Water Physical Stock Account: 1995–2010

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Preface

Water Physical Stock Account: 1995–2010 provides information on New Zealand's national and regional water balance.

Water is valued for many reasons: ecological function, role in supporting industry and maintaining biodiversity, recreational value, and cultural significance. By international standards, New Zealand has a plentiful supply of water due to high levels of precipitation. However, this water is not evenly distributed – some areas experience a surplus while others have seasonal shortages.

The water physical stock account provides information on the inflows and outflows of water through the inland part of the hydrological cycle, changes in water storage, and some estimates of water use. This report is one in a series of environmental accounts published by Statistics New Zealand that provide information on the interaction between the environment and the economy.

Statistics NZ acknowledges the supply of data and advice by the National Institute of Water and Atmospheric Research Ltd, the Institute of Geological and Nuclear Sciences Ltd, and agricultural sector organisations.

Geoff Bascand
Government Statistician

Information about the data

Abbreviations

GNS	Institute of Geological and Nuclear Sciences Ltd
MfE	Ministry for the Environment
NIWA	National Institute of Water and Atmospheric Research Ltd
SEEA	System of Environmental and Economic Accounts
SEEAW	System of Environmental and Economic Accounts for Water
SNA	System of National Accounts

Percentage changes

Percentage movements are sometimes calculated using data of greater precision than that published. This could result in slight variations in the percentages reported.

Rounding procedures

Figures have been rounded, and discrepancies may occur between sums of component items and totals. All percentages have been calculated using unrounded figures.

Source

Data was provided by the National Institute of Water and Atmospheric Research Ltd and the Institute of Geological and Nuclear Sciences Ltd, except where otherwise stated.

Symbols

.. figures not available
… not applicable
-- amount too small to be expressed.

Values

All monetary values are shown in New Zealand currency, except where otherwise stated.

Other sources of data

Livestock numbers used for estimating livestock drinking-water and dairy-shed water requirements come from Statistics NZ's Agricultural Production Survey. Estimates of litres per head per day for livestock were taken from Horizons Regional Council's 2007 report, *Reasonable Stock Water Requirements: Guidelines for Resource Consent Applications*. Additional advice was provided by Fonterra, AgResearch, Beef and Lamb New Zealand, New Zealand Pork Industry Board, Deer Industry New Zealand, New Zealand Equine Research Foundation, Poultry Industry Association of New Zealand, New Zealand Goat Breeders Association Inc, and Dairy Goat Co-operative (NZ) Ltd.

For more information on the definitions used throughout the report please see the Glossary.

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1 Introduction

Integrated environmental and economic accounts

Statistics New Zealand produces a range of environmental statistics about the natural environment and its contribution to the economy, and the impact of the economy and social activities on the environment. These statistics are presented as ‘environmental accounts’, which are based on the United Nations (UN) Statistical Commission’s statistical framework known as the System of Environmental and Economic Accounts (SEEA) *Handbook of National Accounting: Integrated Environment and Economic Accounting 2003* (United Nations, European Commission, International Monetary Fund, Organisation for Economic Co-operation and Development, & World Bank, 2003).

The SEEA is the standard used by many national statistics offices. It provides "internationally agreed and comparable concepts, definitions, classifications, accounting rules, and tables. The SEEA framework follows a similar accounting structure as the System of National Accounts (SNA) in order to facilitate the integration of environmental and economic statistics," (UN et al, 2003). In addition, the SEEA’s integrated approach overcomes the tendency to divide issues along disciplinary lines where analyses of economic and environmental issues are carried out independently of one another.

Statistics NZ has developed environmental accounts for several natural resources, including freshwater, fisheries, energy, forestry, and minerals (available from the Statistics NZ website www.stats.govt.nz). These accounts can be used to assess trends over time and to gauge if New Zealand’s resources are being used sustainably. The development of the accounts reflects an international movement towards compiling information beyond the traditional measures of economic activity, and acknowledges that the environment has a finite capacity to supply materials and absorb waste.

Water physical stock account

The water physical stock account describes how stocks of freshwater are affected by water flows within the hydrological system during accounting periods. The structure of the account is defined by the SEEA handbook and the *System of Environmental and Economic Accounting for Water* (UN, 2007). These frameworks describe a system of stock or asset accounts, with opening and closing stocks of water resources and the flows that affect these stocks.

In the New Zealand water physical stock account, total opening and closing stocks are not quantified (see Exclusions in chapter 4 for details). Instead, the account is presented in terms of inflows, outflows, and changes in storage levels.

Water physical stock account components

For inflows, we report on the key national and regional components:

- precipitation
- inflows from other regions (regional scale only).

The components for outflows are:

- evapotranspiration
- abstraction for hydroelectricity generation
- discharge from hydroelectricity generation
- outflows to sea and net abstraction
- outflows to other regions (regional scale only).

The changes in storage components are:

- net change in lakes and reservoirs
- net change in soil moisture
- net change in snow storage
- net change in ice storage
- changes to groundwater volume.

We also provide estimates of livestock drinking-water and dairy-shed requirements in chapter 3.

Gaps in data

In the New Zealand water physical stock account, significant gaps exist on water use by people (abstraction and discharge) and to a lesser extent, by livestock. These gaps will be filled when comprehensive data becomes available or suitable estimation methods are developed. It is anticipated that the implementation of the Resource Management (Measurement and Reporting of Water Takes) Regulations 2010 (see www.mfe.govt.nz or www.legislation.govt.nz) which calls for water metering and reporting for takes over five litres per second, will be a useful source of water abstraction data for future water physical stock accounts.

There is insufficient data on industry usage at this time to develop flow accounts for water. Flow accounts, if produced, would show exchanges of water between the environment and the economy at an industry level. (See chapter 8, Further developments, for more details.)

Reference period and unit of measurement

This report covers the years ended June, from 1995 to 2010. Each accounting period represents the 12 months from 1 July to 30 June, inclusive. The year ended June 1995, for example, ends on 30 June 1995. The unit of measurement used is millions of cubic metres. One million cubic metres is equivalent to one gigalitre, which is one billion litres.

For more information on integrated environmental and economic accounting please see the United Nations System of Environmental-Economic Accounts webpage.

Revisions to *Water Physical Stock Account: 1995–2005*

Snow storage

This report contains revised figures from the *Water Physical Stock Account: 1995–2005*. The results were revised due to improvements made by the National Institute of Water and Atmospheric Research Ltd (NIWA) to national hydrological modelling, spatial mapping, and measurement. In particular, the accuracy of estimating changes in snow storage in New Zealand has improved due to the integration of a new temperature index component into the TopNet model. Further explanation of the methodology used in estimating the components of the national and regional water balance can be found in *Surface water components of New Zealand's national water accounts* (NIWA, 2011).

Groundwater volume

Groundwater volume figures are provided by the Institute of Geological and Nuclear Sciences Ltd (GNS). These figures are unrevised but updated for the years ended 30 June 2006–10.

Abstraction for livestock use

Estimated volumes of abstraction for livestock use have been revised. Previous water accounts had usage-per-head figures from the *Farm Water Supply Design Manual* (MAFtech, 1987). This report uses updated usage-per-head values based on Horizons Regional Council's 2007 report *Reasonable Stock Water Requirements: Guidelines for Resource Consent Applications* (Horizons Regional Council, 2007). Advice has also been provided by agricultural industry organisations and Fonterra. Abstraction for livestock use estimates now also includes dairy-shed requirements.

Future developments

Statistics NZ welcomes feedback on this report and its future direction. For more detailed information on future developments please see chapter 8. For questions or comments, email environment@stats.govt.nz.

2 Results for the water physical stock account

Highlights

In the year ended June 2010:

- The West Coast region received the highest precipitation.
- Canterbury had the largest volume of groundwater storage, with approximately 70 percent of the New Zealand total.
- Livestock drank approximately 191 million cubic metres of water, equal to more than 55,000 Olympic-sized swimming pools.[1]
- Abstraction for hydroelectricity generation amounted to an estimated 98 cubic metres per person per day, roughly equivalent to 650 full baths[2] of water per person each day.

In the years ended June, 1995–2010:

- The average volume of precipitation was enough to fill Lake Taupo over 10 times each year.
- The total volume of groundwater varied by less than 1 percent.

Between the years ended April, 1995-2010:

- New Zealand's estimated ice volume decreased by 21 percent.[3]

Summary of results

- The lower-than-average national values for precipitation and outflow to sea in some years (1997, 2001, 2003, 2005, and 2008) are mainly caused by low precipitation in the South Island and Taranaki or central North Island.
- Consistent effects of El Niño-Southern Oscillation (ENSO)[4] events on precipitation are not visible at the national scale, because ENSO effects vary by region (Gordon, 1986; Salinger & Mullan, 1999).
- A severe El Niño event occurred in 1997–98, with weak events in some periods (2002–03, 2004–05, and 2006–07).
- Weak La Niña conditions occurred in some periods (1998–2000, 2007–08, and 2008–09).
- The tendency for lower-than-average national precipitation values since 2000 (seven of 11 years) may also reflect a change in the phase of the Interdecadal Pacific Oscillation (IPO)[4] since that time.

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[1] An Olympic-sized swimming pool measures 50 by 23 by 3 metres.

[2] A full bath is estimated to be approximately 150 litres.

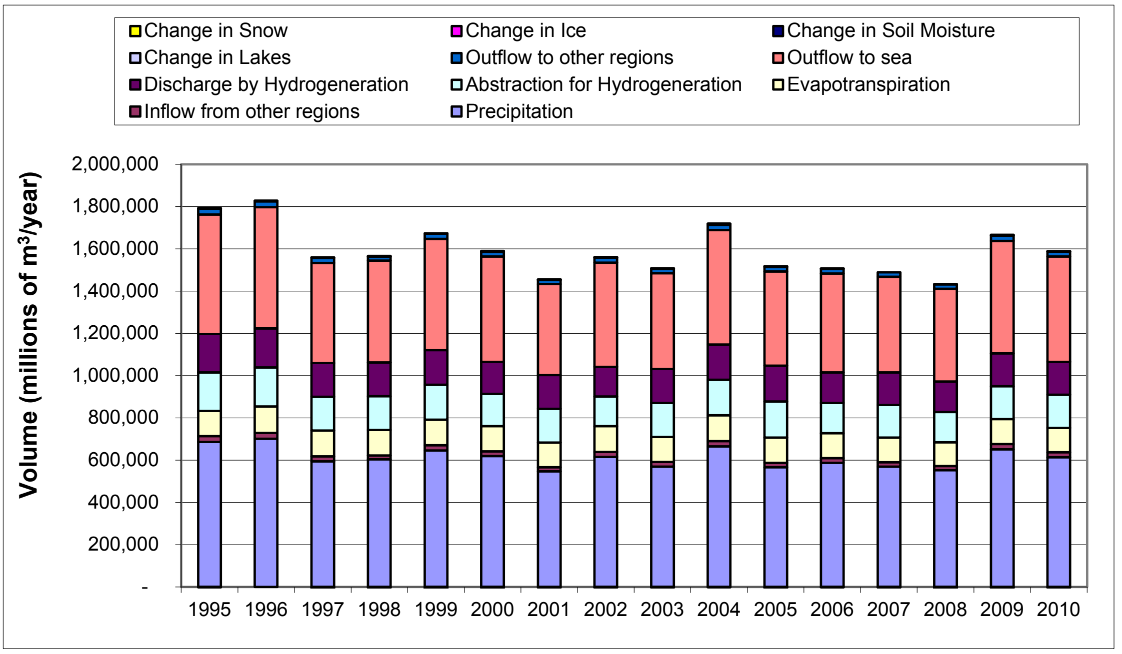
[3] Data provided by NIWA. When the WPSA 1995–2010 went to press the methodology for estimating annual glacier volume changes had been reviewed internally by NIWA, and was being externally reviewed for publication in an international journal.

[4] See Glossary for more details.

- Figure 1 summarises these variations in components. Table 1 shows the water physical stock account for the years ended June, from 1995 to 2010.

Figure 1

Year-to-year variations in components of the national water accounts, 1995–2010



Source: *Surface water components of New Zealand's national water accounts* (NIWA, 2011).

Table 1

Water physical stock account for years ended June, 1995–2010

New Zealand (1)

	Year ended June															
	1995	1996	1997	1998	1999	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010
	Million cubic metres															
Inflows																
Precipitation	684,986	701,394	593,461	603,264	645,603	619,207	546,821	614,630	569,103	664,433	565,889	587,074	568,843	551,635	651,015	613,510
Total inflows	684,986	701,394	593,461	603,264	645,603	619,207	546,821	614,630	569,103	664,433	565,889	587,074	568,843	551,635	651,015	613,510
Outflows																
Evapotranspiration	120,354	125,088	122,180	121,257	120,588	119,478	115,980	121,657	118,545	122,628	119,220	117,729	116,081	112,415	118,374	115,625
Abstraction for hydroelectricity	182,049	184,698	159,743	159,216	164,673	151,867	159,661	140,308	160,850	167,244	170,315	143,725	154,558	143,342	155,088	156,329
Discharge from hydroelectricity generation(2)	-182,049	-184,698	-159,743	-159,216	-164,673	-151,867	-159,661	-140,308	-160,850	-167,244	-170,315	-143,725	-154,558	-143,342	-155,088	-156,329
To sea and net abstraction(3)	558,532	574,722	476,907	482,803	531,872	498,374	432,572	490,035	457,162	536,302	450,462	469,926	455,871	443,190	529,105	495,729
Total outflows	678,886	699,810	599,087	604,060	652,460	617,852	548,553	611,692	575,707	658,931	569,681	587,655	571,952	555,605	647,479	611,354
Change in storage(4)																
Soil moisture	-620	1,838	1,301	-2,085	1,131	-610	41	-909	845	-1,593	1,907	-462	-199	-1,087	1,780	-1,514
Lakes and reservoirs	-289	264	-1,676	1,714	-763	2,357	-3,338	2,124	-761	1,957	-3,336	91	-335	-1,184	2,836	81
Groundwater	4,220	-1,220	-2,480	-830	-1,810	820	290	2,750	-4,480	3,060	-3,130	-440	-2,200	520	2,770	2,890
Snow (5)	1,316	643	-3,986	1,709	-1,953	1,869	508	1,369	-3,158	1,272	-269	1,438	-47	398	-1,688	945
Ice(6)	1,473	60	1,214	-1,304	-3,462	-3,082	767	-2,396	950	807	1,035	-1,209	-327	-2,617	-2,163	-245
Total change in storage	6,100	1,584	-5,627	-796	-6,857	1,354	-1,732	2,938	-6,604	5,503	-3,793	-581	-3,109	-3,970	3,536	2,156

1. Sum of the 16 regions administered by regional councils and unitary authorities.
2. Water used in hydroelectricity generation is returned to the hydrological system. Discharges match abstraction, meaning that 'net' abstraction is zero. However one hydro electricity power station in Southland returns water direct to the sea, thereby preventing others from reusing the freshwater.
3. This is a residual volume and is calculated as the inflow less outflow and change in storage.
   It is the volume of water that leaves the hydrological system, other than by evapotranspiration.
   Net abstraction is the difference between abstraction and discharges. It is not specifically calculated because there is insufficient data on:
   •abstraction of water for irrigation, private domestic use, private industrial use, and geothermal electricity generation
   •discharges of water back into the environment.
4. Change from the end of the previous June year to the end of the current June year.
5. These volumes are for water stored as seasonal snow at an altitude of 900m to 2,000m. Transient snow (below 900m) and perennial snow (above 2,000m) are excluded.
6. These volumes are for water stored in glaciers for the year ended April. Snow above 2,000m will largely be included.

Source: National Institute of Water and Atmospheric Research Ltd; Institute of Geological and Nuclear Sciences Ltd

Component results

Inflows

Precipitation

Between 1995 and 2010, the average annual volume of precipitation (includes rainfall, snow, sleet, and hail) that fell in New Zealand was 611,304 million cubic metres, enough to fill Lake Taupo over 10 times.

Annual precipitation fluctuated over the period, with a high of 701,394 million cubic metres in 1996, and a low of 546,821 million cubic metres in 2001. In 2010, precipitation was 613,510 million cubic metres.

From 1995 to 2010, the West Coast had the largest rainfall volume although it has only the fifth largest land area. Otago, with its extensive dry areas, had only the fifth largest precipitation volume, although it is the second-largest region. Average precipitation per person was highest in the West Coast region and lowest in the Auckland region (which has the highest population density). In 2010, annual precipitation per person in the West Coast region (at 3.91 million cubic metres), was 841 times higher than in the Auckland region.

Inflows from other regions

Between 1995 and 2010, the average annual volume of water that entered each region from rivers outside of that region was 22,992 million cubic metres.

Annual inflow from other regions fluctuated over the period, with a high of 27,853 million cubic metres in 1995, and a low of 18,437 million cubic metres in 1998. In 2010, inflow from other regions was 23,308 million cubic metres.

In general, regions in New Zealand are bounded by catchment boundaries. Most rivers do not flow from one region to another. However, there are exceptions, which are shown in table 3 in chapter 5.

Outflows

Evapotranspiration

Between 1995 and 2010, the average annual evapotranspiration (loss of water by evaporation from the soil and transpiration from plants) was 119,200 million cubic metres. Annual evapotranspiration fluctuated over the period, with a high of 125,088 million cubic metres in 1996, and a low of 112,415 million cubic metres in 2008. In 2010, evapotranspiration was 115,625 million cubic metres.

Abstraction for hydroelectricity generation

Between 1995 and 2010, the average annual abstraction for hydroelectricity generation (total volume of water abstracted from surface water by hydro-generation companies), was 159,604 million cubic metres. Over the period there was a high of 184,698 million cubic metres in 1996 and a low of 140,308 million cubic metres in 2002.

In 2010, abstraction for hydroelectricity generation was 156,329 million cubic metres. This amounts to an estimated 98 cubic metres per person per day.

The volume of water abstracted for hydroelectricity generation averaged 32 percent of the volume of outflows to seas and net abstraction, but includes water that was abstracted several times (because power stations are often built in chains along rivers).

Discharge from hydroelectricity generation

Use of water for hydroelectricity generation is treated as non-consumptive use of water, as the water used is returned to the hydrological system. Volumes of water discharged match those abstracted, meaning that the net abstraction at the national level is zero.

Outflows to other regions

Between 1995 and 2010, the average annual volume of water that leaves a region and flows to another region was 22,992 million cubic metres. Annual outflow to other regions fluctuated over the period, with a high of 27,853 million cubic metres in 1995, and a low of 18,437 million cubic metres in 1998. In 2010, outflows to other regions was 23,308 million cubic metres.

In general, regions in New Zealand are bounded by catchment boundaries. Most rivers do not flow from one region to another. However, there are exceptions. These are shown in table 3 in chapter 5.

Outflows to sea and net abstraction

Between 1995 and 2010, the average annual outflows to sea and net abstraction (abstraction less discharges) was 492,723 million cubic metres. This value fluctuated over the period, with a high of 574,722 million cubic metres in 1996, and a low of 432,572 million cubic metres in 2001. In 2010, outflows to sea and net abstraction was 495,729 million cubic metres. This volume accounted for 81 percent of total outflows for the year, with evapotranspiration accounting for the remaining 19 percent. Net abstraction totals are unavailable, and are therefore included with outflows to sea as a residual volume.

Total outflow

Between 1995 and 2010, the average annual total outflow, being the sum of evapotranspiration, outflow to other regions, and outflow to sea and net abstraction, was 611,923 million cubic metres, enough to fill Lake Taupo over 10 times.

Annual total outflow fluctuated over the period, with a high of 699,810 million cubic metres in 1996, and a low of 548,553 million cubic metres in 2001. In 2010, total outflow was 611,354 million cubic metres.

Change in storage

Soil moisture

Between 1995 and 2010, the largest annual decrease in soil moisture occurred in 1998, while the largest annual increase occurred in 2005. The amount of soil moisture varies according to rainfall, evapotranspiration, and land use.

Lakes and reservoirs

Between 1995 and 2010, the largest annual decrease in lake and reservoir volume occurred in 2001. The largest annual increase was in 2009.

Changes in lake and reservoir levels in the water physical stock account are point-to-point movements from the end of one June year to another and can be influenced by rainfall in the last few days or weeks of each June.

Groundwater

Between 1995 and 2010, the largest annual decrease in groundwater occurred in 2003, while the largest increase occurred in 1995. The variation of total groundwater volume over 1995–2010 was less than 1 percent (GNS, 2011). The estimated groundwater volume in New Zealand aquifers in 2010 was 618,000 million cubic metres.

Canterbury is the region with the largest groundwater storage, estimated to be 431,000 million cubic metres and approximately 70 percent of New Zealand's groundwater. Waikato has the second largest groundwater storage, with approximately 35,000 million cubic metres of water, closely followed by Bay of Plenty with 32,000 million cubic metres of water.

For the 2006–10 period, the mean annual groundwater storage volume (around 614,000 million cubic metres of water) for all of New Zealand was significantly greater than the total groundwater consented allocation, which is 8,000 million cubic metres of water per year (Aqualinc Research, 2010).

The variability in groundwater volume on a national basis was found to be only broadly related to national rainfall variability (White & Reeves, 2002).

Snow

Between 1995 and 2010, the largest annual decrease in the quantity of water stored as snow occurred in 1997. The largest annual increase occurred in 2000. In the water physical stock account, snow is defined as the volume of water stored as seasonal snow at an altitude of 900 to 2,000 metres. Transient snow (below 900m), and perennial snow (above 2,000m), are both excluded from the snow component. Transient snow is captured in the precipitation component while perennial snow is included in changes in ice storage.

Ice

Between the 1995 and 2010 April years, the largest annual decrease in the quantity of water stored as ice occurred in 1999. The largest annual increase in ice occurred in 1995.

The water accounting period for ice begins in 1994 with an initial volume estimate of 51,141 million cubic metres, reaching a maximum of 53,888 million cubic metres in 1997. By 2010, New Zealand's ice volume had decreased to 40,642 million cubic metres. This is an overall reduction of 21 percent between April 1994 and April 2010.

In 2010, the Canterbury and Westland regions contained 92 percent of the ice volume in New Zealand.

The change in the quantity of water stored in ice is measured indirectly in New Zealand, through annual monitoring of the areas and end of summer snowline altitudes of 49 index glaciers. This permits the estimation of changes in mass of the index glaciers, and a spatial mapping technique is then used to extend this to the 3,144 glaciers in the New Zealand glacier inventory.

Total change in storage

Between 1995 and 2010, the largest annual decrease in the total change in storage of water occurred in 1999. The largest annual increase was in 1995.

In 2010, changes in the volume of stored water amounted to less than half a percent of the volume of precipitation falling in New Zealand during that year.

Tables and reports

Tables for this report, and other associated reports listed below, are available from the Statistics NZ website, www.stats.govt.nz:

- *Water Physical Stock Account: 1995–2010* – annual tables
- *Water Physical Stock Account: 1995–2010* – regional tables
- *Surface Water Components of New Zealand's National Water Accounts, 1995–2010* (NIWA, 2011)
- *Annual glacier volumes in New Zealand 1995–2010* (NIWA, 2011)
- *Update of national groundwater volume stock account* (GNS, 2011).

3 Livestock drinking-water and dairy-shed requirements

Highlights

In the year ended June 2010:

- 276 million cubic metres of water were required for livestock drinking-water and dairy-shed requirements, the equivalent of using around 220 Olympic-sized swimming pools[5] of water every day for a year.
- Livestock drinking-water requirements were 191 million cubic metres.
- Dairy-shed water requirements[6] were 85 million cubic metres.

In the years ended June, 1995–2010:

- Livestock drinking-water and dairy-shed requirements increased by 35.8 million cubic metres, an increase of just under 15 percent.
- Livestock drinking-water requirements increased by 7.0 million cubic metres.
- Dairy-shed water requirements increased by 28.8 million cubic metres.

Background

The taking and using of water for stock-drinking purposes is allowed under the Resource Management Act 1991 (RMA) without the need for a resource consent. Specifically, section 14(3)(b) of the RMA allows the taking and using of water for an individual's reasonable domestic needs; or the reasonable needs of an individual's animals for drinking water as long as there is no adverse effect on the environment as a result of taking and using water. With regard to dairy-shed water usage, the RMA delegates the day-to-day management of natural resources to local councils. Therefore, it is the responsibility of regional councils to manage the use of surface and groundwater resources for dairying within their regions.

Volumes for livestock drinking-water and dairy-shed water requirements have been estimated for the years ended June 1995–2010. They are presented in detail in table 2 and included as a line item in the water abstraction and discharge table (annual table 20).

The estimates are calculated using a combination of annual livestock numbers and average water use per-head-per-day values. The livestock numbers are sourced from Statistics NZ's Agricultural Production Survey and Infoshare (available from www.stats.govt.nz and www.stats.govt.nz/infoshare/) while the water use estimates are based on Horizons Regional Council's 2007 report *Reasonable Stock Water Requirements: Guidelines for Resource Consent Applications.* Additional advice was sought from appropriate industry organisations listed under Data sources in this chapter.

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[5] An Olympic-sized swimming pool measures 50 by 23 by 3 metres.

[6] Dairy-shed requirements include water used for cooling milk, washing down, and cleaning plant and equipment.

Data coverage

Estimates of livestock drinking-water requirements are provided for the following livestock types:

- dairy cattle
- beef cattle
- sheep
- deer
- pigs
- poultry (includes chickens, ducks, and turkeys)
- horses
- goats.

Estimates of dairy-shed water requirements are provided for the following livestock types:

- dairy cattle
- dairy goats.

Livestock drinking-water requirements

Livestock drinking-water requirements is an estimate of the amount of drinking water required for New Zealand's livestock. Consumption of drinking water is highly dependent on many factors, including the size of the animal, milk yield, quantity of dry matter consumed, temperature and relative humidity of the environment, temperature of the water, quality of the feed, and moisture content of the feed (Looper & Waldner, 2002). Where possible, estimates of drinking-water requirements have been applied to the age, sex, and lactation state of each livestock type. The per-head-per-day litre values are estimates based on average daily demand.

The livestock drinking-water volumes presented here provide an estimate of how much water animals actually consume. It does not account for losses due to pipe leakage, spills, and evaporation. Consequently, the amount of water abstracted from surface and groundwater will be higher than the amount actually used.

Livestock dairy-shed water requirements

Livestock dairy-shed water requirements is an estimate of the water required to operate New Zealand's dairy (or milking) sheds. Estimates of dairy-shed requirements include water used for cleaning plant and equipment, washing down milking areas, and cooling of milk. The per-head-per-day litre values are based on average daily demand. Estimates are provided for dairy cattle and milking goats but exclude water requirements for yard wash-down and cleaning for other livestock types, such as cleaning horse stables or chicken pens.

The dairy-shed water requirements presented here provide an estimate of how much water is required. It does not account for losses due to pipe leakage. Consequently, the amount of water abstracted from surface and groundwater will be higher than the amount actually used.

Results

Livestock drinking-water and dairy-shed requirements

In 2010, livestock collectively were consuming more water for drinking and dairy-shed purposes than in 1995, with an overall increase of 35.8 million cubic metres. This increase was largely driven by dairy cattle, which used more water for drinking and for dairy-shed requirements. The significant increase in dairy water requirements is primarily associated with an increase of 45 percent in the number of dairy cattle between 1995 and 2010.

Livestock drinking-water requirements

In 2010, the largest drinking-water requirements were for dairy cattle (113 million cubic metres), beef cattle (46 million cubic metres), and sheep (28 million cubic metres). These accounted for the majority (98 percent) of the total livestock drinking-water requirements. This large requirement for water is due to the large number of these livestock types and the comparatively larger volumes of water consumed per head. For example, a dairy cow is estimated to drink approximately 70 litres a day; adult beef cattle 35 litres; while deer stags and dry goats (goats not in milk) drink just four and five litres a day, respectively.

While the drinking-water requirements for dairy cattle increased between 1995 and 2010, these decreased significantly for both beef and sheep, by 24 percent and 34 percent, respectively. These changes reflect the change in livestock numbers, with dairy cattle increasing for the period, and beef and sheep numbers decreasing (Statistics NZ, 2011).

Between 1995 and 2010, of the other livestock types, only poultry showed an increase in drinking-water requirements. Poultry includes chickens, ducks, and turkeys.

Livestock dairy-shed water requirements

Between 1995 and 2010, dairy-shed requirements for dairy cows increased by approximately 29 million cubic metres, an increase of just over 50 percent. This increase is associated with a large rise in the dairy cattle herd over the period, from just over 4 million animals in 1995 to just under 6 million in 2010.

Over the same period, dairy-shed requirements for goats increased in line with an increase in the national dairy goat herd. In 2010, dairy-shed requirements for goats was just 0.1 percent of New Zealand's total dairy-shed requirements.

Table 2 shows the livestock drinking-water and dairy-shed requirements for the years ended June, 1995–2010.

Table 2

Livestock drinking-water and dairy-shed requirements[1]

By livestock type

Years ended June, 1995–2010

Livestock type	Year ended June							
	1995	1996	1997	1998	1999	2000	2001	2002
	Million cubic metres							
Livestock drinking-water requirements								
Dairy cattle	76.9	78.4	79.8	81.2	82.5	87.4	92.3	97.1
Beef cattle	60.4	57.0	55.9	54.8	53.7	52.7	51.9	51.0
Sheep	42.3	41.1	40.5	39.9	39.3	37.6	35.8	34.1
Deer	1.5	1.5	1.7	1.9	2.1	2.1	2.1	2.1
Pigs	0.8	0.8	0.8	0.7	0.7	0.7	0.7	0.7
Poultry	0.9	0.9	0.9	1.0	1.1	1.1	1.2	1.3
Horses	1.1	1.1	1.1	1.1	1.1	1.1	1.2	1.2
Goats	0.5	0.5	0.4	0.4	0.4	0.4	0.4	0.3
Sub-total	184.3	181.2	181.1	181.0	181.0	183.1	185.5	187.7
Dairy-shed water requirements								
Dairy cattle	56.1	57.3	58.8	60.3	61.7	64.9	68.0	71.1
Goats	--	--	--	--	--	0.1	0.1	0.1
Sub-total	56.2	57.4	58.8	60.3	61.8	64.9	68.0	71.1
Total	240.4	238.6	240.0	241.4	242.8	248.0	253.5	258.9

Livestock type	Year ended June							
	2003	2004	2005	2006	2007	2008	2009	2010
	Million cubic metres							
Livestock drinking-water requirements								
Dairy cattle	97.4	99.8	99.7	100.0	101.2	107.4	112.8	113.3
Beef cattle	53.0	51.1	50.9	50.8	50.5	47.9	48.1	45.7
Sheep	34.1	33.8	34.2	34.4	33.1	29.4	27.9	27.9
Deer	2.1	2.2	2.1	1.9	1.7	1.5	1.4	1.4
Pigs	0.7	0.7	0.7	0.7	0.7	0.6	0.6	0.6
Poultry	1.2	1.1	1.1	1.0	1.1	1.2	1.1	1.1
Horses	1.3	1.2	1.1	1.1	1.0	1.0	1.0	1.0
Goats	0.4	0.3	0.3	0.3	0.3	0.2	0.2	0.2
Sub-total	190.1	190.3	190.0	190.2	189.7	189.2	193.1	191.3
Dairy-shed water requirements								
Dairy cattle	72.7	75.9	77.0	75.9	76.3	81.1	85.1	84.9
Goats	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1
Sub-total	72.7	76.0	77.0	76.0	76.4	81.2	85.2	85.0
Total	262.8	266.3	267.0	266.2	266.1	270.4	278.3	276.2

Symbols:

-- amount too small to be expressed

Note:

1. Data may not sum to stated totals due to rounding.

Source: Statistics New Zealand

Data sources

Statistics NZ's Agricultural Production Survey provided the annual livestock numbers used in the drinking-water and dairy-shed requirement calculations. Data was not available for all livestock types for all years. In such cases, the livestock numbers were estimated using imputation and linear interpolation techniques. It is acknowledged that this introduces a level of uncertainty to some values within the time series. However, this approach is considered appropriate for providing high-level estimates that are fit for purpose.

Horizons Regional Council's 2007 report, *Reasonable Stock Water Requirements: Guidelines for Resource Consent Applications*, provided the basis for the livestock drinking-water estimations. This report was selected after a literature search of relevant publications, including documentation from regional councils, Ministry of Agriculture and Forestry Biosecurity New Zealand, and Lincoln University. This search revealed that there is a range of possible values for each livestock type, and some level of broad agreement, but no universally approved values. Therefore, Fonterra and a number of industry organisations were approached for further advice. Statistics NZ appreciates the advice provided by:

- Fonterra
- AgResearch
- Beef and Lamb New Zealand
- New Zealand Pork Industry Board
- Deer Industry New Zealand
- New Zealand Equine Research Foundation
- Poultry Industry Association of New Zealand
- New Zealand Dairy Goat Breeders Association Inc
- Dairy Goat Co-operative (NZ) Ltd.

Revisions to previous water physical stock accounts

The water physical stock accounts for 1995–2001 and 1995–2005 included livestock drinking-water estimates based on average water usage per-head-per-day values from the 1987 draft *Farm Water Supply Design Manual* by MAFtech. Both accounts did not include an estimation of dairy-shed water requirements.

This report uses updated water usage per-head-per-day values based on Horizons Regional Council's 2007 report *Reasonable Stock Water Requirements: Guidelines for Resource Consent Applications*. As a result, the abstraction for livestock use figures presented in 2005 have been revised. The revised values in the abstraction and discharge table (annual table 20) now also include dairy-shed water requirements.

4 Scope of the water physical stock account

Inclusions

Freshwater

The water physical stock account deals with the inland water components 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 and water that may be used in the future. Non-use benefits (such as those for recreational benefit) arise simply by having the resource in existence.

The water physical stock account measures, 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 account. The water abstraction and discharge table (see annual table 20) includes: water use for livestock drinking and dairy shed requirements; and abstraction and discharge for hydroelectricity generation. The use of water for livestock drinking-water and dairy-shed water requirements is included in chapter 3.

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. 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 this account.

Regional and national figures

The water physical stock account is compiled on a regional and national basis. Although New Zealand is a relatively small country, there is considerable variation in precipitation and water availability among regions, especially in the South Island. For example, droughts may occur in Canterbury at the same time as heavy rainfall occurs on the West Coast. Accounts at the regional level allow more meaningful analysis. Such extremes tend to average out at the national level.

Exclusions

Opening and closing stocks

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 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 physical stock accounts therefore, are presented in the form of a water balance, where inflows equal outflows plus changes in stored volumes.

Water abstraction

Currently, there is insufficient data to quantify the actual volumes of water abstracted for irrigation, industrial use, municipal and domestic use, livestock use, and geothermal electricity production.

Outflows to sea and net abstraction are estimated as a residual volume, calculated as the inflow minus other outflow and change in storage.

Net abstraction is the difference between abstraction and discharges. It is not specifically calculated because there is insufficient data on abstraction and discharges back into the environment.

Estimates for these components will be included in future water physical stock accounts as robust and comparable data become available.

Water quality

Water quality is outside the scope of the current water account.

Uses of the water physical stock account

The water physical stock account brings together a variety of hydrological data, including precipitation, evapotranspiration, outflows, and changes in stored water. In addition, the account presents limited information on water abstraction.

The Excel tables that accompany this report can help assess the:

- availability and scarcity of water on a regional and national basis
- effects of El Niño-Southern Oscillation and Interdecadal Pacific Oscillation cycle (see Glossary for definitions)
- interactions between the environment and the economy
- effects of water resource on structural and policy change in other sectors
- national water usage by livestock.

Over the longer term, the water account may also be helpful in assessing the impact of climate change on the hydrological system and on water resources.

Accounting year

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

- June/July is generally a period when storage has been replenished and water levels are stable.
- periods of low flows or drought are of interest and usually occur entirely within a June year
- each June year contains a whole irrigation season

Sources of information on water

Water is valuable for many reasons – drinking, irrigation, energy, recreation, and tourism. Water has cultural values and is essential for the health of the natural environment. Even so, national data on water abstraction and use is limited. Information on the quantity and quality of groundwater, surface water, and coastal water is collected by a diverse range of organisations, headed by regional councils and local territorial authorities, NIWA, and GNS.

MfE prepares a five-yearly state of New Zealand's environment report. The most recent *Environment New Zealand 2007* compiles the available water data for New Zealand. The report provides a general overview of the state of, and pressures on, water resources. The ministry also produces a series of environmental 'report cards' for the 22 national environmental indicators, five of which are for freshwater. The 'freshwater demand' indicator describes the distribution of allocated water across New Zealand, and breaks this down by use (eg irrigation, drinking water) and source (eg groundwater, surface water).

Many regional councils also publish state of the environment reports containing information on water quality and flows. The Institute of Environmental Science and Research, a Crown research institute, manages a drinking-water database for the Ministry of Health.

5 Components of the account

The accounts are in the form of a water balance, where inflows equal outflows plus changes in stored volumes. The components of the accounts are based on the hydrological cycle.

The components of the water physical stock account are:

- precipitation
- inflows from other regions
- total inflows
- evapotranspiration
- outflows to other regions
- abstraction for hydroelectricity generation
- discharge from hydroelectricity generation
- outflows to sea and net abstraction
- total outflows
- changes in soil moisture
- changes in lakes and reservoirs
- changes in groundwater
- changes in snow
- changes in ice
- total change in storage.

Information for all components was obtained from NIWA except for changes in groundwater. Data for changes in groundwater was provided by GNS.

Precipitation

Precipitation is any form of water that falls to the planet's surface, such as rain, snow, sleet, and hail. It is the source of all inflows to the inland part of the hydrological system at the national level.

Daily measurements are obtained from rain gauges around the country and a detailed national rainfall dataset that was developed using spatial interpolation modelling. Rain gauges have a typical measurement uncertainty of 10 percent. Most rain gauges have a tendency to catch less rain than actually falls, especially at windy sites. On average, the standard 300mm-diameter rain gauges used in New Zealand catch about 7 percent less than the rainfall on the ground. Adjustments have not been made for this effect because the adjustment depends on wind speed, which is not known at most rainfall measurement sites. Rain gauges are extremely sparse in remote areas that have high, changeable rainfall. The national rainfall dataset obtained has been calibrated against river flow measurements to reduce the effects of rain measurement error, especially in high rainfall areas where most rainfall leaves as river flow (NIWA, 2011). The derived rainfall dataset is used as an input into a hydrological model and compiled into regional volumes.

Inflows from other regions

In general, regions in New Zealand are bounded by catchment boundaries. Most rivers do not flow from one region to another, but, there are exceptions. The major transfers between regions and rivers are shown in table 3.

Table 3

Surface water transfers between regions

River	From this region	To this region
Motu, Waioeka (and others)	Gisborne	Bay of Plenty
Wairoa (and others)	Gisborne	Hawke's Bay
Whanganui (and others)	Manawatu-Wanganui	Waikato (by diversion)
Clarence	Marlborough	Canterbury
Wairoa	Nelson	Tasman
Waitaki (south bank)	Otago	Canterbury
Mokoreta	Otago	Southland
Kaiwera stream	Southland	Otago
Buller	Tasman	West Coast
Mangatawhiri (and others)	Auckland	Waikato

Source: *Surface water components of New Zealand's national water accounts 1995–2010*. (NIWA, 2011).

Total inflows

Total inflows is the sum of precipitation and inflow from other regions. At the national level, there are no inflows from other regions or countries. Regional inflows and outflows, when summed across all regions, balance each other out.

Evapotranspiration

Evapotranspiration is the loss of water by evaporation from the soil and transpiration from plants. It is one of the main freshwater components of the hydrological system in New Zealand, accounting for about 20 percent of outflows at the national level.

Evapotranspiration is calculated by the Topnet hydrological model[7], which calculates daily actual evapotranspiration using measurements of temperature, wind speed, and solar radiation. The model reports daily values and annual summaries for each catchment, and catchment volumes are then summed into regional and national totals.

Outflows to other regions

Outflows to other regions is a measure of the total quantity of surface water that leaves a region and flows to another region during an accounting period. It is calculated by hydrological modelling on the basis that no abstraction is occurring. At the national level, the outflow across regional boundaries balances the inflow across regional boundaries.

[7] For more information on the Topnet hydrological model, see the NIWA report (2011).

Abstraction for hydroelectricity generation

Abstraction for hydroelectricity generation is a measure of the total volume of water abstracted from surface water by hydro-generation companies during an accounting period. Volumes are presented in the accounts at the national level only. Figures are additive, meaning that water abstracted for use in a power station is often abstracted (and counted) several more times by downstream power stations. Most abstraction by volume occurs in Canterbury, Waikato, and Otago. Water that is stored behind hydro dams is accounted for in changes in lakes and reservoirs.

Discharge from hydroelectricity generation

Water that is abstracted for hydroelectricity generation is also discharged back into the hydrological system. One hydroelectricity power station in Southland returns water direct to the sea, which prevents others from reusing the freshwater. This could be defined as consumptive. The consented weekly allocation for this take is 308 million cubic metres per week, over 40 percent of the total national weekly consumptive allocation (Aqualinc Research Ltd, 2010). However, the SEEAW treats all discharges from hydroelectricity generation as non-consumptive abstraction, regardless of where in the environment or economy the water is discharged.

Outflows to sea and net abstraction

Outflows to sea and net abstraction account for about 80 percent of outflows of freshwater from New Zealand over the 1995–2010 period. Outflow to sea and net abstraction include both the total volume of water that flows to the sea from rivers and a residual net abstraction figure. The net abstraction figure is determined by adding total inflow to a region and subtracting outflows to other regions, evapotranspiration and changes in water storage.

Outflows of water to the sea includes outflows of groundwater and surface water. Groundwater is slow-moving, while surface water may spend just a day or two in New Zealand's network of small catchments and fast-flowing rivers before reaching the sea.

Detailed breakdowns for this component are not available because there is insufficient data for net abstraction volumes and little data or estimation methodology suitable for measuring the volumes for private industrial abstraction at a national level.

Total outflows

Total outflows are the sum of evapotranspiration, outflows to other regions, and outflows to sea and net abstraction (which includes changes in storage). At the national level there are no outflows to other regions or countries. Regional inflows and outflows, when summed across all regions, balance each other out. Water that enters New Zealand's inland part of the hydrological system and that has not left by the end of the June year is dealt with in the storage components below.

Changes in soil moisture

Soil moisture refers to water stored in land and soil – in the rooting zone (typically the top 1 metre, depending on soil and vegetation type). The amount of moisture varies according to rainfall, soil type, land use, and evapotranspiration. In turn, evapotranspiration varies according to air temperature, day length, and vegetation. Soil moisture can vary markedly during the year, with summer levels often being low while winter levels are high. Changes in soil moisture are calculated using the Topnet hydrological model.

Changes in lakes and reservoirs

New Zealand has more than 50,000 lakes (NIWA, 2011). Of these, 3,820 are over 1 hectare in size with 229 lakes being over 50 hectares (MfE, 2010, November).

Lakes and reservoirs store water for irrigation, town supply, and hydroelectricity generation. They are also used for flood control, wildlife, recreation, and transportation. At least 16 artificial lakes have been created for hydro-power stations. The South Island's Lake Benmore, at 7,500 hectares, is the largest of these (MfE, 1997).

The lakes and reservoirs in New Zealand that are monitored and for which data is available are mostly hydroelectricity reservoirs and major lakes. Due to the very large sizes of these monitored lakes, the monitored lake-level data covers approximately 80 percent of the surface area of all lakes and reservoirs in New Zealand. For the water physical stock accounts, it is assumed that those lakes and reservoirs for which data is unavailable will have the same changes in levels as those that are monitored.

The net change in storage for each measured lake or reservoir is the difference in the level of water between the start and end of each accounting period, multiplied by the area of the lake or reservoir. Changes in lake and reservoir levels in the water physical stock account are point-to-point movements from the end of one June year to another and can depend on rainfall in the last few days or weeks of each June.

Changes in groundwater

Groundwater is the water contained in the saturated zone within pores and fractures of rock formations (Fetter, 1994).The saturated rock formations through which groundwater moves are called aquifers. Aquifers yield water in usable quantities and can be classified as unconfined, semi-confined, or confined. Unconfined aquifers are estimated to contain about 96 percent of New Zealand's groundwater, with the Canterbury region having the largest groundwater storage.

Water enters aquifers from precipitation or by seepage from rivers, lakes, and reservoirs. Groundwater in aquifers eventually flows naturally to the surface through springs and seeps, or it can be extracted through wells for agricultural, municipal, and industrial use. Most groundwater replenishment occurs between autumn and spring, when evapotranspiration is low, and soils are moist and unable to absorb much additional water.

On a global scale, groundwater accounts for approximately 20 percent of the world's freshwater (see figure 2 in chapter 7). In New Zealand in 2010, there were over 20,500 resource consents for taking water, with approximately two-thirds of these permitting water to be taken from groundwater sources. However, the volume of water allocated from surface water sources (rivers and streams) was four times higher than from groundwater sources (MfE, November 2010).

Data for groundwater volumes was provided by GNS. The volumes are for water that is contained in aquifers and that is currently used or potentially available for use.

There has been no change to the methodology used in estimating groundwater volumes for the water physical stock accounts. In addition, the indicator wells are the same as those used in the previous water physical stock accounts except for two indicator wells: well 2970710 Takaka marble aquifer, and well 951 Mamaku Ignimbrite aquifer. These wells have replaced well WWD6713 and the Waikato indicator well. Further explanation of the methodology used in estimating groundwater volume can be found in *Update of National Groundwater Volume Stock Account* (GNS, 2011).

Changes in snow

The change in the quantity of water stored as snow is calculated using a component of the Topnet model, similar to the SnowSim model used previously. Both are temperature index models that include factors to simulate the effects of snow ageing and rain on snow events. Snow-water equivalent was accumulated within every Topnet model catchment.

Mountain-fed rivers in the South Island usually have their lowest flows in winter, due to snow-pack accumulation in the mountains. Melting snow in spring and summer raises river flows and, if stored in lakes, can be used later in the year to generate electricity for meeting winter demand.

Changes in ice

The change in the quantity of water stored in ice is measured indirectly in New Zealand, through annual monitoring of the areas and end of summer snowline altitudes of 49 index glaciers. This permits the estimation of changes in the mass of the index glaciers, and a spatial mapping technique is then used to extend this to the 3,144 glaciers in the New Zealand glacier inventory.

A glacier is a body of ice at least one hectare in area that has persisted over the last two decades (NIWA, 2011). The data reported in the water physical stock account is for changes in glacier volume over a glacier accounting year, which ends at the end of summer (March or April). This is so that the glaciers can be observed separately from temporary snow.

Total change in storage

Storage can be viewed as a balancing set of components. If inflows of water to the inland part of the hydrological system exceed outflows then the excess must be going into storage. Conversely, if the total storage volume reduces from one year to the next, then outflows will be higher than inflows. Volumes of water held in storage can fluctuate throughout the year but it is the volumes at the end of each June year that affects the water physical stock accounts. Storage levels are point-to-point movements and are influenced by short-term changes in weather, such as storms and longer-term weather cycles including the El Niño-Southern Oscillation and Interdecadal Pacific Oscillation.

Changes in storage are a relatively minor part of the water physical stock accounts. The total volume of water stored in aquifers, lakes, and reservoirs; and as soil moisture, snow, and ice, is large but the annual changes are relatively small.

6 Gaps in measuring abstraction

Currently, there is insufficient data to quantify the actual volumes of water abstracted for:

- irrigation
- livestock use
- industrial use
- municipal and domestic abstraction
- geothermal electricity generation.

Irrigation

Irrigation accounted for 78 percent of the total weekly consumptive allocated volume (excluding hydroelectricity) in January 2010 (Aqualinc Research, 2010). However, allocated volumes are maximums and tend to overestimate the amount of water actually abstracted. Recent estimates suggest only 65 percent of the maximum consented volume is actually used in New Zealand. In addition, most water abstractions in New Zealand are not currently being actively measured, with approximately two-thirds being unmeasured in 2006 (MfE, 2011).

In November 2010, The Resource Management (Measurement and Reporting of Water Takes) Regulations 2010 took effect. By 2012, approximately 92 percent of the total volume of water allocated by resource consent in New Zealand will be subject to active measurement via water metres. It is anticipated that this data will provide the irrigation statistics required for future accounts.

Livestock use

Estimated volumes for livestock drinking-water and dairy-shed requirements have been included in this report.

The estimates are calculated from livestock numbers and average water usage per head for different types of livestock. The livestock numbers are from Statistics NZ's Agricultural Production Survey while the usage per head figures are based on the Horizons Regional Council's 2007 *Reasonable Stock Water Requirements: Guidelines for Resource Consent Applications*. The volumes are estimates for drinking-water and dairy-shed requirements, not actual volumes abstracted or discharged. Resource consents are not required for livestock water use and thus could not be used as a data source.

Industrial use

Industry is a major user of water. However, there is currently insufficient national data on the volumes supplied from municipal reticulation networks or from private abstraction. Resource consents are required for industrial abstraction but the degree of water metering by regional councils varies. Only a small proportion of resource consents are currently metered. However, the Resource Management (Measurement and Reporting of Water Takes) Regulations 2010 mentioned above include water metering for industrial water takes over five litres per second. From 2013, this should provide comprehensive data on industrial water use.

Municipal and domestic abstraction

Municipal and domestic abstraction was estimated in the *Water Physical Stock Account: 1995–2001* and amounted to approximately 0.2 percent of the annual precipitation volume. It included water supply to domestic, commercial, and industrial users where they were connected to municipal reticulation networks (see annual table 16 of *the Water Physical Stock Account, 1995–2001*). Municipal and domestic abstraction included a private domestic use component which included households and communities that abstract water themselves instead of, or in addition to, using water from municipal reticulation supplies.

The estimates for municipal and domestic abstraction have not been repeated in either the 2005 or this report as they require detailed population mapping and considerable information from district councils.

Geothermal electricity generation

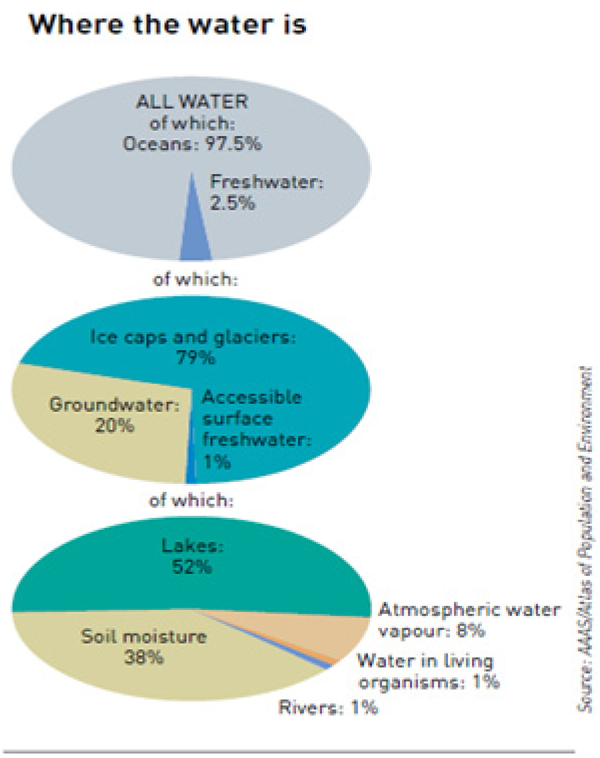
At present, there are no plans to collect data for this type of water abstraction and discharge. In January 2010, of the over 20,500 consented water takes, approximately 2 percent were for geothermal sources (Aqualinc Research, 2010).

7 Water: A global perspective

Most of the world's water is seawater, with freshwater only about 2.5 percent. Ice caps and glaciers account for about 79 percent of freshwater, depending on the information source, while groundwater accounts for about 20 percent. Lakes, soil moisture, atmospheric water vapour, rivers, and water within living organisms account for the remaining 1 percent.

Figure 2

Total global saltwater and freshwater estimates



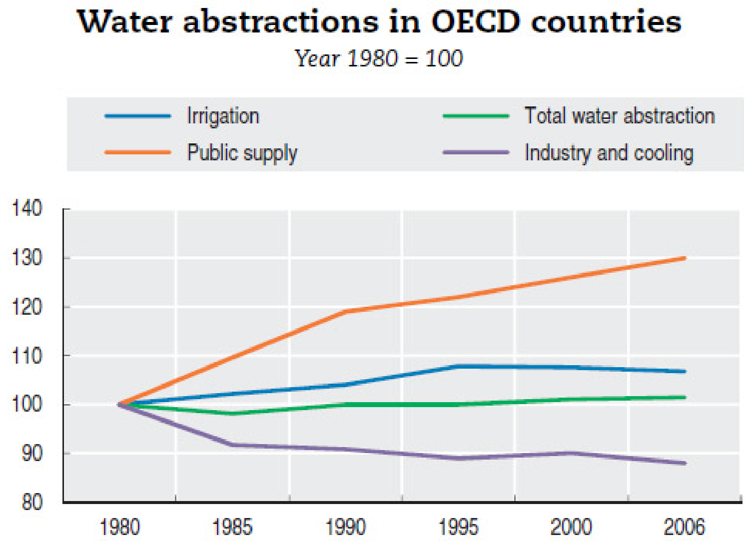
Source: American Association for the Advancement of Science,
Atlas of Population and Environment
http://atlas.aaas.org

Over the last century, it is estimated that at the global level, the growth in water demand was more than double the rate of population growth, with agriculture being the largest user of water (OECD, 2010).

Most Organisation for Economic Co-operation and Development (OECD) countries increased their total water abstractions over the 1960s and 1970s in response to higher demand by the agricultural and energy sectors. However, since the 1980s, some countries have succeeded in stabilising their total water abstractions through more efficient irrigation techniques, the decline of water-intensive industries (eg mining, steel), the increased use of cleaner production technologies, and reduced losses in pipe networks. More recently, this stabilisation of water abstractions has partly reflected the consequences of droughts. Population growth continues to drive increases in public supply (OECD, 2010).

Figure 3

Water abstractions in OECD countries



Source: *OECD Factbook 2010*, www.oecd.org

By international standards, New Zealand has a plentiful supply of water due to high levels of precipitation. For example, between 1995 and 2010 New Zealand's average annual precipitation was 611,304 million cubic metres of water, enough to fill Lake Taupo over 10 times. This relative abundance of freshwater "places New Zealand fourth out of 30 OECD countries for the size of its renewable freshwater resource on a per capita basis," (MfE, December 2010).

However, the availability of New Zealand's freshwater varies significantly both geographically and seasonally. The amount of rainfall received generally decreases as one moves from west to east. For example, the West Coast region has the largest rainfall volume, although it has only the fifth largest land area. In contrast, Otago, with its extensive dry areas, has only the fifth largest precipitation volume although it is the second largest region (NIWA, 2011). 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.

New Zealand's primary industry-based economy has a high proportion of consented water for agricultural irrigation, compared with other OECD countries. In January 2010, 75 percent of the total number of national allocation consents were for irrigation. (Aqualinc Research, 2010).

The hydrological cycle

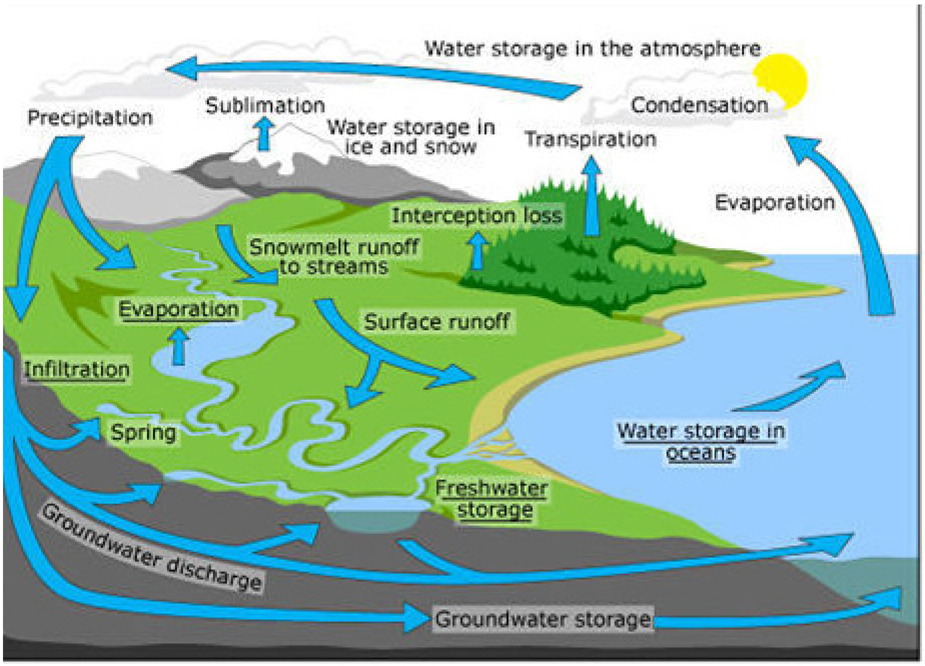
Water has a number of properties that set it apart from other natural resources. Water is constantly moving and transforming into different states over time. Water is also constantly being renewed, but its availability fluctuates over time for different regions, depending on the hydrological cycle, human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

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 framework, 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 (such as 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 surface water and groundwater systems which eventually drain into the sea.

Figure 4

New Zealand's hydrological cycle

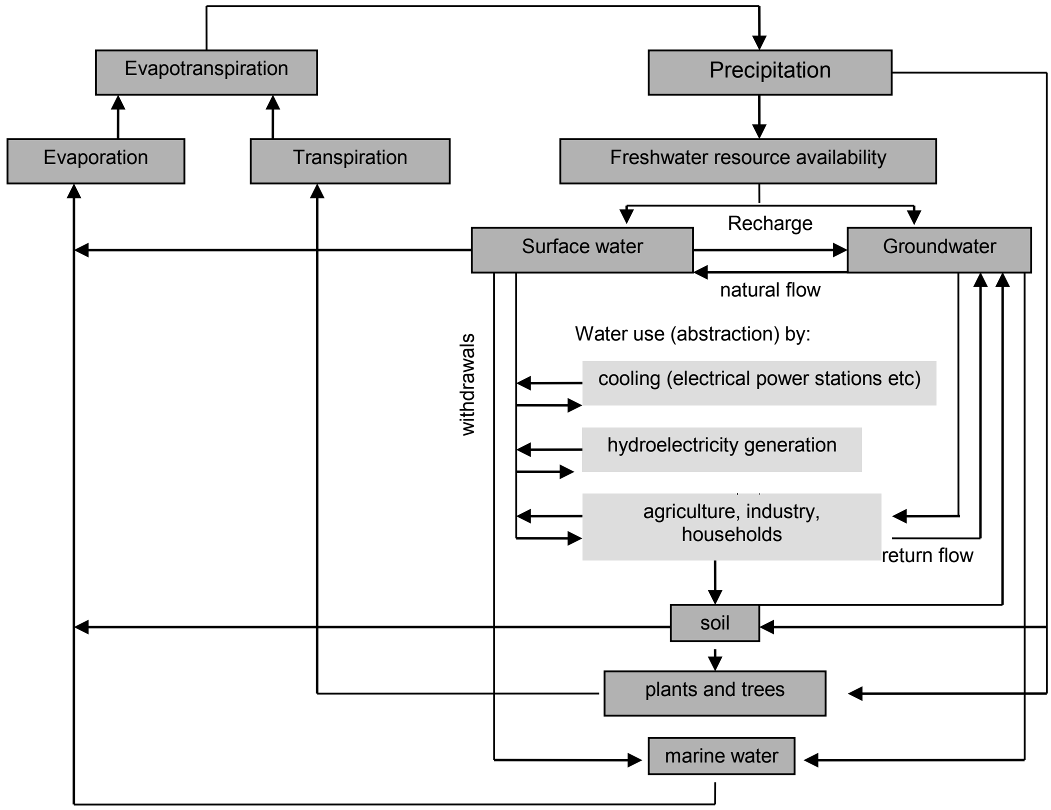


The hydrological cycle is driven by radiation reaching the earth's surface. This radiation increases as greenhouse gas concentrations rise. The greenhouse effect is a warming of the earth's surface and lower atmosphere caused by substances such as carbon dioxide and water vapour which let the sun's energy through to the ground but impede the passage of energy from the earth back into space. As the temperature of the earth's surface increases more water vapour is evaporated. Since water vapour is itself a strong greenhouse gas this is a positive feedback which will tend to amplify the warming effect of (for example) carbon dioxide emissions (NIWA, 1998). Climate scientists expect that there will be significant changes to available water resources if greenhouse gases continue to accumulate in the atmosphere. While it is expected that drought-affected areas will increase in extent, heavy precipitation events are very likely to increase in frequency, and will increase flood risk (Intergovernmental Panel on Climate Change (IPCC), 2007).

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. See figure 5 for links between the hydrological cycle and the economy.

Figure 5

Interaction between the hydrological cycle and the economy



Source: Statistics New Zealand

Water management

In New Zealand, different agencies are involved in the management of water. At the central government level, the Ministry for the Environment (MfE) provides national direction to achieve the sustainable use of New Zealand's water resources. MfE also works with other agencies to support local government's role.

Regional and unitary councils are responsible for making decisions on the allocation and use of water within their boundaries and for managing water quality. They are also 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[8] water supplies in their district (sometimes these community water supplies are privately owned). Crown research institutes, in particular NIWA and GNS, through their research and scientific monitoring roles also contribute to the management of surface water and groundwater resources.

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[8] Community drinking-water supplies are all drinking-water supplies serving more than 25 people for at least 60 days a year (Ministry of Health, 2006).

Unless expressly allowed by a regional plan, the Resource Management Act 1991 requires an approval for the abstraction of water. This approval comes in the form of a resource consent from a regional council. No approval is required for an individual's reasonable domestic use, livestock use, or for fire-fighting purposes. Under these regulations, regional councils are required to keep records of the water permits granted, including the allocated maximum volumes (and the actual volumes abstracted, where information is available). However, allocated volumes are maximums and tend to overestimate the amount of water actually abstracted for the following reasons:

- 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
- reduced abstraction due to wet weather.

Recent estimates, based on available water metering records, suggest that only 65 percent of the maximum consented volume in New Zealand is actually used (Aqualinc Research, 2010).The report highlighted that water meter records were not available for some use types within some regions. This makes the compilation of national aggregates for actual water use difficult and inaccurate.

To address this issue, the Resource Management (Measurement and Reporting of Water Takes) Regulations 2010 were introduced in November 2010. The regulations aim to consistently measure and report actual water taken at the national, regional, and catchment levels. These regulations apply to holders of water permits (resource consents) which allow freshwater to be taken at a rate of five litres or more per second (MfE, 2011). It is estimated that by November 2012, approximately 92 percent of the total volume of water allocated by resource consent will be subject to active measurement. It is anticipated that this new source of data will enable Statistics NZ to fill significant gaps in the water physical stock account.

Since publication of the *Water Physical Stock Account 1995–2005* in June 2007, there have been significant responses to the challenges facing freshwater management and resource limits in New Zealand. One of the first of these was the new National Environmental Standard for Sources of Human Drinking Water, which took effect in June 2008. This standard was intended to reduce the risk of contaminating drinking water sources, such as rivers and groundwater. It required regional councils to ensure that the effects on drinking water sources are considered in decisions on resource consents and regional plans.

In 2008, the Land and Water Forum, a non-governmental group, was established (see www.landandwater.org.nz). The Government asked this forum to conduct a collaborative process that will recommend the reform of New Zealand's freshwater management. In April 2011, the forum delivered its final report to ministers. In response to this report, the Government announced a package of initiatives under the Fresh Start for Fresh Water programme (previously the New Start for Freshwater). The initiatives include:

- national policy statement for freshwater management
- freshwater clean-up fund
- water infrastructure fund for supporting the development of new irrigation, storage, and distribution projects
- further work programme.

In New Zealand, households obtain their water through a piped community water supply that is 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 91 percent of New

Zealand's population was connected to a registered drinking-water supply in 2010 (Ministry of Health, 2011).

Territorial authorities, to varying degrees, collect data on water abstraction by category of users for the municipal and community water supplies they manage. 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 consent. As a result, there is no comprehensive or centralised dataset for such abstractions. An estimate of water use by livestock for drinking and dairy-shed requirements is shown in table 2 under chapter 3. The figures are based on livestock numbers and estimated average daily consumption values.

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 Resource Management Act 1991, which replaced more than 20 major statutes including the Town and Country Planning Act 1953, has changed the focus of water resource management from multiple-use management to environmentally sustainable management.

8 Future developments

As noted in this report, it is expected that over time, initiatives such as The Resource Management (Measurement and Reporting of Water Takes) Regulations 2010 will provide a consistent and comprehensive dataset for water abstraction. It is anticipated that this information will enable improved estimates of water use to be included within the water physical stock account.

Statistics NZ does not currently publish a water physical flow account due to a lack of available data. However, a water physical flow account should be possible once water takes data, associated with the Resource Management (Measurement and Reporting of Water Takes) Regulations 2010, become available from 2013.

A physical flow account for water, when developed, would provide information on the flows of the water resource through the economy. The account would show the volumes of water supplied and used by the various industries in the economy. Flow accounts for natural resources can be used to identify how dependent the New Zealand economy is on those natural resources. The reliance of individual industries can be linked to their contribution to gross domestic product (GDP). This concept is known as decoupling, which occurs when the growth of an environmental pressure (eg water use) is less than that of its economic driving force (eg GDP) over a given period.

To produce a physical flow account for the water resource, information will need to be collected for all water supplied from the environment and abstracted, either for reticulated supply or as private abstraction. It will also be necessary to have information on which sectors of the economy are using the water resource in the economy, and to disaggregate this information using the Australian and New Zealand Standard Industrial Classification (ANZSIC) 2006.

Ideally, the water physical flow accounts will also include information on the volumes of water discharged back into the environment. This may prove the most challenging component of the water physical flow account as this information is inherently difficult to measure.

Glossary

Abstraction (of water): The taking of water from groundwater or surface water sources.

Aquifer: Permeable water-bearing geologic formation capable of yielding exploitable quantities of water.

Catchment: The area from which rainwater flows into a particular river or lake.

Conservation: The management of resources (such as water) to eliminate waste or maximise efficiency of use.

Ecosystem: A system, such as a wetland or forest, in which the interaction between different organisms and their environment generates a cyclic interchange of materials and energy.

El Niño-Southern Oscillation (ENSO): A two–four-year major climate cycle with warm (El Niño) and cool (La Niña) fluctuations in sea surface temperatures in the central and eastern tropical Pacific and associated air pressure changes in the Pacific-Asia region (Southern Oscillation). See also ‘Interdecadal Pacific Oscillation (IPO)’.

Environment: External conditions affecting organisms and social groups. It includes the natural environment (air, water, soil, plants, animals, fungi, and micro-organisms), the built environment (buildings, roads, housing, and recreation facilities), and the social and cultural aspects of our surroundings.

Environmental accounts: Physical stock and flow accounts which analyse the links between the environment and economy.

Environmentally-adjusted GDP: This is also known as ‘green GDP’ or ‘ea-GDP’. The original GDP figure, which measures economic activity, is adjusted to take into account the cost of natural resource depletion and environmental degradation.

Evapotranspiration: Transfer of water from the Earth’s surface to the atmosphere by evaporation of liquid or solid water plus transpiration from plants.

Freshwater: Naturally-occurring water having a low concentration of salts.

Gross domestic product (GDP): A measure of economic activity. It is gross in that depreciation is not deducted and domestic in that it covers only national territory. There are no deductions for natural resource depletion and environmental degradation. The output-based version is the sum of the gross value-added of all resident producers at basic prices, plus all taxes (less subsidies) on imports.

Groundwater: Sub-surface water occupying the saturated zone (in which all voids, large and small, are filled with water), excluding soil moisture.

In-situ freshwater: Freshwater that has not been removed from the lake, river, aquifer or other water body. In situ uses include recreation, tourism, hydroelectricity generation, fish farming, and waste disposal.

Interdecadal Pacific Oscillation (IPO): A long time scale oscillation in the ocean–atmosphere system that shifts climate in the greater Pacific region every one to three decades. In the negative IPO phase, New Zealand generally experiences higher sea levels, and more storm surges and floods in eastern areas. See also ‘El Niño-Southern Oscillation (ENSO)’.

Irrigation: Artificial application of water to lands for agricultural purposes.

Natural resources: Natural assets (raw materials) occurring in nature that can be used for economic production or consumption.

Orographic rainfall: Enhanced rainfall as a result of moist air cooling when it rises to cross a mountain range.

Precipitation: Water in any form (including rain, snow, hail, sleet, and mist) that leaves the atmosphere and reaches the Earth's surface.

Soil moisture: Moisture contained in the portion of the soil that is above the water table. Includes water vapour, which is present in the soil pores.

Supply and use tables: Matrix tables showing commodity quantities (or values) categorised by supplier (domestic industries and imports) and by user (domestic industries, households, and exports). Supply and use tables are collectively known as 'flow' tables or accounts.

Surface water: Water that flows over or is stored on the ground surface.

System of Environmental-Economic Accounts (SEEA): SEEA measures the contribution of the environment to the economy and the impact of the economy on the environment. The system was developed by the United Nations Statistical Division as an extension to the worldwide System of National Accounts (SNA).

System of Environmental-Economic Accounts for Water (SEEAW): A SEEA subsystem that provides compilers and analysts with agreed concepts, definitions, classifications, tables, and accounts for the water accounts.

System of National Accounts (SNA): The international standard framework for compiling macroeconomic accounts.

Unitary authority: A territorial authority (city or district council) which also has the responsibilities, powers, and duties of a regional council.

Water cycle (hydrological cycle): The paths that water takes through its various states (liquid, vapour, solid) as it circulates among the ocean, atmosphere and land.

Water table: The top of the water surface in the saturated part of an aquifer.

Wetland: Semi-aquatic land that is either inundated or saturated by water for varying periods of time during each year, and that supports aquatic vegetation which is specifically adapted for saturated soil conditions.

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