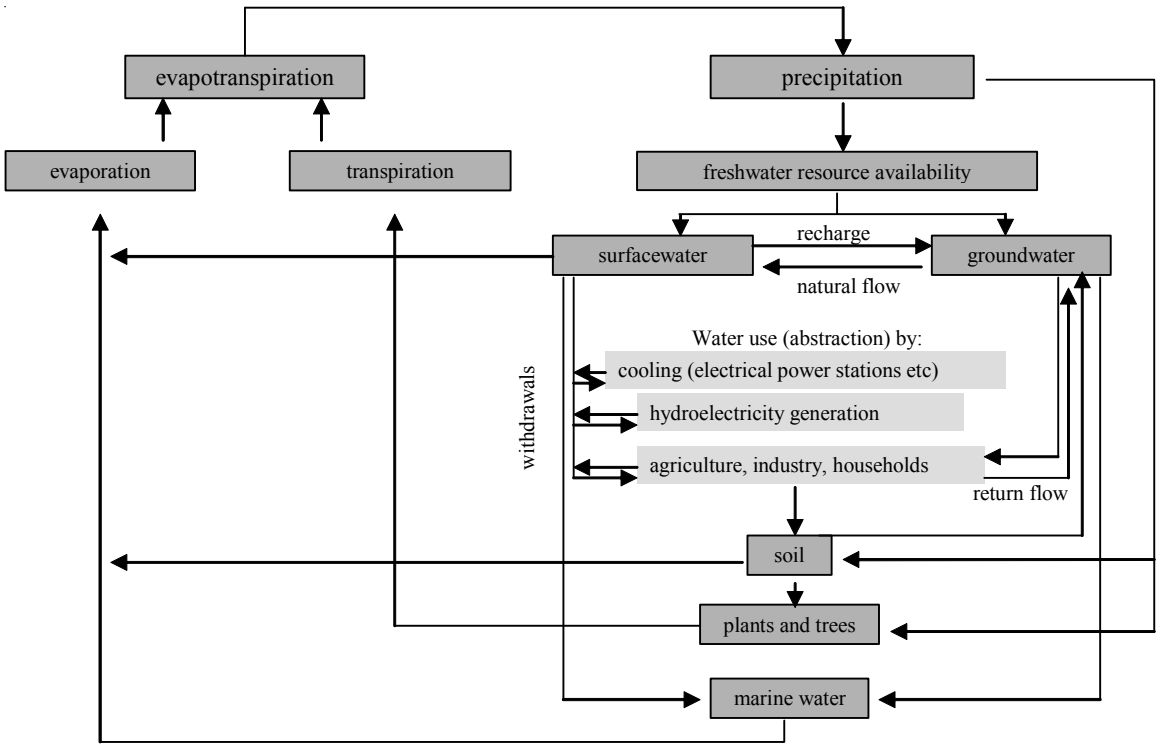


Source: Based on MfE, adapted from Mosley (1993)

8. *Whose Water Is It?,* Parliamentary Commissioner for the Environment (2001).
9. *The State of New Zealand's Environment,* chapter 7.6, MfE (1997).

Figure 5

Interaction between the Hydrological Cycle and the Economy[10]



Water use is dependent on its quality. Humans rely on clean water for drinking while other uses, such as hydropower generation, do not require the same standards of purity. As a result, there may be a plentiful supply of water but it may still be a scarce resource, depending on the planned use of that water.

Water accounting, using the SEEA handbook, is based on the hydrological cycle (see figure 4), which tracks the movement of water through the hydrosphere (the region containing all the water in the oceans, atmosphere and land). In the cycle, water evaporates from oceans and the vapour is carried in air currents. As the vapour cools, it condenses and forms clouds or fog which, with further cooling, may fall on land as precipitation (either rain or snow). This precipitation can then follow a number of pathways. It may be evaporated immediately, be absorbed by plants and vegetation which then release the water back to the atmosphere through transpiration, or drain into surfacewater and groundwater systems which eventually drain into the sea.

"The hydrological cycle is driven by radiation reaching the earth's surface. This radiation increases as greenhouse gas concentrations rise. The incoming radiation strongly influences both the surface temperature and the rate at which water evaporates from land and sea. In turn, the temperature determines the moisture-carrying capacity of the air, and the melt rate of polar ice and alpine snow. Temperature differences also create air pressure differences that give rise to the world's winds. Climate scientists therefore expect significant changes in climate patterns if greenhouse gas pollution continues to force up surface radiation and global temperatures, and these changes would have very significant flow-on effects for water resources."[11]

The natural cycle is also modified more directly through human activities, such as abstractions, discharges, construction of dams, and changes in land use including urbanisation, forest planting and land drainage.

10. Based on *Environmental Indicators for Agriculture, Volume 3, Methods and Results,* OECD (2001). http://www1.oecd.org/publications/e-book/5101011E.PDF [6 July 2004].

11. National Institute of Water & Atmospheric Research Ltd, NIWA, (2004).

Water management

In New Zealand, a number of different agencies are involved in the management of water. Regional councils are responsible for the management of natural water (ie, freshwater, groundwater, geothermal water and coastal water). They are required to safeguard the life-supporting capacity of waters and to ensure that water users avoid, remedy or mitigate any adverse effects on the environment from their use of water. Territorial authorities are generally responsible for the management of the municipal and community water supplies in their district (sometimes these community water supplies are privately owned). Crown research institutes, in particular the National Institute of Water & Atmospheric Research Ltd (NIWA), and the Institute of Geological & Nuclear Sciences Ltd (GNS), through their research and scientific monitoring roles, also contribute to the management of surfacewater and groundwater resources.

Unless expressly allowed by a rule in a regional plan, the Resource Management Act 1991 (RMA) requires approval, in the form of a resource consent from a regional council, for the abstraction of water, except for an individual's reasonable domestic use, livestock use or for fire-fighting purposes. Regional councils keep records of the water permits granted, including the allocated maximum volumes, as well as monitoring records, such as the actual volumes abstracted, when this information is available. Allocated volumes are maximums and tend to overestimate the amount of water actually abstracted. The reasons for this are:

- allocations are based on peak or near-peak demand
- different uses require peak volumes at different times
- not all of the allocated volume is required every year
- some water is not used but reserved for future use
- variation in weather.

As a result, allocated maximum volumes are generally not a good proxy for actual water abstraction. The degree to which actual abstraction is monitored varies greatly between regional councils and there is insufficient coverage for compilation of national aggregates.

In New Zealand, households obtain their water either through a piped community water supply that is usually managed by the local authority (but in some cases is privately owned), or by directly connecting to their own water source through private wells or pumping from streams. Some houses also have rainwater tanks. An estimated 87.5 percent of New Zealand's population was connected to a registered drinking-water supply in 2002.[12]

Territorial authorities, to varying degrees, collect data on water abstraction by category of user, for the municipal and community water supplies they manage. Good information is generally available for large urban water supplies because these supplies are usually metered. The smaller the population served by a water supply, the less likely it is that data is available, because of limited resources for metering and monitoring. Private abstraction of water for reasonable domestic or livestock use is a permitted activity that does not require resource consents. There is no comprehensive data for such abstractions.

Territorial authorities also monitor water quality and administer rules concerning dairy shed effluent, sewage and other discharges of contaminants to water. In addition, regional councils, NIWA and GNS all have water quality monitoring networks. The RMA which replaced more than 20 major statutes, including the Town and Country Planning Act 1997, has changed the focus of water resource management from multiple-use management to environmentally-sustainable management.

Scope of the water accounts

Inclusions

The water accounts deal with the inland water component of the hydrological system. The scope is broad and includes all freshwater (as opposed to seawater) resources, whether above, on or below ground, that provide both direct use and non-use benefits. Direct use benefits include water that can be extracted in the current period as well as water that may be of use in the future. Non-use benefits (such as kayaking) arise simply by having the resource exist.

The stock classification for freshwater resources reflects those components of the hydrological system that are available for water abstraction and that provide direct inputs into the economy.

12. *Annual Review of the Microbiological and Chemical Quality of Drinking-Water in New Zealand 2002,* Ministry of Health (December 2003).

Soil moisture, glaciers and permanent snow are not specifically classified as a 'stock' as water is not abstracted directly from these sources. However, they are important components of the hydrological system and are included in the accounts.

The water stock accounts are compiled on a regional basis as well as a national basis. Although New Zealand is a relatively small country, there is considerable variation in precipitation and water availability from one region to another. For example, droughts can occur in Canterbury at the same time as heavy rainfall occurs on the West Coast. Such extremes tend to average out at the national level. Accounts at the regional level are necessary for meaningful analysis.

Exclusions

Opening and closing stocks are excluded because of difficulties in measuring volumes, particularly for rivers. The SEEA handbook includes opening and closing stocks in the water asset or stock account and suggests that the stock of water in a river can be measured by the volume of the riverbed. However, many South Island rivers are braided and have riverbeds that are constantly shifting. Data is not available for the riverbed volumes in New Zealand. The absence of opening and closing stocks for rivers means that total opening and closing stocks cannot be calculated. The water stock accounts are therefore in the form of a water balance, where inflows equal outflows plus changes in stored volumes.

Water in oceans and seas is not included in the accounts because the volumes of water involved are so large that a stock measure would be meaningless and such water is rarely abstracted for direct use.

Some flows, such as discharges of abstracted water and outflows to sea from groundwater, are not individually included in the accounts. They are included only indirectly or as part of other components.

Water quality is outside the scope of the current water accounts, but could in principle be included in the future.

The water stock accounts are the first attempt at water accounting in New Zealand. Data limitations have made it necessary to adopt a broad approach.

Uses

The physical stock accounts for water bring together abstraction and discharge information with a variety of hydrological data, including precipitation, evapotranspiration, outflows and changes in stored water. The tables in the stock accounts can assist in assessing:

- regional and national availability and scarcity of the resource
- effects of El Niño/Southern Oscillation (ENSO) and Interdecadal Pacific Oscillation (IPO) cycles
- regional and national water usage
- interactions between the environment and the economy
- effects on the water resource of structural and policy change in other sectors.

Water accounting year

The period 1 July – 30 June has been selected as the water accounting year because:

- each June year contains a whole irrigation season
- periods of low flows or drought are of interest for analysis and usually fit well with (ie occur entirely within) individual June years
- June/July is generally a period when storage has been replenished and water levels are stable.

Sources of data

Water is probably the most monitored feature of the New Zealand environment. Even so, national data is rather limited. Information on the quantity and quality of groundwater, surfacewater and coastal water is collected by a diverse range of organisations, headed by regional councils and local territorial authorities (ie district and city councils), NIWA and GNS.

The State of New Zealand's Environment 1997, prepared by the Ministry for the Environment (MfE), compiles the available water data for New Zealand, to provide a general overview of the state and pressures on the water resource. Many regional councils also publish *State of the Environment* reports containing information on water quality and flows, and the Institute of Environmental Science and Research Ltd (ESR), a Crown research institute, manages a drinking-water database for the Ministry of Health.

"From 1983 through to 1988, the Ministry of Agriculture and Fisheries summarised much of the existing information on a region by region basis in a series of reports entitled "Regional modifications to waterways" in the now defunct journal, *Freshwater Catch*. … Apart from this, there have been few attempts to provide a systematic overview of the state of our waters, particularly at the national level. No repetitions of the 1980s baseline surveys have been undertaken to report on trends."[13]

Abstraction data

The physical stock accounts for water measure inflows, outflows and changes in storage between years for inland water (freshwater, as compared to seawater). The accounts also measure, where possible, interactions between the hydrological cycle and the economy. The exchange of water between the environment and the economy is partly represented by net abstraction in the 'outflows to sea and net abstraction' component of the stock accounts and by additional, but incomplete, supplementary tables included with the annual stock accounts. Abstraction, and discharge, of water for hydroelectricity generation involve very large volumes of water and are presented as separate components in the accounts.

For the purposes of the New Zealand accounts, all water abstracted from the environment for human and economic use is considered to enter the economy. It encompasses domestic, commercial and industrial supplies, including water used for electricity generation, irrigation and livestock. Abstraction figures include water that is abstracted more than once. For example, water abstracted for irrigating pasture can seep down into an aquifer and be available for re-abstraction.

Where abstraction volumes are unavailable, plant outflow volumes may be used as a close approximation. Passive uses of water, such as for recreation and transport, are not included in the accounts. The collection of rainwater is also not considered to be water 'abstraction'.

In the SEEA handbook, abstraction is disaggregated into abstraction that is at a 'sustainable' level and abstraction that is considered to be 'depletion'. The distinction between sustainable and depletion is not made in the accounts, primarily due to the complexity in assessing the local levels at which abstraction becomes unsustainable.

The SEEA handbook also makes a distinction between the different sources of water from which water is abstracted, namely surfacewater (rivers, lakes and reservoirs) and groundwater (from aquifers). A supplementary table for stocks of groundwater is included with the annual stock accounts.

Ideally, separate abstraction and discharge volumes for all major abstractive water uses would be detailed in the accounts. In practice, however, comprehensive data is not always available. A model is being developed for estimating abstraction for irrigation, and estimates have been needed for quantifying private domestic abstraction and livestock usage. Private industrial abstraction and abstraction for geothermal electricity generation are presently out of scope of the accounts. Comprehensive data is not readily available for discharges of abstracted water back into the environment.

13. *The State of New Zealand's Environment,* chapter 7.5, MfE (1997).