NIWA
Taihoro Nukurangi

Surface water components of New Zealand's National Water Accounts, 1995-2014

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Prepared by:
Daniel Collins
Christian Zammit
Andrew Willsman
Roddy Henderson

For any information regarding this report please contact:

Roddy Henderson
Group Manager
Applied Hydrology
+64-3-343 7873
roddy.henderson@niwa.co.nz

National Institute of Water & Atmospheric Research Ltd
PO Box 8602
Riccarton
Christchurch 8011

Phone +64 3 348 8987

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Contents

Tables

Figures

Executive summary

The Ministry for the Environment requires data, modelling and analysis of the surface water and glacier ice components of the Water Physical Stock Account (WPSA) for inclusion in the 2015 Synthesis Report. This work will be used for reporting the impacts of the Atmosphere and Climate domain on the state of water and land, under the new Environmental Reporting Framework. The work is to include data up to the end of December 2013, subsequently extended to mid-2014. To supply these requirements we have re-run the national TopNet model from July 1994 to June 2014, extended records of lake volume change and hydro-electric generation water use from recording authorities, and extended the national ice and glacier accounts. This report summarises the water stock accounts of New Zealand and the 16 regions administered by regional councils or unitary authorities, and is derived from a combination of directly measurement and modelled data.

The average annual precipitation across the country was 550,000 m^3/year (equal to over nine times the volume of Lake Taupo), a reduction from the previous water account calculations. Roughly 20% of this evaporates before reaching the coast, leaving an average freshwater flow of 440,000 million m^3/year. There is substantial variation in this water flux from year to year due to a range of climatic factors. Changes in storage – lakes, soil moisture, snow, and ice – represent very small components of the annual water balance. Use of water for hydroelectric power generation represents a significant portion of the nation's freshwater resource, equating to 36% of the total freshwater flows, but this figure includes multiple use of water within the same catchment.

Water fluxes at the regional scale vary depending on the region's size as well as the spatial variability in the delivery and movement of water. The West Coast receives the largest portion of precipitation – 26% of the national total – and possesses 30% of the nation's freshwater flow. Nelson City, due to its small size, accounts for the smallest portion in both cases. Canterbury accounts for the greatest portion of hydro-generation water use (mainly for the Waitaki scheme), followed by Waikato.

There is uncertainty in all aspects of the water accounts procedures, but validation checks of some of the dominant input and output data allows confidence in the process and results.

1 Introduction

The National Institute of Water and Atmospheric Research Ltd (NIWA) has been commissioned by Ministry for the Environment to estimate eleven components of the national and regional water balance of New Zealand to update the previous accounts to 30 June 2014. To do this we have re-run the national TopNet model from July 1994 to June 2014, extended records of lake volume change and hydro-electric generation water use from recording authorities, and extended the national ice and glacier accounts. We report on the full set of accounts from July 1994 to June 2014. Each year runs from 1 July to 30 June, and is referred to by the year at the end of the period (e.g. the 1995 year runs from 1 July 1994 to 30 June 1995). This report is a revision and update of three previous reports on surface water information: Woods and Henderson (2003), Henderson et al. (2007), and Henderson et al. (2011) This information is intended for use by the Ministry for the Environment and Statistics New Zealand to assist them in updating the Water Physical Stock Accounts, as part of the set of environmental accounts[1].

The accounts are presented at two levels of spatial detail: national and regional. The regional boundaries are defined by the 16 areas administered by regional councils and unitary authorities (Table 1). Most of the region boundaries used in this study are essentially the same as those used in the previous edition of the water accounts (Henderson et al., 2011) with the exception of Auckland which reflects changes in Auckland Council's area of jurisdiction.

[1] http://www.stats.govt.nz/browse_for_stats/environment/natural_resources/environmental-accounts.aspx

Table 1. Names and land areas for regional accounting.

Region Name	Region Area (km^2)
Auckland	4,354
Bay of Plenty	11,939
Canterbury	44,915
Gisborne	8,452
Hawke's Bay	14,090
Manawatu-Wanganui	22,198
Marlborough	10,126
Nelson	393
Northland	11,838
Otago	31,828
Southland	29,529
Taranaki	7,196
Tasman	9,548
Waikato	24,320
Wellington	8,012
West Coast	23,204
New Zealand	261,944

The 11 components of the accounts developed in this report and their derivation are listed in Table 2. Unless noted otherwise, all components are reported at both national and regional scales. The components are estimated by a combination of direct calculation from measurements, spatial mapping/modelling, and hydrological modelling. For a full description of how each component is estimated, refer to Henderson et al. (2011).

Table 2. The components of the water accounts covered by this report

Component Name	Description	Derivation
1. Precipitation	The total volume of rain/hail/snow/sleet during an accounting period, before evapotranspiration is taken into account.	National TopNet model rainfall input derived from the Virtual Climate Station Network (VCSN).
2. Inflows from rivers (regional scale only)	The volume of water that enters each region from rivers outside that region (regional accounts only).	GIS analysis of river networks and regional boundaries.
3. Evapotranspiration	The total volume of water lost by evapotranspiration during an accounting period (*actual* evapotranspiration, as opposed to *potential*).	Calculated in the national TopNet model based on potential evapotranspiration and water availability.
4. Abstraction by hydro-generation companies	The total volume of water abstracted from surface water for electricity production by hydro-generation companies during an accounting period.	Derived from power station machine flows, and does not include spill flows.
5. Discharges by hydro-generation companies	The total of water discharged by hydro-generation companies during an accounting period.	Equivalent to abstraction above.
6. Outflows to sea from surface water	The total volume of water that flows to the sea during an accounting period, before any abstractions are removed (does not include any river flow to other regions).	Output of national TopNet model.
7. Outflows to other regions (regional scale only)	The total quantity of surface water that leaves a region and flows to another region during an accounting period (regional accounts only).	GIS analysis of river networks and regional boundaries.
8. Net change in lakes and reservoirs	The change in volumes of lakes and reservoirs during an accounting period.	Derived from recorded lake level data.
9. Net change in soil moisture	The change in volume of water stored in land and soil during an accounting period.	Derived from national TopNet model.
10. Net change in snow	The change in quantity of water stored in snow during an accounting period.	Derived from national TopNet model.
11. Net change in ice	The change in quantity of water stored in ice during an accounting period.	Derived from end-of-summer-snowline survey (EOSS), and observations of pro-glacial lake development and down-wasting.

2 Results

The water accounts in this report comprise eleven component values (measured in m^3), for 16 regions plus the whole of New Zealand, for each of 20 years. These were provided to Ministry for the Environment in spreadsheet form, and will be summarised on their web site when the accounts are published there.

In general one should expect any imbalances between inputs and exports of water to be balanced by changes in storage (lake, soil moisture, snow and ice). This applies at both national and regional scales. Because the lake and ice volumes presented are derived from different data sources to the other variables, slight imbalances remain. If an exact balance is sought, it is recommended that the outflow to sea component be adjusted.

2.1 National Perspective

Over the 20 year study period, 550,000 million m^3 of water fell on New Zealand during an average year. This equates to over 9 times the volume of Lake Taupo. Nearly 20% of this evaporates before reaching the coast, leaving a freshwater resource of 440,000 million m^3. Changes in lake, soil moisture, ice, and snow storages are an extremely small portion of the water budget. Flow between regions is accounted for by the other water fluxes. The total water use for hydro-generation purposes equates to 36% of the total freshwater flows, though much of this water is used multiple times (e.g., the cascade of eight power stations on the Waitaki and Waikato hydro-generation schemes).

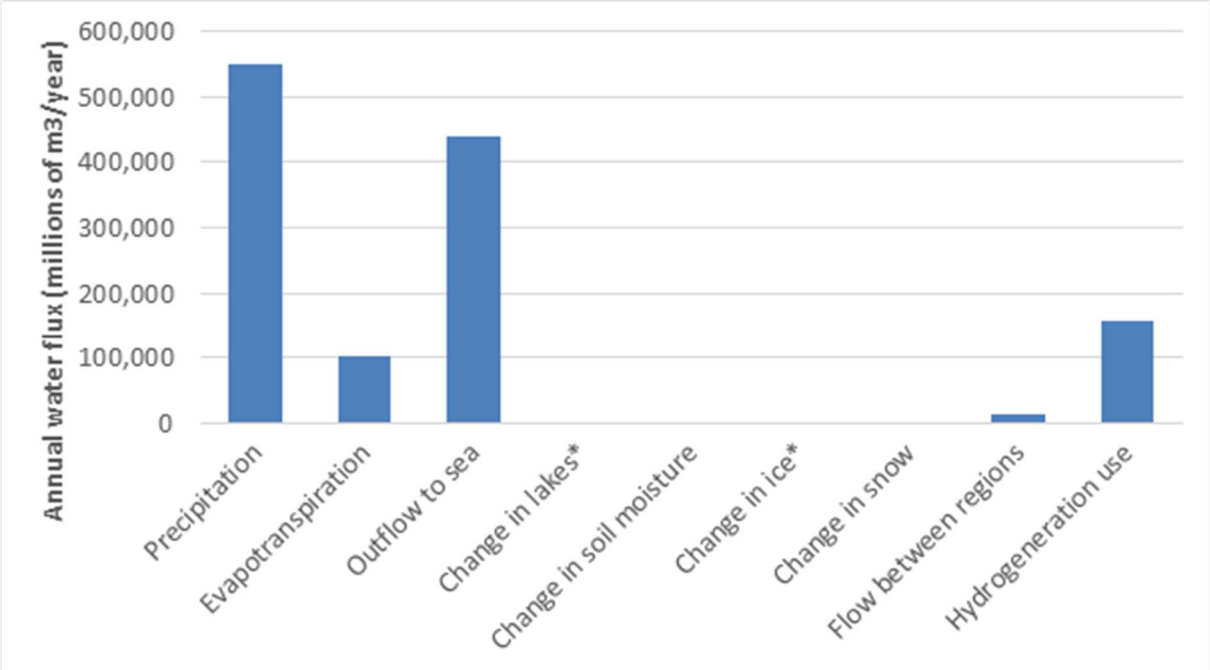

Figure 1. Annual average water fluxes and changes in storage for nine of the 11 variables nationally. Inflow to and outflows from regions must be equal nationally, as are hydro-generation abstraction and returns. Changes in lake and ice storage (marked with *) are negative but too small to resolve on the figure, as are the positive soil moisture and snow storage changes.

2.2 Regional Perspective

Precipitation does not fall uniformly across New Zealand, and combined with the fact that regions have different sizes, some regions are endowed with more or less water than others. Over the extended water account period (1994 to 2014), the West Coast received 26% of national precipitation input, followed by Southland's 14% and Canterbury's 12% (Figure 2). Because evapotranspiration is also non-uniform, the proportion of the nation's freshwater flows (outflows minus inflows) is slightly different, with West Coast accounting for 30%, Southland 15%, and Canterbury 11% (Figure 3).

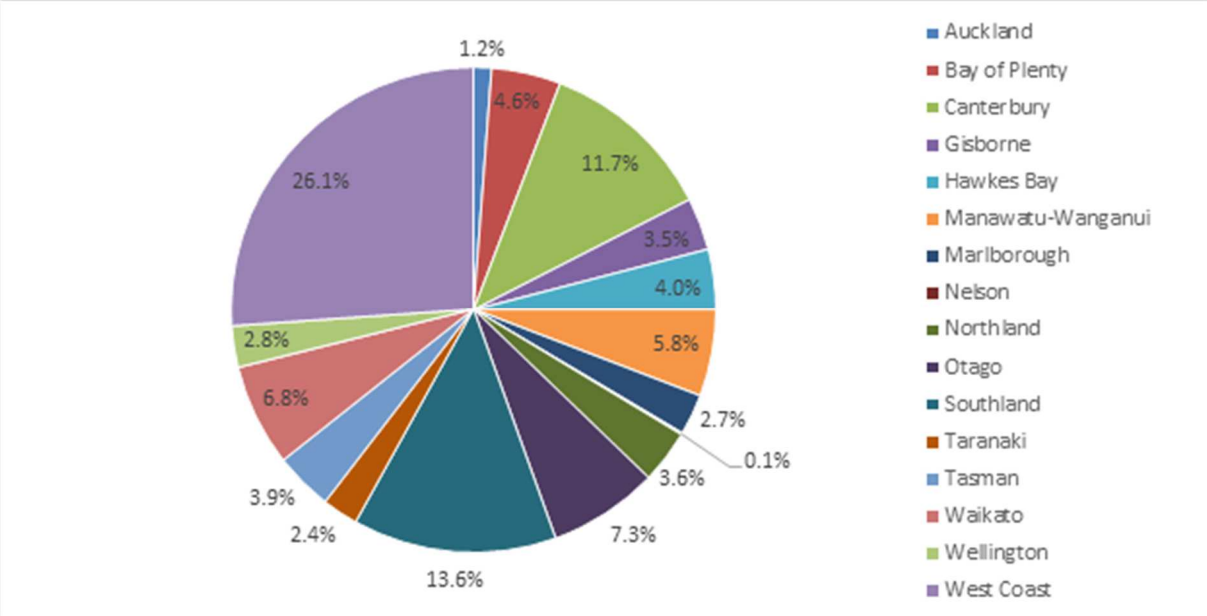

Figure 2. Percentage of the total national precipitation that falls on each region.

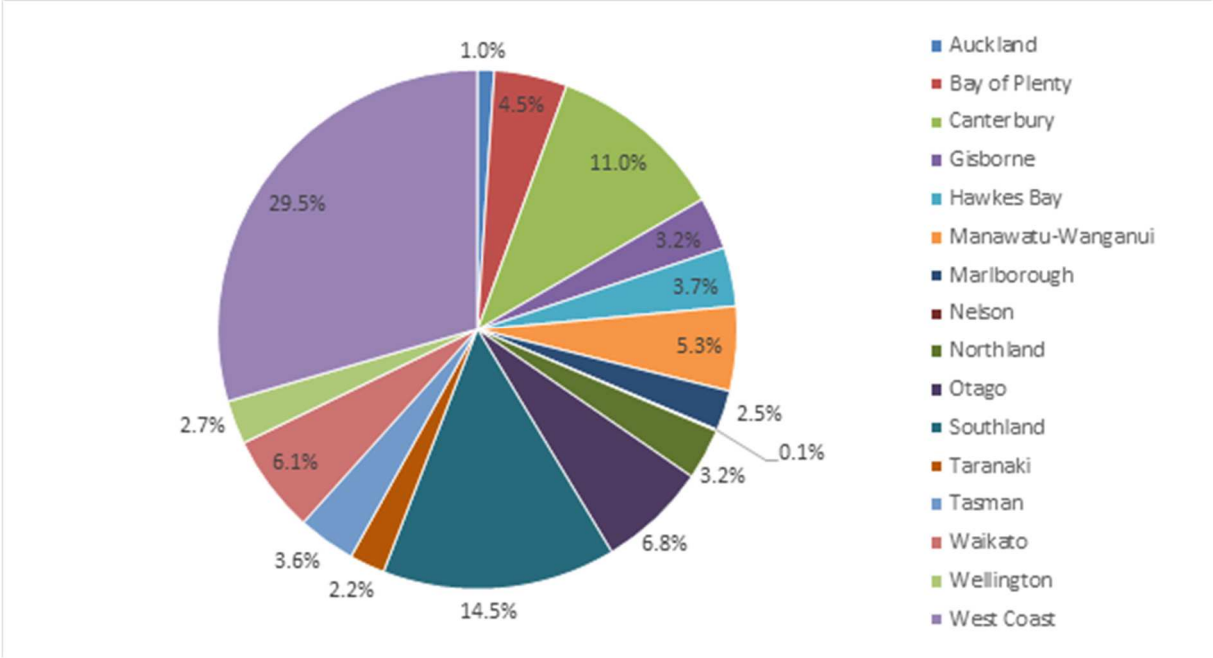

Figure 3. Percentage of the freshwater flows that occur within each region. Sectors of the plot correspond to the legend labels starting left of top centre and proceeding clockwise.

Regional fluxes (1994 to 2014) are dissected further in Figure 4, showing that inflows on average balance outflows and changes in storage. Hydro-generation use can exceed total freshwater availability because of re-use within the same catchment.

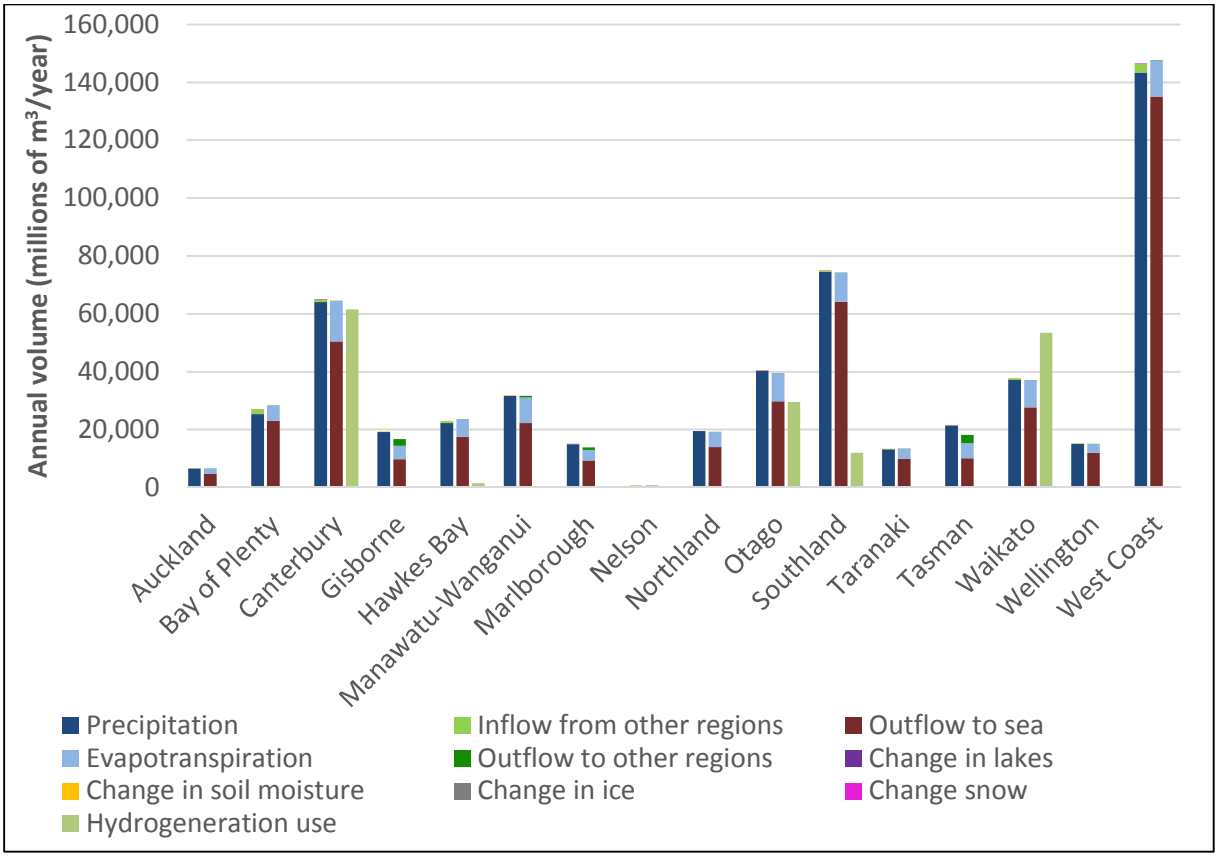

Figure 4. Average annual water fluxes and storage changes by region. Each region is represented by three columns: inflows, outflows, and hydro-generation use (left to right). Negative changes in storage are added to the inflows, and positive to the outflows.

2.3 Year-to-year Variability

The amount of precipitation that falls on New Zealand varies substantially from year to year, as a result of various climatic factors (e.g., El Niño-Southern Oscillation; Southern Annular Mode; Interdecadal Pacific Oscillation), and therefore so do other fluxes (Figure 5). While the long-term average annual precipitation is 550,000 million m^3, this has varied between a low of 470,000 and a high of 640,000 million m^3 – a range that equals 30% of the average. The proportion of the precipitation that evaporates in any one year ranges from 17%-22%.

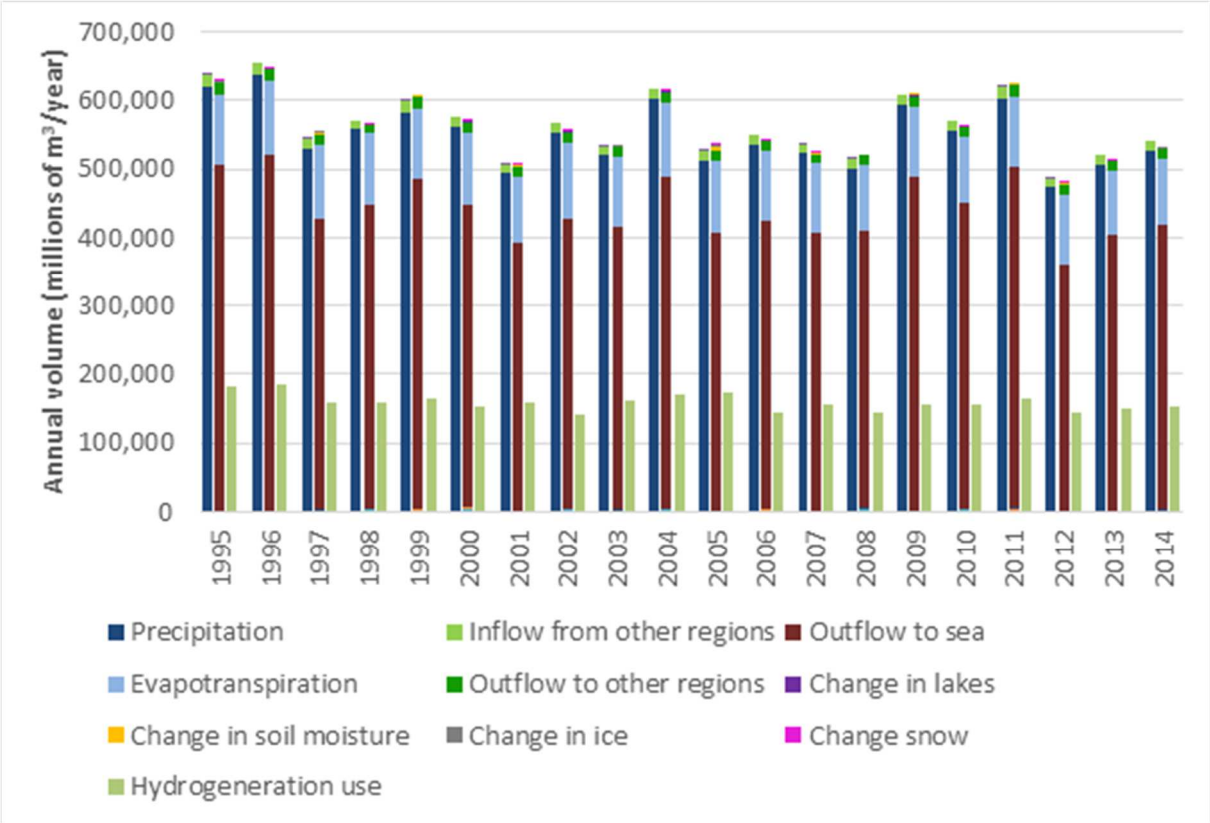

Figure 5. Annual variations in national water fluxes. Each year is represented by three columns: inflows, outflows, and hydro-generation use (left to right). Negative changes in storage are added to the inflows, and positive to the outflows.

3 Discussion

3.1 Uncertainty

The above estimates of water fluxes within New Zealand are based on the best available data and modelling. That said, they are not without uncertainties. The rainfall data that drives the modelling is an estimated data field based on scattered measurements. The model, too, is based on the best available, yet imperfect, data.

These uncertainties can be gauged to some degree by comparing the national estimates reported here to those from earlier studies, using a range of methods and data, including earlier water accounts reports (Table 3). It is difficult to say which study is the most accurate, although it is fair to say that of the four water accounts studies, the present one is indeed the most accurate.

While the new estimate of precipitation falls within the range of earlier studies, modelled evapotranspiration is the lowest reported. This leads to area-averaged runoff that is higher than all but one other study. It is thus plausible that freshwater flows are overestimated. Furthermore, differences between estimates are on par with interannual variations, indicating that the uncertainty, while not overwhelming, is significant.

Table 3: Water balance estimates for New Zealand. Previous estimates provide an indication of the uncertainty with which water fluxes in this report are estimated.

Study	Precipitation mm/year	Evapotranspiration mm/year	Runoff mm/year
Toebes 1972	2059	599	1481
Woods and Henderson 2003	1515	639	808
Woods et al. 2006	1884	683	1365
Henderson et al. 2007	2106	427	1664
Henderson et al. 2011	2321	453	1869
This report	2130	391	1675

Until the development of very detailed rainfall process models at national scale is made, these precipitation estimates are unlikely to be greatly improved. However, progress is currently being made on improving our understanding of evaporation, drawing from a series of intensive field measurements across New Zealand, which will help to improve modelling of freshwater fluxes in the future.

3.2 Validation

Validation of the input and output data from the national model can be approached in many ways. We present two illustrations here. The first (Figure 6) shows regional rainfall versus rainfall from

long-term raingauges in cities within four North Island regions. Cities are not generally in the wettest part of a region and so the relationships are biased but reasonably consistent.

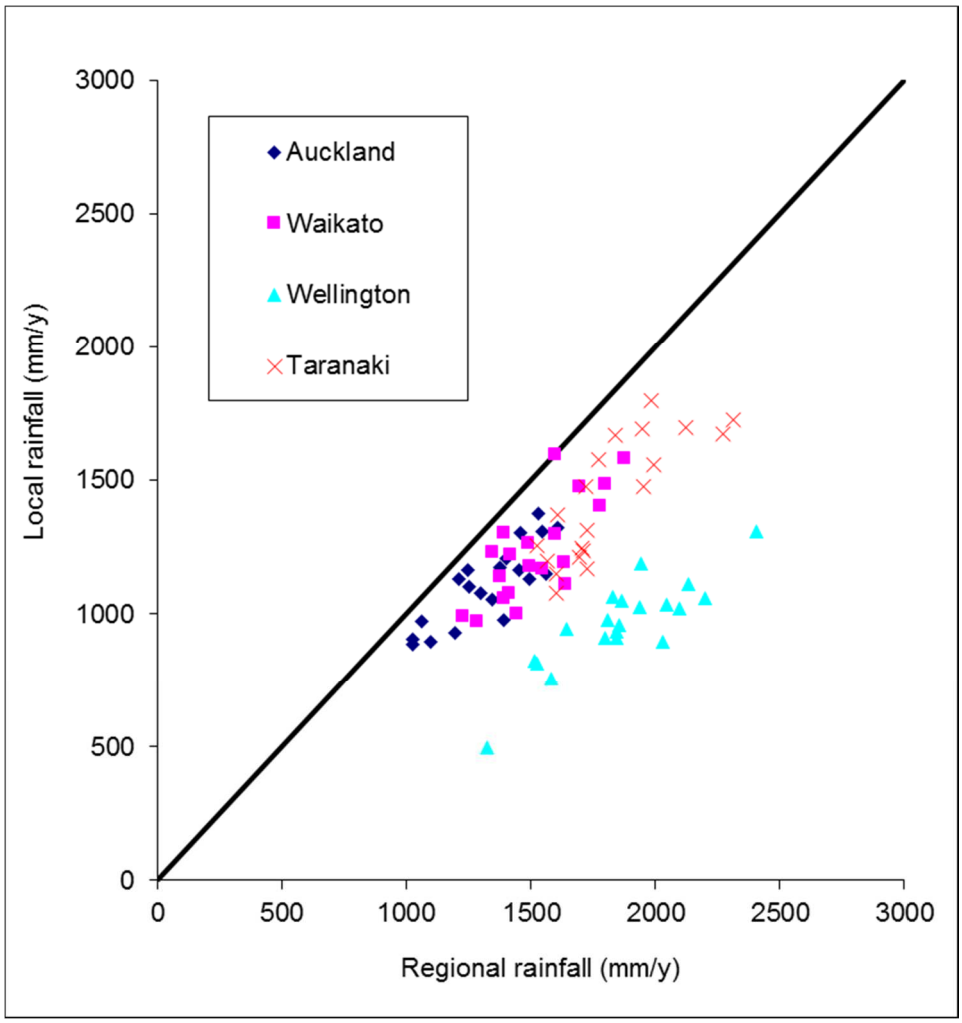

Figure 6: Comparison of annual rainfall at city raingauges with regional rainfall from VCSN. Rain gauges at Auckland, Hamilton, Wellington and New Plymouth.

The second (Figure 7) shows the comparison between water crossing the regional boundary between Tasman and West Coast, compared to the flow record from Buller at Longford, which represents about one third of the area involved. The relationship between annual flows is strong, and the multiplier is of the right order.

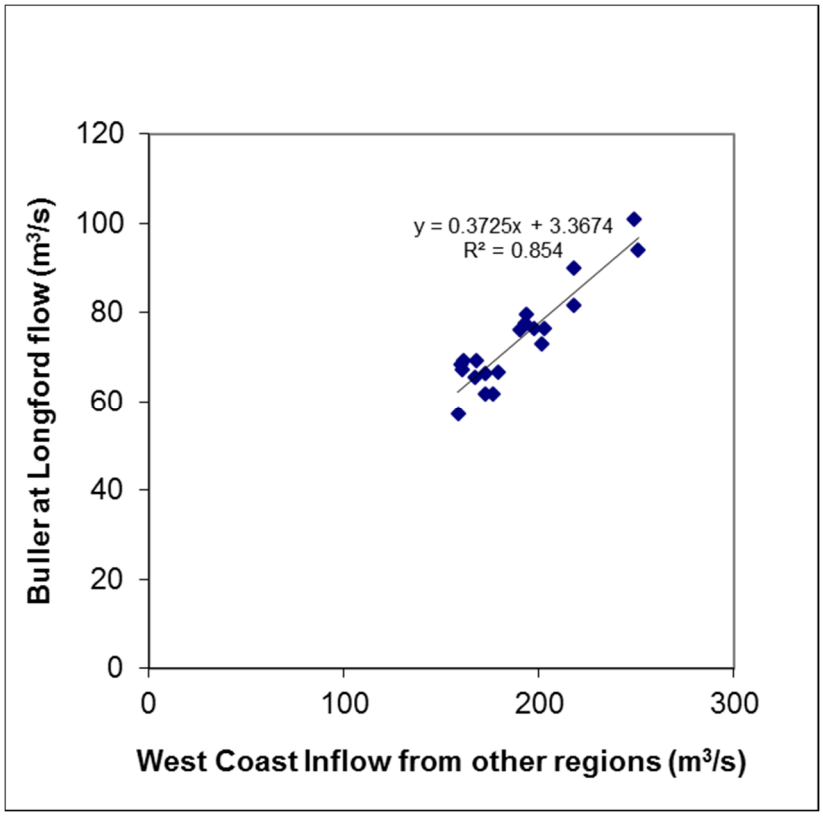

Figure 7: Runoff from Tasman District to the West Coast Region.

4 Conclusions

A set of 11 surface water components for the first set of national and regional water accounts has been developed for New Zealand, for the period 1995-2014. The accounts capture the broad temporal and regional variability of water movement and storage. They show that precipitation, river flow to the sea, and evapotranspiration are the major components, and that abstraction/discharge by hydro-generation is a substantial non-consumptive use.

There is uncertainty in all aspects of the water accounts procedures, but validation checks of some of the dominant input and output data allows confidence in the process and results.

5 Acknowledgements

We acknowledge the following sources of information used in the preparation of these accounts: they gave permission to use the data, and/or helped make it available:

5.1 Hydro-generation data

Contact Energy Ltd
Genesis Power Ltd
King Country Energy
Meridian Energy
Mighty River Power
NIWA (funded by NIWA under Environmental Information Programme 1 (2014/15 SCI))
Opus International Consultants

5.2 Lake level data

Auckland Council
Alpine Energy & ECS
Bay of Plenty Regional Council
Canterbury Regional Council
Contact Energy
NIWA (funded by NIWA under Environmental Information Programme 1 (2014/15 SCI))
NZX
Genesis Energy
King Country Energy
Meridian Energy
Mighty River Power
Opus International Consultants
Otago Regional Council
TrustPower
Waikato Regional Council
Greater Wellington Regional Council

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