Long-Term Water Resource Assessment for Southern Victoria

Overview Report

VICTORIA State Government | Environment, Land, Water and Planning

Acknowledgment

We acknowledge and respect Victorian Traditional Owners as the original custodians of Victoria's land and waters, their unique ability to care for Country and deep spiritual connection to it. We honour Elders past and present whose knowledge and wisdom has ensured the continuation of culture and traditional practices.

We are committed to genuinely partner, and meaningfully engage, with Victoria's Traditional Owners and Aboriginal communities to support the protection of Country, the maintenance of spiritual and cultural practices and their broader aspirations in the 21st century and beyond.

Printed by Department of Environment Land, Water and Planning – East Melbourne
ISBN 978-1-76077-923-8 **(Print)**
ISBN 978-1-76077-924-5 **(pdf/online/MS word)**

Accessibility

If you would like to receive this publication in an alternative format, please telephone the DELWP Customer Service Centre on 136186, email customer.service@delwp.vic.gov.au, or via the National Relay Service on 133 677 www.relayservice.com.au. This document is also available on the internet at www.delwp.vic.gov.au and can be accessed during opening hours at DELWP offices across southern Victoria.

Minister's foreword

Water availability has declined across Southern Victoria in recent decades due to a drying climate.

In many areas, this has meant less water for consumptive users and for environmental flows to protect the health of our waterways.

Recognising and responding to these changes is integral to good stewardship of Victoria's natural resources.

The Long-Term Water Resource Assessment for Southern Victoria is one of a number of studies that will be used by the Victorian Government to determine the best approach to managing Victoria's water supplies now and in the future.

It will help inform decisions made by the Victorian Government on how water is shared between consumptive users and the environment.

It is the first comprehensive technical assessment of how surface water and groundwater availability has already changed across Southern Victoria, and the first large-scale effort to assess long-term changes in waterway health due to flow.

The results of the assessment are sobering – but not surprising.

The assessment does more than show the impact of climate on our water resources.

It demonstrates how the Victorian Government's work to provide secure water supplies for communities, farms and the environment has paid off, alleviating some of the more severe impacts of climate change.

For example, the water grid has enabled Geelong and Ballarat to maintain their water security in the face of reduced inflows to local storages. Modernisation works are creating more efficient irrigation systems, generating water savings to support agriculture and provide environmental flows.

In some basins, the long-term decline in surface-water availability has changed how water is shared between consumptive users and the environment.

In the Barwon, Moorabool, Werribee, Yarra and Latrobe basins the decline in long-term surface water availability has not been shared equally. A smaller share of available water is now protected for the environment than when the last Sustainable Water Strategy was developed.

In the Thomson and Maribyrnong basins, how the water supply system is operated influences how it is shared between consumptive users and the environment.

The Long-Term Water Resource Assessment provides a wealth of data and analysis to inform the development of water policy.

Opportunities to restore the balance in how our water is shared in these river basins will be explored through the new Central and Gippsland Region Sustainable Water Strategy, as part of broader planning to improve water security now and into the future.

The new Strategy will consider the values that underpin how we share our water: economic, environmental and social, including for Traditional Owners and recreation.

The assessment was completed in just over 18 months to include time for extensive community consultation, including information sessions in 9 locations across regional Victoria. I thank all the community members and organisations who provided feedback, as well as EPA Victoria for their independent review.

The Hon Lisa Neville
Minister for Water

Contents

List of tables

Table 2: Results of assessment of impacts of licensed groundwater extraction on waterways 62

Table 3: Changes to water-sharing arrangements since SWS 86

Table 4: Long-term surface water availability and sharing, Yarra basin 113

Table 5: Waterway health indicators 130

Table 6: Water available for consumptive use, EWR and total water for the environment, step A 162

Table 7: Water available for consumptive use, EWR and total water for the environment, step B 163

Table 8: Water available for consumptive use, EWR and total water for the environment, step C 164

Table 9: Changes in the proportions of water available for consumptive uses and for the environment, by step 165

List of figures

Acknowledgements

The Long-Term Water Resource Assessment for southern Victoria was undertaken in collaboration with Water Corporations, Catchment Management Authorities and the Victorian Environmental Water Holder.

A Technical Advisory Group provided specialist advice during the development of the method that was used in the assessment. The group comprised of specialists from the University of Melbourne (A/Prof. Rory Nathan and Dr Avril Horne), Latrobe University (Prof Nick Bond), CSIRO (Dr Francis Chiew) and Aquade Groundwater Services (Alan Wade).

The Arthur Rylah Institute (ARI) undertook the waterway health analysis presented in part B of the assessment. The work undertaken by ARI was led by Dr Ashley Sparrow.

The assessment was completed with contributions from external industry specialists, including: Alluvium Consulting, Brad's Water Balance, CDM Smith, DG Consulting, GHD, Hydrology and Risk Consulting, Jacobs, Jenny Hale and Spatial Vision.

Report produced by:

Department of Environment, Land, Water and Planning

Citation

Department of Environment, Land, Water and Planning (2020) Long-Term Water Resource Assessment for Southern Victoria. Melbourne, Victoria

Abbreviations

DELWP	Department of Environment, Land, Water and Planning
D&S	domestic and stock
EPA	Environment Protection Authority (Victoria)
EWR	environmental water reserve
GL	gigalitre
GMA	groundwater management area
ISC	Index of Stream Condition
LTWRA	long-term water resource assessment
ML	megalitre
OCH	Odonata-Coleoptera-Hemiptera
PCV	permissible consumptive volume
SDL	sustainable diversion limits
SWS	sustainable water strategy
VEWH	Victorian Environmental Water Holder
WSPA	water supply protection area

Glossary

Above-cap water	Water that remains in a system after limits on diversions have been reached, spills from storages and unregulated flows that cannot be kept in storage.
Act, the	Unless otherwise stated, the Victorian *Water Act 1989*.
Allocation	Water that is available to water entitlement holders in a given water season under the terms of their entitlement.
Aquifer	An underground layer of rock or unconsolidated material — gravel, sand or silt — that can store and yield vast volumes of usable water.
Availability	Available for allocation for consumptive uses or the environment through the water entitlement framework.
Basin (river basin)	The area of land into which a river and its tributaries drain.
Bulk entitlement	An ongoing right to take and use water, issued by the Minister for Water, to water corporations, the VEWH and other bodies specified in the Act. A bulk entitlement may include conditions and obligations (such as rules about when, where and how much water can be taken and obligations to release passing flows for environmental uses).
Confined aquifer	An aquifer that is overlain by impermeable material that restricts the upward movement of water. Confined aquifers are under pressure: when the aquifer is penetrated by a well, the water rises above the top of the aquifer.
Commercial and irrigation dam	A small dam (usually on a farm) that stores water for irrigation or commercial purposes. A commercial and irrigation dam must have a licence.
Consumptive uses	All uses of water by individuals, households, agriculture, industry and commerce.
Declared water system	A water system declared in accordance with section 6A of the Act. In a declared water system, the old water rights and take and use licences have been converted into unbundled entitlements.
Domestic and stock (D&S) dam	A small dam (usually on a farm) that stores water for stock watering, domestic supply or aesthetic purposes. A D&S dam doesn't require a licence, unlike a commercial and irrigation dam.
Drought refuge	A site that provides permanent fresh water for plants and animals, acting as a refuge when surrounding areas are affected by drought.
Environmental entitlement	An ongoing right to take and use water allocated under part 4, division 1A of the Act to maintain the EWR and so preserve the environmental values and health of water ecosystems.
Environmental water managers	Catchment Management Authorities and Melbourne Water who make decisions about when and how to use environmental water, especially water available under environmental entitlements, in collaboration with VEWH and water corporations.

Environmental water reserve (EWR)	Water set aside for the environment under part 4A of the Act as an environmental entitlement, through the operation of conditions on any bulk entitlement, licence, permit, authority or management plan or via other provisions in the Act. The EWR helps preserve the environmental values and health of water ecosystems including their biodiversity, ecological functioning and water quality, and other uses that depend on environmental condition.
Flow	Water moving in a waterway.
Flow regime	The patterns of flows that change over time and which are characterised by the magnitude, timing, seasonality, frequency and duration of the flow. The main components of the flow regime are cease to flow, low flow, fresh, high flow and overbank flow.
Groundwater	Water stored in aquifers.
Groundwater availability	The ability of an aquifer to supply water to consumptive users and the environment.
Groundwater management area (GMA)	An area that defines the extent and depth of aquifers which contain usable quantities of groundwater and are currently, or have potential to be, developed by licensed users. A GMA has PCVs set and may be declared as a water supply protection area under the Act.
Groundwater management plan	A plan developed with the community, groundwater users and other stakeholders that defines rules to meet the management objectives of a GMA. A groundwater management plans are a requirement for water supply protection areas under the Act.
Index of Stream Condition (ISC)	An integrated measure of river condition used in Victoria that provides information about five key aspects of river condition: hydrology, streamside zone, physical form, water quality and aquatic life. This information is combined to give an overall measure of environmental condition.
Interception activity	An activity that intercepts surface water or groundwater that would otherwise flow, directly or indirectly, into a waterway or storage.
Millennium Drought	The drought in Victoria that began with low rainfall in late 1996 and ended in 2010, which resulted in the lowest inflows on record into many of the region's catchments.
Minister	The Minister for Water who administers the *Water Act 1989*.
Passing flows	The minimum flows an entitlement holder must pass at a weir or reservoir before taking water for other purposes. Passing flow requirements are specified as obligations in entitlements, and entitlement holders must report on their compliance with these requirements.
Permissible consumptive volume (PCV)	The total amount of water the Minister declares can be taken in a specified area or water system.
Shared benefits	Shared benefits are achieved when water is managed primarily to meet the needs of the entitlement holder, but also provides secondary benefits through decision-making that deliberately targets other outcomes.

State observation bore network	A network of over 2,500 groundwater bores, the primary purpose of which is to collect groundwater data. This data is used to inform the condition of the resource and to manage groundwater.
Surface water	Water found on the surface of the land in waterways (such as in rivers, wetlands and estuaries) and in bodies of water (such as lakes, dams and reservoirs).
Surface water availability	Water in waterways and in bodies of water that can be allocated under Victoria's water entitlement framework to consumptive users or to the environment.
Sustainable diversion limit (Victorian winter-fill SDLs)	The maximum volume that can be diverted from a catchment during July–October, to protect the environmental values of the catchment's waterways. Winter-fill SDLs are included in the Minister's policies for managing take and use licences, which help rural water corporations make decisions about take and use licences.
Sustainable water strategy (SWS)	A document developed through a process which is part of the long-term, statewide water planning required by the Act. An SWS identifies and manages threats to the supply and quality of a region's water resources, and it identifies ways to increase the volume of water for the environment.
Take and use licence	A fixed-term entitlement to take and use water from a waterway, runoff dam, spring, soak or aquifer. The Minister sets conditions on these licences. Take and use licences are typically the entitlement held by diverters on unregulated waterways. Sometimes these licences are referred to as 'Section 51 licences' — a reference to the relevant part of the Act.
Unbundling	A process by which an entitlement previously called a water right (or a take and use licence in a declared water system) is converted into three separate entitlements: a water share, a delivery share or extraction share in a works licence, and a water-use licence.
Unconfined aquifer	An aquifer where the upper groundwater surface — water table— is at atmospheric pressure.
Unincorporated area	Areas outside of a GMA.
Victorian aquifer framework	A state-wide interpretation of hydrogeological formations into 15 aquifers. The aquifers are grouped into upper, middle, lower and basement.
Victorian Climate Initiative	A three-year research program funded by the Victorian Government to improve understanding of past, current and future climate influences on the state. The initiative published its final report in August 2017, and new research is being undertaken through the Victorian Water and Climate Research Initiative.
Victorian Environmental Water Holder	An independent statutory body responsible for holding and managing Victoria's environmental water entitlements.
Water entitlements	Bulk entitlements, environmental entitlements, water shares and take and use licences.

Water grid	Victoria's water grid connects sources of water via a network of natural and built infrastructure to meet the demand for water for people, industries and the environment. The water grid also incorporated the arrangements by which water can be purchased and sold through the water markets and allocated through the water entitlement framework.
Water measurement information system	The primary access point to search, discover and download surface water (water level, flow and water quality) and groundwater (water level and water quality) monitoring data. See www.data.water.vic.gov.au.
Water share	An ongoing entitlement that authorises the taking of water under a water allocation for the share during a water season.
Water supply protection area (WSPA)	An area declared under the Act to protect the groundwater or surface water resources through the development of a groundwater management plan. A water supply protection area is one type of groundwater management unit: a GMA is the other type.
Water year	12-month period comprising 1 July, for any given year, to 30 June of the following year. The water year is designated by the calendar year in which it starts. Thus, the year ending June 30, 2017 is called "2016" water year.
Watertable	The surface of groundwater nearest to the natural surface, which occurs in an unconfined aquifer or an outcropping area of a confined aquifer.
Waterway	Rivers, their associated estuaries and floodplains (including floodplain wetlands) and non-riverine wetlands. The use of the term 'waterways' in the assessment does not replace other important definitions of the term (e.g. the specific definition in the Act).
Waterway health	A general term for the overall condition of key features and processes that underpin functioning waterway ecosystems. It is made up of many components which are influenced by flow in different ways. For the assessment's purposes, it is considered to comprise particular ecological characteristics (such as the presence, abundance and diversity of species, habitat condition and extent, feeding and breeding opportunities, and water quality). There is no precise definition of 'waterway health' in the Act.

At a glance

About the southern Victoria long-term water resource assessment

Water is limited, so under the Act the Minister for Water manages how surface water (water that flows along our waterways and into and out of dams and reservoirs) and groundwater (water stored underground in aquifers) is shared between users.

Water-sharing arrangements need to be kept up-to-date. Long-term water resource assessments (LTWRA) see if long-term water availability has declined since the last sustainable water strategy and if there have been changes in how water has been shared between the environment and consumptive uses – which includes water for farms, industry, cities and towns. It also looks to see whether any changes in the health of our waterways since the sustainable water strategies are due to changes in the flow regime. The findings from a long-term water resource assessment are used to review water-sharing arrangements in a sustainable water strategy.

A long-term water resource assessment is undertaken every 15 years. This is Victoria's first assessment and it covers southern Victoria. An assessment for northern Victoria will start in 2025.

Sustainable water strategies identify and manage threats to the supply and the quality of a region's water resources and identify ways to improve waterway health. These strategies are used to make decisions about how water is shared between consumptive users (people and industry) and the environment across a region.

Photography: Chloe Wiesenfeld

Changes in long-term water availability

The assessment found that long-term surface water availability across southern Victoria has declined by up to 21 per cent. Current long-term surface water availability is less than when it was last estimated for the sustainable water strategies.

The main cause of declines in surface water availability is drier conditions. Upstream interception of water for storage in domestic and stock (D&S) dams and plantations may also be contributing to the decline in surface water availability in some basins.

The decline in water availability has impacted on the environment, industry and other water users.

Water availability for consumptive uses (by people and industry) has declined in most of southern Victoria, with percentage decline varying from 1 per cent to 13 per cent.

Water availability for the environment has declined in all basins except the Otway Coast. The percentage decline varies from 4 per cent to 28 per cent, mainly due to declines in above-cap water which have occurred as a result of reduced water availability. Above-cap water is water that remains in a river after limits on diversions have been reached, as well as spills from storage and unregulated flows that cannot be kept in storage. It makes up 95 per cent of all water for the environment and is the most vulnerable to drying conditions.

The Government anticipated drying conditions and has worked closely with water corporations, and catchment management authorities to manage for these drier conditions. The Victorian desalination project can deliver an additional 150 GL of water a year, alternative water supplies provide for some consumptive uses and the expansion of Victoria's water grid[1] has underpinned security of supply for towns in central Victoria. Environmental water managers carefully manage environmental water to achieve the best waterway health outcomes in the face of declining water availability.

Long-term groundwater availability has declined in some areas of southern Victoria. This has had little impact on consumptive uses, and groundwater extraction has had only a very small effect on water availability for the environment at the regional level compared to other influences, such as climate change.

Sharing of changes in long-term water availability

The assessment found that the decline in water availability has not always been shared equally, the declines have fallen disproportionately on the environment in some basins. A smaller share of available water is now set aside for the environment than when the last sustainable water strategy was developed.

In most basins in the Central region — Barwon, Moorabool, Werribee, Yarra and Latrobe — the decline in long-term surface water availability has not been shared equally: the environment now has a smaller share of the available resource compared to the sustainable water strategy — when water-sharing was last assessed. The environment's proportion would have declined even more had some water not been recovered for the environment (such as by creating new environmental entitlements). This indicates that a review of water-sharing in the Central region may need to be considered.

In the Maribyrnong and the Thomson basins, the environment has the same share of the available resource as at the time when water-sharing was last assessed for the sustainable water strategies. A review may also need to be considered for these basins.

- In the Maribyrnong the environment's share has not changed partly because urban water supplies are being preferentially sourced from the water grid. This could change in the future and reduce the environment's share of the available resources. The Department of Environment, Land, Water and Planning (DELWP) is working with Western Water and other stakeholders to explore the option of the current operational approach becoming ongoing practice, firming up the water-sharing arrangements to maintain the environment's current share.

1 Enhancing the grid: Victoria's water grid partnership in 2018

- The increased volume of environmental entitlements in the Thomson basin since the sustainable water strategy has not changed the proportion of water available for the environment as originally intended because it has been offset by declines in above cap water. Without water recovery the environment's share would have declined.

For the western basins – Glenelg, Portland Coast, Hopkins, Otway Coast, Lake Corangamite and other eastern basins – Bunyip, South Gippsland, Mitchell, Tambo, Snowy and East Gippsland – which have relatively small volumes of water allocated for consumptive uses, the assessment found no change in the environment's share.

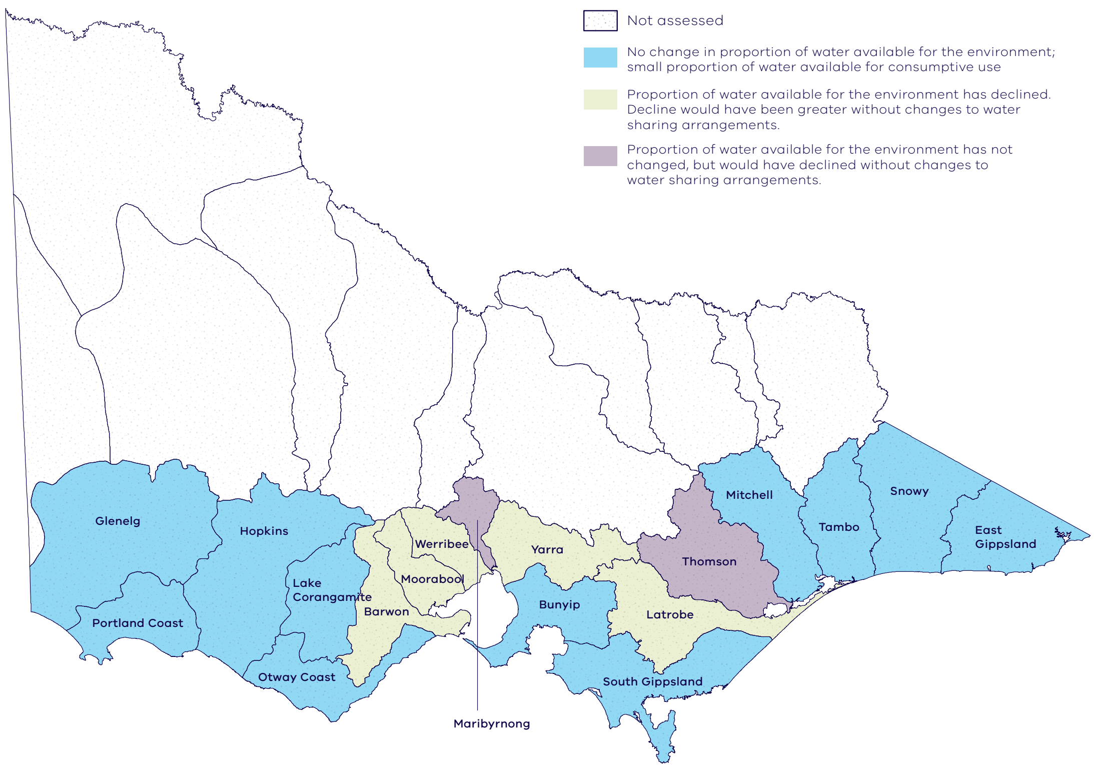


Figure 1: Changes in proportions of water available for the environment and for consumptive uses, by basin

Waterway health

The assessment used available long-term data from 1990-2018 to examine whether waterway health has deteriorated for reasons related to flow. To measure long-term trends this assessment required datasets going back more than 20 years. However, waterway health monitoring programs were not designed to meet the needs of the long-term water resource assessment as the assessment did not yet exist. Consequently, only a limited number of indicators relevant to waterway health have been monitored across the state for the long-term period needed.

Waterway health is a general term for the overall condition of key features and processes that underpin functioning waterway ecosystems. It is made up of many components which are influenced by flow in different ways.

The assessment used the best-available waterway health indicator data (for water quality, macroinvertebrates and native fish) and supplemented it with analyses of flow data over several time periods.

The LTWRA has not clearly identified overall deterioration in waterway health over the period analysed (1990-2018) for reasons related to flow. As expected, there was great variability in most indicators of waterway health through time and amongst basins. This variability is influenced by patterns of rainfall and stream flow through time, as well as differences in the geology and physical form of each basin, and the different plant and wildlife communities within them. This inherent variability prevented basin-scale findings being brought together into a broader picture of waterway health across southern Victoria.

The assessment shows, for each basin, if there have been long-term changes in well-defined environmentally important components of the flow regime in each basin's waterways, and how indicators of waterway health have changed for flow-related reasons.

In basins where water has been recovered for the environment, we are seeing some relative improvements in components of the flow regime that are considered important to waterway health.

Some indicators of waterway health have improved due to changes in flow, while other indicators have deteriorated, and yet others show no discernible trend, sometimes in the same waterway over the same time period. However, as the assessment looked at a limited number of indicators measuring individual aspects of waterway health, and as these long-term datasets were not collected for this specific assessment, they do not provide an overall picture of changes in waterway health for reasons related to flow.

The Government's investment in monitoring waterway health (including through the Victorian Environmental Flows Monitoring and Assessment Program) is already improving data collection for indicators of waterway health, particularly for reasons related to flow. In addition, an examination of this first LTWRA is being undertaken to provide advice for improving waterway health monitoring and methods for future instances of this recurring assessment.

More information

A companion report Long-Term Water Resource Assessment for Southern Victoria: Basin-by-Basin Results is available at **water.vic.gov.au**. The purpose of the Basin-by-Basin Results is to explore in detail the findings for each of the 18 river basins assessed across southern Victoria. If you are interested in the specifics of how water availability and waterway health have changed in a given area — perhaps in your local basin — then that report provides a useful reference.

By exploring the detailed results of the technical assessment, the Basin-by-Basin Results provides a fuller picture of the basis for the conclusions drawn in the Overview Report. Together, these two reports provide a comprehensive assessment of long-term change in the condition and sharing of water resources across southern Victoria.

Next steps

The new Central and Gippsland Region Sustainable Water Strategy (the SWS) will explore actions to restore the balance in water-sharing in the Thomson, Latrobe, Yarra, Maribyrnong, Werribee, Moorabool and Barwon basins. The new SWS provides the opportunity to address both the changes identified in the LTWRA and likely future changes in the availability and demand for water. The process will consider the diverse values that underpin how we share our water: economic, environmental and social, including for Traditional Owners and recreation. This will improve water security now and into the future.

Preparation of a new SWS will take two to three years. The SWS is developed under the guidance of a Consultative Committee whose members have relevant knowledge and experience. A draft SWS will be available for community input prior preparation of the final SWS including a plan for implementation.

1. Introduction

In a first for Victoria, a long-term water resource assessment (LTWRA) has been conducted to identify if water availability has changed for farming, cities, towns and our environment, and to identify changes in the health of our waterways that are due to changes in flow. The assessment will allow Victoria to develop solutions to ensure the long-term resilience of communities and healthy waterways, where there is declining water availability or deterioration in the health of our waterways because of changes in flow.

1.1 About how we share our water

Water is fundamental for our economy, environment and communities. We have many consumptive uses for water. People and animals drink it and clean with it; industries need it for manufacturing, power generation and other purposes; and irrigators are the biggest users of water across the State. Also, our waterways and their surrounds have evolved to rely on the natural flows of water to stay healthy; to provide habitat for plants, animals, including fish and birds; and to be the green, cool, natural places all Victorians, including Traditional Owners, value so highly.

Water is limited, so we must manage the use of it. As well, we must preserve the health, biodiversity, ecological functioning and water quality of waterways. So, under the *Water Act 1989* (the Act), the Minister for Water manages, through the water entitlements framework, how surface water and groundwater are shared between uses.

Access to water is managed mainly with entitlements and licences. The Minister for Water issues bulk entitlements to metropolitan and regional water corporations to take specified volumes of water and percentages of flows from waterways to supply their customers, usually with conditions (such as to maintain minimum flows in waterways). The Minister also issues licences, such as those to almost 19,000 private surface water diverters across the state, to take and use water. Water is also set aside for the environment through environmental entitlements, minimum flows in waterways and limits on consumptive uses. This water helps to protect the native plants, wildlife and overall health of rivers, wetlands, floodplains and estuaries. Water for the environment also provides social, cultural and economic benefits.

Sustainable water strategies (SWSs) identify and manage threats to the future supply and quantity of a region's water resources, as well as identifying means to improve waterway health. These strategies are used to assess options and agree on how water could be better shared between consumptive users and the environment.

1.2 About the long-term water resource assessment

Water-sharing arrangements need to be kept up-to-date. The government must be able to act if the assumptions about volumes of water and river health on which the water-sharing arrangements agreed in the SWSs are based are shown to be no longer valid. In particular, the government might choose to take action to share more equitably the impact of a long-term reduction in water availability or to respond to a discernible downward trend in river health.

The Act requires a LTWRA every 15 years to determine whether:

- a long-term reduction in water availability needs to be shared more equitably between consumptive users and the environment
- water-sharing arrangements need to respond to a deterioration in waterway health related to change in flow.

The LTWRA assesses changes in long-term water availability and waterway health since the last SWS. If the LTWRA finds that a review of water-sharing arrangements is needed, it is undertaken through a transparent, consultative process involving stakeholders and communities to develop solutions to restore an acceptable balance. The review of water-sharing arrangements will be incorporated into a review or development of a new SWS. **Figure 2** shows the relationship between a SWS and LTWRA.

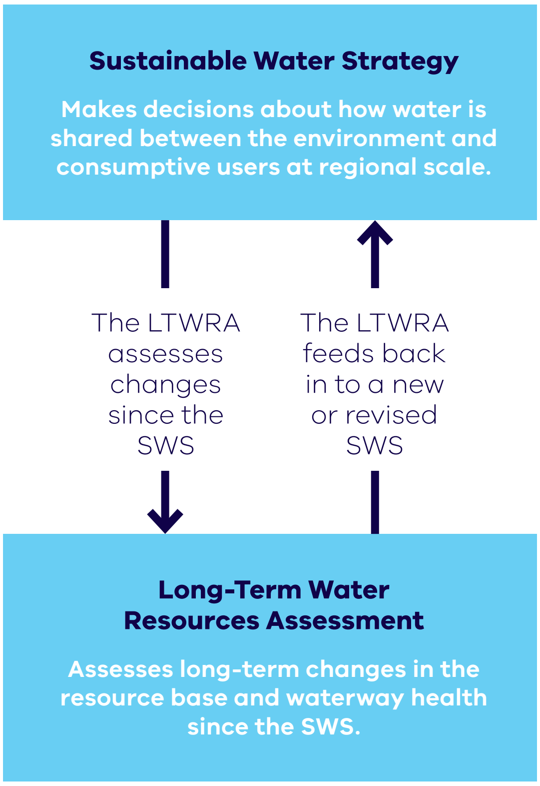


Figure 2: Relationship between Sustainable Water Strategies and a Long-Term Water Resource Assessment

The LTWRA has lots of checks and balances to ensure that if any changes to the existing water arrangements are required, they will only be made following a rigorous technical assessment, once all relevant social, cultural, economic and environmental matters have been considered and after those impacted by possible changes have had the opportunity to have a say.

The evolution of the LTWRA

The LTWRA is another step in a journey going back decades to share our available water to ensure security of water supply for consumptive uses and water for the environment to keep our waterways healthy. Here are some of the steps that have helped shape where we are today.

2004 Our Water, Our Future: Securing Our Water Future Together

In this White Paper, the government set out an ongoing, long-term, water-planning process to ensure Victoria's water security. It committed to developing regional SWSs, which included principles and actions to manage the supply of and demand for water. This ensures a secure supply for consumptive uses and water for the environment to maintain and improve waterway health. The White Paper envisaged the need for governments to act if a long-term reduction in the water resource base was not shared equitably between consumptive uses and the environment, or to change water-sharing arrangements if there was a discernible downward trend in river health. Accordingly, it included a requirement to undertake a LTWRA every 15 years. It established the SWSs as the benchmark against which future resource assessments will measure long-term changes to the resource base and river health.

Water (Resource Management) Act 2005

In 2005, the Act was amended to require development of SWSs and the LTWRA. It also started the clock on the 15-year period during which SWSs would be prepared and at the end of which the LTWRA would be completed.

2006–11 SWSs

SWSs were developed for the Central Region in 2006, the Northern Region in 2009 and the Gippsland and Western Regions in 2011.[2,3,4,5] The SWSs are forward-looking planning tools that make decisions about how water is shared between the environment and consumptive uses at a regional scale. They recognise Victoria will have increased demand in the future and that the water sector and water users need to manage water supply and demand to protect environmental, economic, cultural and recreational values, and to improve waterway health. To do this, the SWSs specified actions and allocated responsibilities to implement those actions.

2012 Murray-Darling Basin Plan

In northern Victoria, the Basin Plan sets limits on how much water can be taken for consumptive uses. The aims of the plan include putting aside water for the environment to protect and restore water-dependent ecosystems of the Murray-Darling Basin. The Basin Plan was signed into law in November 2012 under the *Commonwealth Water Act 2007*. The plan sets sustainable diversion limits (SDLs) on how much water can be taken from the basin in future for consumptive uses; the SDLs take effect in 2019 for northern Victoria only.

2 Department of Sustainability and Environment (2006) Sustainable Water Strategy Central Region: Action to 2055. Published by the Victorian Government, Melbourne, October 2006.
3 Department of Sustainability and Environment (2009) Northern Region Sustainable Water Strategy. Published by the Victorian Government, Melbourne, October 2009
4 Department of Sustainability and Environment (2011) Western Region Sustainable Water Strategy. Published by the Victorian Government, Melbourne, November 2011
5 Department of Sustainability and Environment (2011) Gippsland Region Sustainable Water Strategy. Published by the Victorian Government, Melbourne, November 2011.

2016 Water for Victoria

Water for Victoria is the government's current strategic plan for managing water resources, and it recommitted to starting the LTWRA process in southern Victoria. Since the Water Act established the LTWRA, there have been major changes to entitlements in the north of the state as part of implementing the Basin Plan. The LTWRA for northern Victoria — in the Murray-Darling Basin — will start in 2025, so it provides the best, most up-to-date information on Victoria's water resources to inform the Basin Plan review in 2026.

2018 SWS reviews and five-yearly assessments

The Water Act requires 10-yearly reviews of the SWSs, or reviews at the Minister's request or in response to the LTWRA's findings. The 10-year review of the Central Region SWS found the strategy had improved planning, management, and engagement; helped to reduce demand; secured our water supplies; and helps protect our waterways and aquifers. This was despite the major stressor of the Millennium Drought and extensive changes in water planning and management in Victoria. Five-yearly assessments were also completed for the Gippsland and Western Region SWSs. Progress reports on implementation are being prepared to achieve partly achieved and not-yet-achieved actions, and to maintain effort to continue achieving ongoing actions.

Water and Catchment Legislation Amendment Act 2019

In 2019, the Act was amended to:

- require the LTWRA in northern Victoria — in the Murray-Darling Basin — to start in 2025 instead of in August 2018, so it is completed before the Basin Plan is reviewed
- enable a LTWRA's stage 1 findings about long-term declines in water availability, about unequal sharing of those declines and/or about deterioration in waterway health to be addressed by preparing a new or reviewing an existing SWS (as stage 2 of the LTWRA); thereby better coordinating the SWS and LTWRA processes
- require the Minister to consider Aboriginal cultural values and uses of waterways and recreational matters, as well as considering economic and environmental matters, in a review of water-sharing arrangements or a SWS

All these documents are available on the internet: visit **water.vic.gov.au** and search for the title.

1.3 The long-term water resource assessment process

The LTWRA is a three-stage process, which is shown in **Figure 3**.

Stage 1: Technical assessment

Assessment of long-term water availability and waterway health

→

Stage 2: Review via a SWS

If required for a basin, determine how to restore the balance between consumptive uses and the environment, or how to restore waterway health

→

Stage 3: Implementation

Implementation of actions arising from review

Figure 3: LTWRA stages

1.3.1 Stage 1: Technical assessment

The long-term water resource assessment starts with a technical assessment to:

- establish if there has been a long-term decline in available surface water or groundwater. Where there has been a decline, the assessment examines whether that decline has fallen disproportionately on the water available for the environment or on allocations to people and industries consuming water (which is addressed in part A of this report)
- identify if waterway health has deteriorated because of reasons related to flow (which is addressed in part B of this report).

Part A and part B of the technical assessment are assessed independently of each other and either can lead to a review of water-sharing arrangements.

Contents of a LTWRA

The Act specifies what the LTWRA technical assessment must include.

'A long-term water resources assessment must identify whether or not either or both of the following has occurred—

a. there has been any decline in the long-term availability of surface water or groundwater and whether the decline has fallen disproportionately on the environmental water reserve or on the allocation of water for consumptive purposes;

b. there has been any deterioration in waterway health for reasons related to flow.

- *S.22L, Water Act 1989*

The technical assessment considers changes in how water is shared between the environment and consumptive uses and any deterioration in waterway health. The role of the subsequent review is to determine how to appropriately share water between the environment and consumptive uses; a review would also consider other important uses and values of water.

Water provides many benefits to Victorian communities

Water is fundamental to Victorian communities. Water for Victoria sets out how water will be managed to support a healthy environment, a prosperous economy and thriving communities. It highlighted that:

- Traditional Owners want their values of water to be recognised and expect to be involved in planning and management. The Aboriginal water program[6] aims to better include Aboriginal Victorians in the management of the state's water resources and reconnects communities to water for cultural, economic, customary and spiritual purposes.
- The community wants to be able to enjoy our waterways for recreation. DELWP works with water corporations, catchment management authorities and the VEWH to incorporate recreational values in the way we manage water and waterways.

The technical assessment only considers long-term changes in water availability, the declines that have occurred over decades. The Department also closely monitors seasonal outlooks, dry conditions and current water availability. Up to date information is available through the water snapshot.[7]

The technical assessment is also limited to a retrospective analysis of long-term changes that have already occurred in water availability and waterway health. It does not make projections about future water availability and waterway health. SWSs identify and plan for future risks to water resources.

As this is the first-ever LTWRA, there was no existing method to prepare it. The assessment's method has been developed in consultation with water sector specialists including a technical advisory group. In preparing the assessment, DELWP has drawn on a wide range of technical expertise, to create an accurate picture of long-term trends in water availability and waterway health. It used a consistent approach across the state, while taking account of differences in local conditions and data availability. Water corporations, catchment management authorities and the VEWH have been involved throughout the assessment to ensure that it accurately reflects the waterways and water supply systems they manage.

Under the Act, EPA Victoria has reviewed the draft technical assessment, and reported its findings to the Minister (**Appendix B**). The EPA's key findings are:

1. The method used to assess surface and groundwater availability, as well as water-sharing, is appropriate
2. The data used are appropriate. The primary constraint in assessing historical change in waterway health is the limited data
3. The conclusions reached in the assessment are supported by the method and data.

The review report is available by request from DELWP.

6 www.water.vic.gov.au/aboriginal-values/the-aboriginal-water-program
7 www.water.vic.gov.au/water-reporting/water-snapshot

1.3.2 Stage 2: Review via SWS

Decide if a review is required

The need for a review of water-sharing arrangements in particular basins is decided by the Minister once feedback on the technical assessment has been considered. Under the Water Act, a review of water-sharing arrangements for a basin is needed if the technical assessment finds, for that basin:

- there has been a long-term decline in water and that the decline has not been shared equally between water availability for consumptive uses and for the environment
- (and/or) waterway health has deteriorated due to changes in flow.

If the technical assessment does not find that the above has occurred, then it does not trigger a review. The next LTWRA takes place after another 15 years.

Undertake a review (if and where required)

If a review is needed, the review can be undertaken either as part of the LTWRA process or by preparing a new or reviewing an existing SWS. The Government intends to address the findings of this LTWRA for southern Victoria thought the preparation of a new Central and Gippsland Region SWS. This will ensure that any actions will consider both past findings and future water challenges.

A review determines if and what action needs to be taken to restore the balance between the environment and consumptive uses and/or to restore waterway health. The review will consider relevant social, economic and environmental issues, including relevant Traditional Owner values and uses of water. A review must be conducted in an open, consultative manner. This includes the appointment of a consultative committee to advise the Minister and public consultation. If any changes to existing water-sharing arrangements are required, they will only be made after those affected by possible changes have had the opportunity to have their say.

Actions that could be considered during the SWS process include increasing water supplies, such as increased use of alternative water supplies, investment in improved water use efficiencies and opportunities for achieving shared benefits.

If the SWS does not sufficiently address the findings of the LTWRA, it may be followed by a LTWRA review process. This process can lead to a permanent qualification of rights, a provision in the Act for the Minister to change the water-sharing arrangements under existing entitlements in a given area. A permanent qualification of rights would only be used as a last resort.

1.3.3 Stage 3: Implementation

The final stage of the LTWRA is to implement the review's (or SWS) findings. A statement of the actions needed to implement the review's findings must be published within six months of the review report being published.

1.4 Feedback on the assessment

Community consultation on the draft assessment was undertaken from 30 September to 30 November 2019.

The community provided feedback on the draft assessment through a range of avenues. The draft assessment was published for comment on **water.vic.gov.au**, the Victorian Government's Online Consultation platform. DELWP also hosted open-house sessions in 9 locations across southern Victoria to have conversations with communities about the assessment and regional water issues. These sessions were attended by 170 people. Other opportunities for the community to provide input included briefings for boards and customer committee of water corporations and catchment management authorities, and briefings, and discussions with peak industry groups (Victorian Farmers Federation and Environment Victoria).

The consultation drew 151 public submissions, allowed 2,350 people to engage with the material online and generated over 20,000 views of communications through social media. The results of the assessment largely matched the community's lived experience that it has gotten drier. Most of the submissions supported a review of water sharing. The challenge in balancing in how water is distributed between the environment, farming, industry and urban users was widely acknowledged.

More information about what we heard during consultation can be found at **Appendix A.**

PART A: Long-Term Water Availability

2. Surface water availability

KEY FINDINGS

- Long-term surface water availability across southern Victoria has declined by up to 21 per cent.
- Current long-term water availability – which is calculated as the average since 1975 – is less than when long-term surface water availability was calculated for Victoria's sustainable water strategies (SWS).

2.1 About surface water availability

Surface water is just what the words suggest: it's water found on the surface of the land in waterways (such as in rivers, wetlands and estuaries) and in bodies of water (such as lakes, dams and reservoirs). Although most surface water is runoff from rainfall, groundwater also contributes to the volume of surface water where there are good connections between waterways and aquifers.

Available surface water, for the LTWRA's purposes, is all the surface water that can be allocated under Victoria's water entitlement framework to consumptive uses or to the environment.


168
167

The assessment estimated surface water availability for nearly 200 catchments across 18 river basins in southern Victoria. However, there was insufficient data for some smaller rivers and creeks within these river basins — mostly in coastal or urban areas — to include them in the assessment. The excluded waterways included those in the Millicent Coast basin, for which licensed water volumes are very small (4 ML/yr) and no reliable streamflow data exists. The excluded waterways are a source of water for only 0.4 per cent of water entitlements across southern Victoria and almost all of the available water is for the environment.

Estimates of surface water availability were combined and reported at the outlet of each river basin. A surface water basin is the area of land into which a major river and its tributaries drain. Smaller catchments, usually connected by the same river system, are grouped together into one basin. **Figure 4** shows Victoria's 29 surface water basins. The river basins in the south and east of the state generally drain to the sea and are the subject of this southern Victoria LTWRA; those in the north drain to the River Murray or to terminal lakes.

The assessment accounted for water transferred between river basins in the basin of origin: Victoria's water grid enables water stored in one basin to be transferred to another.

Why isn't all surface water counted towards water availability?

The purpose of the LTWRA is to look at changes in the water available under the water entitlements framework. That is, water that has been allocated for different consumptive users or to the environment.

Not all water consumed is allocated under a water entitlement. Runoff may be intercepted and used before it reaches a waterway, such as by flowing into a Domestic and Stock (D&S) dam or being taken up by vegetation. The assessment does not count this intercepted water towards surface water availability because that water is outside of the entitlement framework. The assessment does consider how catchment interception changes the volume of water that reaches rivers and streams. **Chapter 4** discusses how catchment processes, such as groundwater extraction, D&S dams and land-use change, influence surface water availability for entitlement holders.

Desalinated sea water and recycled water are not counted towards available water because they are not sourced from waterways.

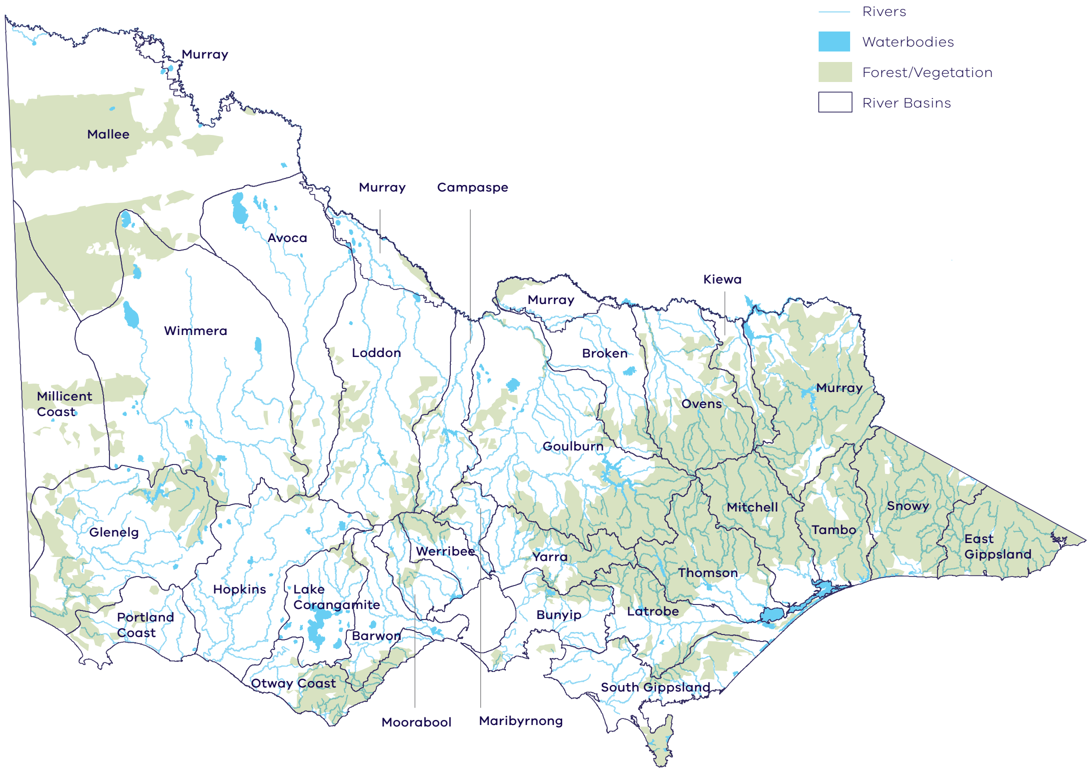


Figure 4: Victoria's surface water basins

Groundwater extractions can affect surface water availability

Rainfall that doesn't return to the atmosphere (via evapotranspiration) or runoff into a waterway, soaks in to become groundwater in the upper aquifers (collectively referred to as the 'upper aquifer'). This aquifer is often connected to waterways, and in many waterways this connection sustains the waterway's flow between rainfall events. This means a decline in rainfall or extraction of groundwater for consumptive purposes can lead to lower groundwater levels, which in turn can reduce flow in waterways.

The assessment considered surface water and groundwater availability (**Chapter 3**) separately, but it also quantified the effects of licensed groundwater extractions (**Chapter 4**) on surface water availability where the two resources are connected.

2.2 How the assessment estimated long-term surface water availability

Figure 5 shows the two-step approach the assessment used to update long-term surface water availability calculated for Victoria's SWSs, which were published between 2006 and 2011.

Step A uses better data and better models than were available when the SWS estimates were made to recalculate long-term surface water availability. This recalculation of the original SWS estimates establishes a more up-to-date benchmark against which the assessment measures long-term changes in surface water availability.

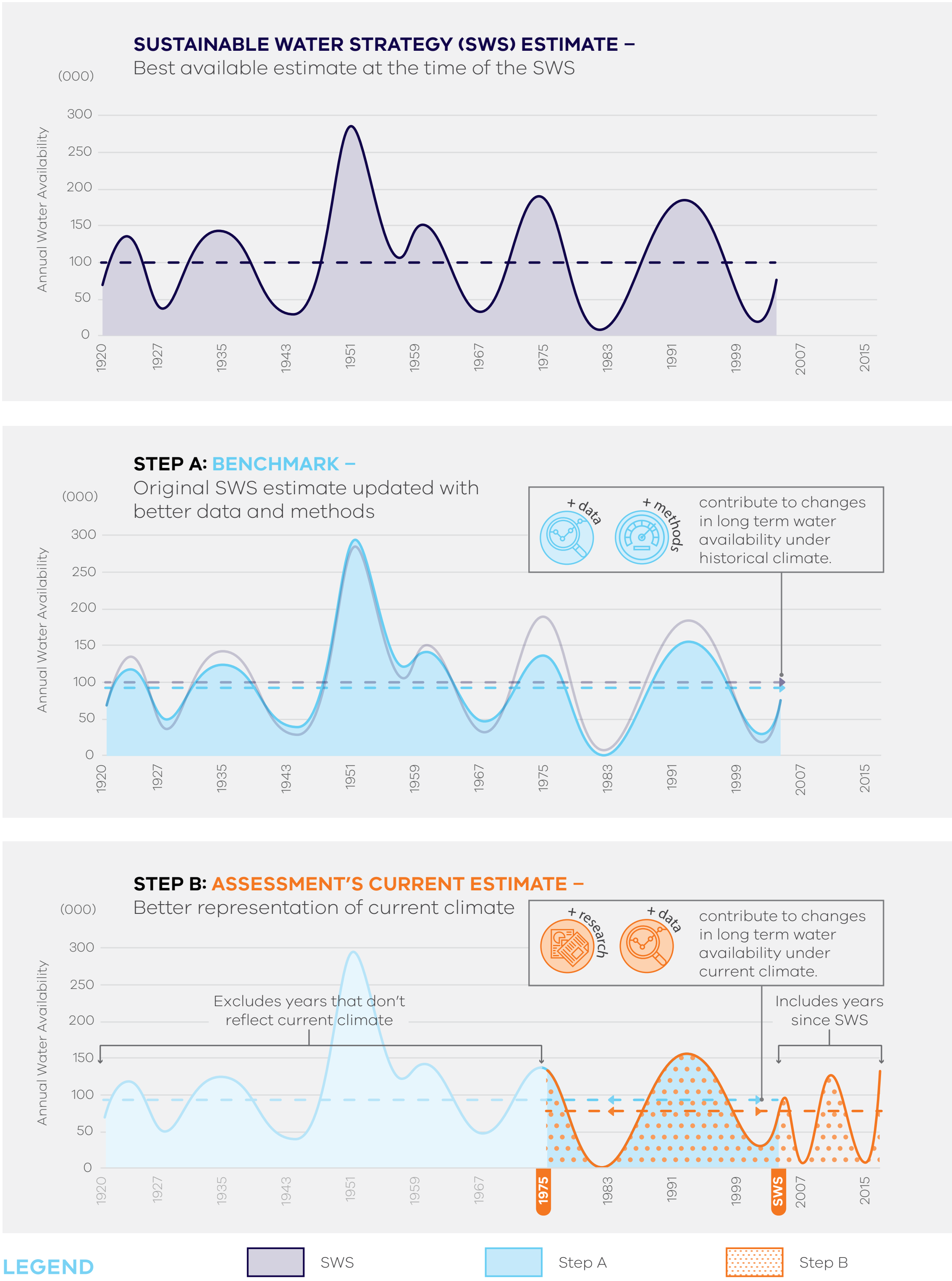


Figure 5: Two-step approach to estimating long-term surface water availability

Note: ***Figure 6*** *shows, for each surface water basin, the years for which measured/model streamflow data was available when the SWS was developed, and subsequent years used in the assessment's estimates.*

Step B updates the period used to estimate long-term surface water availability. When long-term surface water availability was calculated for the SWSs, they used all available historical data (stretching back options to the 1890s for some rivers) to calculate the long-term average. But we now know that climate change is making Victoria warmer and drier, and it's changing long-standing cycles of high and low flows of rivers. Therefore, to calculate available surface water, the assessment changed the climate reference period to be 1975 to present. That period better reflects our current climate under these changed conditions than does the full historical record, while also being long enough to include a range of shorter-term weather influences on water availability (such as droughts and floods).

To determine long-term changes in water availability, the assessment compared the step B estimates with the step A estimates.

2.2.1 Step A: Benchmark (original SWS estimates updated with better data and methods)

When they were produced between 2006 and 2011, the SWSs estimated the volume of surface water available annually for each surface water basin in their region, using measured or modelled streamflow. There are four main methods to measure or model streamflow: gauged streamflow, water balance method, streamflow transposition method and rainfall-runoff models. These methods were used at the time of the SWSs and have been progressively improved since.

Gauged streamflow: This is the best method for estimating available surface water. There are 630 active streamflow gauging sites across Victoria. Streamflow measurement began in the 1880s at a few locations and gradually increased to include all river basins covered by the LTWRA. A widespread streamflow gauging network was established in the 1960s. Streamflow data is available from Victoria's water measurement information system.[8]

Many gauges are downstream of water diversions and they do not represent the full volume of available surface water within the river basin. However, the gauged data can be adjusted to account for the effect of upstream diversions by adding back the historical metered or estimated diversions. Similarly, gauged flow may be downstream of a location where treated waste water or drainage water is discharged to the stream and can be adjusted accordingly.

Where no gauged streamflow data is available, another method is needed and the assessment used one of the following.

Water balance method: This method calculates available surface water when inflows and outflows are known or can be reliably estimated. It is often used to estimate inflows to a reservoir or dam, where changes in the volume of the dam and releases are measured.

Streamflow transposition method: This method is used in catchments where there is no gauged streamflow data. Streamflow recorded in a comparable gauged catchment is used to estimate streamflow in the ungauged catchment, using a transposition factor which scales flows up or down based on differences in the catchment (such as the size of the catchment and rates of rainfall).

Rainfall-runoff models: These models use rainfall data for a catchment to estimate streamflow. Several types of rainfall-runoff models are used in Victoria. Rainfall-runoff models can be extended as far back as there is rainfall data available, which commenced being recorded as early as the late 19th century at some locations in Victoria.

Surface water availability was estimated for sub-catchments within each basin. The choice of methods applied in each basin depended on the nature of the data available for the sub-catchment. Gauged data was used preferentially because it is generally the most accurate, followed by streamflow transposition, water balance methods and rainfall-runoff models. Estimates of surface water availability at the sub-catchment level were combined and reported at the basin scale.

8 http://data.water.vic.gov.au

Regional Water Monitoring Partnerships program – Surface water

Victoria maintains 630 surface flow-monitoring stations through the Regional Water Monitoring Partnerships program. DELWP manages the program on behalf of more than 40 federal, state and local government organisations, which share the costs of collecting water data to a clearly defined and internationally recognised standard. All surface water data collected through the program is publicly available through the Water Measurement Information System (at data.water.vic.gov.au), including real-time data from over 500 sites.

The SWSs estimated long-term surface water availability as the average annual water availability calculated using all the available data for measured or modelled streamflow. **Figure 6** shows (in a light shade), for each basin, the period for which data was available, which was usually up until a few years before the SWS was published. As is explained below, the technical assessment in step B also used data for years after the SWS estimates: these subsequent years are shown in the figure in a dark shade.

The assessment recalculated the SWS estimates, for the same time periods as for the SWSs, using better data and improved modelling methods, if available. The assessment identified the methods used for each SWS estimate and if either the method or the data was not the best available, it recalculated the SWS estimate using the best-available data and methods. For example, the assessment improved the rainfall-runoff models used for the Werribee basin, so they better estimate water availability in dry years. The assessment used the improved models to estimate water availability from July 1920 to June 2005, the same period as for the SWS.

This recalculation of the original SWS estimates established a more up-to-date benchmark against which the assessment measured long-term changes in surface water availability.

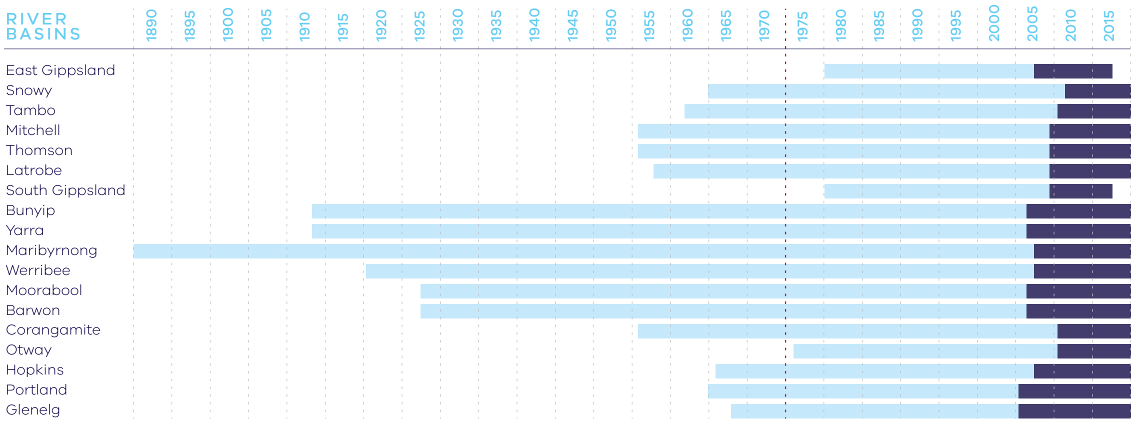


Figure 6: Years with suitable measured or modelled streamflow data for use in the assessment, by river basin

Note: A light shade shows availability for the SWS and subsequent years also available for this assessment are shown in a dark shade. There are no annual estimates for years with no shading; that is, where the bar is white. The vertical dotted line shows the start of the current climate period used for the LTWRA.

2.2.2 Step B: Assessment's (current) estimates

The assessment estimated the current long-term surface water availability:

- using the average annual surface water availability calculated over the period 1975–present as the current climate representative period
- using best-available models — those that we used for the step A estimates — and the most up-to-date data.

To determine long-term changes in water availability, the assessment compared these estimates with the step A estimates.

Current climate representative period (1975–present)

The assessment determined that the period from 1975 to the present better reflects our current climate than does the entire historical period used in the SWSs. The entire historical period — from the beginning of records through to between 2005 and 2011, depending on the SWS — does not include recent years, and it does not reflect the long-term changes that have occurred to our climate that influence water availability. These changes include global greenhouse gas concentrations trending upwards since the mid-19th century[9] and temperatures trending upwards since the start of the 20th century.[10, 11, 12]

Research by the Victorian Climate Initiative has improved our understanding of the behaviour of the large-scale circulation patterns in the atmosphere that influence Victoria's climate.[13] It has found that the tropics are expanding southward, and the sub-tropical ridge has intensified and also shifted southwards, influencing changes in cool season and warm season rainfall in Victoria.

Figure 7 shows the declines in cool season (April–October) rainfall decade-by-decade to 2018.[14] The reductions in rainfall during the cooler months of the year pose a significant

9 Intergovernmental Panel on Climate Change (IPCC) (2014) Climate Change 2014: Synthesis Report. Contribution of Working Groups I, II and III to the Fifth Assessment Report of the Intergovernmental Panel on Climate Change [Core Writing Team, R.K. Pachauri and L.A. Meyer (eds.)]. IPCC, Geneva, Switzerland, 151 pp

10 Intergovernmental Panel on Climate Change (IPCC) (2014) Climate Change 2014: Synthesis Report. Contribution of Working Groups I, II and III to the Fifth Assessment Report of the Intergovernmental Panel on Climate Change [Core Writing Team, R.K. Pachauri and L.A. Meyer (eds.)]. IPCC, Geneva, Switzerland, 151 pp

11 Timbal, B et al. (2015) Murray Basin Cluster Report. Climate Change in Australia Projections for Australia's Natural Resource Management Regions: Cluster Reports, eds. Ekström, M. et al., CSIRO and Bureau of Meteorology, Australia.

12 Grose M. et al. (2015) Southern Slopes Cluster Report, Climate Change in Australia Projections for Australia's Natural Resource Management Regions: Cluster Reports, eds. Ekström, M. et al., CSIRO and Bureau of Meteorology, Australia.

13 Hope, P, Timbal, B, Hendon, H, Ekström, M, Potter, N. (2017). A synthesis of findings from the Victorian Climate Initiative (VicCI). Bureau of Meteorology, 56 pp, Australia

14 Hope, P, Timbal, B, Hendon, H, Ekström, M, Potter, N. (2017). A synthesis of findings from the Victorian Climate Initiative (VicCI). Bureau of Meteorology, 56 pp, Australia

challenge for water availability, because this is the time of year when the lower temperatures mean catchment vegetation is not as thirsty, which results in a greater proportion of rainfall becoming runoff. The trend in reduced cool-season rainfall was particularly evident during the Millennium Drought (1996–2010) but has continued since then. The most recent decade was also influenced by wetter conditions in the 2016 cool season, which mitigated the reductions presented for this decade in **Figure 7**.

As rainfall declines, water availability also declines. Water availability can also decline with changes in rainfall characteristics (such as changes in seasonal rainfall patterns, daily rainfall distribution and sequences of dry years). Scientists have detected declines in surface water runoff in recent decades.[15, 16, 17]

These declining trends in rainfall and run-off show up as declining trends in streamflow, which the assessment detected across southern Victoria. The assessment analysed data from streamflow gauges at seven locations where there are minimal upstream diversions and minimal upstream land-use changes. Data from such locations provides the most accurate basis for determining changes in streamflow as a result of changes in rainfall runoff. The assessment then compared median streamflows over two periods: 1960 – 75 and 1975 – 2017. **Figure 8** shows that the streamflows after 1975 were significantly lower than before 1975 at four of the seven gauges, with a decline of over 50 per cent in the Hopkins basin.[18] There was no observed decline in the selected locations in the far west or far east of the state.

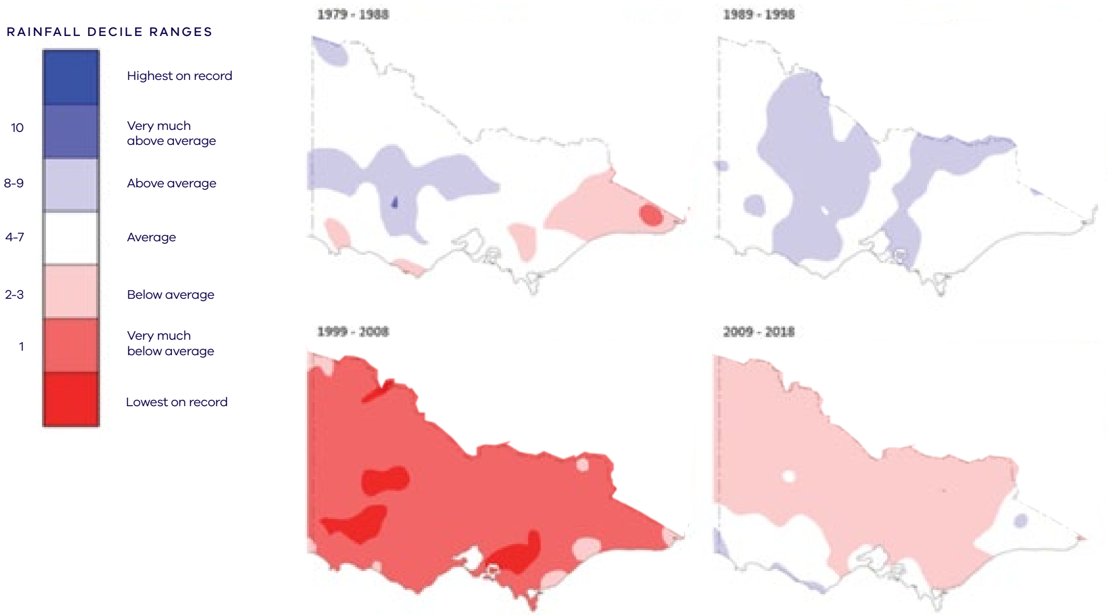


Figure 7: Cool-season (April–October) rainfall, 1979–88, 1989–98, 1999–2008 and 2009–18
Source: Bureau of Meteorology through the Victorian Water and Climate Initiative

15 CSIRO (2008) Murray-Darling Basin Sustainable Yields – Regional Reports.
16 Zhang, X.S., Amirthanathan, G.E., Bari, M.A., Laugesen, R.M., Shin, D., Kent. D.M., MacDonald. A.M., Turner,M.E., Tuteja. N.K (2016). How streamflow has changed across Australia since the 1950s: evidence from the network of hydrologic reference stations. Hydrology and Earth System Sciences. 20, 3947-3965,2016
17 Fiddes, S. and Timbal., B (2016). Assessment and reconstruction of catchment streamflow trends and variability in response to rainfall across Victoria, Australia. Climate Research. Vol. 67: 43 -60, 2016
18 The results from this complementary streamflow gauge assessment are useful for highlighting broad trends but differ to the LTWRA results for two reasons: (1) the streamflow gauge analysis examines change in flow a single location within a basin, whereas the full LTWRA covers as much of a river basin's catchment as possible; (2) the gauge analysis examines change in streamflow over two fixed, non-overlapping periods of time whereas the full LTWRA compares current water availability with availability over the SWS period, such that there are overlapping years.

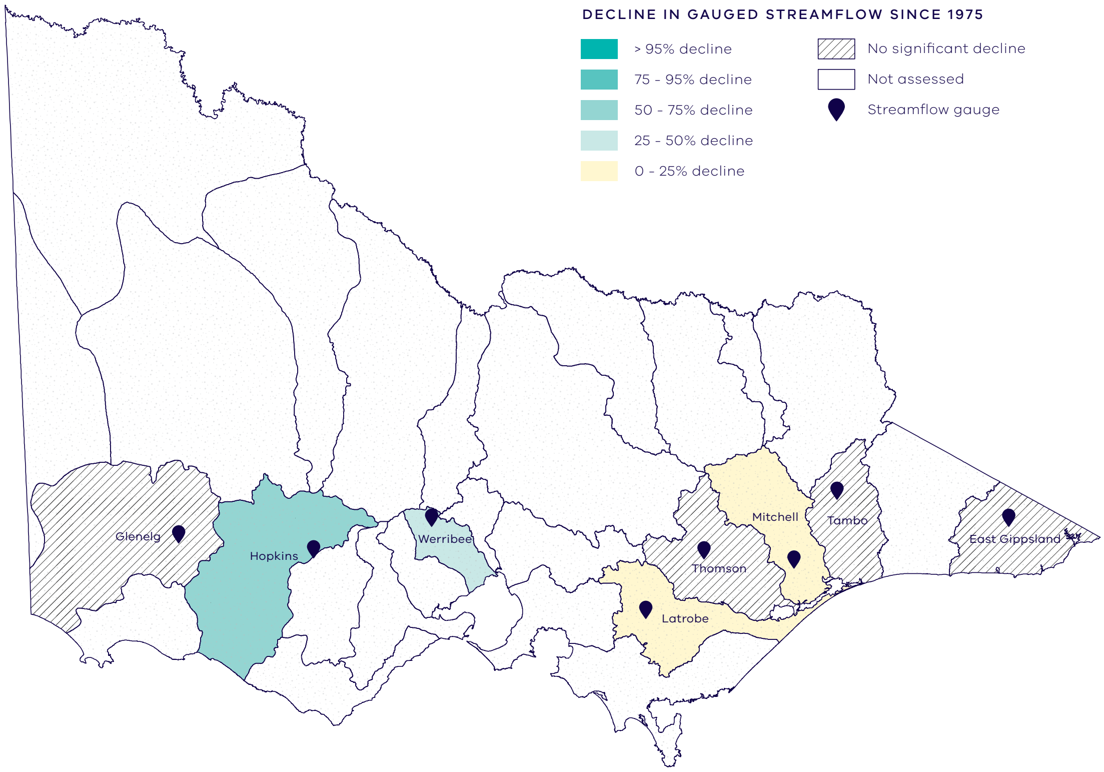


Figure 8: Change in observed streamflow, selected upstream gauges, 1975–2017 cf. 1960–75

The assessment decided to start the period that better reflects our current climate at 1975 for several reasons.

- Excluding data before 1975 when calculating long-term changes in water availability is consistent with research findings by the Victorian Climate Initiative, which concluded that, "In light of the reductions in cool-season rainfall over the past 30 years, it is considered likely that the recent decades provide a better representation of current climate than does the full historical record extending back over the 20th century".[19]
- The Victorian water sector also uses the period 1975–present as the current climate baseline period. DELWP recommended it in the 2016 Guidelines for Assessing the Impact of Climate Change on Water Supplies in Victoria, and it was subsequently adopted by water corporations in the 2017 Urban Water Strategies.
- 1975 – present also includes the period since the SWSs.

The assessment considered, but did not choose, a shorter period (such as since 1997) as representative of the current climate. The shorter period was considered because it appears there might have been a step change in climate around 1997, resulting in large declines in streamflows across Victoria: **Figure 9** shows a significant decline in streamflows before and after 1997 at all seven gauges.[20] The magnitude of the declines varied across the state: they were smallest in Gippsland (about 30 per cent) but over 80 per cent in the west of the state.

19 Hope, P, Timbal, B, Hendon, H, Ekström, M, Potter, N. 2017. A synthesis of findings from the Victorian Climate Initiative (VicCI). Bureau of Meteorology, 56 pp, Australia

20 Based on comparison of median annual gauged streamflow over the period July 1960 – June 1997 with July 1997– June 2017.

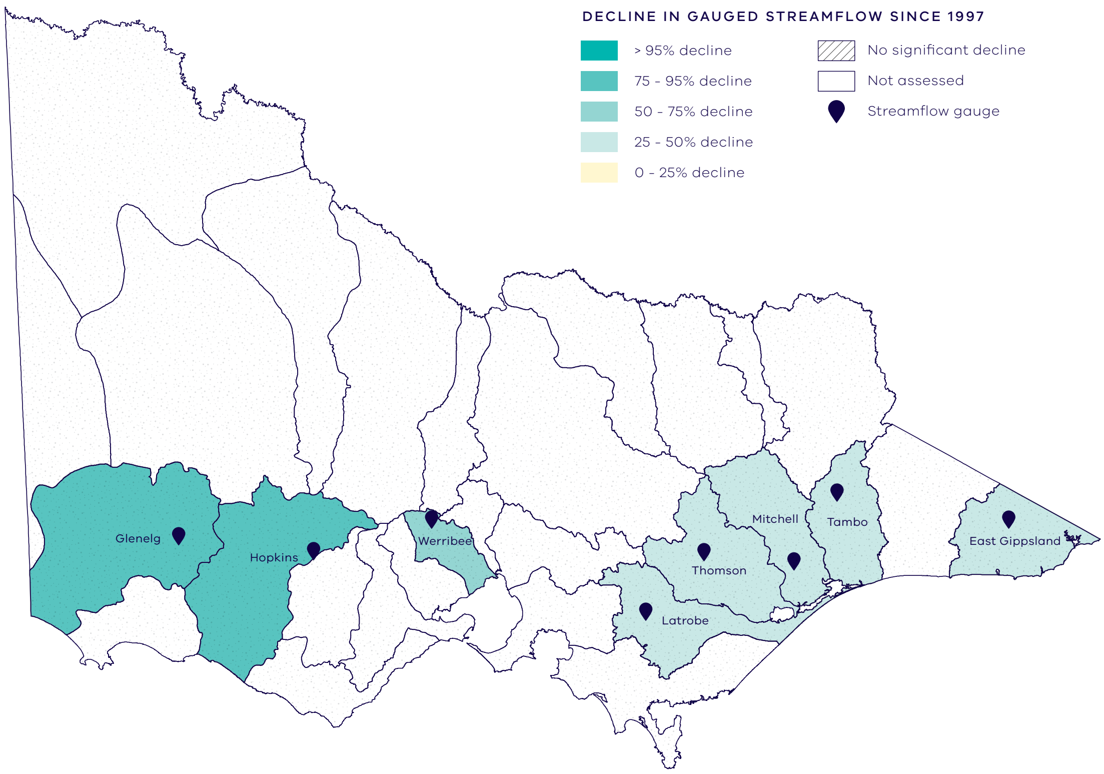


Figure 9: Change in average streamflows, selected upstream gauges, 1997–2017 cf. 1960–97

The assessment decided not to use the period since 1997 because a 20-year period will be influenced by shorter-term variations in Victoria's climate. Climate is variable over decades and less, with some decades cooler and wetter than average (as was the 1970s) and others hotter and drier than average (such as during the Millennium Drought). That's to say, if the assessment had only used either of these decades, it would have overestimated or underestimated long-term water availability respectively.

This can be seen in **Figure 10** which shows the effects of climate variability on water availability in the Yarra River over more than a century. It shows the effects on streamflows of the most consequential floods[21] and droughts that have occurred since streamflow measurement began in the 1920s. Underlying this variability is a long-term trend towards lower rainfall in Victoria over time, that is considered to have made recent droughts more severe.[22] During the Millennium Drought, which began with low rainfall in late 1996 and ended in 2010, and which was the longest drought since European records began,[23] the combined effect of climate variability and longer-term climate change was that water availability was 38 per cent less in the Yarra River than the historical long-term average.

So, the assessment did not use the period since 1997 as the climate change representative period because doing so would reduce confidence that any declines in surface water availability it identified constituted a long-term change and not a shorter-term variation. By using the longer record — from 1975 — we can be more confident that differences between this period and the SWS estimates represent long-term changes in water availability, not just climate variability.

21 www.floodvictoria.vic.gov.au/learn-about-flooding/flood-history
22 CSIRO (2012) *Climate and water availability in south-eastern Australia: A synthesis of findings from Phase 2 of the South Eastern Australian Climate Initiative* (SEACI), CSIRO, Australia, September 2012.
23 DELWP (2016). Managing extreme water shortage in Victoria: Lessons from the Millennium Drought. Department of Environment, Land, Water and Planning.

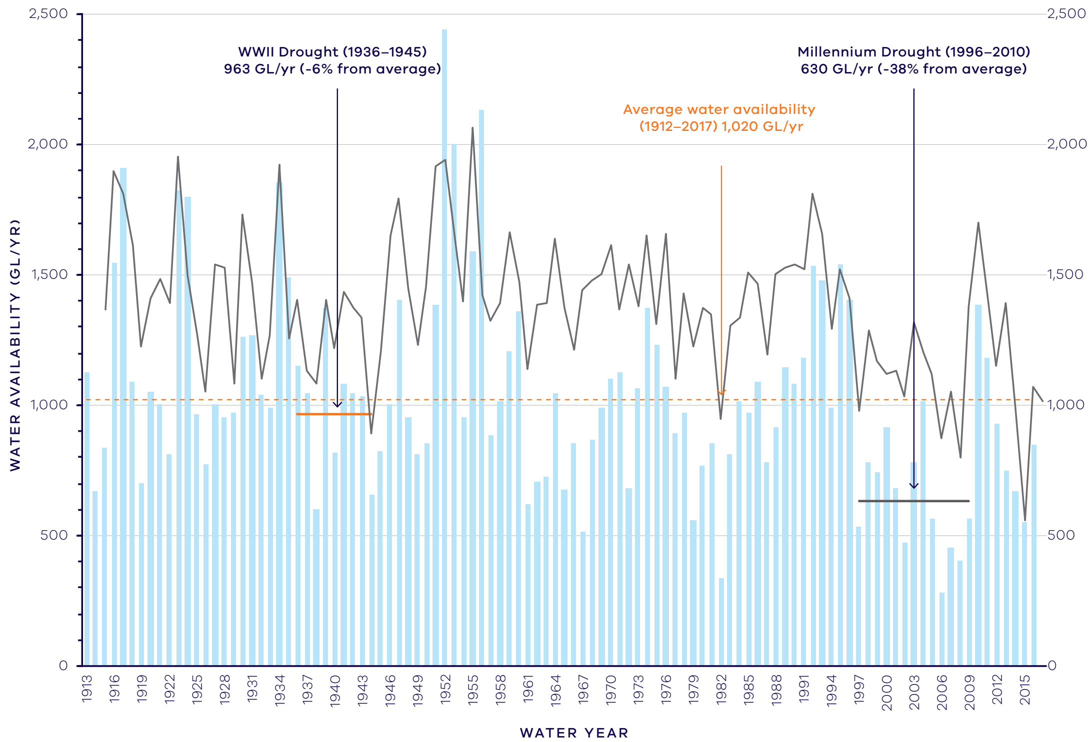


Figure 10: Annual water availability, Yarra River, 1912–2017 (bars) and annual rainfall (grey line)[24]

The relative contribution to observed trends from climate change versus climate variability in the post-1975 period is not precisely known, particularly at a river basin scale. It is noted that changes in long-term water availability in some river basins could be underestimated to the extent that underlying trends are driven by climate change. That is, the period 1975 to date is itself not stationary with respect to some of Victoria's climate influences, rainfall and streamflow. Hence declines in water availability could be expected to be greater by the end of the current climate reference period (i.e. in 2017) than the difference in mean values over the entire current climate reference period (1975 – 2017). The extent of this effect is difficult to quantify due to the difficulty of accurately separating the influence of climate variability and climate change on observed data.

DELWP is working with the Bureau of Meteorology to better understand the current climate. The Bureau's researchers are improving our understanding of different types of weather and their influence on rainfall. They are also looking at ways to better characterise Victoria's current climate and the influence of tropical expansion on Victorian rainfall. This research will help inform the next LTWRA.

24 The water availability presented in this figure is estimated for the Yarra basin and includes inflows into Melbourne Water's major headworks storages plus tributaries and other inflows downstream of storages. The rainfall timeseries is gauged rainfall at Warburton/O'Shannassy Reservoir (weather station 086090).

The Victorian Water and Climate Initiative

As part of implementing the Victorian Government's commitment to continued investment in water-sector research on climate change, the Victorian Water and Climate Initiative has been established. The Victorian Water and Climate Initiative is a Victorian Government program that supports research into the impact of climate change and climate variability on Victoria's water resources. Through the initiative, research is being undertaken by the University of Melbourne, the Bureau of Meteorology and CSIRO on a range of priority research needs for the sector. The Government's ongoing investment in climate and water resources research is an important part of informing the sector's long-term planning and climate change adaptation decisions. For more information, search 'The Victorian Water and Climate Initiative'.

Steps A and B in the Yarra basin

This section of the report explains the assessment's two-step approach to estimating changes in long-term water availability. Here's a short summary of how the approach was applied in the Yarra basin.

When the Central Region SWS was published in 2006, it estimated long-term water availability in the Yarra basin was 1,054 GL/yr. The current assessment had better models and better data than were available in 2006, so the 2006 estimate was recalculated with greater accuracy. With the better models and data now available, the 2006 estimate would have been 1,060 GL/yr. That's step A in **Table 1**.

The assessment, on the basis of the best-available science, concluded that the whole historical record (shown in **Table 1**) no longer reflected our current climate – and therefore wouldn't produce the best estimate of current long-term water availability — but that 1975–2018 would, because it better represents the current climate. That's step B. In this step, the assessment found that long-term water availability in the basin is only 885 GL/yr. This is 175 GL/yr less than the Step A estimate which is a decline of 16 per cent in long-term water availability.

Table 1: Long-term surface water availability, Yarra basin

Long-term surface water availability	SWS estimates	Step A Benchmark estimates	Step B Current climate representative period	A cf. B Change due to different climate period	A cf. B Change due to different climate period (%)
Total water availability (GL/yr)	1,054	1,060	885	-175	-16%

2.3 Changes in long-term surface water availability

To determine if long-term surface water availability had changed, the assessment compared the SWS benchmark (step A) volume of long-term available water with the current (step B) estimate. If the benchmark volume was greater than the current estimate, the assessment concluded long-term surface water availability has declined.

Figure 11 shows the assessment's current (step B) estimates of the gigalitres of water now available on average each year in each basin. The figure shows the basins with the most available surface water have rivers with headwaters in the Victorian Alps.[25] The basins with the most available water are in Gippsland. The basins with the least water are west of Melbourne: they are in a rain shadow created by the Otways.

Figure 12 shows that the largest percentage declines in long-term water availability have been in the basins located in the central west region.

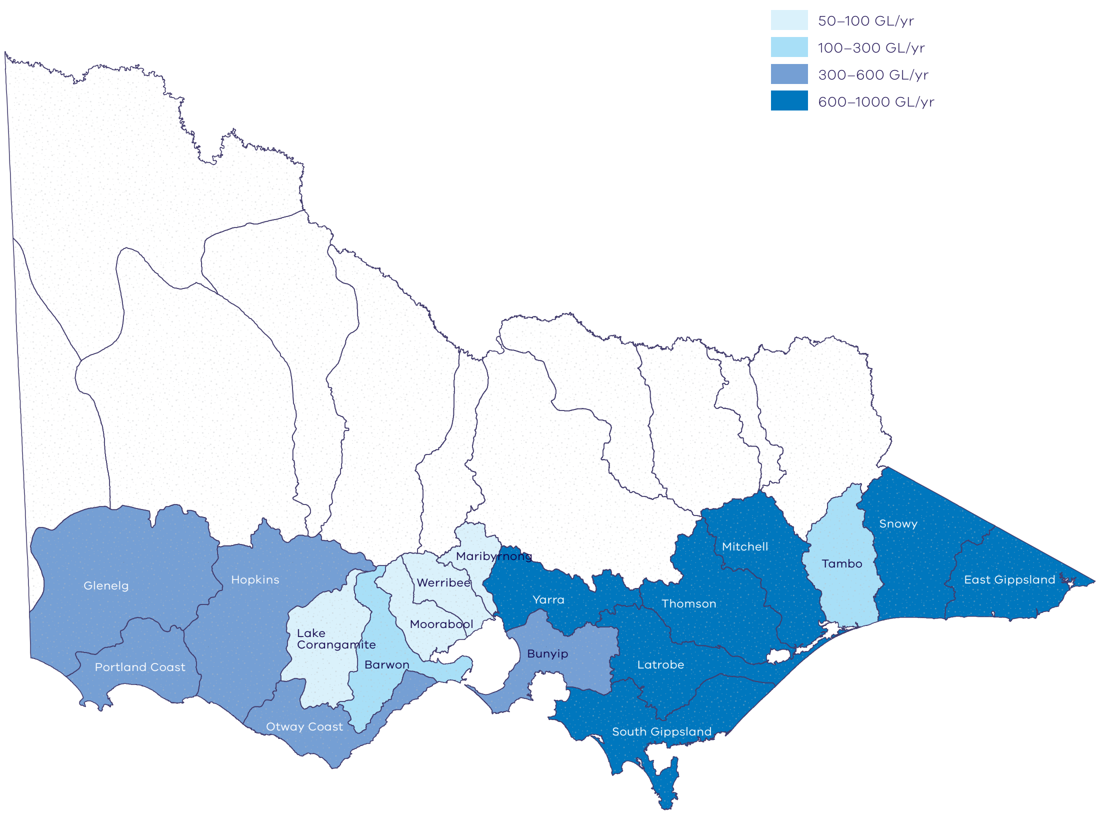


Figure 11: Long-term water availability, by volume, by river basin, step B

Note: The long-term water availability for the Snowy Basin excludes water flowing over the border from New South Wales.

25 Note that the volume of water available in the Tambo basin is lower than surrounding basins in Gippsland because it experiences lower rainfall, has a lower elevation, is less steep and has a smaller assessed area than surrounding basins.

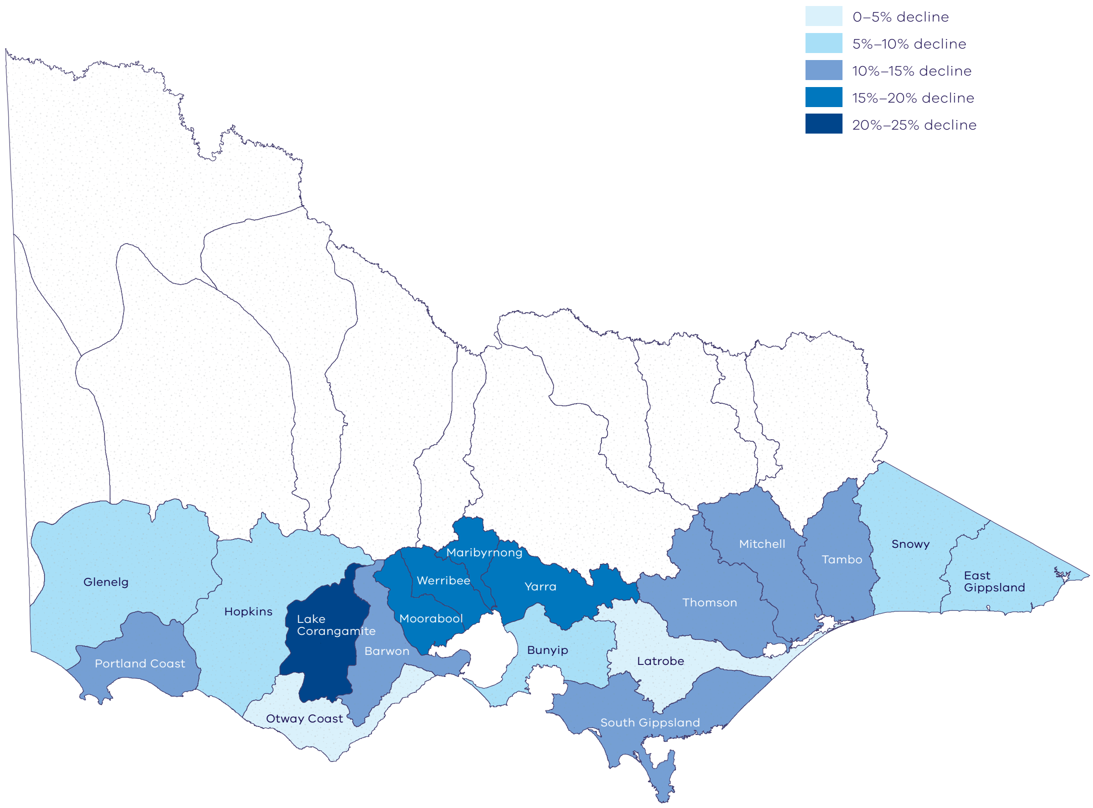


Figure 12: Declines in long-term surface water availability, by percentage, by basin, step A cf. B

The length of datasets available at the time of the SWSs, shown previously in **Figure 6**, has not affected whether a decline in water availability has occurred since the SWSs. However, it has influenced the estimated volume of water available at the time of the SWSs, and hence the magnitude of the decline in water availability since the SWSs. Estimated declines were less than they otherwise would have been where (i) SWS estimates included more data from the latter part of the Millennium Drought and (ii) where SWS estimates had less data available from wetter decades in the 1950s and 1960s. Basins that show a small decline in water availability (such as East Gippsland, South Gippsland, Otway Coast and Glenelg) tend to only have data back to the 1970s, and exclude those earlier, wetter decades. Less data from the latter part of the Millennium Drought was available at the time of the SWSs for the Central Region (which used data up to ~2005), compared to the Gippsland and Western Regions (data available up to ~2010). **Figure 13**, **Figure 14** and **Figure 15** compare, for each basin, the benchmark (step A) long-term water availability with the current (step B) estimate. The figures show that declines have occurred in all basins.

Multiple lines of evidence show that surface water availability has declined across southern Victoria; supplementary analyses of changes in water availability using a variety of statistical methods undertaken as part of the assessment produced consistent results.

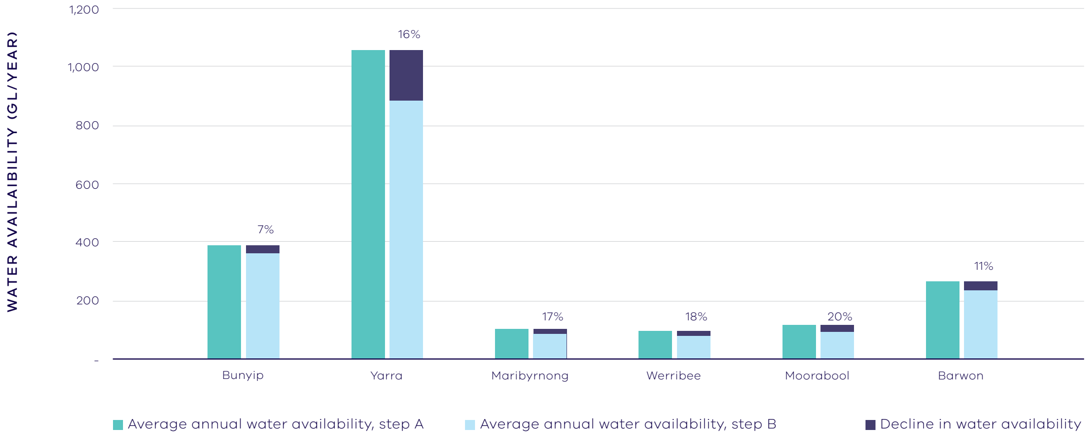


Figure 13: Declines in long-term surface water availability, Central Region, step A cf. B

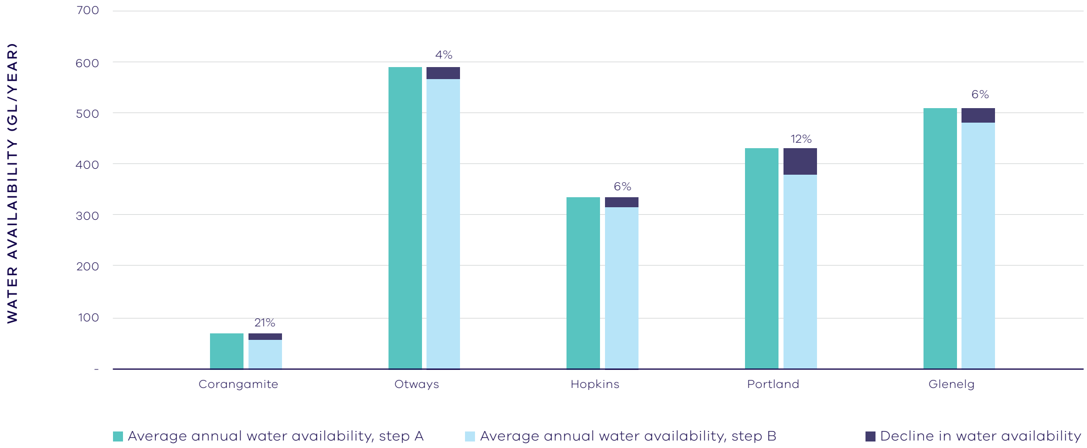


Figure 14: Declines in long-term surface water availability, Western Region, step A cf. B

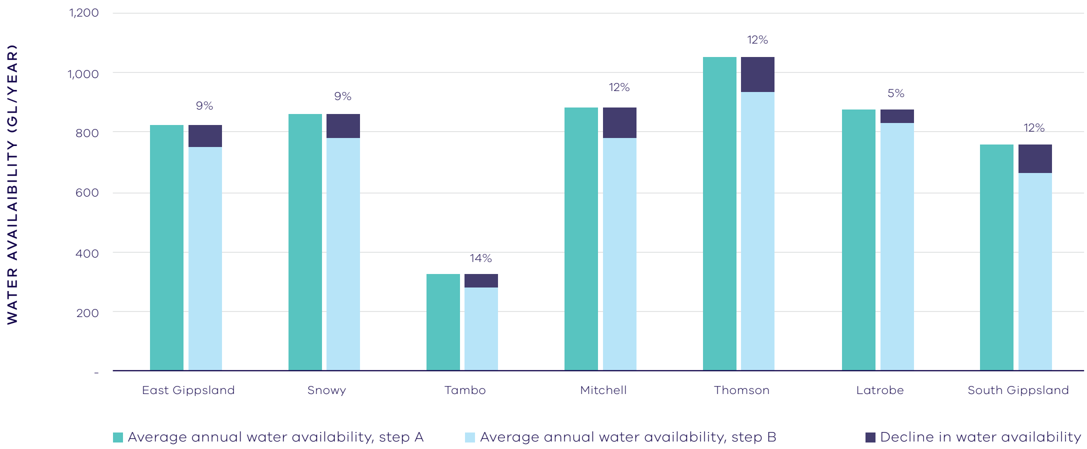


Figure 15: Declines in long-term surface water availability, Gippsland Region, step A cf. B

3. Groundwater availability

KEY FINDINGS

- Long-term groundwater availability has been assessed using groundwater levels as an indicator. Groundwater levels have declined in some areas.
- Declines in groundwater levels in the confined aquifers (mostly the middle and lower aquifers) are mainly due to groundwater extractions. In the Gippsland region this includes groundwater dewatering and depressurisation for the Latrobe Valley coal mines and offshore oil and gas extraction
- Declines in the water table (where the aquifers are unconfined) are mostly due to reduced recharge (generally from changes in climate and rainfall), and if present groundwater use, or land use change. The presence and relative contributions of each of these factors to declines has not been assessed as part of this study.

3.1 About groundwater availability

Groundwater is stored in aquifers, which are underground layers of rock or unconsolidated material — gravel, sand or silt — that can store and yield vast volumes of usable water. Sedimentary aquifers are layered on top of each other and separated by low-permeability aquitards, which restrict the flow of groundwater (**Figure 16**). The Victorian Aquifer Framework defines 11 aquifers, and four aquitards across Victoria. The sedimentary aquifers (and basaltic aquifers) are grouped into lower, middle and upper aquifers with bedrock (or Basement) aquifer underlying all of these aquifers, as illustrated in **Figure 16**.

Photography: David R McPhee

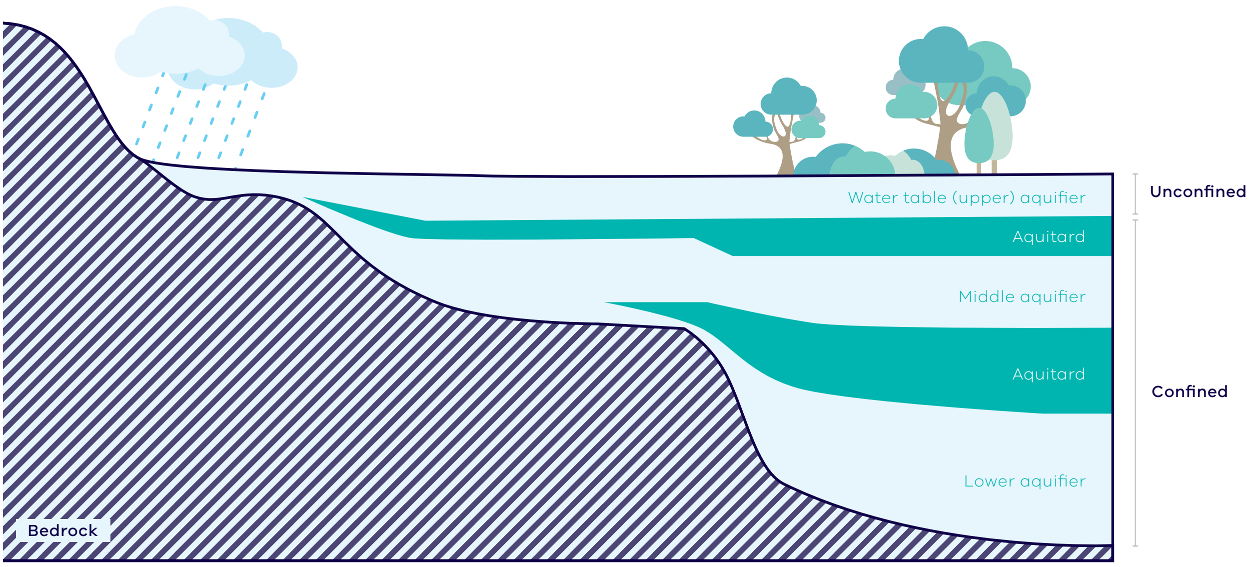


Figure 16: How groundwater is stored

In terms of age, the bedrock aquifer is from the oldest geological period and the upper aquifer from the most recent. At the surface, the middle and lower aquifers may outcrop and become the upper aquifer. This is where these aquifers are unconfined. The upper aquifer is more commonly referred to as the watertable aquifer. The lower and middle aquifers are typically confined or semi-confined.

Aquifers will respond to climate and groundwater process differently depending on whether they are confined or unconfined. The main processes that affect groundwater availability for different aquifers are:

- unconfined aquifers, especially those with shallow watertables (< 20m below natural surface): water seeps from the surface down to these aquifers, which respond relatively quickly to changes in recharge (from rainfall, irrigation or losses from waterways) and discharge processes and extractions
- unconfined aquifers with deep watertables (> 20m below natural surface): water seeps from the surface down to these aquifers which are slow to respond to changes in recharge rates and may have very low rates of recharge and respond to discharge processes very slowly.
- confined and deep: aquifers in which the groundwater is isolated from the atmosphere by impermeable geologic formations. Confined aquifers are generally subjected to pressure greater than the atmosphere and respond more slowly to changes in recharge; groundwater levels in confined aquifers are more responsive to groundwater pumping than to recharge.

The LTWRA defines groundwater availability as the ability of an aquifer to supply water for consumptive users and the environment.

3.2 How the assessment estimated long-term groundwater availability

3.2.1 Groundwater level monitoring

The assessment used groundwater levels as the indicator of groundwater availability. Groundwater levels determine groundwater available for the environment and for consumptive uses. A rise in groundwater levels means:

- more groundwater flows to waterways when they are hydrologically connected, providing water for the environment.
- there is more of the total groundwater resource, which can be made available to consumptive users.

The assessment did not use volumes of available groundwater as an indicator of groundwater availability, because the volumes available do not indicate the contribution of groundwater to streams and wetlands. Also, estimates of volumes of groundwater have a higher level of uncertainty than measured groundwater levels.

Regional Water Monitoring Partnerships program – Groundwater

Victoria currently measures groundwater levels from 1,500 State Observation Bores. Approximately 1,000 State Observation Bores are located in southern Victoria (**Figure 16**). Groundwater levels are monitored monthly in groundwater management areas and study areas, and quarterly in all other areas to a clearly defined standard. All groundwater data is publicly available through the Water Measurement Information System (**data.water.vic.gov.au**) including real time data at over 240 bores.

The LTWRA has used all available data from all bores currently and previously monitored in southern Victoria. **Figure 17** shows which aquifers the bores monitor. Where the basement, lower and middle aquifers outcrop at the surface, they are also watertable bores. The data from these bores is available on the **Water Measurement Information System,** with an example long-term plot of groundwater levels shown in **Figure 17**.

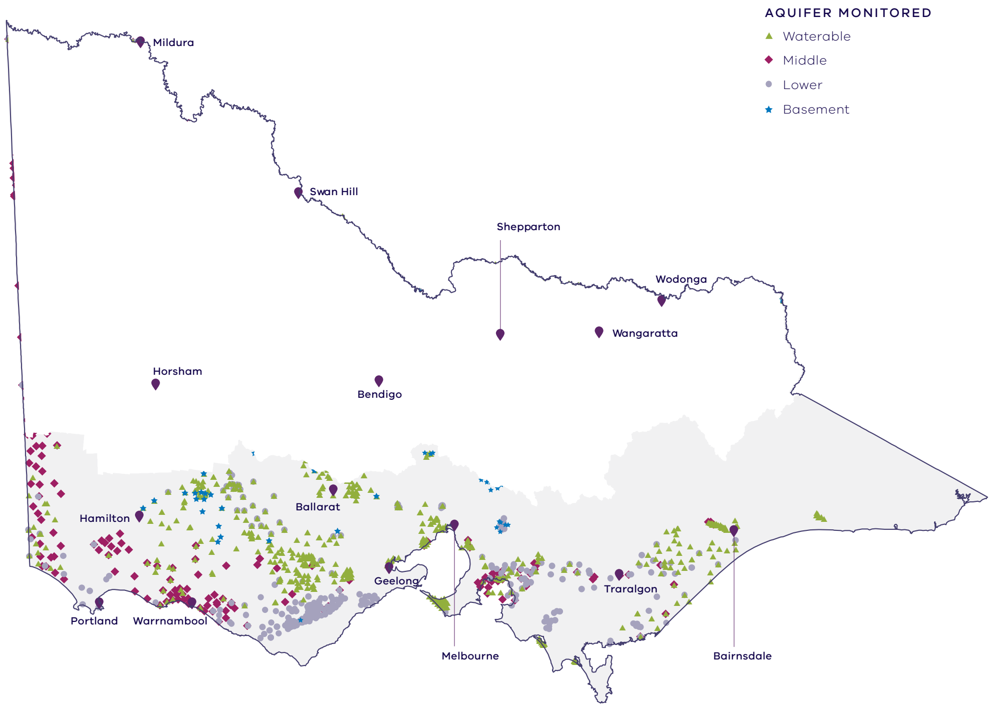


Figure 17: State Observation Bore Network for southern Victoria

Note: Where the basement, lower and middle aquifers outcrop at the surface, bores monitoring these aquifers are also monitoring the watertable.

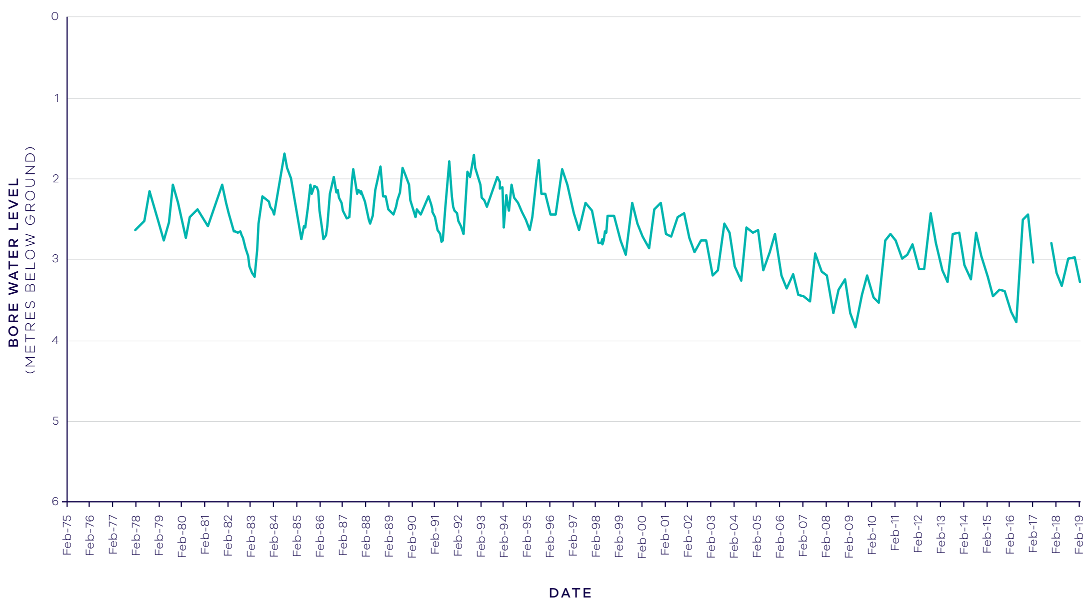


Figure 18: Example hydrograph of groundwater levels from an observation bore, 1975–2016

3.2.2 Baseline and current period determination for the groundwater availability assessment

Groundwater availability was not assessed under the SWSs, which means that there is no benchmark set by any SWS that can be used in the assessment of groundwater availability. This assessment has used 1997 as its benchmark— when water-sharing arrangements were last reviewed statewide and caps on entitlements set in nearly all groundwater management areas (GMAs).

This assessment has compared the median groundwater levels of two time periods:

- a baseline period, from 1975 (or from the beginning of the available data if later) to 1997
- a current conditions period, from 1997 to 2016.

The difference in the median levels indicates a change in long-term groundwater availability since the baseline period.

These periods are different to those used to estimate changes in long-term surface water availability. This is because the last estimates of groundwater and surface water availability were made at different times. It is also because there are big differences in the time periods for which data are available: most observation bore data only goes back to the 1970s, and we don't have the groundwater models to estimate groundwater levels before these times.

Readers should note that the baseline period, which for most bores is 1975–97, takes in only part of the surface water assessment's current climate representative period. Given the below-average rainfall after 1997, the assessment is likely to bias towards identifying declines, particularly the upper aquifer. The effect of this is that more areas are likely to be identified as having declines than might have been if the period 1975–present had been compared with the period from the early 20th century to 1975, as it was with the surface water assessment.

The areas identified with a decline have been mapped by grouping identified trends in the observation bores. These grouped trends are used to delineate the area of the decline, and where it aligns to a GMA that GMA was identified as the area to be assessed by this study.

3.3 Changes in long-term groundwater availability

Changes in groundwater levels have been calculated by comparing median groundwater levels between 1975 to 1997 to median groundwater levels from 1997 to 2016. The results are shown in **Figure 19 – 21** for the different aquifers in southern Victoria. The change in level has been categorised into four groups: < 0.1 m change (within error bounds of monitoring); 0.1 to 1.0 m change (low reduction in groundwater availability); 1.0 - 2.0 m change (medium reduction in groundwater availability); and > 2.0 m (high reduction in groundwater availability).

The units of water level decline used in the assessment are the same for unconfined and confined aquifers. This is likely to overstate the decline in groundwater availability in confined aquifers due to the differences in aquifer storage. Therefore a 1 m decline in an unconfined aquifer is not equal to a 1 m decline in a confined aquifer in terms of a change in groundwater availability.

Figure 19 shows that groundwater levels in the watertable aquifer have declined throughout southern Victoria, likely due to below-average rainfall in recent years, groundwater extraction and, in some areas, land use change. In some unincorporated areas, they have declined more than 2 m in a few areas. Most other areas of the state indicate long-term declines of less than 1 m, or no decline. No information is currently available that attributes the relative causes of these declines.

All areas of intensive groundwater extraction are routinely monitored and reviewed to protect the sustainability of the resource. The influence of groundwater on surface water availability is discussed further in **Chapter 4**.

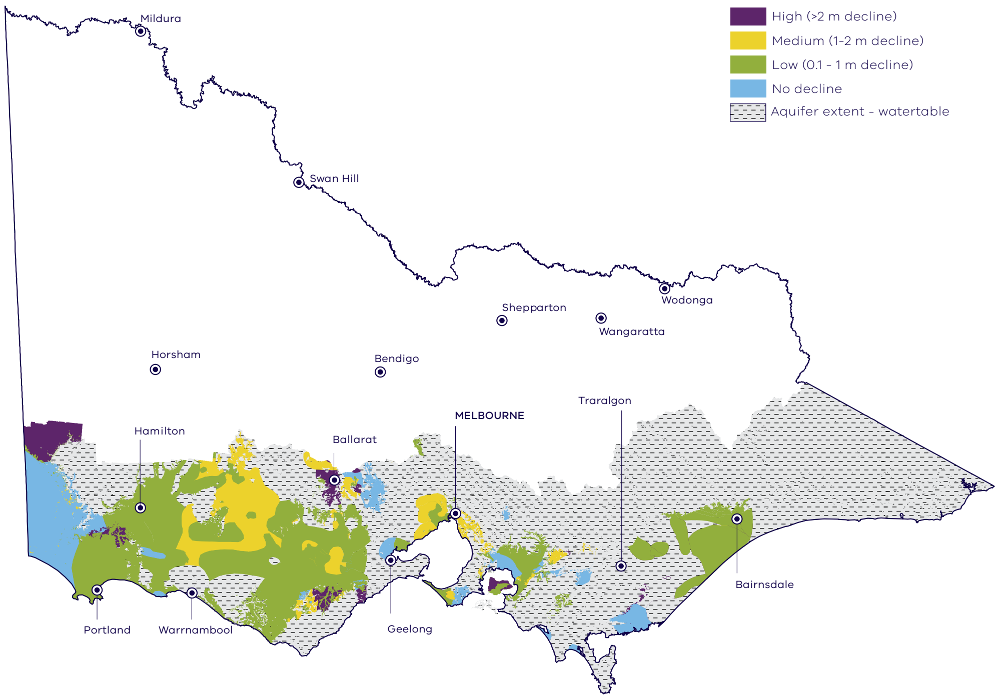


Figure 19: Change in groundwater levels, watertable aquifer, 1997-2017 c.f. 1975-1997

Figure 20 shows that in the middle aquifer — a mostly confined aquifer – there have been since 1997 areas of decline greater than 2 m in Gippsland, as well as in isolated areas in the Otways and the south-west.

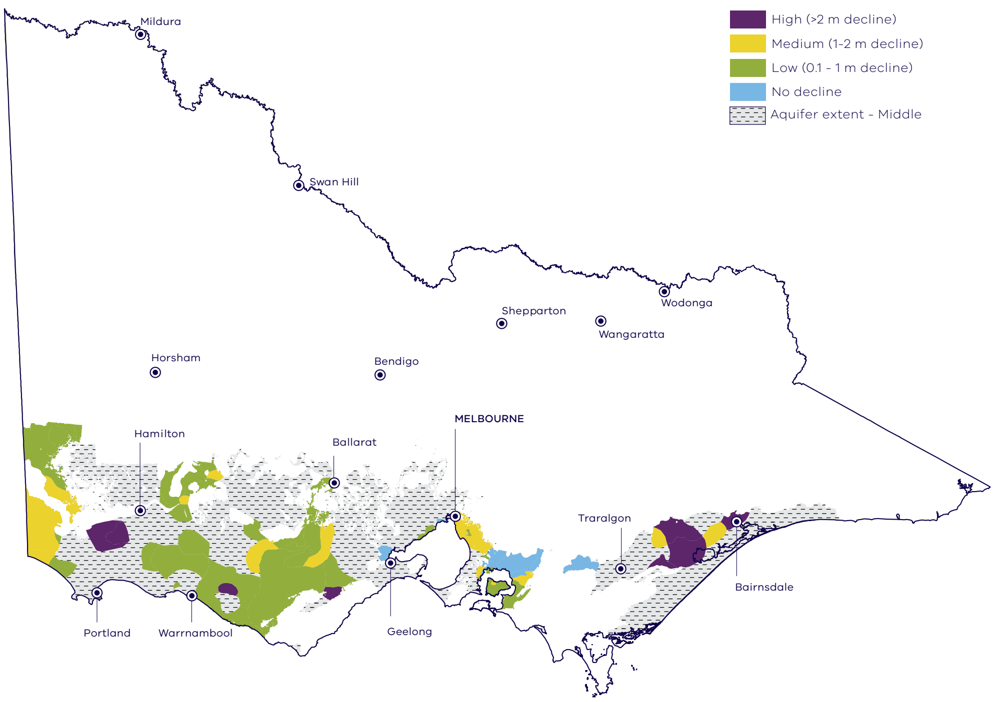


Figure 20: Change in groundwater levels, middle aquifer, 1997-2017 c.f. 1975-1997

Figure 21 shows the most significant declines in the lower aquifer — which is mostly confined — since 1997 have occurred in Gippsland, with declines greater than 2 m extending along the south-central Gippsland coast. These declines are due to coal mining and offshore oil and gas extraction. Other areas of decline are in the Barwon River catchment and around Portland in the south-west.

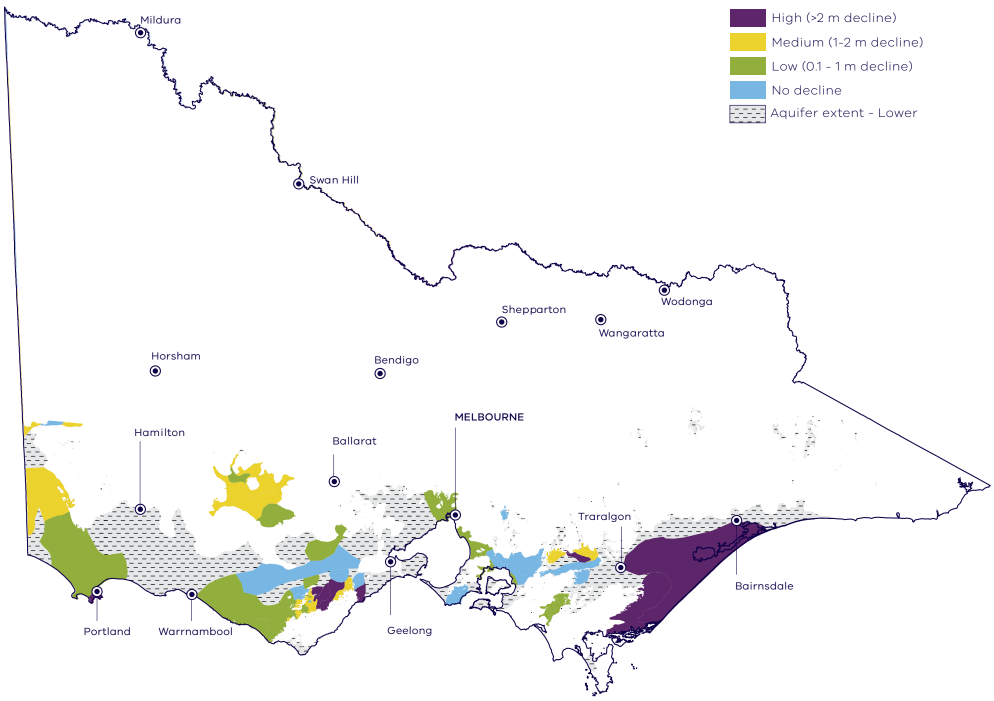


Figure 21: Change in groundwater levels, lower aquifer, 1997-2017 c.f. 1975-1997

All areas identified as having a change in level greater than 0.1 m were assessed to determine potential impacts on surface waters if: they had groundwater extractions greater than 0.5 ML/ha/yr; the aquifer was either a watertable or shallow aquifers defined as <50 m depth from natural surface; and had a waterway or lake in the same area.

4. Factors contributing to changes in long-term water availability

KEY FINDINGS

- The main cause of declines in surface water availability is drier conditions.
- Groundwater extraction has had only a very small effect on surface water availability at the regional level compared to other influences.
- The likelihood that upstream interception of water for storage in domestic and stock (D&S) dams and plantations may be contributing to the decline in surface water availability was the highest in the Glenelg, Barwon, Otway Coast, Hopkins, South Gippsland and Latrobe basins.
- Upstream interception activities are unlikely to be contributing to declines in surface water availability in the East Gippsland, Mitchell, Tambo, Thomson, Yarra, Snowy and Lake Corangamite basins.
- The changes in surface water availability also incorporate the influences of bushfires, historical forestry management, urbanisation and the change in catchment responses to rainfall. Due to the complex nature of these factors, the assessment did not isolate their effect from that of other catchment and climate changes.

4.1 About factors contributing to changes in long-term water availability

The main contributing factor to the declines in long-term surface water availability — current estimates of long-term surface water availability being less than the SWS estimates — is the difference in the climate between the periods used for the SWS estimates and the period 1975–present.

Upstream interception of water also reduces the available surface water for both consumptive uses and the environment. This includes the interception of water for storage in D&S dams, groundwater extractions and large-scale changes in land-cover.

Increases in interception activities may be contributing to a decline in surface water availability but there is not sufficient, consistent data to accurately estimate their contributions to this decline, particularly over long time periods. Instead, the assessment discusses each of these interception activities in turn and their indicative long-term impacts on surface water availability. This provides important additional contextual information about how and why surface water availability has declined since the SWS, for input into any subsequent review of water-sharing.

In catchments with no significant growth in interception activities and/or significant groundwater extraction, the assessment considers reduced rainfall to be the primary cause of a decline in surface water availability.

4.2 Licensed groundwater extraction

Groundwater extraction can contribute to declines in long-term surface water availability because groundwater contributes to the volume of surface water where there are good connections between waterways and aquifers. Therefore, the estimates of long-term surface water availability include the impact of declines in groundwater levels on surface water availability.

Groundwater entitlements were first issued under the *Groundwater Act* in 1969, which was superseded by the Act in 1989. Construction of bores was licensed before 1969 but not the take and use of groundwater. For this reason, there were no groundwater entitlements in place prior to 1969. There was some development of groundwater resources across Victoria but for the purposes of this study the assumption is made that entitlements and use were zero in 1969.

Figure 22 shows that allocation of groundwater in the whole of Victoria for consumptive use steadily increased during the 1970s and 1980s. Caps on groundwater entitlements were first introduced in 1997 which in some cases allowed for some further uptake of new entitlements within the caps. Since 2009, growth in licensed entitlement has plateaued as caps were reached in most areas.

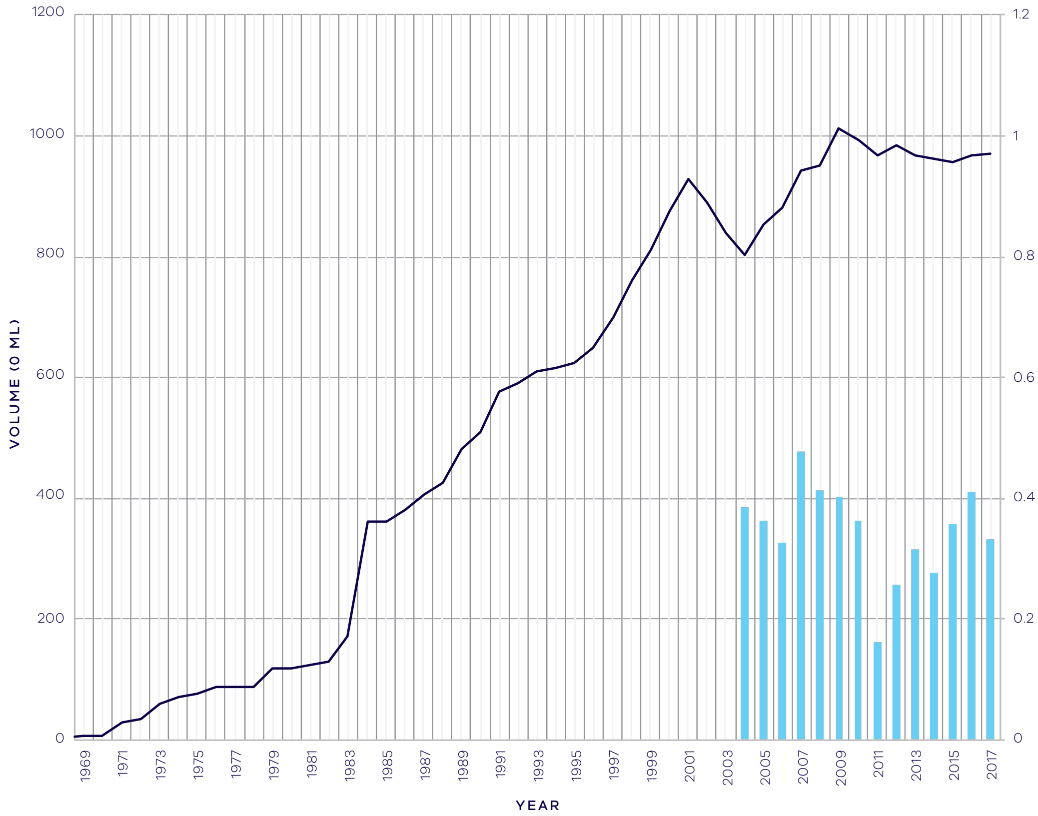


Figure 22: Groundwater licence entitlement (line) and use (columns) in Victoria, 1969-2017

Figure 23 shows twelve areas in southern Victoria where the assessment identified licensed groundwater extractions could contribute to declines in long-term surface water availability. These areas were selected on the basis of the following criteria: the aquifers are unconfined and connected to waterways, have licensed entitlements of greater than 0.05 ML/ha and have had long-term groundwater level declines of more than 0.1 m. To determine the percentage contribution of groundwater extractions to the decline in long-term surface water availability, the assessment estimated the volume of water in waterways that is intercepted by licensed groundwater extractions under current conditions.

Different methods (groundwater modelling, one to one relationship, hydraulic gradient assessment or stream depletion assessment) were used to assess each area depending on the availability of data (**Table 2**). A conservative approach was adopted to provide an upper estimate of the potential impacts on the waterways.

To align the results with the surface water assessment period used, the groundwater impacts on long-term surface water availability were estimated for the step A and step B periods used to assess surface water availability. A linear increase in groundwater use was assumed based on the historical groundwater entitlement volumes between 1969 and 2007 (**Figure 22**). The impact of groundwater extractions on waterways was taken as the difference between the Step A and Step B values, and then calculated as a percentage of the total decline in long-term surface water availability in the river basin.

Figure 23 shows that licensed groundwater extraction contributed only slightly to the changes in long-term surface water availability in all basins except for the Thomson Basin where potential impacts from groundwater extractions are nearly 4 per cent of the estimated change in flow. The other areas assessed accounted for 2 per cent or less of the declines in long-term surface water availability.

Table 2: Results of assessment of impacts of licensed groundwater extraction on waterways

			Impact of licensed groundwater extraction on waterway (GL/yr)				
Study area	**River Basin**	**Average Groundwater Use 2011/12-2015/16 (GL/yr)**	**1:1**	**Ground-water model**	**Hydraulic gradient**	**Stream depletion**	**Result (GL/yr)**
Bungaree	Moorabool	1.6*	-	-	-	0.6	0.6
Denison	Thomson	8.3	8.3	-	-	-	8.3
Deutgam	Werribee	1.7*	-	-		0.4	0.4
Gellibrand	Gellibrand	0	-	0.1**	-	-	0.1
Gerangamete	Barwon	4.6	-	0.6	-	-	0.6
Jan Juc	Otway Coast	2.6*	*Methods not applicable for losing streams, and/or insufficient data to assess*				
Koo Wee Rup	Bunyip	1.3	-	-	-	0.7	0.7
Moe	Latrobe	0.1	-	-	-	0.1	0.1
Nepean	Bunyip	2.1	2.1	-	-	-	2.1
Warrion	Lake Corangamite	5.3*	-	-	0	-	0.0
Wa De Lock	Thomson	6.9	6.9	-	-	-	6.9
Wy Yung	Mitchell	0.6	0.6	-	-	-	0.6

*These groundwater use volumes are based on an apportioned usage for the GMA (and area impacting the waterway).
** Impacts within Gellibrand GMA are from groundwater extractions in the neighbouring GMA (Gerangamete).

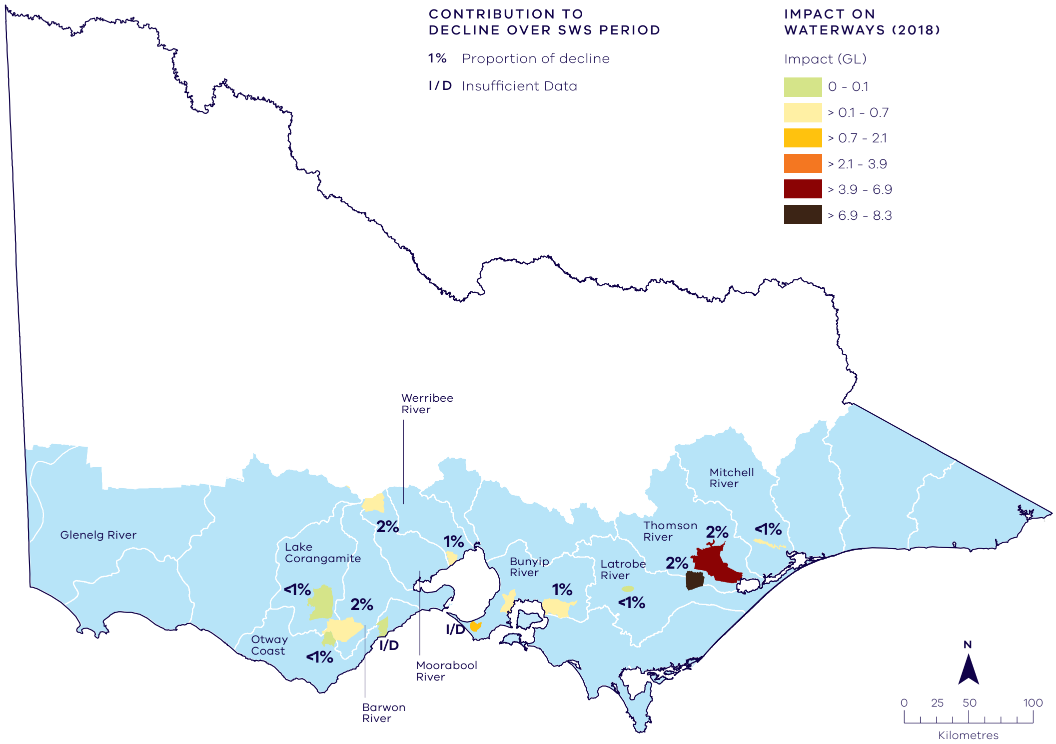


Figure 23: Impact of licensed groundwater extractions on decline in long-term surface water availability

In most areas, the impact of extractions on waterways is less than the total volume of groundwater extracted, because aquifers are recharged with rainfall which reduces the volume intercepted from waterways. For example, in the Bungaree GMA in the Moorabool basin there was 1.6 GL/year of licensed groundwater usage in the areas identified. It is estimated that this usage reduced the volume of groundwater flowing into waterways by 0.6 GL/year, which is 2 per cent of the reduction in long-term surface water availability in the Moorabool River basin. A brief discussion of these areas is provided below.

The impacts of groundwater extractions on waterways can be more significant at local scales, particularly during periods of low flow when the baseflows sustain flow in certain reaches of a river or wetland. These impacts are managed through existing processes which aim to minimise adverse impacts on third parties (i.e. other groundwater users or the environment). These processes include individual assessment of groundwater licence applications, as well as through development of groundwater management plans in consultation with groundwater users and stakeholder groups.

A description of the twelve areas in southern Victoria and the assessment of the contribution of licensed groundwater extractions to declines in long-term surface water availability is as follows.

Bungaree

The Bungaree study area corresponds with part of the Bungaree GMA in the Moorabool River basin. The impact of groundwater extraction on Frawley Creek and Devil Creek was assessed using streamflow depletion equation. Average annual groundwater use in the study area is 1,588 ML/year. Frawley and Devil Creek are tributaries of the Moorabool River, with mean annual flows of 612 and 1,342 ML respectively. The reduction in groundwater contributions to the stream due to groundwater extraction is estimated at 70 per cent and 14 per cent of mean annual flows respectively. The Moorabool River basin has seen a reduction in long-term surface water availability of 20.6 GL/year, of which 2 per cent (0.6 GL/year) is caused by licensed groundwater extraction (see **Table 2**). The impact of these extractions on the unregulated creeks would be through an increase in no flow days when groundwater contributions were the sole source of water for the stream during summer (baseflows).

Denison

The Denison study area corresponds with the boundary of the Denison GMA, a shallow unconfined aquifer in the Macalister Irrigation District situated between the Thomson and Latrobe Rivers. Groundwater extraction occurs for the purposes of irrigation as well as for salinity management. Groundwater control pumps discharge excess groundwater to drains that flow to the Latrobe River. The Thomson River is a losing stream and hence any impact on the Thomson River would be the reduction in flow due to groundwater extractions is due to increased gradients away from the river. The impact of groundwater extraction on surface water availability was assessed based on a 1:1 relationship between the stream and the aquifer. This assumes that all groundwater extractions result in an equivalent reduction in streamflow (i.e. a 1:1 relationship). Average annual groundwater use is 8.3 GL/year, with approximately 1 GL/year taken by public pumps for salinity control. This assessment has used a conservative approach to determine the potential impacts of groundwater extraction which may contribute up to 2 per cent of the decline in long-term surface water availability in the Thomson basin.

Deutgam

The Deutgam study area corresponds with part of the Deutgam GMA in the Werribee River basin. The impact of groundwater extraction on Werribee River was assessed using streamflow depletion equation. Average annual groundwater use in the study area is 1,685 ML/year. The Werribee River is regulated and has a mean annual flow of 77 GL. The reduction in groundwater contributions to the stream due to groundwater extraction is estimated at 456 ML (see **Table 2**) which is less than 1 per cent of annual flow. In low flow periods, impacts are equivalent to 20 per cent of streamflow. Deutgam GMA has groundwater trigger levels set to manage the risk of sea water intrusion at the coast. Restrictions on allocations in the area have been announced in 10 seasons since 1997. Whilst declines in level have occurred in the GMA, there has been no increase in salinity in the aquifer. The main source of recharge to the aquifer is from surface water irrigation in the Werribee Irrigation District.

Gerangamete

The Gerangamete study area corresponds with the western half of the Gerangamete GMA in the Barwon River basin. The impact of groundwater extraction on the Barwon River and Boundary Creek was assessed using the results of a numerical model (Barwon Water groundwater model). Average annual groundwater use during the assessment period in the GMA was 4,597 ML/year. Barwon Water is one of three licensees in the area and has held a large entitlement for the purposes of supplementing Geelong's water supply during periods of water shortage. The impact of licensed extractions (0.6 GL see **Table 2**) equates to 2 per cent of long-term declines in surface water availability in the Barwon River basin. The impact of licensed extraction on Boundary Creek are equivalent to 22 per cent of annual flow and >100 per cent of low flow. Past extraction has adversely impacted the environment and Barwon Water has sought not to use or renew its groundwater licence while it remediates the impacts to the Boundary Creek, Big Swamp and the surrounding environment.

Gellibrand

The Gellibrand study area corresponds with the boundary of the Gellibrand GMA in the Gellibrand River. The impact of groundwater extraction on Gellibrand River was assessed using the results of an existing numerical model (Barwon Water groundwater model). Average annual groundwater use in the GMA is 0 ML/year however the groundwater extraction in adjacent Gerangamete GMA (4,597 ML/year) impacts on the Gellibrand area. The reduction in groundwater contributions to the stream due to licensed extraction is estimated as 0.1 GL which is equivalent to less than 1 per cent of annual flow or losing 6 per cent of low flow. The Gellibrand River basin has seen a reduction in long-term surface water availability of 17 GL/year, of which <1 per cent is caused by licensed groundwater extraction.

Jan Juc

The Jan Juc GMA study area covers the outcropping area of the Lower Eastern View Formation. The conceptual model for this area suggests that water from the creeks (Breakfast Creek, Salt Creek, Painkalac Creek) in this part of the Anglesea River catchment recharge the aquifer (i.e. water flows from the creeks into the groundwater). Barwon Water holds a bulk entitlement to take and use groundwater from the Lower Eastern View Formation in the Jan Juc GMA. Groundwater extractions which contribute to water level decline may increase the rate of loss from the waterway, however there is insufficient data to quantify this impact in the area. A comparison of groundwater levels, metered use data and climate trends indicates that climate is the main driver of long-term reductions in groundwater levels in the area. Therefore, reductions in baseflow to waterways are likely to be climate driven, with low likelihood of impact from extractions.

Koo-Wee-Rup

The Koo-Wee-Rup study area covers two sections on the south-east and south-west flanks of the Koo-Wee-Rup WSPA. The impact of groundwater extraction on the Lang Lang River was assessed using the streamflow depletion equation. Average annual groundwater use in the study area is 1,277 ML/year. Annual streamflow is approximately 84 GL/year with seasonal low flows of 2.8 GL per season. The reduction in groundwater contributions to the stream due to extraction is estimated at 0.7 GL/year (see **Table 2**), equivalent to 1 per cent of mean annual flows or 24 per cent of low flows. Koo-Wee-Rup WSPA has a management plan in place which uses groundwater trigger levels to manage allocations and the risk of seawater intrusion into the aquifer. There is limited usage at present but there remains a significant cone of depression in groundwater levels near the centre of the WSPA from historical extractions. The catchment is heavily modified with drainage of most areas into modified creeks and rivers from reclaimed swamp areas.

Moe

The Moe study area includes a small area in the east of the Moe GMA and extends further to the east to encompass a section of the lower Tanjil catchment. The impact of groundwater extraction on the Latrobe River was assessed using the streamflow depletion equation. Average annual groundwater use in the study area is 81 ML/year. Annual streamflow is approximately 830 GL/year with seasonal low flows of 37 GL. The reduction in groundwater contributions to the stream due to extraction is estimated at 0.1 GL/year (see **Table 2**), or less than 1 per cent of mean annual flows and low flows.

Nepean

The Nepean study area is located on the Nepean and Mornington peninsulas and includes part of the Nepean GMA. The impact of groundwater extraction on Drum Drum Alloc Creek (and Tootgarook Swamp) was assessed based on the assumption that all groundwater extractions result in reduction in streamflow of the same volume (i.e. a 1:1 relationship). Average annual groundwater use in the GMA is 2,163 ML/year, with approximately half the extractions occurring in Drum Drum Alloc Creek catchment. Based on the conceptual model of 100 per cent of groundwater extractions impacting the waterway, the resulting reduction in groundwater contributions to the waterway is 2 GL. This is likely to be an overestimate of the impact, however given the limited data and highly conductive nature of the aquifer is considered appropriate for this assessment.

Warrion

The Warrion study area corresponds with the boundary of the Warrion GMA in the Lake Corangamite basin. The impact of groundwater extraction on the Lake Corangamite complex was assessed based on hydraulic gradient. There are several lakes within the complex, most are through flow lakes and others are drainage features which are not groundwater fed. Average annual groundwater use in the GMA is 4,412 ML/year, primarily for dairy farms and irrigation. Levels in Lake Corangamite are managed via Woady Yaloak Diversion Scheme and are maintained at 114.7 mAHD. For this reason, there are no discernible impacts on Lake Corangamite from groundwater extractions in the area.

Wa De Lock

The Wa De Lock study area corresponds with the boundary of the Wa De Lock GMA, a shallow unconfined aquifer in the Macalister Irrigation District. The aquifer is connected to both the Macalister and Avon Rivers in the Thomson basin. Groundwater extraction occurs for the purposes of irrigation as well as for salinity management. Groundwater control pumps discharge excess groundwater to drains that flow to the Gippsland Lakes. The impact of groundwater extraction on the Avon and Macalister Rivers were assessed based on a 1:1 relationship between the stream and the aquifer. This assumes that all groundwater extractions result in an equivalent reduction in streamflow (i.e. a 1:1 relationship). Average annual groundwater use is 6.9 GL/year with approximately 3.9 GL/year in the Avon River catchment and 3.0 GL/year in the Macalister River catchment. Average annual streamflow in the Avon River is 165 GL/year and in the Macalister River is 750 GL/year. The Avon River is highly connected to groundwater and groundwater extractions are estimated to reduce flows by 3.9 GL/year, which is approximately 2 per cent of the decline in long-term surface water availability in the Avon River. Groundwater extractions are estimated to reduce flow by 3.0 GL/year in the Macalister River which is approximately 1 per cent of the decline in long-term surface water availability. This assessment has used a conservative approach to determine the potential impacts which overall contribute up to 2 per cent of the decline in long-term surface water availability in the Thomson basin.

Wy Yung

The Wy Yung study area corresponds with the boundary of the Wy Yung GMA in the Mitchell River basin. The impact of groundwater extraction on Mitchell River was assessed based on a 1:1 relationship between the stream and the aquifer. This assumes that all groundwater extractions result in reduction in streamflow (via interception) of the same volume (i.e. a 1:1 relationship). Average annual groundwater use is 597 ML. Annual streamflow is approximately 780 GL/year with seasonal low flows of 59 GL (autumn). The reduction in groundwater contributions to the stream due to extraction is estimated at 0.6 GL (see **Table 2**), or less than 1 per cent of mean annual flow and low flow. The system is highly connected with surface waters both receiving and losing to groundwater in different reaches and under different situations (i.e. recharges groundwater during floods and gains from groundwater during low flows).

4.3 Domestic and stock dams

D&S dams — small farm dams that don't require a licence — can reduce long-term water availability, particularly in basins where there are now enough of these dams to capture a substantial volume of runoff.[26] In dry conditions, the volume of water withheld by D&S dams decreases much less than streamflow, because D&S dams capture runoff from the catchment first. The impact of D&S dams on river flows is greatest during dry periods. This is because airspace in these dams is able to capture the majority of water from smaller rainfall events

Across southern Victoria, there are over 220,000 D&S dams with a total estimated volume of about 380 GL.[27] This is roughly one-third of the total capacity of Thomson Reservoir, Melbourne's largest reservoir.

Why aren't the impacts of D&S dams expressed as a volume?

Due to data limitations, the impact of domestic and stock (D&S) dams is expressed as a likelihood of contributing to the long-term decline in flow in waterways, rather than as a volume of water intercepted.

Advances in remote sensing mean that we have a good understanding of the current number and location of D&S dams in Victorian catchments. We are less certain about how the number and location of D&S dams has grown over time, particularly further back in time where there is less remote sensing data available for analysis. Therefore, the impact of these dams cannot be separated from other factors driving long-term reductions in streamflow, and the impact of farm dams in the pre-and post-1975 periods cannot be readily compared. Instead, the assessment broadly indicates D&S dam impacts since 1975 and identifies river basins where growth in D&S dams since 1975 is likely to have contributed to a material reduction in water availability.

While the LTWRA looks at the impacts of D&S dams at the river-basin scale, "hot spots" of high dam density can occur within sub-catchments.

The Victorian Water Accounts include estimates of the current volume of water intercepted by small catchment dams each year. The method used to calculate the impact involves computing the annual water balance for each of the 220,000+ D&S dams across southern Victoria. Confidence in these estimates is limited by uncertainty in several key variables, including the:

- storage capacity of each dam
- annual volume of water extracted from each dam for on-farm use
- net evaporation from the surface of each dam
- variations in water stored in each dam (and hence surface area) throughout the year
- runoff generated in the catchment upstream of each dam
- area of the catchment upstream of each dam.

26 Dams used for commercial or irrigation purposes must be licensed or registered. Because these dams are managed through the water entitlement framework, they are included in the assessment of water for consumptive uses and so not need to be separately considered.
27 From the Victorian Farm Dam Boundaries geospatial layer available at data.vic.gov.au

Figure 24 shows the location of D&S dams identified in the Victorian Farm Dams Spatial Dataset.

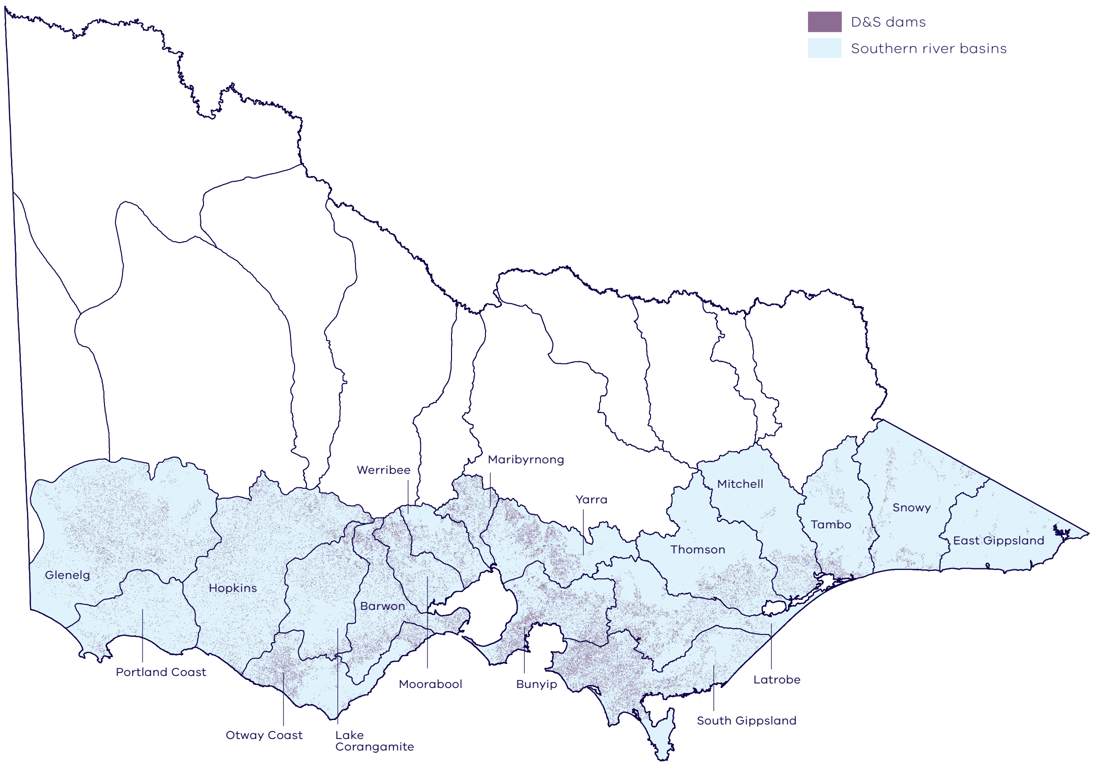


Figure 24: D&S dams

Analysis was undertaken using historical satellite imagery at key sites of D&S dam development to determine approximate rates of growth for this kind of dam. **Figure 25** shows the comparison of a sample site in the Barwon basin which depicts the change in D&S dams between 1976 and 2017.

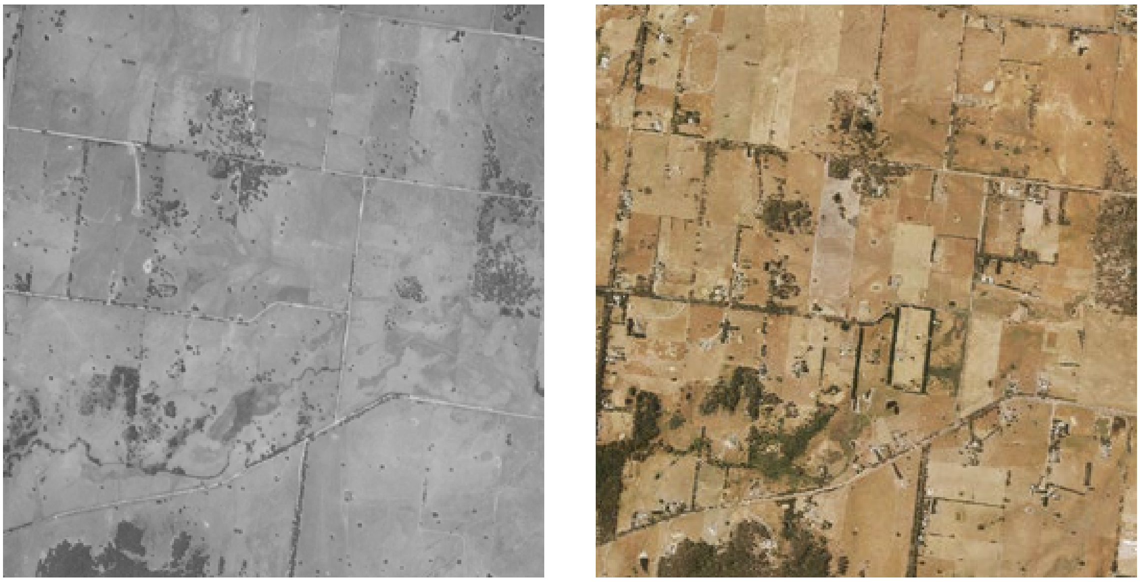


Figure 25: Presence of D&S dams within sample area in 1976 (left) and 2017 (right)

To determine the contribution of D&S dams to the decline in long-term surface water availability, the assessment estimated the volumes of water intercepted by D&S dams over the surface water step A and step B time periods. The difference between step A and step B is the increase (or decrease) in the volume intercepted. It then calculated this volume as a percentage of the decline in long-term surface water availability. To make these estimates, the assessment assumed, on the basis of the limited historical evidence about the location and volume of these dams (including satellite photography from 1975, 1995 and 2016), the volume of runoff dams in 1975 was approximately 50 per cent of what it was in 2010, and that growth in the number of dams from 2010 to 2016 was low. **Figure 26** shows that increases in the volume of water intercepted by D&S dams are more likely to be contributing to the declines in surface water availability in the Bunyip, Maribyrnong and Barwon basins. The findings are presented as a little, low, moderate or high likelihood of contributing to decline rather than as a percentage decline, for the purposes of allowing comparisons between basins.

The impacts of D&S dams on waterways can be more significant at local scales, especially if the density of dams in a given area is high, during rainfall events after extended dry periods and more generally during periods of low flow. The impacts of D&S dams at fine spatial scales and fine time intervals were not considered by the assessment, which has focussed on long-term average changes in water availability at a basin scale.

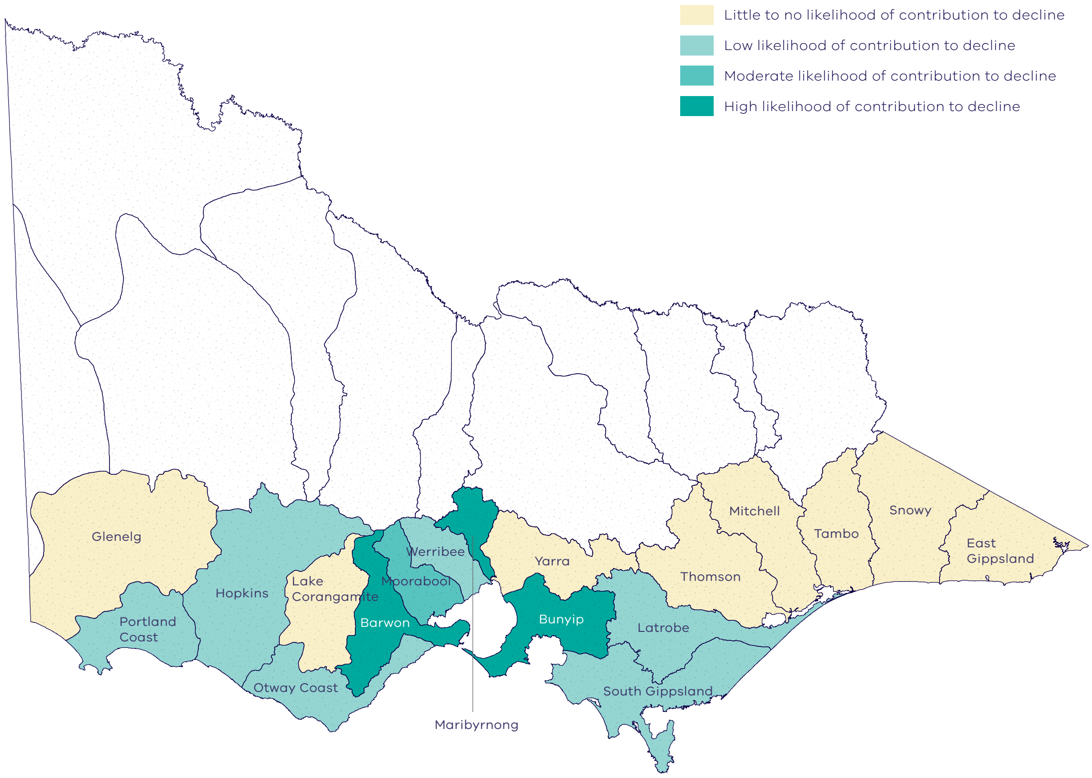


Figure 26: Relative contribution of the increase in interception by D&S dams to the total long-term decline in available surface water

4.4 Land cover

Large-scale changes in land-cover[28] can reduce long-term water availability by intercepting flows before they reach a waterway or recharge an aquifer. The greatest reductions occur where the change is from low-water-use activities (such as dryland pasture) to high-water-use activities (such as commercial timber plantations). Different types of vegetation intercept different amounts of rainfall and extract different volumes of water from aquifers, changing the yield of surface water runoff and the amount of groundwater recharge.

4.4.1 Rural land-cover

Figure 27 shows current land-cover across Victoria. The main land-cover to the east of the state is native forest and annual pasture. To the west of Melbourne, there is more annual cropping and grasslands. The largest areas of plantations are in the far west — in the Glenelg, Portland Coast and Hopkins basins — and in Gippsland — in the Latrobe and South Gippsland basins.

28 Also commonly referred to as land-use

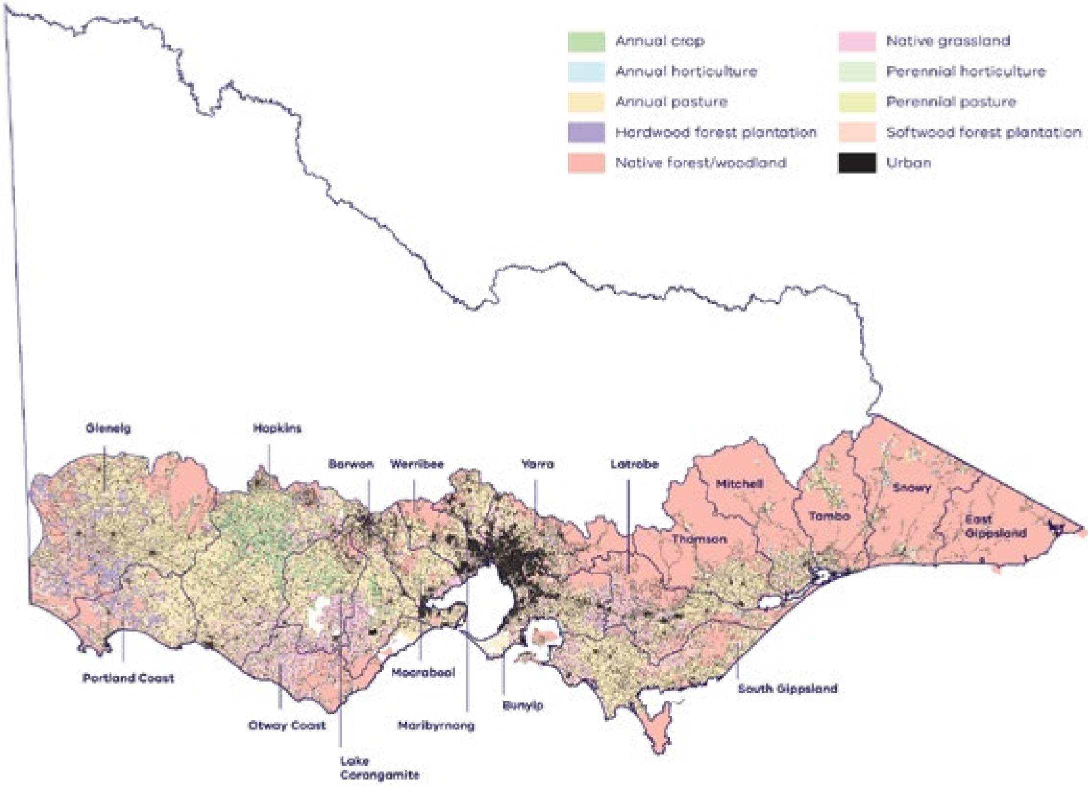


Figure 27: Current land-cover

Note: Land-cover is based on information provided in the 2016 Victorian Land Use Information System and by VicMap.

Since 2009, the area for annual pasture has increased and for annual cropping has decreased, and the total area of forestry plantations across southern Victoria remained largely unchanged, although there have been increases in some areas (such as the Glenelg basin). There is not sufficient, consistent data to identify changes in land-cover statewide before 2009.

The assessment was, however, able to understand changes in the extent of plantations by comparing satellite photography from 1975, 1995 and 2016.

Figure 28 shows the comparison of a sample site in the Glenelg basin which depicts the change in plantation area between 1976 and 2016.

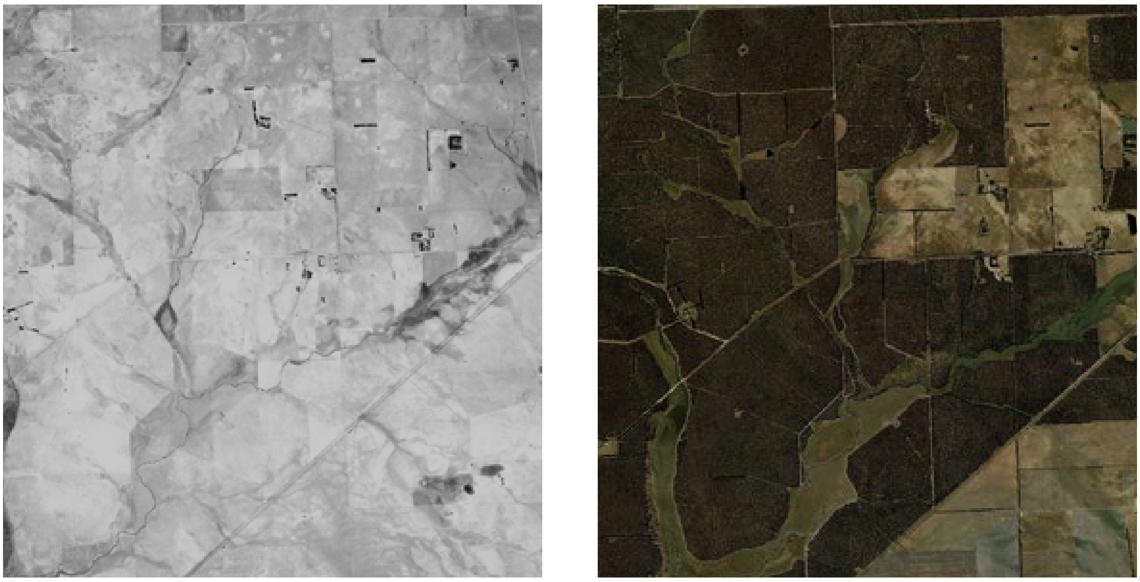


Figure 28: Presence of plantations within sample area in 1976 (left) and 2016 (right)

Total plantation area appears to have increased significantly between 1975 and 1995, with a large area of plantations in the west of the state established after 1975. There have been smaller, yet significant, increases in other areas.

To determine the contribution of plantations to the decline in long-term surface water availability, the assessment estimated the volumes of water intercepted by plantations over the step A and step B time periods. The difference between step A and step B is the increase or decrease in the volume intercepted. It then calculated this volume as a percentage of the decline in long-term surface water availability.

Figure 29 shows that the volume of water intercepted by plantations is a large proportion of the decline in long-term water availability in several basins in the south-west and south-east of the state. Plantations access groundwater as well as intercept surface water, so the assessment could not determine the precise volume of water that would have become inflow into rivers and streams, had there not been plantations. However, given the volumes involved, particularly in the Glenelg, Portland Coast and Barwon basins, the impact of plantations is likely to be significant. The findings are presented as a little, low, moderate or high likelihood of contributing to decline, allowing comparisons between basins.

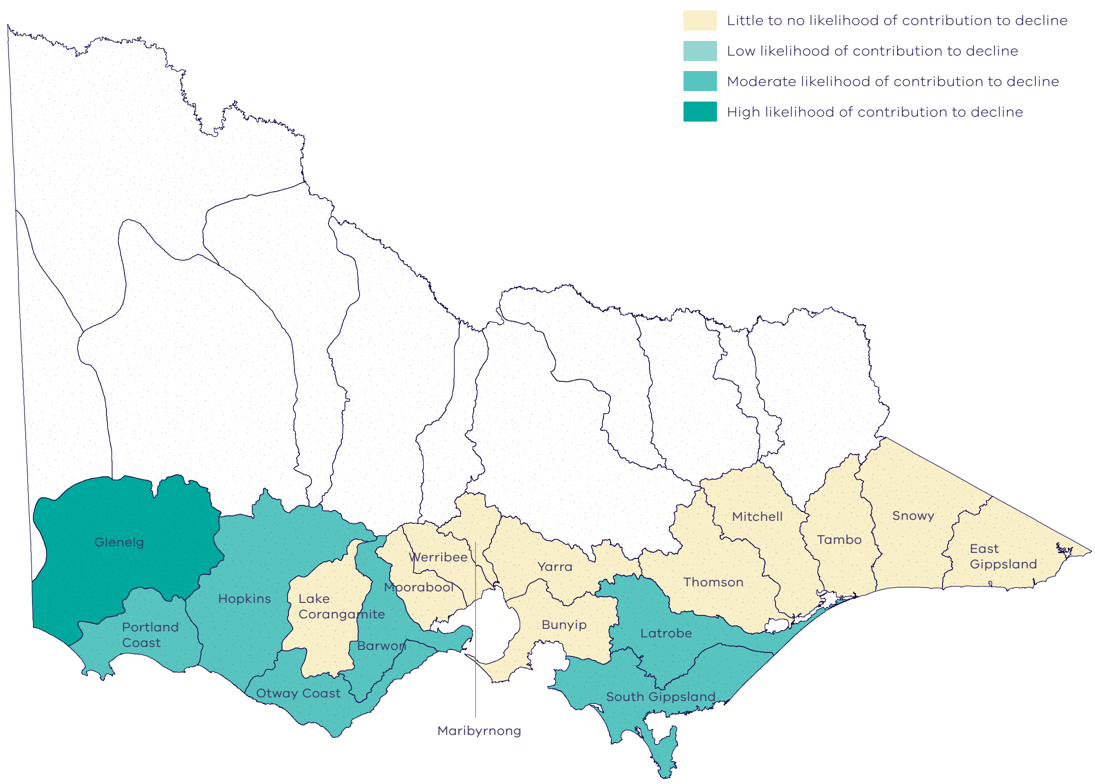


Figure 29: Plantation take as a percentage of declines long-term water availability

4.4.2 Bushfires

In Victoria's recent history, bushfires have been a regular occurrence.[29] Some selected major bushfires that have occurred across Victoria, spanning catchments in multiple river basins, include those in 1851 (Black Thursday), 1939 (Black Friday), 1983 (Ash Wednesday), 2003 (Eastern Victoria Alpine Fires), 2006/07 (Great Divide Fires) and 2009 (Black Saturday). From 2007 to 2017, over two million hectares of land was burnt by bushfires in Victoria.[30]

There are many complex factors that determine how bushfires influence water availability, including the bushfire extent, fire severity, vegetation type, vegetation age, and the climate conditions during regrowth.[31] Several studies have been undertaken to estimate the long-term average impact of past bushfires in Victoria. These studies indicated, for example, that ongoing regrowth from the 1939 bushfires has contributed positively (albeit a small percentage at a ~2 per cent increase in runoff per decade) to water availability in Melbourne's water supply catchments since the Central Region SWS.[32] A study into the combined impact of the 2003 and 2006/07 bushfires was summarised for the Gippsland Region SWS for the catchments draining to the Gippsland Lakes. It estimated that following the fires, initial increases in streamflow could be expected for the first few years, followed by decreases of up to about 8 per cent of the mean annual flow.[33]

29 https://www.ffm.vic.gov.au/history-and-incidents/past-bushfires Accessed 28/6/19
30 Commissioner for Environmental Sustainability Victoria (2018) *State of the Forests. 2018 Report*.
31 DELWP (2011) *Gippsland Region Sustainable Water Strategy – Technical Paper 3 – Bushfire impacts on water quantity and quality.*
32 Mein, RG (2008) *Potential impacts of forest management on streamflow in Melbourne's water supply catchments. Summary report.* May 2008.
33 Sinclair Knight Merz, *Combined impact of the 2003 and 2006/07 bushfires on streamflow: Broadscale assessment.* Report prepared for DSE, July 2009

For the assessment, changes in runoff due to historical bushfires have been incorporated into the estimate of changes in surface water availability, because those changes are embedded within the recorded streamflows utilised in the assessment. However, due to the complex interplay between catchments, climate and vegetation cover after bushfires, the precise historical effect of past bushfires since the SWSs has not been isolated from other catchment and climate changes.

The 2019/20 fire season saw catastrophic bushfires affecting large areas of Victoria, especially the East Gippsland region and North-East Victoria. Due to the timing of the LTWRA and the data available, the technical assessment was not able to account for these fires when estimating water availability in the affected region. At this stage it is too early to know what the long-term changes to the affected catchments will be as a result of these fires.

4.4.3 Timber Harvesting

From 2004/05 onwards, the area of timber harvested from public native forests in any given year ranged from approximately 4,000 hectares per year, to just under 10,000 hectares per year, with no clear trend.[34] This represents, on average, approximately 0.04 per cent of Victoria's forest area being harvested in any given year. These areas are predominantly located in eastern Victoria, due to a combination of proximity to suitable forests and sawmills. Approximately half of this harvested area is dominated by ash species (where impacts of tree harvesting on runoff are greater), and half by mixed eucalypt forest (where tree harvesting impacts on runoff are lower).[35]

Similar to bushfires, timber harvesting can initially increase runoff (due to a reduction in rainfall interception and absence of plant water use), followed by a period of decreased runoff as the forest regrows. As the forest matures, it uses less water than a young forest. However, unlike historical bushfires, timber harvesting is on a much smaller scale. Over the period from 2003 to 2017, a total area of approximately 70,000 hectares was harvested for timber,[36] whilst almost four million hectares was burnt by fire.[37] The relative magnitude of these two factors on water availability was confirmed in a study for Melbourne's water supply catchments. It concluded that changes in annual runoff due to hypothetical alternative timber management regimes were negligible (for long forest rotation options), up to 0.8 per cent per decade (for cessation of all timber harvesting), and much lower than the ongoing effect of the 1939 bushfire.[38]

For the assessment, changes in runoff due to historical forestry management have been incorporated into the estimate of changes in surface water availability, because those changes are embedded within the recorded streamflows utilised in the assessment. However, due to the complex interplay between catchments, climate and vegetation cover, the precise historical effect of forestry management practices since the SWSs have not been isolated from the effect of other catchment and climate changes.

34 Commissioner for Environmental Sustainability Victoria (2018) *State of the Forests. 2018 Report*.
35 Commissioner for Environmental Sustainability Victoria (2018) *State of the Forests. 2018 Report*.
36 Commissioner for Environmental Sustainability Victoria (2018) *State of the Forests. 2018 Report*.
37 Commissioner for Environmental Sustainability Victoria (2018) *State of the Forests. 2018 Report*.
38 Mein, RG (2008) *Potential impacts of forest management on streamflow in Melbourne's water supply catchments. Summary report*. May 2008.

4.5 Urban land cover

Stormwater is the additional runoff generated from the increase in impervious areas (e.g. rooves, roads, footpaths) that occurs as a result of urbanisation. Stormwater can make a significant contribution to available surface water in urban areas. In some instances, recycled water, derived from treated urban wastewater, is also returned to waterways.

For the assessment, changes in the volume of stormwater and recycled water generated have been incorporated into the estimate of changes in surface water availability, where those changes are embedded within the recorded streamflows utilised in the assessment.

In areas urbanised since the SWSs, such as on the fringes of Melbourne, Geelong, and other growing regional centres, increases in stormwater are likely to have increased the estimate of current surface water availability. The extent to which this has occurred has not been quantified for the assessment because stormwater is difficult to separately quantify from other sources of streamflow. The volume of recycled water is small relative to total surface water availability.[39]

In rural areas where the degree of urbanisation is low, and changes in urban area have been minimal, changes in surface water availability due to stormwater and recycled water is likely to have been negligible.

4.6 Response of catchments to drought

During the Millennium Drought, there was an unexpected response in about 75 per cent of Victoria's unregulated catchments: they produced less streamflow for a given amount of rainfall than they did before the drought. There is a range of possible causes, including changes to water uptake by trees and vegetation, and changes to how streams interact with soils and groundwater. While the expected runoff levels in some catchments have recovered, others have not.[40] DELWP is undertaking research as part of the Victorian Water and Climate Initiative to gain a better understanding of this and its implications for our waterways and water resources.

4.7 Cumulative impacts

Given the uncertainties around each assessment method, the cumulative effects of each intercepting activity have not been quantified. However, the combined likelihoods of changes in land cover, runoff dams and licensed groundwater extractions reducing surface water availability since 1975 were highest in the Glenelg, Barwon, Otway Coast, Hopkins, South Gippsland and Latrobe basins. Little to no cumulative impacts on surface water availability from these three intercepting activities since 1975 were considered likely for the East Gippsland, Mitchell, Tambo, Thomson, Yarra, Snowy and Lake Corangamite basins.

39 In some river basins, where it was known that potentially substantial discharges to waterways occur, changes in those discharge volumes were examined as part of the assessment. For example, in the Yarra basin, the volume discharged to waterways from Yarra Valley Water's nine small sewage treatment plants was found to be approximately the same in the most recent Victorian Water Accounts, relative to discharge volumes in the mid-2000s.

40 DELWP, 2018. *Remember the Millennium drought? Well so do our rivers.* Victorian Water and Climate Initiative Factsheet

Complexities of quantifying cumulative impacts – Upper catchment case study

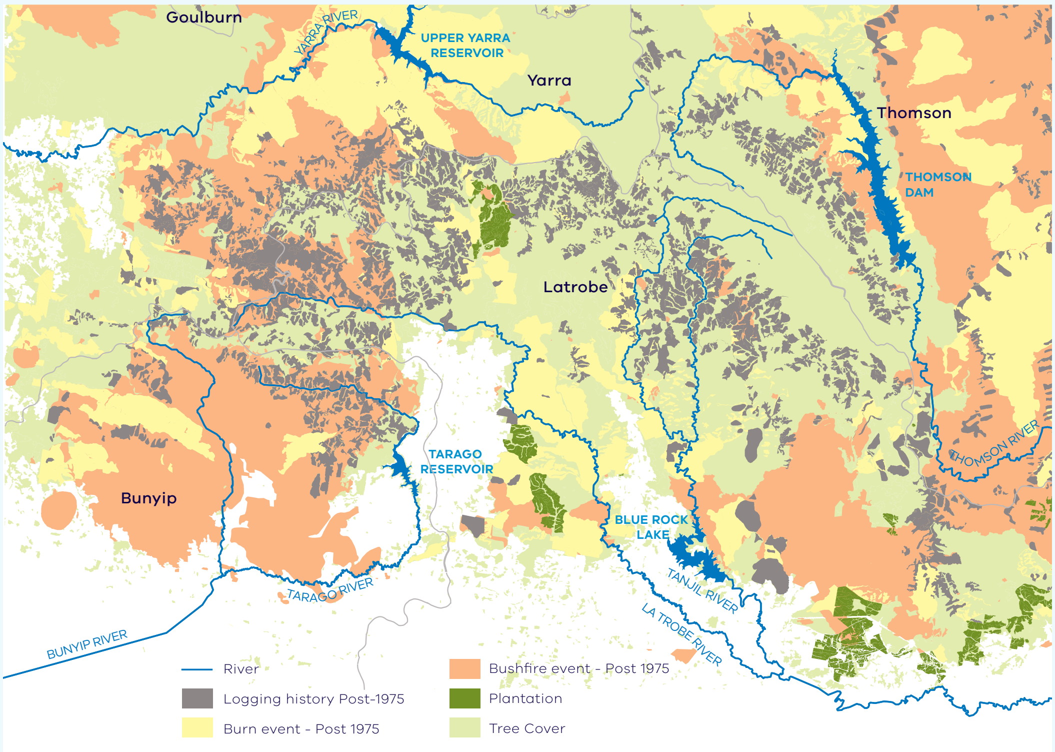


Figure 30: Landscape events and activities potentially contributing to changes in streamflow

The volume and temporal and spatial pattern of rainfall falling on a catchment is the primary determinant of runoff volumes to streamflow, but other factors will affect runoff, including the land use and land cover type. The LTWRA investigated a range of land use changes and landscape events that can contribute to changes in runoff to waterways, including plantations, native forestry operations and bushfires.

Figure 30 shows part of the upper catchment for the Latrobe, Thomson, Yarra and Bunyip basins. The landscape is a mosaic of native forest and plantation forestry with different logging and fire histories, interspersed with cleared areas. The complexity and interplay between forestry and fire events make delineating and quantifying the influence of each on streamflow very difficult, especially across the entire catchment.

Impacts of fire on runoff can vary substantially according to the severity of the fire and the ability of the tree species to survive fire.

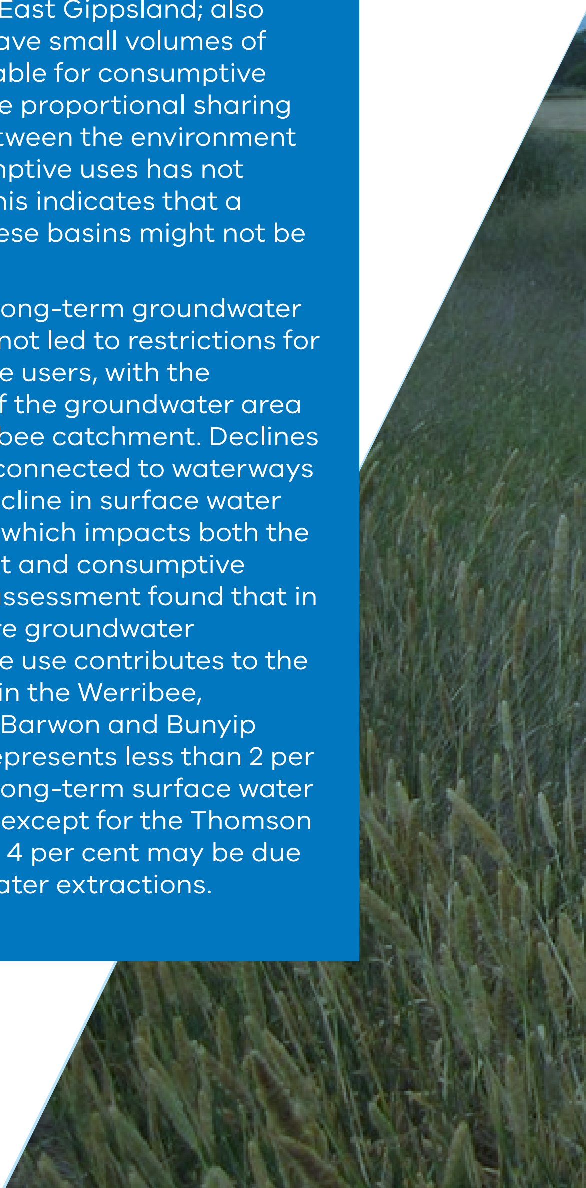
Uncertainties in the contribution of forestry and fire to changes in streamflow are further accentuated by the changing catchment rainfall-runoff relationships as a response to drought discussed in **Chapter 4.6**. The catchments in the upper Latrobe produced less runoff for a given amount of rainfall during the Millennium Drought but have since returned to the pre-drought rainfall-runoff relationship. The causes of this temporary reduction in runoff are not fully understood.

Though the impacts of logging, native vegetation clearing, and bushfires were not separated and quantified by the LTWRA, they are accounted for in the streamflow record which reflects the overall changes in water availability in the catchment.

5. Sharing of changes in long-term water availability

KEY FINDINGS

- The decline in water availability has impacted on the environment, industry and other water users.
- Water availability for consumptive uses has declined in most of southern Victoria, with percentage decline varying from 1 per cent to 13 per cent. DELWP has worked with water corporations and other stakeholders in the past decade to manage risks to water security by diversifying supply options, such as augmenting the water grid.
- Water availability for the environment has declined in all basins except the Otway Coast. The percentage decline varied from 4 per cent to 28 per cent, mainly due to declines in above-cap water.
- The decline in water availability has not been shared equally. A smaller share of available water is now set aside for the environment than when the last sustainable water strategy was developed in many basins.
- In the Barwon, Moorabool, Werribee, Yarra and Latrobe basins the decline in long-term surface water availability has not been shared equally: the environment now has a smaller share of the available resource. The environment's proportion would have declined even more had some water not been recovered for the environment (such as by creating new environmental entitlements). This indicates that a review of water-sharing in these basins might be necessary.
- In the Thomson and Maribyrnong basins the environment has the same share of the available resource. A review in these basins might be needed to take account of water supply arrangements in determining how the long-term decline in surface water availability is shared.
- The western and eastern basins — Glenelg, Portland Coast, Hopkins, Otway Coast, Lake Corangamite, South Gippsland, Mitchell, Tambo, Snowy and East Gippsland; also Bunyip — have small volumes of water available for consumptive uses and the proportional sharing of water between the environment and consumptive uses has not changed. This indicates that a review in these basins might not be required.
- Declines in long-term groundwater levels have not led to restrictions for consumptive users, with the exception of the groundwater area in the Werribee catchment. Declines in aquifers connected to waterways lead to a decline in surface water availability, which impacts both the environment and consumptive users. The assessment found that in basins where groundwater consumptive use contributes to the decline (i.e. in the Werribee, Moorabool, Barwon and Bunyip basins), it represents less than 2 per cent of the long-term surface water availability, except for the Thomson where up to 4 per cent may be due to groundwater extractions.



5.1 About water-sharing between consumptive uses and the environment

Water is limited, and as Victoria's population has grown in past decades we have had to balance increasing demand for consumptive uses with the demand for water to preserve the health, biodiversity, ecological functioning and water quality of waterways. The Act gives the Crown the overall right to the use, flow and control of all surface water and groundwater. Through the water entitlements framework, the Minister for Water manages how surface water and groundwater are shared between consumptive uses and the environment. A strength of the framework is that it provides secure water entitlements while ensuring how we share water is adaptable, to meet the challenges of changing conditions.

Figure 31 shows the water entitlement framework graphically.

5.1.1 About water for consumptive uses

Under the water entitlement framework, the Minister for Water issues bulk entitlements to urban and rural water corporations to take water from waterways to supply their customers for consumptive uses.[41] Bulk entitlements impose conditions on take for reasons such as to maintain passing flows in waterways.

The Minister also issues licences (such as Section 51 licences to almost 19,000 private diverters across the state to take and use water for consumptive uses).

An entitlement is to a share of a nominal volume of water that the entitlement holder is authorised to take, store and use under specific conditions if it is available: it is not an entitlement to actual water under all conditions.

The volume of water actually available for consumptive uses depends on:

- the rules in each water entitlement: for example, typically the entitlement holder is only allowed to take up to a specified volume of water, although there may be much more than that available in the system
- the volume of water available at the point of diversion: in dry years, when there is less water than average, the volume of available water is likely to be less than the face-value volume of the entitlement. In wet (above-average) years, there is normally enough water for the entitlement holder to take up to the face value of their entitlement
- the ability to store and deliver water: for example, the water is available for taking, but the entitlement holder doesn't have the infrastructure to take / store it
- the timing of the demand for water: for example, the water is available, but not when it's needed (such as if it is available in winter but the entitlement holder's crops need water in summer)
- water security considerations: for example, a water corporation will typically hold back some water in reserve in storage to manage the risk of future drought and ensure that water is available for the following year.

Water available for consumptive uses is water that is actually available to be taken under the terms and conditions of entitlements and licences by those who hold them. It is also referred to as water available for allocation.

Water available for consumptive uses is not the same as the volume actually taken in the past: that is, the historical level of use. Water entitlements typically have been issued with an allowance for future growth in demand for water, so actual use can be below the volume allocated to that user.

Some water-taking does not require the Minister's approval: for example, people can take water from a range of sources for domestic and stock purposes as a 'Section 8 private right'. This water is outside of the water entitlement system and therefore, has not been allocated to consumptive use in the assessment.

41 Latrobe Valley power stations also hold bulk entitlements In the Latrobe basin.

Tier 1 - Rights held by Crown

Water entitlements are defined in the Water Act 1989 and are issued by the Minister for Water. A water entitlement is the amount of water authorised to be stored, taken and used by a person under specific conditions.

Tier 2 - Rights to authorities

Environmental water reserve

- Environmental entitlements
- Obligations on consumptive entitlements
- 'Above cap' water

Bulk entitlements

- Source bulk entitlements
- Delivery bulk entitlements

Environmental water reserve

The EWR is the legally recognised amount of water set aside to meet environmental needs. The objective of the EWR is to preserve the environmental values and health of water ecosystems.

Environmental entitlements are generally identical in nature to bulk entitlements. They provide for a share of the available resource.

Obligations on entitlements include the passing flows that water corporations or licensed diverters are obliged to provide out of storage or past a diversion point. The portion of passing flows that is provided to meet environmental needs is considered a part of the EWR.

'Above cap' water includes water that is left over after limits on diversions have been reached and unregulated flows which cannot be kept in storage. Most of the EWR is comprised of 'above cap' water, and this component is most susceptible to climate change.

Bulk entitlements

Held by water corporations with secure tenure in perpetuity. They provide the right to water for system operations, seasonal allocations and other rights and obligations.

Source bulk entitlements provide a share of inflows, storage capacity (if applicable) and releases.

Delivery bulk entitlements provide a set volume of water each year, subject to defined restrictions during periods of water shortages.

Tier 3 - Rights granted to individuals

- Water shares
- Section 51 licences
- Supplies by agreement
- Supplies to urban customers
- Section 8 rights

Water shares have secure tenure held in perpetuity. A share of the available resource in most regulated systems is allocated annually (through seasonal allocations), which can then be ordered to a specified location, at a specified time and rate.

Section 51 take and use licences allow for diversions from unregulated (and some regulated river systems) and extractions of groundwater. Licences are issued for a specified volume, period of time and with a range of conditions.

Section 8 rights provide for an individual to take and use water from a range of surface and groundwater sources for domestic and stock use under certain circumstances without a licence.

Supplies to urban customers must be provided by water corporations throughout their defined districts.

Supplies by agreement are arranged by water corporations to provide water outside of defined districts, and recycled and drainage water in special circumstances.

Figure 31: Victorian water entitlement framework

Availability of alternative, fit-for-purpose water sources, such as recycled water and stormwater is not included in the volumes of consumptive use stated in this overview report, but where it is a large source of water for consumptive users in a particular basin, this is identified in the separate report Basin-by-Basin Results.[42]

5.1.2 About water for the environment

The assessment looked at the availability of water set aside for the environment: environmental entitlements, passing flows[43] and above-cap water. In many basins, the environment also benefits from other water not specifically set aside for it, but this water was not included in the assessment (**Figure 32**). This other water includes deliveries along river channels that also assist in meeting flows for the environment. It can also include adjustments to the timing of those deliveries in order to maximise environmental benefit en route to consumptive water users downstream.

Environmental entitlements

The Victorian Environmental Water Holder (VEWH) holds environmental entitlements and bulk entitlements in 8 river basins in southern Victoria. Generally speaking, these allow access to a share of the available inflows into storages that can be released to meet specified environmental needs, and to storage capacity. For example, the VEWH is entitled to 3.8 per cent of the flow into the West Barwon Reservoir and to a share of the reservoir's storage capacity.

Protecting water in environmental entitlements is valuable. Held environmental water in storage can be actively managed to mimic natural flow events, which now occur more rarely than before river regulation. For example, seasonally optimised pulses of water can be delivered to trigger fish species to reproduce. Also, system managers can use environmental entitlements to mitigate the impacts of drought, for example by ensuring minimum flows keep water in drought refuges. This active management of flows provides environmental benefits.

Passing flows

Bulk entitlements for consumptive uses usually include obligations to deliver passing flows — a specified minimum volume of water the entitlement holder must let flow out of storage or past a diversion point. In some basins (such as the Yarra and Glenelg basins), environmental entitlements specify passing flows. Also, water corporations may restrict or ban diverting water under take and use licences to ensure minimum passing flows in waterways.

Passing flows help maintain environmental values, particularly in dry periods when streamflows may otherwise be very low. In some systems, passing flow rules vary seasonally according to the need for environmental water. In many waterways, passing flows also provide water for (consumptive) domestic and stock purposes.

Above-cap water

A cap is a limit set by the Minister on the amount of water that can be taken from a water source or area. In southern Victoria, caps are put in place mainly by the Minister setting permissible consumptive volumes (PCVs) and winter-fill sustainable diversion limits (SDLs). Water that is available above these caps, including water that spills from storages after high inflows, is called above-cap water.

A PCV is the maximum volume of water that can be allocated in an area or from a water system. A PCV can be set for surface water or groundwater or both. The Minister can use PCVs to prevent adverse impacts from over-allocation of water (such as reduced security of water supply, reduced baseflows in waterways or declines in water quality from salinity). The Minister set surface water PCVs in 2006 and revised them in 2010 for rivers in the Central Region. The PCV Surface Water Order 2010 is being reviewed to be consistent with the Gippsland[44] and the Western Region[45] Sustainable Water Strategies.

42 The Victorian Water Accounts provide more detailed information on the volume and use of recycled water in each basin
43 Acknowledging that passing flows and above-cap are shared-benefits water, and may be taken or used for other purposes such as domestic and stock.
44 Revised caps were established in the Gippsland Region Sustainable Water Strategy (action 5.2, 6.2, 7.2). The status of these actions is provided at www.water.vic.gov.au/planning/sws/gipps
45 Revised caps were established in the Western Region Sustainable Water Strategy (action 8.1). The status of this actions is provided at www.water.vic.gov.au/planning/sws/western

Winter-fill SDLs limit the taking of water in 1,048 catchments across southern Victoria. These SDLs are applied through the Minister's policies for managing take and use licences and would apply to a decision to issue a new bulk entitlement.

Above-cap water provides peak flows, which although are less-frequent than would occur naturally still support valuable ecological functions. Above-cap flows can scour sediment and benthic algae build-up, flush stagnant or poor-quality water, mobilise organic matter and nutrients, connect rivers to floodplain wetlands, inhibit invasive or problem species and provide breeding or migration cues to aquatic life.

Interstate arrangements

Interstate arrangements affect long-term water availability for the environment in the Snowy River.

In the upper reaches of the Snowy River in New South Wales, the major dams and diversion weirs of the Snowy Mountains Scheme collect, store and divert large volumes of the river's water west to the Murrumbidgee River and River Murray, generating electricity in the process. The water diverted to the River Murray contributes to water availability for all River Murray entitlement holders, as well as River Murray Increased Flows. Snowy Hydro Limited's Snowy Water Licence requires it to provide water for the environment through passing flows and environmental releases.

The LTWRA assesses changes in water availability in the Snowy River and tributaries from the unregulated Victorian catchments, which comprise approximately 40 per cent of the basin area. Water availability and sharing within the Victorian portion of the Snowy basin are not affected by the interstate arrangements governing the operation of the Snowy Mountains Hydro-electric Scheme. (For further information, refer to the Snowy Basin overview in the separate report Basin-by-Basin Results.

Environmental water reserve

The Act requires the LTWRA to determine if there has been a decline in the volume of water available for the Environmental Water Reserve (EWR). The EWR is a legally recognised volume of water set aside for the environment to preserve the environmental values and health of water ecosystems including their biodiversity, ecological functioning, water quality and uses that depend on environmental condition.[46]

The environment also benefits from other water that is not included in the EWR. **Figure 32** shows the different sources of water for the environment.

The assessment determined if changes in EWR, plus the water that is above the caps set out in the Gippsland and Western Region SWSs, have occurred. If the Permissible Consumptive Volumes are updated to reflect these caps, this water will be incorporated into the EWR. Inclusion of this water in the assessment provides a more accurate and complete picture of changes in the balance between water for the environment and water for consumptive uses and can inform planning and policy decisions beyond just the LTWRA.

46 *Water Act 1989* [Victoria] s.4A and 4B.

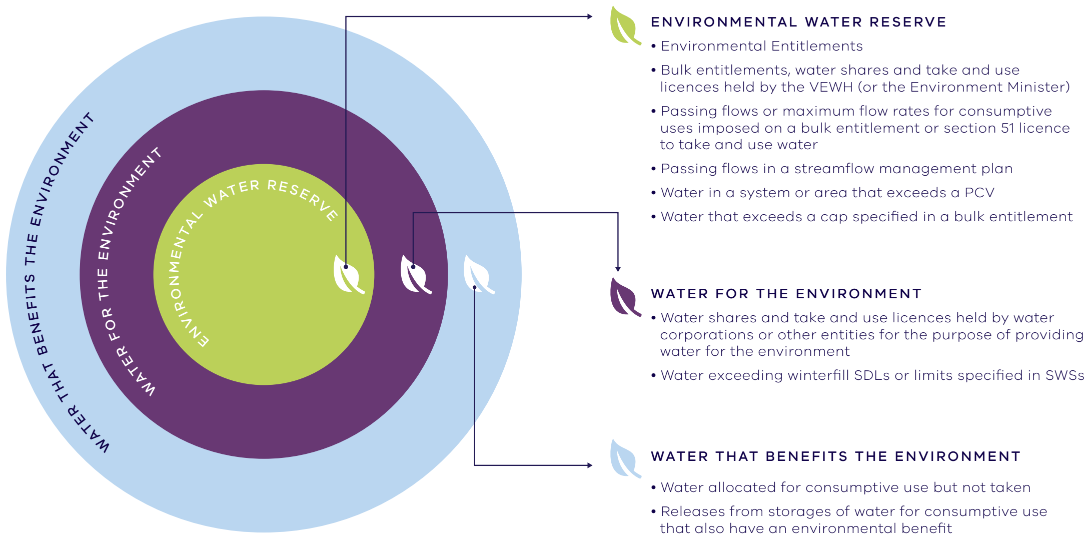


Figure 32: Sources of water for the environment

5.2 About changes to water-sharing arrangements

Since the SWSs were published, there have been many changes to water-sharing arrangements. These include by:

- allocating previously unallocated water for the environment and for consumptive uses (for example, in the Werribee and Latrobe basins)
- reducing system losses by modernising irrigation infrastructure and issuing new entitlements (for example, the Macalister Irrigation District in the Thomson basin)
- creating environmental entitlements and providing supplementary water supplies for consumptive uses (for example, in the Moorabool basin water became available for transfer to an environmental entitlement after supplementary water sources (such as a connection to the Melbourne system) gave the urban water corporations greater operational flexibility)
- changes to infrastructure (such as new pipelines): these have changed how some entitlement holders access and use water under their entitlement
- changes in operating rules in some systems (for example, in the Maribyrnong basin). Water corporations can make decisions about how much water they desire to hold in storage as contingency, operational decisions on transfer of water within the system and operational decisions about when and how much of each water source is used. These operational decisions are not specified in entitlements and can change over time. The assessment is based on the operating rules in place in 2017 and is consistent with the assumptions made in the preparation of the urban water strategies.
- reducing the volume of water available for new consumptive uses and setting it aside for the environment (for example, in the Otway Coast basin)
- purchasing water entitlements for the environment (comparatively rare in southern Victoria).

Water recovery

Victoria has several major infrastructure projects to improve the delivery of water, resulting in changes to water-sharing arrangements.

Southern Rural Water is modernising the Macalister, Werribee and Bacchus Marsh irrigation districts to reduce irrigation distribution system losses, improve customer service and improve waterway health.

Modernisation works reduce the volume of water lost in delivery channels on route to farms, such as from leaks and outfalls. Some of these water reductions have been issued to environmental entitlements. This represents a transfer of water from consumptive use to the environment.

Other savings have been issued as water shares for irrigators. The LTWRA does not assess the increase in water available at the farm gate due to water recovery because it assesses water availability at the bulk level.

The largest changes in water-sharing arrangements have been in basins where water has been recovered for the environment. This has reduced the water available for consumptive uses in some, but not all these basins. This is because environmental entitlements have been created from previously unallocated water or because supplementary water supplies were provided for consumptive use.

Table 3 shows the causes of the main changes to water-sharing arrangements. There is further information in the report Basin-by-Basin Results.

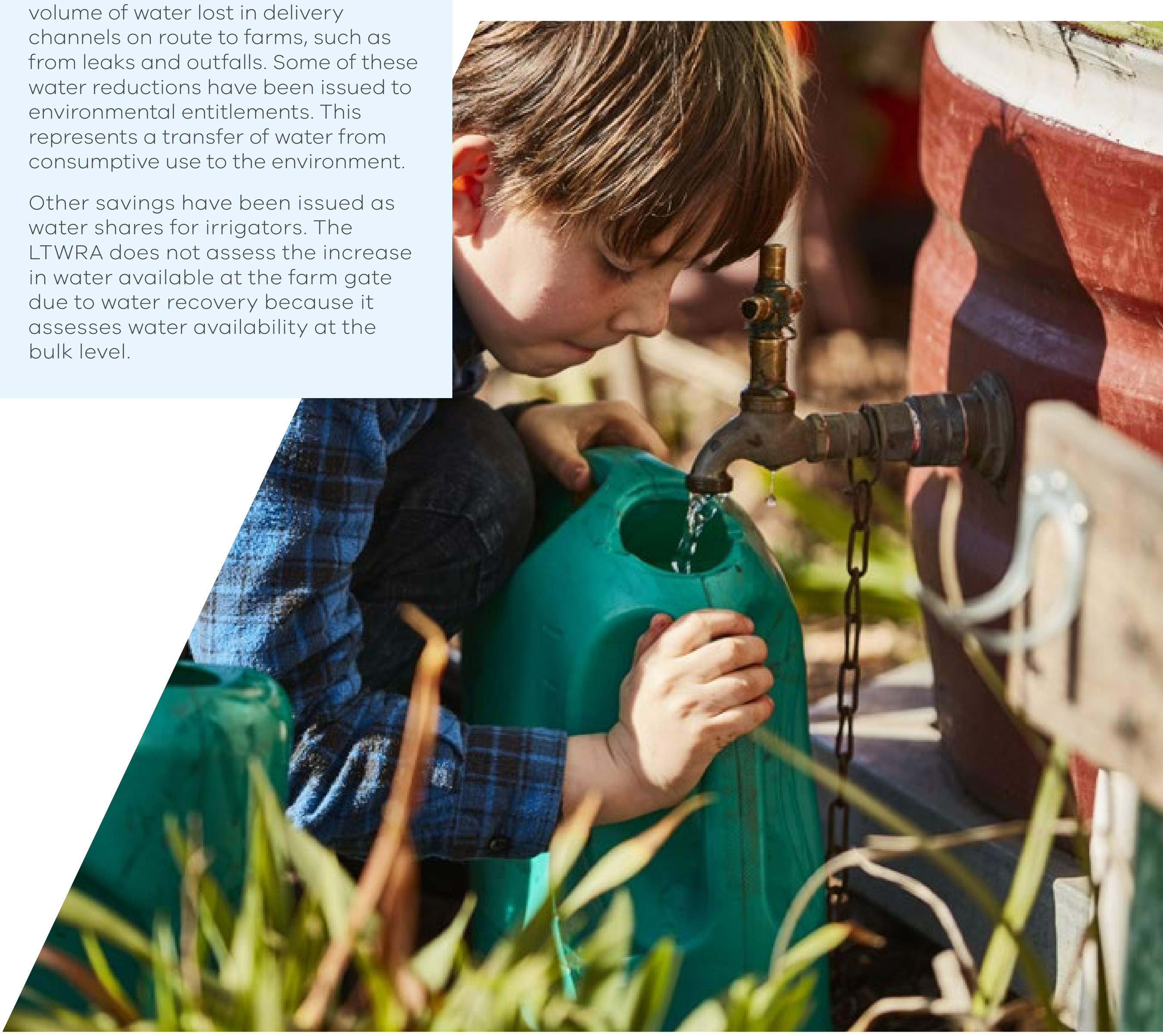


Table 3: Changes to water-sharing arrangements since SWS[47]

Barwon	The connection to the Melbourne system allows Barwon Water greater operational flexibility and more choice about when to divert water from the Barwon basin to urban users.[48] The assessment includes the amendment to Barwon Water's bulk entitlement made in 2018 to create the Upper Barwon River environmental entitlement.
Bunyip	The Tarago and Bunyip Rivers environmental entitlement was created in 2009. It sets aside 10.3 per cent of net inflows into Tarago Reservoir for the environment. The volume of water available for the environment has not changed because the water previously spilled to the environment. The environmental entitlement allows for greater control to flows, to target environmental benefits.
East Gippsland	The Gippsland Region SWS set revised caps on the amount of unallocated surface water available for future winter-fill licences as follows: The Genoa (500 ML), the Cann (500 ML), and 500 ML total across other catchments
Glenelg	Actions arising from the 2014 Bulk and Environmental Entitlements Operations Review changed water-sharing arrangements, leading to small changes in the volume available for consumptive uses. The preferential supply of the Commonwealth Environmental Water Holder environmental entitlement from within the Wimmera basin has reduced inter-basin transfers from the Glenelg River, providing a modest increase in water available for the environment in the Glenelg.
Hopkins	The Western Region SWS set revised caps on the amount of unallocated water available for future winter-fill licences under the sustainable diversion limits as follows: the Merri River 590 ML, and 680 ML in two small coastal areas of the Hopkins basin (Buckley Creek, Nullaware and south of Tower Hill Lake).
Lake Corangamite	To support future growth in consumptive demand, the Western Region SWS identified 2,600 ML/year available for future allocation to winter-fill licences in the Lake Colac catchment. (Surface water in this catchment does not flow to Lake Corangamite.)
Latrobe	The previously unallocated share of Blue Rock Reservoir was allocated through the Blue Rock environmental entitlement, with Gippsland Water also purchasing a share of this resource in 2014. In addition, Gippsland Water's ability to harvest more water has been influenced by shifting demand patterns, with proportionally less water supplied to industrial customers currently than at the time of the SWS, and proportionally more water supplied to urban customers. This change in customer mix means that Gippsland Water can service a greater average level of demand and therefore harvest more water in an average year
Maribyrnong	Western Water's entitlement to the Melbourne system was increased in 2010. This and infrastructure upgrades have allowed more water for urban uses to come from the Thomson-Yarra system and less from waterways in the Maribyrnong basin as a response to reducing flows in the upper Maribyrnong

47 Changes to water-sharing arrangements includes all changes since the SWS, including actions that were identified in the SWS and actions that weren't. The table represents operating conditions that were in place in 2017.

48 The assessment is based on the operating rules that were in place in 2017. Since 2017 Barwon Water has decided to cease long-term harvesting from the Barwon Downs borefield. The system operating rules have been updated to account for this change, but are not reflected in this assessment.

Mitchell	The Gippsland Region SWS allocated previously unallocated water to increase water available for future winter-fill licences to a total 6,000 ML/ year on the Mitchell River. The increase took account of the freshwater needs of the Gippsland Lakes. Water restriction triggers were updated in accordance with the Mitchell River Water Supply System Drought Response Plan.
Moorabool	Major augmentation options for Geelong and Ballarat were completed in 2010, and the government transferred 11.9 per cent of inflow to Lal Lal Reservoir to the Moorabool River environmental entitlement. This water became available for transfer to an environmental entitlement after supplementary water sources (the Goldfields super pipeline, groundwater and connections to the Melbourne system) gave Central Highlands Water and Barwon Water greater operational flexibility
Portland Coast	The Western Region SWS revised the cap on the amount of unallocated water available for future winter-fill diversions in Portland catchments: the Fitzroy River, Darlots Creek, Condah and Louth Drain catchments (2,500 ML), the Surrey River (500 ML), the Eumeralla and Shaw river catchments (500 ML), and six small coastal catchments between Eumeralla River and Darlots Creek (1,800 ML).
Otway Coast	Demand by Colac for water from the Gellibrand River has reduced, because Colac is now partially supplied from the Geelong system. The Western Region SWS revised the cap on the amount of unallocated water available for future winter-fill diversions in Otways catchments as follows: the Curdies and the Port Campbell area (1,500 ML), the Gellibrand (1,000 ML), and 1,000 ML across other catchments.
Snowy	In 2004, the Our Water Our Future White Paper established the Victorian Snowy basin was a fully allocated catchment, so no additional consumption was allowed. Then, the Gippsland Region SWS set a new total cap of 500 ML on the amount of unallocated surface water available for future winter-fill licences in selected catchments in East Gippsland. The LTWRA assumes that 200 ML out of the 500 ML is available for future allocation in the Snowy and Brodribb catchments.
South Gippsland	The model used to estimate consumptive uses was updated for the South Gippsland Water urban water strategy to be fitted over the period July 2009 to June 2016. This period incorporates changes to major industrial water use, and the benefits of town water use behaviour change that were first achieved during the Millennium Drought and which have been sustained thereafter. By way of example, water for consumptive uses in the Agnes River were reduced by 30 per cent and in the Tarra River by 18 per cent compared with the demands estimated at the time of the SWS. The Gippsland Region SWS revised the cap on the amount of unallocated water available for future winter-fill licences: the Tarwin (2,500 ML), the Powlett (500 ML), the Franklin (300 ML), the Albert (300 ML), Ten Mile Creek (300 ML), Dividing Creek (300 ML), Nine Mile Creek/ Shady Creek (300 ML), and 500 ML across other catchments.
Tambo	In the Tambo River catchment, water is available during wetter months to be allocated in future to support growth in consumptive use. The Gippsland Region SWS allocated previously unallocated water to increase water available for future winter-fill licences, to a total 1,500 ML/year on the Tambo River. For the Nicholson River catchment, the cap was revised down, such that no new winter-fill licences can be issued.

Thomson	An extra 3.9 per cent of inflows to the Thomson Reservoir were made available to the Thomson River environmental bulk entitlement, which created an equivalent reduction in the water available for Melbourne. Some of the water recovery from the modernisation of the Macalister Irrigation District has been converted to additional water entitlement under the Macalister River environmental entitlement, further increasing the environment's share and decreasing the consumptive uses share of available water.
Werribee	Individual carryover of water shares in the Werribee and Bacchus Marsh irrigation districts was introduced in 2014–15, allowing unused water allocated against entitlements to be carried over to the next year. In some years, this leads to less water being held in reserve, and less spills. Delivery losses have increased, due to ageing irrigation infrastructure. 10 per cent of inflow to Lake Merrimu has been allocated to an environmental entitlement. Western Water's entitlement to the Melbourne system was increased in 2010. This and infrastructure upgrades have allowed more water for urban uses to come from the Thomson-Yarra system and less from waterways in the Werribee basin as a response to reducing flows in the Werribee basin.
Yarra	The Yarra River environmental entitlement was created in 2006. The number of locations where passing flows are provided along the Yarra River increased.

Aligning long-term planning: LTWRA and urban water strategies

Urban water corporations develop urban water strategies – a key tool to inform long-term planning for water security for cities and towns. Urban water strategies use a 50-year outlook, various climate change scenarios and future demands to identify how much water is available and needed now and into the future. Options for future augmentation of water supplies are tested. Urban water strategies were most recently completed in 2017 and are updated every five years. They are available from the webpage of each urban water corporation.

The LTWRA uses the same figures for how much water is available to urban users under current climate as the 2017 urban water strategies (i.e. climate from 1975). This consistent approach supports a common understanding of how much water is available and how that water is shared.

Urban water strategies are long-term plans, but the assessment of current water availability necessarily reflects the water supply system at a given point in time, in this case 2017. The mix of water supplies available to urban water corporations may change overtime to meet the needs of a growing population, to protect water security in the face of declining streamflow or to manage the environmental or economic impacts of water harvesting.

For example, since the publication of its 2017 urban water strategy, South Gippsland Water has completed the interconnection of Korumburra, Poowong, Loch and Nyora to the Lance Creek and the Melbourne system. Similarly, Barwon Water has decided to cease long-term harvesting from the Barwon Downs borefield.

Operating conditions are especially dynamic for towns interconnected by the Water Grid because there are multiple different sources of water available. These operating changes can alter how water is shared between consumptive users and the environment in local water catchments.

5.3 How the assessment estimated sharing of declines

The Act requires the technical assessment to identify if declines in long-term surface water availability have been shared equally between consumptive uses and the environment, but changes in shares can result from two factors:

- long-term surface water availability declining
- changes to arrangements to share water between consumptive uses and the environment (if such changes have indeed occurred in the relevant basin).

To answer the question that the Act poses, this assessment therefore separates the reduction in water availability from the impact of changes to water-sharing arrangements. Separately assessing these factors enables the cause of any changes to be shown clearly. The approach taken also enables the cumulative impact of both factors on water availability to be estimated for consumptive users and the environment.

The assessment built on the previously explained two-step process shown in **Figure 5** by adding a third step to separate out changes to water-sharing arrangements since the SWS estimates. **Figure 33** shows the three-step process.

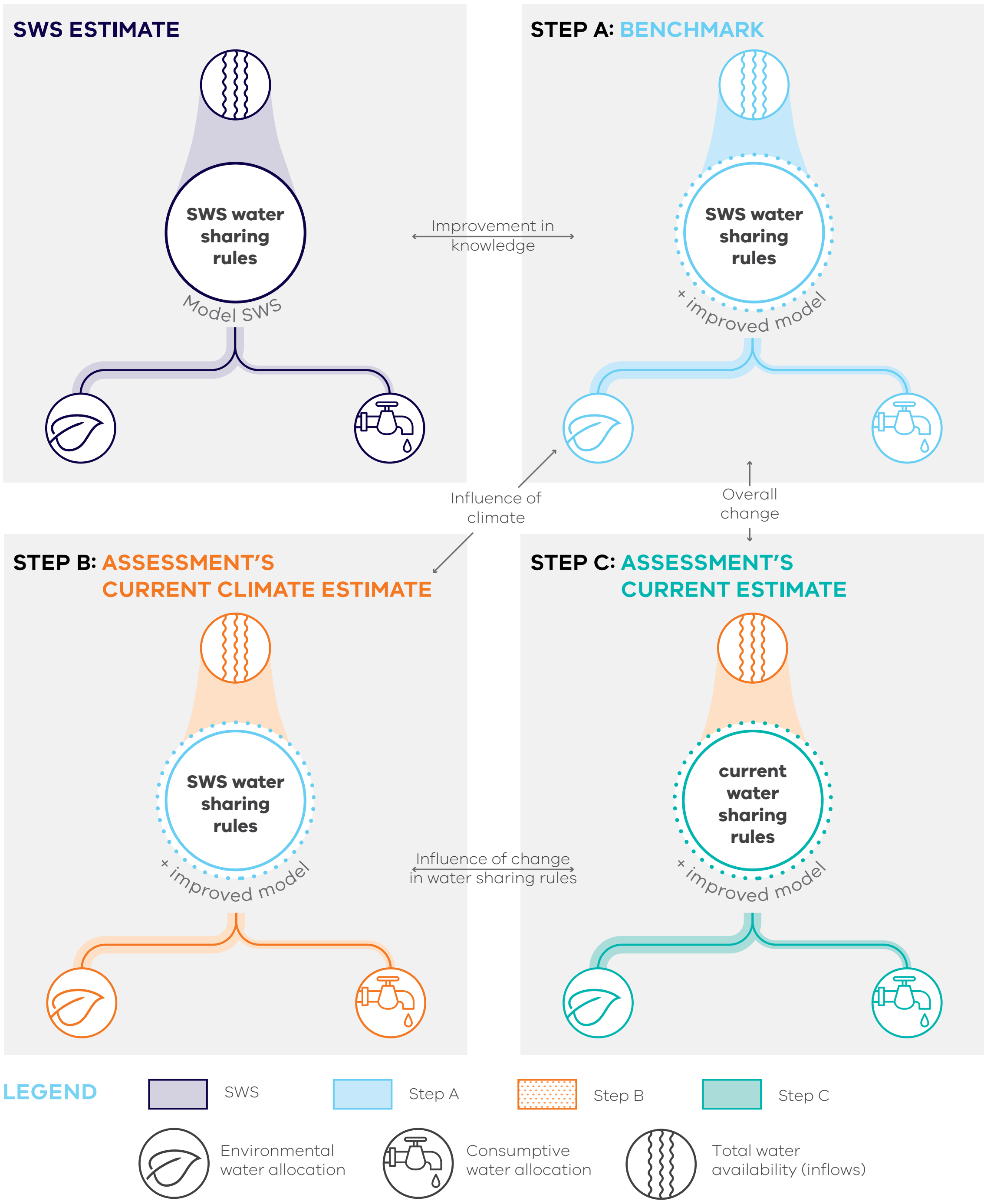


Figure 33: Three-step approach to estimating surface water availability

5.3.1 Step A: Benchmark estimates

When the SWSs were produced between 2006 and 2011, sophisticated computer models of water supply systems were used to estimate how the available water would have been shared between different consumptive user groups and the environment, given climate, water entitlements and operations at that time (**Figure 34**). Since then, the water industry has continuously improved those computer models and their input data.

Water availability is an input to a water resource model.

A water resource model represents how available water is shared between users. It represents infrastructure (like pipes and dams) and water sharing rules.

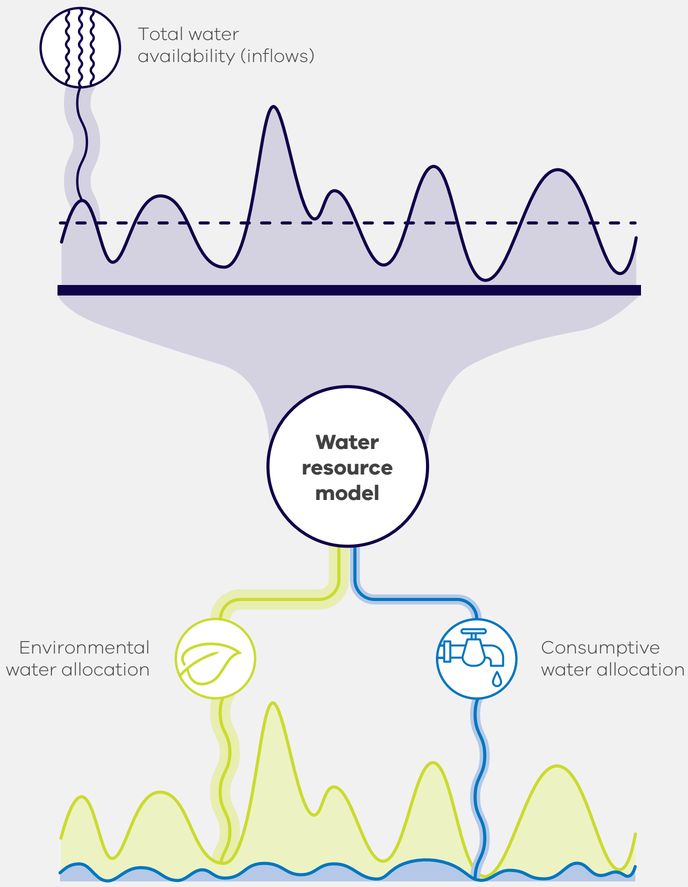


Figure 34: Water resource model

The assessment recalculated the SWS water-share estimates for the same periods as for the SWS, using the improved models and better data. The assessment also made some further improvements to the models. For example, we now have much better information about the size and location of licensed farm dams, and we used this information to improve the water resource models. The assessment also used water resource models developed since the SWSs, and it developed new, simple models for small unregulated rivers that were not modelled for the SWS.

Water resource models use water availability as an input, so the assessment's calculation of water-sharing used the water availability findings from step A. Water resource models represent water-sharing arrangements at a point-in-time. In step A, the models represented the water-sharing arrangements at the time of the SWS.

5.3.2 Step B: Current climate representative period

The assessment estimated how water was shared between consumptive users and the environment using:

- the best-available data and models: those used for the step A estimates
- using the period 1975–present as the current climate representative period, with the model using step B water availability findings as an input
- the water-sharing arrangements at the time of the SWS.

Step B estimates the proportions of water available for consumptive uses and the environment, in the current climate representative period and water-sharing arrangements at the time of the SWS.

The only difference between steps A and B was the water availability used as an input to the model.

5.3.3 Step C: Current estimates

Step C estimates show how water is shared at present. It reflects:

- the best-available data and models (from step A)
- the period 1975–present as the current climate representative period (from step B)
- the current water-sharing arrangements.

The assessment updated the water resource models to represent current water-sharing arrangements.

A comparison of steps B and C shows how changes to water-sharing arrangements since the relevant SWS have changed how much water is available for the environment and consumptive users.

A comparison of steps A and C shows the total change since the SWSs, which incorporates both the influence of the changed climate period and any changes to water-sharing arrangements. This comparison of steps A and C is used to determine if declines in long-term surface water availability have been shared equally between consumptive uses and the environment.

Why aren't declines shared equally?

The impact of declines in long-term surface water availability on different uses depends on where they are located in the catchment, the rules that govern their access to water and the characteristics of water supply systems within the basin. For example, the impact of declines can often be less on licensed irrigation and commercial dams higher in the catchment than on above-cap water for the environment. This is because these dams can harvest runoff before it reaches a waterway while above-cap water is what is available after all other water users have taken their allocation. Similarly, passing flows might be insensitive to declines because they must be provided first, before water can be diverted from rivers for consumptive uses. The reliability of water sources relative to the location of water users is also important, with impacts greater on users (environmental or consumptive) who draw from unreliable water sources in the basin, such as ephemeral creeks, than those in the basin with reliable water sources, such as groundwater-fed springs or soaks.

The assessment could not separate out the effects of groundwater extractions on the environment and consumptive users. In many rivers, groundwater provides baseflows that contribute to the availability of water for both the environment and for consumptive uses. This assessment found that groundwater extractions made a very small contribution to the decline in long-term surface water availability.

5.4 Water for consumptive uses

5.4.1 Long-term surface water availability for consumptive uses

The assessment estimated, in step C — current climate representative period 1975–present, best-available data in models and current water-sharing arrangements — that the average annual volume of surface water available for consumptive uses across southern Victoria is 1,207 GL/year.

Figure 36 breaks down the water available for consumptive use in each basin into the volume available for different types of use. About 31 per cent of this water is for rural use, 56 per cent is for urban use and 11 per cent is for other uses (see **Figure 37**). The largest volumes for urban use come from the Yarra, Thomson and Bunyip basins, to supply Melbourne; the Latrobe basin supplies Traralgon, Moe and Morwell; and the Barwon and Moorabool basins supply Geelong and Ballarat. The greatest volumes of water are available for agriculture from the Thomson and Macalister rivers — which supply water to the Macalister Irrigation District — and from the Werribee River — which supplies water to the Bacchus Marsh and Werribee irrigation districts. Water set aside for power generation is the large "other" use seen in the Latrobe basin. See **Appendix D** for maps showing long-term surface water availability for rural and urban uses.

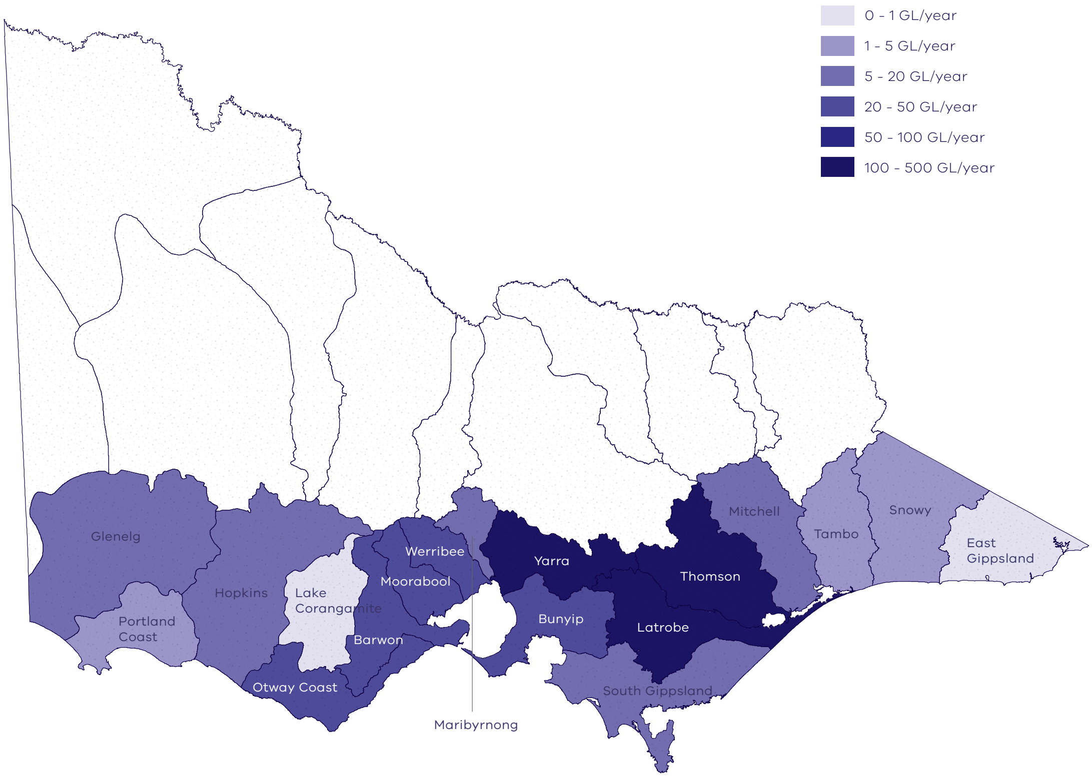


Figure 35: Long-term surface water availability for consumptive uses, step C[49]

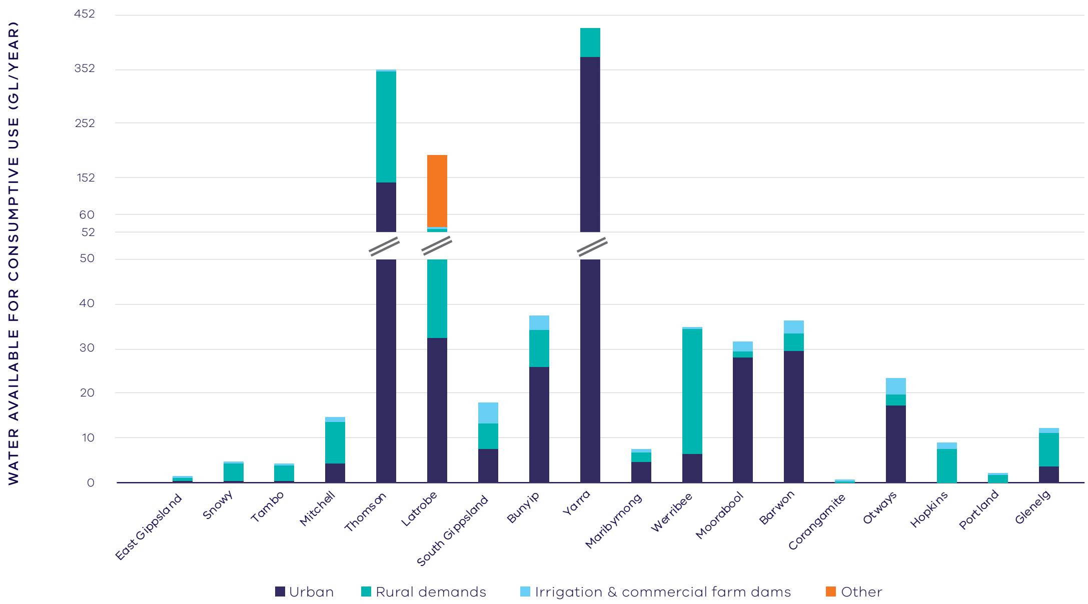


Figure 36: Long-term surface water availability for consumptive uses, by major types of consumptive use, step C
Note: the scale changes above 50 GL/yr to allow the larger and smaller systems to be visualised

49 In the Snowy River the assessment looked at consumptive use within Victoria. It does not account for use within New South Wales, including the major dams and diversion weirs of the Snowy Mountains Hydro-electric Scheme collect, store and divert large volumes of its flow west to the Murrumbidgee River and River Murray, generating electricity in the process.

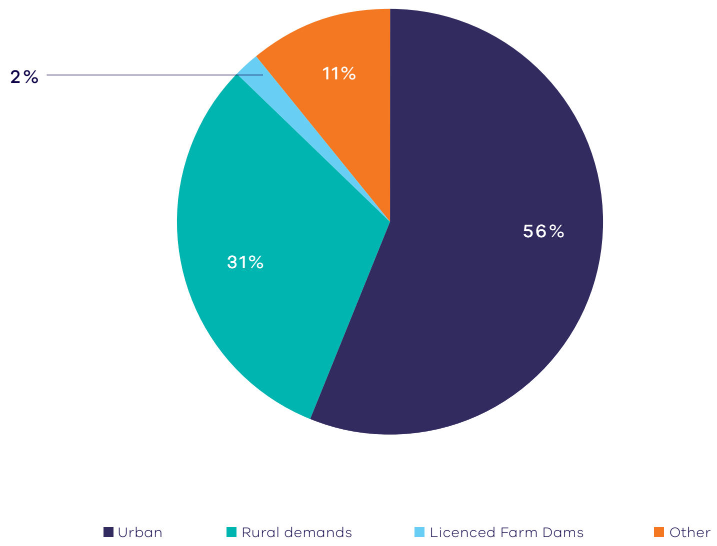


Figure 37: Distribution of surface water availability for consumptive uses, step C
Note: other corresponds to power generation in the Latrobe basin.

Groundwater use

In 2015–16, the total volume of licences issued to extract groundwater was about 454 GL in southern Victoria. The actual volume taken under licences was about 166 GL, or about 36 per cent of the licensed volume.

Most licensed groundwater extraction was for:

- irrigation, with 125 GL extracted or about 75 per cent of total extractions
- power generation, with 33 GL extracted or about 20 per cent of total extractions
- urban use, with about 8 GL extracted, or about 5 per cent of total extractions.

Groundwater resources are continually monitored by observing groundwater levels and metering use. Extraction is restricted when the groundwater drops to a specified level that is needed to protect the environment and or consumptive users.

With the exception of the Deutgam GMA in the Werribee Irrigation District, declines in groundwater levels have not necessitated restrictions on groundwater entitlements in southern Victoria.

5.4.2 Changes in long-term surface water availability for consumptive uses

...due to decline in long-term water availability (step B cf. A)

Figure 38 shows declines in long-term surface water availability for consumptive uses due to the decline in long-term water availability — step B compared with the benchmark (step A) — and not due to any changes to water-sharing arrangements. The figure shows declines in long-term water availability for consumptive uses in almost half the basins across southern Victoria since the SWSs. There have been no declines in basins with relatively small declines in inflows and where consumptive uses are a small proportion of streamflow — the East Gippsland, Snowy,[50] Tambo, Mitchell, Otway Coast and Portland Coast basins. In the Latrobe, large volumes are allocated to consumptive users, but inflows to storages have not declined enough to reduce water availability to consumptive users with entitlements to a share of storage capacity. Even in basins with slight declines in consumptive water availability on average, very significant reductions in water for consumptive uses can still occur in very dry years.

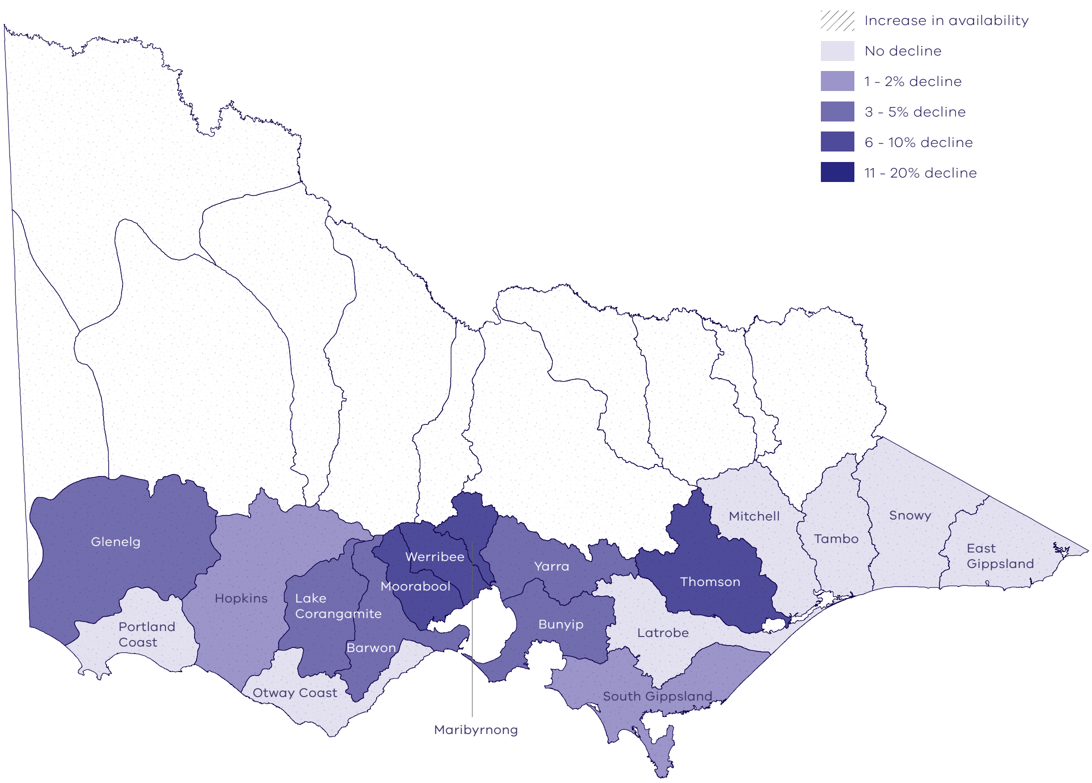


Figure 38: Change in long-term surface water availability for consumptive uses due to decline in long-term water availability (step B cf. A), by basin

50 In the Snowy River the assessment looked at consumptive use within Victoria. It does not account for use within New South Wales, including the major dams and diversion weirs of the Snowy Mountains Hydro-electric Scheme collect, store and divert large volumes of its flow west to the Murrumbidgee River and River Murray, generating electricity in the process.

…due to changes to water-sharing arrangements (step C cf. B)

Figure 39 shows changes in long-term surface water availability for consumptive uses due to changes to water-sharing arrangements (as explained in **Table 2**). Because both step B and step C are run under the same current climate period, the changes in water availability between the scenarios are due solely to changes in water-sharing arrangements. Changes in water-sharing arrangements can have quite different effects:

- In the Thomson and Yarra basins, water was transferred from consumptive users to environmental entitlements, such that the volume available for consumptive users declined.
- In some basins, new consumptive entitlements were issued to previously unallocated water. In the Latrobe, Gippsland Water received a share of unallocated inflows and storage in Blue Rock Lake. In the Hopkins basin, additional winter-fill diversion licences were issued because the system is below its sustainable diversion limit and demand exists for additional water. Changes in the way water supply systems are operated also changed water availability in many basins (South Gippsland, Maribyrnong, Werribee, Moorabool, Barwon, Otway Coast and Glenelg).
- Changes in the way water supply systems are operated also changed water availability in many basins. Expansion of the Water grid interconnected large urban centres with new water supplies. Geelong was interconnected to the Melbourne system and Ballarat to the Greater Goulburn system. This gives urban water corporations flexibility to change the way they operate their systems to provide secure water supplies while still meeting the requirements of their entitlements. In the Moorabool and Barwon basins, more water can be taken without triggering water restrictions because back-up supplies are now available for Geelong[51] and Ballarat. For towns in the Maribyrnong basin, such as Sunbury and Gisborne, supplies are preferentially sourced from the Thomson-Yarra pool, to maintain an appropriate level of water security, rather than from the Maribyrnong basin. Similarly, connecting Colac to the Geelong system reduced reliance on water available from the Otway Coast basin.

  Change to operations affect water-sharing in rural water supply systems too. In the Werribee basin, individual carryover of water shares in the Werribee and Bacchus Marsh Irrigation Districts was introduced in 2014-15, allowing unused water to be retained in storage for the next year. This has the potential to change spill patterns in some years.

51 The assessment is based on the operating rules that were in place in 2017. Since 2017 Barwon Water has decided to cease long-term harvesting from the Barwon Downs borefield. The system operating rules have been updated to account for this change, but are not reflected in this assessment.

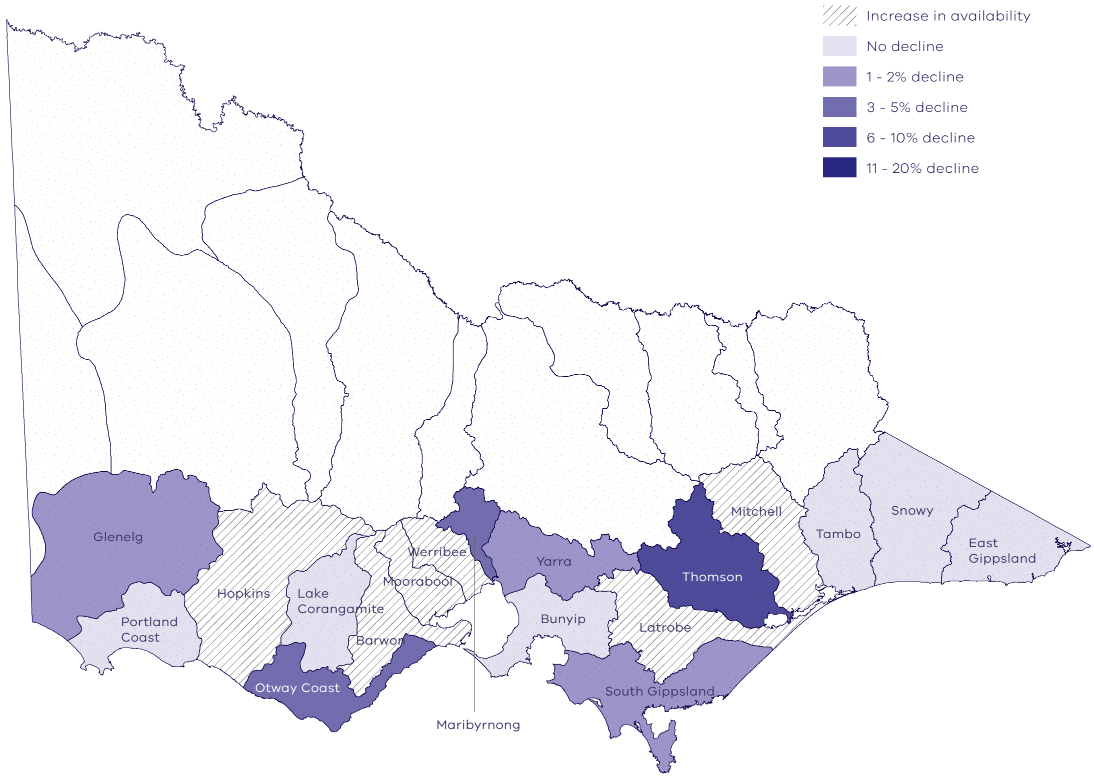


Figure 39: Changes in long-term surface water availability for consumptive uses due to changes to water-sharing arrangements (step C cf. B), by basin

...due to decline in long-term water availability & changes to water-sharing arrangements (step C cf. A)

Figure 40 shows the cumulative changes in long-term surface water availability for consumptive uses due to both the decline in long-term water availability and changes to water-sharing arrangements — step C compared with the benchmark (step A). The figure shows declines in half the basins since the SWSs, with the greatest decline being in the Thomson basin.

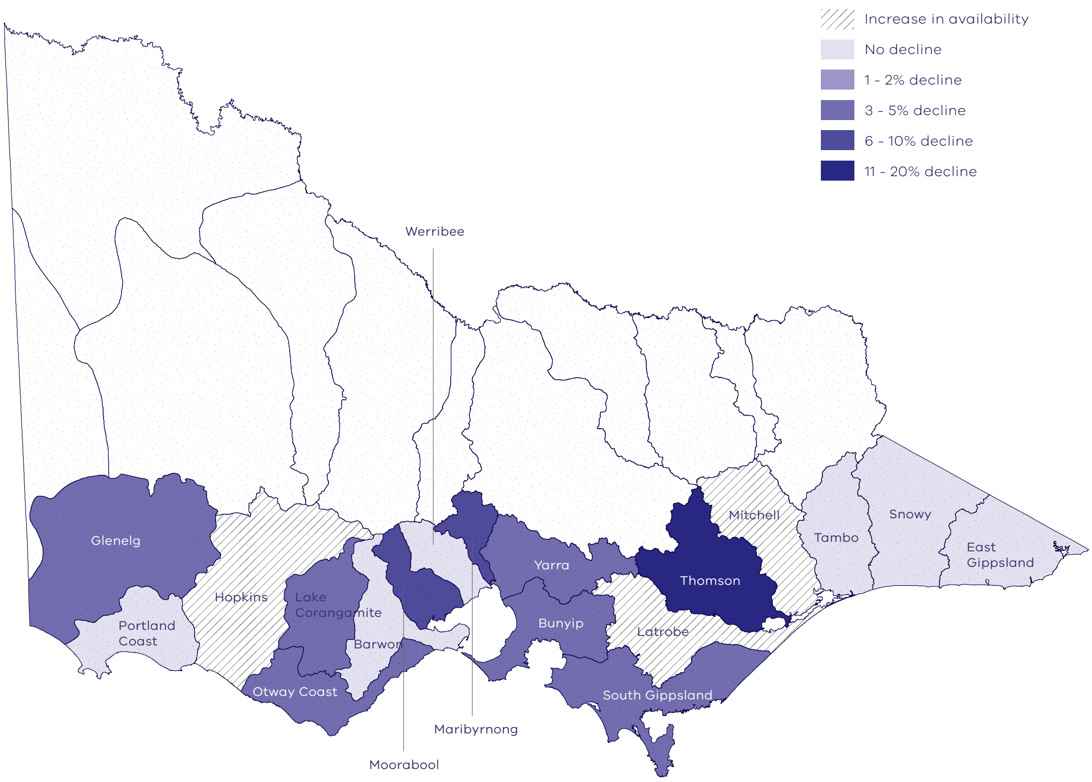


Figure 40: Changes in long-term surface water availability for consumptive uses due to decline in long-term water availability & changes to water-sharing arrangements (step C cf. A), by basin

Figure 41 breaks down the changes in long-term water availability for consumptive uses into their two causative factors: the change in the current climate representative period and the change in water-sharing arrangements. It shows that volumes have changed significantly in four basins, the largest of which is the Thomson where the decline in volume is about equally due to both factors. The decline in the Yarra basin is mainly due to the change in climate period.

Appendix C provides tables that contain the long-term availability of surface water for consumptive uses for each basin for each step of the assessment. **Appendix D** provides maps showing changes in long-term surface water availability for rural and urban consumptive uses.

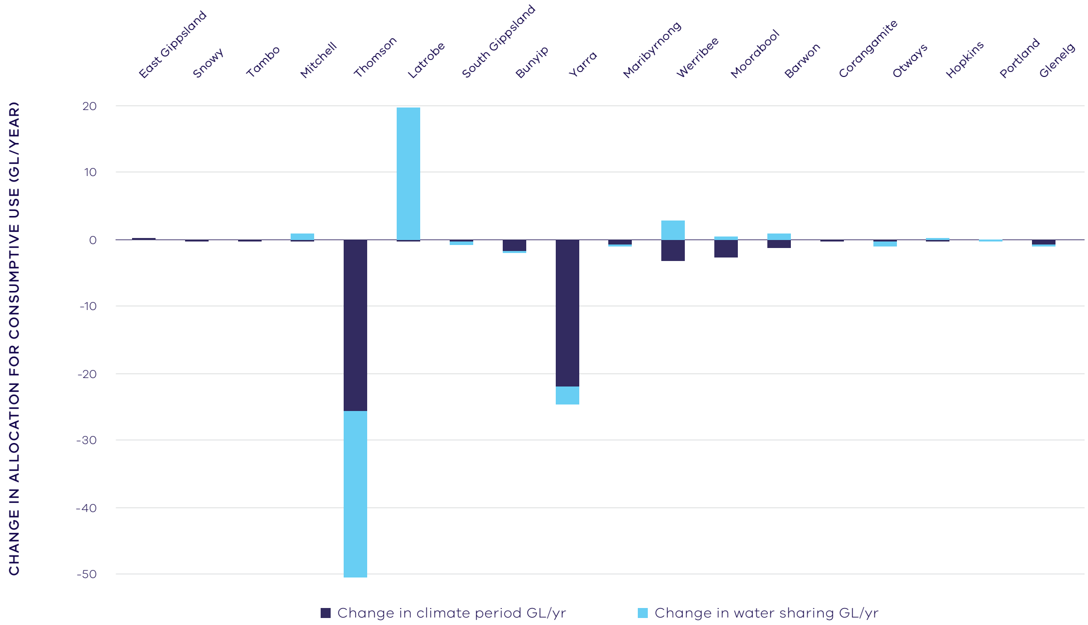


Figure 41: Changes in long-term surface water availability for consumptive uses, contribution of change of climate period and change in water-sharing arrangements

How are declines in long-term water availability for consumptive uses managed?

The Victorian water sector actively plans and manages for declines in long-term water availability for consumptive uses.

The SWSs considered likely long-term water availability, and foreshadowed augmentation and better management of water supplies.

In 2017, urban water corporations released urban water strategies, setting out their plans to meet growing demand for water under future climate conditions.

Victoria's water grid comprises capture, production and storage infrastructure (such as dams, reservoirs, weirs, groundwater extraction locations and the Victorian Desalination Project), delivery infrastructure (such as channels, pipes, pumps and the waterways used to deliver water) and arrangements for the purchase and sale of water through water markets and the water entitlement framework. The water grid allows us to deliver water to where it is most valued. Since the SWSs, regional centres including Geelong have been connected to the Melbourne system, and the Goldfields Superpipe has underpinned security of supply for towns and rural customers in central Victoria.

The Victorian Desalination Project can deliver an additional 150 GL of water a year. The assessment did not include the volume of water the project can produce in the volume of water available for consumptive uses.

Increasingly, alternative water supplies provide for some consumptive uses. Recycled water is an important supplementary supply to the Werribee Irrigation District. Ballarat's Lake Wendouree is filled with stormwater, recycled water and some groundwater, and water from the lake is used to irrigate green spaces around the city.

Modernising irrigation districts is reducing system water losses, with this water being made available for consumptive uses and the environment.

Water trade and changes in carryover rules are among changes since the SWSs that enable irrigators and entitlement holders to better manage their risk.

Victoria continues to fund research to better understand the drivers of Victoria's climate and how climate conditions are likely to change. The results of this research will help us prepare for drier conditions.

The recently released Pilot Water Sector Climate Change Adaptation Action Plan sets out a plan for the Victorian water sector that includes adapting to drier conditions.

SWSs will continue to identify and plan for risks to our water supplies.

Long-term groundwater availability for consumptive uses

Long-term groundwater availability has not declined for consumptive uses: most licence holders have had access to their full annual entitlement. The exception is the Deutgam GMA in the Werribee Irrigation District where there have been ongoing restrictions in place.

5.5 Water for the environment

5.5.1 Long-term surface water availability for the environment

The assessment estimated, in step C — current climate representative period 1975–present, best-available data in models and current water-sharing arrangements — that the average annual volume of surface water available for the environment across southern Victoria is 7,110 GL/year.[52] **Figure 42** shows, for each basin, the contribution of the three components of this volume: environmental entitlements, passing flow obligations on bulk entitlements, and above-cap water. About 1 per cent of this water corresponds to environmental entitlements, 4 per cent is passing flows and 95 per cent is above cap water (see **Figure 43**).

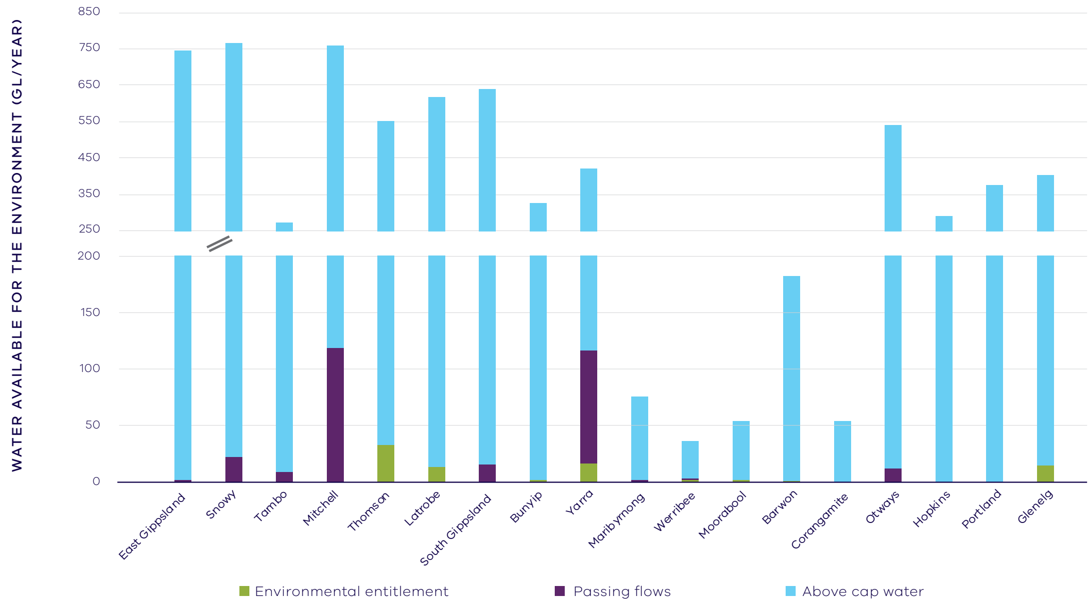


Figure 42: Long-term water availability for the environment, by river basin, 1975–present, step C
Note: the scale changes above 200 GL/yr to allow the larger and smaller systems to be visualised

52 Long-term groundwater availability for the environment is not a consideration for the assessment: water for the environment is not allocated from available groundwater, but from available surface water.

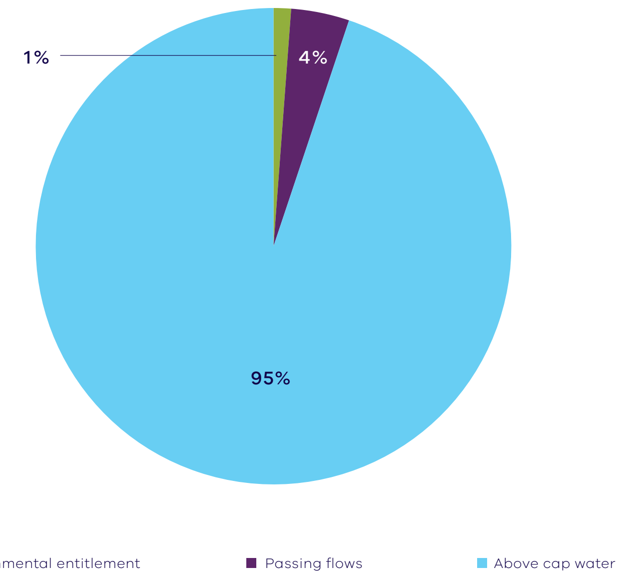


Figure 43: Distribution of water availability for the environment, step C

Environmental entitlements

Figure 42 shows the contribution of environmental entitlements to current long-term water availability for the environment. It shows environmental entitlements comprise a small or no proportion of current long-term water availability for the environment in most basins.

The largest environmental entitlement in Victoria — shown in green in **Figure 42** — is located in the Thomson basin. It has an environmental entitlement of 32 GL/year, but it is just 6 per cent of the total water for the environment in the Thomson basin.

While environmental entitlements constitute a small proportion of the water available for the environment, they provide for controlled releases from storage to meet specific environmental flow targets.

The Basin-by-Basin Results include a case study of environmental water management in each river basin. Environmental entitlements are managed to provide a variety of waterway health outcomes, including to provide refuge pools during dry periods in the Werribee and Moorabool river systems, and to support fish breeding in the Yarra, Thomson and Glenelg.

Flows providing benefit to the environment

The assessment only looked at the volume of water available for the environment. In many basins, the environment may also benefit from other water not specifically available for it, mainly:

- water allocated for consumptive uses but not taken that remains in a waterway and provides environmental benefits
- releases from storages of water for consumptive uses that also have an environmental benefit. Water corporations are required to operate water supply systems to maximise environmental benefit. For example, GWM Water and Glenelg-Hopkins Catchment Management Authority manage releases of the Glenelg River compensation flow from Rocklands Reservoir to benefit consumptive uses and the environment

As well, while any given volume of water for the environment is accounted for only once, it may provide environmental benefits at many sections of the river.

Lastly, although it is important to have enough water (i.e. volume) available for the environment, the timing (e.g. season, duration, etc.) and quality (e.g. salinity, dissolved oxygen, etc.) of this water are also very important. These factors are considered more in part B of the LTWRA.

Passing flows

Figure 42 shows the contribution of passing flows to current long-term water availability for the environment.

Entitlements require passing flows in almost every basin. Minimum passing flows may be required at multiple points along a river and in different tributaries within a river network. The assessment only looked at the passing flows at a single location – typically the most downstream location with minimum passing flows. After the minimum flow passes the most downstream compliance point, then that water is no longer categorised as a passing flow if there are opportunities for that water to be diverted for consumptive use or otherwise lost. Instead, the passing flow water that reaches the end of the river valley is accounted for as above-cap water. Hence, in basins where **Figure 42** shows no passing flow, there may be passing flow rules applicable at upstream sites within that river basin.

Passing flows make up only a small proportion of the total water for the environment, except in the Mitchell and Yarra basins where they make up 16 per cent and 24 per cent respectively of the total volume of water for the environment. The rules in the Bairnsdale bulk entitlement in the Mitchell basin have been specifically designed to minimise the risk to the environment and third-parties by enabling water diversions during periods of high-flow in the cooler months.

Although passing flows provide only a small volume of water, they are essential during low-flow periods, when they can make up all the water for the environment. For example, **Figure 44** shows the modelled volume of water for the environment available in the Yarra River under current water-sharing arrangements over two, five-year periods — a wet period (modelled using 1992–96 data) and a dry period (2005–09) — and the water that was available over the long-term (modelled using 1975–2016 data). It shows that passing flows make only a very small contribution in wet years but comprise most water for the environment in dry years.

Passing flows also provide a shared benefit: they ensure a minimum volume of water is available for domestic and stock use.

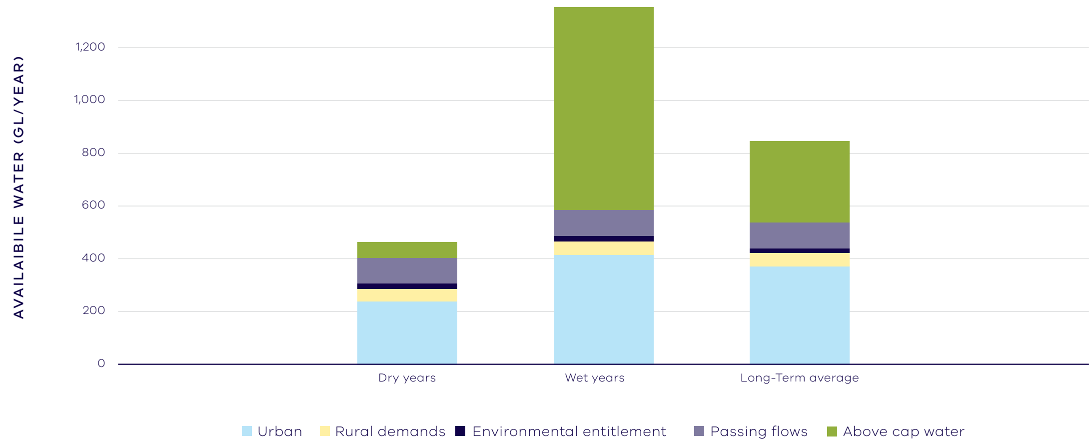


Figure 44: Water for the environment and consumptive use, Yarra River, current water-sharing arrangements, modelled wet and dry periods and long-term

Above-cap water

Figure 42 shows that above-cap water is by far the biggest contributor to the long-term availability of water for the environment: in most basins, it is 95 per cent or more.

Figure 44 is an example of how above-cap water is the first water to be lost when inflows decline. The resilience of above-cap water volumes to declining inflows depends mainly on how much water is allocated to consumptive use, the size of water storages relative to inflows and the location of storages in the catchment. The modelled data in **Figure 44** for the Yarra River shows that in the dry years there would be a much smaller amount of above-cap water available, because approximately 62 per cent of inflows would be allocated for consumptive uses under the current water-sharing arrangements.

5.5.2 Changes in long-term surface water availability for the environment

...due to decline in long-term water availability (step B cf. A)

Figure 45 shows changes in long-term surface water availability for the environment due to the decline in long-term water availability — step B compared with the benchmark (step A) — and not due to any changes to water-sharing arrangements. The figure shows declines in long-term water availability for the environment in all basins across southern Victoria since the SWSs.

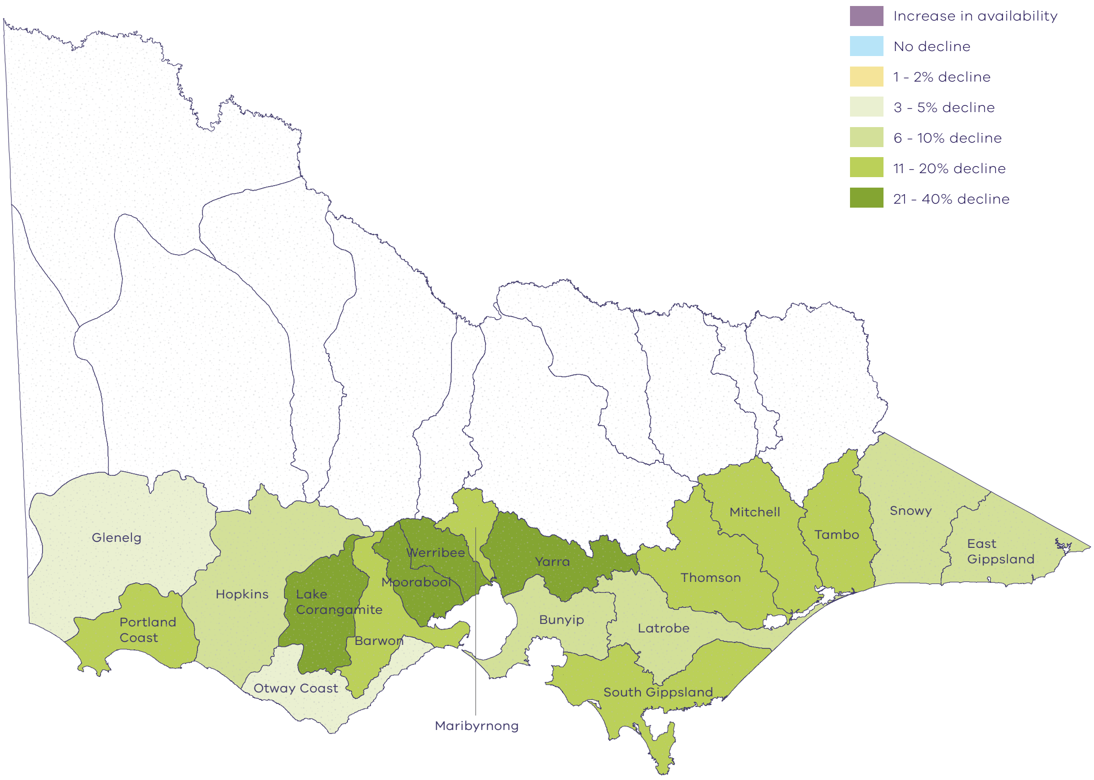


Figure 45: Changes in long-term surface water availability for the environment due to decline in long-term water availability (step B cf. A), by basin

The main reason for the declines is the decline in the volume of above-cap water throughout southern Victoria. The assessment found that this volume is the most vulnerable to changes in overall water availability: **Figure 44** and **Figure 46** show that above-cap water is the first water to be lost when inflows decline. As **Figure 42** shows, above-cap flows make up the largest volume of water set aside for the environment.

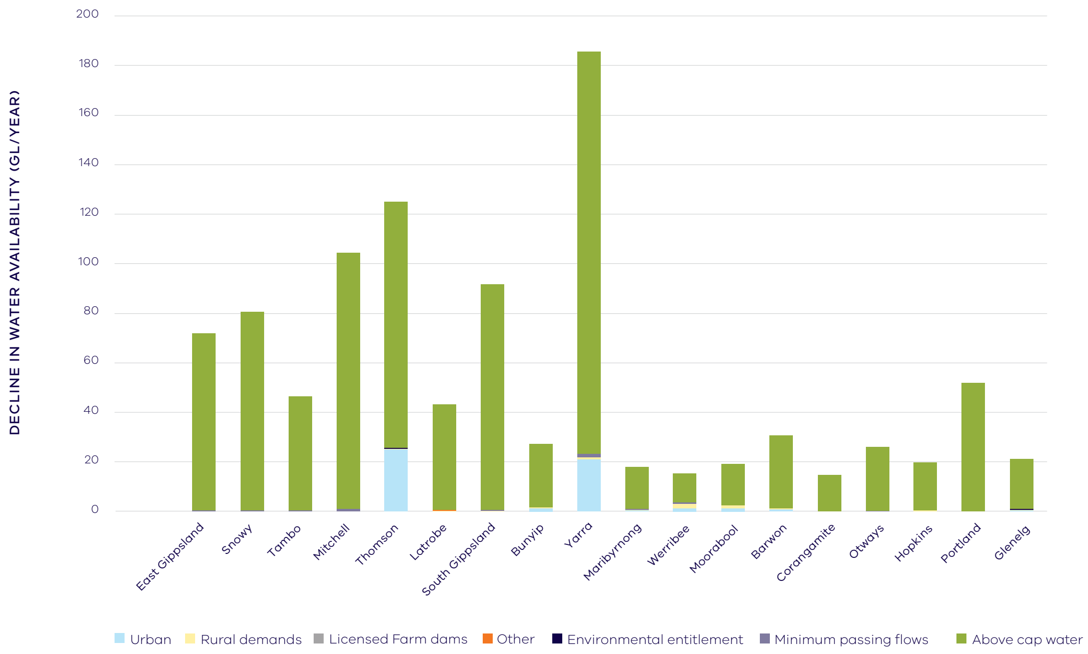


Figure 46: Total declines in water availability for the environment and consumptive use due to decline in long-term water availability (step B cf. A), by basin

The resilience of environmental entitlement allocations to reduced inflows depends on the water-allocation rules in a basin. For example, the Thomson River's environmental entitlement allocates the first 10 GL a year inflow to the Thomson Reservoir to the environment. Inflow to the reservoir has historically been much greater than this, so allocations under the rule have not declined, despite average inflows to the Thomson basin declining by 14 per cent.

Passing flows are somewhat resilient to reduced inflows because they are met first, before any water is taken for consumptive uses. However, the volume of passing flow is typically related to the volume of inflow; where inflows to reservoirs have declined, in general terms, so too have the volumes of passing flow releases.

...due to changes to water-sharing arrangements (step C cf. B)

Figure 47 shows changes in long-term surface water availability for the environment due to changes to water-sharing arrangements. Because both step B and step C are run under the same current climate representative period, the changes in water availability between the scenarios are due solely to changes in water-sharing arrangements.

The number of environmental entitlements has increased since the SWSs, largely because of actions in the strategies. New environmental entitlements have been established in the Upper Barwon, Latrobe, Bunyip/Tarago, Yarra, Werribee and Moorabool rivers, and the volumes of entitlements in the Thomson and Macalister rivers have increased.

The Latrobe and Werribee basins show a decline in total water available for the environment, despite the creation of an environmental entitlement because a concurrent increase in water availability to consumptive users decreased the volume of reservoir spills, and hence, the availability of above-cap water to the environment.

The environmental entitlement created in the Bunyip/Tarago River did not increase the overall volume of water available for the environment, because it led to a corresponding decrease in above-cap flows. However, the entitlement has an important benefit: it gives managers the flexibility to deliver water when it is most needed by exchanging unregulated reservoir spills for releases that are targeted to improve particular ecological values.

The East Gippsland, South Gippsland, Otway Coast, Lake Corangamite, Hopkins and Portland Coast basins have experienced an increase in the water set aside for the environment since the SWS, due to the revised cap on unallocated water available for future winter-fill licences.

The causes and extents of the changes in other basins are largely driven by factors specific to the basin or region. **Table 3** describes these briefly, and the report Basin-by-Basin Results has further information.

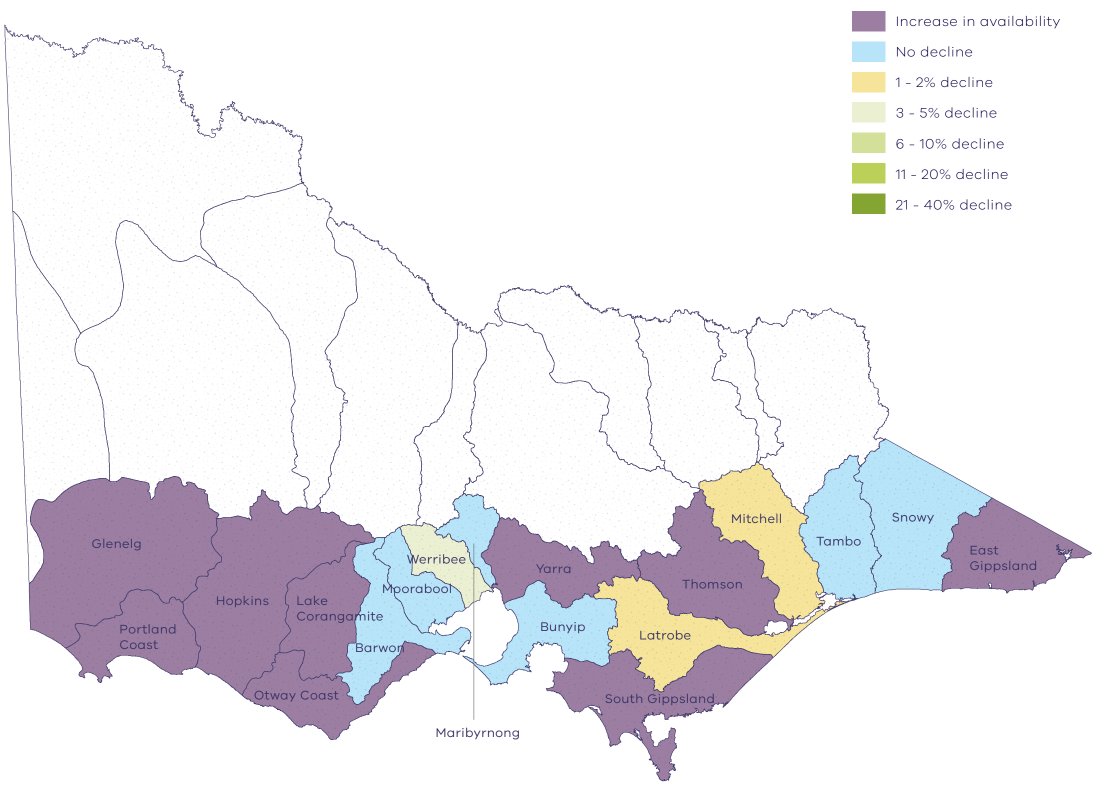


Figure 47: Changes in long-term surface water availability for the environment due to changes to water-sharing arrangements (step C cf. B), by basin

...due to decline in long-term water availability & changes to water-sharing arrangements (step C cf. A)

Figure 48 shows cumulative changes long-term surface water availability for the environment due to both the decline in long-term water availability and changes to water-sharing arrangements — step C compared with the benchmark (step A). The figure shows that water for the environment has declined in all basins except Otway Coast, where there has been no discernible decline.

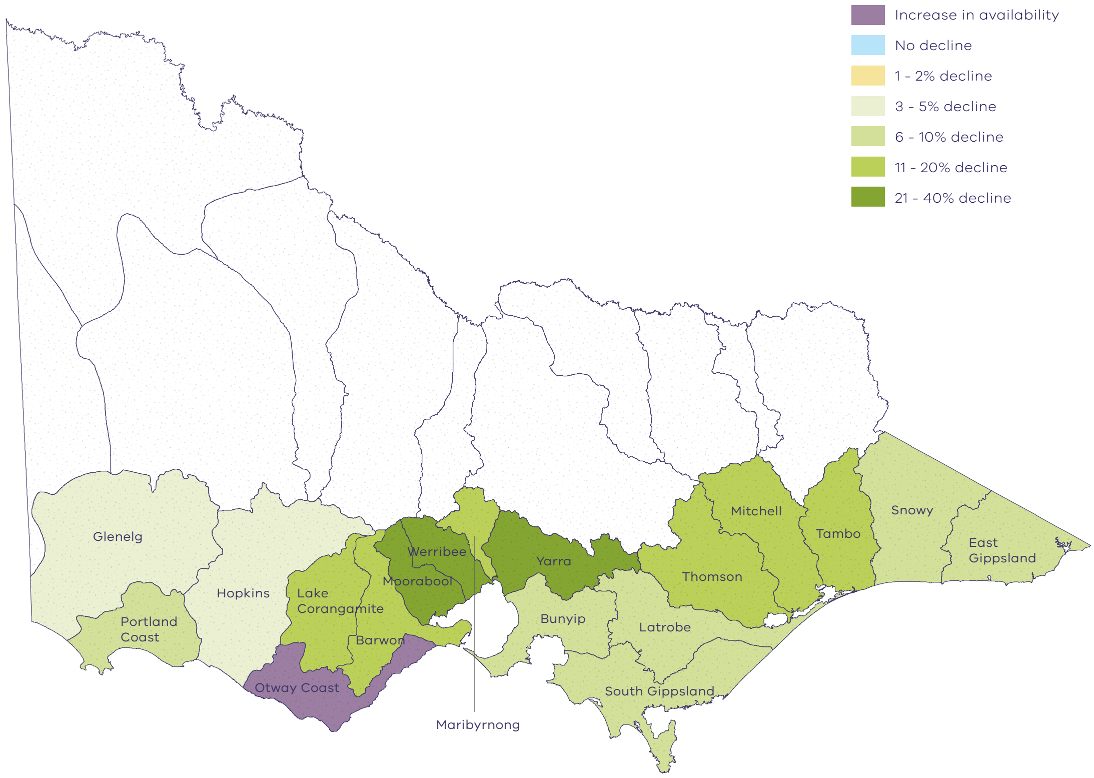


Figure 48: Changes in long-term surface water availability for the environment due to decline in long-term water availability and changes to water-sharing arrangements (step C cf. A), by basin

Since the SWSs, long-term water availability for the environment has declined in most basins because the water recovered for the environment has generally been less than the declines in long-term surface water availability. Long-term water availability for the environment has not increased overall, because the decline in above-cap water has been greater than the water available from the new environmental entitlements.

Changes to water-sharing arrangements in the Werribee and Latrobe basins have also increased water available for consumptive uses. To some extent, this has offset the additional water available for the environment through those basins' environmental entitlements.

Changes vary across a river basin

The assessment looked at changes in long-term water availability for the environment for each basin as a whole, but availability can also change at different places in a basin. For example, water availability for the environment in the upper reaches of the Yarra River has increased since the SWS. In the Werribee River, an environmental entitlement was created that provides benefits in Pyrites Creek, which is immediately downstream of Merrimu Reservoir.

How declines in water for the environment are being managed

The assessment estimates the long-term average water that is available to the environment from various sources (environmental entitlements, passing flows and above-cap water). The assessment is numerical, but numbers alone do not convey the complex decision-making processes that environmental water managers undertake to achieve the best waterway health outcomes in the face of declining water availability.

Environmental water entitlements are key tools for managing waterway health because they enable environmental flows to be targeted to achieve specific objectives, such as maintaining refuge pools for aquatic animals and plants over hot, dry summers. Environmental water managers collaborate with the local communities of different river systems to determine the priority environmental objectives. A technical panel applies the best available science to provide flow regime recommendations to meet those environmental objectives. These flow recommendations are updated as better data become available.

Environmental water managers make decisions about how to use water allocated to environmental entitlements in light of the current and previous years' conditions — drought, dry, average or wet. Managers must follow the prioritisation criteria in the Victorian Waterway Management Strategy, including consideration of a site's watering history, the implications of not watering the site, the degree of certainty about achieving environmental benefits and the capacity to manage the risks of the watering event. This approach ensures that available environmental water is used to best effect.

In some river systems, such as the Werribee and Bunyip/Tarago, environmental water managers have the flexibility to "bank" minimum passing flows and to subsequently release that water from storage at times that provide the greatest benefit for waterway health.

The water sector is increasingly adept at managing all available water to maximise the benefits water provides to consumptive uses and the environment. Victorian policy is to use efficiency tools (for example, reusing flows that have returned to the river after flowing through a floodplain, wetland or forest site, or 'piggybacking' water for the environment on deliveries of water for consumptive use) that can greatly reduce the water for the environment needed to meet specified environmental aims. This assessment does not account for these shared benefits.

Managers also consider opportunities to provide shared cultural and social benefits when delivering water for the environment. The VEWH reports each year on the shared benefits waterway managers achieve with water for the environment. These can include more opportunities for anglers and paddlers to use local rivers and the sharing of Aboriginal knowledge for waterway management.

The management processes above apply to regulated rivers with water storages. In unregulated rivers, flows are typically close to natural but there is much less opportunity to manage the flow pattern to meet environmental needs if natural flow is ever insufficient.

Figure 49 breaks down the changes in long-term water availability for water set aside for the environment into their two causative factors: the change in the current climate representative period and the change in water-sharing arrangements. It shows that although changes in water-sharing arrangements increased the environment's proportion in many basins, this increase was outweighed in most instances by the contribution of change in the climate period.

Appendix C provides tables that contain the long-term availability of surface water for the environment for each basin for each step of the assessment.

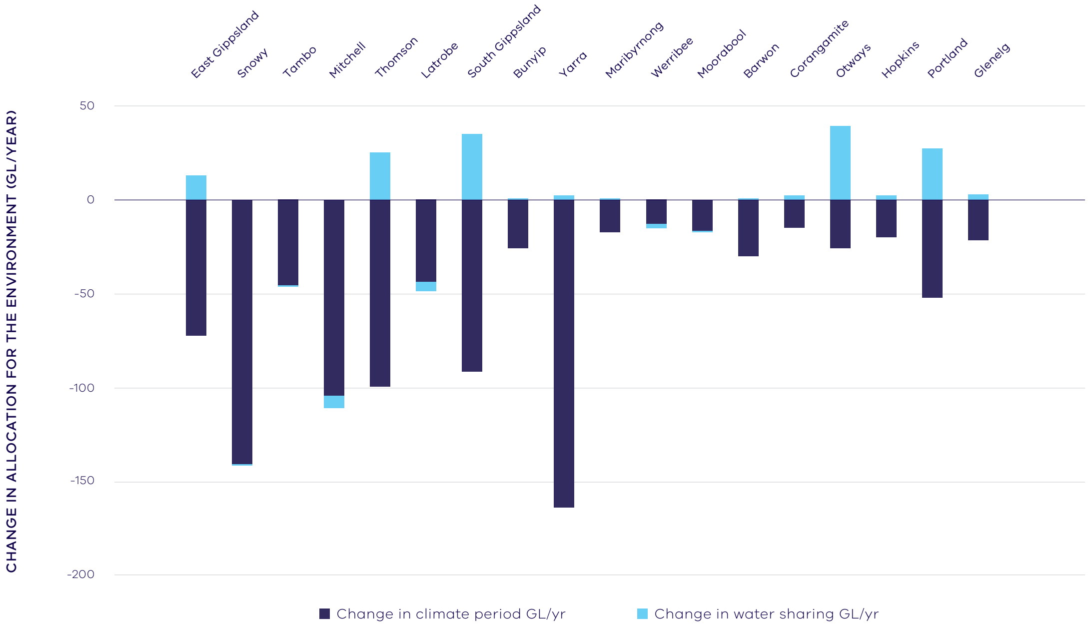


Figure 49: Changes in long-term water availability for the environment, contribution of change of climate period and change of water-sharing arrangements

5.6 Sharing of declines in long-term water availability

The technical assessment is required to determine, for each basin, whether or not declines in long-term surface water or groundwater availability have been shared equally between consumptive uses and the environment, or whether declines have fallen disproportionately on one or the other. To do so, the assessment:

- estimated the proportions of long-term water availability for the environment and for consumptive uses at steps A, B and C: 'Taking account of changes in water-sharing arrangements in the Yarra basin' gives an example of how this works for that basin. These proportions are relative to the sum of water availability for the environment and consumptive users, and exclude volumes that cannot be assigned to either, such as unassigned river losses.
- determined that a decline in long-term water availability in a basin has fallen disproportionately if there has been a change of 1 per cent or more in the proportion available for consumptive uses or the proportion available for the environment.

Even with the best data and models, there is still some uncertainty in all the estimates, uncertainty that stems from limitations in measurement and modelling. The assessment was across a large scale and it was not practical to quantify the precise range of uncertainty for each basin.[53] The assessment considered differences of less than 1 per cent to be sufficiently small as to not be meaningful. In basins where the difference was less than 1 per cent, the assessment concludes that there has been no change the proportions of water available for the environment and consumptive uses. This is considered to be a conservative approach that ensures a review is undertaken in all basins where declines in long-term water availability have not been shared equally.

Results have been presented to the nearest gigalitre in **Table 4** and in similar tables in the appendices of this report. It should be noted when viewing these tables that the uncertainty in water availability for a given scenario may be higher than one gigalitre, but further rounding of these figures has not been undertaken to maintain the transparency of how changes in water availability across scenarios has been calculated.

The assessment only reports on whether declines have been shared equally or not: it makes no comment about the impact of declines on the environment or consumptive uses.

53 The influence of the potential uncertainties in measurement and modelling on the assessment's findings was examined using two case studies. It found that even when there were large uncertainties in the underlying data (such as gauged streamflows) there was generally only a small shift in the environment's share of water availability (less than 0.1 per cent in the two case studies considered). This indicated that the assessment's findings are generally robust to the uncertainty in the two case studies considered, and that re-classification of basins above or below the 1 per cent threshold due to input uncertainty is of low likelihood.

Taking account of changes in water-sharing arrangements in the Yarra basin

Table 1 earlier in this report showed how the assessment estimated long-term water availability in the Yarra basin using the two-step approach. The assessment also used the two-step approach and added a third step, to account for changes to water-sharing arrangements since the SWSs (which **Table 4** explains).

As **Table 4** shows, the assessment found that in the Yarra basin, under all the rules in all entitlements and licences at the time of the SWS, consumptive uses had a 44 per cent share and the environment a 56 per cent share of water availability, upstream of the basin outlet. It also found that if the water entitlements framework operated today exactly as it did in 2006, consumptive uses would now have 51 per cent and the environment 49 per cent. This is a 7 per cent reduction in the environment's share mainly due to so much water for the environment being above-cap water, which is the first water to be lost as streamflow declines.

Water entitlements today are not exactly as they were 2006, and the table shows that water has been recovered for the environment, taking the balance to 50–50 per cent.

Table 4: Long-term surface water availability and sharing, Yarra basin

				Change due to	
	Step A Benchmark estimates	**Step B Current climate reference period**	**Step C Step B + current water-sharing arrangements**	**different climate period (B cf A)**	**different climate period, different water-sharing arrangements (C cf A)**
Long-term surface water availability					
Total water availability (GL/yr)	1060	885	885	-175	-175
Consumptive uses (GL/yr)	451	429	426	-22	-25
Environment (GL/yr)	583	420	423	-163	-160
Not categorised (GL/yr)*	26	36	36	10	10
Water-sharing					
Consumptive uses	44%	51%	50%	7%	7%
Environment	56%	49%	50%	-7%	-7%

* This is water that cannot be reasonably considered as being for consumptive uses or the environment, typically river losses and evaporation from storages. This water was included in the calculation of total water in each system but was excluded from the calculation of whether declines in long-term water availability have been shared equally. Values are rounded to the nearest 0.1 GL. Figures might not add in columns and/or rows, due to rounding.

5.6.1 Changes in proportions

...due to decline in long-term water availability (step B cf. A)

Figure 50 shows the changes in the proportions of water available for consumptive uses and the environment (step B compared with step A). It shows that in almost every basin — had there been no changes in water-sharing arrangements to recover water for the environment — the proportion of water available for consumptive uses would have increased and the proportion available for the environment would have decreased.

Table 4 indicates, for example, that in the Yarra basin the environment's share of water availability has declined by 7 per cent, with a corresponding 7 per cent increase in the share of water available for consumptive uses.

Figure 50 shows this on the right and left axes respectively. Decreases in the environment's share of water availability were the greatest in the Yarra, Werribee, Moorabool, Thomson and Barwon basins. By contrast, the environment's share of the available resource has not changed in several river basins, including the East Gippsland, Portland Coast and Hopkins river basins.

Figure 50 also includes the decline in long-term total water availability on the horizontal axis. The basins closest to the left of the figure (where the decline in total water availability has been lower) have had the smallest proportional changes in the environment's share of that resource. Conversely, the basins furthest to the right of the figure have experienced the largest declines in long-term water availability, and in many cases also exhibit the largest declines in the environment's share of that resource. The exceptions to this are the Maribyrnong and Lake Corangamite basins. Although these two basins have experienced a relatively large reduction in total water availability, because the share of water availability for consumptive use is relatively low (8 per cent and 1 per cent respectively from **Table 6** in **Appendix C**), the environment's share of water availability does not decline by more than 1 per cent. This result may also be influenced by the absence of significant flow regulation by major reservoirs in a large proportion of the area of these two basins.

In contrast, the Yarra, Werribee, and Moorabool basins, where the decline in water available for the environment has been higher, there is both a much higher proportion of water allocated to consumptive users, and significant flow regulation by major reservoirs.

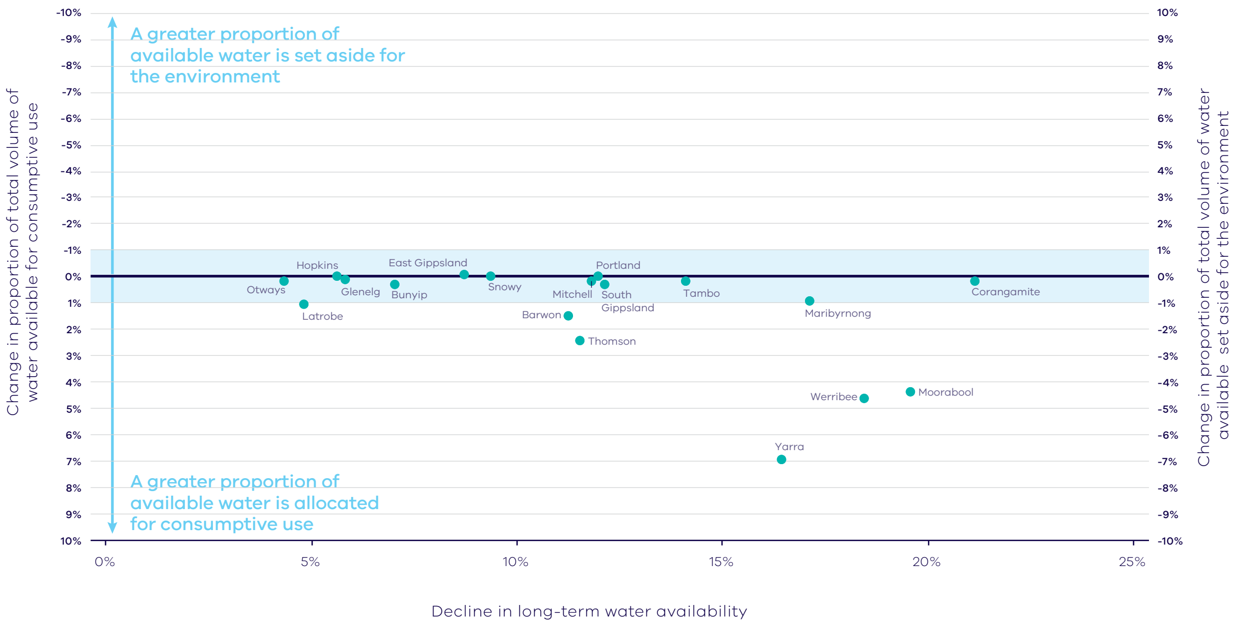


Figure 50: Changes in proportions of water available for the environment and for consumptive uses due to a decline in long-term water availability (step B cf. A), by basin

NOTE: The change in proportion is calculated taking total water availability less not categorised water. Not categorised water is water that cannot be reasonably considered as being for consumptive uses or the environment, typically river losses and evaporation from storages.

...due to decline in long-term water availability & changes to water-sharing arrangements (step C cf. A)

Figure 51 shows changes in the proportions of water available for consumptive uses and the environment (step C compared with step A). It shows the effect of intentional changes to water-sharing arrangements, most of which aimed to recover water for the environment, including by establishing environmental entitlements (see **Table 2**).

When compared with **Figure 50**, the changes in the environment's share of water availability are modest (less than a change of 1 per cent of water availability) for most river basins. An exception is in the Thomson basin, where increases to the environmental entitlement since the SWS have increased the environment's share of water by approximately 3 per cent of water availability. This change has meant that in **Figure 51** the environment's share of current water availability is now just above 50 per cent in the Thomson basin, rather than a few percent below this value prior to the changes in environmental entitlements.

The share of water availability for the environment in the Latrobe basin decreased under current water-sharing arrangements, because even though an environmental entitlement has been created since the SWS, previously unallocated water has also been allocated to consumptive users in this basin, increasing their share of available water.

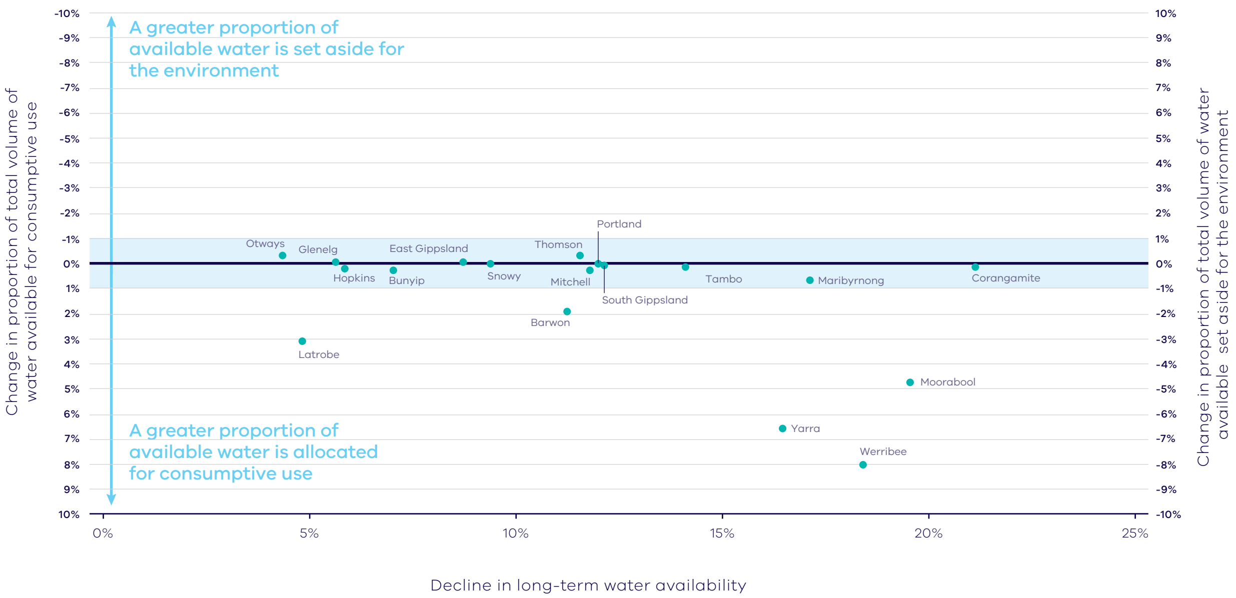


Figure 51: Changes in proportions of water available for the environment and for consumptive uses due to a decline in long-term water availability and changes to water-sharing arrangements (step C cf. A), by basin

Figure 52 gives another view on the information in **Figure 50** and **Figure 51** by showing basins where there was no change in the proportion of water available for the environment and where the proportion of water available for the environment has declined, and the decline would have been greater without water recovery. It can be seen in this map that water recovery efforts in the Central Region of southern Victoria have reduced the decline in the environment's share of water availability since the SWS.

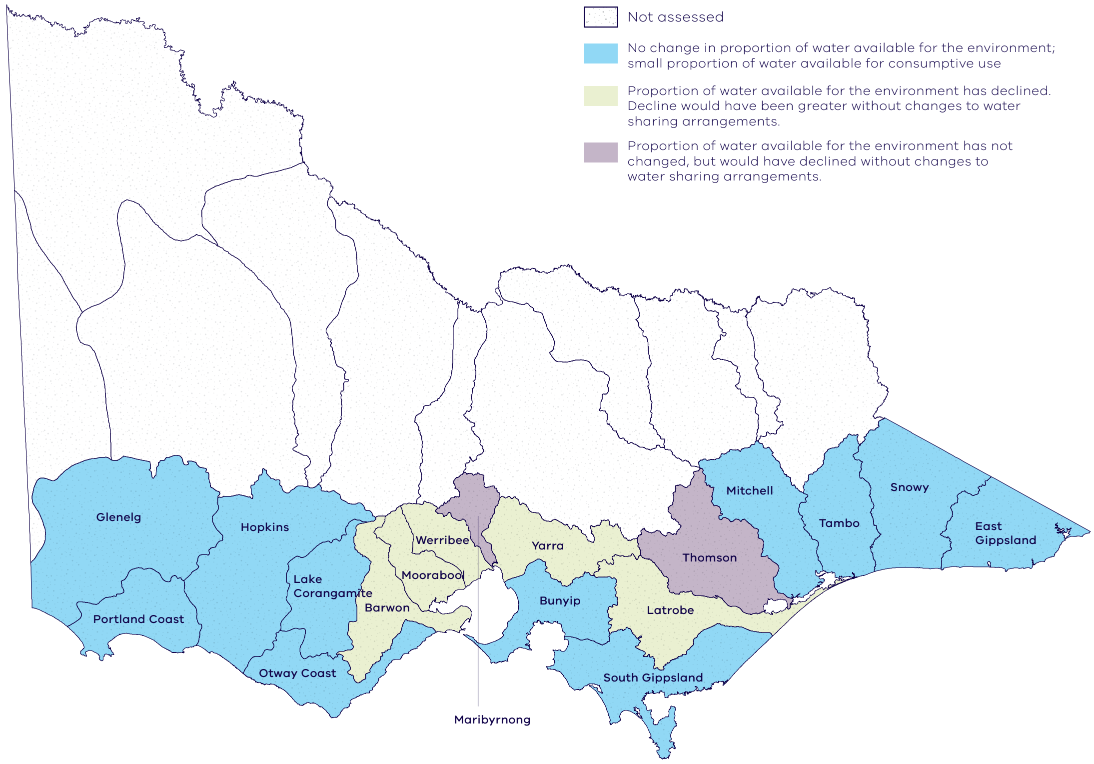


Figure 52: Changes in proportions of water available for the environment and for consumptive uses, by basin

In the Bunyip basin and basins in Gippsland and western Victoria, where relatively small volumes of water are allocated for consumptive uses — typically less than 5 per cent of the total volume available — the assessment found no change (i.e. the change was below the nominated 1 per cent tolerance threshold) in the environment's proportion. Because consumptive uses' proportion is small, the environment's proportion did not change (by more than the threshold value of 1 per cent), even if long-term water availability declined. This indicates that a review in the East Gippsland, Snowy, Tambo, Mitchell, South Gippsland, Bunyip, Corangamite, Otway Coast, Hopkins, Portland Coast and Glenelg basins may not be required.

In most basins of the Central Region, the declines in long-term water availability have not been shared equally. The environment's proportion is now less — up to 8 per cent less — than was estimated for the SWS, even in basins where concerted efforts have been made to recover water for the environment. This is because the decline in the volumes of above-cap water has been greater than the volumes of water recovered for the environment. Had water not been recovered, the environment's proportion would now be even smaller. This indicates that a review in the Latrobe, Werribee, Barwon, Yarra and Moorabool basins may need to be considered.

In the Thomson and Maribyrnong basins the environment has the same share of the available resource as it did at the time of the SWS. Based on the preliminary findings, a review in these basins may also need to be considered because:

- The increased volume of environmental entitlements in the Thomson basin since the SWS has not changed the proportion of water available for the environment because it has been offset by declines in above-cap water. Without water recovery, the decline in water availability falls disproportionately on the environment. The increase in the environmental entitlement in the Thomson basin (as in other basins), as outlined in the Central Region SWS, was the volume required to meet scientific study recommendations of environmental water requirements at that time. It was intended to address shortfalls in critical environmental water that existed prior to the SWS.[54] The shortfall volume was estimated based on knowledge available at the time of the SWS, which included long-term historical climate information. Since that time, climate conditions have become drier. The observed declines in above-cap water for the environment since the SWS were not known or explicitly planned for when adjusting water-sharing arrangements at the time of the SWS. A review would provide an opportunity to examine whether the water secured under current environmental entitlements is sufficient to address shortfalls. Given the integrated management of water resources in the Yarra and Thomson basins, it would make sense to review the two basins together.
- The Maribyrnong basin has experienced one of the largest declines in inflows across Victoria. The proportion of water available for the environment and consumptive uses have not changed, partly because urban supplies are now being preferentially sourced from the water grid, to maintain an appropriate level of water security, rather than from the Maribyrnong basin. That is, a consequence of changes in urban water supply system operation has been to mitigate the impacts of a drying climate on the Maribyrnong basin. The future operation of urban water supply systems in the basin will be influenced by several factors, including the need to service a growing population. The environment's current share is not secured. DELWP is working with Western Water and other stakeholders to explore the option of the current operational approach becoming ongoing practice, firming up the water-sharing arrangements to maintain the environment's current share.

A review would allow the issues in these basins to be explored with the community, to assess the best course of action to address declines in above-cap water for the environment.

The effects of groundwater declines on water-sharing

In most river basins the contribution of groundwater extractions to declines in surface water availability in southern Victoria is small (<2 per cent).

In the Barwon, Werribee, Latrobe and Moorabool basins, declines in surface water availability have resulted in a disproportionate decline in water available for the environment, and licensed groundwater extraction has made a 1-2 per cent contribution to this decline.

In the Otway Coast, Mitchell, Lake Corangamite and Bunyip basins groundwater extraction has reduced surface water availability, but the decline in surface water availability (<1 per cent) has been shared equally between water for the environment and for consumptive use.

In the Thomson basin licensed groundwater extraction has made a 4 per cent contribution to the decline in surface water availability.

54 The volume of the environmental entitlement is less than the 57 GL/year shortfall of environmental water identified by the scientific study, and took into account environmental objectives and the economic implications of different water recovery options.

Wet versus dry years

How water is shared between consumptive uses and the environment can change greatly between wet and dry periods. A string of dry years may change water availability for the environment and consumptive uses much more than long-term declines.

Figure 53 shows the modelled impacts on water-sharing under current arrangements for an example basin (the Yarra River) in two, five-year periods: a wet period (modelled using 1992–96 data) and a dry period (2005–09). In this example, water available for passing flows, the environmental entitlement and rural consumptive uses do not change much between the wet and dry periods. However, in the dry period there is less water available for urban consumptive uses and the greatest reduction is in the volume of above-cap water.

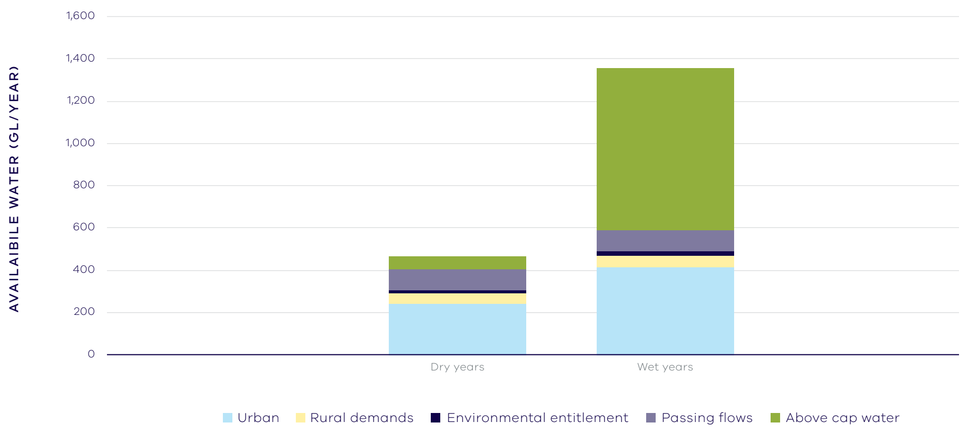


Figure 53: Yarra basin water balance, modelled wet and dry periods

NOTE: the figure is the result of water resource modelling using 1992–96 (wet period) and 2005–09 (dry period) data.

Figure 54 compares the volumes available for consumptive uses in each basin in the wet and dry periods; **Figure 55** makes the same comparison for water available for the environment. The figures show the great extent of the decline in water available for the environment in the dry periods.

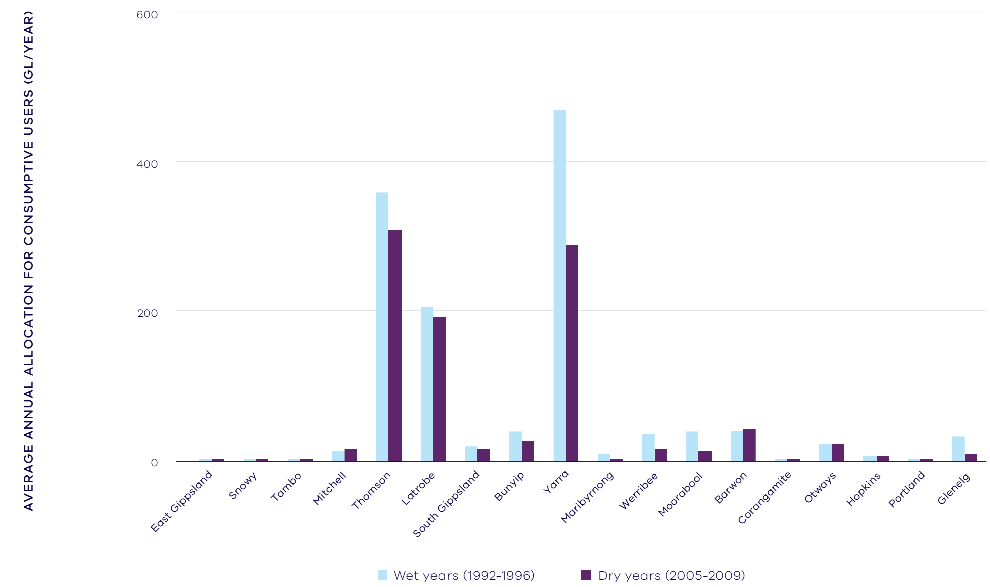


Figure 54: Volumes available for consumptive uses, wet and dry periods, by basin

NOTE: the figure is the result of water resource modelling using 1992–96 (wet period) and 2005–09 (dry period) data.

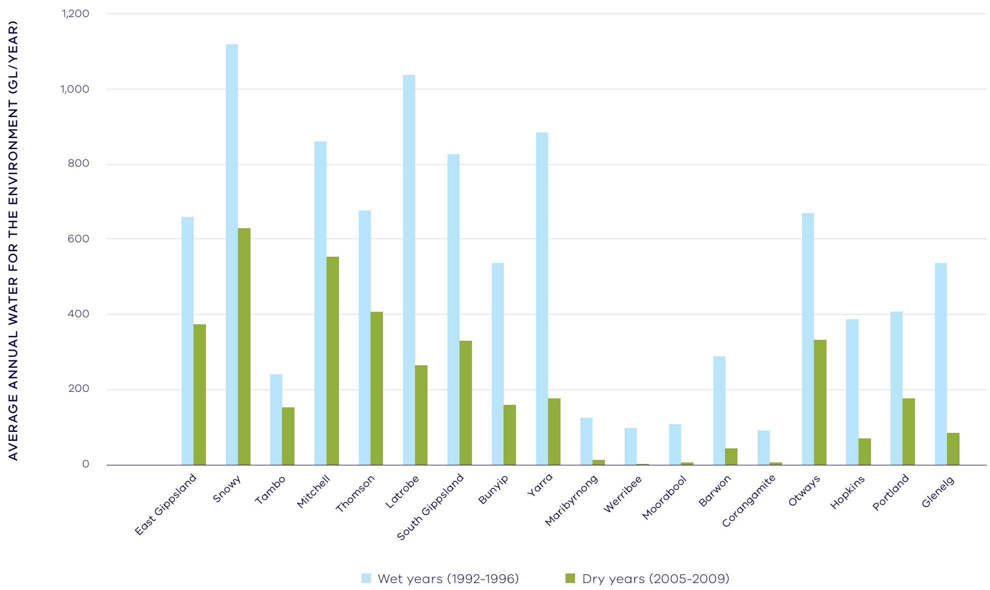


Figure 55: Volumes available for the environment, wet and dry periods, by basin

NOTE: the figure is the result of water resource modelling using 1992–96 (wet period) and 2005–09 (dry period) data.

The way water is shared varies across a river basin: Yarra example

The assessment presents the findings at the basin scale and considers how water is shared between the environment and all consumptive users in the basin. However, the proportion, or share, of water available for the environment and consumptive users varies across the basin. Upstream of the major harvesting reservoirs, for example, all water is available for the environment. After allowing for allocations to consumptive users, immediately below these reservoirs the environment's share of the river flow will be less. The environment's share of the water immediately downstream of these reservoirs is provided through releases for environmental entitlements and passing flows, as well as spills. In the Yarra basin, the environment's share of water available immediately downstream of these reservoirs is 18 per cent of total water available in the basin.

As you travel further downstream from a reservoir, unregulated tributary streams and inflows from groundwater contribute to flow in the main river. These inflows are generally above-cap water that increases the environment's share of flow in the river. At the downstream end of the Yarra, these unregulated inflows boost both total water availability and the environment's share of water. The environment's share at this location increases to 50 per cent of the total available water in the basin.

Overall, the environment's share of water availability has declined by 6 per cent in the Yarra basin due mostly to a decline in unregulated inflows (see **Table 4**). The environment's share of unregulated inflows is now less than it was at the time of the SWS. However, the environment's share immediately downstream of the major water harvesting storages is the same as it was at the time of the SWS (i.e. 18 per cent of total water availability in the basin). The environment's share of water immediately downstream of reservoirs has not changed for two reasons. First, inflows in the upper Yarra catchment have not declined as much as the unregulated inflows lower in the basin. Second, the creation of the Yarra environmental entitlement transferred some water in storage to the environment.

Seasonal changes in water availability in the Yarra basin

How water is shared between consumptive uses and the environment can vary significantly between seasons. **Figure 56** shows the changes in water availability and sharing between seasons in the Yarra River under current climate and current water-sharing arrangements.

Most water is harvested into storages by Melbourne Water during the wetter months of winter and spring. Harvested water is then used throughout the year to meet consumptive urban demand. Rural demands for water to irrigate crops are highest in the summer.

Minimum passing flows for the environment are also higher in the winter and spring because the rules for these flows are designed to mimic natural seasonal cycles. Availability of environmental above-cap water — unregulated river flows and spills from storage — is highest during the spring and lowest during autumn. This reflects the dry autumn conditions experienced over recent decades.

Water-sharing between consumptive uses and the environment changes dramatically between the wet and dry seasons. During winter-spring the ratio of consumptive to environmental water availability is 46%:54% but changes to 59%:41% in the summer-autumn. When calculated over the whole year, the available water is shared 50%:50%.

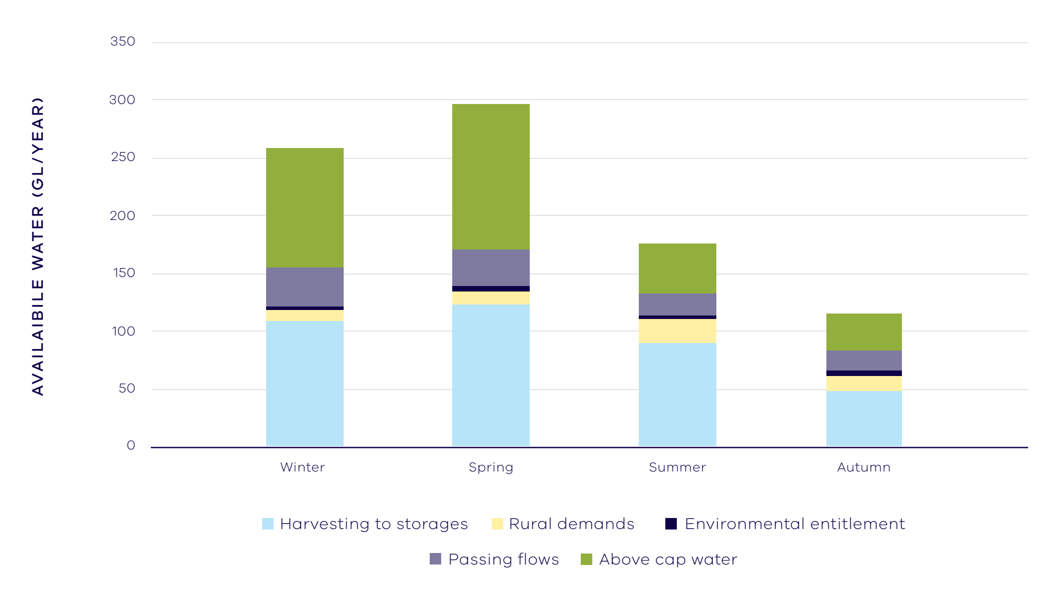


Figure 56: Yarra basin water balance, by season

The Long-Term Water Resource Assessment uses water-sharing across the whole year as a suitable measure for detecting long-term changes. **Chapter 6.3** and **Chapter 6.5** provide a closer look at observed seasonal changes in the flow regime.

PART B: Waterway Health – Long-Term And In Relation To Flow

KEY FINDINGS

- No overall deterioration in waterway health for reasons related to flow could be identified.
- Some indicators of waterway health have improved due to changes in flow, some have deteriorated, others show no discernible trend.
- Historical datasets (beginning prior to LTWRA establishment in the *Water Act* in 2005) are poorly suited to determining an **overall** trend in waterway health for reasons related to flow.
- Appropriate monitoring programs have been established since 2007 which should support future LTWRAs to determine changes in waterway health for flow-related reasons.

6. Change in waterway health

Water is a limited resource, and Victoria's water entitlement framework aims to balance the competing demands for water for consumptive uses and the environment. The framework provides security of supply and flexibility to develop solutions and ensures the long-term resilience of communities and healthy waterways.

Part A of the technical assessment aimed to determine if there has been a decline in long-term water availability that has been shared unequally between consumptive uses and the environment.

Part B of the assessment seeks to determine whether there has been long-term deterioration in waterway health for reasons related to flow. Such deterioration could possibly arise from decreases in long-term water availability or from changes in the water-sharing balance identified in part A. It could also be related to the success or otherwise of SWS actions (such as the creation of new environmental entitlements in many basins) in arresting the deterioration of — or even improving — waterway health, compared with previous arrangements.

The part B findings will inform possible reviews of water-sharing arrangements in particular basins and actions to update current arrangements to improve waterway health.

About waterway health

While the Act defines 'waterway' in detail, for this assessment waterways are defined as including regulated and unregulated rivers, their associated estuaries and floodplains (including floodplain forests and wetlands) and non-riverine wetlands.

Waterway health is a general term for the overall condition of key features and processes that underpin functioning waterway ecosystems. There is no precise definition of 'waterway health' in the Act although it includes in 'the environmental values and health of water ecosystems' their biodiversity, ecological functions and water quality.

For the purposes of this technical assessment, waterway health includes characteristics such as:

- presence, abundance and diversity of species
- extent and connectivity of habitat
- breeding and feeding opportunities for fish, frogs, birds and other animals
- carbon and nutrient cycling and sediment transport processes
- water quality.

A sub-set of these characteristics were examined in this assessment.

About 'reasons related to flow'

Waterway health depends (among many other catchment influences) on the quantity of water in the waterway and on the flow regime and its components, which are defined by the timing, seasonality, frequency and duration of flows. The main components of a flow regime are:

cease to flow, when there is no discernible flow in the waterway

low flow, where there is continuous flow through at least the narrow centre of the channel

fresh, which is a small, short-duration, peak-flow event

high flow, which is a persistent increase in the seasonal baseflow

overbank flow, which inundates adjacent floodplains.

These components support different aspects of ecosystem health as shown in **Figure 57**.

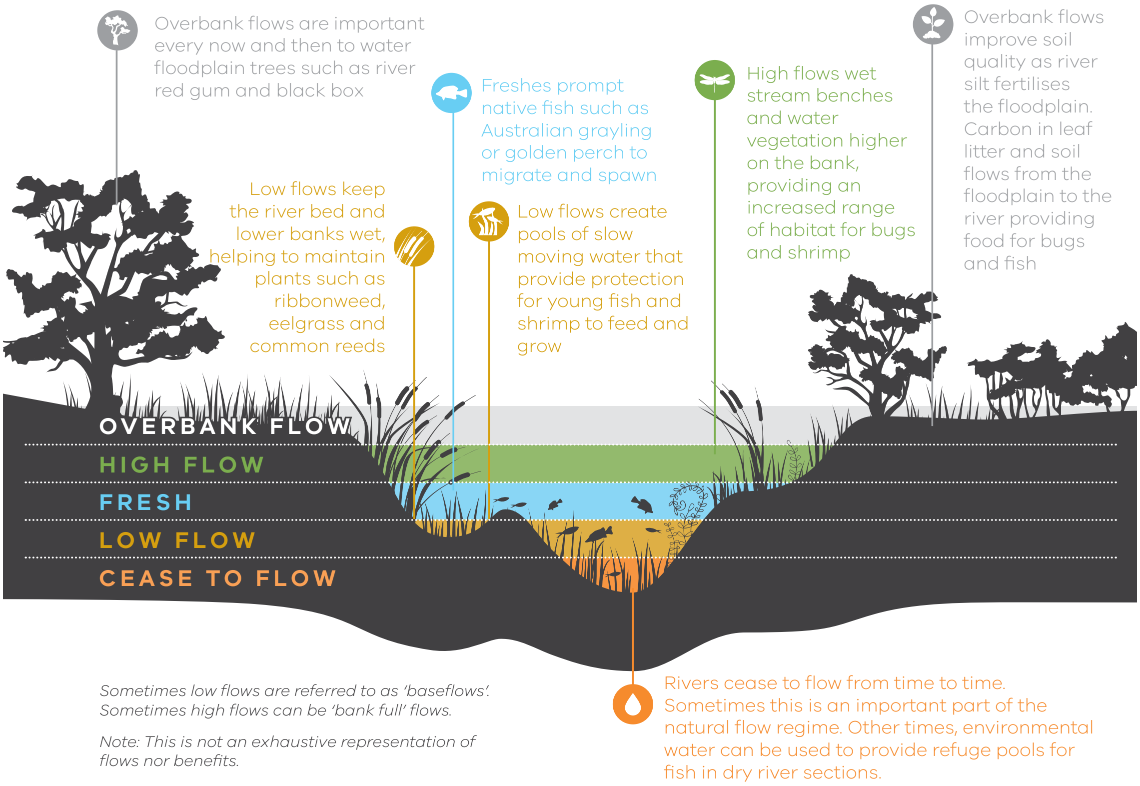


Figure 57: How flow regime components benefit aquatic ecosystems
Source: VEWH fact sheet What does environmental watering aim to achieve?

Many of Victoria's rivers, wetlands and estuaries have been highly modified to provide a stable source of water for consumptive uses. Large volumes of water are now captured in dams or pumped out of waterways for consumptive uses, and the amount and timing of this capture has changed the flow regimes of many waterways.

The aquatic ecosystems of waterways can be harmed when the flow regime to which they have adapted changes. Sustained low flow, sustained high flow or unseasonal flow will change the aquatic conditions that rivers, wetlands and estuaries need to sustain their ecosystems. An example of these changes is maintaining low flow in a river in winter and high flow in summer to meet irrigation needs. These changes influence the extent to which the lifecycle of water-dependent ecosystems can occur. For example, migratory fish species (such as Australian grayling and tupong) require pulses of fresh water of a certain duration within a particular season to trigger downstream migration, breeding, egg/larvae dispersal, and to attract juveniles back upstream into the system. A number of frog and bird species breed in relation to high flow and overbank flow events that also benefit riparian vegetation and inundate wetlands, enabling plant seed dispersal and germination. In these ways, altered flows can affect the productivity of waterways and overall waterway health.

6.1 Approach and general method

Victoria has a wide range of data on individual indicators of waterway health, however there is no agreed method for measuring it as a whole. This is the first-ever LTWRA, and it is the first effort to quantitatively assess changes in waterway health for flow-related reasons over a long, retrospective period across southern Victoria. The assessment took two approaches.

The **first approach** (discussed in full in the technical report on changes in waterway health).[55]

- identified **indicators of waterway health** for which there was adequate long-term data
- conducted a trend analysis, to determine if each indicator was increasing or decreasing
- conducted a causal analysis, to see how much of any trend detected could be attributed to changes in components of the flow regime
- conducted a spatial analysis, to see if the trend and causality analyses differed at the basin, SWS region and state-wide scales.

These analyses enabled the assessment to identify:

- whether the waterway health indicators for the basin are improving or deteriorating, or if no change is detectable
- the extent to which changes in indicators were related to flow (such as largely unrelated or strongly related).

Detailed results for each basin are presented in the separate report Basin-by-Basin Results.

These analyses do not:

- determine the size of any change in an indicator as a result of a trend, as a small change may still be a deterioration (or improvement)
- determine if the current state of any indicator is 'healthy' or 'unhealthy' as the trajectory of the indicator may still be one of deterioration (or improvement).

The **second approach** supplemented this waterway health indicator analysis with two analyses of how the flow components known to be important to waterway health have changed over time (**ecohydrological analyses**). This approach used gauged streamflow data (and not modelling, as used in part A of the technical assessment) to compare, pre- and post-SWS:

- the proportion of FLOWS[56] recommendations that occurred
- ISC hydrological indices[57] important to waterway health.

If a smaller percentage of FLOWS recommendations had occurred or one or more of the ISC indices had substantially post-SWS, the analyses concluded there had been an increased threat to waterway health for reasons related to flow.

To summarise, the waterway health indicators address the question of whether or not specific aspects of waterway health in a basin are deteriorating for reasons related to flow. The ecohydrological analyses indirectly add context by indicating whether or not there has been increased stress on waterway health for flow-related reasons. Where the findings from the two approaches align, there can be greater confidence in whether the waterway is stressed, and its health is deteriorating, due to flows.

The assessment focussed on rivers, as this is where the most suitable long-term data was available. Separate preliminary studies on wetlands and estuaries confirmed lower overall data availability for each type of system. These studies also identified the most prospective wetland system and estuary system likely to have appropriate data for undertaking a long-term assessment of waterway health for reasons related to flow. Case studies for the most likely wetland and estuary were trialled in the technical assessment[55] to confirm if the method and data were suitable and demonstrate how wetland and estuary assessments might be carried out on these other types of waterways, were further suitable data identified.

55 Sparrow, A., Moloney, P., McKendrick, S., Crowther, D. and Johnson, L. (2019). *Assessment of change in waterway health in southern Victoria: A quantitative trend analysis for the Long-Term Water Resources Assessment.* Report for the Water and Catchments Group, Department of Environment, Land, Water and Planning, Victoria. Arthur Rylah Institute for Environmental Research, Department of Environment, Land, Water and Planning, Heidelberg, Victoria.

56 FLOWS is the method used in Victoria to determine the flow requirements of freshwater reaches of waterways. This is described further in **6.3: Method for ecohydrological analyses**.

57 ISC (Index of Stream Condition) is a state-wide integrated measure of river condition. https://www.water.vic.gov.au/__data/assets/pdf_file/0024/34809/ISC_Part1_Introduction.pdf

6.2 Method for waterway health indicator analyses

6.2.1 Identifying the indicators

As this was the first LTWRA technical assessment, the first step was to identify possible indicators of waterway health and the available datasets. Indicators were selected if there was sufficient long-term data: most indicators have not been monitored regularly due to limits on funding, time and scientific and technological knowledge. In addition, as knowledge has improved, the way indicators have been measured has also improved, however such changes sometimes mean that data from earlier decades is not comparable to that currently being collected and could not be used in this assessment. For the LTWRA, long-term datasets require consistent and repeated monitoring from pre-SWS to post-SWS: that is, ideally for at least several decades. The monitoring datasets best meeting these criteria begin in 1990, and most datasets used cover most of the period 1990-2018. An important consideration is that waterway health monitoring programs from decades ago were not designed to meet the needs of the LTWRA (because the assessment did not yet exist). The indicators with long-term data are thus those which had the best data available, not necessarily those which could best demonstrate the impact of changes in flow regime. This is discussed in detail in the technical report on how the method was developed.[58] More recent monitoring is improving data collection for indicators of waterway health, particularly for reasons related to flow, this monitoring is described further in the textbox "Waterway health data".

Waterway health data

The assessment couldn't use several datasets because they didn't start until after the SWS water-sharing actions were implemented, so they cannot show if the SWS actions are improving waterway health for the current LTWRA. These new datasets come from monitoring programs including the Victorian Environmental Flows Monitoring and Assessment Program[59] (VEFMAP) and the Wetlands Monitoring and Assessment Program[60] (WetMAP).

These programs plan to continue to collect data, which will be useful for future LTWRAs because they will provide consistent and repeated long-term monitoring data to determine waterway health trends related to flow.

Several other datasets that provide information directly relevant to waterway health are not suitable for a LTWRA. For example, the ISC[57] collects comprehensive data about waterway health across the state but it is point-in-time and does not demonstrate a trend — a deterioration or improvement over time — as the LTWRA requires, because it was designed for spatial benchmarking. However, the LTWRA uses some of the same datasets used to calculate the point-in-time metrics making up the ISC. For example, the ISC has a biological metric which uses some of the same macroinvertebrate data that the LTWRA uses. Similarly, the ISC has hydrological metrics which use data from some of the same streamflow gauges that the LTWRA uses. Further, the LTWRA has used the definitions of the ISC hydrological metrics in a long-term ecohydrological analysis as described in **Chapter 6.3.2**. Similarly, the Index of Wetland Condition and Index of Estuary Condition are not directly useable for a LTWRA.

58 Sparrow, A. and Bond, N. (2018). *Methods for assessing change in river and stream health in Victoria: A framework for the Long-Term Water Resources Assessment.* Report for the Water and Catchments Group, Department of Environment, Land, Water and Planning, Victoria. Arthur Rylah Institute for Environmental Research, Department of Environment, Land, Water and Planning, Heidelberg, Victoria.
59 https://www.ari.vic.gov.au/research/rivers-and-estuaries/assessing-benefits-of-environmental-watering
60 https://www.ari.vic.gov.au/research/wetlands-and-floodplains/assessing-wetland-response-to-water-for-the-environment

Table 5 shows the waterway health indicators selected and what an increase or decrease indicates for waterway health. The assessment identified that the only indicators which met the long-term requirements were for water quality and macroinvertebrates. The assessment complemented these with some native fish datasets. Monitoring fish is more labour- and resource-intensive than monitoring water quality or macroinvertebrates, so fish have not been monitored for as long nor as frequently: there is limited fish data from before 2005.

The technical report on methods[61] describes how the method was developed and identified and assessed the indicators and datasets. The technical report on the assessment[62] details the final method and datasets used and full results, while this overview report and the companion report, Basin-by-Basin Results, provide the overall findings.

Table 5: Waterway health indicators

Type	Indicator	Improvement	Deterioration
		indicated by ...	
Native fish	Nativeness by biomass	Increase	Decrease
	Observed-to-expected	Increase	Decrease
	Observed-to-predicted	Increase	Decrease
Macroinvertebrates	SIGNAL2 (stream invertebrate grade number - average level)	Increase	Decrease
	Odonata-Coleoptera-Hemiptera (OCH)	Decrease	Increase
Water quality	Dissolved oxygen	Increase	Decrease
	Salinity (electrical conductivity)	Decrease	Increase
	Turbidity	Decrease	Increase
	Total suspended solids	Decrease	Increase
	Total phosphorus concentration	Decrease	Increase
	Nitrogen (nitrate-nitrite)	Decrease	Increase

NOTE: a single indicator does not indicate if waterway health is improving or deteriorating. For further information, particularly about limitations on interpreting the turbidity, total suspended solids, phosphorus and nitrogen indicators, see **Limitations on interpreting indicators** later in this chapter.

The only biodiversity indicators are the macroinvertebrate and fish indicators. There was insufficient data for many other biodiversity values (such as for in-stream and riverside vegetation, waterbirds, amphibians and platypus). Nor was there adequate data for indicators of ecosystem function (such as processing of nutrients or production of overall biomass).

61 Sparrow, A. and Bond, N. (2018). *Methods for assessing change in river and stream health in Victoria: A framework for the Long-Term Water Resources Assessment.* Report for the Water and Catchments Group, Department of Environment, Land, Water and Planning, Victoria. Arthur Rylah Institute for Environmental Research, Department of Environment, Land, Water and Planning, Heidelberg, Victoria.

62 Sparrow, A., Moloney, P., McKendrick, S., Crowther, D. and Johnson, L. (2019). *Assessment of change in waterway health in southern Victoria: A quantitative trend analysis for the Long-Term Water Resources Assessment.* Report for the Water and Catchments Group, Department of Environment, Land, Water and Planning, Victoria. Arthur Rylah Institute for Environmental Research, Department of Environment, Land, Water and Planning, Heidelberg, Victoria.

6.2.2 Native fish indicators

Fish are a good long-term waterway health indicator, because some fish have long lifespans such as golden perch, which can live more than 25 years, or Murray cod, which can live for several decades.

The variety and abundance of fish species in a given waterway can also indicate its health and specifically the availability of habitat. Because they move around, fish can indicate the state of waterway health at many sites.

The assessment used three fish indicators.[63] If a score for an indicator increased, the assessment considered waterway health had improved.

Nativeness by biomass

This indicator is the proportion of the total weight of fish of a native species, rather than of an introduced species (such as common carp), in a sample. A high score indicates native species dominate the sample; a low score indicates introduced species dominate the sample.

Observed-to-expected

This indicator is the number of native species observed and recorded at a site as a proportion of the number of native species that would have been expected to occur at the site before European settlement.

Observed-to-predicted

This indicator is the number of native species that have been observed and recorded as a proportion of the number of native species that are predicted to be caught by electrofishing. This is a subset of 'observed-to-expected', because it excludes rare fish that are unlikely to be caught regularly.

6.2.3 Macroinvertebrate indicators

Macroinvertebrates are animals without a spine that are large enough to be seen with the naked eye. They include worms, aquatic insects, crustaceans and molluscs. Macroinvertebrates are typically less mobile than fish, so they are a useful indicator of a waterway's condition at a particular site over time. The assessment used two macroinvertebrate indicators.

SIGNAL2

This indicator (stream invertebrate grade number - average level) is a well-established, rapid, bioassessment index that uses the pollution tolerance of different types of macroinvertebrates to provide a score. The higher the score, the more pollution-intolerant macroinvertebrates are present. The assessment considered an increase in SIGNAL2 over time indicates improved waterway health.

OCH

This indicator is a measure of the abundance and diversity of three groups of macroinvertebrates — dragonflies (Odonata), water beetles (Coleoptera) and water bugs (Hemiptera) — relative to other groups of macroinvertebrates. In general, these three groups of macroinvertebrates are adapted to intermittent streams, and an increase in this indicator can be taken to represent a decrease in permanent water and a move towards intermittent streams. Although some waterways in Victoria are naturally intermittent — they dry during summer — most data the assessment used are from sites that are naturally permanent-flowing systems. Therefore, the assessment considered a decrease in OCH — taken to mean more permanent water — over time indicates improved waterway health.

63 Fish indicator metrics as developed for the Sustainable Rivers Audit, described in Davies, P.E., Harris, J. H., Hillman, T. J., and Walker, K. F. (2010). The Sustainable Rivers: assessing river ecosystem health in the Murray–Darling Basin, Australia. Marine and Freshwater Research 61(7) 764-777 https://doi.org/10.1071/MF09043.

6.2.4 Water quality indicators

Water quality is generally not managed with water for the environment. There are a small number of reaches in some systems where water for the environment is sometimes used to manage high levels of salinity or low levels of dissolved oxygen. None of the water quality indicators are expected to have a simple direct relationship to the flow regime, however as they provide the longest term and most frequent data for an aspect of waterway health it was important they were included in the analysis to check there was no unexpected deterioration for reasons related to flow. There are many other factors which were expected to have as much or more influence on water quality as the flow regime, for example surrounding land that is the source of suspended solids, turbidity and nutrients.

Dissolved oxygen

This is an indicator of oxygen gas in the water. Dissolved oxygen is strongly affected by and strongly affects biological activity (via respiration and photosynthesis), and it can vary considerably through the day. Most concern is about low levels of oxygen, although excess macrophytes or algae can also cause high levels (from photosynthesis during the day). The animal and plant life that access oxygen from the water (such as fish, tadpoles and macroinvertebrates) are highly susceptible to decreases in dissolved oxygen, and mass deaths of these organisms can occur if dissolved oxygen reaches critically low levels. For this reason, the assessment considered an increase in dissolved oxygen over time indicates improved waterway health.

Salinity

This indicator is a measure of the total concentration of inorganic salts in the water. The assessment used electrical conductivity — the ability of water to conduct an electrical current — to measure salinity. Salinity is an important aspect of water quality and can profoundly affect aquatic biota either by being toxic or by disrupting ecosystem processes and functions. Increased salinity in Australian freshwater systems can reduce the diversity and abundance of native fish, frogs, macroinvertebrates and aquatic and streamside vegetation. The assessment considered a decrease in salinity over time indicates improved waterway health.

Turbidity

This indicator is a measure of particulate matter — sediment particles, organic matter and phytoplankton — suspended in the water: the water's cloudiness. Turbidity can affect aquatic ecosystems by decreasing light penetration and inhibiting photosynthesis — which reduces the growth of submerged plants — and by reducing underwater visibility, which affects visual feeders including some species of fish, turtle and waterbird. The assessment considered a decrease in turbidity over time indicates improved waterway health.

Total suspended solids

This indicator measures the weight of particulate matter — sediment particles, organic matter and phytoplankton — suspended in the water. It is related to but different from turbidity: as well as reducing visibility and underwater light, high levels of suspended matter in the water can harm the gills of fish and macroinvertebrates and smother aquatic vegetation and fish breeding sites. The assessment considered a decrease in total suspended solids over time indicates improved waterway health.

Phosphorus

This indicator is of total phosphorus: that is, the combination of dissolved — bioavailable — phosphorus and particulate phosphorus within the cells of algae or attached to sediment. Phosphorus is a plant nutrient that stimulates the growth of algae and aquatic macrophytes. In Victorian streams, phosphorus in water is increased by human activities (such as by agricultural runoff of fertilisers, and animal waste) and by the discharge of treated wastewater. High levels of phosphorus can lead to algal blooms that can be toxic to fish, and the decay of the algae can lead to lower oxygen levels in affected waterways. The assessment considered a decrease in phosphorus over time indicates improved waterway health.

Nitrogen

This indicator is of nitrate-nitrite, a dissolved, inorganic form of nitrogen that is readily used by aquatic plants including algae. Like phosphorus, nitrate-nitrite can increase due to fertiliser runoff, animal waste and discharge of treated wastewater. High levels of nitrate-nitrite can lead to algal blooms that can be toxic to fish, and the decay of the algae can lead to lower oxygen levels in affected waterways. The assessment considered a decrease in nitrogen over time to indicate improved waterway health.

Limitations on interpreting indicators

When interpreting whether a single indicator suggests improving or deteriorating waterway health, the researcher (and reader) must keep in mind that:

- a single indicator in isolation can be misleading: it might be improving but waterway health might well be stable or deteriorating. For example, a salinity indicator might show a decrease in salinity in a basin over time, but other indicators might be deteriorating. An analogy is human health: someone may have recovered from a cold, but still be unwell due to a heart condition.
- a single indicator only indicates a subset of waterway health: for example, water quality, macroinvertebrate and fish community indicators are not proven indicators for all dimensions of waterway health
- water quality is generally not managed with water for the environment (with exceptions in some reaches of a few systems where high salinity or low dissolved oxygen are managed), and thus the indicators of water quality used would generally not be expected to show improvement even where the flow regime is actively managed
- turbidity, suspended solids, phosphorus and nitrogen can have complicated relationships with the flow regime. For example, during very dry conditions these indicators may decrease (a nominal 'improvement' for that specific indicator) because there is no runoff to transport sediment and pollutants from the land into a waterway, but such a decrease does not indicate improved overall waterway health.

These analyses of indicators do not:

- determine the size of any change in an indicator as a result of a trend – a small change may still be a deterioration
- determine if the current state of any indicator is 'healthy' or 'unhealthy' – the trajectory of the indicator may still be one of deterioration.

The assessment did not seek to identify factors responsible for the indicator's deterioration or improvement, other than flow. Waterway health is affected by various factors according to the scale:

- at a large spatial scale, factors include the volume of rainfall and runoff, how the catchment land is used (such as for cropping, grazing, forestry, mining and towns) and how much water is captured or taken out for use
- at a local scale, factors include grazing, pollution, invasive species, local land-use changes (such as clearing or urbanisation), modification of river channels (such as by removing debris and snags) and the specific volume and timing of the flow regime in a waterway.

Although the assessment's methods account for these other factors in aggregate, this report and the companion report, Basin-by-Basin Results, do not explain them because the assessment is concerned solely with the flow regime; there is more information about this topic in the technical report on the assessment.[64]

64 Sparrow, A., Moloney, P., McKendrick, S., Crowther, D. and Johnson, L. (2019). *Assessment of change in waterway health in southern Victoria: A quantitative trend analysis for the Long-Term Water Resources Assessment.* Report for the Water and Catchments Group, Department of Environment, Land, Water and Planning, Victoria. Arthur Rylah Institute for Environmental Research, Department of Environment, Land, Water and Planning, Heidelberg, Victoria.

6.2.5 Selecting time periods

The flow regimes in southern Victoria's waterways have historically been highly variable: for example, they are affected by rainfall variability (which increases or decreases flows), storage (which interrupts and changes the timing of flows), and water extraction (which reduce flows downstream of storage). That said, the Millennium Drought (1996–2010) saw a large departure from the historical range of variability, with strongly depleted flows in our rivers.

It is important that the time period chosen to identify a long-term decline in waterway health is not unduly affected by prolonged outlier events, such as the Millennium Drought. For example, comparing an indicator in 1990 and 1996 might show a severe decline; comparing it in 1990 and 2011, after the drought ended in 2010 with major rainfall and flooding, might show a much smaller decline, or even an improvement.

To understand the effects of SWS water-sharing actions on waterway health the assessment also needed to separate the periods before and after the SWS actions were implemented. The Central Region SWS was published in 2006, thus marking when SWS actions began to be implemented in the Central Region basins, while the Western and Gippsland Region SWSs were published in 2011.

Accordingly, the part B assessment used three time periods:

1990–2005 (before SWS for all basins): *Our Water Our Future* was released in 2005, marking significant change in water-sharing arrangements. Therefore, the period prior to 2005 is used as the baseline for comparing whether waterway health has deteriorated for reasons related to flow. The waterway health indicators the assessment used had fit-for-purpose data back to 1990 for most but not all basins. Also, although the Millennium Drought started in 1996, its most severe impacts on water availability were from 2006. The environmental impacts of the drought within the 1990-2005 period were within the range of historical variability.

2006–10 (during Millennium Drought and also after SWS for Central Region basins): was the first part of the part B assessment period, checking how SWS water-sharing actions affected waterway health. This period was separated out as it also shows the strongest effects of the Millennium Drought: effects outside of the range of historic variability. In addition, many Central Region SWS actions were expected to take time to begin to have an influence, or take time to implement, for example SWS recommendations to create environmental entitlements in several basins could not be implemented, because there wasn't enough water to do so.

2011–18 (post Millennium Drought and after SWS for all basins): was the second part of the part B assessment period of the LTWRA. The Millennium Drought ended in 2010 with major rainfall and flooding. This restored flows to rivers, and there was enough water to begin to provide the SWS-recommended environmental entitlements in many waterways. This would have given aquatic ecosystems the opportunity to begin to recover, if and where their health depended on the flow regime rather than on other factors.

All the datasets the assessment used included some data for the 1990–2005 period, so that pre- and post-SWS waterway health could be compared. The most consistent, long-term datasets (which predate the SWSs) were for water quality (for example, salinity and dissolved oxygen) and macroinvertebrates.

As the data in all regions were analysed across all three time periods, changes due to SWS actions would be identified in the second time period for the Central Region basins (post-2006 after the Central Region SWS was published, if not confounded by the effects of the Millennium Drought) and continue into the third time period, while for Western and Gippsland basins changes due to SWS actions would be detected in the third time period (post-2011).

It is not possible in 2019 to fully detect the effects of SWS water-sharing actions on waterway health. Important actions for waterway health (such as the creation of environmental entitlements) take time, and some have been, achieved only gradually or been only partly achieved thus far.[65] Additionally, many of the intended outcomes for waterway health also take time to be fully realised (for example, the recovery of a riverside forest), and the datasets the assessment used may not yet indicate successful outcomes (for example, recovery of a fish population that benefits from snags from the recovered riverside forest). The full benefits of actions to restore waterway health might not be detectable for 30 years or more.

6.2.6 Interpreting the indicators

For each indicator, the assessment determined whether there was a deteriorating or improving trend in each indicator and how much of any identified trend could be attributed to changes in the flow regime. Specifically, the assessment:

- conducted a trend analysis, to see if the indicator had changed over time, and if so, if trends differed between the three time periods described above in **Chapter 6.2.5**.
- for each waterway health indicator data point, looked at gauged streamflow data to see what the flow was during six (increasingly long) periods preceding the time and place the waterway health indicator data was recorded (30 days, 60 days, 90 days, 120 days, 240 days and 365 days)
- conducted a causality analysis, to see how much of any trend in each waterway health indicator was related to different flow components calculated to occur during the six time periods from the gauged streamflow data
- conducted a spatial analysis, to see if the trend and causality analyses differed at different spatial scales — the basin, SWS region and State.

The assessment used the segmented regression method, which involves nominating breakpoints — in this case, the beginning of 2006 and the beginning of 2011, for the reasons explained above (**6.2.5**) —and detecting any change in trend for an indicator between the breakpoints. This makes explicit the indicator's state before the start of any SWS water-sharing arrangements and its state under severe drought and post-drought conditions. **Figure 61** shows hypothetical trends using this method: deterioration in the first period, greater or lesser deterioration in the second and recovery or continued deterioration in the third. Note this example is most similar to the case for basins in the Central Region where "start of SWS" was 2006 and after the Millennium Drought was 2011. For Western and Gippsland Region basins, these dates coincide at 2011, although the period between 2006 and 2011 is still analysed and detects whether there is a trend and if it is different to the surrounding periods.

65 The 2016 stocktake of the SWSs found that of the 300 SWS actions planned across the four regions, 82% had been completed. The status of these actions is being further updated as part of the SWS five-yearly assessments and 10-yearly reviews. For more details, see the *Gippsland Region Sustainable Water Strategy five-yearly assessment report*, the *Western Region Sustainable Water Strategy five-yearly assessment report* and the *Central Region Sustainable Water Strategy Review report*, all at Sustainable water strategies.

Alternative methods to assess change in waterway health: 'segmented regression' and 'simple trend'

In developing the method for the LTWRA, scientists considered many different possible approaches to answer the question "Has waterway health deteriorated for reasons related to flow?"

The **segmented regression method** was selected as the most suitable because it:

1. accommodates the limitations in the available data
2. enables change in waterway health due to flow to be separated from other causes
3. ensures the Millennium Drought is accounted for in a transparent manner and does not bias results, and
4. provides useful information to environmental water managers about how waterway health is performing under current management practices.

The trends in waterway health indicators presented in **Chapter 6.4** and in the Basin-by-Basin Results are from the application of the segmented regression method. The findings about changes in waterway health indicators from the application of that method were inconclusive.

In reviewing the draft LTWRA, EPA Victoria suggested trying an alternative method, a **simple trend method** because it might produce more easily interpretable results.

Figure 58 illustrates how quite different trends could be derived from the same set of data using these two alternative methods. The key difference between the methods is how well they are able to detect changes in the direction of trend. Only the segmented regression method is suitable to test whether an initial decline in any given waterway health indicator has been reversed or halted in recent years.

To test whether the alternative method would produce clearer results, the analysis of change in waterway health indicators was repeated using the simple trend method. The results for the analysis over 1990 – 2018 are shown in **Figure 59**.

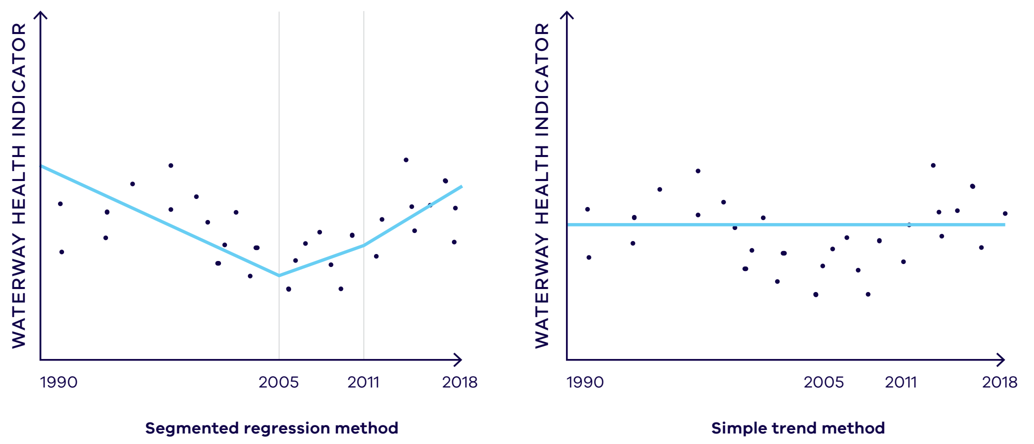


Figure 58: Conceptual illustration of using different methods to assess change in waterway health - segmented regression method and simple trend method

	Barwon	Bunyip	East Gippsland	Glenelg	Hopkins	Lake Corangamite	Latrobe	Maribyrnong	Mitchell	Moorabool	Otway Coast	Portland Coast	Snowy	South Gippsland	Tambo	Thomson	Werribee	Yarra
Fish	1	1	1	2	1	1	1	1	1	2	1	1	1	1	1	1	1	1
Macroinvertebrates	2	1	2	2	1	2	2	1	2	2	4	2	4	4	2	2	1	1
Salinity	2	1	3	2	2	4	4	4	3	4	2	3	3	4	3	2	3	2
Dissolved oxygen	4	1	4	4	4	4	4	4	4	4	4	4	4	2	4	4	4	4
Turbidity	2	1	4	4	2	4	4	4	4	4	4	4	4	3	4	4	4	3
Total Suspended Solids	3	1	2	2	3	4	4	2	4	2	2	2	4	3	4	3	2	3
Phosphorus	3	1	4	4	4	4	3	4	4	4	2	4	4	3	4	3	2	3
Nitrogen	3	1	2	4	3	3	2	3	2	3	2	4	4	2	2	4	3	4

Fish
Macroinvertebrates
Salinity
Dissolved oxygen
Turbidity
Total Suspended Solids
Phosphorus
Nitrogen

1 Not enough data
2 No statistically significant trend
3 **Improving** trend
4 **Deteriorating** trend

Figure 59: Results from an alternative analysis of waterway health data from 1990-2018 using simple trend method

The simple trend results across southern Victoria over 1990 – 2018 show more than two thirds of the statistically significant trends deteriorating. The Millennium Drought is considered highly likely to be the cause of these deteriorating trends in water quality. The segmented regression also found declines in water quality indicators over the worst of the Millennium Drought (2006 – 2010). The deteriorating simple trend results are in contrast to the results from the last period of a segmented regression analysis, where more than two thirds of indicators show an improvement over 2011 – 2018. It is not possible to fully separate the effect of the drought ending from the water quality benefits of waterway and catchment management activities. Nevertheless, the last seven years data are showing improvement in some water quality indicators.

Neither method was able to detect trends in many indicators of the health of aquatic animal communities, due the limited long-term data on macroinvertebrates and fish.

No matter which statistical method is applied, overall there are very mixed trends for waterway health indicators within each basin. There is no basin where indicators are all improving or all deteriorating. Data limitations, not statistical method, are responsible for the inconclusive findings on changes in waterway health indicators.

Advances in data availability and computing software mean that refinements to the statistical method may be appropriate in future Long-Term Water Resource Assessments.

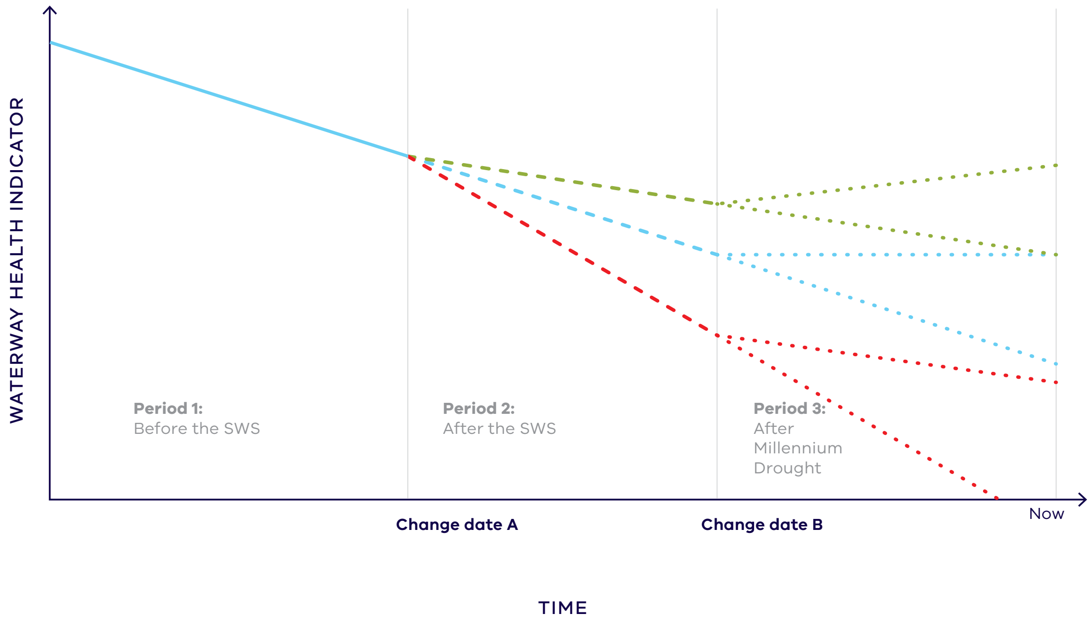


Figure 60: Segmented regression method, hypothetical trends

6.3 Method for ecohydrological analyses

To supplement the analyses of waterway health indicators, two ecohydrological analyses were also undertaken. These looked at changes pre- and post-SWS in flow regimes at sites with suitable streamflow gauging, to indicate where changes in the flow regime might threaten waterway health. The analyses did not seek to identify causes (such as climate change, consumptive uses or management practices) of changes. The year that defines the pre- and post-SWS period was 2006 for the Central Region and 2011 for the Western and Gippsland Regions. Sites were selected to maximise the pre-SWS data record available to form a meaningful benchmark, however the available data varies for each site and this inconsistency may have influence over the results, particularly in sites with a shorter data record. Also, making a meaningful comparison of a waterway's flow regime for the pre-SWS and post-SWS periods is challenging due to the large difference between the two periods of record. Many streamflow gauges have data which extend back to the middle of the 20th century, while the post-SWS period is almost always less than a decade and can be as little as 5 years depending on the region. To mitigate this, a rolling average based on the length of the post-SWS period was used for the data analysis of the pre-SWS period for each of the indices. These averages are then used as a benchmark to compare the period since the implementation of the SWS. This broad comparison enables detection of long-term changes to flow regimes that may indicate an increased threat to waterway health.

6.3.1 FLOWS recommendations analysis

Forty-two environmental FLOWS studies[66] have been done across southern Victoria from 2003 to 2017. FLOWS studies follow a defined process, and expert technical panels working with local communities and stakeholders undertake them. They typically define multiple, flow-dependent waterway health objectives in different parts — reaches — of a river or creek (for example, increasing the abundance of a fish species valued in that river) and recommend flow components to achieve the objectives.

This analysis identified what percentage of the FLOWS recommendations had occurred in full each year, in reaches where the streamflow data needed to do this had been collected (which was in 86 reaches across 46 rivers and creeks). FLOWS recommendations can be met as a result of management action (such as the timed release of water for the environment or passing flows) or due to naturally occurring flows.

FLOWS studies for different rivers and reaches have different types of recommended flow components. This analysis grouped components into five categories, to allow comparisons between reaches, rivers and basins. The categories were:

summer baseflow:
for duration-based recommendations that typically require several months of continuous minimum flow during summer and autumn

winter baseflow:
for duration-based recommendations that typically require several months of continuous minimum flow during winter and spring

summer fresh:
for event-based recommendations that typically require several days above a peak-flow threshold and which must occur during summer or autumn

winter fresh:
for event-based recommendations that typically require several days above a peak-flow threshold and which must occur during winter or spring

any-period event flows:
for other event-based recommendations that either have more-specific timing requirements (such as they can only occur in September) or more generalised timing requirements (such as they can occur in any month). Overbank flows were included in this.

66 DEPI (2013). *FLOWS – a method for determining environmental water requirements in Victoria*, Edition 2. Report prepared by Sinclair Knight Merz, Peter Cottingham and Associates, DoDo Environmental and Griffith University for the Department of Environment and Primary Industries, Melbourne.

6.3.2 Index of Stream Condition hydrological indices analysis

Where there were no FLOWS recommendations available for a particular waterway, this analysis used metrics which are part of the ISC, a statewide review of river condition conducted in Victoria three times since 1999. The latest ISC used five flow indices to determine the threat to river health from the existing levels of streamflow. The five indices are:

high flow:
daily flow that is exceeded 10 per cent of the time

low flow:
daily flow that is exceeded 90 per cent of the time

zero flow:
percentage of days with no flow

variability:
how much monthly flow varies, compared to the average annual flow

seasonality:
the month in which the highest and lowest flows occur.

If post-SWS results were within the range observed pre-SWS, the assessment concluded there had been no change to the flow regime and therefore any increased threat to waterway health might also be within the natural range of variation. For example, pre-SWS (1890–2005) a river may have had a high flow ranging from a minimum 5 ML a day (which occurred in 1940, a dry year) to a maximum high flow of 140 ML a day (in 1972, a wet year). If post-SWS (since 2006) the high flow every year has been 5–140 ML a day, it's within its pre-SWS range.

If post-SWS results were outside the pre-SWS range, the assessment concluded there had been an increased threat to waterway health for flow-related reasons. For example, the river above may have had a high flow of less than 5 ML a day in one or more years post-SWS. Also, the river, like most rivers, has much more pre-SWS than post-SWS data and therefore a wide pre-SWS range, meaning any post-SWS results outside this wide range may be of concern.

For some rivers, post-SWS results were within but at the low end of the pre-SWS range. For example, the river above may have only had high flows of 5 ML a day four times pre-SWS but twice in the much shorter post-SWS period. This might indicate an increased threat to waterway health, but the indication is not as definitive as post-SWS results outside the pre-SWS range.

6.4 Waterway health indicator findings

Figure 61 shows assessment findings, for each basin, of trends in the waterway health indicators. In many basins, there was insufficient data to determine a statistically significant trend. Where a trend was identified, it could at least partly be explained by flow in many basins. Note that the results for each basin are discussed in the companion report, Basin-by-Basin Results.

	Barwon	Bunyip	East Gippsland	Glenelg	Hopkins	Lake Corangamite	Latrobe	Maribyrnong	Mitchell	Moorabool	Otway Coast	Portland Coast	Snowy	South Gippsland	Tambo	Thomson	Werribee	Yarra
Fish	1	1	1	2	1	1	1	1	1	2	1	1	1	1	1	1	2	1
Macroinvertebrates	2	1	2	2	2	2	2	2	2	2	3b	1	1	1	1	3b	2	1
Salinity	4a	1	4b	3b	4a	4a	3b	4a	4b	3a	2	3a	4b	4b	4a	4a	4a	2
Dissolved oxygen	4a	1	3b	3b	4a	3b	3a	3a	3b	3a	4a	4a	3a	3a	3a	3a	4a	3a
Turbidity	3a	1	3a	3a	3a	3b	3a	3a	3a	3a	3a	3a	4a	4a	3a	3a	3a	3a
Total Suspended Solids	3a	1	3a	2	4a	3b	3a	3a	3a	3a	3a	3a	4a	3a	4a	3b	3a	3a
Phosphorus	3b	1	3a	3a	3b	3b	3a	3a	4a	3a	2	3b	4a	4a	3a	4b	3a	3a
Nitrogen	3a	1	4b	4b	3a	2	2	3a	3b	4a	2	3a	4b	4a	3a	3b	4a	3a

Fish
Macroinvertebrates
Salinity
Dissolved oxygen
Turbidity
Total Suspended Solids
Phosphorus
Nitrogen

1	Not enough data
2	No statistically significant trend
3a	**Improving** trend at least partly explained by flow
3b	**Improving** trend but mostly not explained by flow
4a	**Deteriorating** trend at least partly explained by flow
4b	**Deteriorating** trend but mostly not explained by flow

Figure 61: Changes in waterway health for reasons related to flow in southern Victoria, by basin, 2011-2018. For the three fish indicators all basins had either not enough data or no statistically significant trend. For macroinvertebrate indicators basins generally had either not enough data or no trend, the two statistically significant results shown are for SIGNAL2 score where OCH showed no trend. Note that improvements and deteriorations are relative to the previous period (2006-2010).

The variability between basins in the trends for any single indicator is such that the findings at the basin scale cannot be aggregated into one overall picture of waterway health.

The assessment found the macroinvertebrate and fish indicators mostly showed no trend. They generally did not show statistically significant trends where there was enough data (such as in 10 of the 18 basins for both OCH and SIGNAL2 macroinvertebrate indicators) and in many basins there was not enough data (such as for fish). In the few basins where there were statistically significant results (the SIGNAL2 indicator for macroinvertebrates in two of the 18 basins, while OCH showed no trend), there was an improving trend since the end of the Millennium Drought that is mostly not attributed to changes in the flow regime.

Across southern Victoria, many indicators showed a deterioration in trend relative to the previous period during the Millennium Drought and showed an improvement in trend relative to the previous period after the drought ended in 2010. However, the salinity indicator continued to deteriorate in several basins after the drought ended. Note that the trend assessment detects specifically whether an indicator is changing (increasing or decreasing) over time, the key requirement of the LTWRA. This method does not directly show the size of any change or whether an improvement in trend relative to the previous period leads to an actual improvement in the indicator. It also does not show whether the value of any indicator is in a healthy or unhealthy condition. That is, any deterioration (or improvement) detected may be very small and/or not ecologically significant.

This overview report focuses on the current period (2011-2018) as most pertinent to identification of deterioration in waterway health for reasons related to flow. A brief comparison to previous time periods is given below, with further detail summarised in **Appendix E** and provided in detail in the technical report.[55]

Across southern Victorian basins, in the 1990–2005 (pre-SWS) period:

- water quality indicators had mixed improving and deteriorating trends, likely related in part to what is described in the section on "Limitations on interpreting indicators". Note that some of the less-developed river basins (such as the Otway Coast basin) showed few, weak trends for any water quality indicator.
- macroinvertebrates demonstrated trends in only two basins, Otway Coast (improving) and South Gippsland (deteriorating) — but these were mostly unrelated to changes in flow.
- there was not enough fish data to assess trends in fish communities during this period.

In the 2006–10 period (post-SWS for the Central Region and during the last half of the Millennium Drought):

- trends in water quality indicators vary greatly between basins. Turbidity and total suspended solids showed deterioration in trend (relative to the previous period) in many basins. However, at low flows these indicators have complicated relationships with the flow regime.
- the macroinvertebrate indicators continued to generally deteriorate where significant trends were detected, but remained mostly unrelated to changes in flow
- there was not enough fish data to assess trends in fish communities during this period.

In the 2011–18 period (post-SWS for all regions and after the Millennium Drought ended):

- trends in water quality indicators vary greatly between basins. In some basins (such as the Glenelg and Moorabool basins) there were improvements in trend relative to the previous period for many water quality indicators, but in other basins (such as the Hopkins basin), there were mixed improving and deteriorating trends (relative to the previous period)
- where enough data was available, macroinvertebrate indicators improved (such as the Otway Coast and Thomson basins), but this remained mostly unrelated to flow
- fish indicators mostly did not have sufficient long-term data to identify trends, and where there was sufficient data, no statistically significant trend was detected.

There has been continuing deterioration in the salinity indicator in many basins since the Millennium Drought ended in 2010. Turbidity, suspended solids, nitrogen and phosphorus indicators often improved in trend relative to the previous period. Also, as noted in **Limitations on interpreting indicators**, these water quality indicators are not managed with water for the environment. At low flows these indicators may decrease because there is less runoff to transport sediment and pollutants into waterways from the surrounding land. Under low flows, a decrease in the turbidity, suspended solids, nitrogen and phosphorus indicators are unlikely to reflect improved waterway health.

Case study:

Long-term change in estuarine health due to flow in the Gippsland Lakes

A preliminary study found most estuarine monitoring data of waterway health indicators come from short-term studies of individual estuary systems.[67] The existing estuary data were found not to extend as far back as needed for the long-term water resource assessment. However, the Victorian Fisheries Authority have collected data on black bream in the Gippsland Lakes at variable frequencies between 2008–18, so the assessment tested this data with stream gauge data from rivers flowing into the lakes complex to see if changes to estuarine health for reasons related to flow can be detected over this medium-term period.

Method

The assessment used the daily inflows for the gauged rivers divided into three zones — western, central and eastern — in the lakes complex. In each zone the inflow data was used to calculate five potentially ecologically influential flow indicators: mean flow, maximum flow, days of no flow, days since end of last no flow, and a baseflow index. These flow indicators were further calculated for six time periods: 30, 60, 90, 120, 240 and 365 days prior to each fish monitoring data point. It assigned black bream total numbers and biomass to each zone, according to the location of the monitoring site. For western zone sites, the three gauged rivers were the Avon, Latrobe and Thomson rivers. For eastern zone sites, the assessment used the sum of the daily inflows of the Mitchell, Nicholson and Tambo rivers, which flow into that zone. For central zone sites, the assessment used the average of the two sums of the daily inflows in the western and eastern zones. The assessment then tested for a causal relationship between the black bream population and the flow indicators.

Results

Black bream decreased in the three zones during 2006–10 in both number and biomass and increased during 2011–18. The assessment could not assign these decreases or increases to the influence of the flow indicators tested at the zone scale. However, as black bream are episodic spawners, quite long lived (~30 years) and can move widely throughout the Gippsland Lakes system, it is not unexpected that relationships between the aggregated measures of total number and biomass and flow were not detected. Other studies have shown an influence of flow and the related salinity stratification on the reproduction and age of bream. This case study points to future refinements to the LTWRA method for specific application to estuaries.

67 Jenkins, G., Morris, E., and Morrongiello, J. (2018). Investigation into data and methods available to determine estuarine health for the long-term water resources assessment. Report prepared for the State of Victoria Department of Environment, Land, Water and Planning. p.24

6.5 Ecohydrological analyses findings

6.5.1 FLOWS recommendations analysis findings

Even though, as part A of this report shows, long-term surface water availability has declined, environmental entitlements have resulted in water for the environment being delivered in some waterways, providing environmental benefits.

Generally, achievement of FLOWS-recommended components is more likely to have improved post-SWS in basins with an environmental entitlement. In basins without an environmental entitlement, FLOWS-recommended components are more likely to have declined post-SWS. Specific results for each basin are presented in the Basin Overviews.

The Millennium Drought is likely to have reduced the average post-SWS improvement in achieving recommended FLOWS components, however this was not directly analysed.

The greatest increases in the percentage of FLOWS recommendations occurring have been in the Glenelg, Yarra and Thomson basins, all of which have environmental entitlements. All other southern-flowing basins have seen a decline in the percentage of FLOWS recommendations occurring. This finding does not imply that all FLOWS recommendations have occurred in the basins that have shown improvement — the statistics demonstrate that they have not — but rather that a higher percentage of recommendations have occurred since the SWS. More detailed results for any changes in the occurrence of FLOWS recommendations are described in the companion report, Basin-by-Basin Results.

Environmental entitlements are important for supporting the achievement of FLOWS recommendations, but this support is not always detected by this assessment. For example, the assessment is less able to detect the impact of an environmental entitlement that was created late in the post-SWS period. Additionally, where there is limited water available for an entitlement, or where there are delivery constraints from infrastructure or operations in some rivers, FLOWS recommendations are sometimes only partly met. The analysis does not detect partial achievement, although such an event may still provide environmental benefit.

Case study:

Changes in the provision of environmental flow recommendations in the Yarra River

Waterway health is not only dependent on the quantity of water in the waterway, but also on how flow varies. The pattern of flow — the timing, size and duration of events — influences waterway health. Different components of the flow regime support different aspects of ecosystem health, as shown in **Figure 57**.

Streamflow gauge data were analysed for changes in flow components that support different aspects of ecosystem health. Provision of environmental flow components was compared before and after the Sustainable Water Strategy. **Chapter 6.3.1** provides more information on the analysis of change in flow patterns.

Generally, achievement of recommended environmental flow components is more likely to have improved in waterways with an environmental entitlement. In waterways without an environmental entitlement, provision of recommended environmental flows is more likely to have declined.

Figure 62 shows this for the Yarra river system, and an equivalent graph is provided for each system in the Basin-by-Basin Results. This analysis used 7 gauges where there was an environmental entitlement (EE) and 10 gauges in tributaries without an EE. The extreme water shortages of the Millennium Drought delayed water becoming available under the Yarra River environmental entitlement until 2010 — four years after the SWS was published. Nevertheless, since the SWS, provision of winter freshes has improved in river reaches where the Yarra River environmental entitlement is available, but declined in some tributaries without an environmental entitlement, such as Woori Yallock Creek and Diamond Creek.

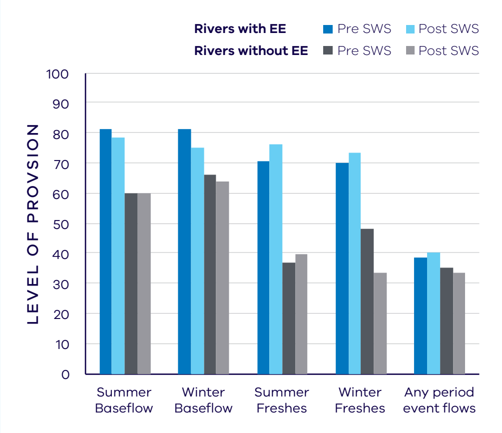
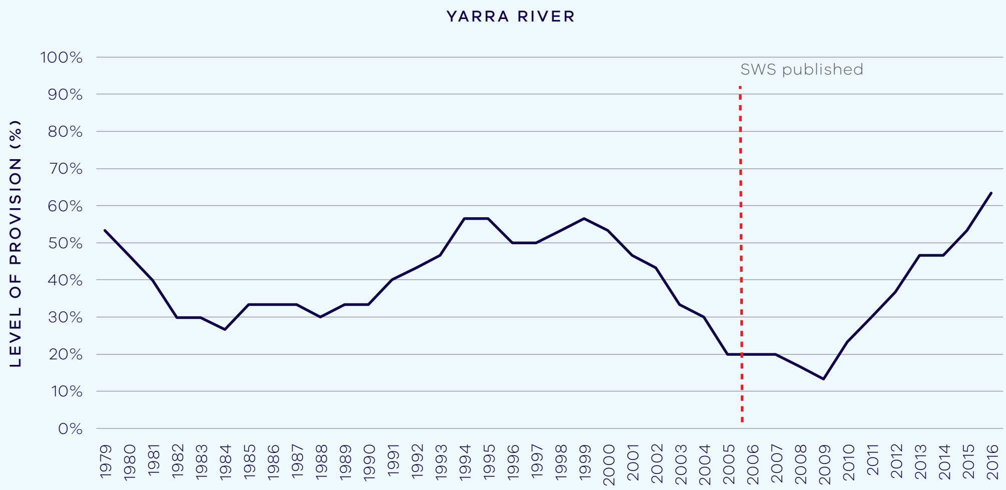


Figure 62: Average change in ecologically important flow components in rivers with an environmental entitlement (EE) and without; pre-SWS (1975 – 2006) and post-SWS (2007 – 2018)

Patterns of flow are highly variable between waterways and river reaches. In the Yarra River between Armstrong Creek and Millgrove, summer freshes have experienced marked improvements since the SWS (**Figure 63**). This improvement is due to targeted releases of water available under the Yarra environmental entitlement from Upper Yarra Reservoir to achieve summer freshes to flush pools, protecting water quality and maintaining aquatic habitat.

In contrast, provision of summer freshes has declined in Woori Yallock Creek — an unregulated tributary of the Yarra River (**Figure 63**). Because there is no water held in storage for the environment in Woori Yallock Creek (i.e. there is no environmental entitlement and no storage), the drier climate has reduced the frequency of summer freshes. There are other factors that may influence the provision of environmental flow recommendations, including the timing and volumes of water pumped out of the waterway for irrigation.

It is important to note that the assessment of change in provision of flow components is not a quantification of the health of the waterway, but rather a measure of the potential increase in threat or benefit from flow regime change being experienced by the system.



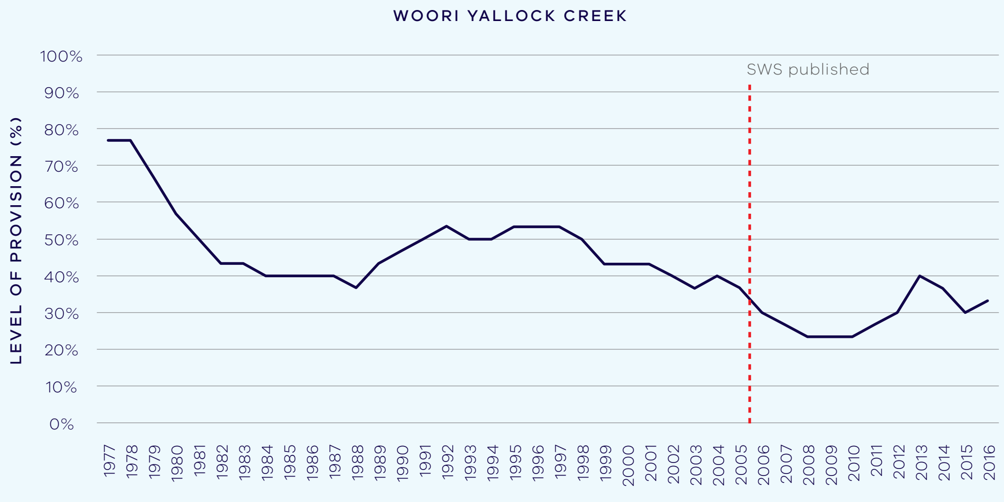


Figure 63: Contrasting change in provision of summer freshes with an environmental entitlement (Yarra River) and without an environmental entitlement (Woori Yallock Creek)

6.5.2 ISC hydrological indices analysis findings

The relatively dry post-SWS conditions have led to changes in the flow regime in many rivers, and to particularly low flows in western Victoria.

The ISC ecohydrological analysis was conducted at 89 gauges across southern Victoria and found that:

- high flows have declined at more than 60 per cent of sites post-SWS: an example impact of this is that native migratory fish are less able to leave or return to a river system for breeding
- low flows have declined at more than 50 per cent of sites post-SWS: an example impact is reduced area of habitat for riverbed-dwelling macroinvertebrates
- flow variability has increased at more than 50 per cent of sites post-SWS: although flow variability can be beneficial for waterway health, changes to that variability can have undesirable impacts – an example impact is increased abundance of invasive fish species better-suited to variable flows
- the percentage of days with zero flows has increased for more than 40 per cent of sites post-SWS: an example impact is reduced fish habitat and movement.

As an example of just one of the indices — low flows — **Figure 64** shows that more than one-third of sites analysed had flows post-SWS that were outside — on the lower side — of the pre-SWS range. These were mostly in western Victoria and the Central Highlands, where pre-SWS low flows were already substantially lower than pre-European-settlement conditions. Although this ISC ecohydrological analysis was undertaken separately and independently of the long-term surface water availability assessment in part A, there is notable agreement with some of those outputs (e.g. see **Figure 12**), supporting the efficacy of the two different approaches. Low flows were outside the pre-SWS range — on the high side — at eight sites across southern Victoria: and in most cases, delivery of water for the environment had increased (such as specific reaches in the Glenelg, Thomson and Macalister rivers). The results for the other ISC flow indices are described in the basin overviews, if the basin doesn't have the more-specific FLOWS recommendations analysis.

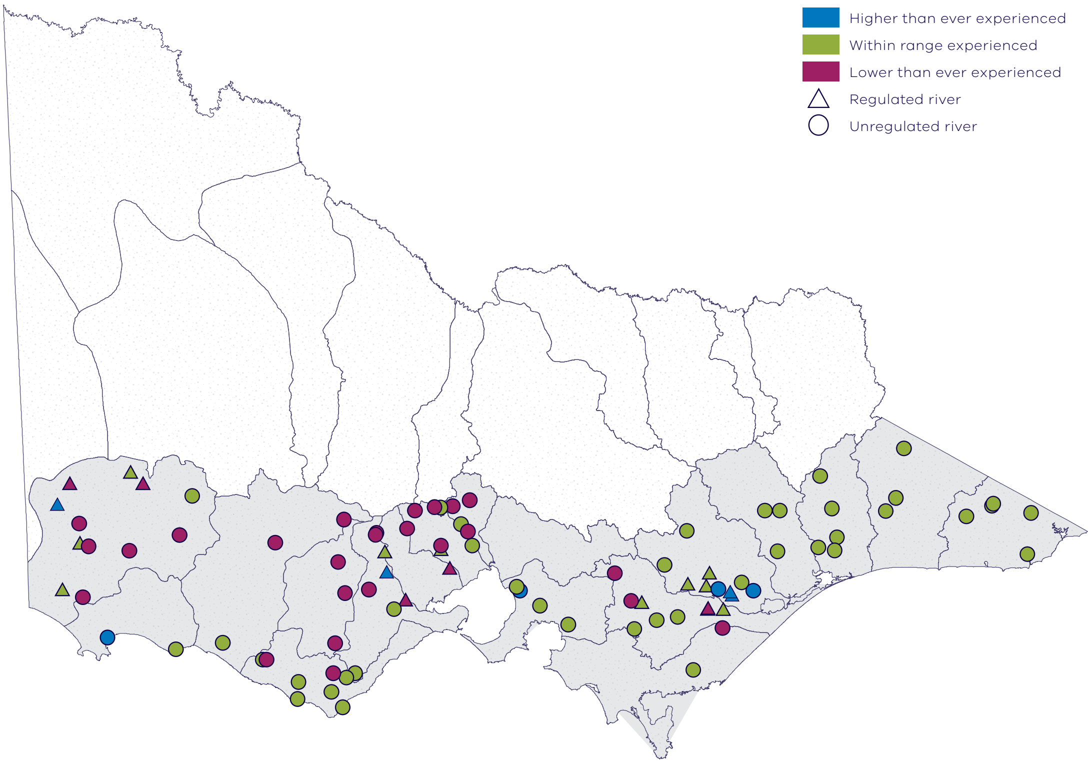


Figure 64: Low-flow findings, post-SWS compared to pre-SWS.

6.6 Change in long-term waterway health for reasons related to flow

This first LTWRA has not clearly identified overall deterioration in waterway health for reasons related to flow over the time period for which suitable data were available (1990-2018). Available datasets show that some indicators of waterway health have improved due to changes in flow, while other indicators have deteriorated, and yet others show no discernible trend, sometimes in the same basin over the same time period. The indicators for which suitable datasets are available were not collected with the aim of delivering this specific assessment, and so are insufficient to provide an overall picture of waterway health. More targeted waterway monitoring programs (including the Victorian Environmental Flows Monitoring and Assessment Program (VEFMAP) and the Wetlands Monitoring and Assessment Program (WetMAP)) have been established and developed since 2007 to look at the impact of water for the environment on Victoria's waterways. Longitudinal datasets from these programs should support future LTWRAs to more effectively determine overall improvement or deterioration in waterway health for reasons related to flow.

For more detailed results on change in specific components of flow regime, the changes in specific indicators of waterway health for reasons related to flow, and how these compare in each basin, please see the companion report results.

7. My basin, at a glance

GLENELG

The basin experienced a decline in water availability. Because only a small proportion of available water is for consumptive use, with most going to the environment, there has been no disproportionate impact.

There have been improvements in several ecologically important aspects of the flow regime due, in part, to the use of water available under the environmental entitlement to create environmental flows. The improvement in water regimes in reaches that received managed environmental flows occurred despite an overall decline in water availability.

The improvement in flows was matched to improvements in several water quality indicators strongly linked to flows, such as turbidity and total phosphorus. However, no long-term flow-related trends were seen in aquatic animal indicators. Overall, the findings for waterway health are inconclusive.

PORTLAND COAST

Most rivers in the basin experienced a decline in water availability. Because only a small proportion of available water is for consumptive use, with most going to the environment, there has been no disproportionate impact.

There have been improvements in ecologically important aspects of the flow regime, and minor improvements in some water quality indicators, although no trend was detected in aquatic animal indicators of waterway health. Overall, the findings for waterway health are inconclusive.

HOPKINS

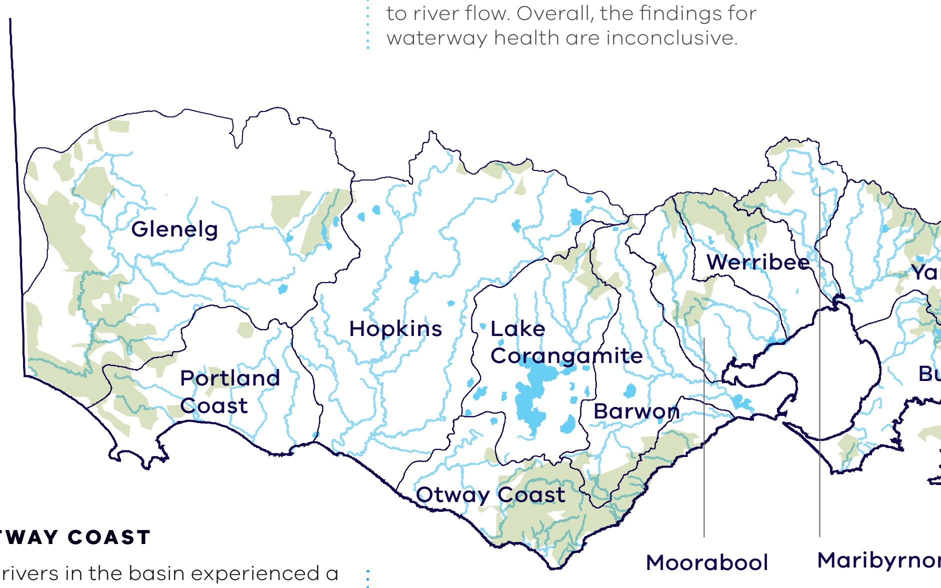
The basin experienced a decline in water availability. Because only a small proportion of available water is for consumptive use, with most going to the environment, there has been no disproportionate impact.

There have been moderate declines in ecologically important aspects of the flow regime in the Merri River. There were large differences in the trends in waterway health indicators between rivers in this basin, making it difficult to provide a basin-wide assessment. Overall, the findings for waterway health are inconclusive.

LAKE CORANGAMITE

The Lake Corangamite basin experienced a decline in water availability, particularly in the Woady Yaloak River. There has been a decline in water available for consumptive use and the environment due to changes in climate. Because only a small proportion of available water is for consumptive use, with most going to the environment, there has been no disproportionate impact.

There have been severe declines in ecologically important aspects of the flow regime, with an increase in salinity strongly linked to flow. However, the limited availability of data meant that overall the findings for waterway health are inconclusive.



OTWAY COAST

Most rivers in the basin experienced a decline in water availability. However, the Otway Coast is the only basin in southern Victoria where the volume of water available to the environment has increased. This is because the amount of water ear-marked for meeting future consumptive demand has been revised down. Because only a small proportion of available water is for consumptive use, with most going to the environment, there has been no disproportionate impact.

There have been moderate declines in ecologically important aspects of the flow regime, particularly summer baseflows. While there were small improvements in some waterway health indicators, overall the findings for waterway health are inconclusive.

BARWON

The basin experienced a decline in water availability. Consumptive users have diversified their water supply options, offsetting the decline in availability. There has been a decline in the amount of water available to the environment, despite the creation of an environmental entitlement, because of a reduction in water available from unregulated inflows. There has been a disproportionate impact on the environment with its share of total resource decreasing from 86 to 84 per cent.

Ecological health indicators since 2011 show mixed results, with a deterioration in dissolved oxygen and salinity, but an improvement in turbidity and total suspended solids, all moderately linked to river flow. Overall, the findings for waterway health are inconclusive.

MOORABOOL

Waterways in the Moorabool basin experienced a large decline in water availability. Consumptive users have diversified their water supply options, partly offsetting the decline in availability. There has been a large decline in the amount of water available to the environment, despite the creation of an environmental entitlement, because of a reduction in water available from unregulated inflows. There has been a disproportionate impact on the environment, with its share of total resource decreasing from 68 to 63 per cent.

There have been small declines in several ecologically important aspects of the flow regime, which have been ameliorated to some degree by the use of environmental water entitlements. Overall, the findings for waterway health are inconclusive.

MARIBYRNONG

The Maribyrnong basin has experienced one of the largest declines in inflows across Victoria (17 per cent). Whether or not the environment's share of available water has declined depends on how much of the urban water supply is sourced from within the Maribyrnong basin and how much is sourced from elsewhere.

Overall, the findings for waterway health are inconclusive.

WERRIBEE

The basin experienced a decline in water availability. There has been a decline in water available for consumptive use because of changes in climate, although changes in operating rules have helped to mitigate some of this impact. The decline in water available to the environment has been considerable, despite the creation of an environmental entitlement, because of a reduction in water available from spills from storage. There has been a disproportionate impact on the environment, with its share of total resource decreasing from 59 to 51 per cent.

Overall, the findings for waterway health are inconclusive.

YARRA

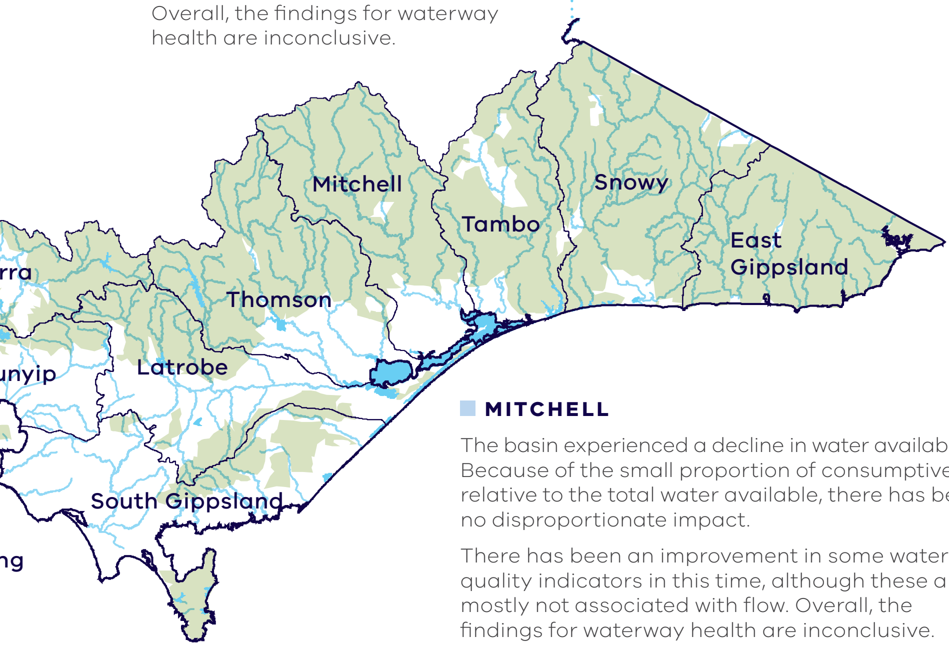
The basin experienced a decline in water availability. There has been a decline in water available for both consumptive use and the environment due to changes in climate. The decline in water available to the environment has been considerable, despite the creation of an environmental entitlement, because of a reduction in water available from unregulated inflows. There has been a disproportionate impact on the environment, with its share of total resource decreasing from 56 to 50 per cent.

Overall, the findings for waterway health are inconclusive.

THOMSON

Both the Thomson–Macalister and Avon rivers have experienced a decline in water availability. In the Thomson basin, the volume of environmental water entitlements has been increased to partially meet the environmental water requirements identified by a scientific study. However, the increased volume of environmental entitlements has not changed the proportion of water available for the environment as originally intended, because it has been offset by declines in spills and unregulated inflows. Without water recovery, the environment's proportion would have declined.

There is good short-term evidence that environmental water in this basin is helping to restore the native fish population, including the threatened Australian grayling. However, overall the findings for waterway health are inconclusive.



MITCHELL

The basin experienced a decline in water availability. Because of the small proportion of consumptive use relative to the total water available, there has been no disproportionate impact.

There has been an improvement in some water quality indicators in this time, although these are mostly not associated with flow. Overall, the findings for waterway health are inconclusive.

TAMBO

Both the Tambo and Nicholson rivers experienced a decline in water availability. Because only a small proportion of available water in the basin is for consumptive use, with most going to the environment, there has been no disproportionate impact.

There were mixed results for waterway health indicators partly linked to river flow in the basin. Overall, the findings for waterway health are inconclusive.

SOUTH GIPPSLAND

Most rivers in the basin have experienced a decline in water availability, with one experiencing a small increase. In most rivers, only a small proportion of available water is for consumptive use, with most going to the environment. Overall, there has been no change in how water is shared between consumptive uses and the environment.

The findings for waterway health are inconclusive.

BUNYIP

The basin experienced a decline in water availability. There has been a decline in water available for consumptive use and for the environment, despite the creation of an environmental water entitlement. The decline in water availability has been shared proportionally between consumptive uses and the environment.

Ecologically important aspects of the flow regime in the Bunyip and Tarago Rivers — the two rivers in this basin with an environmental entitlement — have been maintained. However, overall the findings for waterway health are inconclusive.

SNOWY

The assessment only examined change in water flows from the Victorian part of the Snowy basin, where the rivers experienced a decline in water availability. Because only a small proportion of available water is for consumptive use, with most going to the environment, there has been no disproportionate impact.

There has been a deterioration in some water quality indicators, although not all of these are related to flow. Overall, the findings for waterway health are inconclusive.

EAST GIPPSLAND

All rivers in the basin experienced a decline in water availability. Because only a small proportion of available water is for consumptive use, with most going to the environment, there has been no change in how water is shared.

Overall, there is no conclusive evidence for a flow-related deterioration in waterway health in the basin.

LATROBE

The basin has experienced a decline in water availability. There has been an increase in water available for consumptive use. This is due to the allocation of a previously unallocated share of flows into Blue Rock Reservoir. Water available to the environment has declined, despite the creation of an environmental entitlement, because of a reduction in water available from spills and unregulated inflows. There has been a disproportionate impact on the environment, with its share of total resource decreasing from 79 to 76 per cent.

Overall the findings for waterway health are inconclusive.

Appendix A – Insights from public consultation

DELWP undertook a community engagement program to gain feedback on the draft Long-Term Water Resource Assessment for Southern Victoria. The engagement ran from 30 September to 30 November 2019, and used both web-based and face-to-face communication. **Figure 65** is a snapshot of the program.

The purpose of the engagement was to:

- clearly communicate the findings of the draft LTWRA to the community
- test the representation/recognition of regional issues in the draft LTWRA with community
- meet the requirements of the Water Act 1989
- inform the Minister's decision about the need to undertake a review of water-sharing arrangements in some basins
- create awareness of how water is managed in Victoria (including the Sustainable Water Strategy process) and highlight work already being undertaken to manage water security across southern Victoria.

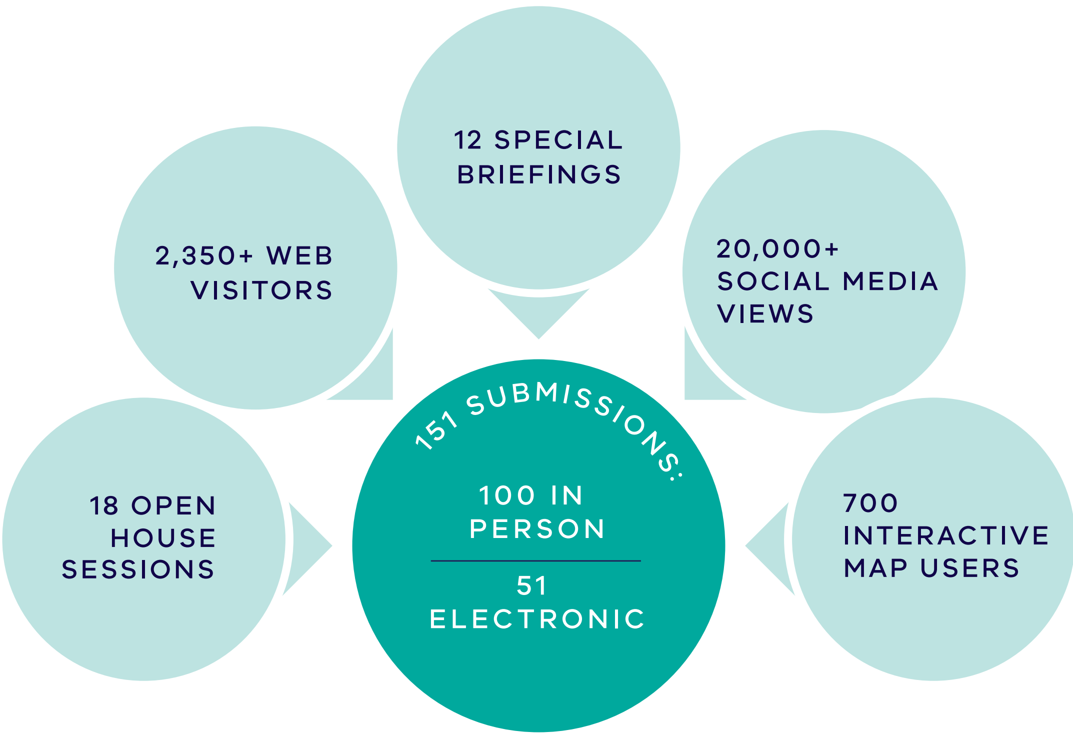


Figure 65: Engagement snapshot for the draft Long-Term Water Resource Assessment for Southern Victoria

Online engagement

Engage Victoria is the State's online consultation platform provided through the Department of the Premier and Cabinet. Engage Victoria gives the Victorian community an easy to find, central point of contact to be involved in government decisions.

To support the public in providing informed responses to the consultation questions, the LTWRA page contained a variety of materials to make the findings of the LTWRA as accessible as possible at a range of experience levels.

In-person engagement

Open house sessions were held throughout October 2019 in nine locations; Ballarat, Geelong, Colac, Warrnambool, Traralgon, Bairnsdale, Sunbury, Werribee and Melbourne. An open-house is a relatively informal event, designed to allow people to drop in, obtain information, ask questions and engage in discussion. Information was displayed around the venue and printed materials were available.

The open houses were presented as an opportunity to consult with relevant organisations about water in Victoria. Water corporations and catchment management authorities were invited to attend relevant open houses to discuss local issues and answer questions, providing a broader perspective on water management in the local area. The DELWP Sustainable Water Strategy team attended all open houses to provide process information on the forthcoming Central and Gippsland Region Sustainable Water Strategy. Some other DELWP teams and organisations used the open houses to consult on their own projects.

The external facilitators greeted attendees and explained the process of the open-house. DELWP staff helped people understand information about the LTWRA and SWS, discussed and noted their questions and ideas, asked the consultation questions and noted down the feedback. This approach allowed for personalised one-on-one or small group conversations.

Although a relatively small number of people participated in some of the open house sessions, the quality of conversations at all sessions was very high. Many respondents were very knowledgeable about the topics and gave detailed feedback. Respondents commented that commented that they enjoyed the approach, which enabled them to have quality discussions with a range of people with appropriate knowledge and skills.

Submissions

Over 200 people actively participated in the engagement. Of the 170 people who attended the open houses, 100 people chose to respond to the LTWRA questionnaire. A further 51 electronic responses to the questionnaire were received.

The engagement questions are listed below:

1. Do you feel that a review of water-sharing arrangements is needed?
   - Scale: yes/no/unsure.
2. Are you surprised by the results?
   - Scale: very surprised/somewhat surprised/expected/not surprised.
   - Respondents were then asked why they answered the way they did.
3. Is there anything you would like to tell us about water in your area?
   - An open comment response was allowed.
4. Is there any information you feel should be included in the engagement report?
   - An open comment response was allowed.

Respondents used any or all of the open-ended questions to provide their responses to the LTWRA or concerns about water. Comments in response to the open questions have been aggregated and are reported as overall themes.

Location of respondents

Responses were grouped by postcode into four regions:

1. Barwon-Moorabool (Barwon and Moorabool basins)
2. Central (Yarra, Bunyip, Maribyrnong and Werribee basins)
3. Gippsland (East Gippsland, Snowy, Tambo, Mitchell, Thomson, Latrobe and South Gippsland basins)
4. Western (Lake Corangamite, Otway Coast, Hopkins, Portland Coast and Glenelg basins).

Figure 66 is the breakdown of from where responses came. Responses were received from right across southern Victoria, although Western Victoria drew proportionally fewer responses, possibly reflecting current levels of community involvement in water issues and/or population size.

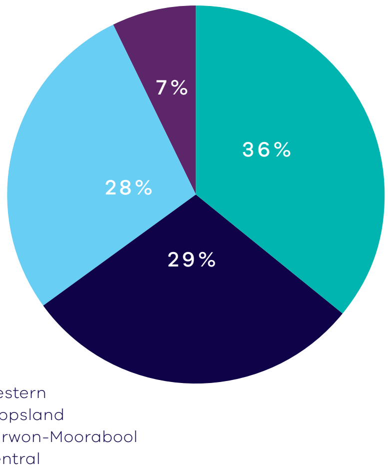


Figure 66: Where respondents live

Results

Question 1: 'Is a review of water-sharing arrangements needed?'

88 per cent of respondents felt that a review was needed (**Figure 67**) and there was clear support for this view across all regions.

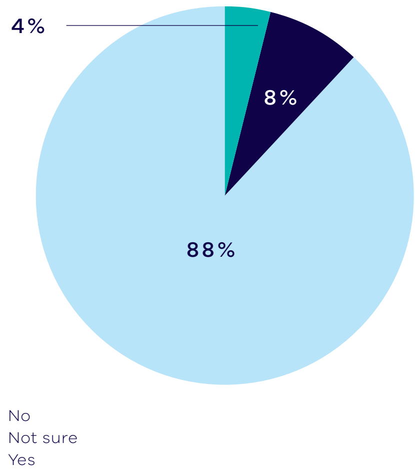


Figure 67: 'Is a review of water-sharing arrangements needed?' - all regions

Question 2: 'Are you surprised by the LTWRA results?'

80 per cent of respondents were either not surprised or the results were what they expected (**Figure 68**). The trend was similar across all regions.

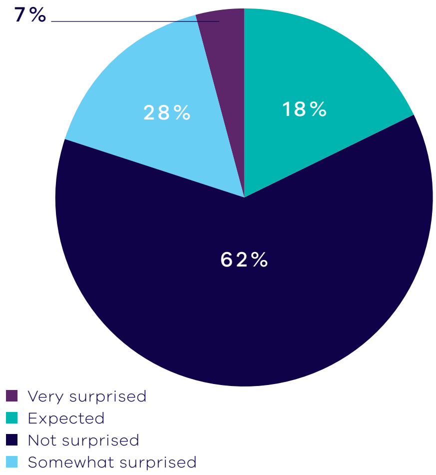


Figure 68: 'Are you surprised by the LWTRA results?' - all regions

Themes from the open-ended responses across southern Victoria

Respondents were asked two open-ended questions:

- Is there anything you would like to tell us about water in your area?
- Is there any information you feel should be included in the engagement report?

Key themes that recurred during the consultation are below in **Figure 69**

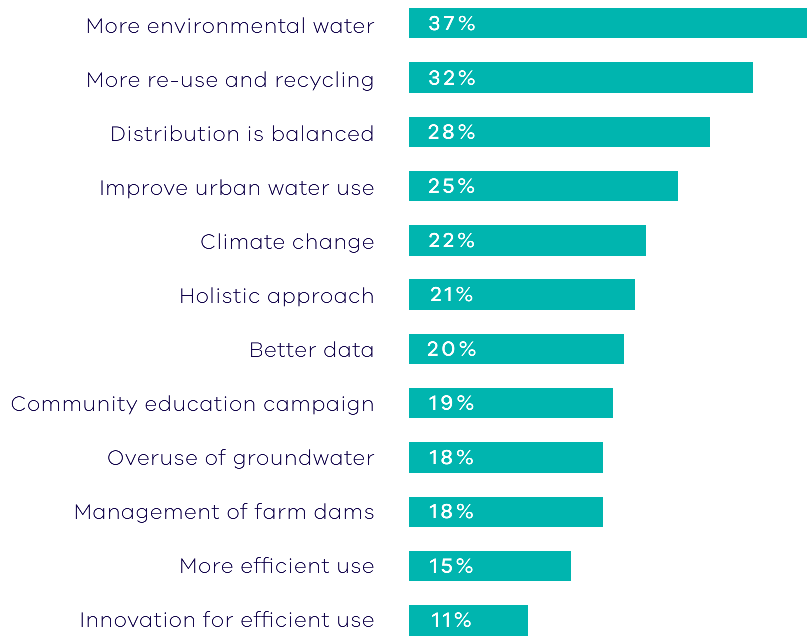


Figure 69: Key themes across all regions

What we heard

37 per cent of respondents indicated that they want more water allocated towards the environment. They said that more environmental water is needed to manage and improve or maintain the health of rivers and wetlands, including the plants and animals that depend on them.

32 per cent of respondents indicated that more re-use and recycling of water is needed. They expressed concern that, as populations grow and urban development increases, there will be a greater demand upon water supplies. Moreover, as conditions get drier, some respondents considered that southern Victoria may need to consider using recycled and re-purposed water for households.

28 per cent of respondents indicated that they want to ensure that the distribution of water in southern Victoria is balanced. Respondents want healthy rivers, lakes and bays, and viable industries. They know that cities and urban developments also require water security now and into the future.

25 per cent of respondents expressed concern about urban water use. Some of these respondents stated that the cities are taking water from regional and rural areas, and they are concerned about how much water will be required in the future for growing urban environments. A number of comments were made around capturing and using stormwater, rainwater and recycled water. Respondents said that we need to become more innovative in the ways that water is supplied to urban areas.

22 per cent of respondents directly mentioned concerns about climate change. They attribute LTWRA's findings that southern Victoria is getting drier due to climate change and said that they are concerned that we are 'acting as business as usual', not addressing climate change fast enough or with enough consideration about what happens to water into the future in a changing climate.

Other key themes include:

- 21 per cent say that a holistic 'big picture' approach to water management is required.
- 20 per cent say that better data is required to inform decision making.
- 19 per cent say that there is a need for more community education campaigns around water scarcity and effective management, so that more people understand that there is less water available and that water efficiency needs to improve.
- 18 per cent are concerned about the overuse of groundwater with insufficient time for aquifers to regenerate and that this resource is not being used sustainably.
- 18 per cent call for better management of farm dams, saying that the use of on- and off-stream dams should be better managed. Concerns include farmers wanting to be able to store water at high rainfall times to use for the drier seasons, removal of aesthetic dams, and that dam use is reducing flows needed for waterway health and downstream users.
- A theme emerged across responses about increasing efficiencies in water use (15 per cent) and the need for more innovative solutions to 'do more with less' (11 per cent). This includes more efficient agricultural, business and domestic uses of water.

Longer submissions

The following organisations, as well as a few individuals, provided written submissions that did not specifically answer the consultation questions, but provided information about the organisation's or individual's position on the findings of the LTWRA:

- Corangamite Catchment Management Authority
- Environment Victoria
- Victorian Farmers' Federation
- West Gippsland Catchment Management Authority
- Yarra Riverkeeper Association.

Key points of these submissions are included below.

Corangamite Catchment Management Authority

Recommends a review of water-sharing arrangements

Made some technical suggestions that helped with finalisation of the LTWRA.

Environment Victoria

Qualification of rights should be a last resort even as a temporary measure, and the environment's share of water should be given greater protection from qualification under the Water Act.

A review of water-sharing arrangements is required, especially in catchments where demand for water is high.

The methodology used in the LTWRA is conservative, and likely to underestimate the decline in water availability and the impacts of climate change, and therefore the impact on the environment's share of water.

The LTWRA needs to better assess how the environmental water reserve meets or fails to meet the environmental water reserve objective.

Victorian Farmers' Federation

Opposes the Minister's powers to permanently qualify rights and recommends that the Water Act is amended to ensure the permanent qualification of rights clause as a result of a LTWRA is removed.

The legislation is too narrow when looking at waterway health as it only relates to flow.

Due to increasingly drier conditions, the need to change environmental objectives must be considered before recovering more water for the environment.

West Gippsland Catchment Management Authority

Supports a review of water-sharing arrangements in the Latrobe and Thomson basins, considering the findings of the LTWRA, Latrobe Valley Regional Rehabilitation Strategy and other relevant information, including the technical work currently being undertaken by the organisation

Made some technical suggestions that helped with finalisation of the LTWRA.

Yarra Riverkeeper Association

The increase in urban water use in the Yarra basin at a time of declining available water is cause for concern. Strategies for more efficient urban water use should be a key feature of improving availability.

It is necessary to maintain waterway health when there will be less water within the system and increased use, although the environmental demand necessary to maintain waterway health, will not diminish.

Appendix B – EPA Review of the Long-Term Resource Assessment for Southern Victoria

EPA VICTORIA

Environment Protection Authority Victoria

200 Victoria Street
Carlton VIC 3053

GPO Box 4395
Melbourne VIC 3001

DX 210082

T 1300 372 842
1300 EPA VIC

W epa.vic.gov.au

Our Ref: MA008262
Your Ref: MBR040315

The Hon Lisa Neville MP
Minister for Water
8 Nicholson Street
EAST MELBOURNE VIC 3002

Dear Minister

Review of the draft Long-Term Water Resource Assessment for southern Victoria

Thank you for your letter of 16 September 2019, submitting the draft Long-Term Water Resource Assessment (LTWRA) for southern Victoria to the Environment Protection Authority Victoria (EPA) for review.

In accordance with the requirements of section 22N of the *Water Act 1989* (Water Act), EPA reviewed the LTWRA for southern Victoria. The review included:

a) the methodology adopted to carry out the draft assessment;

b) whether or not the data used in the draft assessment was the best data available;

c) whether or not the conclusions reached in the draft assessment are supported by the methodology and data; and

d) any other matter required by the Minister.

EPA conducted the review by convening an independent panel of qualified experts. The review was based on the draft LTWRA reports, including the background technical reports and further information and clarifications sought from the Department of Environment, Land, Water and Planning (DELWP) as this work progressed.

Please find EPA's full review attached. The key findings, in relation to the aspects assessed under legislation (above) include:

a) The methods adopted to assess surface and groundwater availability as well as water sharing availability are appropriate.

b) The data used for the purpose of this assessment was appropriate. EPA notes and supports the view outlined in the LTWRA, that the primary constraint in assessing waterway health was the limited data available.

c) The conclusions reached in the reached in the assessment are supported by the methodology and data. EPA notes that data constraints have impacted the ability to make conclusive findings about waterway

VICTORIA State Government

health, and that, given these constraints, the inconclusive finding is appropriate.

These findings have been shared with DELWP at officer level. As an outcome from this review, EPA has also provided recommendations to DELWP which could support future assessments.

EPA recommends further fit-for-purpose monitoring and assessment programs to better inform the assessment of waterway health. This should include the addition of biologically and ecologically significant waterway health indicators in the State's monitoring program. EPA also recommends that future assessments encompass a broader review of appropriate statistical methods.

EPA will liaise with DELWP in relation to the timing of publication of the review on EPA's website, as required by Clause 22N of the Water Act.

Yours sincerely

DR CATHY WILKINSON
CHIEF EXECUTIVE OFFICER
ENVIRONMENT PROTECTION AUTHORITY VICTORIA

29/11/2019

Encl.

Appendix C – Water availability for consumptive use and the environment

Table 6: Water available for consumptive use, EWR and total water for the environment, step A

River basin	Step A average annual water availability (ML/yr)				% Water Available	
	Consumptive	Environment	Other	Total water available	Consumptive	Environment
East Gippsland	1,221	803,163	14,793	819,177	0%	100%
Snowy	4,656	846,536	0	851,192	1%	99%
Tambo	4,251	318,737	757	323,744	1%	99%
Mitchell	13,443	867,937	768	882,147	2%	98%
Thomson	401,712	626,563	21,827	1,035,603	39%	61%
Latrobe	174,422	666,952	30,843	872,217	21%	79%
South Gippsland	18,532	695,708	38,897	753,137	3%	97%
Bunyip	39,002	351,273	-2,284[68]	387,990	10%	90%
Yarra	450,566	583,419	25,662	1,059,646	44%	56%
Maribyrnong	8,062	93,010	1,633	102,705	8%	92%
Werribee	34,658	50,855	9,904	95,417	41%	59%
Moorabool	33,261	70,479	10,926	114,666	32%	68%
Barwon	36,045	212,610	13,435	262,090	14%	86%
Lake Corangamite	710	66,148	2,568	69,426	1%	99%
Otway Coast	23,892	525,509	40,244	589,645	4%	96%
Hopkins	8,680	305,809	3,364	317,854	3%	97%
Portland	1,705	399,373	30,782	431,860	0%	100%
Glenelg	12,657	419,925	77,885	510,467	3%	97%

68 This volume includes a negative value to avoid double counting of "return flows" that initially are taken for consumptive uses and then returned to the environment.

Table 7: Water available for consumptive use, EWR and total water for the environment, step B

	Step B average annual water availability, step B (ML/yr)				% Water Available	
River basin	Consumptive	Environment	Other	Total water available	Consumptive	Environment
East Gippsland	1,222	731,244	14,796	747,262	0%	100%
Snowy	4,665	766,076	-	770,741	1%	99%
Tambo	4,241	272,502	915	277,658	2%	98%
Mitchell	13,443	763,506	784	777,733	2%	98%
Thomson	376,196	527,234	21,520	914,072	42%	58%
Latrobe	174,416	623,948	31,392	829,757	22%	78%
South Gippsland	18,305	604,367	38,910	661,582	3%	97%
Bunyip	37,494	325,569	-2,706[69]	360,357	10%	90%
Yarra	428,695	419,664	36,530	884,889	51%	49%
Maribyrnong	7,454	75,839	1,770	85,064	9%	91%
Werribee	31,597	38,368	7,825	77,790	45%	55%
Moorabool	30,822	53,748	7,610	92,180	36%	64%
Barwon	34,988	183,127	14,393	232,508	16%	84%
Lake Corangamite	684	51,440	2,579	54,703	1%	99%
Otway Coast	23,828	499,735	40,234	563,797	5%	95%
Hopkins	8,632	288,591	3,364	300,588	3%	97%
Portland	1,702	347,485	30,784	379,972	0%	100%
Glenelg	12,151	399,160	70,294	481,605	3%	97%

69 This volume includes a negative value to avoid double counting of "return flows" that initially are taken for consumptive uses and then returned to the environment.

Table 8: Water available for consumptive use, EWR and total water for the environment, step C

River basin	Step C average annual water availability, step C (ML/yr)				% Water Available	
	Consumptive	Environment	Other	Total water available	Consumptive	Environment
East Gippsland	1,222	744,689	1,351	747,262	0%	100%
Snowy	4,665	765,876	-	770,541	1%	99%
Tambo	4,241	272,002	1,415	277,658	2%	98%
Mitchell	14,415	757,264	6,053	777,733	2%	98%
Thomson	351,405	552,541	20,870	914,072	39%	61%
Latrobe	194,186	618,967	17,058	830,211	24%	76%
South Gippsland	17,897	639,515	4,120	661,532	3%	97%
Bunyip	37,413	325,585	-2,641[70]	360,358	10%	90%
Yarra	426,056	422,467	36,367	884,890	50%	50%
Maribyrnong	7,222	76,156	1,685	85,063	9%	91%
Werribee	34,498	36,466	6,826	77,790	49%	51%
Moorabool	31,314	53,690	7,164	92,168	37%	63%
Barwon	36,160	183,186	13,885	233,231	16%	84%
Lake Corangamite	684	54,020	-	54,703	1%	99%
Otway Coast	23,052	539,091	3,334	565,476	4%	96%
Hopkins	8,982	291,715	240	300,938	3%	97%
Portland	1,702	374,843	3,426	379,972	0%	100%
Glenelg	12,075	402,364	73,995	488,434	3%	97%

70 This volume includes a negative value to avoid double counting of "return flows" that initially are taken for consumptive uses and then returned to the environment.

Table 9: Changes in the proportions of water available for consumptive uses and for the environment, by step

River basin	% water available						% change					
	Step A		Step B		Step C		B cf. A		C cf. B		C cf. A	
	Cons	Env	Cons	Env	Cons	Env	Cons	Env	Cons	Env	Cons	Env
East Gippsland	0%	100%	0%	100%	0%	100%	0%	0%	0%	0%	0%	0%
Snowy	1%	99%	1%	99%	1%	99%	0%	0%	0%	0%	0%	0%
Tambo	1%	99%	2%	98%	2%	98%	0%	0%	0%	0%	0%	0%
Mitchell	2%	98%	2%	98%	2%	98%	0%	0%	0%	0%	0%	0%
Thomson	39%	61%	42%	58%	39%	61%	3%	-3%	-3%	3%	0%	0%
Latrobe	21%	79%	22%	78%	24%	76%	1%	-1%	2%	-2%	3%	-3%
South Gippsland	3%	97%	3%	97%	3%	97%	0%	0%	0%	0%	0%	0%
Bunyip	10%	90%	10%	90%	10%	90%	0%	0%	0%	0%	0%	0%
Yarra	44%	56%	51%	49%	50%	50%	7%	-7%	0%	0%	7%	-7%
Maribyrnong	8%	92%	9%	91%	9%	91%	1%	-1%	0%	0%	1%	-1%
Werribee	41%	59%	45%	55%	49%	51%	5%	-5%	3%	-3%	8%	-8%
Moorabool	32%	68%	36%	64%	37%	63%	4%	-4%	0%	0%	5%	-5%
Barwon	14%	86%	16%	84%	16%	84%	2%	-2%	0%	0%	2%	-2%
Lake Corangamite	1%	99%	1%	99%	1%	99%	0%	0%	0%	0%	0%	0%
Otway Coast	4%	96%	5%	95%	4%	96%	0%	0%	0%	0%	0%	0%
Hopkins	3%	97%	3%	97%	3%	97%	0%	0%	0%	0%	0%	0%
Portland	0%	100%	0%	100%	0%	100%	0%	0%	0%	0%	0%	0%
Glenelg	3%	97%	3%	97%	3%	97%	0%	0%	0%	0%	0%	0%

NOTE: The % change does not always match the difference between the steps presented in the tables. This is due to rounding. For example, in the Tambo basin, from step A to step B, the proportion of water available to consumptive users is reported as increasing from 1% to 2% when rounded to the nearest whole percentage. The actual change is from 1.3% (rounded down to 1%) to 1.5% (rounded up to 2%). The difference is calculated based on the unrounded percentages (i.e. in this example, 1.5%-1.3%=0.2% rounded down to a 0% change in the column of change for B cf. A).

Appendix D – Availability of water for urban and rural uses

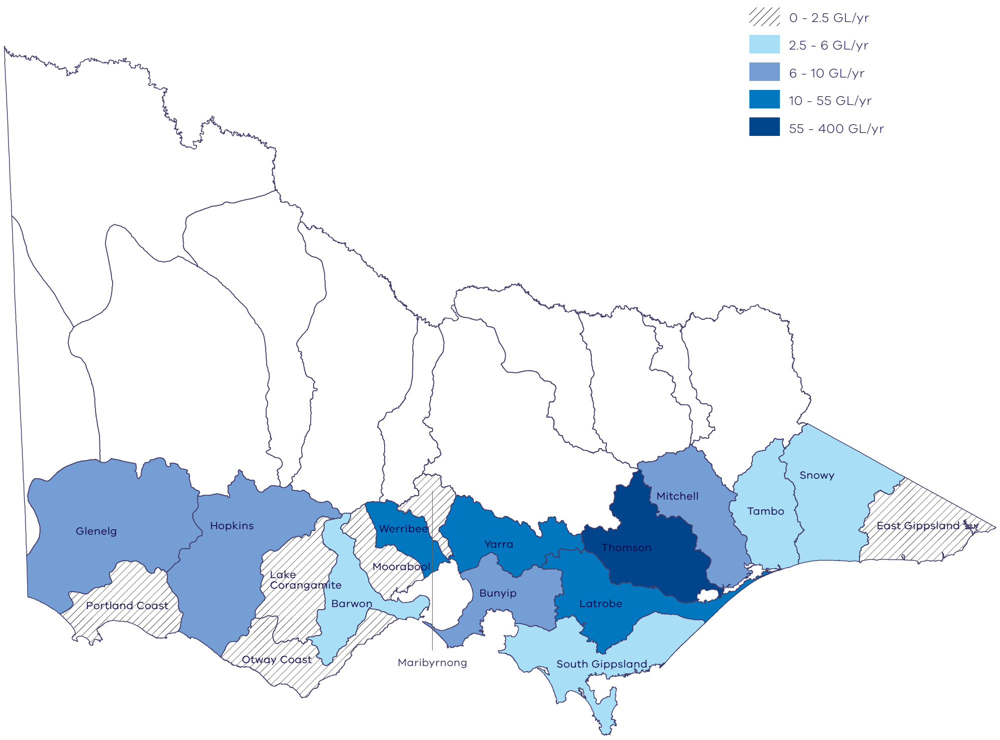


Figure 70: Long-term surface water availability for rural consumptive uses, step C

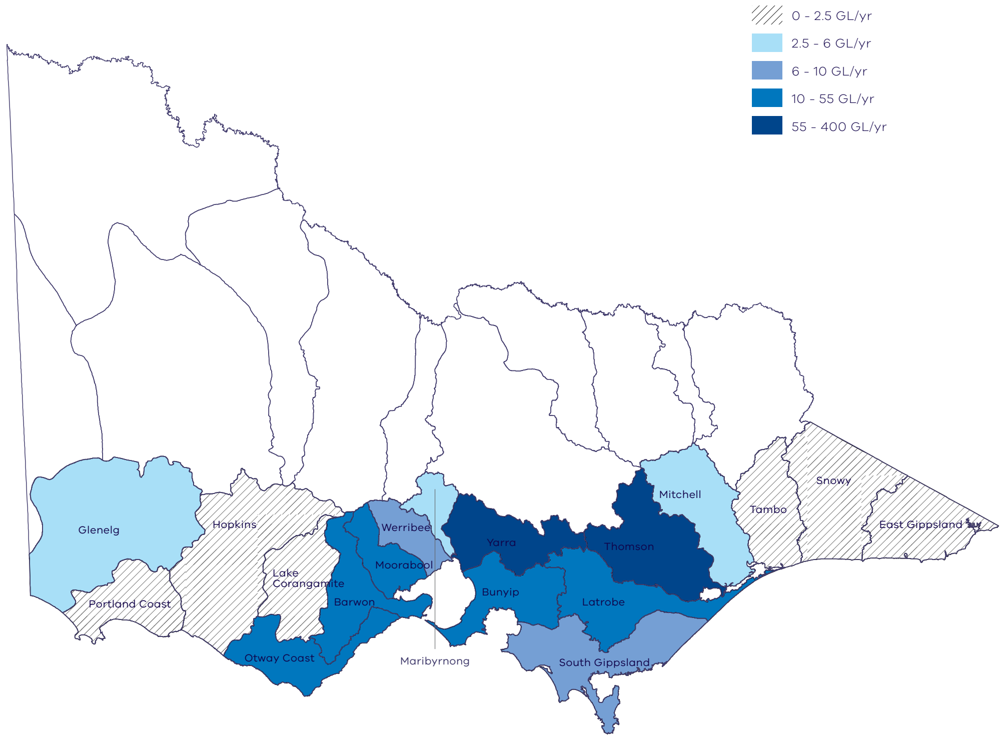


Figure 71: Long-term surface water availability for urban consumptive uses, step C

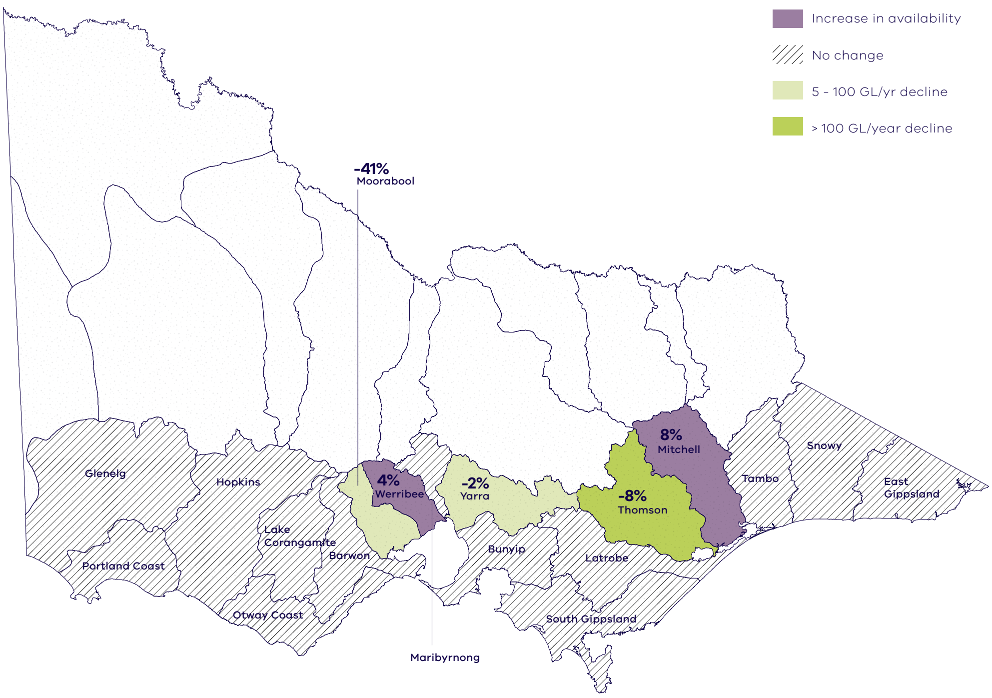


Figure 72: Change in long-term surface water availability for rural consumptive uses due to decline in long-term water availability (step C cf. A), by basin

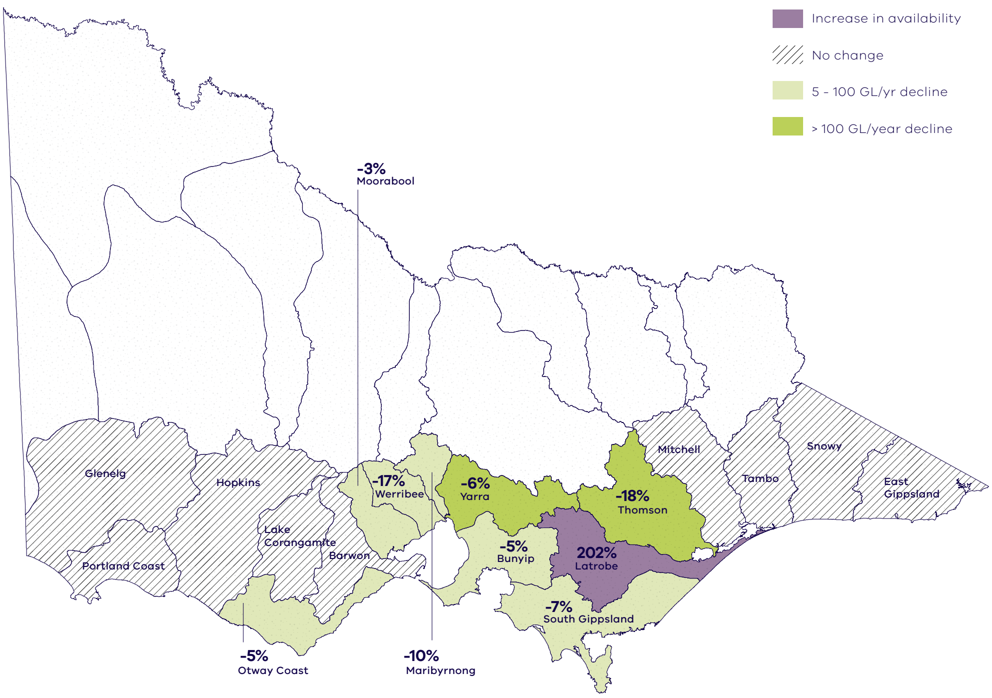


Figure 73: Change in long-term surface water availability for urban consumptive uses due to decline in long-term water availability (step C cf. A), by basin

Appendix E – Changes to waterway health for reasons related to flow

	Barwon	Bunyip	East Gippsland	Glenelg	Hopkins	Lake Corangamite	Latrobe	Maribyrnong	Mitchell	Moorabool	Otway Coast	Portland Coast	Snowy	South Gippsland	Tambo	Thomson	Werribee	Yarra
Fish	1	1	1	2	1	1	1	1	1	2	1	1	1	1	1	1	2	1
Macroinvertebrates	2	1	2	2	2	2	2	2	2	2	4b	2	4b	4b	2	3b	2	1
Salinity	2	1	3a	3b	3a	3a	3b	3a	4b	3a	2	3a	3a	3b	3a	3a	3a	2
Dissolved oxygen	4a	1	4a	4a	4a	3a	3a	3a	3b	3a	4b	4a	3a	3a	3a	3a	4a	3a
Turbidity	3a	1	4a	4a	4a	4a	4a	4a	4b	4a	4a	4a	4a	4a	4a	4a	4a	4a
Total Suspended Solids	3a	1	4a	3b	4a	4a	4a	4b	4b	4a	4a	4a	4a	3a	4a	4a	4a	4a
Phosphorus	3b	1	4b	4b	3b	4b	3a	3a	3b	4a	2	4b	4a	4a	3a	3b	4a	4a
Nitrogen	3a	1	2	4b	3a	2	2	3a	3b	4a	2	3b	3b	4a	2	3b	4a	3a

- Fish
- Macroinvertebrates
- Salinity
- Dissolved oxygen
- Turbidity
- Total Suspended Solids
- Phosphorus
- Nitrogen

1	Not enough data
2	No statistically significant trend
3a	**Improving** trend at least partly explained by flow
3b	**Improving** trend but mostly not explained by flow
4a	**Deteriorating** trend at least partly explained by flow
4b	**Deteriorating** trend but mostly not explained by flow

Figure 74: Changes in waterway health for reasons related to flow in southern Victoria 2006-2010. Note that improvements and deteriorations are relative to the previous period (1990-2005)

	Barwon	Bunyip	East Gippsland	Glenelg	Hopkins	Lake Corangamite	Latrobe	Maribyrnong	Mitchell	Moorabool	Otway Coast	Portland Coast	Snowy	South Gippsland	Tambo	Thomson	Werribee	Yarra
Fish	1	1	1	2	1	1	1	1	1	2	1	1	1	1	1	1	1	1
Macroinvertebrates	2	1	2	2	2	2	2	2	2	2	3b	1	2	4b	1	2	1	1
Salinity	2	1	4b	2	2	4a	4b	4b	3b	4a	2	4a	3b	4b	3b	2	3b	2
Dissolved oxygen	4a	1	3b	4a	4a	3a	3a	3a	3b	4a	4b	4a	4a	2	4a	4b	4a	4a
Turbidity	2	1	4a	3b	2	3b	4b	3a	4b	3a	3b	3a	4a	3a	4b	4b	3b	3a
Total Suspended Solids	3a	1	2	2	3a	4a	3a	2	4b	2	2	2	3a	3a	3a	4a	2	3a
Phosphorus	3b	1	3b	4b	4b	4b	3a	3a	4b	4a	2	4b	3a	3a	3a	3b	2	3a
Nitrogen	3a	1	2	4b	4a	2	2	3a	2	3a	2	4b	4a	2	2	4b	3a	3a

Fish
Macroinvertebrates
Salinity
Dissolved oxygen
Turbidity
Total Suspended Solids
Phosphorus
Nitrogen

1	Not enough data
2	No statistically significant trend
3a	**Improving** trend at least partly explained by flow
3b	**Improving** trend but mostly not explained by flow
4a	**Deteriorating** trend at least partly explained by flow
4b	**Deteriorating** trend but mostly not explained by flow

Figure 75: Changes in waterway health for reasons related to flow in southern Victoria 1990-2005

delwp.vic.gov.au