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Hydrological monitoring technical report

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Contents

1. Introduction

1.1 What is this report about?

Surface water resources of the Wellington Region support a wide range of values and uses. Water is taken out of our rivers, streams and lakes for irrigation, human and stock drinking water, and industrial use. These uses must be managed to avoid adverse effects on instream uses and values associated with our waterbodies, such as recreational, aesthetic, ecological and cultural values. Knowledge of hydrological patterns and trends is vital for achieving sustainable management of water resources.

This report describes the state of, and trends in, surface water resources of the Wellington Region in terms of water quantity, using rainfall, river flow and lake level data collected as part of Greater Wellington Regional Council's hydrological monitoring programme. The report addresses the following questions:

- What are the general patterns of surface water quantity in the Wellington Region?
- What were the surface water quantity patterns and trends since the last State of Environment Report for the Wellington Region (1999)?
- Are there any long-term trends or changes in surface water quantity of the region, and if so, what are the possible reasons for these trends?

The analyses contained in this report will be used to assess the effectiveness of the Regional Policy Statement (Wellington Regional Council, 1995), in particular the Objective 1 relating to freshwater quantity:

The quantity of freshwater meets the range of uses and values for which it is required, safeguards its life supporting capacity, and has the potential to meet the reasonably foreseeable needs of future generations.

1.2 Scope of analysis

Greater Wellington collects information from rainfall and water level stations across the region, as described in Section 3. In general only data from representative stations is shown in this report's graphs and tables. The representative stations are those which have long enough records for reliable statistical analyses, and are known to give an accurate picture of surface water quantity in that area (such as the water level station that is least affected by abstraction).

To simplify the analyses, the region has been divided into three sub-regions: Kapiti Coast (all area west of the Tararua Range, from Paekakariki to the north western region boundary), central Wellington (includes Wellington city and peninsula, and the catchments of Porirua, Pauatahanui, Hutt, Wainuiomata and Orongorongo), and Wairarapa (all area east of the Tararua and Rimutaka Ranges, to the northeastern region boundary) (Figure 1).

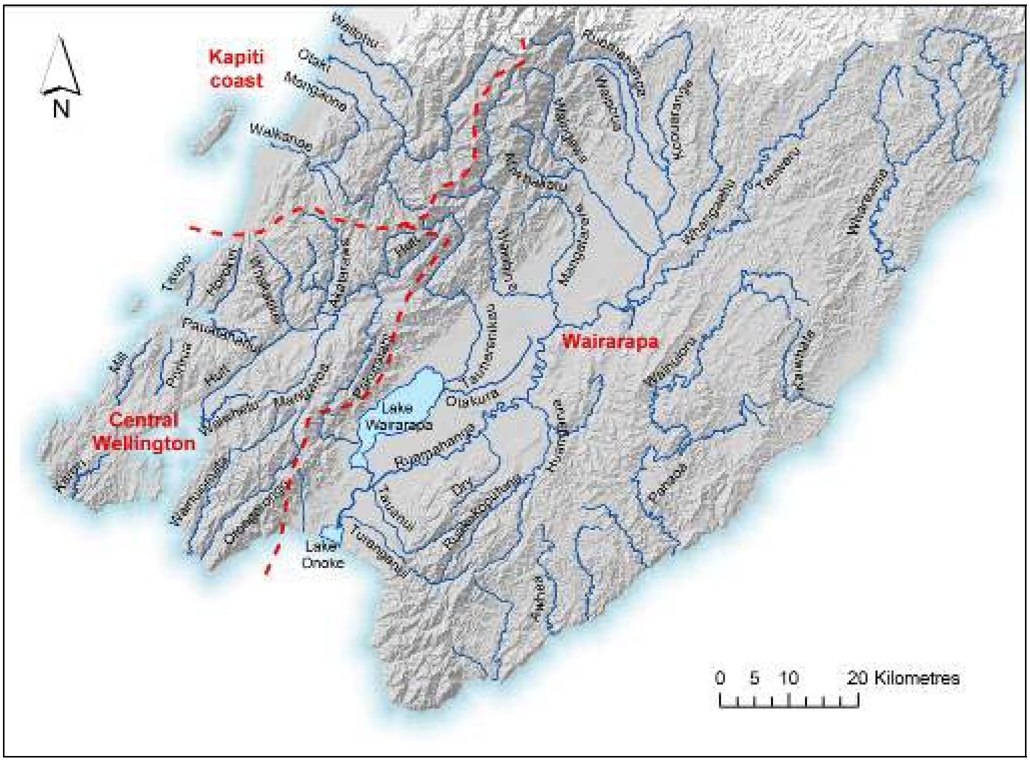


Figure 1: Sub-regions, main rivers, and selected streams of the Wellington Region

1.3 Report structure

Section 2 of this report describes the factors that affect, and place pressure on, surface water quantity in the Wellington Region. These factors are important for controlling the trends in water availability discussed later in the report.

Section 3 describes Greater Wellington's hydrological monitoring programme.

Section 4 gives a general overview of spatial and seasonal patterns in surface water quantity in the Wellington Region.

Section 5 describes the trends and temporal patterns in surface water quantity (rainfall, river flows and lake levels) in the Wellington Region during the reporting period (1999-2004), focussing on how this period compared to 'normal' and the significance of extreme hydrological events in that timeframe.

To fit this into the big picture, Section 6 analyses the longest rainfall and river flows records of the region to assess how water quantity varies over time and whether or not there are any detectable long-term trends.

Section 7 gives a brief overview of Greater Wellington's scientific and management responses to the pressures on and trends in surface water quantity and describes likely future information needs.

2. Pressures on surface water quantity in the Wellington Region

Pressures on water resources are factors that may influence the ability of the resource to meet its range of uses and values, or factors which may compromise the life supporting capacity of our rivers, lakes, streams and wetlands. These pressures are both natural (such as climate cycles) and related to human activities (such as climate change, land use change, and abstraction).

2.1 Climate cycles

Natural variations in climate occur from year to year but also over scales of decades, centuries and thousands of years. We still have much to learn about how the climate of the Wellington Region varies naturally over long timescales. However, with the improved hydrological monitoring in New Zealand over the last century, we are becoming more aware of how natural climate cycles affect our water resources.

2.1.1 El Nino Southern Oscillation (ENSO)

The El Nino Southern Oscillation is the primary mode of natural climate variability that affects our precipitation in the two to seven year time scale (Salinger *et al*., 2004). The ENSO is a result of a cyclic warming and cooling of the surface of the central and eastern Pacific Ocean. Under normal conditions the climate of the south Pacific is influenced by northeast trade winds, cold ocean currents flowing up the coast of Chile, and upwelling of cold deep water off the coast of Peru. At times, the influence of the cold waters wanes, resulting in a weakening of the winds in the South Pacific (El Nino). At other times, the injection of cold water becomes more intense than usual, strengthening the trade winds (La Nina) (Daly, 2003).

An indicator of the state and intensity of ENSO events is the Southern Oscillation Index (SOI), a measure of the atmospheric pressure difference between Tahiti and Darwin. When the SOI is positive it indicates La Nina and when it is negative it indicates El Nino.

El Nino is associated with more frequent southwest flows over New Zealand. During El Nino summers, stronger or more frequent than normal westerly winds lead to cooler conditions and more rain in western areas, and can lead to drought in eastern areas. During the winter, El Nino conditions tend to result in more frequent winds from the south, resulting in cooler conditions, and in spring and autumn southwesterlies tend to be stronger and more frequent (Harkness, 2000).

Conversely, La Nina conditions lead to more frequent northeast winds, which bring warm air over New Zealand. The north of the county is wetter than normal, with drier conditions in the south. During La Nina summers, when wind tends to be easterly, there is an increased probability of tropical cyclones passing close to or over New Zealand (McFadgen, 2001).

2.1.2 Influences of ENSO on Wellington's water resources

ENSO events can be seen as a pressure on surface water resources because both El Nino and La Nina can increase the probability of low rainfall and river flows in the Wellington Region. The effects of the phenomena vary across the region.

Kapiti Coast. Both La Nina and El Nino can lead to droughts on the Kapiti Coast. When an El Nino occurs during spring, westerly winds tend to be more from the southwest and the Kapiti Coast is to some extent sheltered by the South Island. Similarly, autumn and winter El Nino events can also lead to dry conditions on the Kapiti Coast as winds tend to be more southerly (Harkness, 1999). However, overall La Nina conditions have a more consistent impact on Kapiti Coast droughts and low flows. The more pronounced easterly and northeasterly conditions of La Nina lead to less rainfall on the Kapiti Coast and in the western Tararua Range. La Nina conditions at all times of the year have been correlated with low flows in the Otaki and Waikanae Rivers (Harkness, 1998a).

Central Wellington. Although El Nino can lead to droughts in central Wellington, there is a stronger correlation between La Nina and low flows in the Hutt, Wainuiomata and Orongorongo catchments (Lew, 1997). The influence of La Nina is greatest during spring and summer in these catchments, when winds tend to be more easterly.

Wairarapa. Although both La Nina and El Nino can cause low seasonal rainfall in the Wairarapa, overall El Nino has a greater influence due to the enhancement of westerly conditions. However, during a La Nina summer, increased easterly conditions mean the Wairarapa plains can expect extended dry spells punctuated by heavy rain events due to the influence of ex-tropical cyclones. In general, in the Wairarapa if an El Nino event is present the chance of low *summer* rainfall increases, and if a La Nina event is present the chance of low *autumn* rainfall increases (Harkness, 2000).

2.1.3 Interdecadal Pacific Oscillation (IPO)

The Interdecadal Pacifical Oscillation is an oscillation in the ocean-atmosphere system that affects decadal climate variability. Three phases of the IPO have been identified during the 20th century: a positive phase (1922-1944), a negative phase (1947-1977), and another positive phase (1978-1998). There is now evidence that the most recent positive phase has ended (Salinger *et al*., 2004) (Figure 2), although monitoring for a few more years is required before the shift to a negative phase can be confirmed.

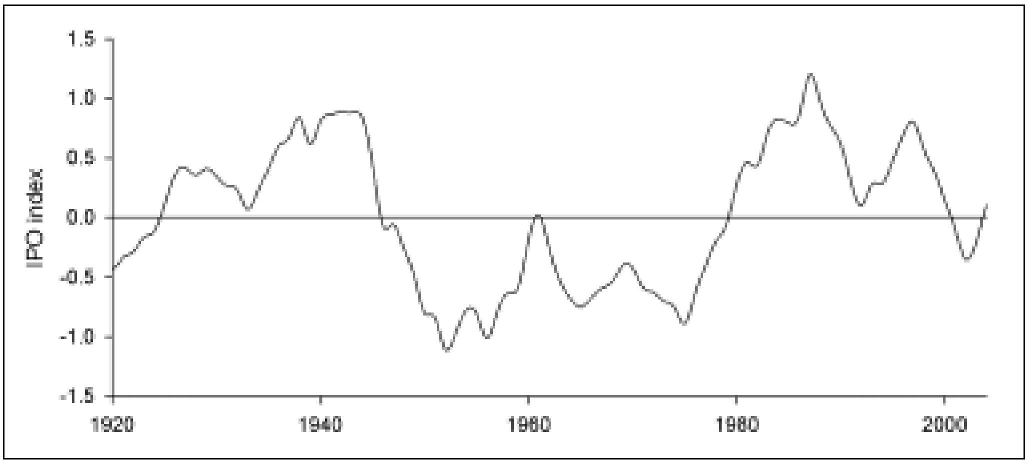


Figure 2: Smoothed time series of an index of the IPO, 1920-2004

The IPO is regarded as a pressure on Wellington's surface water resources because it modulates the frequency of El Nino and La Nina phases of the ENSO (McKerchar & Henderson, 2003). The period 1930-1950, which roughly corresponds with a positive phase of the IPO, was one of more south to southwest flows over New Zealand and a long-lived El Nino episode occurred in this period (1939-1942). Conversely, the period 1951-1975, which corresponds approximately with the negative IPO phase, saw an increase in flows from the east and northeast. The 1970s were notable for prominent La Nina events (Salinger *et al*., 2004).

The latest positive phase of the IPO, since the late 1970s, has corresponded with an increased occurrence of west to southwest flows over New Zealand (Mullan *et al*., 2001) and compared with the previous IPO phase there have been more frequent and intense El Nino episodes. There has also been a trend towards an increased occurrence of anticyclones over northern New Zealand (Salinger, 2004).

If the assumed shift to a negative phase of the IPO holds true, over the next 20 to 30 years weaker westerly flows compared to the last 20 years are likely, and more La Nina events (and fewer El Nino) can be expected (Tait *et al*., 2002). The possible effects on the Wellington Region's surface water resources are:

- An increased probability of low rainfall and river flows on the Kapiti Coast and western central Wellington catchments throughout the year;
- Overall a decreased chance of drought in the Wairarapa particularly during summer, but there is an increased chance of low flows during autumn if La Nina events occur over summer/autumn; and
- An increased probability of ex-tropical cyclones affecting the region from the east.

Some of these effects may already be apparent in our recent rainfall and river flow records (see Section 6).

2.2 Climate change

In addition to natural variations in climate, anthropogenic (human-induced) factors may also affect the future climate of the Wellington Region, placing pressure on our surface water resources. Human activities such as the burning of fossil fuels add greenhouse gases to the atmosphere causing Earth to heat more and, therefore, have a potential impact on our climate.

Scientific models of the global climate system still have many uncertainties, particularly due to uncertainties surrounding projected concentrations of greenhouse gases in the atmosphere. In addition, downscaling global projections to estimate likely changes in climate at the scale of the Wellington Region introduces further uncertainties (Tait *et al.*, 2002).

Based on current scenarios of potential future greenhouse gas emissions, the Ministry for the Environment (2001, 2004) published likely impacts on the New Zealand climate as a result of human-induced climate change. These included that average rainfall is expected become higher in the west and lower in the east of New Zealand. The risk of flooding is expected to increase in most regions due to a general increase in heavy rainfall, while the lower average rainfall is expected to increase the drought risk in eastern regions. Most changes are likely to be more pronounced during winter than in summer.

Tait *et al*. (2002) investigated the potential impacts of climate change on meteorological hazards in the Wellington Region. They concluded that over the next 50 years the occurrence of heavy rainfall events is likely to increase. Specifically, the rainfall intensity during periods of heavy rainfall might increase by up to 10%, and consequently the return period of severe floods might decrease by about half over this period. For example, an event previously considered a 1 in 100 year flood may become a 1 in 50 year flood. This is consistent with more recent generic guidance on changes in flood risk provided by the Ministry for the Environment (2004).

Potential changes to the climate of the Wellington Region by between the years 2070 and 2099 are:

- Average summer precipitation will increase by 5 to 10% on the Kapiti Coast and in the central Wellington Region, but will decrease by up to 5% in eastern Wairarapa;
- The risk of summer drought is likely to increase in the Wairarapa;
- Average winter precipitation will increase by 10 to 15% on the Kapiti Coast and in central Wellington Region, but will decease by up to 10% in the Wairarapa;
- The risk of heavy rainfall events is expected to increase in both western and eastern regions, with specific changes likely to be dependent on catchment characteristics and the degree of temperature increase (Tait *et al*. 2002; Ministry for the Environment, 2004); and

- Temperatures will increase by between 0.8°C and 2.7°C throughout the region (Ministry for the Environment, 2001, 2004).

Obviously the impacts of this potential climate change are wide-ranging for the Wellington Region, from increased hazard of landslides and flooding through to changes in agricultural productivity. In terms of water availability, it is likely that the impacts will be more severe in the east of the Wellington Region. The potential decrease in rainfall there will lead to lower river flows and less recharge to groundwater systems. At present there is insufficient information about climate variability to estimate changes in drought risk on the Kapiti Coast, but higher summer temperatures are likely to increase general water demand.

Potentially increased flood frequency as a result of climate change will place pressure on flood protection measures throughout the region. Other impacts of climate change for the Wellington Region include possible changes in freshwater quality through changes in temperature and trophic conditions.

2.3 Land use change

Land use change can place pressure on surface water resources by altering hydrological regimes, therefore affecting both water availability (base flows) and flood frequency (Table 1). There have been few studies completed in the Wellington Region to quantify the impacts of land use change on surface water hydrology. One investigation found that urbanisation of a small catchment on the Kapiti Coast has caused a reduction in or loss of base flow, a significant increase in peak storm flow, and quicker runoff following rainfall (Watts & Hawke, 2003). It is possible these effects have occurred in small streams in many coastal areas of the Wellington Region given the expansion of urban development in these areas; for example, the number of houses in Paraparaumu increased by nearly 100% between 1986 and 2001 (Statistics NZ, 2002).

Table 1: Hydrological impacts of land use change

Land use change	Hydrological effect
Forest/scrub to pasture	Increase in water yield, higher flood peaks, lower base flow.
Native forest to pine	Water yield increases after clear felling but returns to normal after about 5 years, and eventually is lower than before disturbance.
Gorse/scrub to pine	Water yield increases after clear felling but returns to normal after about 5 years, and eventually is lower than before disturbance.
Pasture to pine	Annual water yields reduce by up to 50%, low flows may fall by 50% and peak flows by 80%.
Rural/forest to urban development	Increase in the size of floods, flood peaks occur more quickly, reduced groundwater infiltration leads to lower base flow.
Wetland to pasture or urban development	Lower base flow in streams previously connected to wetlands, higher flood peaks, floods occur more quickly.

Conversion to pine plantation, particularly from pasture, is likely to have had a localised impact on catchment water yields in the Wellington Region. In the five years between 1996 and 2001 the area planted in pine forest in the region increased by nearly 1900 hectares, and the total area in pine plantation in 2001 was nearly 53,000 hectares or about 6.4% of the land area of the Wellington Region. No work has been completed to quantify the impact on water resources; Rowe (2003) investigated land cover for catchments with river flow records but did not conclude if any impact of land use change was shown in those records.

2.4 Abstractive demand

Abstraction of surface water can create pressure on our rivers, lakes and streams, by reducing the amount of water available for aquatic habitat, ecological and chemical processes, recreational activities and other instream uses and values. Most water abstraction from surface water in the Wellington Region is ‘run-of-river’; i.e. with no water storage. The demand for water from rivers and streams is often greatest when flows are at their lowest; abstraction of water can therefore increase both the severity and duration of low flows.

Surface water abstraction in the Wellington Region occurs as both permitted (no consent required) and consented activities. A water take is a permitted activity if it is less than 20,000 litres/day, subject to four conditions. No information is currently available on the location or effect of permitted activity abstractions on our surface water resources, therefore only consented water use is analysed in this report.

2.4.1 Current extent of water allocation and use

There are currently nearly 200 resource consents to take surface water in the Wellington Region. The majority of these abstractions (just over 150 consents) are in the Wairarapa, where most of the permits are for irrigation purposes (Figure 3). In central Wellington the abstractions are predominantly for public water supply and industry, and tend to be in the Wainuiomata, Orongorongo and Hutt catchments. On the Kapiti Coast most abstractions are from small streams for irrigation, although the larger Waikanae River provides water for public supply.

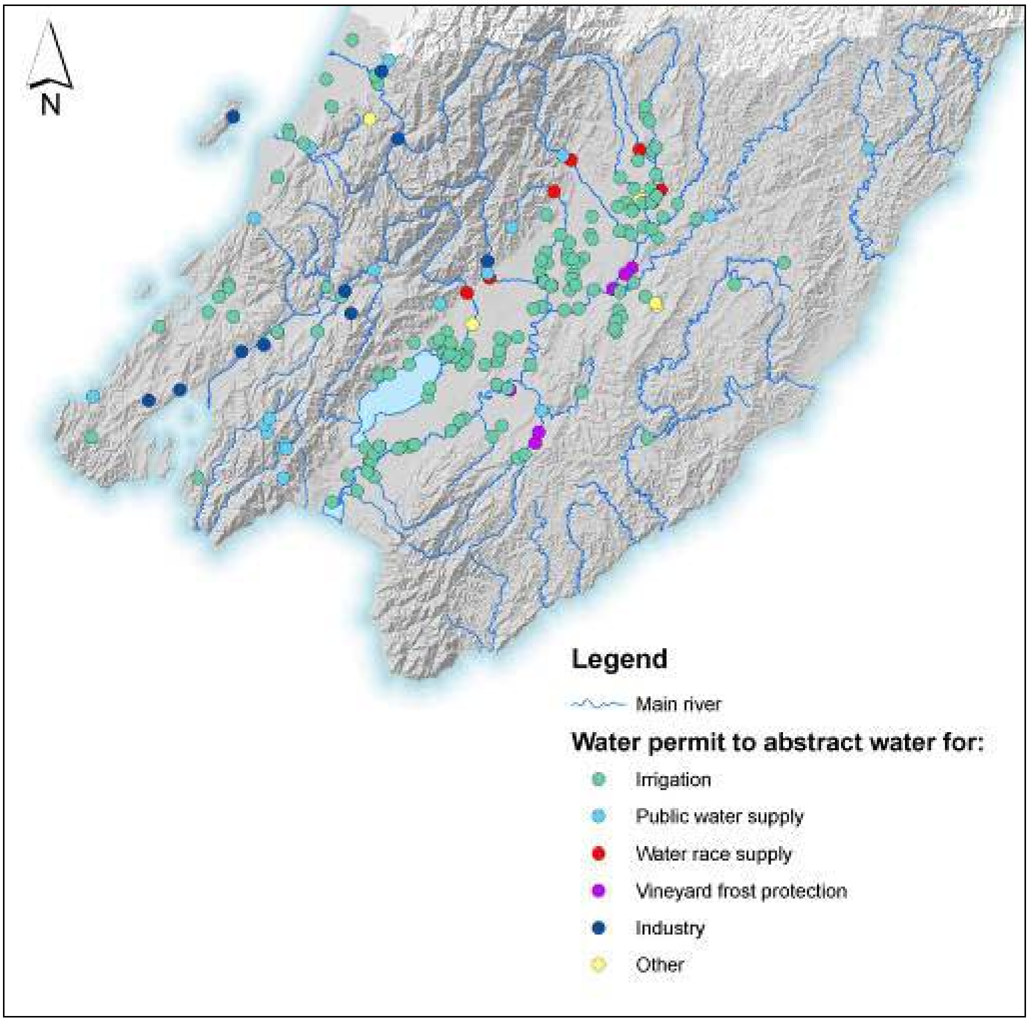


Figure 3: Location of resource consents to abstract water in the Wellington Region

The amount of surface water allocated is also greatest in the Wairarapa (7221 l/s), where most of the water taken is for irrigation and rural water race supply (Figure 4). However, significant proportions are also taken for public water supply and vineyard frost protection. In central Wellington (total allocation 4206 l/s) nearly all of the allocated water is for public water supply. On the Kapiti Coast much less water is allocated than in the other two sub-regions (604 l/s), and most of the allocated water is for the water supplies of Waikanae, Paekakariki and Otaki[1].

Abstraction of water for industry, public water supply and water race supply occurs year-round. Demand for irrigation water is greatest during the period October to April, which generally coincides with the lowest river flows. Demand for water for frost protection occurs in the spring, before river flows reach their lowest, although large abstraction rates are required for this use. For this reason, most resource consents to take water for frost protection specify that abstraction can only occur if river flows are above a certain level.

1 The resource consent for Otaki water supply is now only used as an emergency water supply

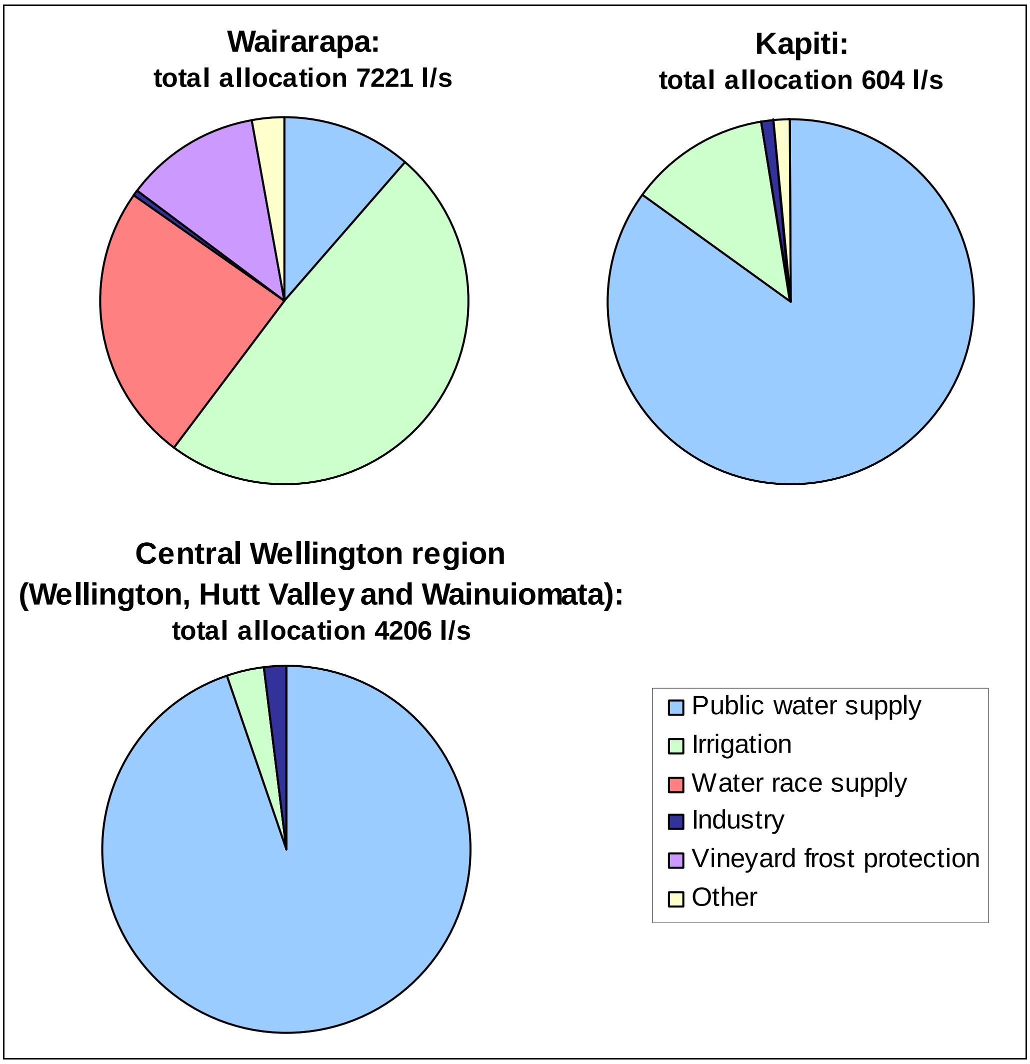


Figure 4: Instantaneous allocation of water in the Wellington Region according to use

To determine which surface water resources are under pressure from abstraction the amount of water allocated is divided into management zones or catchments (Table 2). The highest total allocations are from the Ruamahanga River (2394 l/s), Hutt River (1981 l/s), Orongorongo River (1132 l/s), Waingawa River (1089 l/s), and Wainuiomata River (999 l/s).

Table 2: Allocation of surface water in the Wellington Region by management zone. W = Wairarapa, C = central Wellington Region, K = Kapiti Coast.

Sub-region	Management zone	Waterbodies	Core allocation (l/s)	Total allocated (l/s)	Percentage of core allocation used*
W	Aorangi	Dry River, Tauanui River, Turanganui River, Whangaehu River (southern)		82	
W	Dock Creek	Dock Creek and tributaries		207	
W	Eastern Wairarapa hills	Pahaoa River, Whareama River, Wainuioru River		37	
W	Huangarua	Huangarua River, Ruakokoputuna Stream		244	
W	Kopuaranga	Kopuaranga River	125	125	100%
W	Lake Wairarapa	Lake Wairarapa		456	∇
W	Makahakaha	Makahakaha, Mangahuia, Maringiawai Streams		46	
W	Mangatarere	Mangatarere River		276	
W	Masterton streams	Manaia Drain and Fleet Street, Kuripuni and Makoura Streams		40	
W	Otakura	Otakura Stream, Battersea Drain		74	
W	Papawai	Papawai Stream, Tilsons Creek		226	
W	Parkvale	Parkvale Stream and tributaries, Booths Creek		279	
W	Rimutaka	Abbotts & Donalds Creeks, Owhanga & Boars Bush Streams, Onoke Drain)		188	
W	Ruamahanga – upper	Ruamahanga River from its headwaters to the confluence with the Waiohine River	800	1171	97%
W	Ruamahanga – lower	Ruamahanga River from Waiohine River confluence to CMA boundary	1500	1223	81%^
W	Tauherenikau	Tauherenikau River, Murphys Line Drain, Taits Creek	405	472	84%
W	Tauweru	Tauweru River and Kourarau Stream		215	

Sub-region	Management zone	Waterbodies	Core allocation (l/s)	Total allocated (l/s)	Percentage of core allocation used*
W	Waingawa	Waingawa River, Hyslops Drain, Kells Stream	1040	1089	100%
W	Waiohine	Waiohine River	740	734	99%
W	Waipoua	Waipoua River	90	209	88%
W	Whangaehu	Whangaehu River (northern)		28	
C	Hutt River – upper	Hutt River to the confluence with the Pakuratahi River	Not specified	1850	
C	Hutt River – lower	Hutt River from Pakuratahi River confluence to CMA boundary	300	131	44%
C	Orongorongo	Orongorongo River and its tributaries	Not specified	1132	
C	Pauatahanui Inlet tributaries	Pauatahanui Stream, Horokiri Stream, Duck Creek		27	
C	Wainuiomata	Wainuiomata River, Gollans Stream	Not specified	999	
C	Wellington streams	Horokiwi, Karori, Ngauranga, Opau Streams		43	
K	Mangaone	Mangaone Stream	25	28	100%
K	Kapiti streams	Te Rere, Waimanu, Waimeha, Wainui, Wharemauku Streams		66	
K	Otaki	Otaki River	2120	24	1%
K	Waikanae	Waikanae River and tributaries	Not specified	478	
K	Waitohu	Waitohu Stream	57	32	56%#

*Resource consents which specify abstraction can only occur at high flows are not included in the core allocation.

∇Considered under pressure because of significant increased demand for water and uncertainty over target lake level effectiveness.

^Considered under pressure because of significant increased demand and potential impacts of groundwater abstractions.

May also be affected by streamflow depletion from nearby groundwater abstractions.

For some rivers a maximum amount of water that can be taken when river flows are above the minimum flow has been defined in the Regional Freshwater Plan; this is known as the core allocation. Those rivers that have abstraction totalling more than 95% of the core allocation are shaded red in Table 2. However, many of the waterbodies from which water is abstracted do not have core allocations specified in the Regional Freshwater Plan. The waterbodies without core allocations which are considered to be under pressure from abstraction are shaded yellow. The pressure classification was based upon the priority rankings for instream flow assessment carried out by Greater Wellington, which took into account water allocation relative to the 1 in 10 year low flow and historical water issues in the catchment.

All the shaded (red and yellow) water management zones in Table 2 are classed as under pressure from water abstraction. Although this is not meant to imply that abstraction has had an adverse effect on instream values in those waterbodies, it indicates that in many Wellington Region catchments additional surface water may not be available for allocation during times of low flow. In particular, in the Wairarapa there are very few major waterways that are not considered to be under pressure from water abstraction (Morgan, 2000). This is a general assumption, and in most cases investigations are required to determine if additional water can be taken without adversely affecting instream values.

2.4.2 Trends in demand

The amount of surface water allocated in the Wellington Region showed a general increase during the reporting period. Figure 5 shows the change in allocation on an annual basis since 1999. Ignoring the increases in allocation in 1999 and 2001 for public water supply (which were due to the consenting of previously existing abstractions) the growth in surface water allocation prior to 2003 was generally for irrigation purposes. The interest in obtaining resource consents to take water for irrigation generally increases during or following times of drought. This can be seen in Figure 5, where growth in the allocation of water for irrigation was higher in 2001 and 2003 (which had dry summers) than in 2002 and 2004. The year 2003 saw a significant increase in the amount of surface water allocated, primarily due to demand for water for vineyard frost protection; a relatively new water use for the Wellington Region.

Allocation of surface water for irrigation is not likely to increase significantly in the future because many surface water resources of the region are considered to be near to fully or fully allocated. However, it is possible that in the future there may be an increase in demand for surface water for public water supply, frost protection, and community irrigation schemes; uses which require large volumes of water. Surface water may only be available for these uses if water storage, high flow harvesting, or flow sharing methods are utilised.

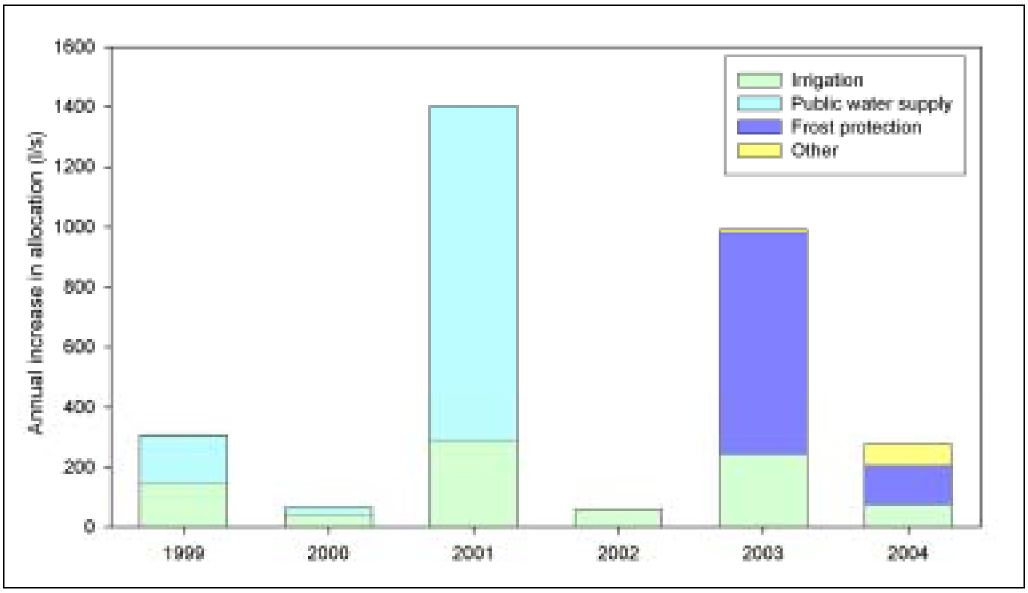


Figure 5: Growth in surface water allocation 1999 – 2004 in the Wellington Region[2]

2.5 Summary points

- There is pressure on the water resources of the Wellington Region from natural climate variations, land use change and abstraction.
- Both El Nino and La Nina can increase the probability of low rainfall and river flows in the Wellington region.
- The Interdecadal Pacific Oscillation affects Wellington's surface water quantity by modulating the frequency and intensity of El Nino and La Nina episodes. Over the next couple of decades it is possible that we will have an increased occurrence of easterly flows and La Nina events, if the IPO has shifted to a negative phase.
- Many of the water bodies from which water is currently taken are considered to be near to fully, or fully, allocated. In the Wairarapa in particular, there are very few waterways that are not considered under pressure from abstraction.
- The increase in surface water allocation over the reporting period was mainly due to demand for water for irrigation and for crop frost protection.
- In the future, in many waterbodies of the region, additional surface water allocation may only be possible if water storage, high flow harvesting, or flow sharing methods are utilised.
- Land use change is likely to have altered hydrological processes of the Wellington region in a range of ways. However, no region-wide work has been done to quantify this impact.

[2] Does not include renewal applications or any decrease in allocation caused by surrendered resource consents.

- Human-induced climate change has the potential to create significant pressure on water quantity over the next century. In particular, the risk of heavy rainfall events (and therefore flooding) is likely to increase, as is the probability of drought in the Wairarapa.

3. Monitoring surface water quantity

The surface freshwater resources of the Wellington Region include rivers, streams, lakes and wetlands. Knowledge of how much water there is in these resources and how it varies over time is central to sustainable water management. Carrying out hydrological monitoring on a long-term basis is vital for the early identification of any trends, and for assessing the potential impacts of those trends on water availability.

Greater Wellington has an extensive programme for monitoring the region's surface water resources. The information collected is important for policy and plan development and review, resource consent management, and flood and drought warning and mitigation. The programme includes monitoring rainfall, river levels and flows, lake levels and wetlands[3] at strategic locations across the region.

The majority of surface water hydrological monitoring sites are linked to the Greater Wellington offices by telemetry. That is, the data collected and stored in a data logger at the monitoring site is transmitted to the Greater Wellington offices via radio or cell phone. This allows real-time monitoring of the resource, which is particularly important for services such as flood warning and minimum flow compliance.

3.1 Monitoring rainfall

Greater Wellington monitors rainfall at 42 automatic rainfall stations across the region (Figure 6), 38 of which are telemetered to the Wellington and Masterton offices. In addition, several automatic rainfall stations are run by other organisations; these are also shown in Figure 6. An example of a rainfall station is shown in Figure 7.

In general, automatic rainfall stations were installed in the region from the 1980s. However, many of the stations have daily rainfall records before that time. The length of record varies with the oldest records for the region beginning in the late 1800s. The start dates for each of the rainfall stations are shown in Appendix 1.

The National Climate Database, which is maintained by National Institute of Water & Atmospheric Research (NIWA), contains additional rainfall data for the region, including daily records from manually read rainfall stations. Some of these records are useful for assessing long-term trends by supplementing data in the Greater Wellington archive; those which are used in this report are shown in Figure 8.

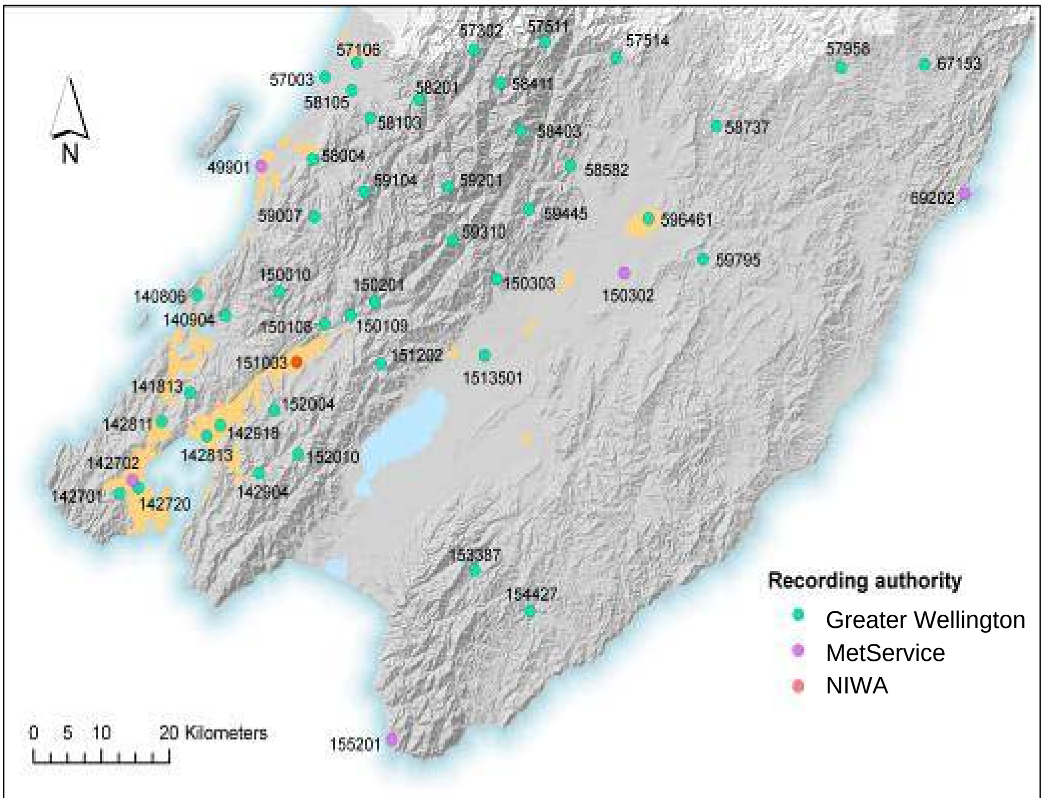
3.2 Monitoring river flows and lake levels

River flow information is collected by continuously monitoring water level in a stream or river, and converting the water level data to flow using a predetermined relationship. Greater Wellington continuously monitors river

[3] Wetland monitoring will not be covered in this report. For details of wetland hydrological monitoring in the Wellington region, refer to the Groundwater monitoring technical report.

and stream flows at 34 automatic monitoring stations across the region (Figure 9), 29 of which are telemetered to the offices. Additional river flow data is collected at stations operated by NIWA. Automatic monitoring of lake levels is carried out at four sites, located on Lake Wairarapa and Lake Onoke. The dates from which the records begin are listed in Appendix 1.

In addition to data collected at the continuous monitoring stations, river flows are manually measured as part of low flow gauging programmes. Generally, this low flow data is collected to ensure resource consent compliance, but it also gives a picture of how low flow magnitude varies across the region.



Station number	Name	Station number	Name	Station number	Name
49901	Paraparaumu Aerodrome	59104	Kapakapanui	142918	Birch Lane
57003	Sims Road	59201	McIntosh	150010	Blue Gum Spur
57106	Otaki Depot	59310	Bull Mound	150108	Cemetery
57302	Oriwa	59445	Valley Hill	150109	Te Marua
57511	Bannister	59795	Te Weraiti	150201	Kaitoke Headworks
57514	Mt Bruce	67153	Tanawa Hut	150302	East Taratahi
57958	Castlehill	69202	Castlepoint	150303	Phelps
58004	Water Treatment Plant	140806	Whenua Tapu	151003	Wallaceville
58103	Transmission Lines	140904	Snodgrass	151202	Centre Ridge
58105	Centrepoint	141813	Waynes Mistake	152004	Tasman Vaccine Limited
58201	Taungata	142701	Karori Reservoir	152010	Orongo Swamp
58403	Angle Knob	142702	Kelburn	153387	Iraia
58411	Carkeek	142720	Regional Council Centre	154427	Stoney Creek
58582	Waingawa	142811	Seton Nossiter Park	155201	Ngawi
58737	Waihi	142813	Shandon Golf Course	596461	Masterton Office
59007	Warwicks	142904	Wainuiomata Reservoir	1513501	Alloa

Figure 6: Automatic rainfall stations in the Wellington Region

Figure 7: Transmission Lines rainfall station

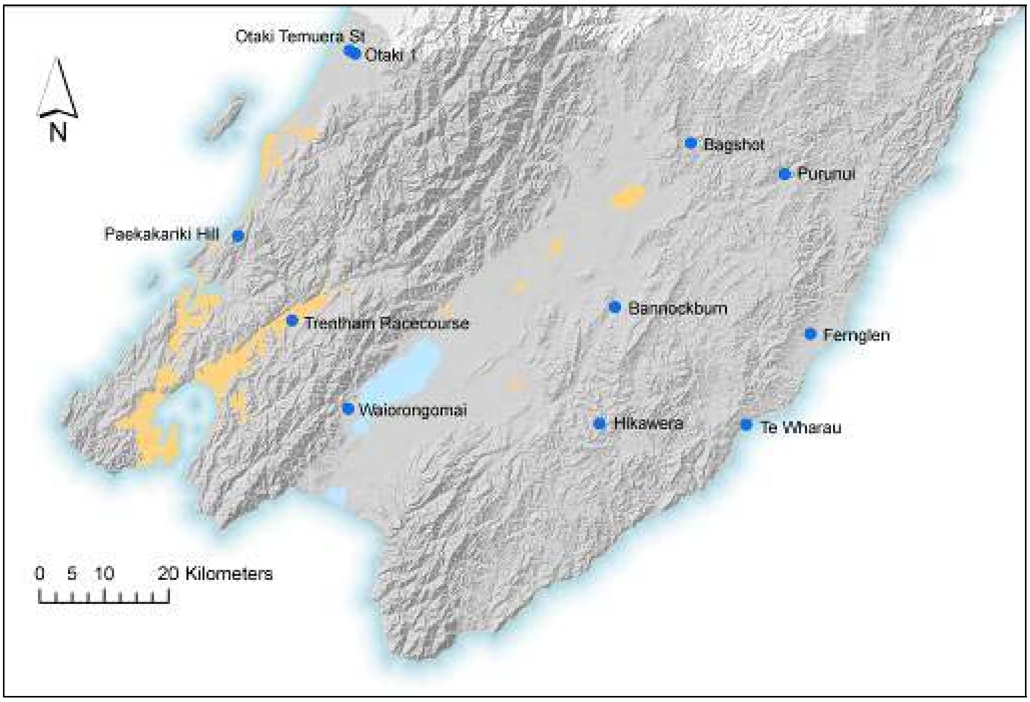
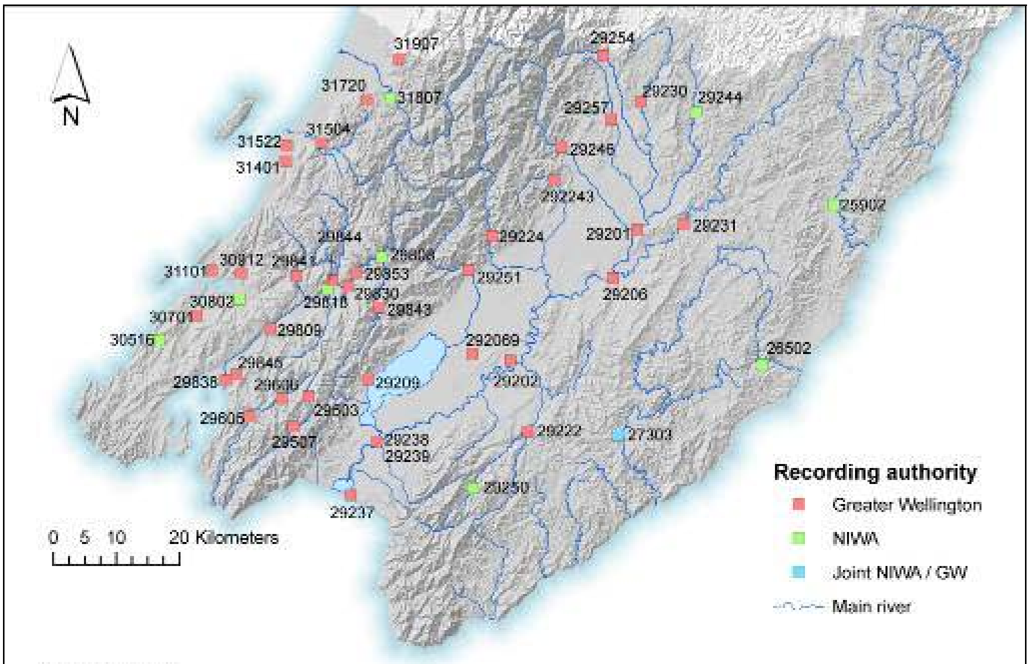


Figure 8: Daily rainfall stations (privately operated) referred to in this report



River level sites:

Station number	Name	Station number	Name
25902	Whareama at Waiteko	29818	Hutt at Birchville
26502	Kaiwhata at Stansborough	29830	Mangaroa at Te Marua
27303	Pahaoa at Hinakura	29838	Hutt at Estuary Bridge
29201	Ruamahanga at Wardells	29841	Whakatikei at Dude Ranch
29202	Ruamahanga at Waihenga	29843	Pakuratahi at Centre Ridge
29206	Ruamahanga at Gladstone	29844	Akatarawa at Cemetery
29222	Huangarua at Hautotara	29845	Waiwhetu at Whites Line East
29224	Waiohine at Gorge	29853	Hutt at Te Marua
29230	Kopuaranga at Palmers	30516	Mill Creek at Papanui
29231	Tauweru at Te Weraiti	30701	Porirua at Town Centre
29244	Whangaehu at Waihi	30802	Pautahanui at Gorge
29246	Waingawa at Upper Kaituna	30912	Horokiri at Snodgrass
29250	Ruakokoputuna at Iraia	31101	Taupo at Flax Swamp
29251	Tauherenikau at Gorge	31401	Wharemauku at Coastlands
29254	Ruamahanga at Mt Bruce	31504	Waikanae at Water Treatment Plant
29257	Waipoua at Mikimiki	31522	Mazengarb at Scaife Drive
29503	Orongorongo at UDS	31720	Mangaone at Ratanui
29507	Orongorongo at Truss Bridge	31807	Otaki at Pukehinau
29605	Wainuiomata at Leonard Wood Park	31907	Waitohu at Water Supply Intake
29606	Wainuiomata at Manuka Track	292069	Otakura at Weir
29808	Hutt at Kaitoke	292243	Mangaterere at Gorge
29809	Hutt at Taita Gorge		

Lake level sites:

Station number	Name
29209	Lake Wairarapa at Burlings
29237	Lake Onoke
29238	Lake Wairarapa at Barrage Gates North
29239	Lake Wairarapa at Barrage Gates South

Figure 9: Automatic water level monitoring stations in the Wellington Region

4. Surface water quantity in the region – on average

Knowing how much water is in our rivers, streams and lakes is essential for ensuring sustainable management of our water resources and as a baseline for assessing long-term trends. This chapter contains information on the spatial and seasonal patterns of rainfall, river flows and lake levels within the Wellington Region.

4.1 Variation across the region

Mean annual rainfall varies significantly within the Wellington Region (Figure 10), and to a large extent the variation is determined by the topography of the region. Moving from west to east, annual rainfall increases from approximately 1000 mm on the Kapiti Coast to nearly 7000 mm in parts of the of the Tararua Range, down to 700-1000 mm on the Wairarapa plains, and up to 1400-1600 mm in the eastern Wairarapa hills.

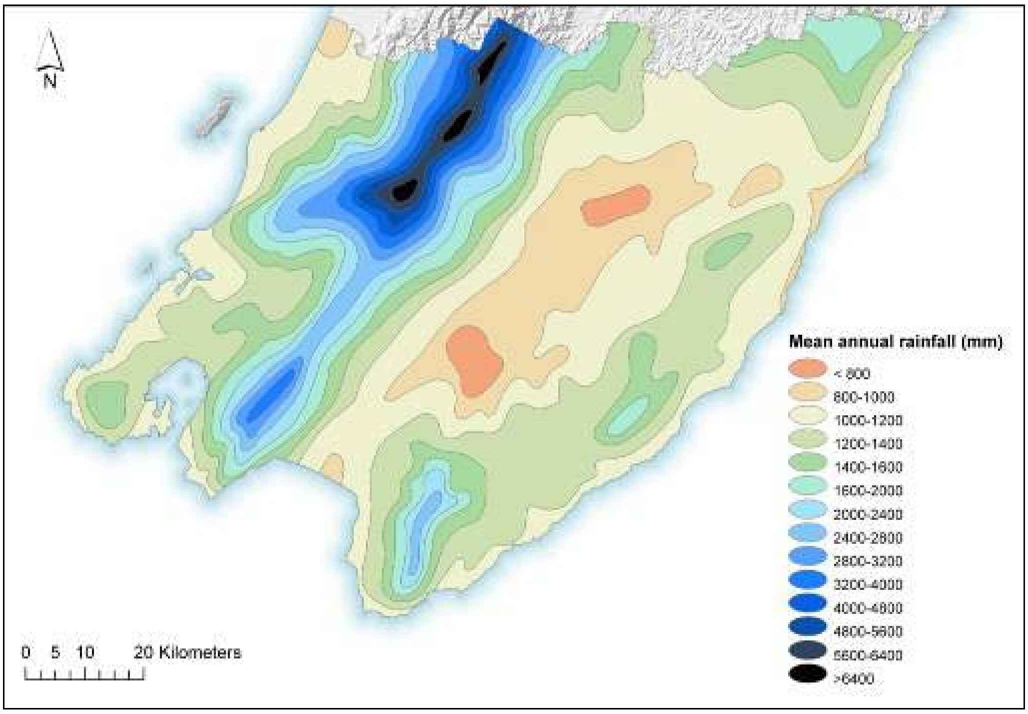


Figure 10: Mean annual rainfall variability in the Wellington Region. Source: Metservice Ltd

The wettest parts of the region are the Tararua, Rimutaka and Aorangi Ranges. However, the highest rainfall in the Tararua Range occurs at an elevation of 800 to 1100 metres rather than in the tops of the range (Thompson, 1982). The driest part of the region is the Wairarapa plains particularly around Martinborough and to the east of Carterton and Masterton. The plains lie in a rainshadow[4] of the Tararua and Rimutaka Ranges, as the prevailing wind is westerly. The Aorangi Range also shelters the Wairarapa plains to some extent from easterly and southeasterly rainfall.

[4] An area having relatively little rainfall due to the effect of a barrier, such as a mountain range, that causes the prevailing winds to lose their moisture before reaching it.

The Ruamahanga River is the largest river in the Wellington Region, and has several major tributary rivers. Its total catchment of 3353 km^2 covers about 41% of the Wellington Region. Other major catchments are the Hutt (657 km^2), Pahaoa (650 km^2), Whareama (532 km^2), and Otaki (348 km^2).

The flow in rivers and streams varies across the region according to location and catchment characteristics such as size, altitude, lithology, slope, vegetation cover, and connections with groundwater systems. These characteristics affect how much rainfall is received, how much rainfall becomes runoff and how much is fed to streams as base flow, how quickly water drains from the catchment, and how much streamflow is lost to, or gained from, groundwater aquifers.

An indicator of water availability across the region, with the effect of 'freshes' removed, is the specific 7-day mean annual low flow. This is the lowest flow sustained for a period of 7 days which occurs, on average, once per year. The 'specific' flow refers to the flow per unit area, in this case litres per second per square kilometre; by removing the effect of catchment size the low flows from different rivers can be directly compared.

Figure 11 shows how the specific 7-day mean annual low flow in the monitored catchments varies across the region, from less than 1 l/s/km^2 in the eastern Wairarapa hills to 10 – 20 l/s/km^2 in catchments with headwaters in the Tararua Range. Thus, on average, a river in the eastern hills will drop to a significantly lower flow each year than a river of the same size catchment with headwaters in the Tararua Range. In fact, some of the eastern Wairarapa rivers, such as the Whareama and Kaiwhata, can dry up during times of low flow. Harkness (1998b) found that rainfall is the dominant control on spatial variation in the 7-day mean annual low flow, but catchment lithology, slope and vegetation cover are also important influencing factors.

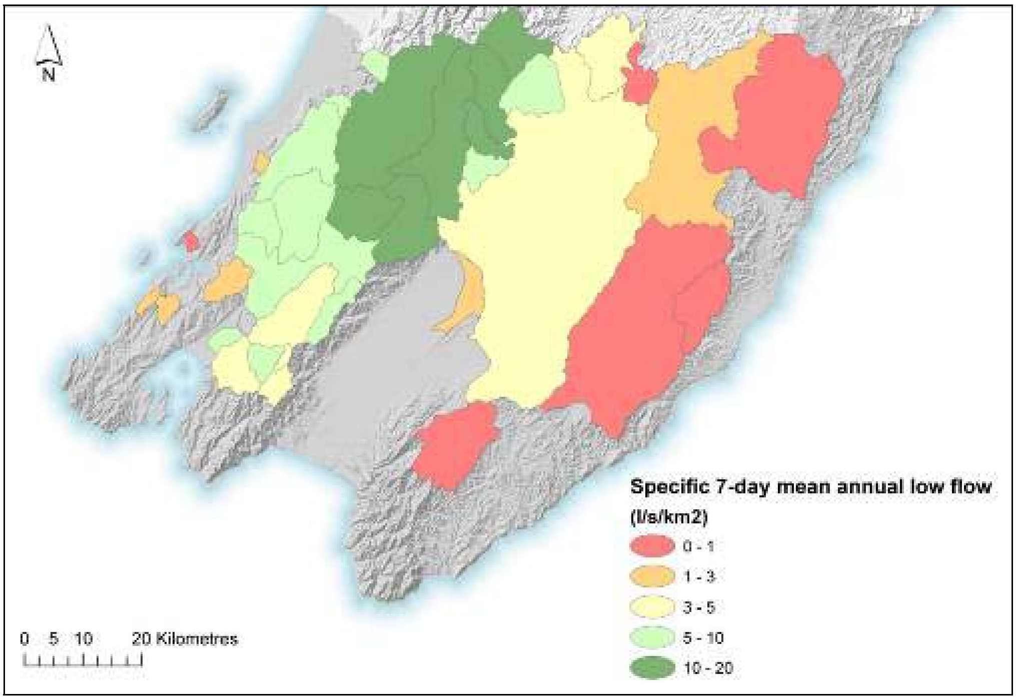


Figure 11: Specific low flows in monitored catchments in the Wellington Region

4.2 Seasonal variations in water quantity

Rainfall in the Wellington Region follows a seasonal pattern typical of temperate climates, with rainfall at its highest in winter and spring and lowest in summer (Figure 12). The wintertime maximum is a reflection of the increased frequency of depressions which cross the North Island during this period (Goulter, 1984). A secondary maximum in spring occurs in places with a more westerly exposure – the Kapiti Coast and the Tararua Range and its foothills – this reflects the westerly flows that prevail over New Zealand at that time of the year. The driest months throughout the region are usually January to March, during which period rainfall totals vary from about 150 mm in Martinborough to about 1300 mm in the tops of the Tararua Range.

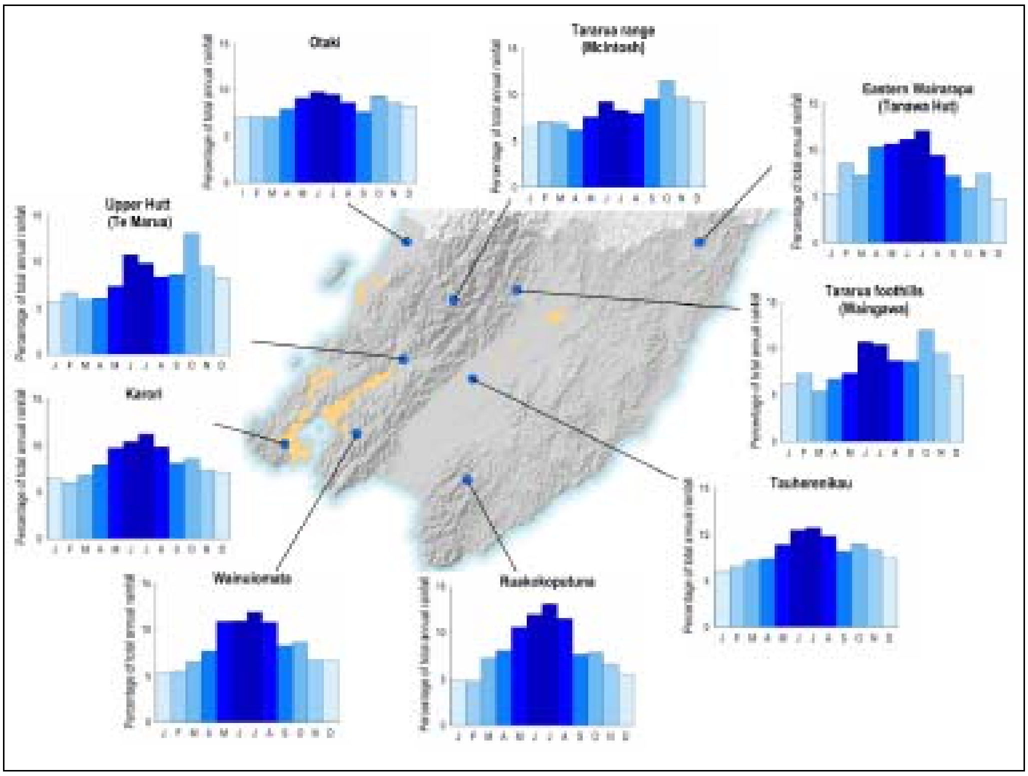


Figure 12: Mean monthly rainfall totals as a percentage of total annual rainfall at key rainfall stations in the region

As shown by Figure 12, the range of monthly rainfall totals within an average year is greater in the east of the region than in the west. In the eastern Wairarapa hills and to a lesser extent in eastern parts of central Wellington (e.g. Wainuiomata) the intra-annual rainfall distribution is affected by the occurrence of southeasterly storms which are more likely during the winter months. In addition, in spring and summer, when the prevailing westerlies are strongest and most frequent, dry foehn[5] conditions occur to the east of the Tararua Range. The result is that, in eastern areas, monthly rainfall totals during winter tend to be two to three times the monthly rainfall totals of summer. However, on the Kapiti Coast and in the Tararua Range and its foothills, the smaller variation between monthly rainfall is a result of the westerly weather patterns which occur throughout the year, and the lesser

[5] A warm dry wind coming off the lee slopes of a mountain range

effect of southerly systems in comparison to their impact in central Wellington and Wairarapa. Otaki displays the least temporal variation in monthly rainfall over a year, with June rainfall being on average only 140% of the rainfall during January.

Seasonal variations in river flows are controlled by rainfall variations and catchment characteristics (which affect runoff rates and base flow recession). The range of monthly average stream flows over a year is greatest for the eastern Wairarapa rivers, such as the Whareama River, where flows are on average highest in the winter months but less than 25% of average annual flow during December and January (Figure 13).

In contrast, large rivers fed from the Tararua Range such as the Hutt, Otaki and Waiohine Rivers have much less monthly mean flow variability over a year. Rivers that are largely influenced by westerly rainfall – e.g. Otaki River, Hutt River, Porirua Stream and to a lesser extent western Wairarapa rivers – tend to have a secondary peak in spring caused by the prevailing westerly frontal rainfall events that occur at that time of the year. Smaller lowland streams, such as the Porirua Stream, are not influenced by rain in the ranges and therefore have greater seasonal flow variability than the larger Tararua-fed rivers.

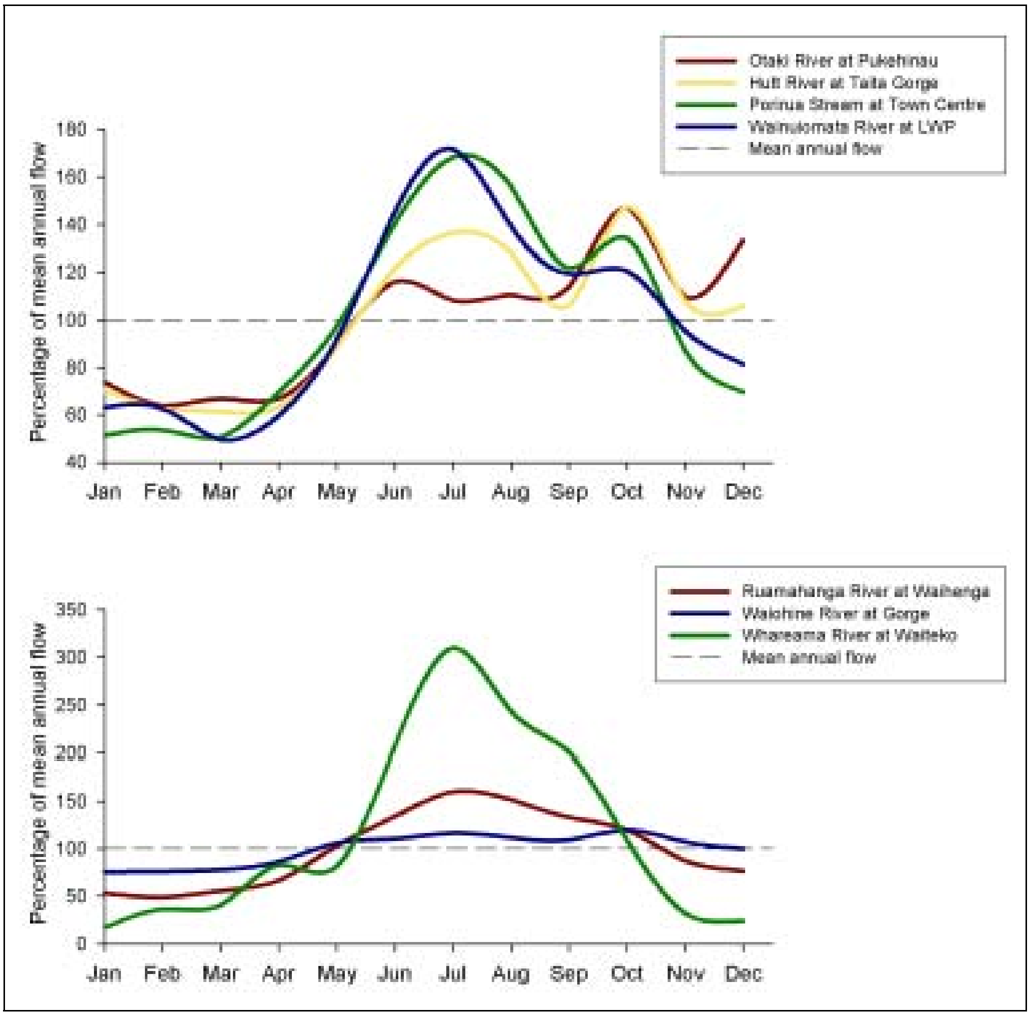


Figure 13: Monthly average river flows as a percentage of mean annual river flow

Lake Wairarapa levels tend to be highest in winter and spring (Figure 14). Since the construction of the Lower Wairarapa Valley Development Scheme in the 1960s and 1970s water flow into and out of Lake Wairarapa has been artificially controlled by the Barrage Gates, and the Ruamahanga River now bypasses the lake. During large floods in the Ruamahanga River, floodways divert some floodwaters into Lake Wairarapa where the water is stored until it can be discharged out through the Barrage Gates into the receding river. Large floods can happen at any time of the year and therefore do not have a strong influence on the monthly average lake levels.

The intra-annual variability in Lake Wairarapa level is now mainly due to the inflows from other contributing catchments along its western and northern shoreline, in particular the Tauherenikau River. The high winter peak reflects the higher winter inflows, and during late spring the increased prevalence of northwesterly frontal rainfall in the surrounding catchments influences lake levels.

Lake Onoke tends to be at its highest level for the year during autumn (Figure 14). The lake levels are influenced by sea conditions and flow in the Ruamahanga River, which in turn dictate whether or not there is an outlet in the shingle bar which separates Lake Onoke from the sea. During autumn, river flows are generally low yet sea conditions start to become rougher, which can result in the outlet being closed and the water levels in Lake Onoke rising. During winter, river flows are higher and assist in keeping the outlet open, therefore dropping lake levels. In spring (September/October) rough sea conditions prevail yet Ruamahanga River flows begin to drop (as shown in Figure 13), which may again result in closure of the shingle bar and increased levels in Lake Onoke.

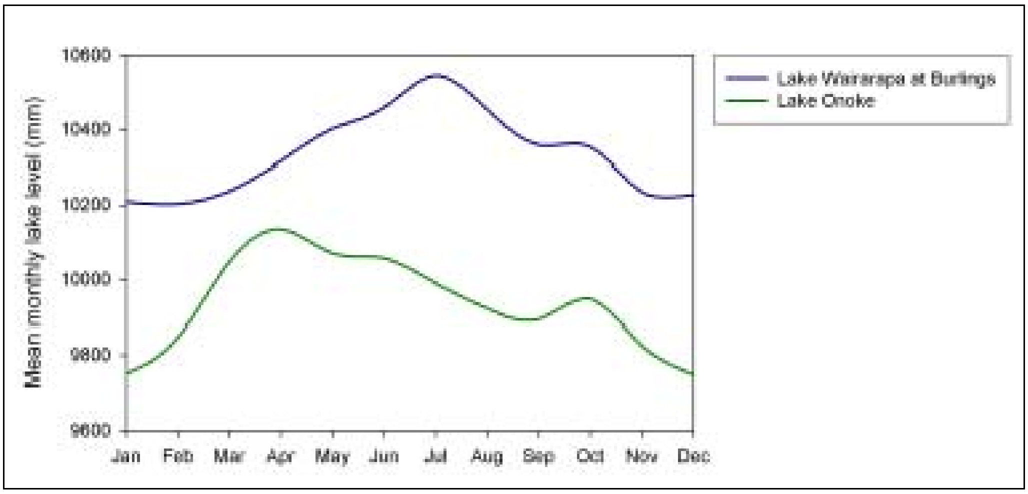


Figure 14: Monthly mean lake levels – Lake Wairarapa and Lake Onoke

4.3 Summary points

- Annual rainfall variation across the region is largely dictated by the topography – in particular the Tararua Range – and the prevailing westerly flows. Annual rainfall is highest in the Tararua Range and lowest on the Wairarapa plains.

- Low flows across the region are dictated by rainfall distribution and catchment characteristics. Low flow yields are highest in the rivers that are fed from the Tararua Range, and are lowest in eastern Wairarapa (where some rivers can dry up).

- On the Kapiti Coast and in the Tararua Range there is relatively little variation in monthly rainfall totals over a year, compared to that of eastern Wairarapa and eastern central Wellington. Rainfall in the Wellington Region tends to peak in winter (and spring in areas with a westerly exposure), and is lowest in summer.

- Similarly, river flow variations over a year are greatest in the east and least for rivers fed from the Tararua Range. Monthly average river flows tend to be highest in winter and lowest between January and March.

- Lake Wairarapa levels peak during winter, when inflows are at their highest, and are lowest over summer. However, Lake Onoke tends to have its highest levels in autumn.

5. Surface water quantity 1999 to 2004

This chapter looks in detail at the surface water quantity data collected by Greater Wellington during the State of Environment reporting period[6]. In particular, annual rainfall totals, monthly rainfall and river flows, low flows and floods are analysed to determine how the period 1999 to 2004 compared to normal. For waterbodies with minimum flows or levels specified in the Regional Freshwater Plan, the water availability during the reporting period is compared to these policies.

5.1 Annual rainfall

Table 3 shows annual rainfall totals during the reporting period at representative rainfall stations around the region. The highlighted cells show when annual rainfall was below the 25th percentile (shaded red), indicating relatively low rainfall, and above the 75th percentile (shaded blue), indicating relatively high rainfall. The percentiles were calculated using the entire length of record at each station.

Table 3: Annual rainfall totals 1999 – 2004 at representative rainfall stations

Location	Rainfall station	Mean annual rainfall (mm)	1999	2000	2001	2002	2003	2004
Kapiti Coast	Otaki Depot	1010	1108	821	1048	1050	1039	1517
	Waikanae WTP	1210	1070	1091	1207	1091	952	1735
Wellington	Karori Reservoir	1232	1525	1070	895	1305	1023	1539
Upper Hutt	Wallaceville	1300	1211	1088	1003	1205	1020	1760
Wainuiomata	Wainui Reservoir	1927	1931	1744	1691	1703	1695	2603
Orongorongo	Orongo swamp	2609	2574	2413	2092	2869	2953	3956
Tararua Range	McIntosh	5300	4749	4819	4765	5637	4536	6436
	Angle Knob	6728	7011	7425	6175	8192	6678	9308
Tararua foothills	Waingawa	2060	1992	2065	1635	2067	1667	2683
Wairarapa plains	Alloa	1075	1078	865	863	992	973	1441
NE Wairarapa	Tanawa Hut	1308	1076	1080	1089	1027	1271	1816
SE Wairarapa	Iraia	1804	1692	1674	1384	1805	1530	2501

[6] Data from NIWA stations is also used where necessary

During the six year period all parts of the region experienced at least one year of relatively low rainfall, with some stations having three years in the lowest 25% of annual rainfall totals on record. The pattern of low annual rainfall was not consistent across the region. The driest year in the reporting period for Wairarapa plains, Wellington, Hutt Valley, Wainuiomata and Orongorongo was 2001. Many of these places also had low rainfall totals in 2000. The Kapiti Coast, Wainuiomata, Wellington, Upper Hutt and the Tararua Range and its foothills had low rainfall totals in 2003. The year 2004 was a very wet year for all parts of the region, with totals tending to be about 150% of average.

5.2 Monthly rainfall and river flows

Calendar-year annual rainfall totals may mask wet and dry periods in the reporting period. In the following analysis, monthly rainfall totals and monthly mean river flows are plotted as deviations from the long-term median (one indicator of 'normal'). A 3-month cumulative deviation from median is used to highlight phases of above or below normal water availability.

5.2.1 Kapiti Coast

On the Kapiti Coast and in the Tararua Range there were two main periods of below median rainfall in the reporting period: one from November 2000 until about June 2001, and the second from August or September 2002 through until May 2003 (Figure 15). The below normal rainfall period beginning November 2000 was preceded by a relatively dry winter, coinciding with an extended phase of positive values of the Southern Oscillation Index (Figure 16) which indicates La Nina conditions.

However, the dry spell of 2002/03 had a longer consecutive period of monthly rainfall totals below median on the Kapiti Coast and in the Tararua Range. This phase of below normal rainfall coincided with an extended period of negative values of the Southern Oscillation Index indicating El Nino. Both La Nina and El Nino can increase the probability of low seasonal rainfall totals on the Kapiti Coast (see Section 2.1.2). As an indication of the significance of the 2002/03 dry spell, during this period:

- The minimum 3-month rainfall total in the Tararua Range was the lowest on record (since 1980 at *Warwicks* and 1991 at *Taungata*); and

- The 3-month rainfall total starting mid-December 2002 was the third lowest since records began in 1893 in Otaki (28.5 mm), the second lowest in Waikanae (48 mm) since 1970, and the third lowest since 1951 in Paraparaumu (43 mm).

During the reporting period there were also two main phases of above median rainfall on the Kapiti Coast: from late 2001 to early 2002, and from late 2003 to March 2004. This second wet phase was greatly influenced by a significantly wet February 2004, which was the wettest February in Otaki since records began in 1893[7]. Rainfall totals were boosted by several northwesterly storm events in January and February 2004.

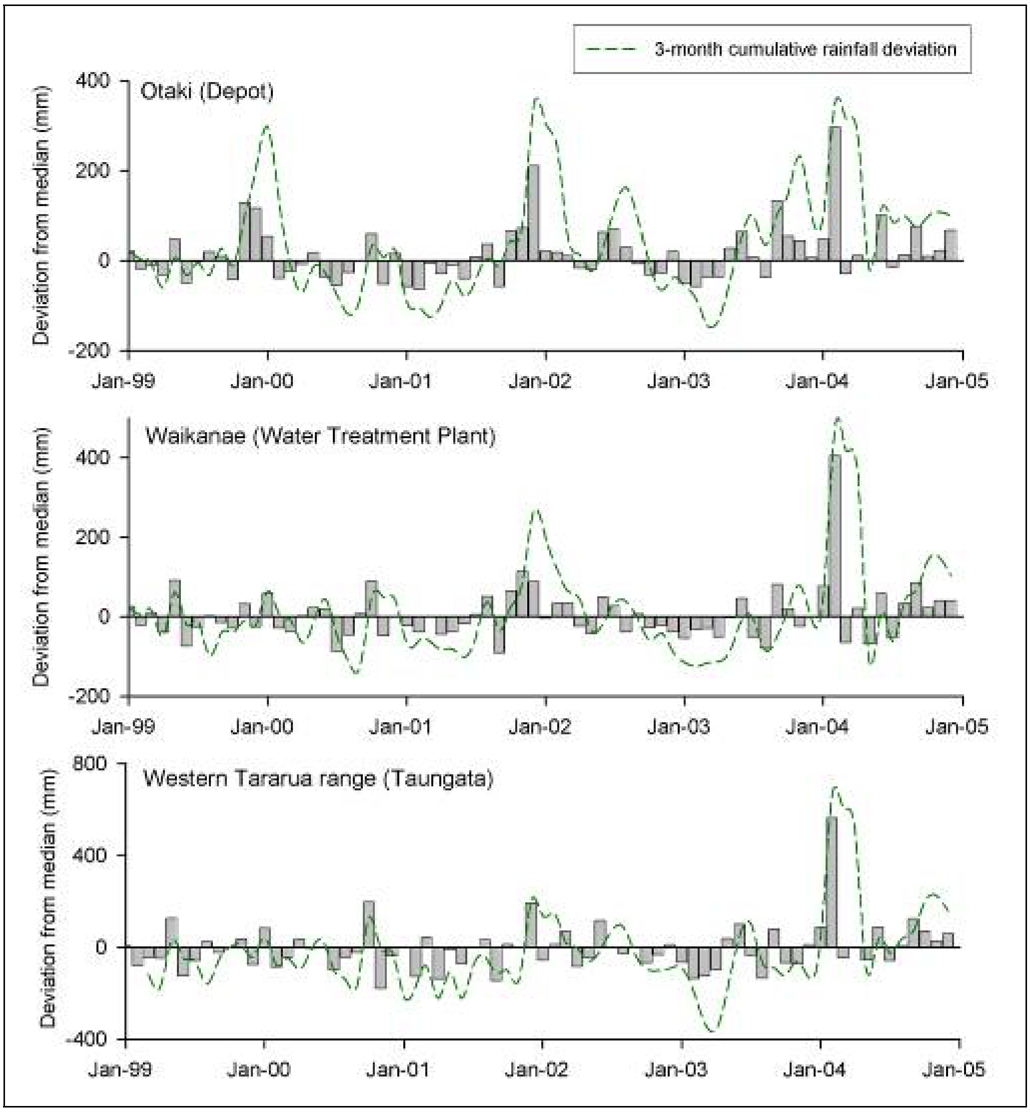


Figure 15: Kapiti Coast monthly rainfall deviation from median 1999 – 2004

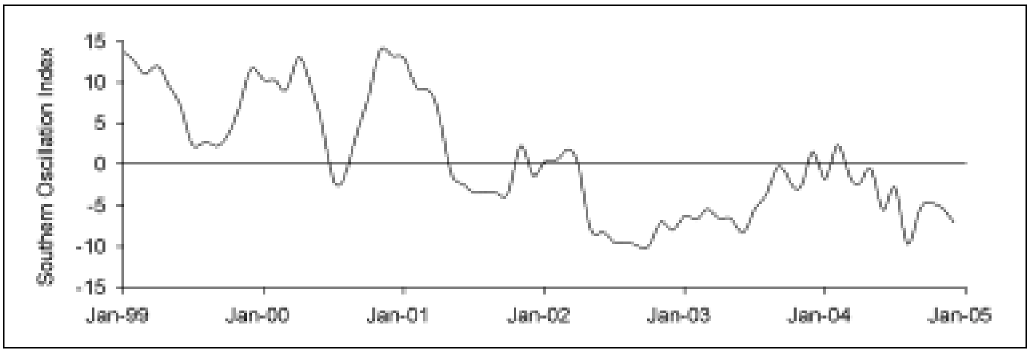


Figure 16: 3-month running mean Southern Oscillation Index, 1999 – 2004

[7] Statistic derived by combining the rainfall records from Otaki 1, Otaki Temuera Street and Otaki Depot

The departure of monthly mean river flows from normal in the Waikanae and Otaki Rivers reflected a similar pattern to the monthly rainfall deviation (Figure 17). Monthly river flows tended to be below normal from the start of the reporting period until about November 2001. Monthly river flows remained in an above normal phase for much of 2002 but dropped at the start of 2003 reflecting the extended period of low rainfall during the summer 2002/03.

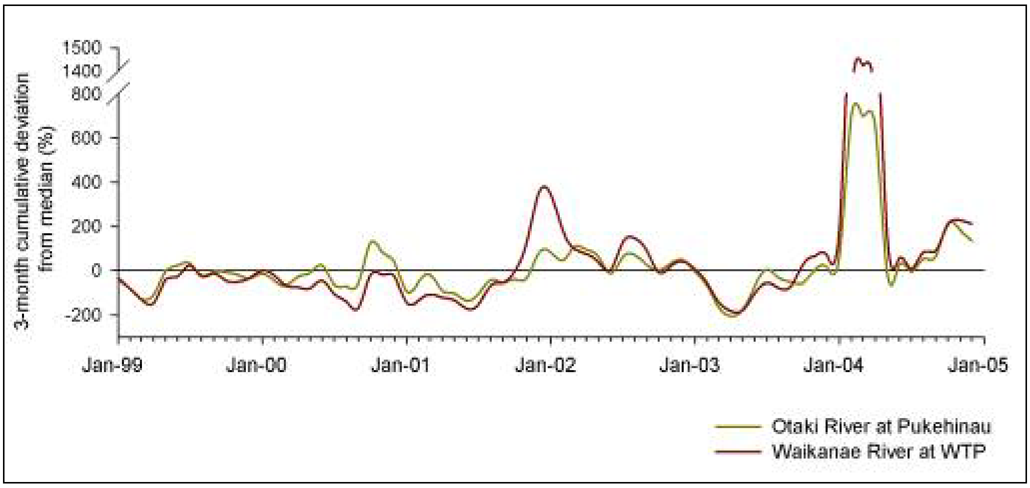


Figure 17: Monthly mean river flows on the Kapiti Coast as a 3-month cumulative deviation from long-term median

From late 2003 through to the end of 2004 the rivers tended to remain in an above median phase, and during January and February 2004 reached record high monthly mean flows for the time of the year. The smaller monitored Kapiti Coast streams followed a similar trend.

5.2.2 Central Wellington Region

Figure 18 shows the deviation of monthly rainfall from the long-term median at representative sites in central Wellington Region. The most significant period of below normal rainfall in this part of the region was through summer and autumn 2001, although in Wellington City (*Karori Reservoir*) the trend of low rainfall began in about July 2000. This phase of below normal rainfall coincided with a La Nina episode (Figure 16), and 2000/01 was probably the driest summer in Wellington city since 1907/08[8]. At both *Orongorongo Swamp* and *Wallaceville* the 3-month rainfall minima for the 2000/01 drought are the lowest on record (records begin in 1980 and 1939 respectively), and at *Wainuiomata Reservoir* the 3 months from the end of January 2001 were the third driest since records began in 1890.

[8] Note the Karori Reservoir rainfall station has missing record during January 2001 so an exact rainfall total for the period is not known.

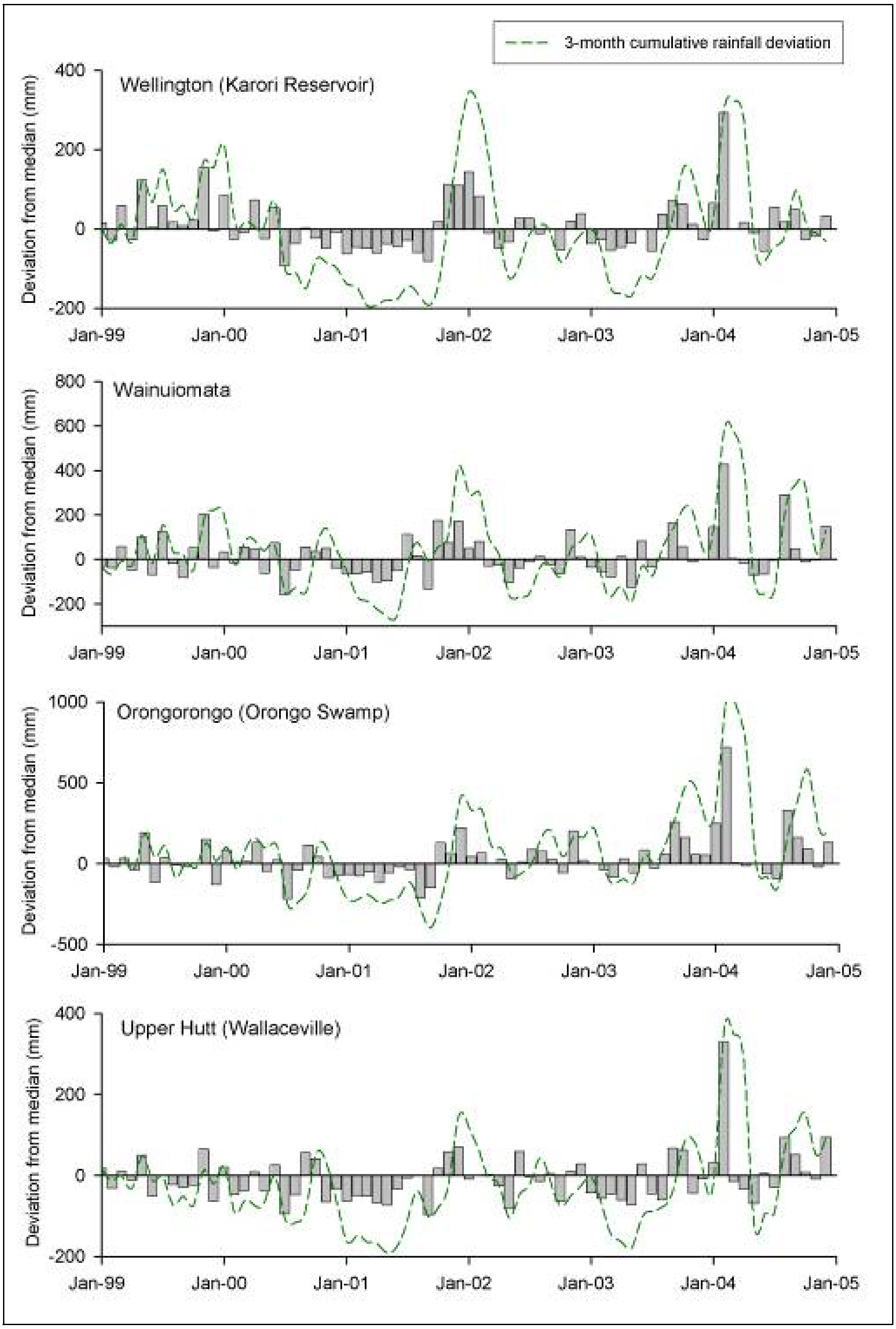


Figure 18: Monthly rainfall deviation from median 1999 – 2004, central Wellington Region

A second phase of below median rainfall in central Wellington Region occurred during January to July 2003, although the rainfall totals were generally not as low as the 2000/01 dry spell. However, the exception is to the north of central Wellington – in the headwaters of the Hutt catchment – where summer and autumn 2003 tended to be the driest phase of the reporting period.

The summer 2001/02 had above normal rainfall throughout central Wellington Region. Rainfall remained in surplus compared to normal through until autumn 2002. The beginning of 2004 was significantly wet in all parts of the central Wellington Region. As previously mentioned, there were several storm events during this time. In particular, a significant southeasterly storm on 15-16 February 2004 contributed to very high February rainfall totals in central Wellington.

Monthly mean river flows in the central part of the Wellington Region followed the trend of rainfall, with extended phases below normal in early 2001 and again in early 2003 (Figure 19). Summer La Nina conditions, as experienced in 2000/01, have been shown to increase the probability of autumn low flows in these catchments (Lew, 1997). Monthly mean flows during the summers of 2001/02 and 2003/04 remained above the normal, significantly so in January to March 2004 as a result of several floods.

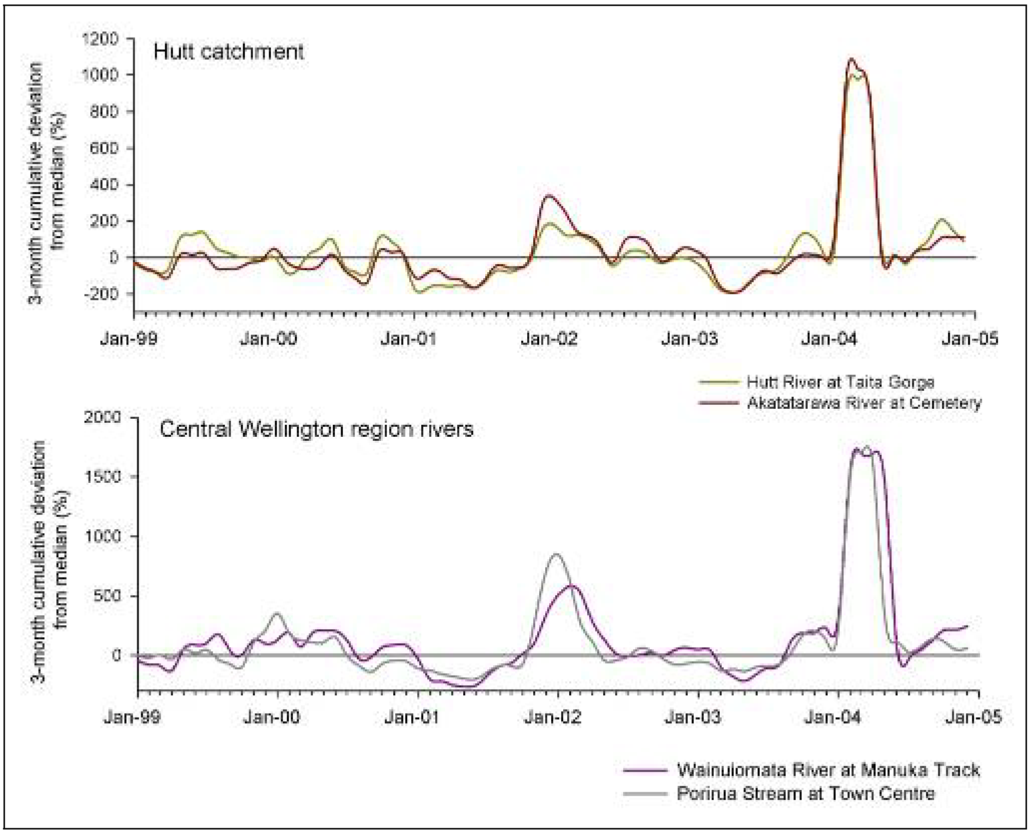


Figure 19: Monthly mean river flows in central Wellington Region as a 3-month cumulative deviation from median

5.2.3 Wairarapa

Rainfall in the Wairarapa during the reporting period followed similar trends to those of central Wellington and the Kapiti Coast. That is, there were two main phases of below normal rainfall: one from January through until winter 2001, and a second over summer 2002/03 through until about July 2003 (Figure 20).

In southern Wairarapa the most pronounced dry spell was in early 2001. The lowest 3-month rainfall totals of the reporting period at *Iraia* (71 mm) and

Waiorongomai (112 mm) began in January 2001, and this was the driest 3 months since records began at *Iraia* in 1969. The highest rainfall deficits were reached in autumn 2001; a reflection of the preceding summer's La Nina conditions.

In western and central parts of the Wairarapa the lowest monthly rainfall totals of the reporting period were in early 2003, which is a reflection of the prevailing westerly conditions associated with the El Nino. During this time very low rainfall totals were recorded in the Tararua Range and its foot hills, and the 3-month rainfall total on Wairarapa plains beginning February 2003 (69 mm) is the lowest since records began at *East Taratahi* in 1981.

In northeast Wairarapa the most pronounced phase of rainfall deficit of the reporting period was in autumn 2002. The March to May total of 101.4 mm makes 2002 the driest autumn since records began at *Tanawa Hut* in 1956. This dry spell was also apparent in eastern parts of central Wellington (e.g. Wainuiomata). However, as it followed a relatively wet summer, river flows did not drop to significantly low levels.

From September 2003 through until the end of 2004 monthly rainfall totals tended to be above normal in the Wairarapa. This was largely influenced by a very wet summer during 2003/04 including the significant storm events of February 2004, and also was boosted by a southeasterly storm which affected the Wairarapa in August 2004.

Following the pattern of rainfall in the Tararua Range the rivers in western Wairarapa tended to be in a below normal phase up until January 2002 (Figure 21). The most extended phase of below normal monthly flows in all Wairarapa rivers was from January through until autumn 2001. However, some rivers experienced lower short-duration low flows in early 2003 (see Section 5.3). All Wairarapa rivers had extremely high monthly mean flows compared to normal in early 2004, and flows remained above normal for much of that year.

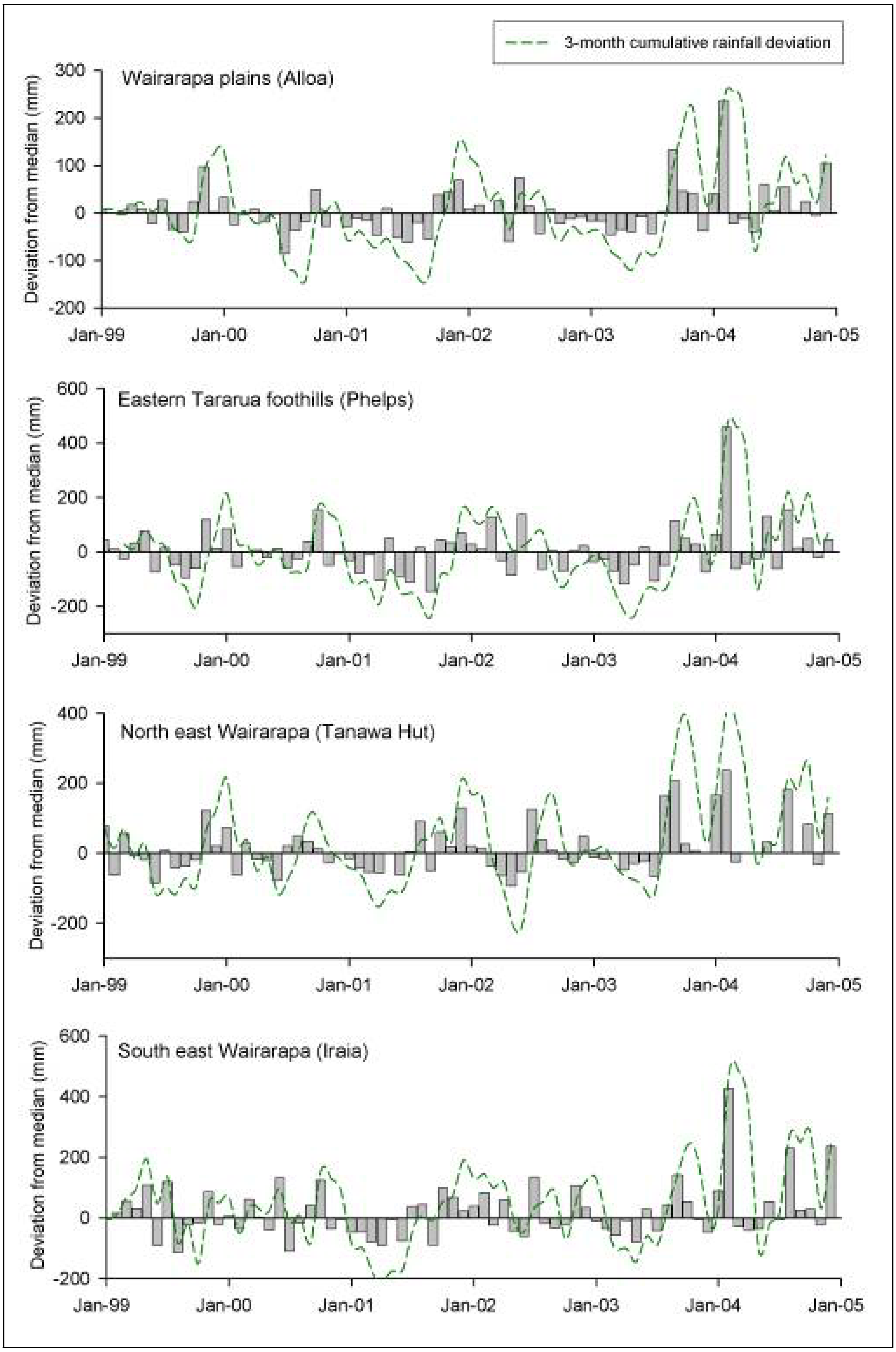


Figure 20: Monthly rainfall deviation from median 1999 – 2004, Wairarapa

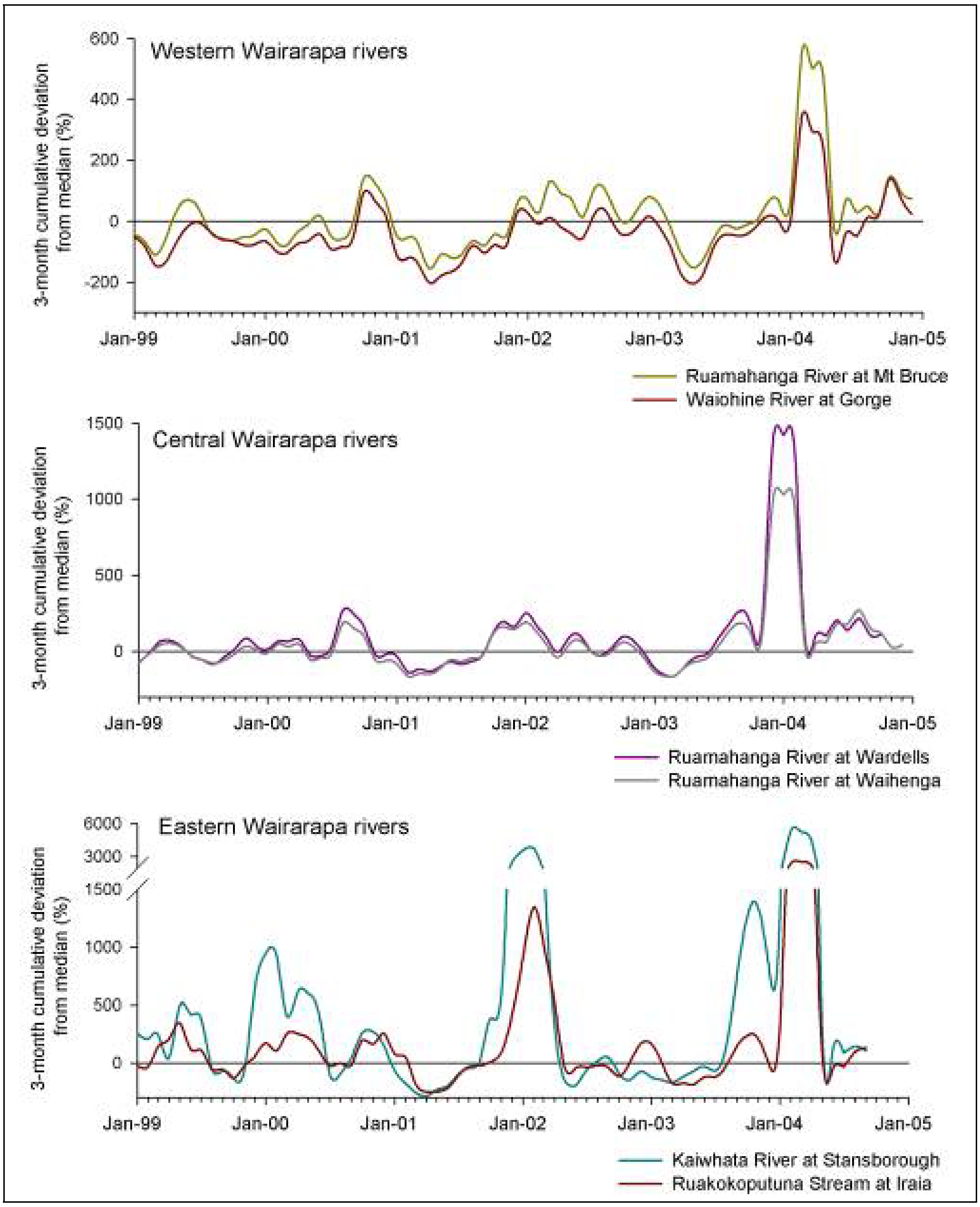


Figure 21: Monthly mean river flows in selected Wairarapa rivers as a 3-month cumulative deviation from median

5.3 Low flows

The severity of low river flows during a dry spell can vary greatly across the Wellington Region, depending on the spatial distribution of any rainfall as well as the catchment characteristics which affect base flow recession. Low flows can last for long periods, and the longer the low flows the greater the impact will be on the community and the environment. Abstraction of water can exacerbate conditions by extending the duration of low flows and causing flows to drop lower than they would naturally. In addition, in some catchments of the region, land use changes may have decreased low flow yields (for example, if extensive urbanisation has occurred in the catchment), although as previously discussed there is little information available to quantify this impact.

In the previous section monthly river flow deviation from normal gave an indication of long-term river flow phases of the reporting period. However, a shorter-duration flow, such as the 7-day low flow (Table 4), provides a standard to compare low flow severity across the region during the reporting period.

Table 4: Lowest flows at selected river flow monitoring stations, 1999 – 2004[9]

Station	Lowest recorded 7-day flow (l/s)	Start date of lowest flow	Estimated return period (years)
Otaki River @ Pukehinau	3327	25/4/2003	30
Waitohu Stream @ WSI	69	23/4/2003	n/a
Waikanae River @ WTP	665	24/4/2003	20
Mangaone Stream @ Ratanui	46	19/3/2001	15
Hutt River @ Kaitoke	1065	22/3/2003	7
Pakuratahi River @ Truss Bridge	189	22/3/2003	3
Mangaroa River @ Te Marua	214	22/3/2003	5
Akatarawa River @ Cemetery	677	25/4/2003	30
Whakatikei River @ Dude Ranch	221	25/4/2003	7
Wainuiomata River @ Manuka Track	99	19/3/2001	20
Orongorongo River @ UDS	21	20/3/2001	7
Porirua Stream @ Town Centre	67	26/4/2001	8
Pauatahanui Stream @ Gorge	43	19/3/2001	10
Ruamahanga River @ Mt Bruce	1100	19/3/2001	4
Ruamahanga River @ Wardells	1953	22/3/2003	9
Ruamahanga River @ Waihenga	6707	20/3/2001	15
Kopuaranga River @ Palmers	268	26/3/2001	2
Whangaehu River @ Waihi	15	8/2/2003	4
Waingawa River @ Kaituna	1175	26/4/2001	4
Waiohine River @ Gorge	2847	22/3/2003	6
Ruakokoputuna Stream @ Iraia	18	26/4/2001	20
Tauherenikau River @ Gorge	1022	19/3/2001	5
Whareama River @ Waiteko	1	19/2/2003	7
Kaiwhata River @ Stansborough	0	7/4/2001 & 10/3/2003	See text
Pahaoa River @ Hinakura	13	14/4/2001	8

As shown by Table 4, the lowest flows in the monitored rivers during the reporting period all occurred during the periods March to April 2001 and February to April 2003. The 2000/01 dry spell produced the lowest flows of the reporting period in the Porirua and Pauatahanui Streams and Wainuiomata and Orongorongo Rivers, which are known to show a correlation between La Nina

[9] Stations with inadequate low flow rating curves not shown; nor are stations on Hutt, Wainuiomata and Orongorongo Rivers that are located downstream of Greater Wellington water supply abstractions.

and low flow occurrence (Lew, 1997). The main Kapiti Coast rivers and the Hutt catchment had their lowest flows in early 2003, reflecting the record-low rainfall in the Tararua Range at that time (Figure 22).

Figure 22: Low flow in the Waikanae River, April 2003

In the Wairarapa, some catchments had their lowest flows in 2001 and others in 2003. In general, the La Nina associated 2000/01 dry spell produced the lowest flows of the reporting period in the southeastern catchments (Pahaoa and Ruakokoputuna) and smaller Tararua-fed catchments (Waingawa, Tauherenikau and Ruamahanga River at Mt Bruce). The dry spell of early 2003 produced lower flows in the larger Tararua catchments (Waiohine and Ruamahanga River at Wardells) and the northeastern catchments (Whangaehu and Whareama). The Kaiwhata River at Stansborough dried up during both years, which is a fairly usual occurrence.

Although the Ruamahanga River had low flows in both years, it is difficult to determine which dry spell produced lower flows because the Ruamahanga River is significantly impacted by abstraction (at both Wardells and Waihenga). Inadequate abstraction data is available to allow naturalisation of flow records for the reporting period.

During the reporting period the lowest flows on record occurred in the Mangaone Stream, Pautahanui Stream, Wainuiomata River and Ruakokoputuna River (in 2001), and the Akatarawa River, Otaki River and Waitohu Stream (in 2003); although it must be kept in mind that most river flow records for the region are only 20 to 30 years long. Significant low flows occurred in these rivers, and also in the Waikanae River and Ruamahanga River at Waihenga, although the severity of the low flow at this latter site may have been exacerbated by upstream abstractions. In general the other monitored rivers had low flows that were no more severe than to be expected during a 6-year reporting period.

5.4 Minimum flows and target lake levels

The Regional Freshwater Plan provides minimum flows for some of the region's rivers, and target lake levels for Lake Wairarapa, to protect instream values from adverse effects associated with abstraction (Table 5). River flows may drop below minimum flows naturally, and this may occur frequently if the minimum flow is set high relative to the mean annual low flow. If river flows drop below the minimum flow (or below first 'step down' levels which are not shown in Table 5) then restrictions will be applied to abstractions.

During the reporting period, river flows dropped below the minimum flows every year except 2002 and 2004 in the Waitohu Stream, Wainuiomata River at Leonard Wood Park, Kopuaranga River and Ruamahanga River. The Orongorongo River, Waingawa River and Tauherenikau River also had flows less than minimum during some years.

The number of days below minimum was greatest during 2001 in the Wainuiomata River and most Wairarapa catchments, indicating prolonged low flows that year, as a result of the La Nina related dry spell which lasted well into autumn. Rivers affected by rainfall in the Tararua Range (Ruamahanga River, Kapiti Coast rivers and Hutt River) had their highest number of days below minimum in 2003, when well below average rainfall occurred in the ranges.

Some of the rivers included in the Regional Freshwater Plan did not fall below their minimum flows during the reporting period. Significant low flows did occur in the reporting period, and so this suggests that for some of the waterbodies (Mangaone Stream and Otaki, Hutt and Waiohine Rivers) the minimum flows are set very low relative to the mean annual low flow. For the Otaki and Hutt Rivers, the minimum flows were set according to results from instream habitat assessments (Wellington Regional Council, 1995; after Jowett, 1993) and incorporating assumed downstream loss of water to groundwater systems. For the Waiohine River the minimum flow was set using a correlation with the flow deemed appropriate for protecting aquatic life in the Ruamahanga River (Wairarapa Regional Water Board, 1975). Further discussion of minimum flows is contained in Section 7.2.

Table 5: River flow compliance with minimum flows in the Regional Freshwater Plan, 1999 – 2004

Station	Minimum flow (l/s)	1999		2000		2001		2002		2003		2004	
		No of days below min.	Lowest flow (l/s)	No of days below min.	Lowest flow (l/s)	No of days below min.	Lowest flow (l/s)	No of days below min.	Lowest flow (l/s)	No of days below min.	Lowest flow (l/s)	No of days below min.	Lowest flow (l/s)
Waitohu Stream at WSI	140	31	129	3	136	29	110	0	181	101	64	0	197
Otaki River at Lower Gorge	2550	0	3890	0	4249	0	3936	0	5846	0	3143	0	6482
Mangaone Stream at Ratanui	22	0	57	0	68	0	44	0	106	0	49	0	116
Waikanae River at WTP	750	0	850	0	984	3	538	0	1056	47	654	0	1432
Hutt River at Kaitoke WS	600	n/a											
Hutt River at Birchville	1200	0	1571	0	2282	0	1564	0	3006	0	1694	0	5043
Wainuiomata at Manuka Track	100	0	126	0	189	7	98	0	250	0	113	0	323
Wainuiomata River at LWP	300	92	157	7	286	149	161	0	341	84	194	0	407
Orongorongo River at Truss Bridge	100	n/a						6	80	24	78	0	203
Ruamahanga River at Wardells	2400	12	1898	9	11991	12	1973	0	3534	25	1848	0	2967
Ruamahanga River at Waihenga	8500	12	6799	10	6508	31	5731	0	11828	19	6630	0	11741
Waipoua River at Mikimiki	250	n/a											
Waiohine River at Gorge	2300	0	2796	0	2555	0	2681	0	3719	0	2735	0	3750
Tauherenikau River at Gorge	1100	8	991	0	1113	27	948	0	1320	11	981	0	1615
Waingawa River at Kaituna	1100	8	986	2	1072	8	997	0	1485	0	1212	0	1612
Kopuaranga River at Palmers	270	11	225	11	250	5	259	0	392	9	260	0	333

Target levels for Lake Wairarapa are set in the Regional Freshwater Plan, consistent with the National Water Conservation (Lake Wairarapa) Order 1989. Figure 23 shows levels in Lake Wairarapa at Burlings during the reporting period, compared to the target lake levels.

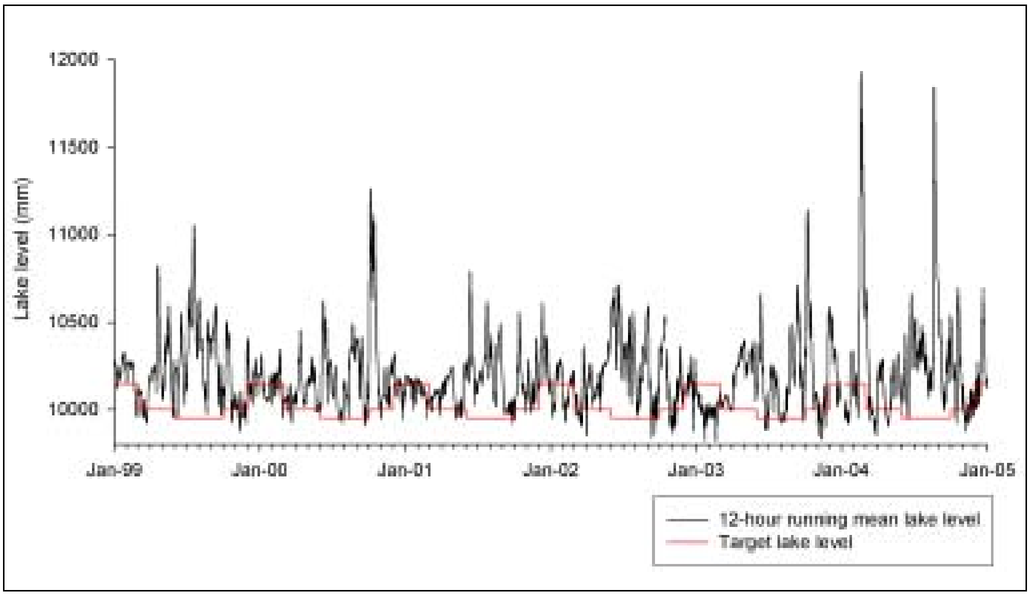


Figure 23: Lake Wairarapa levels 1999 – 2004 compared to target levels specified in the Regional Freshwater Plan

During autumns and winters the lake was well above the target lake levels most of the time. During winter the target level is set low at 9950 mm, to allow for storage of flood waters if necessary. To try and keep the lake down to this level requires discharging water via the Barrage Gates to the Ruamahanga River and then downstream to Lake Onoke. Because the mean lake level in Lake Onoke is rarely below this level, it is often not possible to lower Lake Wairarapa to the target level. Also, the higher flow in the Ruamahanga River during winter and more frequent 'freshes' keep the level on the downstream side of the Barrage Gates above the level on the upstream (Lake Wairarapa) side.

During summers the lake frequently dropped below the target levels. The level during summer will be influenced by the inflow from the Tauherenikau River (and other tributaries), and if Lake Onoke is open to the sea it is sometimes not possible to keep the lake above the target minimum, particularly during times of low flow when water must still pass out of the lake through the fish pass under Barrage Gates. When levels in the lake get low, water from the Ruamahanga River actually flows back through the fish pass. This inflow carries saline water up into the southern end of Lake Wairarapa.

Consented abstraction of water from Lake Wairarapa currently equates to 456 l/s, and is mainly for the irrigation of dairy pasture. The abstraction will affect water levels in Lake Wairarapa during the irrigation season. However, the degree of the effect has not been quantified, and is likely to be small relative to the loss of water from the lake to evaporation in the height of summer. It is unlikely that abstraction has had a significant impact on non-compliance with target lake levels during the irrigation season.

5.5 Floods

To give an indication of flood magnitude during the reporting period the largest floods of the period 1999 to 2004 are shown in Table 6. Note that the return periods assigned are statistical estimations, the reliability of which depends on the record length. The return periods are subject to change as floods occur in the future, because the parameters of the frequency distribution may change in order to provide the best possible fit to the flood series.

At least one flood greater than would usually be expected during a six year period occurred in each monitored river, with the exception of the Kapiti Coast rivers (where all floods were of five year return periods or less). The most significant floods (in terms of return periods) occurred in the Waiwhetu Stream (45 years), Wainuiomata River (50 years), Ruamahanga River (up to 50 years), and the eastern Wairarapa rivers (up to 30 years).

During the reporting period several rivers experienced their largest, or approximately equal largest, flows on record. Those rivers, with their record start dates in brackets, are Mangaroa River (1977), Whakatikei River (1976)[10], Waiwhetu Stream (1978), Kopuaranga River (1985), Waingawa River (1976), Mangatarere River (1999), and Huangarua River (1968).

The largest floods of the reporting period occurred on the following dates:

- 28 May 1999 in the southern Kapiti catchments;
- 1-2 October 2000 in the Otaki, Waitohu and Hutt catchments;
- 3 October 2003 in the Whakatikei and Pauatahanui catchments;
- 12 February 2004 in the northern Wairarapa Tararua-fed rivers (Upper Ruamahanga, Waipoua, Waingawa and Waiohine);
- 16 February 2004 in the Mangaroa River, Waiwhetu Stream, Wainuiomata River, Ruamahanga River and majority of the eastern Wairarapa rivers (Kopuaranga, Huangarua, Ruakokoputuna, Kaiwhata and Pahaoa); and
- 18 August 2004 in the other eastern Wairarapa rivers (Tauweru and Whareama).

The highest flood return periods of the reporting period were produced by the southeasterly storm that occurred on 15-16 February 2004 and affected southern and eastern parts of the Wellington Region (Watts, 2004) (Figure 24). The peak flows were exacerbated by wet antecedent catchment conditions and river flows that were already high in some places from rainfall in the few days leading up to the event. Significant flooding in the eastern Wairarapa rivers occurred again in August 2004. Other floods of 2004 (which was known as a year of floods) occurred on 21 January, 12 February, and 19-20 February.

[10] This flow has since been exceeded, on 6 January 2005

Table 6: Maximum river flows during the reporting period at selected monitoring stations[11]

Station	Highest recorded flow 1999-2004 (m^3/s)	Date	Estimated return period (years)
Otaki River @ Pukehinau	1175	1/10/2000	5
Waitohu Stream @ WSI[12]	68	1/10/2000	4
Waikanae River @ WTP	192	28/5/1999	4
Mangaone Stream @ Ratanui[13]	14	28/5/1999	<2
Hutt River @ Kaitoke	359	2/10/2000	10
Hutt River @ Birchville	1108	2/10/2000	7
Hutt River @ Taita Gorge	1252	2/10/2000	7
Pakuratahi River @ Truss Bridge	124	10/6/2003	10
Mangaroa River @ Te Marua	252	16/2/2004	15
Akatarawa River @ Cemetery	415	2/10/2000	5
Whakatikei River @ Dude Ranch	180	3/10/2003	20
Waiwhetu Stream @ WLE	37	16/2/2004	45
Wainuiomata River @ Manuka Track	91	16/2/2004	50
Wainuiomata River @ LWP	173	16/2/2004	30
Porirua Stream @ Town Centre	53	22/11/2001	8
Pauatahanui Stream @ Gorge	65	3/10/2003[14]	13
Ruamahanga River @ Mt Bruce	445	12/2/2004	13
Ruamahanga River @ Wardells	814	9/10/2000	25
Ruamahanga River @ Waihenga	1950	16/2/2004	50
Kopuaranga River @ Palmers	200	16/2/2004	n/a
Waipoua River @ Mikimiki	317	12/2/2004	10
Whangaehu River @ Waihi	60	16/2/2004	30
Waingawa River @ Kaituna	425	12/2/2004	15
Tauweru River @ Te Weraiti	465	18/8/2004	30
Waiohine River @ Gorge	1362	12/2/2004	15
Mangatarere River @ Gorge[15]	122	16/2/2004	20
Huangarua River @ Hautotara	519	16/2/2004	n/a
Ruakokoputuna River @ Iraia	73	16/2/2004	30
Tauherenikau River @ Gorge	420	9/6/2003	6
Whareama River @ Waiteko	684	18/8/2004	15
Kaiwhata River @ Stansborough	334	16/2/2004	20
Pahaoa River @ Hinakura	1022	16/2/2004	30

[11] Stations with inadequate high stage ratings not shown
[12] Flood frequency estimate based on relatively short flood record
[13] Flood frequency estimate based on relatively short flood record
[14] Approximately equal flow occurred again on 16 February 2004
[15] Flood frequency estimate based on relatively short flood record

Figure 24: Floods of 16 February 2004 in the Waiwhetu Stream (left) and Ruamahanga River (right)

5.6 Summary points

- During the reporting period there were two main phases of below normal rainfall and river flows in the Wellington Region: one from late 2000 through until mid to late 2001, and one from late 2002 through until mid-2003.

- The 2000/01 dry spell was associated with La Nina, and had the greatest impacts in central Wellington and southeast Wairarapa. Record low rainfall totals were recorded in some of these places, and it was probably the driest summer in Wellington city since 1907/08.

- The lowest 7-day flows of the reporting period in the Wainuiomata River, Orongorongo River, Wellington streams, smaller Tararua-fed Wairarapa rivers, and southeastern Wairarapa rivers occurred in autumn 2001. The low flows that occurred in the Wainuiomata and Ruakokoputuna Rivers had an estimated return period of 20 years.

- The 2002/03 dry spell was associated with El Nino, and had the greatest impacts on the Kapiti Coast, Tararua and Akatarawa Ranges, and the Wairarapa plains. During this time Otaki had its third lowest 3-month rainfall total since records began in 1893.

- The lowest 7-day flows of the reporting period in the Kapiti Coast rivers, Hutt catchment, and northeastern Wairarapa rivers occurred in early 2003. The low flows were particularly significant on the Kapiti Coast with estimated return periods of 20 to 30 years.

- Abstractions are likely to have had an impact on low flow duration and severity in many of the region’s waterways. However, the impact has not been quantified, and naturalisation of low flow records is not possible at this stage.

- Restrictions were required on water abstraction from many of the region’s rivers and streams during the reporting period. The highest number of days below minimum flows (therefore indicating the frequency of restrictions) occurred in 2001 and 2003.

- Lake Wairarapa target levels were frequently not achieved during the reporting period. The lake tended to fall below target level during summer, and remained above the target level during winter and autumn.

- The year 2004 was generally a wet year region-wide and monthly river flows in many of the region’s rivers remained above normal for much of the year.

- Most rivers in the region had at least one significant flood (return period greater than two years) during the reporting period, and many of the region’s rivers had large magnitude floods (estimated return periods greater than 10 years).

- The storm of 15-16 February 2004 produced the largest region-wide floods of the reporting period, with estimated return periods of up to 50 years.

6. Long-term perspective

The detection of trends in water quantity is vital for planning future water resource management and hazard mitigation. Analysis of long-term records allows us to put the variations in rainfall and river flows experienced in the reporting period into context with expected levels of variation in the Wellington Region. However, hydrometric records for the region are relatively short – generally less than 50 years – and it is difficult to draw conclusions for all parts of the region. In this section some of the longest records for the region are examined for trends and levels of variability.

6.1 Climate patterns of the 20th century

In Section 2.1 some of the phenomena which affect our natural climate variability were discussed. These factors – El Nino, La Nina and the IPO – have had a large impact on our climate in the last century. In summary, some of the climate phases of the 20th century were:

- During 1930-1950 a predominance of south to southwest flows over New Zealand and a long-lived El Nino episode from 1939 to 1942;

- During 1951-1975 an increase in air flows from the east and northeast, and notable La Nina events during the 1970s; and

- During late 1970s to late 1990s an increase in west to southwest air flows and more frequent and intense El Nino episodes, and a trend toward more anticyclones (Mullan *et al*., 2001; Salinger *et al*., 2004; Salinger, 2004).

These phases, which coincide with shifts in the IPO, should be kept in mind when analysing for trends in Wellington's rainfall and river flows.

6.2 Trends and variability in annual rainfall

Analysis of trends in annual rainfall allows us to make an assessment of whether the 'big picture' of water availability is changing. Figure 25 to 27 show annual rainfall deviations from the long-term mean, at some of the longest running rainfall stations in the Wellington Region. A 5-year running mean shows the underlying trends in annual rainfall by removing some of the year-to-year variability.

The only stations which show an overall significant trend in annual rainfall (detected using a Mann-Kendall test) are *Karori Reservoir* and *Otaki*. Both these records show an increase in annual rainfall since the start of record. However, this increase may only be apparent because rainfall was relatively low in the period from the 1890s through until the 1920s. A longer length of monitoring is required to determine if these trends are real or an effect of the timing of the start of record.

The graphs show the inherent variability of annual rainfall. However, the variation tends to be cyclic, with annual rainfall falling into 'wet' and 'dry' phases (as indicated by the running mean annual rainfall). These phases vary in duration over the length of the records, but in general seem to persist for 5 to 10 years. These phases are likely to be related to some extent to the ENSO cycle (as indicated by the Southern Oscillation Index in Figure 28).

Over the last century, annual rainfall tended to be at its highest in the late 1970s in most parts of the Wellington Region. However, on the northern Kapiti Coast (*Otaki*) annual rainfall tended to be higher in the mid-1990s; this is a reflection of the enhanced westerly conditions during that period.

In the reporting period annual rainfall in central Wellington and the Wairarapa tended to be below average (except for in 2004) and was notably lower than the totals in the late 1970s. Similarly, on the Kapiti Coast, rainfall totals for the period 1999-2003 showed a decrease compared to annual rainfall in the mid-1990s. However, in the context of past variations in annual rainfall, the reporting period did not have significantly low rainfall. Phases of lower rainfall in the last 120 years have generally occurred in:

- The 1880s and early 1890s;
- 1914 through to early 1920s in Wellington and Wainuiomata;
- The 1930s in the Hutt Valley, Kapiti Coast and southwest Wairarapa (possibly related to La Nina);
- The late 1950s and early 1960s in Wellington, southwest Wairarapa and the Kapiti Coast (possibly related to La Nina);
- The late 1960s and early 1970s in Wainuiomata, Hutt Valley, Wairarapa and Kapiti Coast; and
- The mid-1980s in the Wairarapa (possibly related to El Nino).

The graphs also show that the year 2004 – which was generally regarded as a very wet year – was not significantly high in the context of the last century (i.e. it was not a statistical outlier compared to other annual rainfall totals). However, it was the wettest year in the 110 years of record at Otaki, and was one of the highest annual totals in Wainuiomata, the Hutt Valley and eastern Wairarapa.

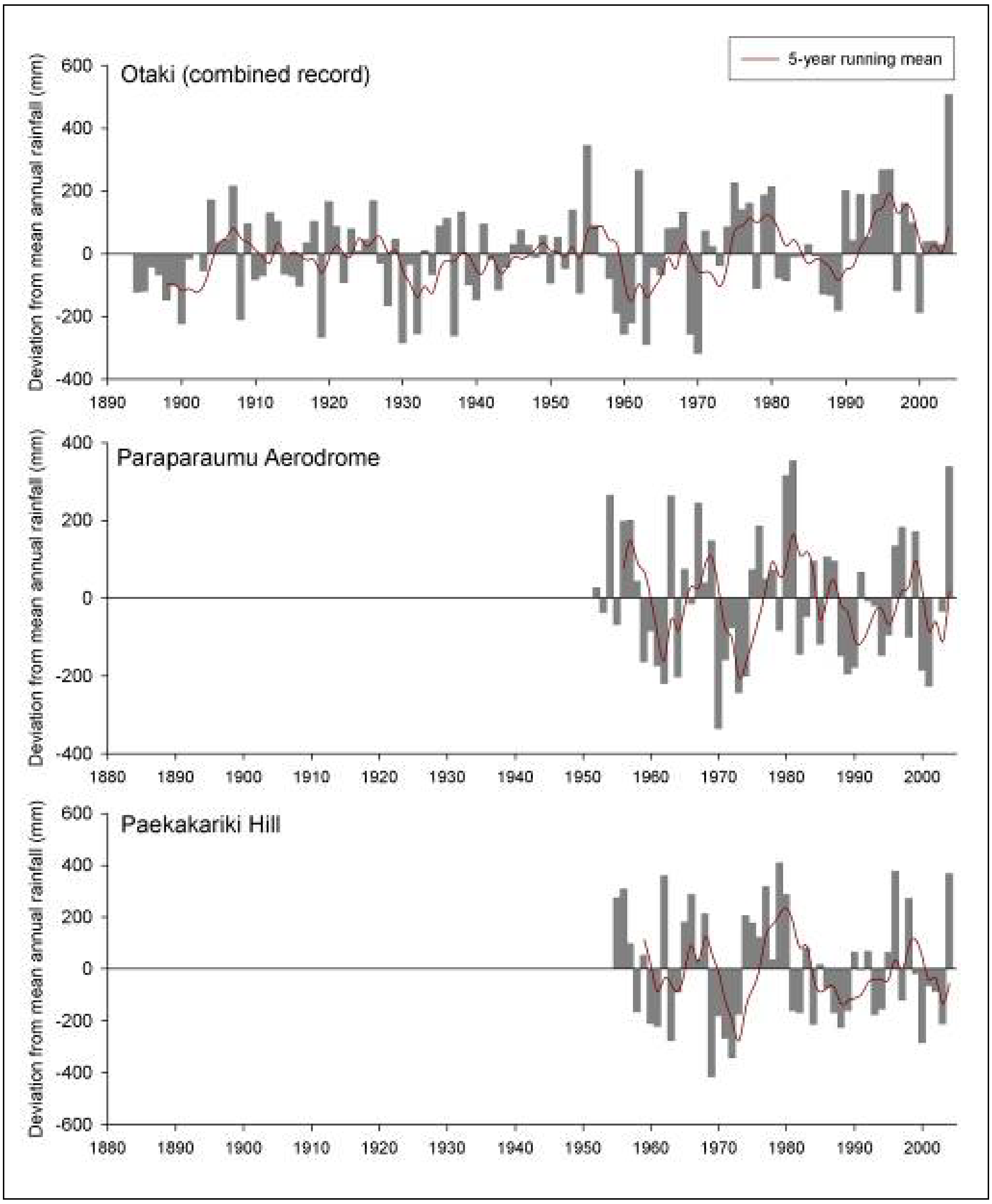


Figure 25: Deviation of annual rainfall from long-term average, Kapiti Coast

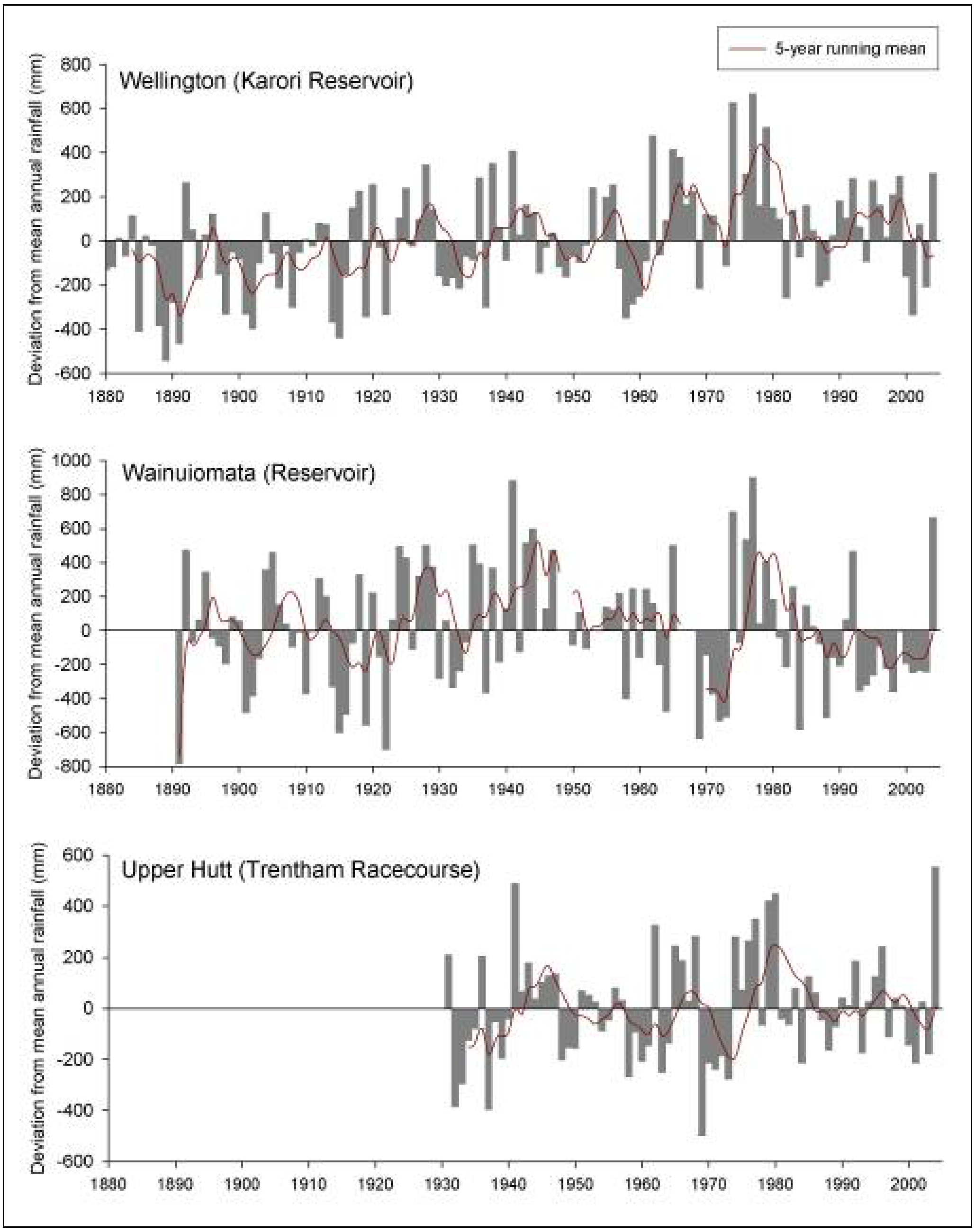


Figure 26: Deviation of annual rainfall from long-term average, central Wellington Region

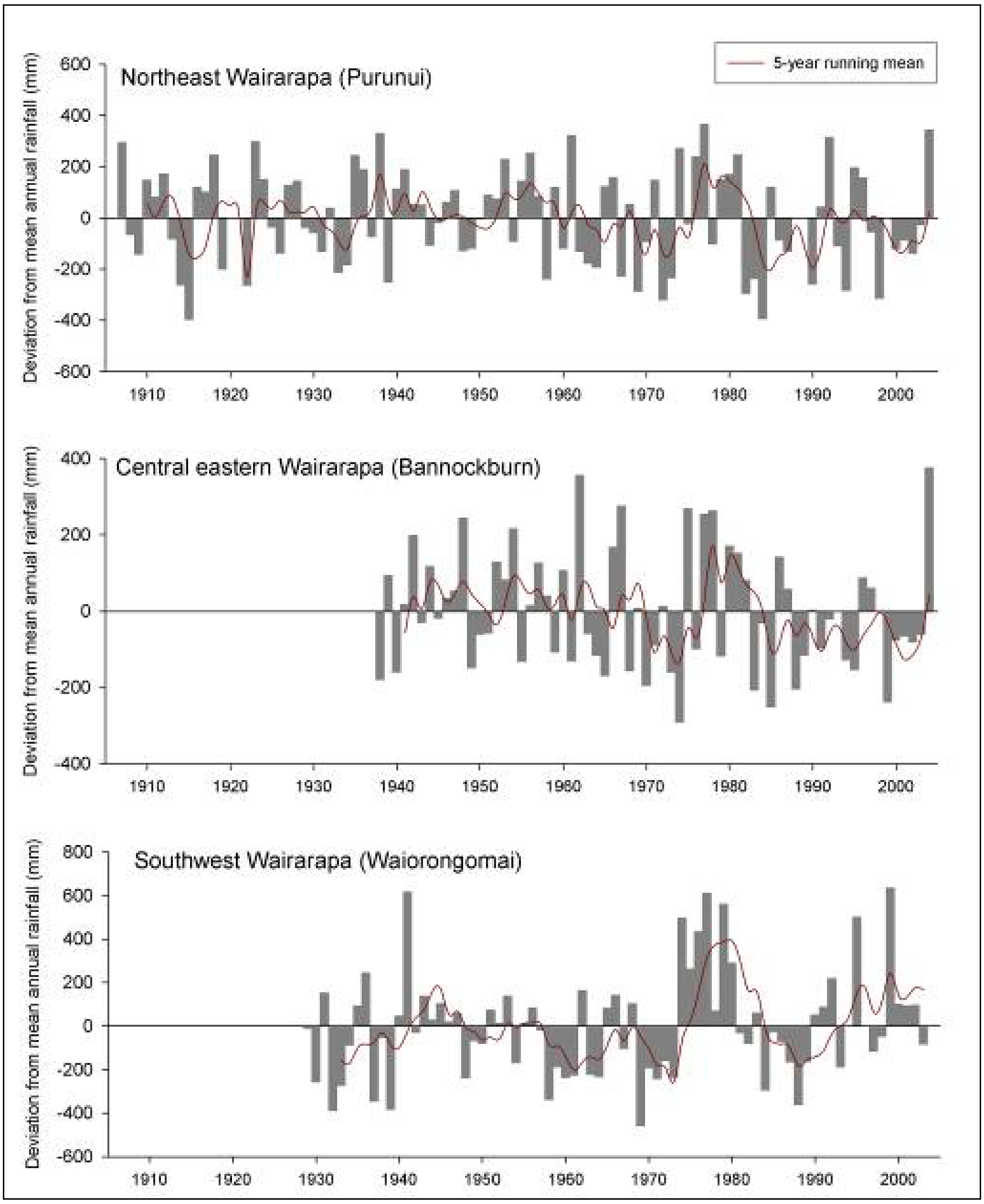


Figure 27: Deviation of annual rainfall from long-term average, Wairarapa[16]

[16] Note that 2004 rainfall total for Waiorongomai is not shown

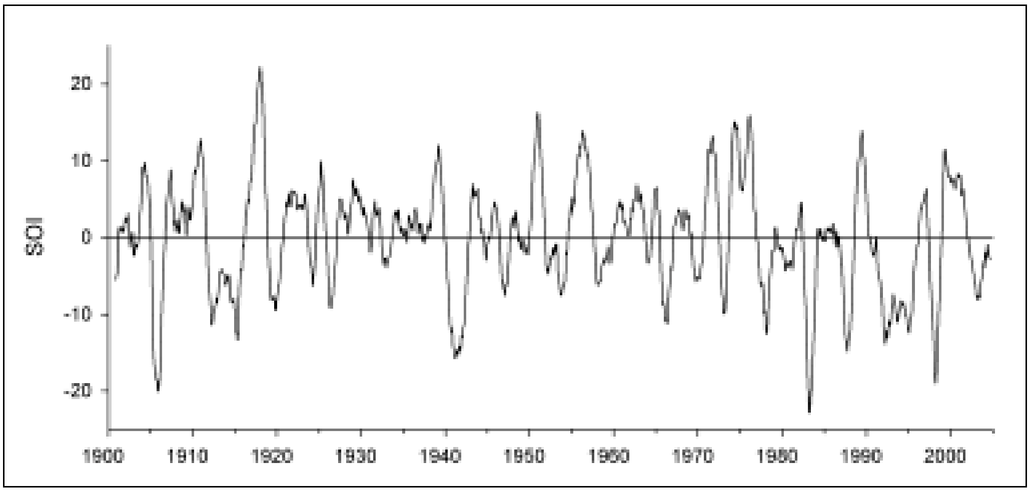


Figure 28: 1-year running averages of the Southern Oscillation Index (SOI). Positive values indicate La Nina, negative values indicate El Nino.

The plots of annual rainfall deviation highlight the wet and dry phases, and the degree of interannual variability in rainfall. To better show any long-term patterns of change in the rainfall records, the cumulative deviation of annual rainfall from average over the length of the record is plotted (known as a CUSUM). This type of graph essentially exaggerates shifts from the baseline therefore highlighting periods when annual rainfall is increasing or decreasing. Figure 29 shows the CUSUM of annual rainfall for the station with the longest rainfall record from each sub-region, with both *Karori Reservoir* and *Wainuiomata Reservoir* shown to represent central Wellington. The plots show:

- The Kapiti Coast experienced a ‘dry trend’ (annual rainfall trending below average) from the start of record at *Otaki* (1893) through until the 1970s. Since that time the Kapiti Coast appears to have been in a ‘wet trend’ (rainfall in surplus compared to mean annual rainfall).

- Annual rainfall in western central Wellington (*Karori Reservoir*) trended below average from the start of record (1880) until about 1920. For the next 40 years rainfall fluctuated fairly steadily around the mean, until a wet trend began in the 1960s, which is particularly obvious from the mid-1970s. Rainfall records from the Hutt Valley and western parts of the Wairarapa (e.g. *Waiorongomai*) follow similar trends.

- Eastern central Wellington (*Wainuiomata Reservoir*) had a general trend of increasing rainfall from the 1920s through until the 1970s. Since about 1980 there has been a tendency toward below average rainfall.

- In eastern parts of the Wairarapa annual rainfall follows a similar pattern to that of *Wainuiomata Reservoir*. Annual rainfall trended above average from the 1930s until about the 1960s, and has tended to be below average since the early 1980s and in particular since the mid-1990s.

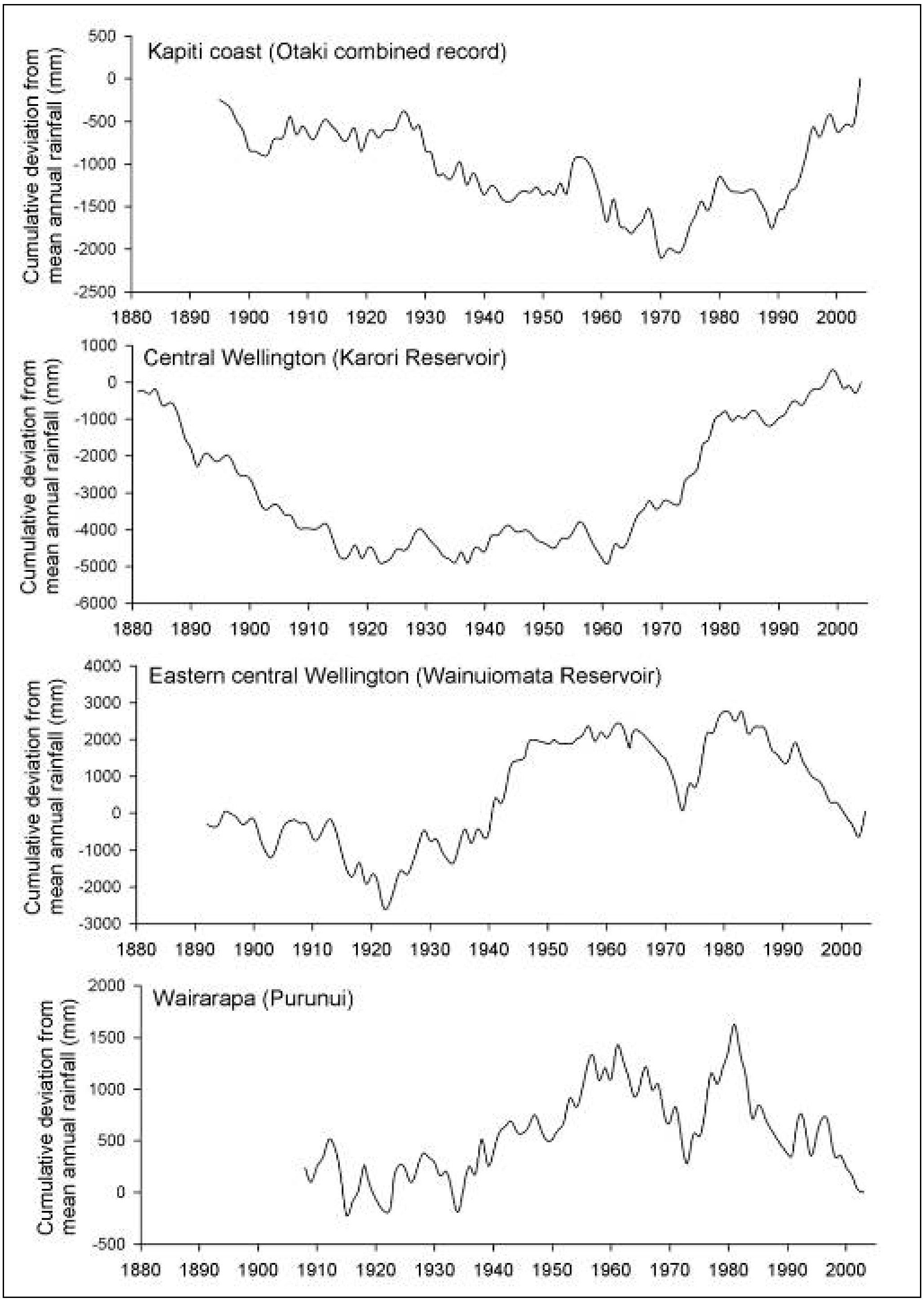


Figure 29: Cumulative sum of annual rainfall deviance from average for the longest rainfall records in the Wellington Region[17]

[17] Note that the y-axis scale in the CUSUM plots are to some extent irrelevant for the purpose of this analysis.

The CUSUM analysis highlights the effect of the IPO on Wellington's climate. In particular, the tendency towards westerly flows since the mid-1970s (when the IPO shifted to a positive phase) has resulted in a general trend toward above average rainfall in Kapiti Coast, Wellington City, Hutt Valley, and southwest Wairarapa (despite annual rainfall being below average in many parts of the region during the first five years of the reporting period). Over the same time there has been a trend toward below average annual rainfall in the Wairarapa and eastern parts of central Wellington that are to some extent sheltered from westerly flows.

6.3 Droughts and low flows

Analysis of trends and variability in droughts and low flows is important for assessing future water availability, to ensure the needs of future generations are provided for in a sustainable way. The indicators of drought and low flow used in this analysis are: annual 7-day flow minima, number of days per year with rainfall, and dry spell duration.

To assess if low flows in our rivers are changing over time, annual 7-day flow minima are plotted for representative river flow stations with the longest records (Figure 30 to 32). Although these graphs show that low flows vary from year to year, none of the records show a significant long-term trend in low flow magnitude. The results are consistent with the analysis of McKerchar & Henderson (2003), which found no significant increase or decrease in low flow magnitude in North Island records.

The graphs of 7-day low flows also show that the flows during the reporting period (1999-2004) were within the expected range. Despite the high return periods assigned to some of the low flows in Table 4, the flows were not *significantly* lower or higher than low flows experienced in the past.

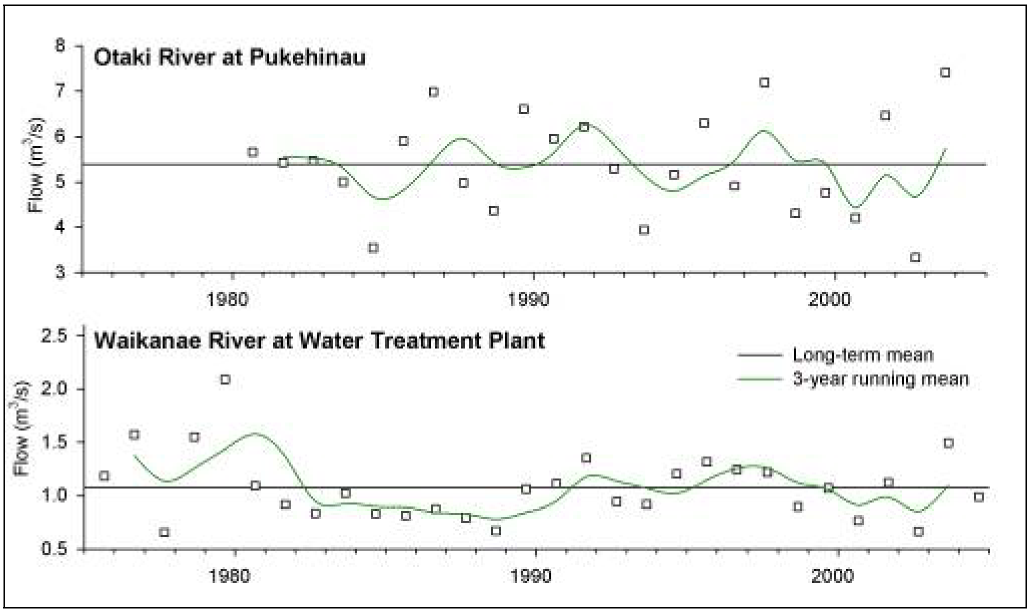


Figure 30: 7-day annual low flows at selected river flow monitoring stations, Kapiti Coast

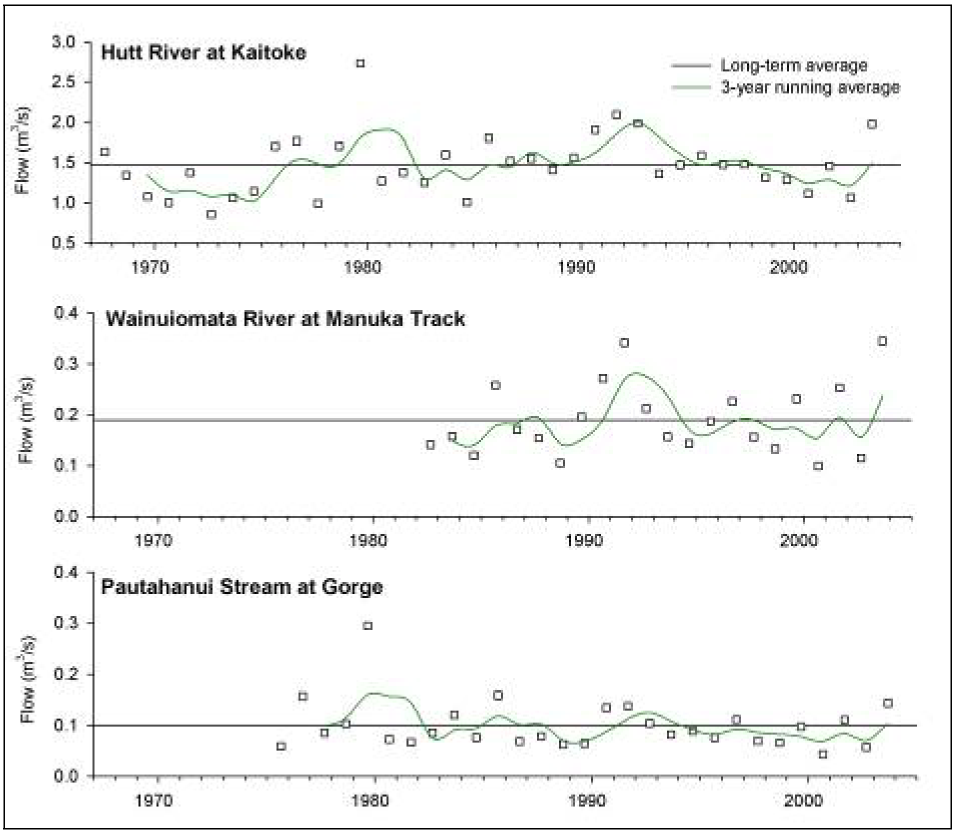


Figure 31: 7-day annual low flows at selected river flow monitoring stations, central Wellington Region

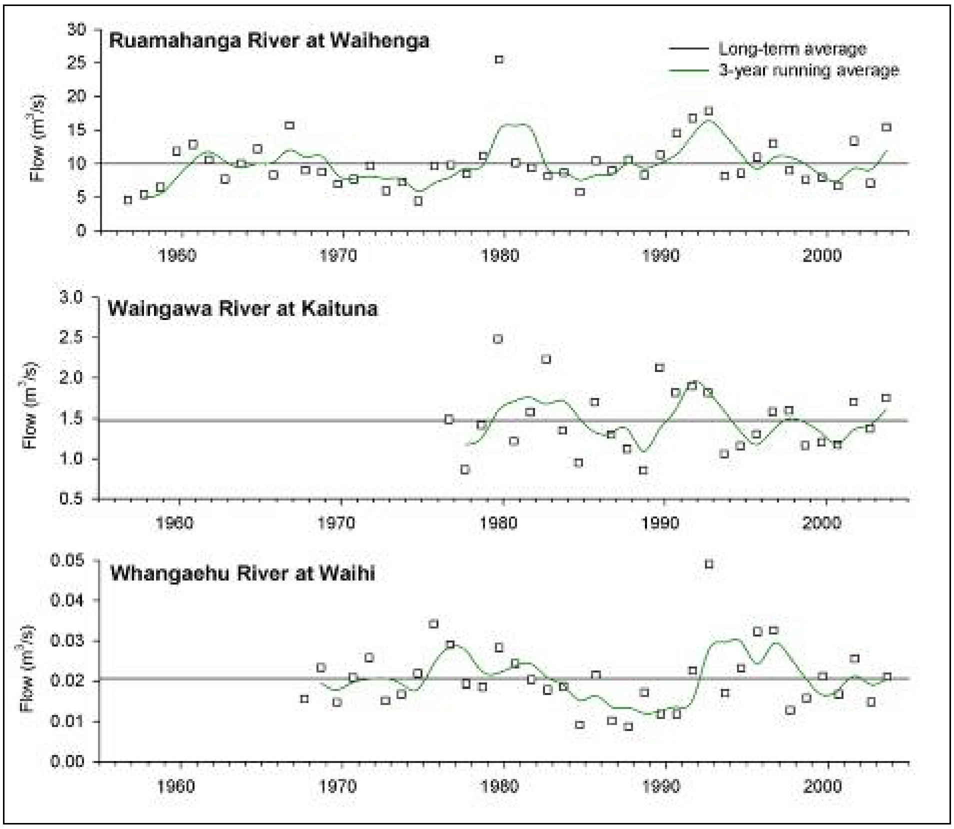


Figure 32: 7-day annual low flows at selected river flow monitoring stations, Wairarapa

A rainfall indicator of drought or low water availability is the number of days per year with rainfall. A number of sites in the Wellington Region show a trend of decreasing number of days per year with rainfall (some of which are shown in Figure 33 and 34). A Mann-Kendall trend test found that the decrease over the length of record is significant (to a confidence level of 99%) for the records of *Karori Reservoir*, *Wallaceville*, *Otaki* (combined record), *Paraparaumu Aerodrome*, *Bagshot* and *Hikawera*. *Wainuiomata Reservoir* shows a significant decrease since the mid-1920s. Rainfall records from northeast and east coast Wairarapa (*Purunui*, *Fernglen* and *Te Wharau*) show an increase in the number of rain days per year particularly since about 1990, after a decrease in the 1970s.

The trend towards decreasing number of days per year with rainfall in many parts of the region, which has occurred particularly since about 1980, coincides with the phase of increased westerly flows over New Zealand. Within this period there has been a trend towards more anticyclones over northern New Zealand; anticyclones generally suppress rainfall and, in particular, days of light rainfall. The recent increase in days per year with rainfall in eastern Wairarapa could be a result of the possible shift of the IPO to a negative phase, promoting easterlies and hence more frequent rainfall in eastern Wairarapa (Salinger, 2004).

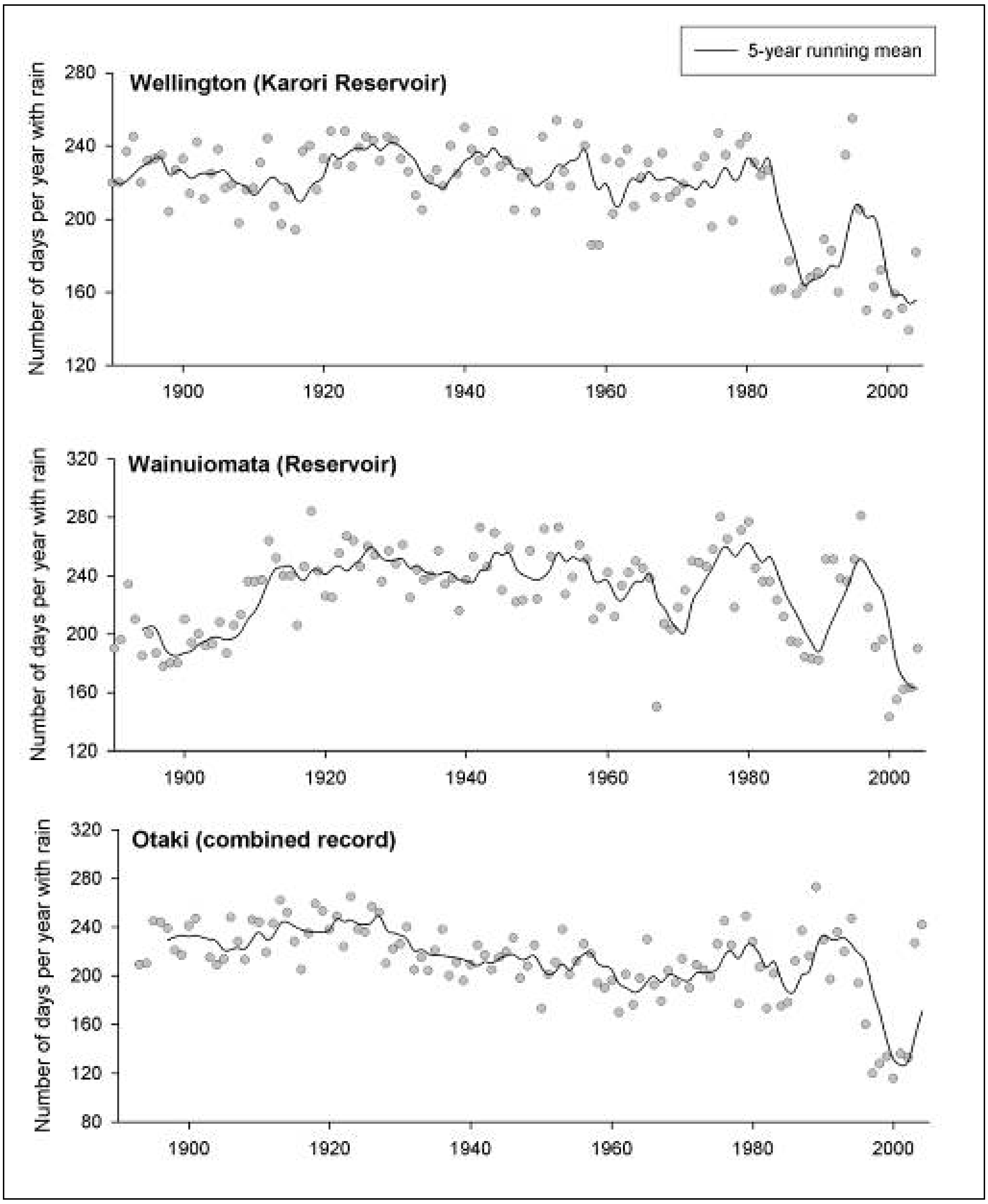


Figure 33: Number of rain days per year, central Wellington Region and Kapiti Coast

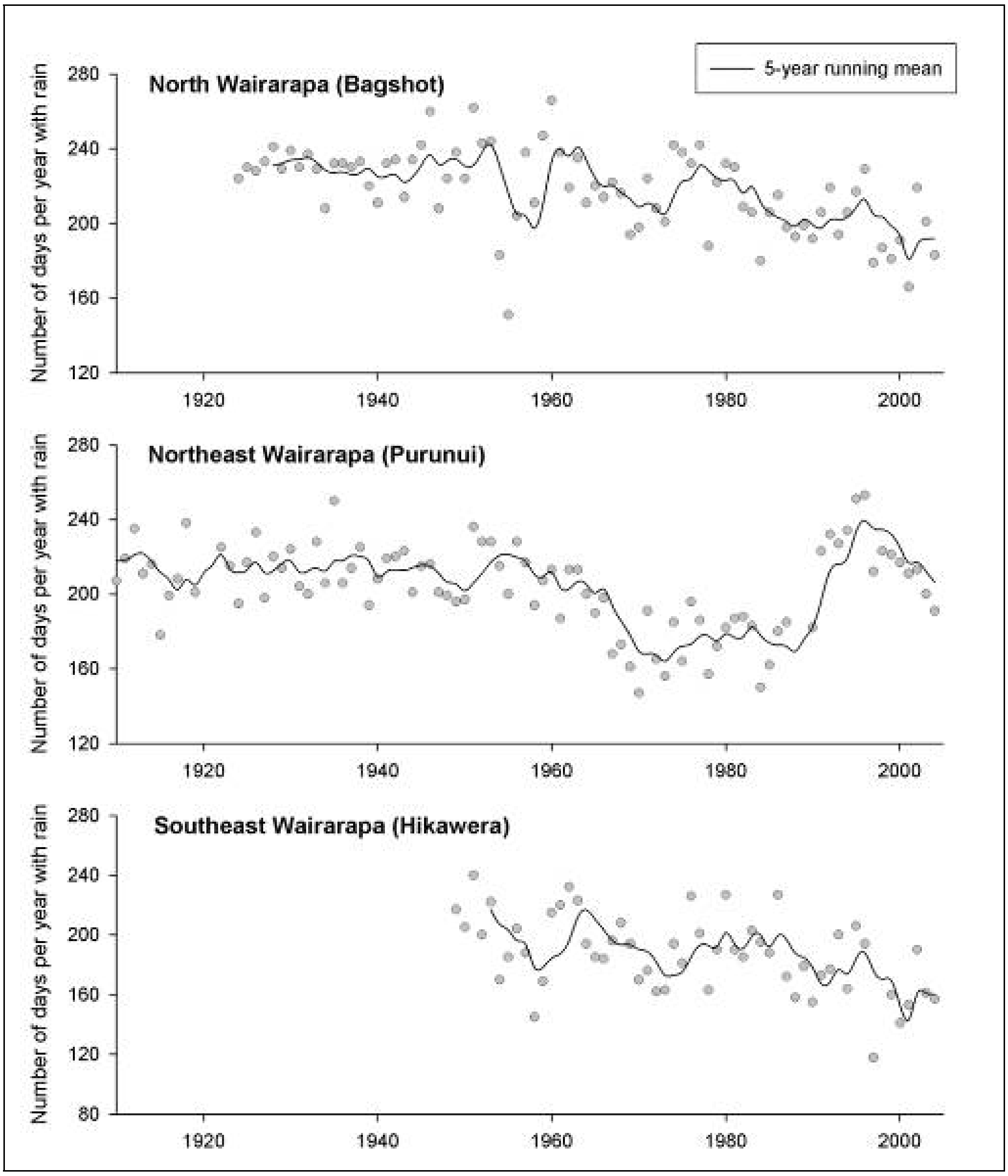


Figure 34: Number of rain days per year, Wairarapa

To assess if the length of dry spells is changing, Salinger and Griffiths (2001) looked for trends in the number of consecutive days per year with rainfall less than 1 mm, at three sites in the Wellington Region (in Masterton, Paraparaumu and Wellington City). They found that the only significant trend was an increase in the length of dry spells in Wellington City, a trend that appeared to begin in about 1980. This coincides with the start of a significant decrease in the number of days per year with rainfall at *Karori Reservoir* (Figure 33). Once again, the increasing length of dry spells since about 1980 is probably a result of the trend toward more anticyclones that has occurred under the recent positive phase of the IPO.

6.4 Extreme rainfall and floods

Detection of trends in the magnitude and frequency extreme rainfall events and floods is important for mitigating flood hazard. Previous studies have detected changes in rainfall extremes and flood regimes in New Zealand over the last century (Salinger & Griffiths, 2001; McKerchar & Henderson, 2003). To determine if there are any changes in the Wellington Region, the following indicators are used:

- Number of days per year with significant rainfall;
- Annual maximum daily rainfall;
- Number of floods per year; and
- Annual maximum flood.

There were no consistent region-wide trends in the number of days per year with 'significant' rainfall (greater than 20 mm). However, the records from *Karori Reservoir*, *Otaki*, and *Waiorongomai* show a general increase particularly since the mid-1970s (Figure 35). The analysis indicates that extreme rainfall events are becoming more frequent in the western parts of the region (Kapiti Coast, western central Wellington Region, and southwest Wairarapa). The trend is not apparent in eastern Wairarapa or in eastern parts of central Wellington.

The areas which show an increase in the number of days per year with significant rainfall receive their main rainfall from southerly, northwesterly and southwesterly synoptic scale events. The fact that days of significant rainfall have increased suggests more of these events – which is supported by the fact that westerly flows have been more predominant under the last positive IPO phase. For Wainuiomata and eastern parts of the Wairarapa, the most significant rainfall tends to occur from southeasterly events; the evidence suggests that this pattern has not changed (Salinger, 2004).

The records which display an increase in the number of days with significant rainfall also show an increase in the annual maximum daily rainfall (Figure 36). At *Karori Reservoir* the annual maximum daily rainfall has increased by 80% over 125 years, at *Otaki* it has increased 70% over 112 years, and *Waiorongomai* has seen an increase of 60% over 75 years. However, the increase is particularly apparent since the 1990s. All other Wairarapa rainfall records display a trend of overall decreasing annual maximum daily rainfall, particularly since the late 1970s.

The trend indicates that rainfall events appear to be becoming more extreme in the west of the Wellington Region yet less severe in the east. Once again, the enhanced westerly flows since the 1970s partly explain why there is a west/east difference in trends, which is consistent with the conclusions of Salinger & Griffiths (2001). The increased intensity of rainfall events in the west may also be a result of a warmer atmosphere that can hold more moisture: temperatures have increased by 1°C over the last century (Salinger, 2004). Some of this temperature rise may be related to increased concentrations of greenhouse gases in the atmosphere.

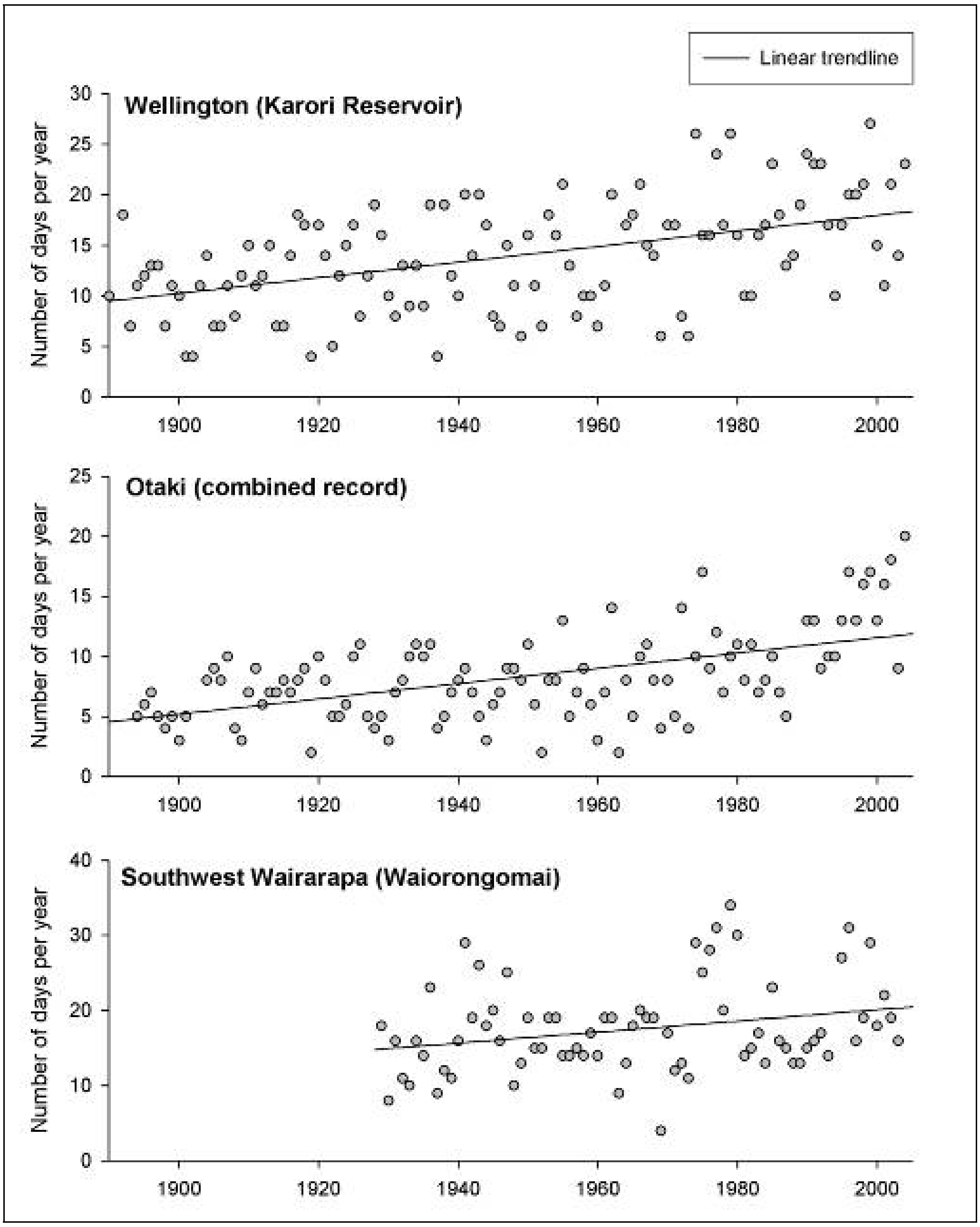


Figure 35: Number of days per year with significant rainfall (greater than 20mm) at selected rainfall stations

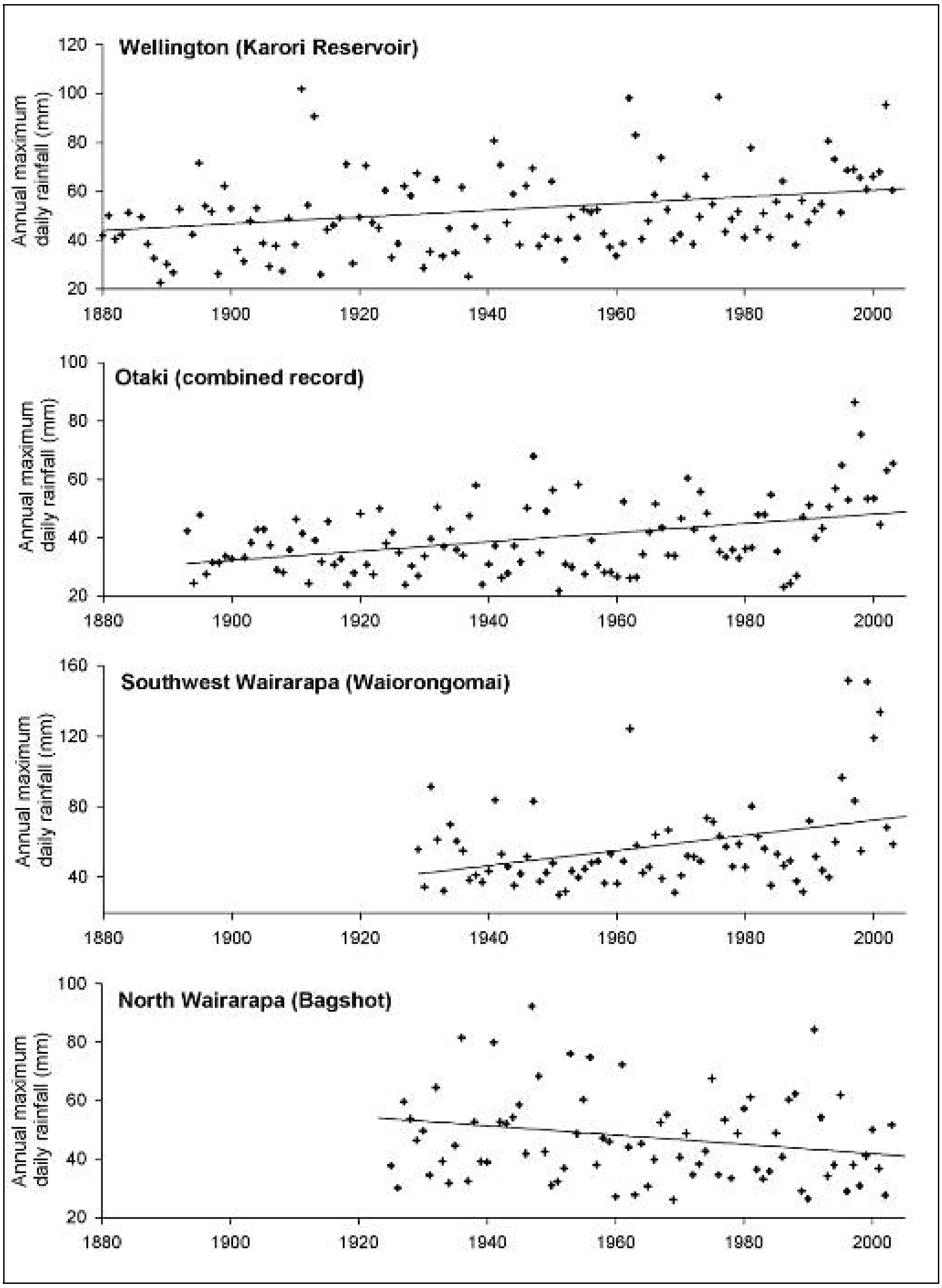


Figure 36: Annual maximum daily rainfall trends at selected rainfall stations

Analysis of flood records similarly showed changes in some places but not in others. Statistically significant trends of increasing number of floods per year were detected in the records of Hutt River at Kaitoke and Ruamahanga River at Wardells (both to a 95% confidence level), and Porirua Stream at Town Centre (to an 80% confidence level) (Figure 37). The increase in flood frequency in these catchments is consistent with the general increase in the frequency of significant rainfall observed in western areas particularly since the 1970s. It is assumed that the rainfall trend is the same for the Tararua Range (which will affect flood flows in the Ruamahanga River at Wardells).

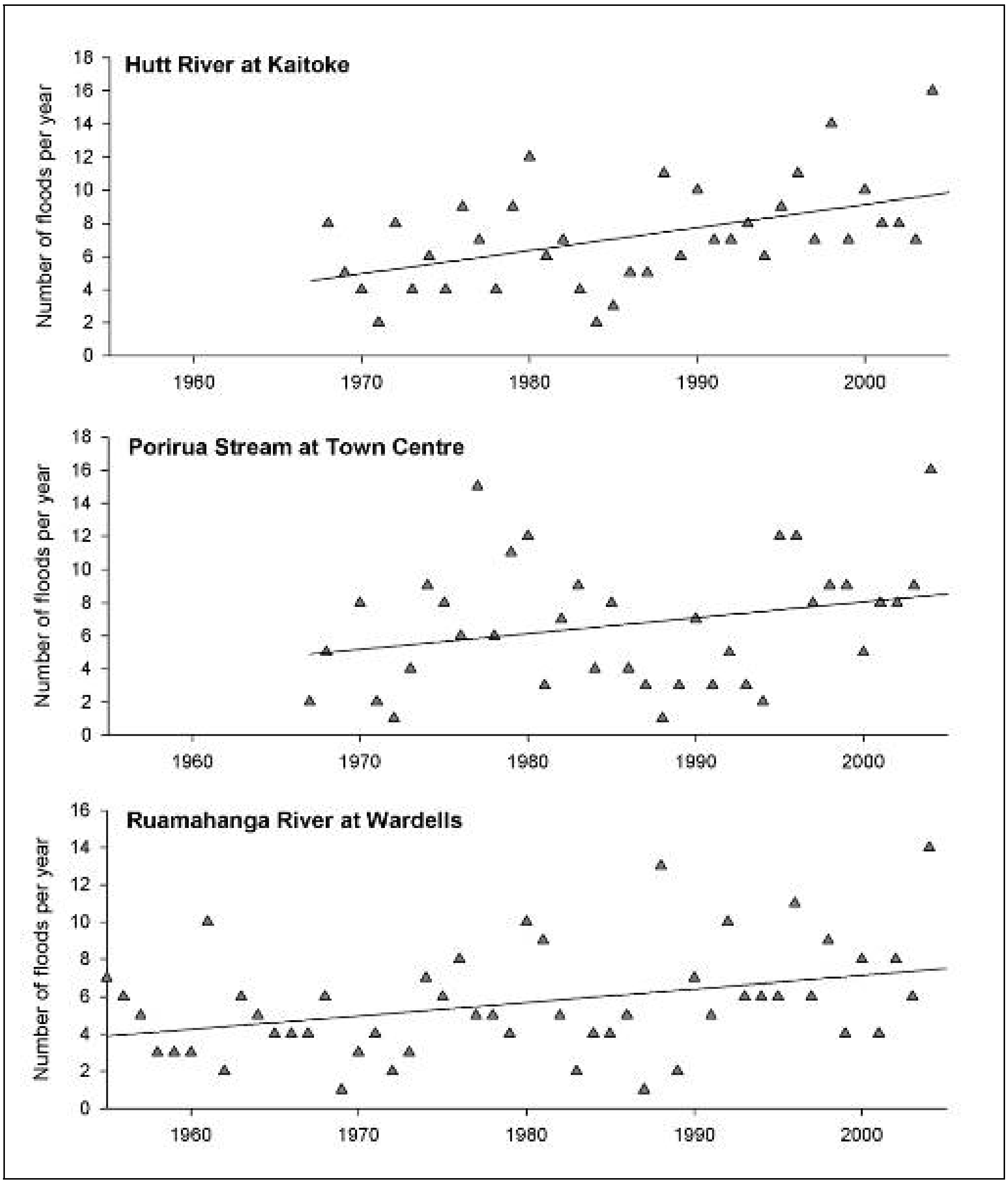


Figure 37: Trends in number of floods per year for selected rivers in the Wellington Region

No changes in flood frequency in the Otaki and Waikanae Rivers were observed, despite the increase in frequency of days with significant rainfall in Otaki. The lack of an observed increase may be due to the relatively short records of these rivers; i.e. the flood records begin after the switch to the positive IPO phase in the mid-1970s.

There were no statistically significant changes in flood frequency in eastern areas, although the Tauweru and Whareama flood records showed a slight decrease in flood frequency since about 1980. The higher flood frequency in these rivers in the early 1970s reflects the enhanced easterly conditions associated with the negative IPO phase at that time, and the decrease in floods since the early 1980s coincides with the period of enhanced westerly flows (from which eastern Wairarapa catchments are sheltered).

There were no region-wide trends in annual flood magnitude. However, an increase in flood size was noted in the Hutt River (at both Kaitoke and Birchville) and the Ruamahanga River (at both Wardells and Waihenga) (Figure 38). The trend of increasing flood magnitude in these rivers is consistent with the trend of increasing annual maximum daily rainfall in western areas (and presumably the Tararua Range) particularly since the late 1970s. In the Ruamahanga River at Wardells, which has the longest complete flood record of the region, the annual maximum flood for the period 1978-2004 was approximately 25% greater than the mean annual flood prior to 1978. McKerchar & Henderson (2003) found similar increases in flood magnitude post-1978 in the south and west of the South Island, which they attributed to the shift in the IPO.

The lack of a significant increase in flood size in the Kapiti Coast rivers, despite the observed increase in maximum daily rainfall at Otaki, is probably due to the relatively short records for these rivers. None of the eastern Wairarapa Rivers display a have had a significant change in annual maximum flood size.

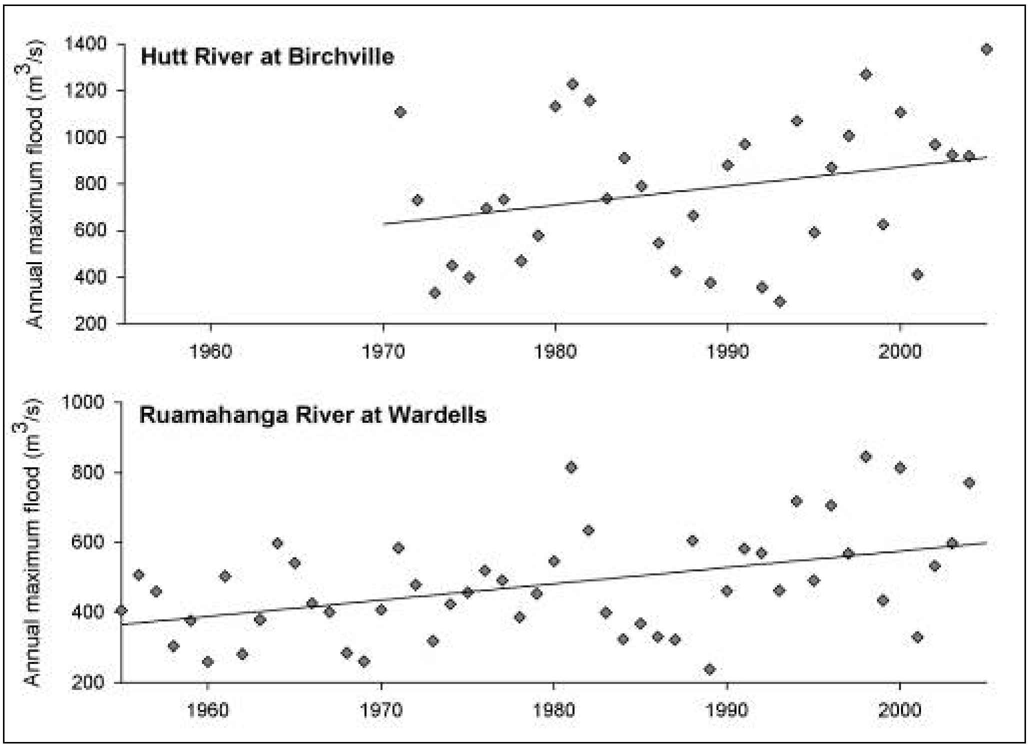


Figure 38: Trends in annual maximum flood series for selected rivers in the Wellington Region

6.5 Summary points

- Annual rainfall is highly variable, and is affected by cycles such as the ENSO. Although annual rainfall totals in the reporting period were generally below average (with the exception of 2004) and were notably lower than in the mid to late 1970s, there have been several phases of lower rainfall throughout the last century.

- Although 2004 was regarded as a wet year, the annual total was generally not *significantly* higher than other annual totals on record, although in many parts of the region it was one of the wettest years of the last century.

- Low flows during the reporting period were also not particularly unusual. Although some of the low flows experienced were assigned high return periods, the flows recorded were generally not significantly lower than past low flows.

- The analysis of the longest rainfall and flood records for the region showed the following trends, particularly since the mid to late 1970s:

  - A tendency toward above average annual rainfall in western areas, including Wellington city, Kapiti Coast, Hutt Valley and western Wairarapa;

  - A tendency toward below average annual rainfall in eastern areas (eastern Wairarapa and the Wainuiomata and Orongorongo catchments);

  - An increase in the number of days per year with significant rainfall and an increase in the annual maximum daily rainfall in parts of the region that received rainfall from westerly type events;

  - An increase in flood frequency and flood magnitude in the Hutt and Ruamahanga Rivers;

  - A decrease in annual maximum daily rainfall in some parts of northern and eastern Wairarapa, and a general (non-significant) decrease in flood frequency in some eastern Wairarapa rivers; and

  - Overall a decline in the number of days per year with rainfall, particularly in the west of the region, but a recent increase in rain days in eastern (coastal) Wairarapa.

- The above trends indicate that the enhanced westerly conditions, more frequent El Nino events, and more frequent anticyclones since the 1970s (attributable to the positive IPO phase) have caused more frequent extreme rainfall events and floods, a tendency toward above average annual rainfall, but also more settled conditions between extreme rainfall events in western parts of the region. In the east rainfall has been below average and the frequency of extreme rainfall events has not significantly changed.

- It is possible that these trends will be reversed if the IPO has shifted to a negative phase of the IPO, under which easterly conditions are enhanced and La Nina become more prominent.

- The pressures of land use change and abstraction are likely to have had an impact on low flow duration and severity in some parts of the region, and land use change may also have affected flood regimes. However, insufficient data is available to quantify these impacts on a region-wide basis.

7. What are we doing?

In this report the pressures on surface water quantity in the Wellington Region were discussed, and patterns and trends in water availability were investigated. Some of the information gaps, and Greater Wellington's response to the pressures on water quantity, are described in this section.

7.1 Predicting impacts of natural climate variations

The impacts of natural climate cycles on Wellington's water resources are significant. In particular, in this report recent phases of low rainfall and river flows were attributed to El Nino and La Nina episodes, and long-term patterns in rainfall and river flows were linked to the IPO.

Although El Nino and La Nina do not always lead to drought, and droughts can occur under neutral conditions, positive correlations between both El Nino and La Nina and low rainfall or river flows in the Wellington Region have been found to exist. Warning of a potential drought can help alleviate the pressure on water resources, as water supply managers can plan for a worst case scenario. Greater Wellington has developed drought predictive models that use the Southern Oscillation Index as an indicator of a potential drought (for example Harkness, 1999). Although these models require ongoing testing they provide the best possible method for giving advanced warning of a drought in the Wellington Region.

The potential hydrological impacts of a shift in the IPO were outlined in Section 2.1.3. Greater Wellington will continue following the results of global monitoring programmes, which will confirm if there is a shift occurring. Knowledge of how the IPO affects Wellington's rainfall and river flows, as described in Chapter 6, will help us predict what is likely to happen under a negative IPO phase.

7.2 Managing abstractive demand

Many waterbodies in the Wellington Region were found to be under pressure from abstraction. The responses of Greater Wellington to reduce the pressure from abstraction on surface water quantity include the following policies and methods, as outlined in the Regional Freshwater Plan:

- Core allocations and minimum flows for certain rivers and streams (Policy 6.2.1);
- Target levels for Lake Wairarapa;
- Priority of abstraction for public water supply over abstraction for other uses (Policy 6.2.5);
- Maximum allocation of water for irrigation (350 m^3/ha/week) (Policy 6.2.6);

- Encouragement of the use of groundwater as an alternative to surface water (Policy 6.2.7); and

- Collection of information to establish minimum flows for water bodies where there is potential for water shortages to occur (Method 8.5.5).

Core allocations and minimum flows for some of the region's rivers are specified in the Regional Freshwater Plan. However, many of the waterbodies from which water is taken do not currently have minimum flows in the Plan. In fact, most of the catchments deemed to be under pressure from abstraction (see Section 2.4.1) do not have core allocations or minimum flows in the Plan. Although these catchments may have unofficial minimum flows which are used when setting conditions on resource consents, often the flows are based on historical flow analyses rather than studies of the flow requirements to sustain instream values.

To ensure that abstraction is not adversely affecting our rivers and streams, Greater Wellington has a programme of investigating flow requirements to sustain the instream values in catchments under pressure from abstraction. Since the last State of Environment Report for the Wellington Region, instream habitat assessments have been carried out on the Wainuiomata River, Hutt River, Waikanae River, Waipoua River, Kopuaranga River, Mangatarere River and Upper Ruamahanga River. However, there are many catchments that still require investigations. Also, additional work is required to determine if the minimum flows already specified in the Regional Freshwater Plan are protecting instream values from adverse effects associated with abstraction.

In some of the region's waterbodies stream flow depletion, caused by groundwater abstractions located near to the river or stream, may have a significant impact on low flows. At this stage, Greater Wellington does not have a strategy for assessing the impacts of groundwater abstraction on low flows, although some stream flow depletion quantification models have been used. Further work is needed to validate such models for use in the Wellington Region, so that policies relating to potential stream flow depletion can be developed.

Much of the demand for water in the Wellington Region, particularly in the Wairarapa, is for irrigation. To ensure that an adequate amount of water is allocated for this use, while preventing water wastage, a maximum irrigation rate (350 m^3/ha/week) is specified in the Regional Freshwater Plan. To help ensure fair and appropriate allocation of water in the future, over the year 2005/06 Greater Wellington plans to develop a tool for estimating crop water requirements based on soil and climate combinations in the Wairarapa.

In this report, the effect of abstraction on low flow duration and severity could not be quantified. This is because Greater Wellington does not require abstraction data from all consent holders. Collection of abstraction data (through improved metering) will allow low flow records for downstream monitoring sites to be naturalised. It will also give a better picture of how actual water use (as opposed to consented use) affects low flow regimes.

7.3 Ongoing hydrological monitoring

In addition to the specific methods mentioned above, ongoing monitoring of rainfall, river flows and lake levels will ensure detection of long-term trends, such as those associated with climate change. Monitoring will also allow adverse effects of abstraction to be avoided by ensuring water restrictions can be implemented prior to river flows reaching specified minimum flows.

The hydrological monitoring programme is reviewed periodically to ensure that the necessary information is being collected to allow Greater Wellington to carry out its functions effectively. A regional review of the hydrological monitoring programme will be completed in 2005. The review will take into account the pressures and information gaps outlined in this report.

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Dr Andy Reisinger (New Zealand Climate Change Office, Ministry for the Environment) kindly reviewed the section on climate change impacts in the Wellington Region.

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Appendix 1: Hydrological monitoring station details

Table 7: Rainfall stations

Site Name	Hilltop number	Climatological network number	Recording authority	Start date
Alloa	1513501		Greater Wellington	01/03/1963
Angle Knob	58403		Greater Wellington	27/12/1974
Bannister	57511		Greater Wellington	30/09/1974
Birch Lane	142918		Greater Wellington	25/04/2001
Blue Gum Spur	150010		Greater Wellington	13/10/1981
Bull Mound	59310		Greater Wellington	23/03/1976
Carkeek	58411		Greater Wellington	30/09/1974
Castlehill	57958		Greater Wellington	10/04/1991
Cemetery	150108		Greater Wellington	29/03/1988
Centre Ridge	151202		Greater Wellington	06/04/1984
Centrepoint	58105		Greater Wellington	18/02/2003
Iraia	153387		Greater Wellington	09/04/1969
Kaitoke Headworks	150201		Greater Wellington	02/01/1991
Kapakapanui	59104		Greater Wellington	06/09/1991
Karori Reservoir	142701		Greater Wellington	2/1/1879
Masterton Office	596461		Greater Wellington	18/08/2000
McIntosh	59201		Greater Wellington	26/09/1981
Mt Bruce	57514		Greater Wellington	30/07/1984
Oriwa	57302		Greater Wellington	08/09/1991
Orongo Swamp	152010		Greater Wellington	03/10/1980
Otaki Depot	57106		Greater Wellington	18/07/1984
Phelps	150303		Greater Wellington	02/01/1974
Regional Council Centre	142720		Greater Wellington	26/07/1996
Seton Nossiter Park	142811		Greater Wellington	06/07/1992
Shandon Golf Course	142813		Greater Wellington	03/04/2000
Sims Road	57003		Greater Wellington	08/02/2003
Snodgrass	140904		Greater Wellington	21/08/2002
Stoney Creek	154427		Greater Wellington	01/02/1969
Tanawa Hut	67153		Greater Wellington	01/01/1956
Tasman Vaccine Limited	152004		Greater Wellington	03/05/1968
Taungata	58201		Greater Wellington	06/09/1991
Te Marua	150109		Greater Wellington	22/07/1993
Te Weraiti	59795		Greater Wellington	09/09/1997
Transmission Lines	58103		Greater Wellington	13/10/1992
Valley Hill	59445		Greater Wellington	21/04/1997
Waihi	58737		Greater Wellington	10/01/2001
Waingawa	58582		Greater Wellington	09/05/1994
Wainuiomata Reservoir	142904		Greater Wellington	1/1/1890
Warwicks	59007		Greater Wellington	16/06/1980
Water Treatment Plant	58004		Greater Wellington	02/08/1969
Waynes Mistake	141813		Greater Wellington	28/03/1984
Whenua Tapu	140806		Greater Wellington	17/04/1991
Castlepoint	69202	D06922	MetService	
East Taratahi	150602	D15062	MetService	
Kelburn	142702	E1527P	MetService	
Ngawi		D15521	MetService	
Paraparaumu Aerodrome	49901	E04991	MetService	
Wallaceville	151003	E15101	NIWA	
Bagshot		D05872	Private (Climate Database)	
Bannockburn		D15161	Private (Climate Database)	

Site Name	Hilltop number	Climatological network number	Recording authority	Start date
Fern Glen		D16101	Private (Climate Database)	
Hikawera		D15262	Private (Climate Database)	
Otaki 1		E05711	Private (Climate Database)	
Otaki Temuera St		E05713	Private (Climate Database)	
Paekakariki Hill		E14091	Private (Climate Database)	
Purunui		D05991	Private (Climate Database)	
Te Wharau		D15282	Private (Climate Database)	
Trentham Racecourse		E15101	Private (Climate Database)	
Waiorongomai	152101	D15211	Private (Climate Database)	

Table 8: Water level monitoring stations

Site Name	Hilltop number	Recording authority	Start date
Whareama at Waiteko	25902	NIWA	09/04/1970
Kaiwhata at Stansborough	26502	NIWA	28/07/1988
Pahaoa at Hinakura	27303	NIWA	04/09/1986
Ruamahanga at Wardells	29201	Greater Wellington	10/11/1954
Ruamahanga at Waihenga	29202	Greater Wellington	31/12/1956
Ruamahanga at Gladstone	29206	Greater Wellington	06/06/1992
Huangarua at Hautotara	29222	Greater Wellington	01/01/1968
Waiohine at Gorge	29224	Greater Wellington	27/12/1954
Kopuaranga at Palmers	29230	Greater Wellington	15/03/1985
Tauweru at Te Weraiti	29231	Greater Wellington	10/12/1969
Whangaehu at Waihi	29244	NIWA	10/05/1967
Waingawa at Upper Kaituna	29246	Greater Wellington	14/05/1976
Ruakokoputuna at Iraia	25250	NIWA	29/05/1969
Tauherenikau at Gorge	29251	Greater Wellington	30/03/1976
Ruamahanga at Mt Bruce	29254	Greater Wellington	01/01/1975
Waipoua at Mikimiki	29257	Greater Wellington	05/02/1979
Orongorongo at Upper Dam Site	29503	Greater Wellington	09/10/1980
Orongorongo at Truss Bride	29507	Greater Wellington	12/03/1998
Wainuiomata at Leonard Wood Park	29605	Greater Wellington	14/04/1977
Wainuiomata at Manuka Track	29606	Greater Wellington	10/06/1982
Hutt at Kaitoke	29808	NIWA	21/12/1967
Hutt at Taita Gorge	29809	Greater Wellington	16/03/1979
Hutt at Birchville	29818	NIWA	07/09/1970
Mangaroa at Te Marua	29830	Greater Wellington	20/05/1977
Hutt at Estuary Bridge	29838	Greater Wellington	28/09/1976
Whakatikei at Dude Ranch	29841	Greater Wellington	08/09/1976
Pakuratahi at Truss Bridge	29843	Greater Wellington	22/05/1978
Akatarawa at Cemetery	29844	Greater Wellington	19/02/1979
Waiwhetu at Whites Line East	29845	Greater Wellington	31/05/1978
Hutt at Te Marua	29853	Greater Wellington	05/03/1984
Mill Creek at Papanui	30516	NIWA	24/04/1969
Porirua at Town Centre	30701	Greater Wellington	08/09/1965
Pautahanui at Gorge	30802	NIWA	30/05/1975
Horokiri at Snodgrass	30912	Greater Wellington	15/02/2002
Taupo at Flax Swamp	31101	Greater Wellington	17/08/1979
Wharemauku at Coastlands	31401	Greater Wellington	16/12/1980
Waikanae at Water Treatment Plant	31504	Greater Wellington	03/03/1975
Mazengarb at Scaife Drive	31522	Greater Wellington	03/05/1995
Mangaone at Ratanui	31720	Greater Wellington	13/01/1993
Otaki at Pukehinau	31807	NIWA	17/07/1980
Waitohu at Water Supply Intake	31907	Greater Wellington	17/10/1994
Otakura at Weir	292069	Greater Wellington	17/12/1997
Mangaterere at Gorge	292243	Greater Wellington	09/02/1999
Lake Wairarapa at Burlings	29209	Greater Wellington	18/09/1953
Lake Onoke at Lake Ferry	29237	Greater Wellington	27/04/1953
Lake Wairarapa at Barrage Gates North	29238	Greater Wellington	01/01/1974
Lake Wairarapa at Barrage Gates South	29239	Greater Wellington	01/01/1974